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Research Article

Frequency Coding of Speech Stimuli at Subcortical Level Using Speech Evoked ABR in Children at Risk for Central Auditory Processing Disorders

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Abstract

Central auditory processing is the processing of complex sounds after the initiation of transduction of sound energy via external ear into neural activity of the cochlea. Disruption of central auditory processing may lead to deficit in perception of speech, environmental sound or music in the absence of peripheral hearing loss. The present study was carried out to assess the coding of fundamental frequency and different harmonics using speech evoked auditory brainstem responses. Thirty children at risk of central auditory processing deficit were compared with age matched typically developing children in the age range of 8-14 years. The responses were analyzed offline using Fast Fourier Transform with the help of MATLab (version 7.0) software. Statistical analysis was done using ANOVA. The result revealed no significant differences between ear and hence both ears data were combined. Further results showed there was no significant main effect for fundamental frequency (F0) [$F(1, 118) = 0.122$; $p = 0.727$], whereas statistically significant main effect observed for second harmonics (H2) [$F(1, 118) = 14.494$; $p = 0.000$], third harmonics (H3) [$F(1, 118) = 4.822$; $p = 0.029$] and fourth harmonics (H4) [$F(1, 118) = 7.332$; $p = 0.008$]. These findings suggest that probably their pitch encoding is intact whereas the harmonics are compromised. The differences between two groups in terms of harmonics was attributed to brainstem timing deficit in children at risk of central auditory processing disorder in comparison to typically developing children.

Keywords: Pitch Encoding; Speech Evoked ABR; CAPD; Fundamental Frequency

Introduction

Central auditory Processing [(C)AP] includes the auditory mechanisms that underlie the following abilities or skills: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal integration, temporal discrimination, temporal ordering, and temporal masking; auditory performance in competing acoustic signals and auditory performance with degraded acoustic signals [1,2]. (Central) Auditory Processing Disorder [(C)APD] refers to difficulties in the perceptual processing of auditory information in the central nervous system as demonstrated by poor performance in one or more of the above skills.

[3] estimated that auditory processing disorder occurs in 2 to 3 \% of children, with a 2:1 ratio between boys and girls. Poor temporal processing is one of the characteristics of APD and is a key component of auditory function [4]. The underlying physiological neural mechanisms for temporal processing may be assessed by behavioral and electrophysiological means. The brain response to sounds can be analyzed using electrophysiological tests. Auditory processing at sub-cortical level can be evaluated using speech evoked ABR [5,6].

The speech-evoked ABR waveforms to a syllable /da/ consist of onset and sustained responses. The onset responses are wave V, A and slope of V/A. The sustained and offset response includes wave D, E, F and wave O respectively. This frequency following response peaks are believed to involve encoding of periodicity and are prominent enough to provide reliable latency information. The sustained portion of the response is defined by its periodicity. It has been described to follow the frequency information contained in the stimulus [7]. Several studies have been carried out to see the encoding of speech stimuli in central auditory processing disorder [8], auditory based learning disorder and reading disorder [9]. They have studied the latency parameter, fundamental frequency and first formants. In spite of several studies focused towards significance of latencies of speech evoked ABR, different harmonics are not given importance. Further, there is a dearth of information in this regard. Hence the present study aimed to evaluate the Fast Fourier Transform (FFT) analysis of speech-evoked ABR in children with (C)APD [9].

Method

There were 30 children with [(C)APD] along with age matched 30 typically developing children in the age range of 10 to 14 years. Participants with normal hearing sensitivity (≤ 15 dBHL) in the frequency range of 250 to 8000 Hz, normal click evoked ABR, and normal middle ear functions were included in the study. Further, participants with peripheral hearing loss, clinically abnormal/absent click-evoked ABR, any middle ear pathology, and attention deficit hyperactivity disorder were excluded from the study.

Procedure

The study was carried out in two phases. Phase I includes basic audiological evaluation and test for [(C)APD]. A basic audiological test includes pure-tone audiometry to measure the hearing threshold [10] Immittance to rule out any middle ear pathology and click evoked ABR to rule out any retrocochlear pathology. The [(C)APD] tests include administration of Screening Checklist for Auditory Processing (SCAP) [11] and Screening Test for Auditory Processing (STAP) [12]. Phase II consisted of speech-evoked ABR, which was elicited with a 40 ms synthetic /da/ speech sound presented at an intensity of 80 dB HL. The electrode montage was involve the placement of non-inverting electrode at the Vertex (Cz), inverting electrode at the test ear mastoid (A1/A2), and the ground electrode on non-test ear mastoid (A1/A2), based on international 10/20 System. The absolute and inter-electrode impedance was maintained below 5 kΩ and 2 kΩ respectively. Speech stimulus such as /da/ contains broad spectral and fast temporal information characteristic of stop consonants and spectrally rich formant transitions between the consonant and the steady-state vowel. The fundamental frequency (F0) of the /da/ stimulus was linearly rising from 103 to 125 Hz and first formant (F1) also increases from 220 to 720 Hz. The second formants (F2) were decreases from 1700 Hz to 1240 Hz. The fourth formant (F4) and Fifth formants (F5) were kept constant at 3600Hz and 4500 Hz respectively. The voicing started at the duration of 5ms and noise burst at 10 ms. The speech-evoked ABR were recorded with filter setting of 100 Hz to 3000 Hz at repetition rate of 7.1/s. FFT analysis was done on the sustained portion of the response to measure the average spectral amplitude corresponding to the fundamental frequency and harmonics of the speech stimuli. For this purpose, Matrix Laboratory (MATLAB) software (version 7) with Brainstem Toolbox software was used [13].

Result and Discussion

Descriptive statistics includes mean and standard deviations of fundamental frequency, and harmonics. The mean of fundamental frequency were higher than other harmonics in both the groups. Further, overall mean of children with (C)APD were lesser (poorer) than typically developing children (Table 1).

Spectral analysis of speech evoked ABR were carried out using Analysis of Variance (ANOVA) to compare the difference between two groups. The result of ANOVA revealed statistically significant main effect observed for second harmonics (H_2) [F(1, 118) = 14.494; p = 0.000], third harmonics (H_3) [F(1, 118) = 4.822; p = 0.029] and fourth harmonics (H_4) [F(1, 118) = 7.332; p = 0.008]. However, no significant main effect for fundamental frequency (F_0) [F(1, 118) = 0.122; p = 0.727] were observed between two groups.

The result showed a significant difference for second, third and fourth harmonics whereas a lack of difference in fundamental frequency between groups. These results have been well supported by different researchers in children with (C)APD [8], auditory based learning difficulty [14], and children with reading difficulty [3,6] studied the spectral encoding in children with (C)APD, learning difficulty and typically developing children. They analyzed the spectral encoding in terms of fundamental frequency, first formants and high frequency. Their findings also suggested no significant difference in coding of fundamental frequency among different groups. The present findings of the study can be explained based on obser-

Amplitude (μV)	Ear	Control group (N = 30)	Experimental group (N = 30)	p-value
		Mean ± SD	Mean ± SD	
Fundamental frequency	RE	0.033 ± 0.003	0.031 ± 0.022	0.70
	LE	0.033 ± 0.003	0.031 ± 0.022	0.59
Second harmonics	RE	0.014 ± 0.005	0.010 ± 0.004	0.01
	LE	0.014 ± 0.005	0.011 ± 0.004	0.01
Third harmonics	RE	0.004 ± 0.002	0.002 ± 0.001	0.05
	LE	0.003 ± 0.001	0.003 ± 0.001	0.24
Fourth harmonics	RE	0.007 ± 0.002	0.005 ± 0.002	0.23
	LE	0.006 ± 0.002	0.005 ± 0.003	0.05

Table 1: Descriptive statistics (mean and SD) of spectral component of Speech-evoked ABRs in both groups.

RE: Right Ear; LE: Left ear; N: Number of ears; SD: Standard Deviation; μV: Microvolt; 'p': Level of significance.

vation found who noticed that the important phonetically aspect of speech have no influence of pitch and it is independent of pitch [16]. Similarly these findings have also been observed in children with auditory based learning difficulty and in children with reading disability [3,7,12]. Hence it shows that the transient portion of speech and harmonics are more important for discrimination of phoneme and pitch is not a major factor in differentiating between two phonemes. Hence poor coding of harmonics are also an indicative of neural responses are independent of pitch [17]. Abnormal encoding of transient information has also been found consistently in learning impaired children [12]. Hence the present study shows that harmonics responses play a crucial role in processing of verbal information. The responses to fundamental frequency which reflects the prosodic coding in brain-stem is independent from the phonetic information of stimulus. These findings are in agreement with other auditory based learning disorder [7].

Summary and Conclusion

The present study showed similar coding of pitch in both the group and difference in coding of higher harmonics. They have normal coding of pitch since the phonetically important component of speech signals is independent of voice pitch where as abnormal coding of higher harmonics which suggests that at higher frequencies that require more precise, rapid activation and recovery mechanisms are affected in children with (C)APD. To conclude, higher harmonics are important tools to measure using speech evoked ABR in these individuals.

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