Does overload training or partial sleep deprivation alter electro-cortical brain dynamics at rest?

UNIL | Université de Lausanne
Institut des sciences du sport de l'Université de Lausanne

Di Muccio F.[1,2], Oesch G.[3], Brandner C. [1,2] , Millet G.[3], Barral J. [1,3]

[1]Brain Electrophysiology Attention Movement Laboratory, University of Lausanne, Switzerland
[2]Institute of Psychology, University of Lausanne, Switzerland
[3]Institute of Sport Sciences, University of Lausanne, Switzerland

UNIL | Université de Lausanne
Institut de psychologie (IP)

1. Introduction

Resting state Electroencephalography (EEG) is an interesting way to understand the spontaneous brain activity without external stimulation. How increased load of physical exercise or sleepless nights can alter brain spontaneous functioning remains unclear. These questions were explored by microstates analysis of EEG signal, allowing to understand the temporal dynamics of brain function at rest. Microstates have been defined as short periods (80 – 120ms) during which the signal remains quasi-stable[1]. In addition, literature have reported that four specific microstates (A, B, C and D) explain about 80% of the variance across participants at all ages[2]. It has been shown that these four topographies are associated to fMRI resting state networks (respectively: Auditory, Visual, Salience and Attention)[3]. According to Chronic Fatigue Syndrome (CFS) studies, salience network seems to be particularly sensitive to fatigue state[4]. Recent findings showed that microstate C is modulated after physical exercise making this neuro-imaging analysis useful to identify activity-related brain changes[5]. Moreover, studies have shown that overload training and sleep deprivation seems to alter brain functioning[6,7].

The main purpose of these two studies was to investigate the effects of overload training and partial sleep deprivation on the four EEG microstates.

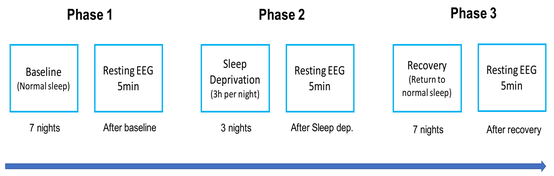
2. Method

Overload Training

- 15 young adults (7 women, 25 ± 5 years old).
- 2 weeks of baseline physical training (measured with a heart rate monitor, Polar V800).
- 3 weeks of overload physical training (40% above the baseline).
- After each phase, EEG at rest was recorded during five minutes with eyes closed followed by a running 3km maximal test to estimate the degree of overreach.

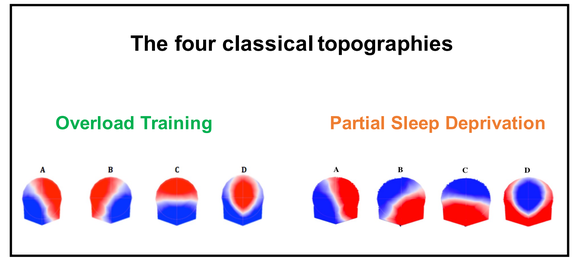
Partial Sleep Deprivation

- 15 young adults (8 women, 22 ± 2 years old).
- 7 days of normal nights (baseline).
- 3 days of sleep deprivation (3 hours per night).
- 7 days of recovery (return to normal nights).
- After each phase, EEG at rest was recorded during five minutes with eyes closed.



3. EEG Microstates Analysis

- Continuous EEG was recorded with a 64-channels Biosemi Active Two system (Biosemi, Amsterdam, Netherlands) at a sampling rate of 2048 Hz in a quiet and dark room.
- Offline analyses were conducted with Cartool software (brainmapping.unige.ch/cartool)
- After the pre-processing, the Global Field Power (GFP) peaks were used for the microstates analysis.
- For each study, the two (study 1) or three (study 2) datasets were concatenate into one file and submitted to a k-means clustering to identify the map topographies (microstates) that explain the best the variance of the map topographies.
- The best representative microstates of each participant were used to compute a grand clustering to obtain the four conventional map topographies which were then used as templates.
- Spatial correlation was computed between the map topographies within the initial datasets of each participant in each condition (study 1 or study 2) and the templates of 4 microstates. At each time point, the topography was associated to the microstate that correlates the best.
- This procedure allowed to compute the functional microstate parameters: Global Explained Variance (GEV), Mean duration, Time coverage and Frequency of occurrence.



4. Results

Overload Training

Results of the 3km maximal test after each phase allowed to determine two groups: **Overreach (OR)** and **Non-Overreach (NOR)**. Participants who improved their performance after the overload phase were included in the NOR group (7 participants) and those who decreased their performance in the OR group (8 participants).

Whatever the map, mean duration significantly decreases (fig. 1; TIME by Group interaction) and frequency of occurrence significantly increases (fig. 2; TIME by Group interaction) in the OR group after overload training (* p<0.05).

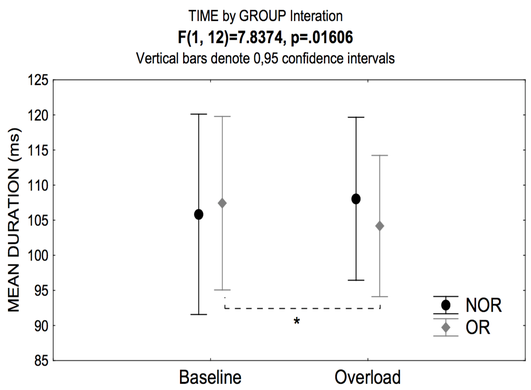


Figure 1

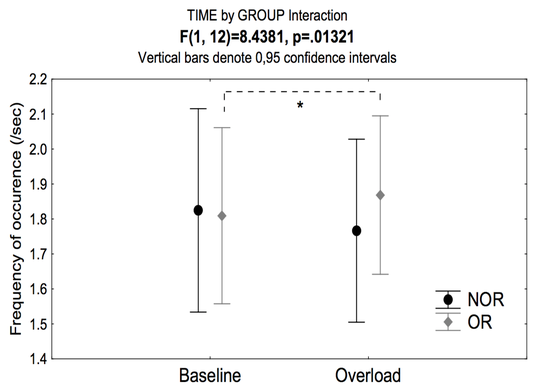


Figure 2

Partial Sleep Deprivation

The ANOVA revealed a TIME by MAP interaction (fig. 3) for the mean duration with a significative decreases for the map C only after 3 nights of sleep deprivation and a significant increased to baseline after one week of recovery (* p<0.05).

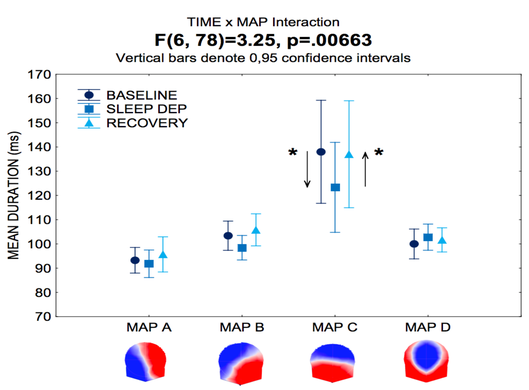


Figure 3

5. Conclusion

Results show that, in the first study, overload training induced a significant decrease of mean duration and an increased frequency of occurrence for the four maps. In the second study, a partial sleep deprivation induced a significant decrease of map-C duration and a return to its baseline after recovery. Interestingly, map-C has been associated with salience resting-state network, characterized by the insula and cingulate cortex which are sensitive to multisensory inputs[8]. Moreover, this network seems to be particularly sensitive to sleep deprivation induced fatigue[6]. Together, these results suggest a temporal reorganization of resting brain after two fatiguing conditions.

6. Message and perspective

- **These studies showed that electro-cortical brain dynamics at rest are modulated by different types of fatiguing conditions.**
- **These changes in EEG microstates could be potentially relevant to predict or monitor mental or physical exhaustion.**
- **In the future, it would be interesting to investigate the link between EEG microstates modulations and behavioural measures.**

7. References

1. Khanna et al. (2015). Microstates in resting-state EEG: Current status and future directions. *Neuroscience & Biobehavioral Reviews*, *49*, 105 113.
2. Koenig et al. (2002). Millisecond by Millisecond, Year by Year: Normative EEG Microstates and Developmental Stages. *NeuroImage*, *16*(1), 41 48.
3. Britz et al. (2010). BOLD correlates of EEG topography reveal rapid resting-state network dynamics. *NeuroImage*, *52*(4), 1162 1170.
4. Wortinger LA, Endestad T, Melinder AMD, Øie MG, Sevenius A, Bruun Wyller V (2016) Aberrant Resting-State Functional Connectivity in the Salience Network of Adolescent Chronic Fatigue Syndrome. PLoS ONE 11(7): e0159351
5. Spring et al. (2017). A single-bout of Endurance Exercise Modulates EEG Microstates Temporal Features. *Brain Topography*, 1 12.
6. Lei,et al. (2015) Large-Scale Brain Network Coupling Predicts Total Sleep Deprivation Effects on Cognitive Capacity. PLoS ONE 10(7).
7. Kreher, J., & Schwartz, J. (2012). Overtraining Syndrome. *Sports Health: A Multidisciplinary Approach*, *4*(2), 128-138.
8. Menon, V. (2015). Salience Network. In Brain Mapping (p. 597-611). Elsevier.

Contact: francesco.dimuccio@unil.ch