Towards implicit control through steady-state somatosensory evoked potentials

Thorsten Oliver Zander[1,2,*], Wouter Vos[1], Marc Grootjen[1]

[1]Eagle Science, Lommerlustlaan 59, Haarlem, BZ, 2012, NL

[2]Team PhyPA, Berlin Institute of Technology, Berlin, Germany

Objective The study presented here aims at establishing implicit control over a Human-Machine System [Roetting 2009]. Tasks usually taking a great share of the user's attention would be replaced by new forms of interaction that does not require as much cognitive resources or, in the best case, can be handled mostly subconsciously. One way to achieve this goal is using technology developed for Brain-Computer Interfaces (BCIs) [Wolpaw 2002]. Especially, reactive and passive BCIs [Zander 2008, Zander 2011] are developed to reduce cognitive demands for human-machine interaction [Zander 2012]. We focus on utilizing reactive BCIs (rBCIs) for providing a solution for implicit control.

Prior work in the field of rBCIs was mainly based on visual stimulation. Some work also included tactile [Brouwer 2010] or auditory [Nijboer 2008, Hoehne 2010] stimuli, providing a proof of concept, that this approach can potentially be transferred between modalities. Most rBCIs detect two different types of features in the EEG. Firstly, there are systems detecting changes in the event related potential consisting of a negativity around 200 ms followed by a positive peak around 300 ms on central-central sites of electrodes distributed along the standardized extended 10/20 system [Homan 1987]. This P300 or Oddball ERP is modulated with the level of attention the subject is focusing on the perception of the related stimulus. Secondly, there are steady state evoked potentials. These are differences in a specific frequency of the spectral domain of the EEG that are evoked from perceiving a stimulus that is modulated in the same specific frequency.

As the visual and the auditory domain of users in Human-Machine Systems usually are occupied during operation, we investigate rBCIs that rely on tactile stimulation. Our approaches transfer the knowledge gained from the rBCIs mentioned above to this modality and investigate the reliability of the resulting implicit control. We modulate specific frequencies in the EEG by steady-state somatosensory evoked potentials (SSSEPs) with a tactile belt.

Tactile Hardware: The hardware used for our experiments is based on previously developed technology (Eagle Science, Haarlem, The Netherlands). The tactile hardware was designed to control frequency and amplitude of the tactor vibration separately. Therefore several problems needed to be solved. As frequency and amplitude both originate from rotational speed of the vibrator motor, they are coupled as a consequence; the higher the speed, the higher the frequency and amplitude. Also the amplitude and frequency depend on the loading of the tactor, in other words how it is fixed. The tighter it is fixed, the higher the frequency and the smaller the amplitude. The system we designed solving these problems and additionally allows for measuring at what frequency the tactor is stimulating.

Experimental design: Data sets from 14 participants (six males; age mean: 26 years) were included in the analysis. EEG was recorded using 64 impedance-optimized electrodes (BrainProducts, Gilching, Germany). Two tactors were placed on the upper body of the participants, one on the left side the other on the right side below the armpits. Each tactor was vibrating constantly with a specific frequency. Each trial started with a presentation of a randomly selected letter from the set {‘L’,”R’} for one second in the center of the screen. Then this letter was replaced by a fixation cross displayed for 7 seconds. Participants were advised to focus their attention at the vibration of the tactor on the left hand side if the initial letter was ‘L’ and on the vibration on the right hand side otherwise. Participants completed 200 trials, 100 for each tactor.

Offline BCI classification: Single-trial offline classification of EEG signals between both conditions was performed with BCILAB [Delorme 2011], generating a model for each participant. We used the Common Spatial Patterns approach on the seven seconds time window after the letter presentation and performed a crossvalidated classification with regularized linear discriminant analysis (LDA). Mean classification error across participants was 33 %.

Conclusion & outlook: The results of this study represent a first step towards implicit control in Human-Machine Systems based on SSSEPs. The classification accuracy potentially can be improving the specificity of the tactor hardware and novel BCI approaches adapted more closely to the SSSEP approach.

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