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Patient-Specific Visual Neglect Severity Estimation for Stroke Patients using an AR and EEG based BCI

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Introduction: Visual spatial neglect is a condition that causes inattention to contralesional stimuli after a stroke. It disrupts basic and instrumental activities of daily living (such as dressing and driving) and increases the risk of falling and hospitalization. The current standards for neglect detection are successful in identifying neglect but do not provide any information on the extent/severity of neglect, i.e., the neglected field of view (FOV), which can be useful to inform personalized neglect rehabilitation. Previously, we built a BCI system called Augmented Reality-based EEG-guided Neglect Detection, Assessment, and Rehabilitation System (AREEN). We have already shown that the AREEN BCI system, using EEG can detect neglect with high accuracy and can classify among neglected and non-neglected visual targets [1]. In this work we aim to expand upon the previous findings, and develop and evaluate a machine learning method for the estimation of neglected FOV.

Material, Methods and Results: For FOV estimation, we propose EEG-based Spatio-Temporal Network (ESTNet) that captures essential EEG frequency band/time information associated with visual neglect. Through a Bayesian fusion, ESTNet combines EEG evidence with probabilistic prior information on potentially neglected visual field, which we denote as FOV correction module. ESTNet also generates an average saliency map to improve the explainability of the network model and identifies EEG time ranges (i.e., potential event related potentials – ERPs) and frequency bands most informative on neglected FOV estimation. Using our proprietary AREEN dataset (a total of 20 stroke patients including 11 with visual neglect and 9 without neglect), the performance of ESTNet is compared to benchmark machine learning models in a leave-one-subject-out (LOSO) manner. ESTNet outperformed the benchmark machine learning methods for FOV estimation, achieving 79.62% accuracy, 76.71% sensitivity, and 86.36% specificity. Average saliency map (Fig. 1) demonstrates the frequency/time ranges for each EEG channel identified to be most informative for FOV estimation: (i) ERPs in the 100-150 ms and 300-400 ms range associated with visual attention tasks [2, 3]; (ii) alpha and beta bands which are biomarkers associated with visual attention [4] and visual task correction [5].

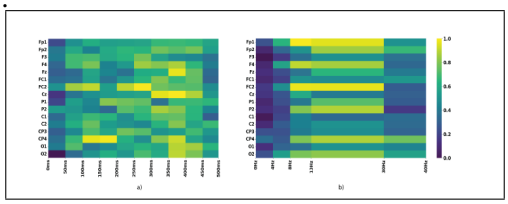

Figure 1: *Average saliency maps for a) time domain and over 50ms long windows and b) frequency domain data over EEG bands delta (0-4Hz), theta (0-8Hz), alpha (8-13Hz), beta (13-30Hz) and gamma (30-40Hz). Note that both domains are normalized within themselves for better visibility and model/data explainability.*

Conclusion: The AREEN BCI system with high accuracy can estimate neglected FOV. This severity assessment does not require any input from stroke patients, could potentially supplement other clinical neglect related disability measures, and in the future could inform personalized neglect rehabilitation.

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