SOMATOSENSORY CORTEX ACTIVITY IN RESPONSE TO FINGERTIP STIMULATION CAN INCREASE WITH REMOTE SUBTHRESHOLD VIBROTACTILE NOISE: AN EEG STUDY

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INTRODUCTION

Subthreshold vibrotactile noise at the wrist or dorsal hand can improve touch sensation of the fingertip in stroke survivors, as measured by the monofilament clinical test [1]. This finding extends the concept of stochastic resonance [2], by showing that noise applied remotely from the fingertip could influence sensation at the fingertip. Its mechanism, however, is unknown. The objective of this preliminary study was to investigate the effect of remote vibrotactile noise on the electroencephalography (EEG) activity in response to monofilament stimulation at the fingertip. We hypothesized that EEG activity increases with remotely applied subthreshold, but not suprathreshold, vibrotactile noise. Understanding of the mechanism behind sensory enhancement with remote subthreshold noise may help guide its clinical application to enhance patients' touch sensation.

METHODS

Monofilament touched one healthy young subject's index fingertip pad (Fig. 1a,b) while subthreshold (60% of the sensory threshold), suprathreshold (120% of the sensory threshold), or no vibrotactile noise was applied at the dorsal hand skin over the 2nd metacarpal bone (Fig. 1c). EEG activities were continuously recorded. A total of 150 monofilament touches were made for each of the three noise conditions, with the testing order randomized in multiple blocks. The interval between consecutive monofilament touches was random between 1 and 2 seconds. The location and parameters of the noise were chosen based on the previous study [1]. The vibrotactile noise was a white noise with frequencies between 0 to 500 Hz generated by C-3 Tactor (Engineering Acoustics Inc., Casselberry, FL, USA).

The 64 channel EEG data were collected at 1kHz in the international 10-20 system (Brain Products GmbH, Gilching, Germany) with a Synamps^2 amplifier system (Advanced Medical Equipment Ltd., Horsham, West Sussex, UK). To minimize auditory and visual artifacts, the subject wore ear plugs and headphone with white noise and was instructed to look at a fixation dot throughout the experiment, while the subject's hand, monofilament, and vibrotactile noise device were hidden behind a cardboard box (Fig. 1a).

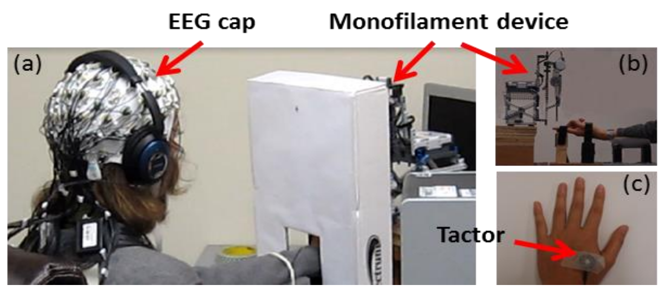

Figure 1: Experimental setup.

For initial analysis, the C4 electrode activity was examined for its location near the contralateral hand sensorimotor area (Fig 2). Event-related potentials (ERP) and power spectral densities (PSD) were analyzed, both in the time period between 350 ms before and 650 ms after the monofilament touch, using MATLAB (v8.0; The MathWorks, Natick, MA) and the EEGLAB toolbox [3]. The EEG data were initially filtered at 0.5-50 Hz to remove slow drifts and line noises. Independent component analysis was used to remove artifacts [4]. The 150 epochs were then averaged to have an ERP for each condition. Two-sample *t*-tests were used to compare the ERP peak to peak amplitudes and PSD at three different frequencies (5, 10, and 23 Hz) between the subthreshold and no noise conditions as well as between the suprathreshold and no noise conditions. The p-values were adjusted by the false discovery rate (FDR) correction.

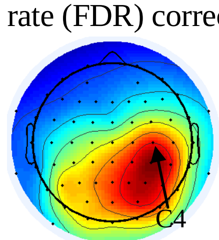

Figure 2: Independent component reflecting somatosensory cortex activity with the fingertip tactile stimulation shown in red.

RESULTS AND DISCUSSION

The peak to peak ERP in response to the monofilament stimulation of the fingertip significantly increased with the subthreshold vibrotactile noise (Fig. 3a) compared to the no noise condition (p<0.001). However, the suprathreshold noise did not significantly affect the peak to peak ERP compared to the no noise condition (Fig. 3b).

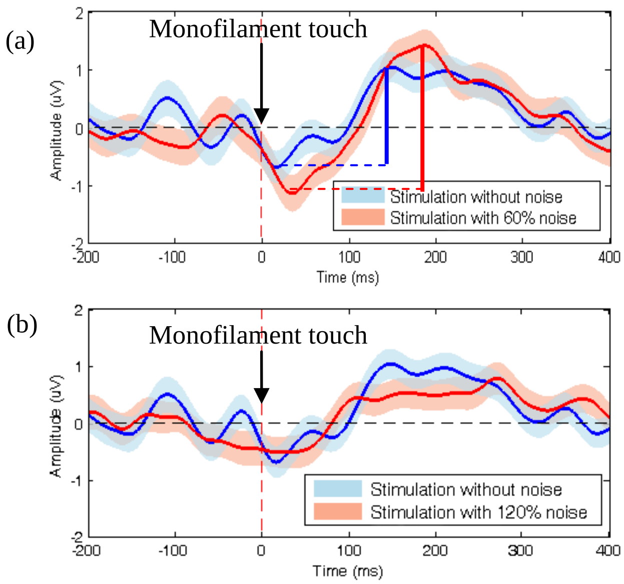

Figure 3: ERP when the dorsal hand received the subthreshold (a, 60% of the sensory threshold) and suprathreshold (b, 120%) vibrotactile noise compared to no noise

PSDs was also significantly affected by the subthreshold noise (Fig. 4a), but not the suprathreshold noise (Fig. 4b). With the subthreshold noise, upper β band activity (22-30 Hz) increased (p_{FDR}=0.01) and α band activity (around 10 Hz) decreased (p_{FDR}=0.05), compared to the no noise condition (Fig. 4a). Increased β band activity is known to be associated with strengthening of sensory feedback [5], and decreased α band activity is associated with increased sensorimotor information processing of related areas [6]. Subthreshold remote vibrotactile noise appears to facilitate reception of fingertip tactile sensation by increasing β band activity and decreasing α band activity at the hand area of the primary somatosensory cortex.

CONCLUSIONS

The subthreshold, but not suprathreshold, vibrotactile noise at the dorsum hand changed the brain activity

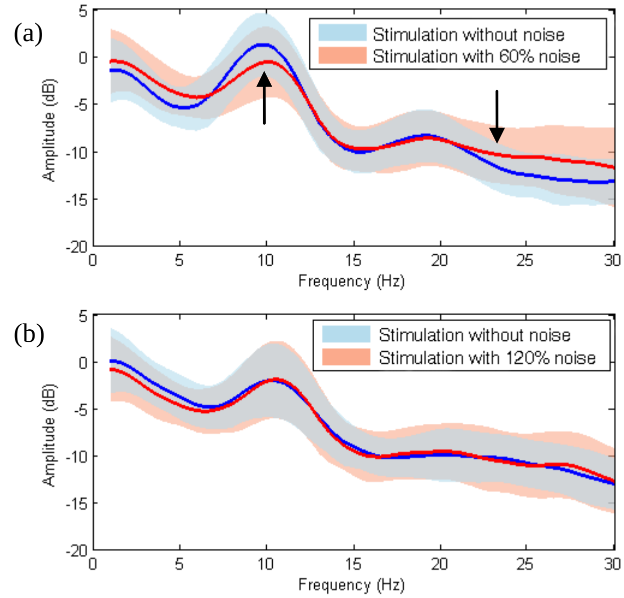

Figure 4: PSD when the dorsal hand received the subthreshold (a, 60% of the sensory threshold) and suprathreshold (b, 120%) vibrotactile noise compared to no noise

of the somatosensory cortex hand area in response to fingertip stimulation with increased event-related potentials and increased β and decreased α band activity, indicating strengthened sensation/sensory feedback and sensorimotor information processing. This study supports the role of remote subthreshold noise in enhancing touch sensation via cortical influence. Understanding of this mechanism may lead to a novel rehabilitation engineering technique for sensory enhancement in patients and older adults.

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