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# Measuring oddball responses to vibrotactile textures

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**Abstract.** Using a fast-periodic oddball paradigm, together with EEG frequency-tagging, we aimed to assess the possibility of measuring periodic responses to rapid changes in a vibrotactile texture. Sequences consisting of standard (A) and oddball stimuli (B) were presented in an AAAAB pattern, with a base and oddball presentation rate of 8 Hz and 1.6 Hz (8/5 Hz), respectively. A and B stimuli either differed in frequency and intensity, or in terms of their complex spectrotemporal composition. Preliminary results suggest that the protocol can be successfully used to record EEG correlates of the cortical processing of haptic textures.

**Keywords:** Somatosensory, vibrotactile, EEG.

## 1 Introduction

Oddball paradigms, together with EEG frequency-tagging, can be employed to investigate responses to changes occurring within fast, continuous sequences of stimuli, and represent a useful tool to investigate somatosensory processing of haptic textures, with an extensive body of literature employing such methods in the auditory [1] and visual [2] domains. In recent years, it was shown that EEG frequency-tagging can be used to study haptic processing in conditions of passive dynamic touch using a textured surface varying periodically in intensity while it slides against the participants' fingers [3]. Whether the discrimination of complex textures varying in terms of their spectrotemporal pattern involves the primary somatosensory cortex (S1) is debated. Our aim was to determine whether it is possible to record tactile oddball responses to changes in the spectrotemporal content of a complex vibrotactile texture, and to assess whether these responses follow the somatotopical organization of S1.

## 2 Methods

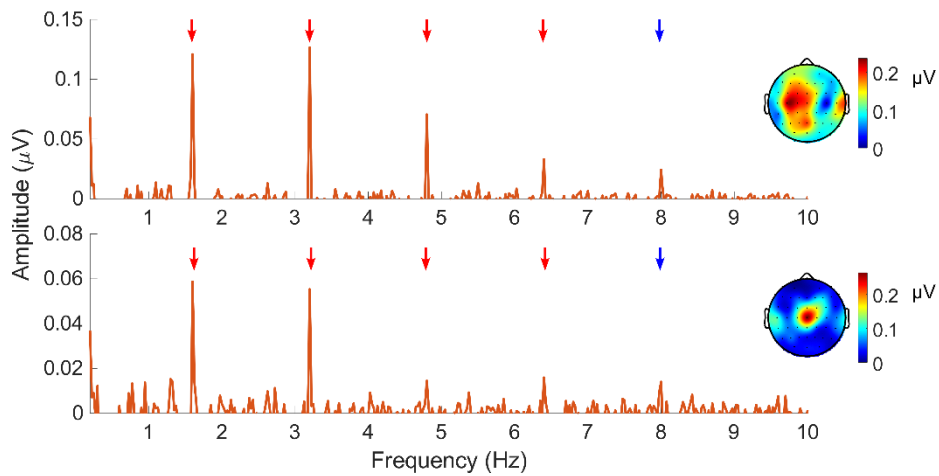
Vibrotactile stimuli were designed in MATLAB (version R2020b) and consisted of sequences of 125 ms vibrations presented according to an established (AAAAB) oddball fashion. In a first condition, we aimed to achieve a frequency/intensity contrast, where As and Bs had a frequency of 300 Hz and 200 Hz, respectively. In a second condition, vibrations were composed of bandpass-filtered (40-200 Hz) white noise sequences,

where As and Bs were matched in terms of intensity and average frequency content but differed in their spectrotemporal distribution. Each AAAAB sequence lasted 625 ms and was repeated 64 times per trial, for a total of 40 seconds. Stimuli were delivered to the participants' right hand or foot using a vibrating device (Minishaker Type 4810, Bruel & Kjaer) connected to a power amplifier (Type 2718, Bruel & Kjaer). A 64 Ag-AgCl electrode cap (ANT) was used for EEG recordings and placed on the participants' scalp according to the International 10/10 system. Signals were recorded using an average reference. Sample rate was 2000 Hz and impedances were kept below 10 k $\Omega$ .

EEG data analysis was performed using the Letswave6 (<http://letswave.org>) Matlab toolbox. After preprocessing, EEG signals were averaged across trials in the time domain, and a fast Fourier Transform (FFT) was applied to obtain amplitude spectra with a resolution of 0.025 Hz. Finally, a baseline subtraction was performed to remove, at each frequency bin, the average of the 24 neighboring frequency bins, excluding immediately adjacent bins.

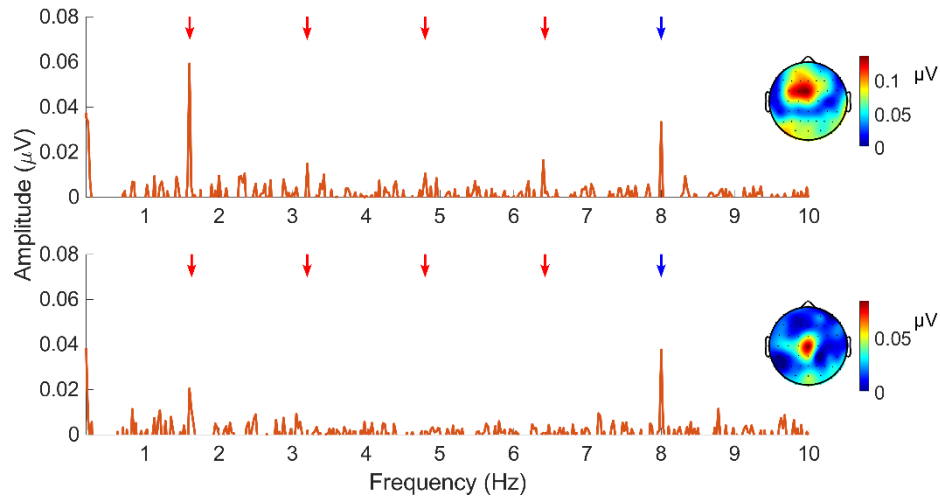
### 3 Preliminary results and conclusion

Preliminary results ( $N = 3$ ) show that for both hand and foot stimulation, the control condition elicited responses at the base (8 Hz) and oddball frequencies (1.6 Hz and harmonics) for both hand and foot stimulation (Fig. 1).



**Fig. 1.** Baseline-subtracted spectrum of the EEG responses to frequency/intensity contrasts delivered to the right hand (top) and foot (bottom) (average across all scalp channels). Oddball and base frequencies and their harmonics are shown in red and blue, respectively. The topographical maps shows the response at the oddball frequency (1.6 Hz).

Similarly, responses to spectrotemporal contrasts could be recorded for both stimulation sites at the base and oddball frequencies (Fig. 2).



**Fig. 2.** Baseline-subtracted spectrum of the EEG responses to spectrotemporal contrasts delivered to the right hand (top) and foot (bottom) (average across all scalp channels). Oddball and base frequencies and their harmonics are shown in red and blue, respectively. The topographical maps show the response at the oddball frequency (1.6 Hz).

The topographical distribution of EEG responses to spectrotemporal contrasts was localized over contralateral frontal and parietal electrodes following right hand stimulation, and over central electrodes following right foot stimulation, consistent with activity originating from the hand and foot representation of S1. In conclusion, EEG frequency tagging can be used to capture cortical activity specifically associated with a contrast in the spectrotemporal distribution of complex vibrotactile stimuli matched in terms of intensity and average frequency distribution, with implications for the design of virtual textures for haptic displays. The topographical distribution of the EEG responses suggests that this activity originates, at least in part, from the contralateral S1.

### Acknowledgements

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