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NEUROENGINEERING AND FUNCTIONAL NEUROIMAGING ADVANCES FOR ASSESSING SLEEP QUALITY ON REMOTE ENVIRONMENTS

Abstract

Sleep in microgravity and analogue environments has been shown to be a challenging task due to the detrimental effects on human physiology induced by the confined environment and the weightlessness. Despite the efforts of space agencies there is currently no countermeasure maintaining optimal sleep quality. Except from the ongoing effort to assure the adaptation of humans on those remote environments there is also lack of an objective way to quantify the robustness of the proposed countermeasures. Most of the previous studies were based on subjective reports. However, sleep polysomnography (PSG) may offer a cheap, non-invasive, low-cost and efficient way to track with excellent temporal resolution the dynamics of the sleeping brain. Contemporary mathematical tools offer the feasibility to analyze the PSG data in a way that identifies the functional organization of the brain activity and the interactions among cortical regions associated with sleep. More specifically, network-based statistics and graph theory allow a functional neuroimaging analysis that enhances our understanding on the evolution from sleep onset to slow wave sleep and REM, while we could also estimate the effect of weightlessness and the countermeasure on sleep quality. Except from the formation of cortical networks during sleep, neuroengineering advances give rise to the formation of multi-organ networks which quantify the interactions among cortical, electrocardiographic, electroculogrammic and electromyographic interactions during sleep. The latter facilitates the understanding of how remote environments influence the entire human physiology during sleep and how arousal models of sleep pathology are also evident during space missions. The proposed framework was applied on a 6 head down tilt, bed-rest study performed in the 'envihab' premises of the German Space Agency (DLR) in Cologne. This ESA funded project simulated the microgravity effect on human physiology during long-term missions. It employed 23 healthy, young volunteers who were assigned either to a control or training, through high-intensity jumps, group. Our results demonstrate the efficacy of the proposed countermeasure to induce sleep onset. However, sleep quality was generally poorer during the experiment's evolution due to the sustained activation of cortical regions with pivotal

role in pathological (insomnia) sleep. Compensatory mechanisms of the brain activity were also evident. Our results demonstrate that identification of an efficient countermeasure is still an unresolved issue. However, an integrative evaluation framework would enhance our efforts towards the implementation of long-term manned missions.