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Gender disparity in subcortical encoding of binaurally presented speech stimuli: An auditory evoked potentials study

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ABSTRACT

Objectives: To investigate the influence of gender on subcortical representation of speech acoustic parameters where simultaneously presented to both ears.
Methods: Two-channel speech-evoked auditory brainstem responses were obtained in 25 female and 23 male normal hearing young adults by using binaural presentation of the 40 ms synthetic consonant-vowel /da/, and the encoding of the fast and slow elements of speech stimuli at subcortical level were compared in the temporal and spectral domains between the sexes using independent sample, two tailed *t*-test.
Results: Highly detectable responses were established in both groups. Analysis in the time domain revealed earlier and larger Fast-onset-responses in females but there was no gender related difference in sustained segment and offset of the response. Interpeak intervals between Frequency Following Response peaks were also invariant to sex. Based on shorter onset responses in females, composite onset measures were also sex dependent. Analysis in the spectral domain showed more robust and better representation of fundamental frequency as well as the first formant and high frequency components of first formant in females than in males.
Conclusions: Anatomical, biological and biochemical distinctions between females and males could alter the neural encoding of the acoustic cues of speech stimuli at subcortical level. Females have an advantage in binaural processing of the slow and fast elements of speech. This could be a physiological evidence for better identification of speaker and emotional tone of voice, as well as better perceiving the phonetic information of speech in women.

1. Introduction

Gender-related differences could be easily tracked in almost every stage of auditory system ranging from cochlea to subcortical and cortical auditory areas. Morphological, physiological and biochemical distinctions in intra sexes has already been the topic of an inordinate number of investigations [1–4]. Females have better hearing thresholds, higher susceptibility to noise exposure, shorter latencies in their auditory brain-stem responses, enhanced spontaneous otoacoustic emissions (SOAEs), and stronger click-evoked otoacoustic emissions than males. However, males show better sound localization, distinguish more binaural beats, and recognize signals in complex masking tasks better than females do [5,6]. With respect to electrophysiological measures at subcortical level, distinct differences for female vs. male adults have been reported. Females show earlier latencies and larger amplitudes than males do for click-evoked auditory brainstem response (ABR), a response that reflects the activation of high frequency regions of the cochlea [7,8] and mainly convey rapid acoustic information of auditory signals. However, no gender differences were detected for encoding of low frequency sinusoids that transmit slow acoustic information at brainstem level [5,9].

Simple acoustic stimuli such as clicks and puretones show poor resemblance to the behaviorally relevant sounds man confronts in real life circumstances and therefore, auditory neuroscience has transitioned to properly use complex sounds such as speech stimuli [10]. Commonly used for investigating the subcortical encoding of acoustic elements of the speech, speech-evoked auditory brainstem responses (Speech-ABR), are scalp recorded

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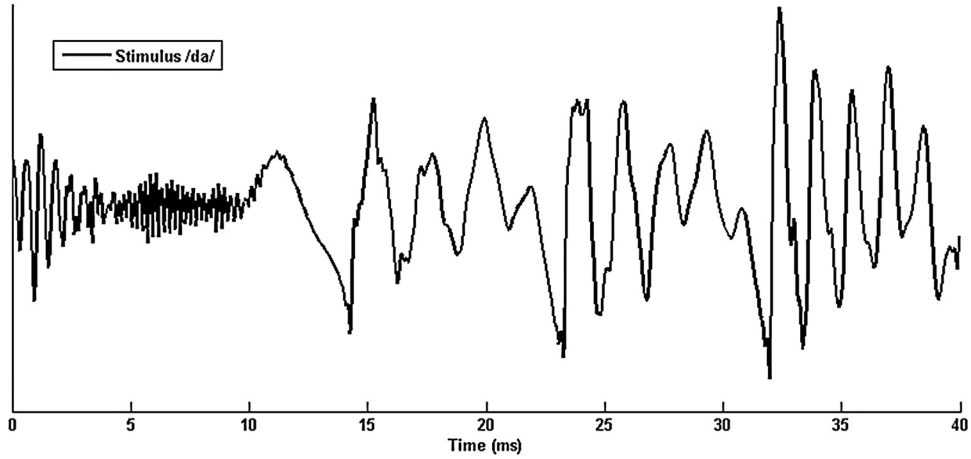

Fig. 1. Time-domain waveform of the 40 ms speech syllable /da/. This synthetic stimulus evokes seven prominent peaks in the Speech-ABR that have termed V, A, C, D, E, F and O.

neural events that are synchronously lock to acoustic elements of speech stimulus [11–13], and involve presenting a consonant-vowel (CV) speech syllable. The stimulus is made up of sharp onset burst, a brief period of formant transition, and a longer period correlated with the vowel [11]. Recent studies revealed that auditory brainstem has considerable fidelity in representing the basic acoustic features of this stimulus through highly precise spectral and temporal neural codes [10,14].

In a primal study to determine if the subcortical response to a complex auditory stimulus is encoded differently between the sexes, Krizman et al. [5] recorded the Speech-ABR to the stop consonant-vowel /da/ presented to the right ear in a normal hearing, young adult population. Their findings demonstrated gender differences in the encoding of rapid, but not slow features of speech, while females showed significantly earlier and greater response to only transient portion of stimulus compared to males. No gender-related distinction was reported in response to slower elements, indicating similar neural phase-locking between sexes [5]. Although, in real situations we usually use our two ears for listening and auditory subcortical nuclei plays an important role in binaural processing [15]. Therefore, it seems that binaural stimulation is preferred for studying the role of the auditory brainstem in encoding of the speech elements and warrants further investigation.

The current study aimed to compare the gender-related differences in brainstem encoding of the acoustic parameters of speech in response to binaural presentation of the stimulus. The authors premise was that gender has distinctive effect on encoding of rapid (high frequency) vs. slow (low frequency) components of speech. More specifically, we hypothesized that binaural presentation of speech syllables in females would lead to earlier, stronger and more robust response compared to males.

2. Materials and methods

2.1. Participants

Forty-eight volunteer students from school of rehabilitation, Iran University of Medical Sciences, 25 female and 23 male, aged 20–28 years (females: mean ± SD = 22.56 ± 1.73, males: mean ± SD = 23.00 ± 2.37), registered to initiate the experiment. None of the subjects had a history of auditory, learning or neurologic problems. All were right handed and monolingual Persian speakers by self-report. All had normal middle ear function supported by immitance findings and performed within normal limits on pure tone audiometry (Air conduction thresholds ≤20 dB HL for octave frequencies 250–8000 Hz). None of the female subjects had used oral contraceptives or underwent hormonal therapy. Subjects gave their written consent to intensively participate. All procedures were approved by deputy of research review board, Iran University of Medical Sciences.

2.2. Stimuli and recording parameters

Brainstem responses to speech sound were subject to be elicited and collected using a Biologic Navigator Pro (Natus Medical Inc., San Carlos, CA, USA). The stimuli consisted of a 40 ms synthesized stop consonant /da/ provided with the BioMARK module (Fig. 1). The syllable contains initial noise burst, a formant transition between the consonant and a steady-state vowel with a fundamental frequency (F0) that linearly rises from 103 to 125 Hz; the voicing begins at 5 ms with an onset release burst during the first 10 ms. The first formant (F1) frequency linearly 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 (F5) formants remain constant at 3600 and 4500 Hz, respectively [14,16]. For recording electrophysiological responses, the Subjects were asked to be pacifically seated in a quiet room. Using Ag-AgCl electrodes, two channels Speech-ABR were collected with Vertex (Cz) electrode as noninverting, earlobes as inverting and forehead (Fpz) as ground. During the recording session, impedance was kept below 5 kΩ and inter-electrode impedance below 3 kΩ. For each subject, Stimuli were presented binaurally through Biologic insert earphone (580-SINSER) at 80 dB SPL in alternating polarity and at a rate of 10.9 s^{-1}. A time window of 85.33 ms (including a 15 ms pre-stimulus time) and online filter setting of 100–2000 Hz were used for recording purposes. Individual traces exceeding ±23.8 μV were rejected from the average and a total of 6000 (two subaverages of 3000 sweeps) artifact free responses were obtained.

2.3. Data analysis

For each participant, the peak picking criteria stated by Krizman et al. was used [5]. The latencies of all peaks of interest were marked by first experimenter and consequently verified by second author. The speech-ABR comprises of a series of seven peaks, including the onset (V and A), onset of voicing (C), frequency following response (FFR) (D, E and F) and finally offset (O) peaks. For analyzing the response waveform, the timing and magnitude of both the discrete peaks and FFR aspects were evaluated. Composite