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A BRAIN NETWORK FRAMEWORK FOR INVESTIGATING MICROGRAVITY EFFECT AND EVALUATING THE EFFICACY OF COUNTERMEASURES ON SLEEP QUALITY

Abstract

Despite the promising results from various countermeasures that have been proposed, adaptation of human physiology to long-term manned missions remains an unresolved issue. Nervous system disruptions are among the major effects of weightlessness, deteriorating both mental and physical well-being. Circadian rhythm alterations and sleep disorders remain a frequent symptom among crew members. Aiming to better understand how microgravity affects sleep quality and to objectively quantify the countermeasure efficacy, we performed polysomnographic (PSG) data acquisition within the context of the 6 head-down tilt bed-rest study in Cologne, Germany, which was funded by the European Space Agency. PSG data were gathered during a baseline period, 21, 35 and 50 days after bed-rest initiation and 7 days after the end of the microgravity simulation. The experiment recruited 23 healthy, young volunteers who were assigned either to a control or to a countermeasure group performing high-intensity jumps. Data acquisition involved electroencephalographic (EEG) recordings from 19 electrodes. An elaborate pre-processing phase resulted in artifact-free, high quality, 30 seconds duration EEG epochs, which were assigned manually to the various sleep stages according to the American Association of Sleep Medicine (AASM) criteria. For each epoch, functional connectivity analysis was performed on the entire EEG signal and the oscillatory activity of individual rhythms (delta, theta, alpha, beta and gamma band). It resulted in 19 19 synchronization matrices which then were represented by brain networks. Graph theory metrics were used to estimate the network properties which were dependent by the sleep staging, validating previous findings on connectivity alterations due to the sleep evolution. However normal sleep patterns were disrupted due to the microgravity simulation through patterns associated with increased hyperarousal and sustained activity. This was most prominent during the light sleep, while the countermeasure seems to facilitate sleep onset. Arousal effects were evident during deeper sleep stages and were associated with increased number of awakenings and poorer sleep quality. This decline pattern seems not to be gradual due to the compensatory mechanisms of the sleeping brain. The findings were derived by contemporary mathematical tools examining the macroscopic brain properties. The study also demonstrates the efficacy of network science to detect dynamic changes in the brain across the various sleep stages on extreme environments.