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Exploring wearable High Density Diffuse Optical Tomography (HD DOT) as a real-time BCI

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Introduction:

HD DOT is an advanced implementation of fNIRS (functional Near Infrared Spectroscopy) offering the promise of a wearable, inexpensive and non-invasive BCI. Current fNIRS BCI implementations are still prone to slow information transfer and high error rates[1]. This project proposes using a new generation of wearable HD DOT technology[2] to overcome these drawbacks. High Density data allows us to reconstruct 3D images of hemodynamic activity using DOT[2]. We aim to implement the first real-time HD DOT BCI and explore novel deep learning classification methods using physiologically interpretable images as inputs. Neural networks will be more robust in classifying these images than raw data streams - spatial and temporal HD DOT images promise enhanced classification accuracy.

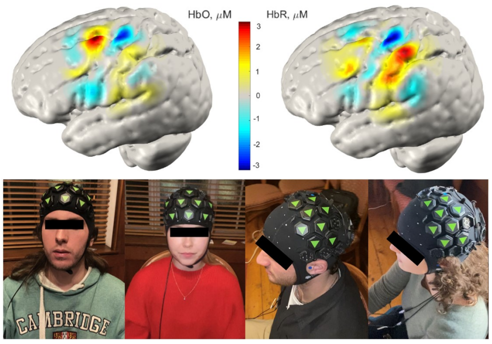

Figure 1: HD DOT images showing ***changes*** *in molar concentrations of oxygenated (HbO) and deoxygenated (HbR) hemoglobin during a motor task*

Materials, Methods and Results:

The LUMO[Gowerlabs, UK] is the state-of-the-art device used in this experiment, which offers a 100 fold improvement in cortical sensitivity compared to traditional fNIRS devices as used in previous BCI studies[2]. Currently, 13 participants have performed Motor Execution (ME), Motor Imagery (MI) and Mental Arithmetic (MA) tasks for our study. We used an interleaved experimental structure to obtain 660 unique activation blocks. Preliminary data analysis shows higher signal to noise ratio for MA tasks due to lower hair coverage over the prefrontal cortex. Using a 0.5Hz low-pass filter, we remove unwanted physiological noise (e.g. ∼1Hz heartbeat) and data with motion artefacts or low coupling efficiency has been separated. Offline regression using Linear Discriminant Analysis is being implemented with the preprocessed data to examine performance of the HD DOT BCI. We are analysing the HD data in a down-sampled and optimised fNIRS configuration to allow direct comparison with classical NIRS BCI implementations. HD DOT will give immediate improvements in classification accuracy - most classical studies arbitrarily place source-detectors in the appropriate region, whereas the high-density configuration allows us to choose the most responsive channels from more source-detector combinations. Choice classification mechanisms are being implemented to ensure smooth transition of the classifiers to real-time.

Discussion:

HD DOT images of the subjects have comparable resolution to fMRI[2] whilst allowing increased subject mobility - Figure 1 demonstrates the noticeable increase in concentration of oxygenated hemoglobin in the motor cortex during a motor task. Using real-time reconstruction of these images, deep learning classification methods are being implemented. This pioneers a completely novel classification mechanism for fNIRS BCIs.

Significance:

With the exponential growth in the BCI sector, a variety of different neuroimaging techniques are being explored. Unreliable and slow classification has rendered fNIRS not being as appealing to pursue commercially. HD DOT changes this, promising a higher performance, wearable, inexpensive and non-invasive alternative to the invasive BCI methods being explored. This research is foundational as no formal investigation into a real-time HD DOT BCI has been conducted - it would establish this novel neuroimaging technique as a competitive and convenient BCI allowing for wider funding and research.

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