Proceedings of the 6th International Brain-Computer Interface Conference 2014 DOI:10.3217/978-3-85125-378-8-71

Spatial masking might increase classification accuracy in tactile ERP-BCIs

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Abstract

Tactile ERP-BCIs provide unique advantages over visual ERP-BCIs but suffer from lower classification accuracies due to lower discrimination between target and non-target ERPs. In this study we analyzed whether spatial masking can reduce non-target ERPs to improve discrimination. Two different tactile stimulation setups designed to produce simultaneous stimulation with and without masking were compared to a classic oddball stimulation in three healthy subjects. Spatial masking decreased the average number of sequences required to achieve 100% classification accuracy. Preliminary data indicate that spatial masking might have a beneficial effect on classification accuracy.

1 Introduction

Whenever possible assistive technology should strive to be unobtrusive for the end-user. Visual ERP-BCIs generally restrict the end-users‘ perception of his environment and are difficult to conceal due to the necessary display devices. Tactile ERP-BCIs on the other hand allow the user to retain his visual and auditory senses and tactile stimulation devices (tactors) can easily be hidden below layers of clothing. While information transfer rates of most tactile BCIs are lower than those of comparable visual BCIs [1], the unobtrusive nature of tactile ERP-BCIs might be a crucial advantage for certain applications such as wheelchair control [3]. In daily life, vibrotactile stimulioccur rarely compared to visual and auditory stimuli. Therefore, tactile stimuli are difficult to ignore and are most likely perceived as odd stimuli. Consequently tactile stimulation elicits significant ERPs for target and non-target stimuli [3]. While tactile ERPs from target and non-target stimuli are sufficiently different for classification, reduced non-target ERPs may increase classification accuracies. For this purpose, we investigated whether we can accustom a user to the tactile stimulation to reduce non-target ERPs. We applied spatial masking to allow for continuous stimulation on all tactors while still maintaining an oddball task. When multiple tactile stimuli are applied at the same time, but one stimulus is significantly stronger than the remaining ones, the strongest stimulus can mask the other stimuli [7]. Therefore, only one stimulus is perceived despite all locations being stimulated. In this study, we investigated the effect of spatial masking on classification accuracy.

2 Methods

Different stimulation patterns were applied to N=3 healthy subjects using 8 vibrate transducers (C2 tactors; Engineering Acoustic Inc., USA). EEG signals were recorded from 16 passiv Ag/AgCl electrodes and amplified using a g.USBamp amplifier (g.tec Engineering GmbH, Austria). Stimulation was applied to the lower and upper arms (see Figure 1) with a stimulus-duration of 240ms and an inter-stimulus-interval of 400ms.

Three different stimulations setups were compared in this study (see Figure 1):

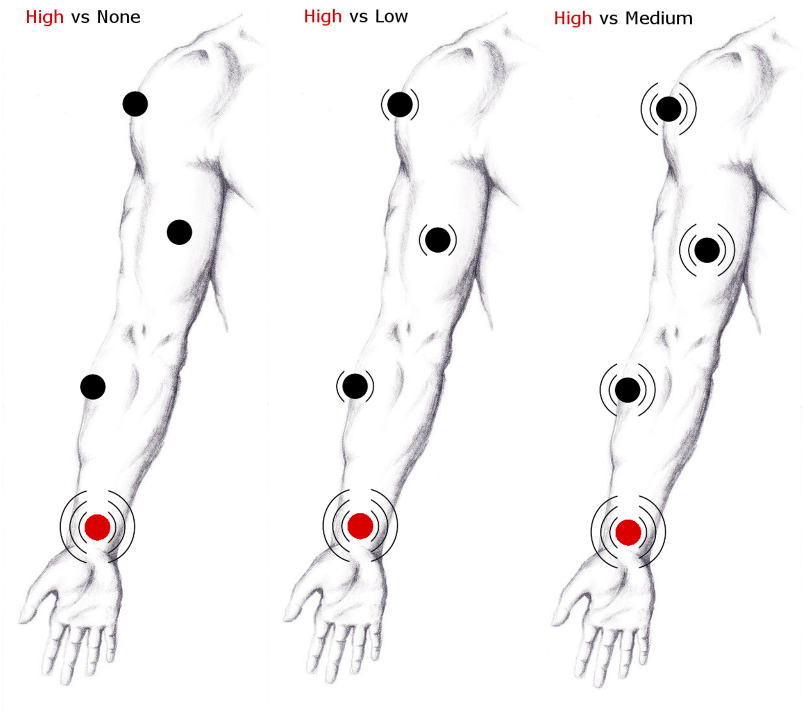

Figure 1: Overview of the three different stimulation setups. Tactors were placed along both (right and left) lower and upper arms (red and black dots). The **High vs None** setup was a classical oddball where the target stimulus (red) was vibrating with high intensity and non-target stimuli (black) were inactive. For the **High vs Low** setup the target stimulus (red) was vibrating with high intensity and non-target stimuli (black) were vibrating with low intensity. For the **High vs Medium** setup the target stimulus (red) was vibrating with high intensity and non-target stimuli (black) were vibrating with medium intensity. Target stimuli were presented in randomized order and all stimulations were above detection threshold.

High vs None
: Classical oddball where the target stimulus (odd) is vibrating with high intensity while non-targets (frequent) are inactive.

High vs Low
: Modified oddball where the target stimulus (odd) is vibrating with high intensity while non-targets (frequent) are vibrating with low intensity.

High vs Medium
: Modified oddball where the target stimulus (odd) is vibrating with high intensity while non-targets (frequent) are vibrating with medium intensity.

Subjects were not informed about the difference between the three stimulation setups, but it was ensured that low stimulation was above detection threshold for all subjects. Participants had to perform a calibration-task for each stimulation setup, using 15 sequences, meaning each tactor was the target stimulus 15 times. Afterwards they had to perform three copy-spelling tasks, selecting each of the 8 body locations once, with each setup, using 10, 5 and 3 sequences.

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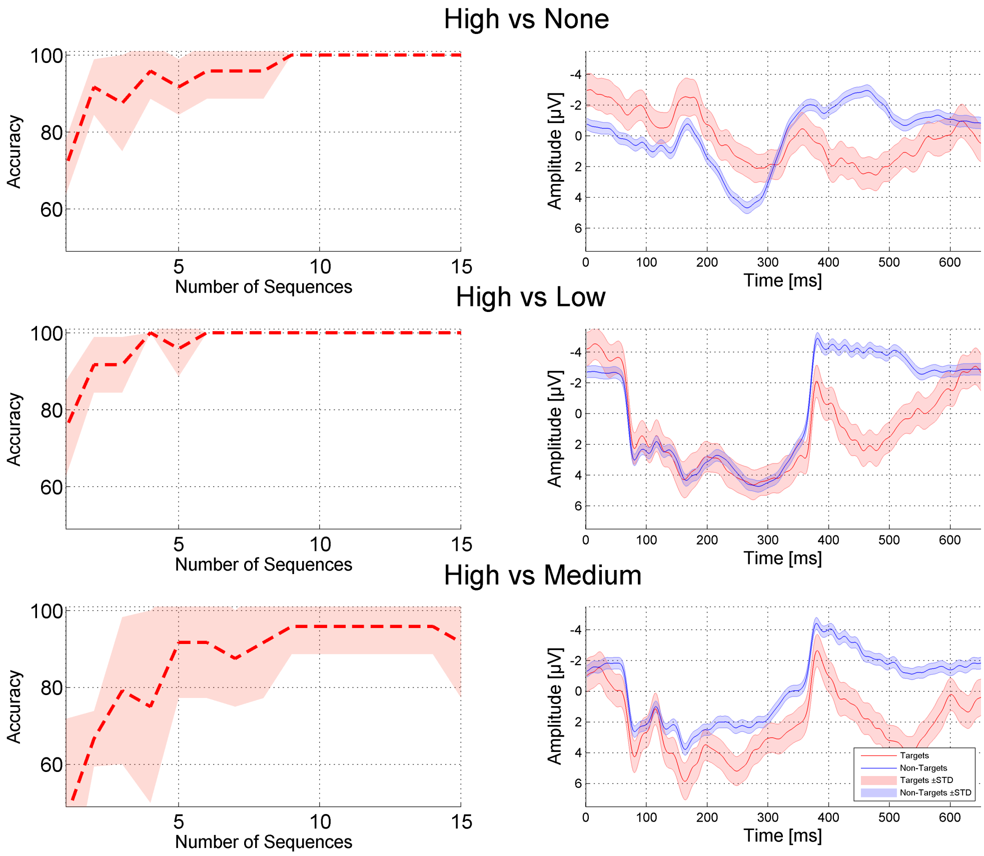

Figure 2: Calibration task results for different stimulation setups. Left: classification accuracy as a function of number of sequences is shown. Right: averaged ERPs for position Cz. Red: Targets, Blue: Non-targets.

3 Results

After the experiment, participants were asked to report the felt difference between the **High vs None** and **High vs Low** setup. All participants stated that there was either no difference at all or that they could feel an additional active tactor from time to time. None reported that they could reliably feel multiple active tactors. For the **High vs Medium** setup all participants reported feeling multiple tactors simultaneously.

All participants achieved 100% classification accuracy in 9 sequences or less with the **High vs None** setup (see Figure 2). In the **High vs Low** setup all participants were able to reach 100% classification accuracy with 6 sequences or less. Two participants achieved 100% classification accuracy in the **High vs Medium** setup (4 and 8 sequences needed), one participant was unable to achieve 100% classification accuracy. All stimulation setups elicited event-related-potentials in all participants. Simultaneous activation of all 8 tactors resulted in stimulation artifacts in the **High vs Low** and the **High vs Medium** setup (see Figure 2). Performance in the copy-spelling tasks appeared to be equal for all stimulation setups, but due to the small sample size no statistics were calculated (see Table 1).

Table 1: Mean performance in the copy-spelling task

	10 Sequences	5 Sequences	3 Sequences
High vs None	87.5%	70.8%	45.8%
High vs Low	83.3%	75%	50%
High vs Medium	83.3%	70.8%	50%

4 Discussion

These preliminary results suggest that spatial masking (**High vs Low**) might have a beneficial effect as it reduced the required number of sequences to reach 100% classification accuracy below that of the default setup (**High vs None**). However no performance difference could be observed in the copy-spelling task for this limited sample. Due to stimulation artifacts a direct comparison between the ERPs of **High vs None** and **High vs Low** condition was difficult. The Source of the artefacts was identified as an unintended flow of current between tactors and skin and will be eliminated for future studies. More data is needed to verify whether tactial masking provides beneficial effects on target or non-target ERPs. Spatial masking is only one out of a multitude of different spatial, temporal and spatio-temporal effects relevant for tactile stimulation [5]. Further research is needed to assess whether additional effects such as apparent location [4], temporal summation [6] and tactile illusions [2] have to be circumvented when designing a tactile BCI or might even prove to be useful for good control of a BCI driven application.

4.1 Acknowledgments

This study was funded by the European Community for research, technological development and demonstration activities under the Seventh Framework Programme (FP7, 2007-13), project grant agreement number 288566 (BackHome). This paper reflects only the authors views and funding agencies are not liable for any use that may be made of the information contained herein.

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