

Examining the Differing Functional States of the Brain in Resting-State and Under Cognitive Workload via Electroencephalography

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Introduction: Complex neurological functions are permitted by the intricate functional networks that form on the basis of an anatomical connection between different brain regions. In our previous study, we showed that the functional connectivity (FC) of the cortex – which can be mapped out using electroencephalography (EEG) – is correlated with the intensity of the cognitive workload and cognitive performance measured during the tests. However, we did not compare the changes precipitated by mental stimuli to the conditions observed in a resting state. In our current study our goal was to identify the possible relationship between these two cognitive states.

Methods: The study included 20 healthy volunteers: 7 females and 13 males, with a mean age of 24 ± 2.64 years. The EEG activity was recorded of 14 cortical regions with a sample rate of 1000 Hz, which was downsampled to 128 Hz internally. The recording consisted of two resting state and a task state measurement. During the prior, the individuals were instructed to sit comfortably and relatively motionless, first with open and then with closed eyes. In the latter, task state contained of three difficulty levels (0-, 2- and 3-back) which were presented repeatedly, in random order. Cognitive performance was measured by recording the accuracy (AC) of and reaction time (RT) needed for the answers. After preprocessing the EEG data, it was segmented, separating the focus time periods from the recording. These segments were used to calculate the phase lag index, which characterizes the strength of functional connectivity between separate cortical regions. The thus reconstructed network's topology was described by connection density (D) and modularity (Q). The network and performance parameters relating to the five different states were compared using Friedman tests and post-hoc paired Wilcoxon tests, while the relationship between the resting state FC and task performance was examined using linear regression (with a significance level of: $p < 0.05$).

Results: Q showed a marked decrease as a result of cognitive stimuli being introduced. However, it was unable to differentiate between the varying levels of cognitive workload. Contrary to this, D decreased proportionally to task difficulty. However, it was unable to differentiate between resting and control stimulatory states. Also, the Q in theta band that was acquired during closed eyed resting state showed a significant positive correlation with RT in 2-back and with AC in 0-back conditions.

Conclusion: Our results show that the neural functional network's density and modularity are related to different aspects of cognition. Furthermore, our results indicate that functional networks reconstructed using data acquired in a resting state may be useful in estimating cognitive performance.