Local sleep episodes during wakefulness and space travel

Study reference number: 17-9701
Type of activity: Standard study (30k€)

Project Summary

Objective

The aim of the project is to assess how space travel modifies local sleep episodes during wakefulness.

Target university partner competences

EEG data acquisition, pre-processing and further analysis

ACT provided competences

EEG data processing, local sleep episodes detection and further analysis

Keywords

Electroencephalography, ISS, signal processing, attention, fatigue, sleep

Study Objective

Using scalp EEG during wakefulness, local sleep episodes have been studied in rodents and in humans. The aim of the project is to assess how space travel modifies local sleep episodes during wakefulness by analysing human wake EEG data acquired on board of the ISS during the Neurospat experiment (Erasmus experiment archive: Exp 9143).

Background and Study Motivation

The prospect of long-term space missions, assessed during a 520 days analogue mission, has shown the importance of an adapted wake/sleep routine for the crewmembers alertness and performances when exposed to prolonged confinement [1]. Experimental evidence indicates that astronauts tend to experience sleep deficiency on board of the international space station (ISS), at least until their circadian clock is realigned with the new environment [2] [3]. It has been reported that a majority of the ISS crewmembers are using sleep promoting medication in response to a sleep deficiency during their mission [4], raising the question on appropriate sleep promoting methods. Napping could help to counterbalance the total loss of sleep over time, however the resulting sleep inertia do not benefit vigilance and alertness [5]. Most of the ISS studies focus on chronobiology and only a few reports from the MIR station and the Columbia space shuttle days contain sleep EEG. However, no conclusion on sleep qualitative changes could be made so far [6], [7].

Regulated separately but in concomitance with the circadian pacemaker, sleep pressure builds up with the time spent awake. High sleep pressure can be observed during wakefulness, by a reinforcement of theta activity, and while asleep, by an increase of delta activity, also called slow wave activity (SWA) [8]. Recently, chronic sleep restriction has shown to have local effects on slow wave activity in the prefrontal cortex during NREM sleep, which in turn push the subjects to take riskier decisions [9].

Slow wave sleep during NREM sleep is thought to be the time when neurons perform cellular maintenance and sleep in general has many restorative features [10]. It has been shown that similar local sleep episodes can be observed during wakefulness. In rodents, after an intense period of activity some neurons are turning "off" for a moment in local cortical areas, in what are termed local sleep episodes [11]. Frontal local sleep episodes happening 300-800ms before performing a grasping task have been associated with a decrease of performances [11]. Local sleep episodes have also been studied using human scalp EEG by showing an increase of theta activity during sleep deprivation in humans [12]. Recently, local sleep episodes have been further characterized in Children [13].

Proposed Methodology

By taking advantage of MEEMM (Multi-Electrode Electroencephalography Module) recordings of ISS crew members, we attempt to study local sleep episodes changes over time. Five male astronauts (54.2 ± 2.6 years old) took part in the Neurospat experiment between 2011 and 2013 [14]. During their 6 months mission on ISS, they reported their sleep quality and their medication intake. Some astronauts have experienced long-term weightlessness before and might adapt faster than others to the new environment. The astronauts were tested twice on earth before the experiment (42.6 ± 0.9 and 28.0 ± 0.4 days before take-off), twice during the mission (8.8 ± 1.8 and 54.6 ± 3.7 days of weightlessness) and four times at their return on earth (3.0 ± 0.4, 7.0 ± 1.2, 16.8 ± 0.64 and 20.2 ± 1.04 days after landing). On Earth, the subjects performed the experiment seated at a table, on the Columbus module they were free floating but remained strapped to the EPM rack. The subjects were told to look straight ahead at a laptop screen through a form-fitting facemask, fitted with a cylindrical designed to remove any external visual cues.

As part of Neurospat experiment, a control task of the arrest reaction [15], (eyes closed- eyes opened, 1min.-1min.) was recorded in the beginning of the experiment protocol. In EEG studies, closed eyes alpha oscillations preponderances is thought to maintain tonic alertness to sensory information [16]. After the closed eyes to open eyes paradigm [17], tonic alertness should be maximal and enabling to study local sleep episodes occurrences. After 70 min of performing the Neurospat protocol experiment we are willing to assess changes in the fatigue dynamics by looking at another 1 min recording of resting state with open eyes.

To look for evidence of local sleep episodes during wakefulness, we will extract the theta waves from the recordings by a similar method as Hung and colleagues [12]. Influenced by the field of slow oscillations analysis during NREM sleep [18][19], we will assess the amplitude (μV) and the slope (μV/s) of the theta oscillations and apply the qualitative analysis developed by Fattinger and colleagues [13].

<u>Extra:</u>

With the advent of resting state fMRI studies, the resting state network and more specially the default mode network has been associated with topographical EEG power ranges. However, relation between the BOLD (Blood Oxygen Level Dependant) effect and the difference of potential observed at the scalp level, is still poorly understood [20]. In this study, by coupling high density EEG and a MRI scan, 3D reconstruction of the brain is possible (i.e. LORETA - Low Resolution Brain Electromagnetic Tomography), this to determine the loci of a neuronal event [14].

ACT Contribution

The ACT will contribute in collaborating during the data analysis and in providing expertise in sleep research to detect the local sleep episodes.

References

[1] M. Basner *et al.*, "Mars 520-d mission simulation reveals protracted crew hypokinesis and alterations of sleep duration and timing," *Proc. Natl. Acad. Sci. U.S.A.*, vol. 110, no. 7, pp. 2635–2640, 2013.

[2] N. Yamamoto *et al.*, "Effects of long-term microgravity exposure in space on circadian rhythms of heart rate variability.," *Chronobiol. Int.*, vol. 528, no. November 2016, pp. 1–14, 2015.

[3] E. E. Flynn-evans, L. K. Barger, A. A. Kubey, J. P. Sullivan, and C. A. Czeisler, "Circadian misalignment affects sleep and medication use before and during space fl ight," *NPJ Microgravity*, vol. 2, no. 2016, pp. 1–6, 2016.

[4] L. K. Barger, E. E. Flynn-Evans, and C. A. Czeisler, "Prevalence of Sleep Deficiency and Hypnotic Use Among Astronauts Before, During and After Spaceflight: An Observational Study," *Lancet Neurol.*, vol. 102, no. 9, pp. 1207–1211, 2014.

[5] B. M. Hartzler, "Fatigue on the flight deck: The consequences of sleep loss and the benefits of napping," *Accid. Anal. Prev.*, vol. 62, pp. 309–318, 2014.

[6] A. Gundel, V. V Polyakov, and J. Zulley, "The alteration of human sleep and circadian rhythms during spaceflight," *J. Sleep Res.*, vol. 6, no. 1, pp. 1–8, 1997.

[7] A. R. Elliott *et al.*, "Microgravity reduces sleep-disordered breathing in humans," *Am. J. Respir. Crit. Care Med.*, vol. 164, no. 3, pp. 478–485, 2001.

[8] A. A. Borbély, S. Daan, A. Wirz-Justice, and T. Deboer, "The two-process model of sleep regulation: A reappraisal," *J. Sleep Res.*, vol. 25, no. 2, pp. 131–143, 2016.

[9] A. Maric *et al.*, "Chronic sleep restriction induces risk-seeking," *to be Publ.*

[10] V. V Vyazovskiy and K. D. Harris, "Sleep and the single neuron: the role of global slow oscillations in individual cell rest," vol. 14, no. June, pp. 443–451, 2013.

[11] Y. Nir *et al.*, "Regional Slow Waves and Spindles in Human Sleep," *Neuron*, vol. 70, pp. 153–169, 2011.

[12] C.-S. Hung *et al.*, "Local Experience-Dependent Changes in the Wake EEG after Prolonged Wakefulness," *Sleep*, vol. 36, no. 1, pp. 59–72, 2013.

[13] S. Fattinger, S. Kurth, M. Ringli, O. Jenni, and R. Huber, "Theta waves in Children 's waking electroencephalogram resemble local aspects of sleep during wakefulness," *to be Publ.*

[14] A. M. Cebolla, M. Petieau, B. Dan, L. Balazs, J. McIntyre, and G. Cheron, "'Cerebellar contribution to visuo-attentional alpha rhythm: insights from weightlessness,'" *Sci. Rep.*, vol. 6, no. July, p. 37824, 2016.

[15] H. Berger, "Über das Elektrenkephalogramm des Menschen.," *Arch. Psychiatr. Nervenkr.*, vol. 87, pp. 527 – 570, 1929.

[16] S. Sadaghiani, R. Scheeringa, K. Lehongre, B. Morillon, A.-L. Giraud, and A. Kleinschmidt, "Intrinsic Connectivity Networks, Alpha Oscillations, and Tonic Alertness: A Simultaneous Electroencephalography/Functional Magnetic Resonance Imaging Study," *J. Neurosci.*, vol. 30, no. 30, pp. 10243–10250, 2010.

[17] G. Cheron *et al.*, "Effect of gravity on human spontaneous 10-Hz electroencephalographic oscillations during the arrest reaction," *Brain Res.*, vol. 1121, no. 1, pp. 104–116, 2006.

[18] N. Tesler *et al.*, "Ascent to moderate altitude impairs overnight memory improvements," *Physiol. Behav.*, vol. 139, pp. 121–126, 2015.

[19] A. Mensen, B. Riedner, and G. Tononi, "Optimizing detection and analysis of slow waves in sleep EEG," *J. Neurosci. Methods*, 2016.

[20] I. Neuner *et al.*, "The default mode network and EEG regional spectral power: A simultaneous fMRI-EEG study," *PLoS One*, vol. 9, no. 2, 2014.