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Functional brain state monitoring based on real-time EEG source localization analysis

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***Abstract*— Using real-time electroencephalography (EEG) source localization techniques, we demonstrated the monitoring of functional brain network dynamics. EEG data was recorded before and after sleep when subjects were in task positive (active) and task negative (relaxed) states. The recorded data was processed in real-time to locate the activation source. The activation rate changes of different brain networks are consistent with corresponding behavior activities.**

***Clinical Relevance*— The monitoring of functional brain activities has implications for characterizing attention and central execution functions associated with disorders like ADHD, depression and characterizing intervention effects associated with sleep.**

I. Introduction

Electroencephalography (EEG) has high temporal resolution but only shows 2D brain activities. With source localization that solves inverse problem, 3D brain activity monitoring can be accomplished. We conduct a simple experiment to statistically compare activation rate changes among different brain networks when subjects in task positive or relaxed brain states before and after sleep. Although with fewer electrodes the accuracy of source localization may be a concern, the result shows that the expected brain network activation rate changes are well matched with corresponding behavior activities.

II. Methods

As shown in Fig. 1, EEG Data was recorded using Lab Streaming Layer (LSL) through OpenVibe acquisition server in our customized python based NeuroPype (Intheon Labs, San Diego, CA) with a 14 channels Emotiv-EPOC headset at the rate of 128 samples per second. As a testing experiment, two healthy subjects were recruited for two sessions of 4 min for EEG recording before and after sleep. During the first 2 min. of recording time, subjects were actively looking at the screen of their real-time brain activities and trying to link activation transitions with their own thought changes. In the following 2 min. subjects were relaxed in their resting states. The recorded 2D EEG data was subsequently converted to 3D cortical source estimates with real-time sLORETA processing [1]. In this work, we used the refined head model by Collins for source localization implementation [2]. The cortical region current densities were derived by summing them from voxels inside each region. Time course of each brain regions were then obtained. To binarize the time course data, we averaged the 2 minutes long current densities and used this mean value as a threshold. If the current density values are above the threshold, we set it to 1 and set it to 0 when the values are below the threshold. Different brain regions are then categorized into 7 distinct brain networks which are attention, auditory, visual, salience, sensorimotor, frontoparietal and default mode. Total number of activations as well as activations in different brain networks were calculated. The activation rate of active state was then compared with relaxed state data before and after sleep.

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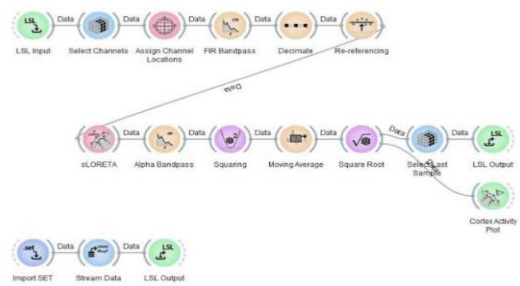

Figure 1. Processing pipeline for real-time cortical activation neurofeedback system.

III. Results

We compared the data for 2 subjects and observed that the total number of activations after sleep increases for both subjects. For both subjects, the attention network activation rate also increased which implies that a person's brain is more alert after sleep. In the task positive and negative comparison part of work, for both before-sleep and after-sleep cases, the frontal-parietal network activation rate decreased in relaxation states for both subjects. The activation rates of attention, visual and salience networks increased in relaxation state. In terms of the relative network resource redistribution caused by these transitions (total percentage of activation rate equals to 100%), for both subjects and after sleep, the attention network shows an increment of relative activation rate and the visual and sensorimotor networks show a decrease of relative activation rate.

IV. Discussion & Conclusion

The proposed EEG source localization method has demonstrated reliable functional brain state monitoring capability and can be extended for portable monitoring with high temporal resolution.

References

[1] "OpenViBE: An Open-Source Software Platform to Design, Test, and Use Brain–Computer Interfaces in Real and Virtual Environments | PRESENCE: Virtual and Augmented Reality | MIT Press.", <https://direct.mit.edu/pvar/article/19/1/35/18759/OpenViBE-An-Open-Source-Software-Platform-to> (24 March 2021).

[2] Collins, D. L., "3D Model-based segmentation of individual brain structures from magnetic resonance imaging data" (1994).