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Electrophysiological and phonological change detection measures of auditory word processing in normal Persian-speaking children

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ABSTRACT

Objective: Auditory phoneme discrimination is a basic and important prerequisite for acquiring speech, reading, and spelling skills. Children, who are unable to perceive auditory phoneme discrimination, cannot develop phonemic representations. Therefore, the early identification of these deficits and application of effective therapeutic approaches is a necessity. We need to assess appropriately word or sound discrimination in normal populations using an objective passive task such as mismatch negativity (MMN). Therefore, the aim of the present study was to investigate MMN responses using speech stimuli (words) in 6–7 year-old normal Persian-speaking children.

Methods: Ten right-handed Persian-speaking children with normal visual and auditory acuity, aged from 6 to 7 years, participated in the study. Recording of electroencephalography (EEG) was done by 64 A g/AgCl electrodes. A new auditory paradigm was used with three deviant stimuli (/gam/,/jam/, and/tam/) which differed in the first consonant from a repeated standard word (/dam/). A total of 1500 stimuli, 750 standards and 750 deviants (250 each deviant), were presented by Cogent 2000 running in MATLAB software using two loud speakers.

Results: MMN peaked over the fronto-central sites at around 380–424 ms after the onset of the stimulus. The comparison of the MMN amplitudes elicited by three deviants revealed a significant "initial phoneme type" effect in Fz and Cz ($p < 0.05$). This negativity was found to be larger for manner and voicing deviants compared with that of the place of articulation ($p < 0.001$) on midline scalps. The comparison of the MMN latencies revealed no significant main effect of all variables ($p > 0.05$). Also, the results revealed that only the MMN amplitude for the/gam/deviant correlated with the percentage of correct responses ($R = -0.86$, $p < 0.01$).

Conclusion: The current study showed that words can elicit MMN responses in ~200 ms after the onset of changes. We can objectively evaluate children's neural speech sound discrimination using the developed paradigm in a natural word context. This paradigm can be useful objectively for investigating distinctive features of sounds and phonological discrimination development in normal children.

1. Introduction

Auditory phoneme discrimination is a principal section of phonological processing [1,2] as poorly phonemic representations may lead to deficits in the ability to segment phonemes, and in acquiring the relationship between graphemes and phonemes [3]. Many children with speech and language impairments such as specific language impairment (SLI), speech sound disorders (SSD), and hearing loss (HL) have problems in auditory phoneme

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representation [4,5]. Therefore, the early identification of these deficits and application of effective therapeutic approaches is a necessity.

Behavioral tasks had previously been used most commonly in investigating auditory phonemic discrimination abilities in normal and clinical populations [3]. These tasks often include words that are presented in pairs with acoustic or phonological differences that require active attention to tasks, the instruction, and a verbal or motor response [3]. However, children with different speech and language impairments often show difficulties in accomplishment of these demands [3]. Therefore, appropriate assessment of word or sound discrimination in normal and clinical populations should include a passive task in which no motor or verbal response, instruction, or active attention is needed [3].

Evoked Response Potentials (ERPs) is a value tool for examining the microstructure of speech and language processes and also a suitable diagnostic method for passive assessment of auditory and phonemic discrimination [2,6]. An ERP component often used for investigating auditory discrimination in a passive task is the mismatch negativity (MMN) [6]. The MMN is elicited when sudden acoustic changes occur in stimulation, often created by deviant stimuli [6]. MMN probably reflects pre-attentive levels of information processing and sensory analysis of auditory input and its encoding into memory trace [7,8]. The MMN response is likely generated by a mismatch process between the auditory sensory input from a deviant stimulus and a neural sensory-memory trace representing the physical features of the standard stimulus [7,9]. Therefore, the MMN opens the unique possibility to objectively measure the central presentation of auditory discrimination, sensory memory and involuntary attention [7]. The most generators of MMN are temporal and frontal areas of topographic scalp maps [6]. It seems that the brain reactions to speech sounds discrimination can effectively predict their later language development [6,10]. Thus, MMN may provide a new diagnostic method for early identification of developmental language and literacy disorders.

The MMN is elicited by both non-speech and speech stimuli, and it has been shown to be of greater magnitude if the speech sounds belong to the native language of the listener [11,12]. Further, recording of MMN from subjects with difficulties in phonological processing may reveal different profiles of central auditory processing for speech and non-speech sounds [13,14]. Partanen et al. [15] noted that speech discrimination studied in children using pure tone, single syllables and vowels cannot successfully indicate change detection in a natural word context, because former and latter sounds of words can influence on central auditory processing. Some studies, in different languages, investigated central auditory phonological processing using speech stimuli beyond phonemes and syllables in normal children and papulations with speech, cognitive and language disorders. For example, Korpilahtli et al. [16] reported MMN responses using complex tone, pesodowords and words in 10 normal children aged from 4 to 7 years. Strong MMN for words ([tu:li] vs [tuli]) obtained about 400 ms after stimuli onset. MMN waveform for pseudowords ([tu:ni] vs [tuni]) was observed to be weaker than that for words. Wehner et al. [17] compared the brain activation patterns of 7–13 year-old normal and impaired readers on speech perception using whole-head magnetoencephalography (MEG) by an auditory word discrimination task. They used from the three deviant stimuli (/bat/,/kat/,/rat/) which are different in the degree of phonological contrasts (one versus three features) from those of a repeated standard word (/pat/). All children responded slowly to deviants that were phonologically very much similar to the standard word. In another study, Ludlow et al. [18] investigated auditory change detection in 11 children with Autism Spectrum Disorder (ASD) and 11 normal boys in order to determine event-related potentials to meaningless ([bajp] and [pajt]) and meaningful ([bajt]/bite/and [pajp]/pipe/) speech stimuli. The results revealed that compared to controls, the children with ASD showed significantly reduced MMN responses to both words and pseudowords in the frontal regions of the brain. It seems that particularly in children, early MMN that peaked in 100–250 ms after stimuli onset can be followed by a late MMN peaking between 400 and 500 ms with word stimuli [16]. Other studies investigating 5-8 year-old children reported MMN peak latencies between 190 and 270 ms for frequency deviance [19–23] and between 180 and 350 ms using phoneme or word deviance [16,24,25]. Despite these investigations, there is no firm conclusions about MMN latencies in words.

Although there are many studies accomplished about the neuronal bases of auditory discrimination in normal children and clinical populations, but studies used from complex speech stimuli such as words with minimal sets and sentences via an electrophysiological technique are rare especially in children with other languages. Therefore, in the present study, we used form the Persian words differed in the initial phoneme by one phonetic feature (placement, manner or voicing). Due to the complexity of central auditory processing functions and speech comprehension processes, usage of speech stimuli such as words/sentences can be helpful in identification of cortical malfunctions. Therefore, the present study aimed at characterizing spatiotemporal scalps in brain activation related to the phonological processing of Consonant-vowel-consonant (CVC) stimuli in 6–7 year-old normal Persian-speaking children during auditory perception of deviant words that differed in the phonological contrasts from those of a repeated standard word.

2. Methods

2.1. Participants

Ten right-handed Persian-speaking children (5 girls and 5 boys), with normal visual and auditory acuity and no history of neurological and psychological disorders, aged from 6 to 7 years ($M = 6.2$; $SD = 0.058$) participated in this study. The nonverbal intelligence with Goodenapgh test of the all participants was in range of normal ($IQ > 90$). The consent form approved by all parents. All children were monolingual and had Persian as their primary language. The study was approved by the Ethical Committee of the Iran University of Medical Sciences (Code number: 94/d/105/5123).

2.2. Stimuli

Three native Persian speakers (one female, two males) produced four words [/dam/(trap),/gam/(stride),/jam/(cup), and/tam/(full)] several times (10 times) at a 44.1 kHz sampling rate with neutral intonation in a sound treated room. All records were edited in Audacity software and listened to by three experts (one linguist and two speech and language pathologists). The four words that had perceptually the most similarity to each other and were the best tokens for each speaker's speech, were selected by as experimental stimuli. Finally, tokens produced by the female speaker were selected as final stimuli.

For controlling of the acoustic differences between the stimuli, we used from the PRAAT analyzer software [26]. Duration of standard stimuli was 406 ms and duration of three deviants (/gam/ ,/jam/, and/tam/) were 406, 436, 470 ms respectively. Duration differences between standard stimuli and two deviants (/jam/, and/ tam/) existed because of affricative manner of articulation of/j/ consonant (noise duration: 36 ms) and voice onset time (VOT) of/t/ and/d/consonants (+110 ms vs −10 ms, respectively). Also, place of articulation of initial consonant was different in standard stimuli