Novel Ultra-Long Term Subcutaneous EEG Monitoring System

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Background

A novel subcutaneous two-channel EEG recording system was tested with regard to data quality over a prolonged period of recording. The system includes an implantable electrode wire with a coil for inductive, transcutaneous transmission of power and EEG signal to an external device. The external device collects data for online or offline signal analysis.

Usage

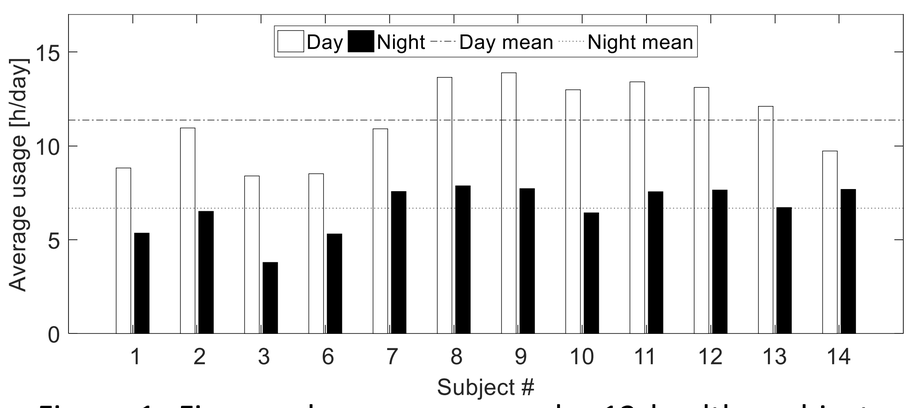

Figure 1: Five week average usage by 12 healthy subjects. After subject 6, an improved attachment system was introduced leading to higher average usage. The average overall usage was above 18 hours/day and almost 20 hours/day with the new attachment system.

Methods

Data were recorded for approximately six weeks on 14 healthy subjects. Two subjects had to be excluded due to a bug in the system software. Trends in impedances as well as 10 minutes average signal power in standard frequency bands (δ: 0-4 Hz, θ: 4-8 Hz, α: 8-13 Hz, β_{low}: 13-20 Hz and β_{high} 20-30 Hz) were analyzed visually to demonstrate the robustness of the device. Finally, the amount of good EEG was assessed based on the percentage of time with amplitudes below 50 µV during daytime and 100 µV during night.

Impedance

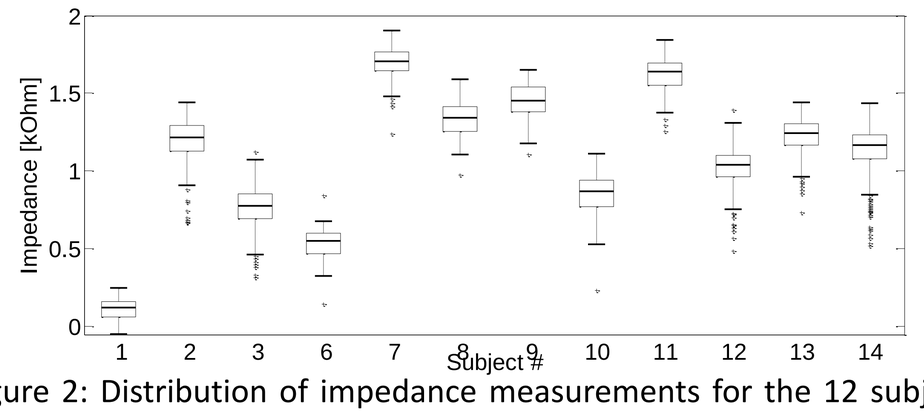

Figure 2: Distribution of impedance measurements for the 12 subjects. Every time the implant was powered up an impedance was measured. Due to fabrication process variation in the silicium the impedances can vary up to ±1.2kΩ. However, even the most conservative estimation places all impedances below 3kΩ. Looking at the impedances over time, no trend was observed for any of the subjects.

EEG morphology

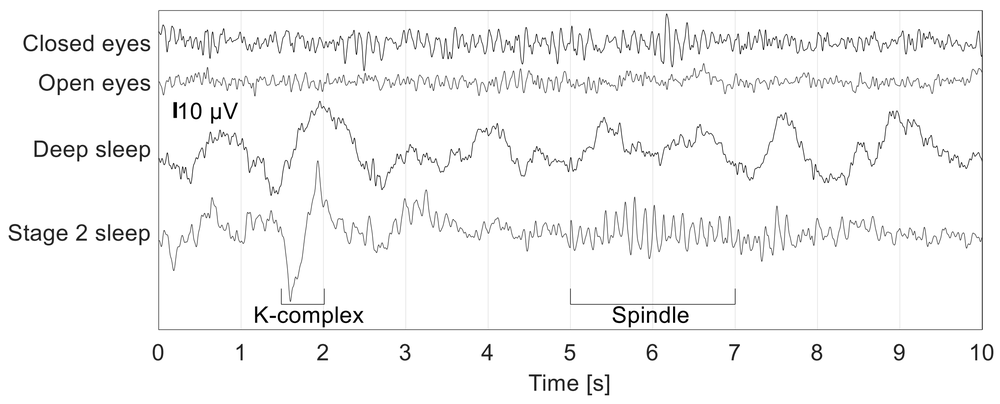

Figure 3: Examples of recognisable, normal EEG patterns measured by the subcutaneous system. A visual comparison of standard scalp EEG and the subcutaneous EEG by two board certified neurophysiologists showed that the signal quality was comparable (Duun-Henriksen et al., 2015).

Longitudinal analysis

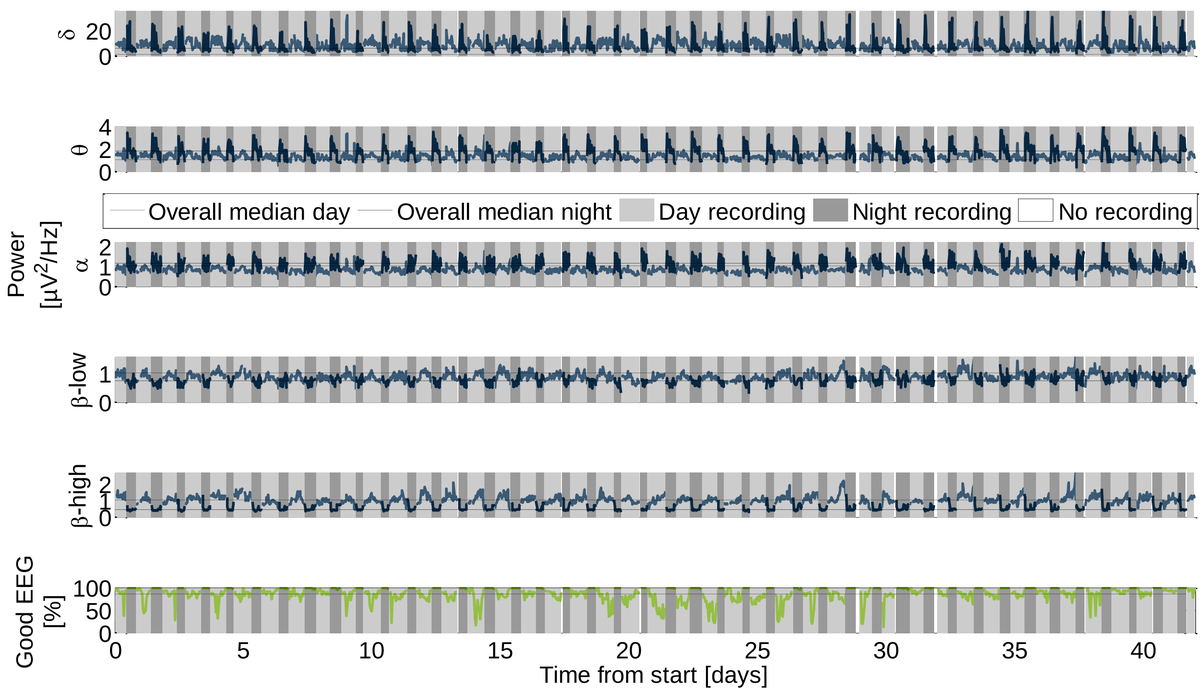

Figure 4: The average power in the δ, θ, α, β_{low}, and β_{high} bands over the entire recording for a single patient as well as the percentage of time the EEG quality was assessed as being of good quality. By visual inspection, the power for all of the bands does not change significantly over the entire course of the recording while intra day and night patterns might be observable. Except for periods of eating, the percentage of good EEG was constantly high. During nights almost no artifacts were present.

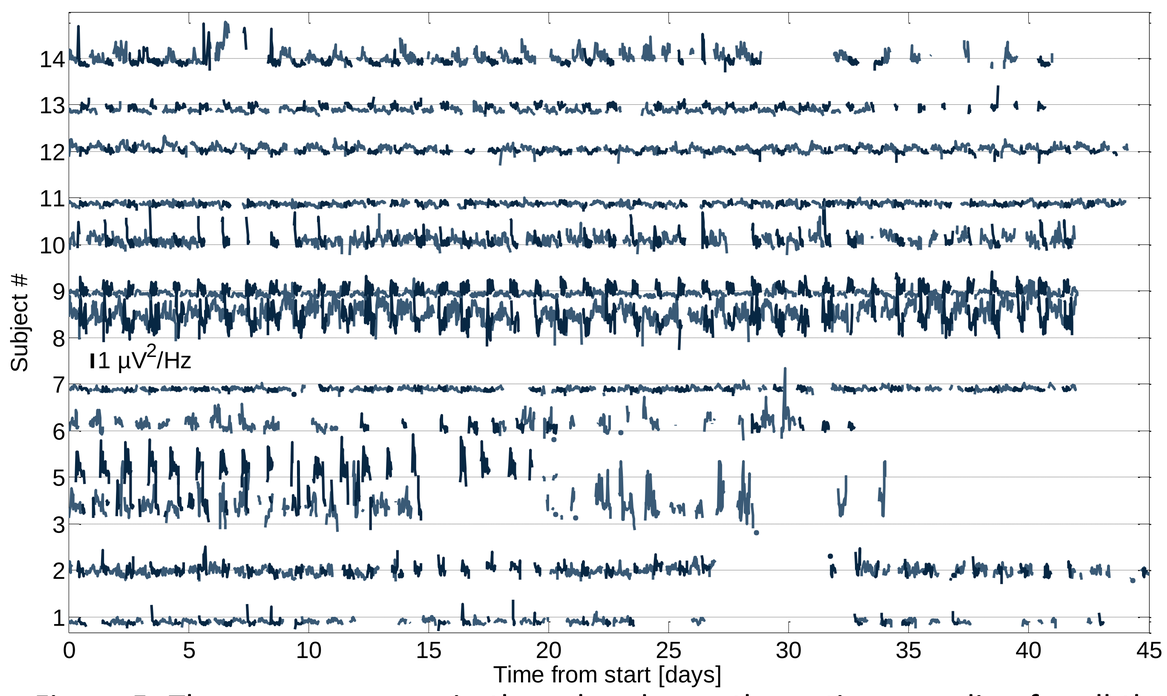

Figure 5: The average power in the α-band over the entire recording for all the subjects. The power does not change for any of the patients over time. After subject 6 a new attachment system was introduced which increased the average usage. The horizontal grid lines are placed at 1µV²/Hz for each subject.

Conclusion

Well-described normal EEG patterns were easily recognizable in the measurements. A high average usage time as well as a signal quality and impedance measurements that does not seem to change over a six week period of continuous use lead us to conclude that the subcutaneous EEG monitoring system provides a convenient and unobtrusive method of ultra-long term EEG recording when a small number of EEG electrodes are sufficient.

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Declaration of interest: Jonas Duun-Henriksen, Sirin W Gangstad and Lykke Blaabjerg are all full time employed at Hypo-Safe A/S developing and producing devices for unobtrusive subcutaneous EEG monitoring.

References: Duun-Henriksen et al., "EEG Signal Quality of a Subcutaneous Recording System Compared to Standard Surface Electrodes," Journal of Sensors, 2015.
Elsborg et al., " Detecting Hypoglycemia by Using the Brain as a Biosensor", Biosensors for Health, Environment and Biosecurity, 2011