Noise sensitivity modulates the auditory-cortex discrimination of sound feature changes

Marja HEINONEN-GUZEJEV[1]; Marina KLYUCHKO[2]; Kauko HEIKKILÄ[1]; Vittoria SPINOSA[2]; Mari TERVANIEMI[2]; Elvira BRATTICO[3]

[1] University of Helsinki, Hjelt Institute, Department of Public Health, Finland

[2] University of Helsinki, Cognitive Brain Research Unit (CBRU), Finland

[3] University of Helsinki, Cognitive Brain Research Unit (CBRU) & Aalto University, Brain & Mind Laboratory, BECS, Finland

ABSTRACT

Noise sensitivity refers to physiological and psychological internal states of any individual, which increase the degree of reactivity to noise. There are only few studies on the neural mechanisms underlying noise sensitivity. Mismatch negativity (MMN) is a component of the auditory event-related potential (ERP), generated in the supratemporal lobe of the brain, that is elicited by any discriminable change in some repetitive aspect of the ongoing auditory stimulation. In this study, we recruited 61 healthy adult subjects (age range 19-46 years) and measured their MMN to several sound feature changes inserted in a music-like sequence and administered the noise sensitivity questionnaire. With the help of this method we studied how the neural discrimination of sound changes (as indexed by MMN) is associated with noise sensitivity (as indexed by the questionnaire). The results showed that noise sensitivity had an influence on MMN to sound changes in timbre, with lower MMN responses in individuals with high noise-sensitivity scores than in those with low noise-sensitivity scores. According to the literature available this is the first study on this topic.

Keywords: Noise Sensitivity, Mismatch Negativity (MMN)   I-INCE Classification of Subject Number 61

1. INTRODUCTION

Noise sensitivity, predictor of noise annoyance (1) is a stable personality trait covering attitudes to noise in general (1, 2). It refers to physiological and psychological internal states of any individual, which increase the degree of reactivity to noise in general (3). Noise sensitivity is a common trait and the percentage of noise-sensitive persons has varied between 20% and 43% in previous studies (4). Noise sensitive individuals have a predisposition to attend to sounds and to perceive them negatively and they display stronger emotional reactions to noise. Noise sensitivity has not been associated with auditory acuity (1, 5, 6, 7).

Noise sensitivity increases the harmful health effects of noise (8, 9). It has been associated with both poor somatic and mental health and poor sleep quality (9, 10). Noise may prevent individuals with high noise sensitivity from achieving the same work results compared to less sensitive individuals leading to psycho-somatic, neurotic and other difficulties while individuals with lower noise sensitivity may be expected to better adapt to noise during mental performance (11).

The mismatch negativity (MMN) is a negative component of the auditory event-related potential (ERP), which is usually peaking at 100–250 ms from stimulus onset. It is elicited by any discriminable change in some repetitive aspect of the ongoing auditory stimulation irrespective of the direction of the subject's attention or task (12, 13).

Subjects continuously exposed to noisy auditory environments but without a peripheral damage

[1] marja.heinonen@helsinki.fi

may have subpathological changes in cortical responses to sounds. For instance, a pioneering study showed that in control subjects the (MMN) was larger to non-speech than speech sounds, while it did not differ between the sound types in the noise-exposed subjects (14). In exposed workers the MMN to speech sounds was lateralized to the right hemisphere, while in control subjects it was left-hemisphere predominant. Thus, long-term noise exposure altered the strength and the hemispheric organization of speech-sound discrimination and decreased the speed of sound-change processing.

Speech and non-speech sounds are processed differently both in silent and noisy conditions according to the MMN results, whereas there are no effects of stimuli or noise on the behavioral responses. Speech processing is more affected than non-speech processing in all noise conditions. Different noise types have a differential effect on the pre-attentive discrimination, as reflected in MMN, on speech and non-speech sounds. Babble and industrial noises dramatically reduce the MMN amplitudes for both stimulus types, while traffic noise affected only speech stimuli (15).

Stryrov et al. (1998) found that in silence MMNm to speech stimuli, registered from the auditory cortex, is stronger in the left than in the right hemisphere. When speech signals are presented in white noise background, MMNm in the left hemisphere diminishes while that in the right hemisphere increases in amplitude and dipole moment. Thus, in silence, speech signals are mainly discriminated in the left hemisphere's auditory cortex. However, in noisy conditions the involvement of the left hemisphere's auditory cortex in speech discrimination is considerably decreased, while that of the right hemisphere increases (16).

The aim of this study was to determine how the neural discrimination of sound changes (as indexed by MMN) is associated with noise sensitivity (as indexed by the questionnaire).

2. MATERIALS AND METHODS

2.1 Subjects

Subjects were 61 healthy adults. The age range was from 19 to 46 years. Data of all 61 subjects were used for MEG analysis, and 57 were accepted for EEG analysis.

2.2 Noise sensitivity questionnaire

Noise sensitivity was studied using the Weinstein’s Noise Sensitivity Scale (17). It consists of 21 items, which were presented on a 6-point scale rating from “agree strongly” [1] to “disagree strongly” [6]. Several items are scored in opposite direction before responses are summed and those items were scored in opposite direction.

2.3 The MEG/EEG recordings

The MEG/EEG recordings were performed at the BioMag Laboratory, HUSLAB, Helsinki University Central Hospital (HUCH) (Picture 1).

We measured MMN to several sound feature changes inserted in a music-like sequence and administered the noise sensitivity questionnaire. With the help of this method we studied how the neural discrimination of sound changes (as indexed by MMN) is associated with noise sensitivity (as indexed by the questionnaire).

Picture 1 – The MEG/EEG recordings were performed at the BioMag Laboratory

2.4 Data analysis

MEG/EEG data were preprocessed with BESA Research 6.0 Software (BESA GmbH, Munich, Germany). For EEG preprocessing after a visual inspection any channels with noisy signal were replaced by interpolating the data of the surrounding channels. The data were further processed by an automatic eye-blink correction. Any artifacts were removed automatically using ±100 µV rejection threshold for EEG data and 1200 fT/cm for MEG data. Thereafter the EEG and MEG responses were epoched time-locked to the stimulus onset and baseline corrected. The epochs were 500 ms long including 100 ms of baseline prior to the stimulus onset. The data were averaged according to the stimulus type. The resulting ERP waveform for standard stimulus was subtracted from each deviant ERP. The resulted difference waveforms were analyzed in order to define MMN peak. Then, the latency and the mean amplitude of MMN (±20 ms centered at the peak) were extracted. For the statistical analysis the brain responses were tested with ANOVA, where MMN amplitudes at selected channels were used as dependent variables, with the score on noise sensitivity scale as a co-factor. Post hoc comparisons were done with Least Significant Different test.

3. RESULTS

The results showed that noise sensitivity had an influence on MMN to sound changes in timbre, with smaller MMN responses in individuals with high noise-sensitivity scores than in those with low noise-sensitivity scores. The MMN latency to the rhythm deviant recorded at Fz electrode correlated with noise sensitivity, meaning that higher noise sensitivity corresponded to the faster MMN to the rhythm change.

4. DISCUSSION

This study shows that that noise sensitivity has an influence on MMN to sound changes in timbre, with smaller MMN responses in individuals with high noise-sensitivity scores than in those with low noise-sensitivity scores. Noise sensitivity is affecting the MMN response and the cortical sound discrimination process underlying its elicitation.

A recent EEG (electroencephalogram) study showed in noise sensitive participants a tendency to be aroused by noise easily regardless of the magnitude of annoyance while non-noise sensitive were aroused only at the presence of most annoying sounds indicating a difference in processing. In addition a protective effect against noise was found among non-noise sensitive participants (18). In that study MMN was not investigated.

According to available literature the current study is the first study investigating noise sensitivity and MMN. More studies are needed to investigate the neural mechanism of noise sensitivity.

5. CONCLUSIONS

Noise sensitivity has an influence on MMN to sound changes in timbre, with smaller MMN responses in individuals with high noise-sensitivity scores than in those with low noise-sensitivity scores.

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