Profiling the central auditory processing of speech sounds: a MMN multifeature study

Maria Ioanna Zavogianni[1,2], Ferenc Honbolygó[1,3]
[1]Brain Imaging Centre, Research Centre for Natural Sciences, Hungary
[2]Multilingualism Doctoral School, University of Pannonia, Hungary
[3]Institute of Psychology, ELTE Eötvös Loránd University, Hungary
https://doi.org/10.36505/ExLing-2021/12/0067/000540

Abstract

Multifeature paradigms record fast Mismatch Negativity (MMN) ERP responses and investigate the central auditory processing. Our speech multifeature paradigm included changes in vowel, consonant, word stress, frequency and intensity. We investigated adults' involuntary discrimination of speech sound features which are phonetically or acoustically altered. Participants watched a film without sound while pseudowords were presented through headphones. The deviants elicited MMN responses with different amplitudes. The vowel and consonant elicited the largest MMNs, while the intensity and pitch deviants the smallest. Word stress deviants elicited a double negativity. This multifeature paradigm could be utilized to record MMN, and allows to apply the MMN as assessment tool for profiling the central auditory processing of speech sounds.

Keywords: MMN, multifeature paradigm, speech, central auditory processing

Introduction

The Mismatch Negativity (MMN) is an Event-Related Potential (ERP) component which is elicited in an auditory environment. According to Näätänen et al. (2007), the MMN is evoked by a detectable change (i.e., a 'deviant' stimulus) during the presence of regular features (i.e., a 'standard' stimulus). The experimental design which records MMN responses is the speech multifeature paradigm, during which one 'standard' stimulus and several 'deviant' stimuli are presented (Pakarinen et al., 2009). Previous studies have applied the multifeature paradigm with focused alterations on the phonetic or acoustic parameters of the syllables of the certain stimuli; these studies reported that all changes in the sound stimuli allowed the statistically significant elicitation of the MMN responses (Pakarinen et al., 2009; Pakarinen et al., 2013). The aim of our study was to investigate the MMN correlates of speech sound processing in a paradigm that allows the fast recording of ERP responses to different kind of speech features.

In the current study, we constructed a multifeature paradigm with one standard stimulus and five deviant stimuli with phonetic (i.e., vowel, consonant, prosody) or acoustic (i.e., frequency and intensity) changes. This study is the first to involve a change in prosody to the multifeature paradigm. We expected to find that these speech sound features were detectable in an involuntary manner.

Materials and methods

Participants

Twenty-five native Hungarian speakers (14 female) participated in our study. Their mean age was 25 years (SD: ± 5.6, range: 19-38); none of them reported any neurological issue, hearing or speech-related issue.

Stimuli and procedure

The stimuli were CVCV pseudowords. The standard stimulus was a four-syllabic Hungarian pseudoword (/ˈkeke/). The deviant stimuli were formulated through the alterations to the standard stimulus at the first syllable. The deviants consisted of a vowel (/ˈkike/), a consonant (/ˈpeke/) and a stress deviant, where the stress was on the second syllable (/ˈkeke/); additionally, the deviant stimuli consisted of a frequency (F0 ±8%) and an intensity deviant (±6 dB).

Stimuli were presented in a multifeature paradigm with a stimulus onset asynchrony (SOA) of 750 ms. Participants were auditorily presented with 315 standard and 300 deviant stimuli; the experiment began with fifteen standard stimuli and the deviants were randomly presented to participants. During the EEG experiment, participants were required to listen to the stimuli while watching a movie with no sound, which they were asked not to be attentive to. The total duration of the recording time was 17 min.

EEG Recording and data analysis

The EEG was recorded using a 64-channel recording system (BrainAmp amplifier and BrainVision Recorder software, BrainProducts GmbH). The sampling rate was 1000 Hz and electrode Fz was used as a reference. The EEG data were analysed with Brain Vision Analyzer. To test the significant appearance of the MMN component, one-sample t-tests were performed between 176 and 500 ms from the deviation onset at Fz electrode; difference curves of the ERP waveforms were calculated by subtracting the ERPs of the standard condition from the ERPs of the deviant condition.

Results

All deviant conditions elicited significant MMN peaks (Figure 1) in different time windows. A detailed statistical description of the ERP results can be found in Table 1.

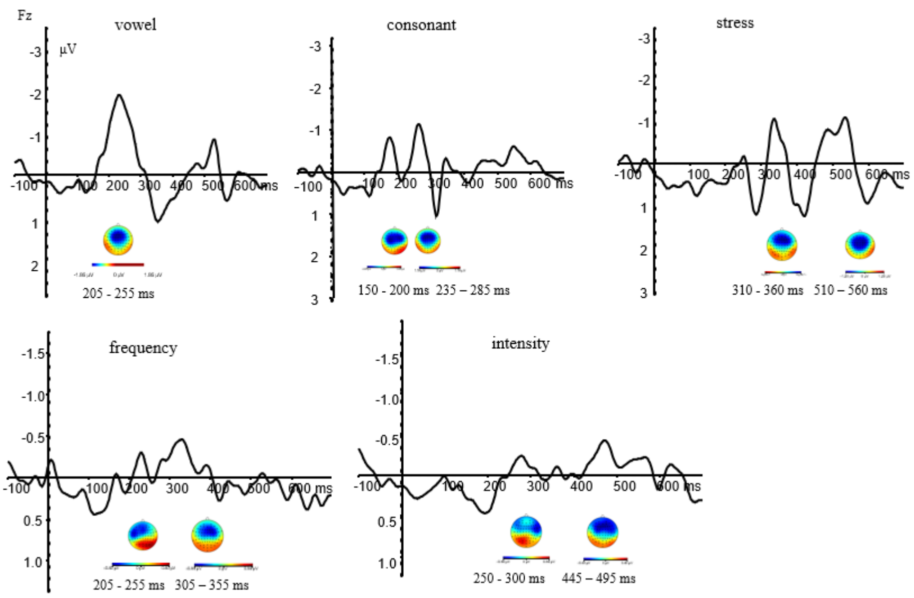

Figure 1. Deviant -standard subtraction waveforms for the five deviant conditions(vowel, consonant, stress, frequency, intensity) at Fz electrode.

Table1. One-sample t-tests of the EEG difference curves.

Conditions	Time windows	Mean	Confidence Interval		t
			Lower	Upper	
vowel	205-255 ms	-1.66	-1.96	-1.35	-11.16***
early consonant	150-200 ms	-.529	-.86	-.19	-3.28**
late consonant	235-285 ms	-.79	-1.22	-.36	-3.80**
early stress	310-360 ms	-.61	-.95	-.26	-3.64**
late stress	510-560 ms	-.81	-1.09	-.52	-5.81***
early pitch	205-255 ms	-.14	-.45	.17	-.92 n.s.
late pitch	305-355 ms	-.37	-.61	-.13	-3.22**
early intensity	250-300 ms	-.16	-.47	.16	-1.02 n.s.
late intensity	445-495 ms	-.33	-.53	-.12	-3.28**

Note: $^{**}p < .01$. $^{***}p < .001$. n.s.: non significant

Discussion

The results showed that all conditions elicited MMN responses, each of which were shown at different time windows. Like in previous studies (Pakarinen et al., 2009), vowel and consonant deviants elicited the most significant MMN responses; these stimuli facilitated the auditory processing of the participants since they could discriminate them in a more significant way than the rest of the stimuli. Furthermore, as previously reported, the stress deviant elicited a double negativity. Pitch and intensity deviants did not evoke significant MMN responses at the early time windows, a finding which is inconsistent with previous literature (Pakarinen et al., 2009; Pakarinen et al., 2013). Pitch and intensity alterations might not be as detectable by Hungarian speakers as by Finnish. The significant activation of the late time windows indicates the activation of later cognitive processes. To conclude, our speech multifeature paradigm can be applied to the investigation of adults' central auditory processing; it can also provide a further insight to underlying deficits (e.g., phonological processing) of reading disorders.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant agreement No.813546.

References

Näätänen, R., Paavilainen, P., Rinne, T., Alho, K. 2007. The mismatch negativity (MMN) in basic research of central auditory processing: a review. Clinical neurophysiology, 118(12), 2544-2590.

Pakarinen, S., Lovio, R., Huotilainen, M., Alku, P., Näätänen, R., Kujala, T. 2009. Fast multi-feature paradigm for recording several mismatch negativities (MMNs) to phonetic and acoustic changes in speech sounds. Biological psychology, 82(3), 219-226.

Pakarinen, S., Teinonen, T., Shestakova, A., Kwon, M. S., Kujala, T., Hämäläinen, H., Näätänen, R., Huotilainen, M. 201). Fast parametric evaluation of central speech-sound processing with mismatch negativity (MMN). International Journal of Psychophysiology, 87(1), 103-110.