Ultra-long term EEG Reveals Circadian Trends

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Purpose

The development of wearable, unobtrusive EEG equipment opens up for longer recordings than ever before. Ultra-long term monitoring of brainwaves in a patient's everyday life allows us to obtain a circadian model for the typical electrographical patterns of the brain, which in turn allows us to detect patterns on any given day that deviate from the norm.

Method

- 4 healthy adults were monitored continuously with the subcutaneous EEG recording system depicted in Figure 1 for more than 40 days each.

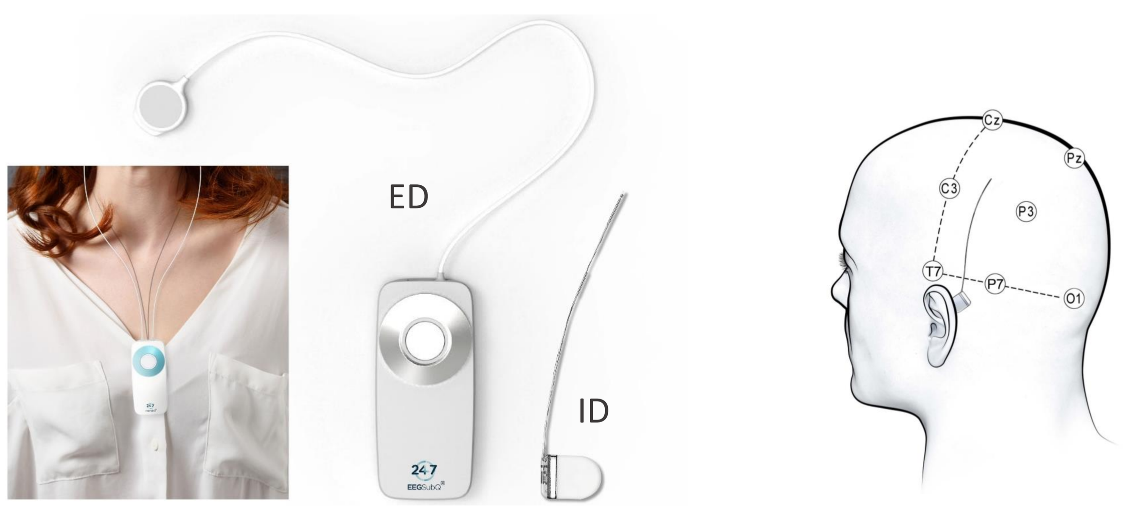

Figure 1
Left: The EEG recording device consists of an implantable device (ID) with three electrodes, and an external device (ED) containing data storage and power supply. The ID and ED communicates wirelessly through the skin.
Right: The ID was implanted subcutaneously above the ear.

- EEG was scored as either "awake" or "asleep" by an EEG expert.
- Artifact rejection based on amplitude, 50 µV (awake)/100 µV (asleep)
- The remaining EEG filtered into traditional frequency bands (δ: 0-4 Hz, θ: 4-8 Hz, α: 8-13 Hz, βlow: 13-20 Hz, and βhigh: 20-30 Hz), and median filtered to reduce noise.
- The power in each frequency band was aligned relative to sleep onset (**SO**) and sleep end (**SE**) for each day, such that the power could be analyzed not with respect to time of day, but with respect to circadian rhythm.

Results

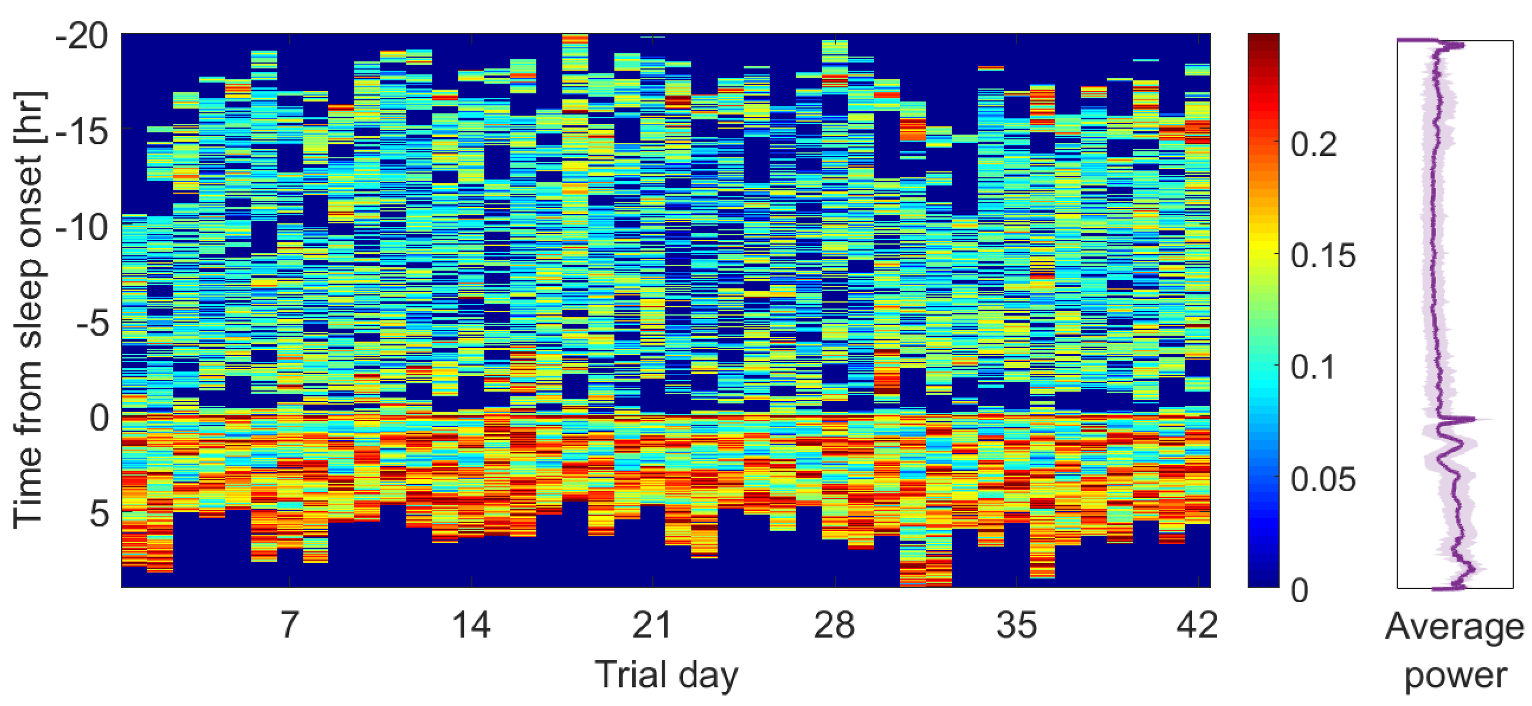

Figure 2
The relative power in the θ: 4-8 Hz band plotted as function of hours from Sleep Onset (y-axis), across all days in the trial (x-axis), for a representative subject (subject 3). The difference between awake and asleep EEG is quite clear, as is the different stages of sleep. The daily pattern is strikingly stable across the trial days. The average power across all days is plotted in the panel to the far right.

Results continued

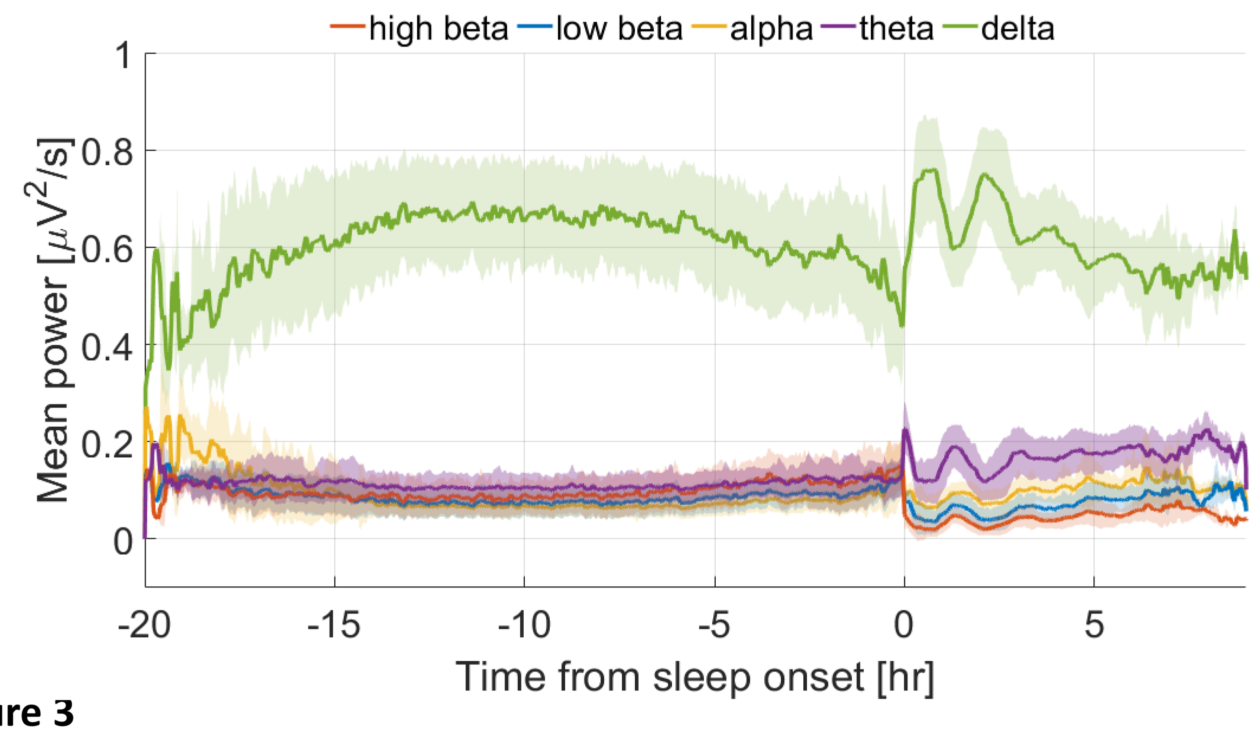

Figure 3
The mean relative power and standard deviation of each frequency band across days for the same subject as in Figure 2. Each band show distinct characteristics as the circadian cycle progresses. The night show especially clear and stable patterns, with the lowest frequency band (delta) oscillating in antiphase w.r.t. the higher frequency bands.

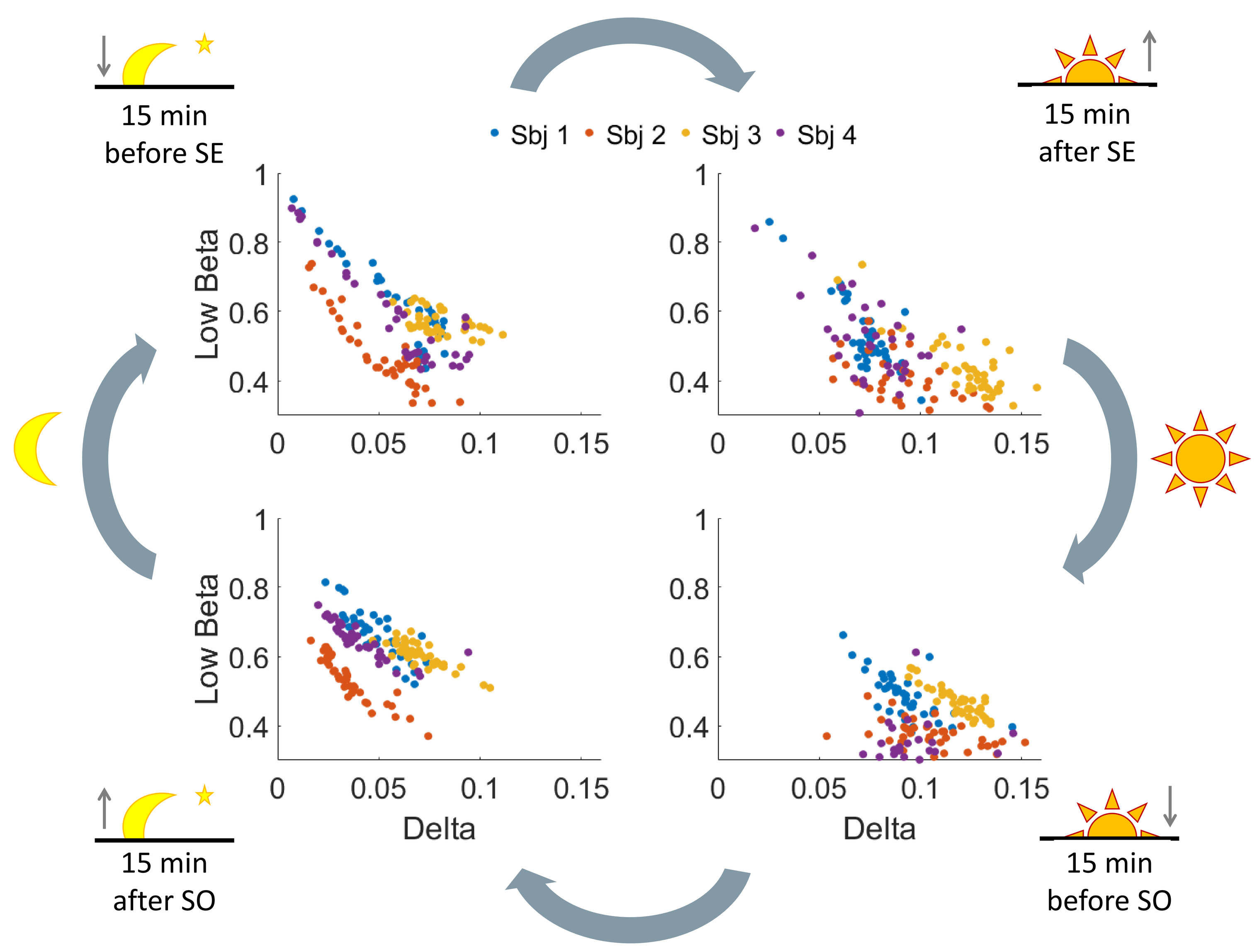

Figure 4
The relative power in the delta vs. the lower beta band over a 15 minute period, at four different times during the circadian cycle: before sleep end, after sleep end, before sleep onset and after sleep onset. The four colors represent the four test subjects, and each data point represent one day/night-cycle. Within each subject, there is some variation across days, but the variation between subjects is larger. This indicates that statistical models for circadian rhythms are subject specific.

Conclusion

We have shown that circadian patterns can be quantified over extended periods of time under normal life conditions. The patterns appear to be stable across time, but with high inter-person-variability. With a circadian model it is possible to quantify how seizures, which are known to disrupt the normal sleep pattern, affect the otherwise statistically stable sleep trends in the EEG. **In the future, features from ultra-long term EEG will likely play a significant role in optimization of diagnostics and treatment in epilepsy and a range of diseases with circadian patterns**.

References

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