Binaural Interaction Component in Children using Click and Speech Stimuli

[1]Sonitha Kumar & [2]Sujeet Kumar Sinha

Abstract

The study was carried out with an aim of studying the maturational changes of binaural interaction component in children in the age range of 6-12 years using speech stimuli. In addition, the study also aimed to compare the maturational changes in binaural interaction component for speech and non speech stimuli. In the present study 100µs Click, and 40 ms CV syllable /da/, were used to elicit the responses. The binaural interaction component (BIC) was determined by subtracting the binaurally evoked auditory potentials from the sum of the monaural auditory evoked potentials. Results revealed that with maturation there is no significant difference in the latency and amplitude obtained for summed monaural, binaural and binaural interaction component for click stimulus. However, for the speech stimuli, latency of BIC for the I and II group was longer compared to the other groups. This was statistically significant compared to the other groups this indicated that the BIC for speech stimulus continues to develop till 8 years of age. However, the amplitude of BIC recorded for both stimuli i.e. the click and the speech stimulus had a large standard deviation for all the age groups. Hence, from the study it can be concluded that the BIC of auditory brainstem responses can be used to evaluate the binaural interaction in children, and latency of the BIC is a better parameter to evaluate the binaural interaction compared to the amplitude, as the amplitude of the BIC shows a very large variation.

Key Words: *Binaural interaction component (BIC), auditory brainstem responses, speech ABR*

Introduction

In the real-world listening situations, auditory information is processed by two ears, often in the presence of background noise (Durrant & Lovrinic, 1995). The processing of auditory information through ears is known as binaural processing. Binaural processing is evaluated clinically by behavioural assessment of skills such as, auditory localization and the masking level difference. There have been attempt made by the researchers to use the measurement of binaural processing through binaural interaction component of the auditory brainstem responses. The development of such a physiological measurement is essential to provide objective information in difficult to test population.

The auditory brainstem responses (ABR) have been used for studying binaural interaction component elctrophysiologically. The Binaural interaction component (BIC) is derived by subtracting the ABR obtained with binaural stimulation from the waveform obtained by adding the responses from the left and right monaural stimulation. This concept is expressed as: Binaural difference waveform=(L+R) BI; where, L+R is the sum of the left and right evoked potentials obtained with monaural stimulation, and BI is the response acquired from binaural stimulation. The BIC is most apparent in the binaural difference waveform obtained in humans at 4.5 to 7.0 ms after the stimulus onset for click stimulus, which is coincident with waves IV to VI (Wrege & Starr, 1981).

Binaural interaction is reflected in electrophysiological activity of neurons activated by binaural stimulation central to the cochlear nucleus (Jiang & Tierney, 1996). Binaural interaction is known to occur at three levels of the brainstem: the superior olivary complex, the nuclei of lateral lemniscus, and the inferior colliculus (Moore, 1991). BIC manifest binaural interaction (Debruyne, 1984; Dobie & Wilson, 1985; Hendler, Suires, & Emmerich, 1990) and are valid and proven responses which reflect ongoing binaural processing (Fowler & Swanson, 1988; Jiang & Tierney, 1996).

Recently the ABRs have also been recorded using the speech stimulus. The speech evoked auditory brainstem response is considered to provide a direct electrophysiological measure of sensory processing in the auditory brainstem (Galbraith, et al., 2000). Several studies have linked stimuli pattern to speech ABR component characteristic and investigated the magnitude and one-to-one correspondence to spectral peaks (Wible, Nicol & Kraus, 2004; Russo, Nicol, Mussachia & Kraus, 2004). In addition several studies have pointed out the potential usefulness of speech ABR in the diagnosis of speech processing impairment (Russo, et al., 2004; Johnson, Nicol & Kraus, 2005). In addition language experiences were also shown to have a significant effect on FFR synchronization (Krishnan, Xu, Gandour, & Cariani, 2004, 2005; Chandrasekaran

[1] E-mail: sonitha.kumar@gmail.com; [2]Lecturer in Audiology, E-mail: sujitks5@aiishmysore.in

& Kraus, 2010). Furthermore it has also been reported that the musicians have enhanced FFR synchronization to CV syllable /da/ and to music stimuli than non-musicians (Mussacchia, Sams, Skoe & Kraus, 2007).

Earlier the ABR has been recorded using simple stimuli such as a click or tone burst. Although clicks and tones have been instrumental in defining these basic response patterns, they are poor proximations of the behaviorally relevant sounds that we encounter in daily life. Therefore there is a need to study the encoding of speech sounds at the brainstem level. Furthermore there are several behavioural tests to evaluate the binaural processing in children. But the major problem with the behavioural test is it requires a behavioral co-operation from the children.

Speech ABR is an electrophysiological test that doesn't require any co- operation from the children and gives reliable information about brainstem encoding of speech sounds. It has been found as a useful tool in the diagnosis of learning disability and poor readers (Russo, et al., 2004; Abrams, Nicol, Zecker & Kraus, 2009). Deficits in binaural processing can lead to various degrees of auditory processing disorders. Assessing binaural interaction can serve as a diagnostic tool especially in children with auditory processing disorders, as binaural interaction tasks are frequently affected in those children (Delb, Struss, Hohenberg & Plinkert, 2003).

Hence there is a need to establish the binaural interaction component in normal hearing children, as to compare them with children having auditory processing problem. Also, binaural interaction component of ABR has been studied using non speech stimulus like click stimuli, however, there is a dearth of information regarding the binaural interaction component of ABR using speech stimuli. So there is a need to understand the binaural interaction component using speech stimuli. There are also studies (Johnson, Nicol & Kraus, 2008), which suggest a different development pattern for click and speech stimuli. The click ABR matures by the age of 18-24 months, whereas the speech ABR continues to develop till 5 years of age (Johnson, et al., 2005). Hence, it may be hypothesized that such differences may occur for click and speech evoked BIC.

The present study aimed to determine the maturational changes of BIC using speech stimuli for different age groups and to determine the maturational changes in BIC for click stimuli for different age groups.

Method

Participants

A total of 60 normal hearing children in the age range of 6 to 12 years participated in the study. They were basically categorized into 6 groups (10 subjects per age group); Group I: 6 to 6; 11 years. (Mean age-6.35 years), Group II: 7 to 7; 11 years. (Mean age-7.60 years), Group III: 8 to 8; 11 years. (Mean age-8.30 years), Group IV: 9 to 9; 11 years. (Mean age-9.75 years), Group V: 10 to 10; 11 years. (Mean age-10.35 years) and Group VI: 11 to 11; 11 years. (Mean age-11.45 years).

Characteristics of the participants: The participant's air conduction thresholds were less than or equal to 15 dB HL in the octave frequency range of 250 Hz to 8000 Hz and bone conduction thresholds less than or equal to 15 dBHL in the octave frequency range of 250 Hz to 4000 Hz. All the participants had 'A' type tympanogram and presence of acoustic reflexes. None of them had any history of otological symptoms (ear ache, ear discharge, and tinnitus or hearing loss).None of the children had any neurological problems or any other general weakness. They had no history of poor academic performance as reported by the parents and/or teachers. All the children had to pass SCAP (Screening Checklist for Auditory Processing developed by Yathiraj & Mascarenhas, 2004). All of them had normal click ABR. i.e. identifiable auditory brainstem response peaks (wave I, III & V) within normal latency.

Test stimulus for speech ABR

The test stimulus which was used for speech evoked ABR in the present study was a synthesized /da/ syllable. The stimulus is available in evoked potential system with the BioMARK protocol. The /da/ stimulus is a 40 ms synthesized speech syllable produced using KLATT synthesizer (Klatt, 1980). This stimulus simultaneously contains broad spectral and fast temporal information characteristics of stop consonants, and spectrally rich formant transitions between the consonant and the steady-state vowel. Although the steady-state portion is not present, the stimulus is still perceived as being a consonant-vowel syllable. The fundamental frequency (F0) linearly rises from 103 to 125 Hz with voicing beginning at 5 ms and an onset noise burst during the first 10 ms. The first formant (F1) rises from 220 to 720 Hz, while the second formant (F2) decreases from 1700 to 1240 Hz over the duration of the stimulus. The third formant (F3) falls slightly from 2580 to 2500 Hz, while the fourth (F4) and fifth formants (F5) remain constant at 3600 and 4500 Hz, respectively. Figure 1 shows both

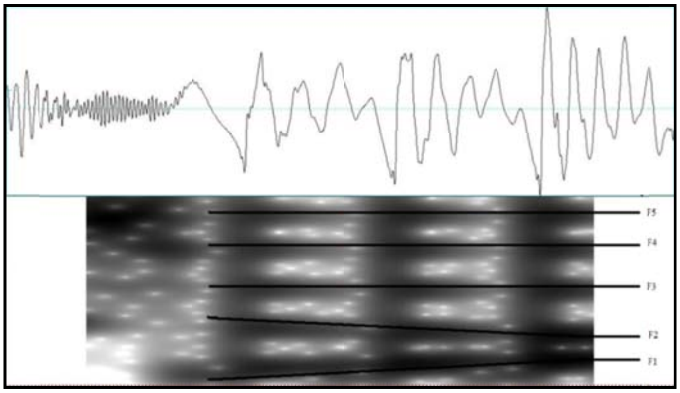

Figure 1: Spectral and temporal aspects of the speech stimulus /da/ used in the present study. The top one represents the temporal details of the waveform whereas the bottom one depicts the spectral details.

the time and spectral domain of the stimulus used in the present study.

Procedure

To screen the hearing sensitivity, normal middle ear functioning and no auditory processing problems following tests were carried out; Puretone audiometry, Tympanometry, Screening checklist for auditory processing. Once the subjects passed the selection criteria, they were subjected to electrophysiological testing. Click and speech evoked ABR was recorded monaurally for both ears and binaurally. Monaural responses were added together to obtain summed monaural wave form. To determine the binaural interaction component binaural responses were subtracted from the summed monaural responses for both click as well as speech stimulus.

BIC=[(left monaural+right monaural)-Binaural]. Click ABR and Speech ABR was recorded using the following protocol (Table 1).

Analysis

Click and speech evoked ABR were recorded monaurally from the two ears and binaurally. Response was obtained by giving the stimulus monaurally (right and left ear) separately and then binaurally. The binaural interaction component (BIC) was determined by subtracting the binaurally evoked auditory potentials from the sum of the monaural auditory evoked potentials:

BIC = [(left monaural + right monaural)-Binaural]

The latency and amplitude of click evoked and speech evoked ABR was estimated for monaural and binaural recordings. Latency and amplitude of V peak in particular was estimated in both speech and click evoked ABRs. For both click and speech evoked ABR, amplitude was estimated by taking the peak which has got maximum energy within 10ms. For click evoked ABR, the peak which comes under 5-6 ms was estimated for obtaining the latency of the V peak.

Table 1: Parameters for recording click evoked ABR and speech evoked ABR

	Click evoked ABR	Speech evoked ABR
Stimulus, duration	Click, 100µs	CV syllable /da/, 40 ms
Level	80 dB SPL	80 dB SPL
Filter band	100 to 3000 Hz	100 to 3000 Hz
Rate	10.1/s	10.1/s
No of sweeps	1500	3000
Transducer	ER-3A Insert ear phone	ER-3A Insert ear phone
Polarity	Alternating	Alternating
Time window	12 ms	12 ms
Electrode montage	Non-inverting electrode: Vertex, Inverting electrode: nape of the neck, Ground electrode: forehead.	Non-inverting electrode: Vertex, Inverting electrode: nape of the neck, Ground electrode: forehead.

Whereas, for speech evoked ABR, the peak which comes under 5-7ms was estimated for obtaining the latency of the V peak. Finally, the amplitude and latency of BIC was also estimated.

Results

Latency of BIC

Latency of BIC using click stimulus: ABR for click stimulus was recorded for right ear and left ear separately first, then the two responses were added together to get a summed monaural responses. Binaural ABR was recorded using simultaneous presentation of click stimulus to both the ears. BIC for click was derived by subtracting binaural responses from summed monaural responses. The representative waveform of summed monaural, binaural and binaural interaction component has been given in the Figure 2. Click evoked ABR for the right and the left ear separately as well as binaurally could be recorded for all the subjects. Binaural interaction component of wave V was present for all the subjects. Latency of wave V of the summed monaural waveform, binaural waveform and binaural interaction component was measured.

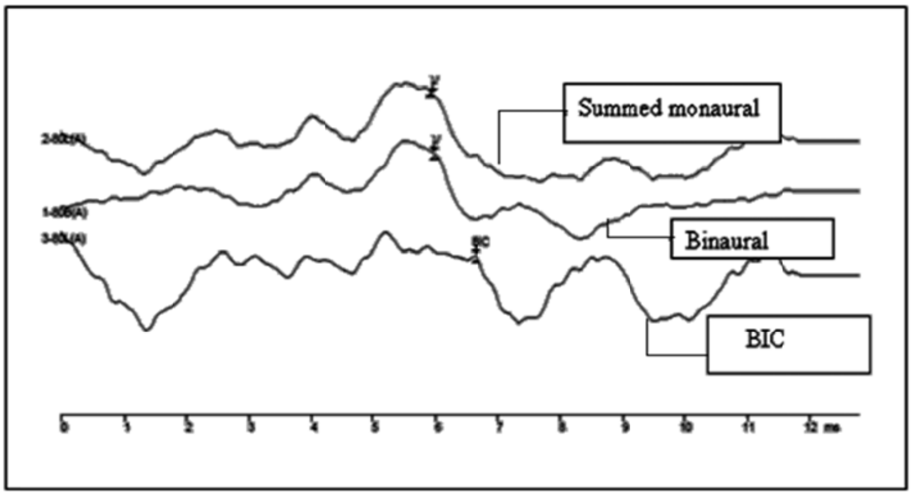

Figure 2: Representative waveform of summed monaural Binaural and Binaural interaction component using click stimuli recorded in one subject.

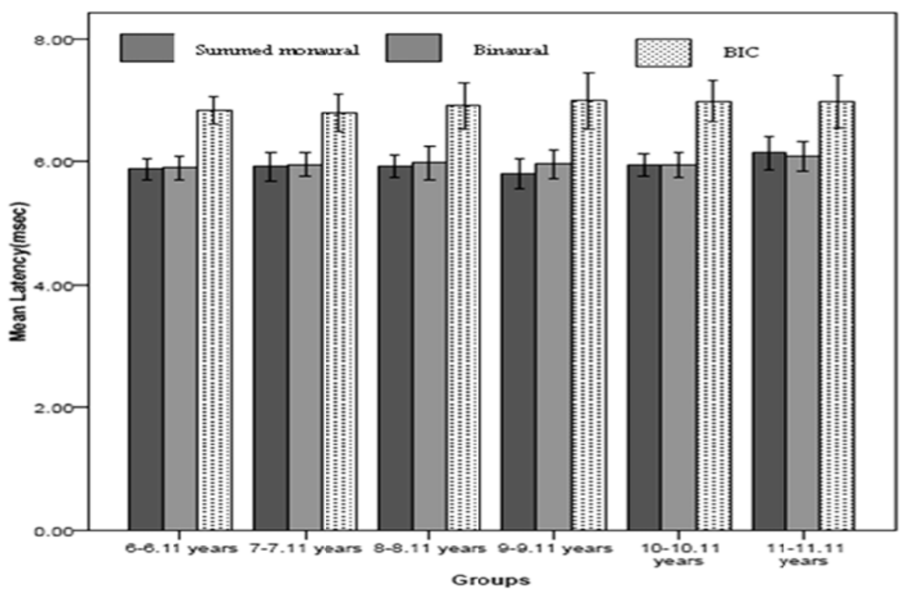

Figure 3: Mean and Standard deviations for the summed monaural, binaural and binaural interaction component for the latency parameter for the different age groups.

Descriptive statistics was done to find out the mean and standard deviation of latency for summed monaural, binaural and binaural interaction component of ABR for the click stimulus. The details of the mean and standard deviation are given in Figure 3

As we can see in Figure 3 at the mean latency of wave V of summed monoaural response, binaural response and the BIC elicited using click waveforms is similar across different age groups except for Group IV and VI in summed monoaural response and Group VI in binaural response. The latency of wave V in these two groups (Group IV and VI) is slightly higher compared to the other groups for summed monaural responses. The mean latency of wave V of binaurally recorded ABR was higher for Group VI compared to the other groups. It can also be seen from Figure-3 that the mean latency of BIC is almost similar for I and the II Group whereas the mean latency of BIC for the III, IV, V and VI Group is almost similar.

Multiple analysis of variances (MANOVA) test was carried out to check the significant difference in the mean values of the latency obtained for click stimuli across all the groups. MANOVA analysis revealed no significant difference for wave V latency of summed monaural recording for click stimuli across all the age groups [F(5, 54=1.42, P>0.05] and also for the latency of wave V of binaural recording for click stimuli across age groups [F(5, 54=0.38, P>0.05]. MANOVA also failed to show any significant difference for latency of binaural interaction component for click stimuli across different age groups [F(5, 54=0.27, p>0.05].

Latency of BIC using Speech stimulus: ABR for speech stimulus was recorded for right ear and left ear separately first, then the two responses were added together to get a summed monaural responses. Binaural speech ABR was recorded using simultaneous presentation of speech stimulus /da/ to both the ears. BIC for speech was derived by subtracting binaural responses from summed monaural responses. The representative waveform of summed monaural, binaural and binaural interaction component has been given in the Figure 4.

Descriptive statistics was done to find out the mean latency of the binaural interaction component, and mean latency for the wave V of summed monoaural and binaural responses. The details of the mean and standard deviation (S.D) of latency of BIC and wave V latency of summed monoaural and binaural ABR are given in Figure 5.

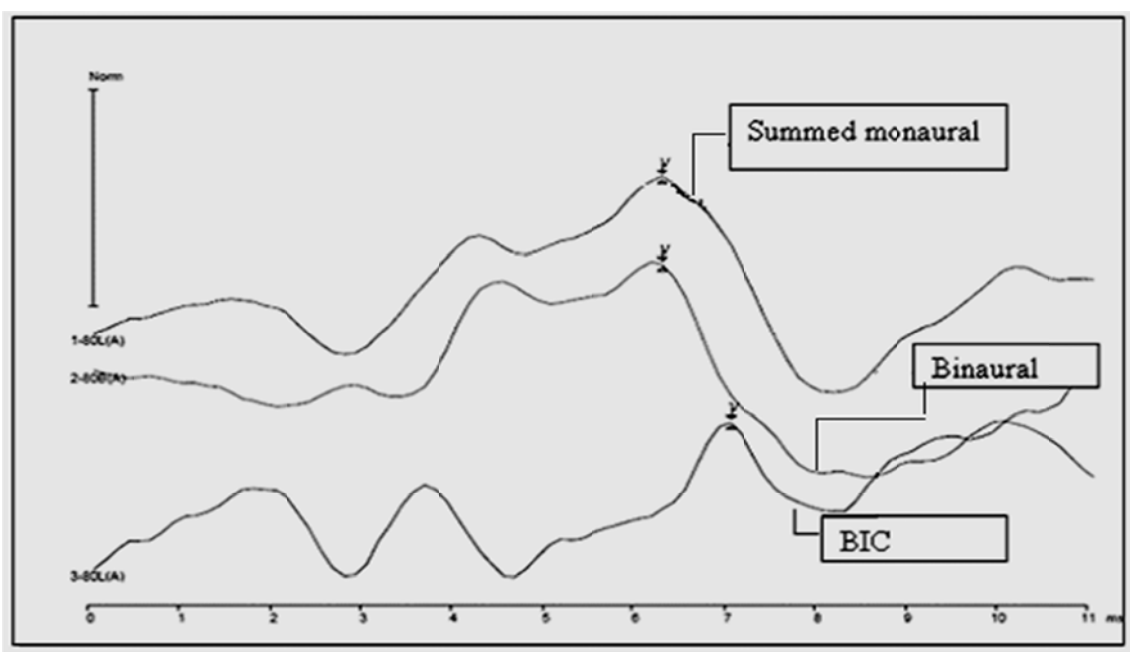

Figure 4: Representative waveform of summed monaural Binaural and Binaural interaction component using speech stimuli.

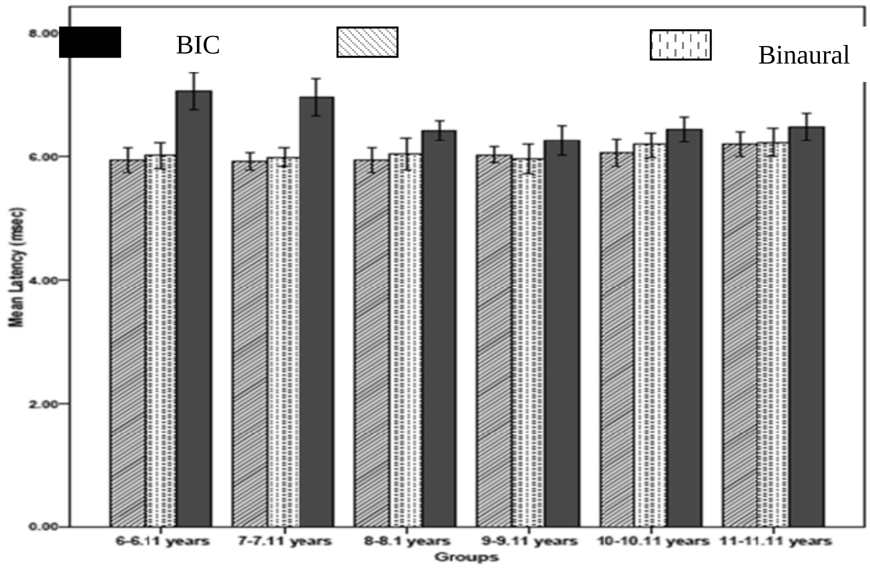

Figure 5: Bar graph of the latency of BIC, and wave V of summed monaural and binaural ABR for speech stimulus for different age groups.

From Figure 5, it is clear that the latency of wave V of summed monoaural response is almost similar for I, II and III Group, whereas latency is slightly longer for the IV, V and VI group. It can also be seen from Figure 5 that the latency of wave V of the binaural response elicited using speech waveforms is variable across the age groups. Further, it can also be seen that the latency of BIC obtained for I and II Group were longer compared to the other four groups.

Multiple analysis of variance (MANOVA) test was carried-out to check the significant difference in mean latency of summed monaural, binaural and binaural interaction component for speech stimuli across each groups. MANOVA results indicated no significant difference for wave V latency of summed monaural recording for speech stimuli across age groups [F(5, 54)=1.63, P>0.05]. MANOVA also revealed no significant difference for wave V latency of binaural recording for speech stimuli across age groups [F(5, 54)=1.32, P>0.05]. However, MANOVA revealed a significant difference for the binaural interaction component for the speech stimulus [F(5, 54)=9.35, P<0.05]. To further understand the group differences, the Duncan's post hoc analysis test was done. The results of Duncan's post hoc analysis shows that the latency of BIC for the I and the II group did not differ significantly whereas, the latency of BIC for the I and II groups were significantly different from each other.

Amplitude of BIC

Amplitude of BIC for Click stimulus: Click evoked ABR could be recorded for all the subjects. Binaural interaction component of wave V was present for all the subjects. Amplitude of binaural interaction component and wave V of the summed monaural and binaural ABR was measured.

Descriptive statistics was done to find out the mean and standard deviation of amplitude for the binaural interaction component, summed monaural and binaural component for the click stimuli. The details of the mean and standard deviation are given below in Figure 6. As it can be seen from the Figure 4.5 that the mean amplitude of wave V for the summed monoaural response is slightly higher for I and II groups compared to the other four groups, the amplitude of the wave V for other four groups were almost similar. The amplitude of wave V for the binaural responses and BIC is slightly varying across all the age groups. It can also be noted that the standard deviation for the amplitude of summed monaural, binaural and BIC is very high for all the age groups.

MANOVA test was carried-out to check the significant difference in mean values of the amplitude obtained for BIC, summed monaural and binaural waveform across each groups. MANOVA results revealed no significant difference for wave V amplitude of summed monaural recording for click stimuli across all the age groups [F(5, 54)=1.83, P>0.05]. There was also no significant difference for wave V amplitude of binaural recording for click stimuli across all the age groups [F(5, 54)=0.73, P>0.05]. MANOVA also failed to show any difference for the amplitude of binaural interaction component of the click stimuli across different age groups [F(5,54)=0.86, P>0.05].

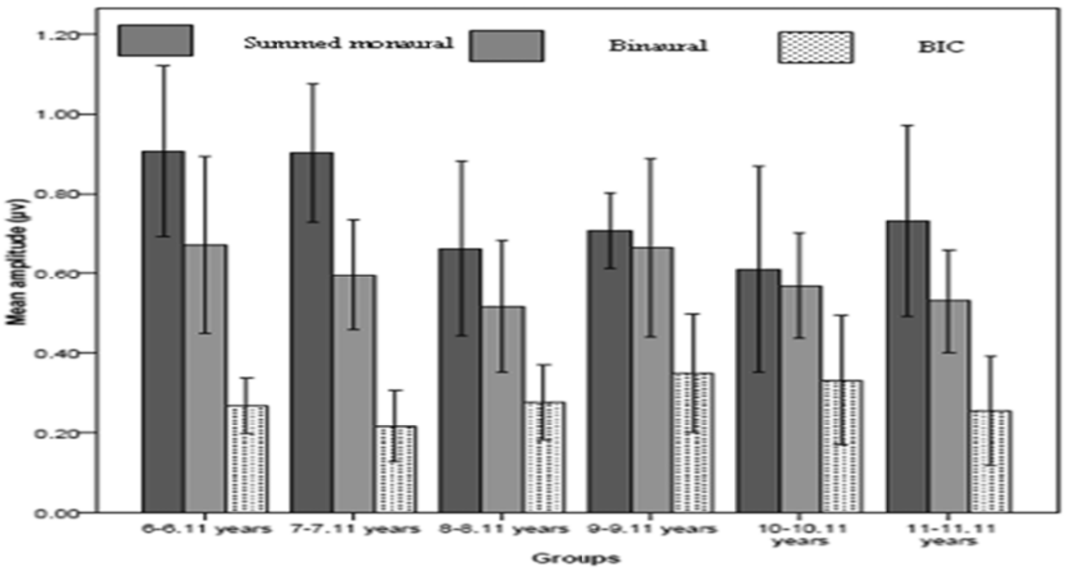

Figure 6: Bar graph of amplitude of BIC and amplitude of wave V of summed monaural and binaural waveform for different age groups for click stimulus.

Amplitude of BIC for speech stimulus: Speech evoked ABR could be recorded for all the subjects. Binaural interaction component of wave V was present for all the subjects. Amplitude of wave V of the summed monaural waveform, binaural and binaural interaction component was measured. Descriptive statistics was done to find out the mean and standard deviation of amplitude for summed monaural, binaural and binaural interaction component for the speech stimuli.

As can be seen in Figure 7, the mean amplitude of wave V recorded for summed monaural waveform is more for I and II Group (i e., age range of 6- 6.11 years and 7- 7.11 years). The amplitude of the wave V of binaural waveforms however varies across the different age groups. The amplitude for the binaural interaction component is also higher for the I Group compared to the other groups. It can also be noted that the standard deviation for the amplitude of summed monaural, binaural and BIC is very high for all the age groups.

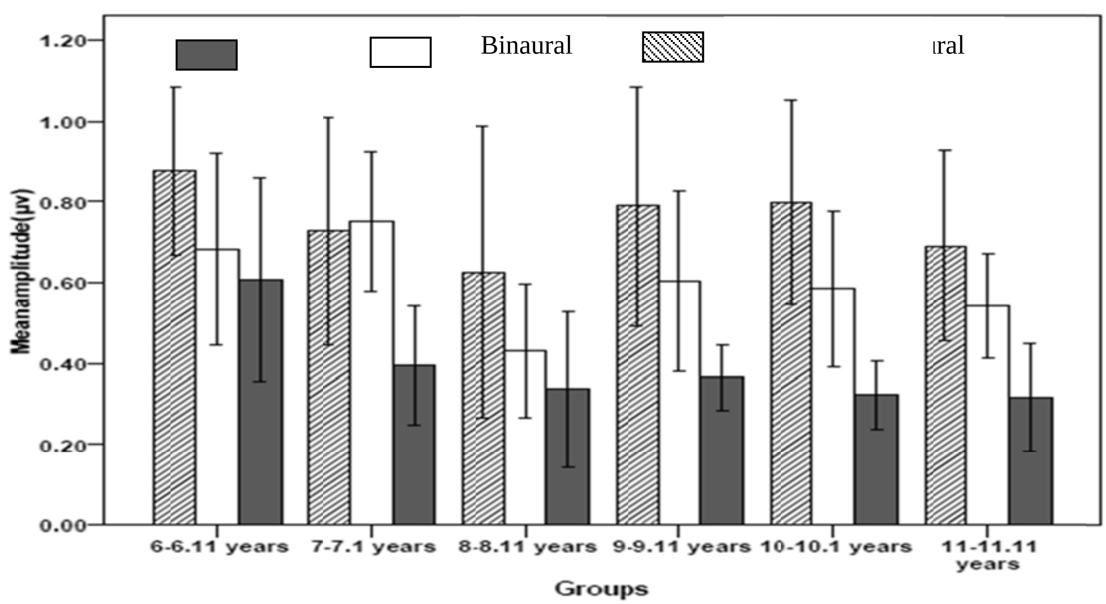

Figure 7: Bar graph of amplitude of summed monaural, binaural and BIC evoked using speech stimuli for different age groups.

MANOVA test was carried out to check the significant difference in mean values of the amplitude of BIC, summed monaural and binaural for different age groups. No significant difference was observed for wave V amplitude of summed monaural recording for speech stimuli across age groups [F(5, 54)=0.51, P>0.05]. There was also no significant difference for wave V amplitude of binaural recording for speech stimuli across age groups [F(5, 54)=1.74, P>0.05]. But significant difference was observed for amplitude of binaural interaction component for speech stimuli across different age groups [F(5, 54)=2.42, P<0.05]. Duncan's Post hoc analysis was done to check which group was significantly different from each other. The results of the Duncan's Post-Hoc analysis shows that the amplitude of BIC for the first group was significantly higher compared to the other groups.

To summaries the results, with maturation there is no significant difference in the latency and amplitude obtained for summed monaural, binaural and binaural interaction component for non speech stimulus i.e, click stimulus. However, there was a significant difference obtained for the latency of the BIC of the speech stimuli. Latency of BIC for the I and II Group was longer compared to the other groups and this was statistically significant compared to the other groups. However, the amplitude of BIC recorded for both stimuli i.e. the click and the speech stimulus had a large standard deviation for all the age groups.

Discussion

The aim of the study was to determine the maturational changes in the binaural interaction component using click and speech stimuli for the children in the age range of 6 years to 12 years.

Latency of BIC for click and speech stimuli

The result of the present study showed that there was systematic age related change in the latency of the speech evoked binaural interaction component (BIC). Latency of BIC of speech obtained for children in the age range between 6-6.11 years and 7- 7.11 years were significantly prolonged compared to the children in the age range between 8 to 12 years, whereas there was no difference for the BIC evoked by the click stimulus.

In the present study the mean latency of the binaural interaction component for the click stimulus was found to be in the range of 6.80 - 6.99 ms for the different age group of children. The latency obtained for BIC for the click stimulus in the present study is longer compared to the earlier studies (Chiappa, Gladstone, & Young, 1979; Hosford-Dunn Mendelson & Salamy, 1981; Gopal & Pierel, 1999) reported in the literature. Chiappa, et al., (1979) reported a mean latency of 5.75± 0.25 ms, Dunn et al., obtained BIC latency as 5.67±0.21 msec, Gopal and Pierel reported latency as 5.63±0.26ms. The prolonged latency of BIC for the click stimulus in the present study can be attributed to the intensity of the stimulus used in the present study. Earlier studies have used an intensity of 80 dBnHL to record the auditory brainstem responses whereas, in the present study an intensity of 80 dBSPL was used. Thus, the lower presentation of the stimulus level would have caused a delay in the latency of the BIC obtained for the click stimulus.

For the speech stimulus, the latency of BIC recorded was in the range of 6.25-7.06 msec. In the literature there are only a few studies which have reported the BIC using speech stimulus. Deepti (2008) reported a latency of 6.99± 0.29 msec for the BIC using speech stimulus in a group of children. The present study is in agreement with the latency reported by Deepti (2008).

However, latency of BIC for speech stimulus obtained for children in the age range between 6-6.11 years and 7- 7.11 years were significantly prolonged compared to the children in the age range between 8 to 12 years. Prolonged latency of the BIC for speech stimulus in the age group of 6-6.11 and 7-7.11 years indicates that the BIC continues to develop till 8 years of age. Maturation of the binaural interaction component using the auditory brainstem responses is thus analogues to the other tasks of binaural interaction component such as masking level difference (MLD), which continues to develop till 6 years of age.

Hall and Grose (1990) found that the MLD for a pure-tone presented in a wide band (300 Hz) masker progressively increased up to approximately 5 to 6 years of age. In addition, MLD presented in a narrow band (40 Hz) masker continued to be smaller in the 6 years-old children compared to the adults. The authors concluded that these developmental changes observed in the MLD of children up to 6 years of age are most likely related to the central auditory processing development than to sensitivity to interaural timing cues.

However, the auditory brainstem responses to click stimulus reaches adult values by the age of 18-24 months in children, indicating the maturation of brainstem pathway by this age, whereas, the brainstem responses to speech continue to develop till 5 years of age (Johnson, et al., 2008). This dichotomy suggests that brainstem neurons react differently to encode click versus speech sounds. There may be a possibility that the higher level processing responsible for integration and process of binaural cues for speech stimulus may continue to mature beyond this age i.e. 5 years of age. Thus, the prolonged latency obtained for BIC of the speech stimulus for the lower age groups in the present study reflects a neuromaturation development of binaural interaction component.

The prolongation in latency of BIC was not seen for the click stimulus. Latency of click evoked BIC for all the age groups was similar. Auditory brainstem responses using speech stimulus has been found to be superior to click stimulus in evaluating the children with learning problems. According to Wible, et al., (2004) onset of the speech sound /da/, i.e. wave V of the auditory brainstem response (ABR) had a significantly shallower slope in learning impaired children. The authors suggested that poor representation of crucial component i.e. the onset responses of speech sounds could contribute to difficulties with higher-level language processes. Also Goncalves, et al., (2011) reported a longer latency for wave V of speech ABR in children with phonological disorders compare to normal children with age range of 7- 11 years.

The difference in the latency of the BIC obtained for speech and click stimuli can be attributed to stimulus differences. Whereas, clicks contain a broad range of frequencies, speech is more spectrally shaped. In addition, the onset of the /da/ stimulus occurs more gradually relative to the instantaneous rise time of the click. The onset of the /da/ syllable may also be more susceptible to the effects of backward masking by the larger-amplitude formant transition (Johnson, Nicol, Zecker, & Kraus, 2007). Finally, brainstem activity can be experience dependent (Tzounopoulos & Kraus, 2009), i.e. the latency effects of the two stimuli may be due to the greater exposure to and use of speech sounds.

Although the acoustic differences discussed above may be partially responsible for the findings in this study, it is important to know that human beings are exposed to speech stimulus in the environment and not the click stimulus. Particularly relevant is that brainstem encoding of sound has been shown to be shaped by lifelong linguistic and musical experience (Krishnan, et al., 2004, 2005; Musacchia, et al., 2007; Wong, et al., 2007). That is, brainstem activity evoked by Mandarin tones and music is enhanced in musicians and speakers of tonal languages relative to non-musicians and non-native speakers. Additionally, short-term training has been shown to lead to changes in speech-evoked brainstem responses (Russo, Nicol, Zecker, Hayes, & Kraus, 2005; Song, Skoe, Wong, & Kraus, 2008). Also the reversed speech is processed differently at the brainstem level compared to the forward speech (Sinha & Basavaraj, 2010), indicating a differential processing of a forward and reversed speech at the brainstem. Moreover, a previous study in animals has also shown that experience can lead to large-scale reorganization of the inferior colliculus tonotopic organisation (Yu, Sanes, Aristizabal, Wadghiri, & Turnbull, 2007) and that experience dependent pruning of synaptic inputs is important for the maturation of the functional inhibition in brainstem nuclei (Magnusson, Kapfer, Grothe, & Koch, 2005).

If it is assumed that humans have little exposure to clicks and that clicks have little relevance, regardless of age, the auditory system would not be expected to change its response to such a stimulus. Conversely, with speech, which is relevant in the real world, experience dependent pruning is necessary. Because younger children have less linguistic and phonemic exposure, it is perhaps the case that synaptic pruning has not been fully refined such that young children have delayed/less precise neural response timing when encoding acoustic elements that are relevant to speech (Johnson, et. al., 2008). Thus, it is reasonable to speculate that the developmental differences found in the present study for the BIC of speech stimulus may not be just from acoustic differences of the stimuli but also perhaps from their extensive use and relevance.

Amplitude of BIC for click and speech stimulus

In the present study there was no variation in the amplitude of BIC obtained for click and speech stimulus across the different age groups. Amplitude obtained for click stimulus was within the range of 0.21-0.35 µV, whereas, amplitude obtained for speech stimuli was within the range of 0.31-0.60 µV. Group I showed significant difference from the other groups for BIC of speech stimulus. For the speech as well as the click stimulus the amplitude variation was large for all the age groups i.e. the standard deviation was very high. Large standard deviation in amplitude of BIC might be a result of the large standard deviation obtained for the summed monoaural and binaural recordings. Large standard deviation might be a reason that the first group attended a significant difference in terms of amplitude for speech stimulus.

Previous studies (Hurley, 2004; Deepti, 2008) have also reported a very large variation in amplitude of the binaural interaction component recorded with click or speech stimulus. It is known that the electrophysiologic recordings often don’t replicate well and the peak-to-peak measures of the components vary widely. This has led to many researchers to believe that amplitude measure of the ABR components is highly variable

(Burkard, Eggermont & Don, 2007). While it is true that the measurements often vary widely from run to run, it is not necessarily true that the variation is solely due to electrophysiologic changes. The measured average waveform (i.e. the ABR amplitude) is composed both of synchronous neural component-the true electrical potential and the residual noise. Therefore, it is possible that the variation in the measurement is due to the variation in the residual noise and that there is little or virtually no variation in the evoked potentials component. Also there are episodic noise bursts or changes in the level of background noise from one run to the other. As a result, the residual noise can vary greatly from one run to the next when a fixed number of sweeps are used, and a fixed number of sweeps will not guarantee the same SNR for repeated runs (Hall, 1992; Hood, 1998; Burkard, et al., 2007). The measured amplitude thus is influenced by many factors such as recording bandwidth, stimulus type, individual's gender, anatomy and physiology, the technique used by the software for averaging, impedance at the surface electrode (Hall, 1992; Hood, 1998; Burkard, et al., 2007).

Conclusions

The BIC of auditory brainstem responses can be used to evaluate the binaural interaction in children. This will be helpful in diagnosis of the children with (C)APD who have binaural interaction component. Additionally the test does not require any behavioural co-operation from the client, hence can be administered easily. However, latency of the BIC is a better parameter to evaluate the binaural interaction compared to the amplitude, as the amplitude of the BIC shows a very large variation.

Implications of the Study

It can be used to evaluate the neural encoding of speech sounds at the brainstem level. It can serve as a diagnostic tool to evaluate the binaural interaction task in children. BIC for speech can be a useful diagnostic tool in assessing the binaural interaction task in children with auditory processing problem.

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