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Unifeature vs. multifeature oddball and magnitude of deviance effects on the mismatch negativity

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Abstract

The mismatch negativity (MMN) is commonly studied in oddball paradigms comprising only one deviant. Recently, multifeature oddball paradigms comprising multiple deviants have been developed and might represent a valuable tool in clinical assessment where time is a limiting factor. This study addressed whether (1) duration MMNs elicited by physically identical stimuli differ between a unifeature vs. multifeature oddball paradigm, and (2) the magnitude of the standard vs. deviant difference would affect the MMN amplitude. Event-related potentials were recorded in 26 healthy participants who listened to three oddball paradigms (two unifeature, one multifeature). Results showed that (1) duration deviants elicited larger MMNs in the multifeature oddball, and (2) MMN amplitudes increased with increasing deviant-minus-standard distance in terms of the target stimulus feature. Taken together, duration oddballs elicit reliable MMNs in multifeature paradigms and may therefore represent a valuable tool in clinical settings.

1 Introduction

The mismatch negativity (MMN) is frequently used to investigate discrimination skills and residual cognitive functioning in patients with disorders of consciousness (DOC). These results may then serve as a basis for the future application of a brain-computer interface (BCI). Traditionally, the MMN is studied in auditory oddball designs using a secondary task to prevent elicitation of an N2b contaminating the MMN effect. It peaks between 150 and 250 ms (Duncan et al., 2009). Typical paradigms comprise one standard and one rare deviant, thus focusing on only one feature of auditory stimuli. However, attention span of DOC patients is short, so paradigms have to be brief, with a maximum on information, but at the same time allow for a reliable detection of MMNs in single subjects. Using oddball paradigms comprising several deviant tones in various dimensions may be a promising tool to record event-related potentials (ERPs) in response to more than one deviating stimulus within a short period of time. These multifeature oddball paradigms were first developed by Näätänen, Pakarinen, Rinne, and Takegata (2004) whose tone sequence comprised deviants in five different dimensions: frequency, intensity, location, duration, and a silent gap in the middle of a tone. They found MMN responses in the multifeature paradigm to be as large as in the traditional unifeature oddball, which was also supported by (Pakarinen et al., 2009).

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With this study we addressed whether (1) the MMNs elicited by physically identical stimuli differ as a function of paradigm uni- vs. multifeature oddball), and (2) the amplitude of the MMN increases with the increasing deviant-minus-standard distance (DSD) in terms of the target stimulus feature in three different dimensions (frequency, intensity, and duration).

2 Methods

Event-related potentials were recorded in 26 healthy participants (mean age = 34.1 years, SD = 9.9, 14 females). EEG was recorded with a 32 active electrodes system (gTec, Graz, Austria) with a sampling frequency of 512 Hz. The data were filtered online between 0.1 to 100 Hz (butterworth). The paradigms were presented while participants watched a silent movie and were required to press a key when a certain scene appeared. A scale for subjectively experienced effort ranging from 0 to 220 (Eilers, Nachreiner, & Hänecke, 1986) was administered after each paradigm.

Auditory stimulation was realized in three different paradigms. All paradigms shared the same harmonic tone as standard with 500+1000+1500 Hz, 75 ms duration (rise/fall 5 ms) and an intensity of 70dB. The paradigms used were the following: (1) a duration oddball called MMNAbsolut comprising 900 standards and 100 odds differing in duration (50 ms), (2) a second duration oddball paradigm called MMNProportion comprising 900 standards and 100 odds differing in duration as well (37 ms) and (3) a multifeature oddball called MMNMultifeature with 600 standards and 600 deviants varying in three dimensions: duration, frequency, and intensity. The deviants in the multifeature paradigm were 37 and 50 ms in the duration domain, 450+900+1350 and 400+800+1200 Hz in the frequency domain, and 65 and 60dB in the intensity domain. Stimulus onset asynchrony was 500 ms in all paradigms.

Offline, the EEG data were band-pass filtered between 0.1 and 25 Hz, automatic artefact correction was performed, and segments from 0 to 500 ms were averaged. Finally, grand averages were obtained. For all calculations, mean amplitudes under the curve for the electrode Fz were entered into analyses. All analyses were carried out in MATLAB (The Math Works, Inc., M.A.), statistics were calculated in SPSS 17.0 (SPSS Inc., IL). Relevant time windows for component analyses in all paradigms were defined by visual inspection and set to 120 to 245 ms post-stimulus in all paradigms.

3 Results

Results were obtained in repeated measures ANOVAs including the factors paradigm (unifeature vs. multifeature), DSD (small vs. large), and deviant type (duration, frequency, intensity).

3.1 Subjective effort

Ratings for subjective effort did not vary according to the paradigm ($F(2, 56) = .165$, $p = .848$). Thus, listening to the various paradigms was judged to be equally effortless ($M_{MMNAbsolut} = 57.58$, $SD = 42.81$, $M_{MMNProportion} = 53.79$, $SD = 38.62$, $M_{MMNMultifeature} = 54.39$, $SD = 45.52$).

3.2 Physiological data

Figure 1 and Figure 2 show the recorded MMN potentials for all paradigms and deviant types at electrode position Fz.

First, we calculated an ANOVA including the factors paradigm and DSD to compare MMN amplitudes elicited by physiologically identical duration deviants of different DSDs in the unifeature vs. multifeature paradigm. An MMN was elicited in all conditions. The results reveal a significant main effect of paradigm ($F(1, 25) = 6.29$, $p = .019$) with larger amplitudes in the multifeature paradigm ($M_{Multifeature} = -2.73$, $M_{Unifeature} = -2.26$) and a significant main effect of DSD ($F(1, 25) = 22.03$, $p < .001$) with larger amplitudes when DSD was large ($M_{DSD\ small} = -1.76$, $M_{DSD\ large} = -3.23$). Thus, for duration deviants, larger amplitudes were found in the multifeature paradigm and when the DSD was large.

Secondly, we calculated an ANOVA including the factors deviant type and DSD to compare MMN amplitudes elicited by duration, frequency, and intensity deviants in the multifeature paradigm. An MMN was elicited in all conditions. MMN amplitudes did not differ according to the deviant type, but varied as a function of DSD ($F(1, 25) = 71.95$, $p < .001$) with larger amplitudes for large DSDs ($M_{DSD\ small} = -1.97$, $M_{DSD\ large} = -3.34$). Furthermore, DSD effects varied as a function of deviant type ($F(2, 50) = 3.45$, $p = .040$): The difference in MMN amplitudes between small and large DSD was smallest for frequency deviants ($M_{Diff\ frequency} = .76$), larger for duration deviants ($M_{Diff\ duration} = 1.48$), and largest for intensity deviants ($M_{Diff\ intensity} = 1.85$). All SIDAK corrected post-hoc comparisons between DSDs were significant ($p < .013$).

Thus, also for intensity and frequency deviants, MMN amplitudes increase with larger DSDs.

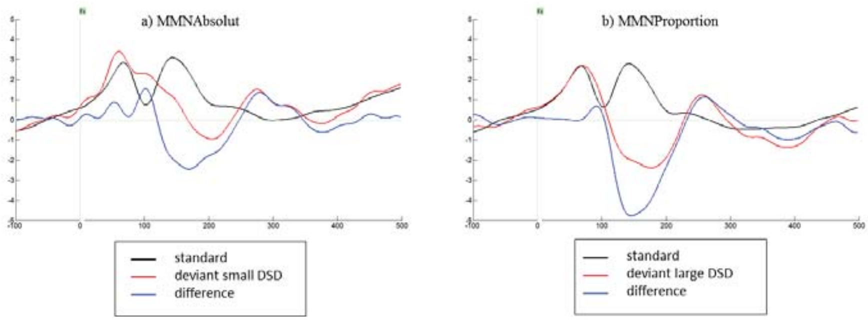

Figure 1: recorded MMN potentials at Fz in the unifeature oddball paradigms MMNAbsolut (a) and MMNProportion (b)

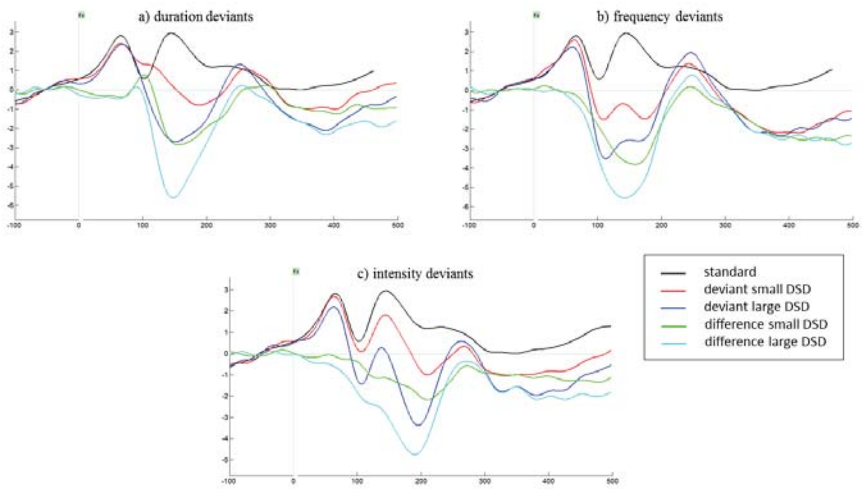

Figure 2: recorded MMN potentials at Fz in the multifeature oddball paradigm for duration deviants (a), frequency deviants (b), and intensity deviants (c)

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4 Discussion and Conclusion

Duration, frequency and intensity oddballs elicited reliable MMNs also in multifeature paradigms. For duration deviants, we can even assert that physically identical deviants elicit higher MMNs in the multifeature than in the unifeature oddball paradigm. Higher amplitudes in multifeature paradigms may be of benefit in patient setting: Firstly, patients often exhibit smaller amplitudes in general. Secondly, testings are based on single subject analysis, and thirdly, time and attentional awareness are a limited resources. These benefits are supported by our finding that listening to a multifeature paradigm is judged to be as effortless as listening to a unifeature oddball.

Like previous studies, our results show an increase in MMN amplitudes for high DSDs (e.g. Jaramillo, Paavilainen, & Näätänen, 2000). However, Horváth and colleagues (2007) postulated that this difference might only be due to a contamination with N1 effects. By minimizing the N1 effect, they did not find a significant variation according to the magnitude of deviance. May and Tiitinen (2010) summarized that any measurable MMN is N1-contaminated. This might also be the case in our study and definite quantification of MMN vs. N1 needs to be further investigated.

Taken together, our results indicate multifeature oddball paradigms to be a suitable tool to investigate auditory discrimination profiles. Eliciting larger duration MMNs than the unifeature oddball paradigm, renders them especially interesting for research in DOC patients. In these patients, successful completion of such basic tasks is a precondition for the application of more complicated tasks like BCIs that also require prolonged attention and the switching of the attentional focus.

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