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Comparing EEG and fNIRS for a covert attention BCI

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Introduction: Visual hemispatial neglect is a common post-stroke neuropsychological deficit, impairing the ability to deploy spatial attention towards one side of the visual field. Neurophysiological studies have unveiled neural correlates of covert attention deployed towards the left versus the right hemifield, using both functional magnetic resonance imaging (fMRI, [1]) and electroencephalography (EEG, [2]). If such covert visual attention states could be reliably discriminated at the single trial level, providing BCI-decoder feedback to patients could be used to promote those desirable neural correlates, thus improving recovery through plastic changes in the brain [3, 4]. In this work we investigated if the single trial decoding performance of functional near-infrared spectroscopy (fNIRS), as an alternative to fMRI, can supplement EEG to improve decoding accuracy.

Material, Methods and Results: Parieto-occipital cortical activity was measured with fNIRS (44 channels) from five subjects during a two-sided covert attention task (left and right, 40 trials each). The same experiment was repeated while recording EEG (60 channels). We derived oxygenated and reduced hemoglobin levels (HbO/HbR) from the fNIRS signal and one-Hertz frequency bands spanning alpha, beta and gamma activity (8-33 Hz) from the EEG. Highest discriminant activity was found across subjects in the time window 1.5-3.5 s after trial onset for the EEG and at 5-12 s for the fNIRS, respectively, reflecting the delay of the hemodynamic response [5]. Mean activity was computed across these windows for each trial and channel and used as input to the classifier. For the grand averages, t-statistics (2-sided t-test) of left-right differences were calculated across trials and then averaged across subjects. The grand averages showed an expected contralateral alpha-power decrease over the occipital cortex, which corresponds to lower HbO levels (Fig. 1,A-B) [2, 5]. Classification of left versus right covert attention was performed using 10 times 10-fold cross-validation with a random forest classifier [6] and assessed using the area under the curve (AUC). Classification results were significantly above chance level (pointwise confidence bounds, FPR = 0.5, $p < 0.05$) for two subjects with EEG and for four subjects with fNIRS. AUC averaged at 59.8% (± 11.0%) for the EEG and at 69.9% (± 7.3%) for the fNIRS (Fig. 1, C).

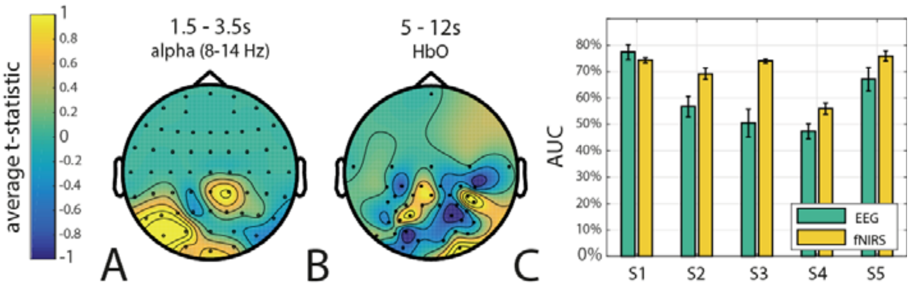

Figure 1: (A),(B) Grand averages of channel-wise t-statistic of left versus right covert visual attention for the alpha band (8-14 Hz) in EEG (A) and the HbO in fNIRS (B). Channels frontal of the coronal midline are muted. (C) Classification performance for EEG and fNIRS for five subjects.

Discussion: In this pilot study we demonstrated that covert attention can be detected and classified using fNIRS signals, and that it compares favorably to the EEG. Since classification performance for both modalities can differ substantially (Fig 1, C S3), a combined EEG-fNIRS BCI offers usability to people who struggle with either one or the other modality alone. For classification performance above chance level in both modalities, a fusion approach could improve the system accuracy. In a next step, these results have to be validated with more subjects in a simultaneous recording setup of EEG and fNIRS to avoid confounds between the recordings like different levels of attention or fatigue. Also, finding optimal fusion methods constitute the target of further work.

Significance: We found evidence supporting the use of fNIRS for decoding covert visual attention at the single trial level. Therefore, supplementing EEG with fNIRS seems promising to improve the decoding accuracy for covert visual attention, which is a key factor for a BCI-based rehabilitation application for hemispatial neglect.

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