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The effects of aging on early stages of the auditory deviance detection system

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HIGHLIGHTS

- This study examined the effects of aging on early auditory deviant-related responses.
- No evidence of deviance detection was observed in the middle-latency range in the aged subjects.
- Results suggest that regularity encoding ability, at early and late stages, declines with age.

ABSTRACT

Objective: The aging effects on auditory change detection have been studied using the Mismatch Negativity (MMN) potential. However, recent studies have found earlier correlates of deviance detection at the level of the middle-latency response (MLR) and the effects of aging on this deviant-related response have not yet been clarified. The purpose of this study was to examine the effects of aging on both levels of the auditory deviance detection system.
Methods: MMN and MLR responses were recorded in 33 young and 29 older adults from 32 scalp electrodes during frequency oddball and swapped-oddball conditions.
Results: In the young group, modulation of MLR and a clear MMN response were observed, whereas in the aged group, no evidence of deviance detection was found at the level of MLR and the MMN amplitude was significantly diminished.
Conclusions: Based on the obtained results, aging affects both levels of the auditory deviance detection system which seems to be a result of deficits in regularity encoding along the auditory hierarchy.
Significance: The current findings suggest that age-related physiological changes result in deficits in regularity encoding, starting from early stages of processing. This might eventually affect stream segregation and induce difficulties in understanding speech in complex environments.
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1. Introduction

The ability of the auditory system in extracting acoustic regularities and signaling deviance detection is critical for survival as it enables fast processing of novel events and preparing the organism to react quickly to potentially significant stimuli. Moreover, these two functional properties underlie the formation and

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segregation of auditory objects, which are necessary for solving the cocktail party problem and understanding speech in complex and noisy environments.

Findings from a recent series of studies suggest that pre-attentive auditory deviance detection includes two stages of processing: an earlier stage, in the time range of the Middle-Latency Response (MLR) of the auditory evoked potential, and a higher stage, in the time range of mismatch negativity (MMN; (Aghamolaei et al., 2016). In support of differential roles of these two levels, several studies have revealed that simple deviations in basic acoustic features such as frequency (Slabu et al., 2010; Grimm et al., 2011; Alho et al., 2012; Leung et al., 2012), location (Cornella et al., 2012; Grimm et al., 2012), intensity (Althen et al., 2011) or temporal features (Leung et al., 2013) result in the modulation of MLR components, whereas detection of complex acoustic deviations, such as feature conjunctions (Althen et al., 2013), sequential patterns of sounds (Recasens et al., 2014) and tone alterations (Cornella et al., 2012), occurs only at the higher stage of deviance processing in the time range of MMN. The anatomical dissociation between these stages of deviance processing has also been documented in a MEG study, in which deviance-related MLR modulations originated from lower cortical regions compared to the MMN origins (Recasens et al., 2012).

Physiologic aging is associated with changes in brain processes resulting in a general cognitive decline. This cognitive decline, along with the effects of aging on different levels of the auditory system could have adverse effects on auditory change detection and might account for the difficulties that elderly persons have in processing complex auditory scenes. The effects of aging on automatic auditory change detection have been studied mostly by means of MMN. In some of these studies, older adults have been found to have smaller MMN amplitude than young adults (Czigler et al., 1992; Alain and Woods, 1999; Gaeta et al., 2001; Cooper et al., 2006) while in other studies, young and older adults displayed similar MMN amplitudes (Pekkonen et al., 1996; Amenedo and Dıaz, 1998a; Mueller et al., 2008). According to the recent evidence on the existence of a hierarchical deviance detection system at multiple levels of the auditory hierarchy, it can be assumed that the aging effects on auditory change detection processes might be prevalent also at the lower levels of auditory processing. In fact, aging affects the earlier afferent cortical responses leading to an enhancement of MLR amplitudes in older adults as a result of deficient central inhibition of subcortical auditory structures (Woods and Clayworth, 1986; Azumi et al., 1995; Amenedo and Díaz, 1998b; Yamada et al., 2003). However, to the best of our knowledge, no study has investigated to date the effects of aging on early deviance-related responses. In the present experiment, the effects of aging on early and late auditory deviant-related responses were examined using a frequency oddball paradigm.

2. Materials

2.1. Participants

Thirty-three healthy young adults (mean age: 24.7 ± 3.4; fifteen men; all right-handed) and twenty-nine healthy older adults (mean age: 67.5 ± 3.5; fifteen men; all right-handed) took part in the study after giving written informed consent. The study was approved by the Ethics committee of Tehran University of Medical Sciences (Tehran, Iran). The young individuals were university students who received monetary compensation for participating in the study, and the elderly were recruited from retirement clubs and cultural centers and were compensated for their travel costs. All subjects had hearing thresholds below 20 dB HL in the frequency range of 500–4000 Hz and reported no history of neurological or psychiatric disorders, family history of schizophrenia and drug or alcohol abuse. None of them had cognitive impairment based on the Persian version of Mini-Mental State Examination (MMSE) questionnaire with the cutoff 21 (mean MMSE scores: 29.42 ± 0.70 for the young and 27.77 ± 1.08 for the aged group) (Foroughan et al., 2008) and none were taking medications that affect the central nervous system; no one had formal musical training. Originally, thirty-three older adults and thirty-five young adults were studied from which six were excluded from final analyses due to excessive noise, technical problems during the EEG acquisition or subjects' wish to abort the measurement session. The older adults were matched in gender and educational level with the young group.

2.2. Stimuli and procedure

Participants were seated in a sound-attenuated room and watched a silent movie with subtitles. They were asked to ignore the sounds presented binaurally through insert earphones (ER-3A, Etymotic Research, Inc., Elk Grove Village, IL). The experiment consisted of eight oddball blocks and two swapped-oddball blocks. Within the oddball blocks, a repetitive 1200 Hz tone-burst of 50 ms duration and 5 ms rise/fall time was presented as the standard stimulus (probability = 0.8), and an 800 Hz tone-burst occurred randomly (probability = 0.2) as the deviant stimulus, with the restriction that at least two standard stimuli preceded each deviant. The stimuli were presented at 70 dB SPL with an SOA of 300 ms. The swapped blocks were applied to allow the comparison of brain potentials elicited to identical physical stimuli in the role of standard and deviant, precluding feature-specific processing effects. Hence, the standard and deviant stimuli of the oddball blocks were switched, so that the 800 Hz tone was presented as standard stimulus and the 1200 Hz tone as deviant stimulus. All blocks were mixed and presented in random order. Each block consisted of 600 standard and 150 deviant stimuli. In total, 1200 deviant and 1200 swapped standard stimuli were presented.

2.3. EEG recording

The EEG was recorded from 32 Ag/AgCl scalp electrodes set in an elastic cap (Waveguard, ANT, Netherlands) according to the international 10–20 system at the positions of FP1, FPz, FP2, Fz, F3, F4, F7, F8, FC1, FC2, FC5, FC6, Cz, C3, C4, T7, T8, CP1, CP2, CP5, CP6, Pz, P3, P4, P7, P8, POz, Oz, O1, O2, A1 and A2. All the electrodes were referenced to an electrode positioned on the tip of the nose. Two bipolar electrodes were placed above and below the right eye (Vertical electrooculogram, VEOG) and two electrodes at the outer canthi of each eye (horizontal electrooculogram, HEOG) to measure eye movements. All electrode impedances were maintained below 5 kΩ. A 64-channel amplifier (ANT, Enschede, Netherlands) was used to amplify EEG signals. EEG signals were online bandpass-filtered from 0.05 to 500 Hz and recorded at a sampling rate of 2048 Hz using ASA 4.7.1 software (ANT, Enschede, Netherlands).

2.4. EEG analysis

For MLR analysis, raw EEG data was filtered using a band-pass filter of 15–200 Hz and re-referenced to the linked mastoids. Eye blinks, movement and myogenic artifacts were removed using independent component analysis (ICA); (Delorme and Makeig, 2004; Delorme et al., 2007). The data was segmented into epochs of 150 ms, ranging from −50 to 100 ms relative to sound onset and averaged separately for deviant and swapped-standard stimuli. All artifactual epochs with voltage changes exceeding ±50 μV were rejected from the averages. The components of MLR including

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