Open-science: validation of „neuro-startups”

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Open-science

One of most successful Polish startup companies, Neuroon, made a claim they can automatically classify sleep stages and increase sleep quality using a small wearable mask. Using open-science tools[1] (github.com/pawelchojnacki/sleep_project) we compared the sleep stage classification produced by Neuroon with a clinical standard polysomnography recording[2].

Sleep stage classification assesment

Sleep consist of several stages, which differ in their function and physiological correlates. Polysomnograhy (PSG) is a study of sleep using multiple bio-signal sensors to classify sleep stages. A hipnogram is a graph representing sleep stages during the night. We compared the Neuroon hipnogram with the PSG hipnogram.

- First we assessed whether the Neuroon EEG signal is similar at any point in time to the PSG EEG signal (Time-synchronization).

- Second we assessed accuracy with which Neuroon predicted the sleep stage (Confusion Matrix).

- Third we assessed whether there is enough information in the power spectrum of EEG signal to discriminate between the sleep stages (Spectral Analysis).

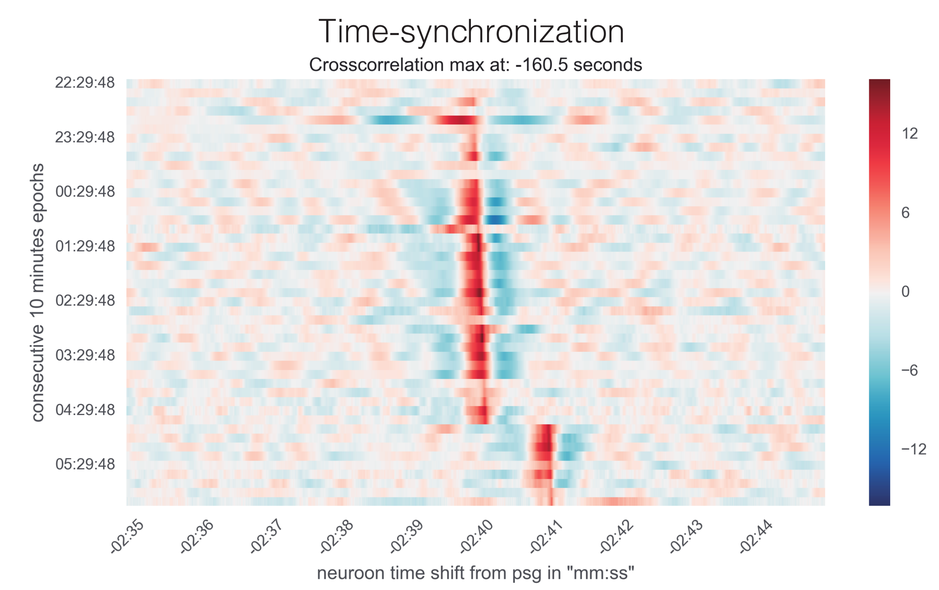

Figure 1.1: Neuroon and PSG were recorded on devices with unsynchronized clocks. The peak in cross-correlation function represents the time offset between the two EEG signals. The peak occurs at 160 seconds in consecutive 10-minute slices of EEG signals (Top-row).

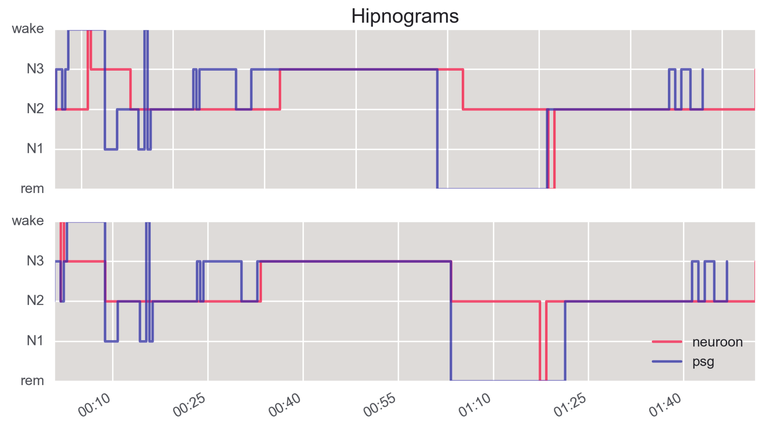

Figure 1.2: The hipnograms were corrected for the time shift. Top row represents un-corrected hipnograms, in the bottom row neuroon hipnogram is shifted 160 seconds backwards.

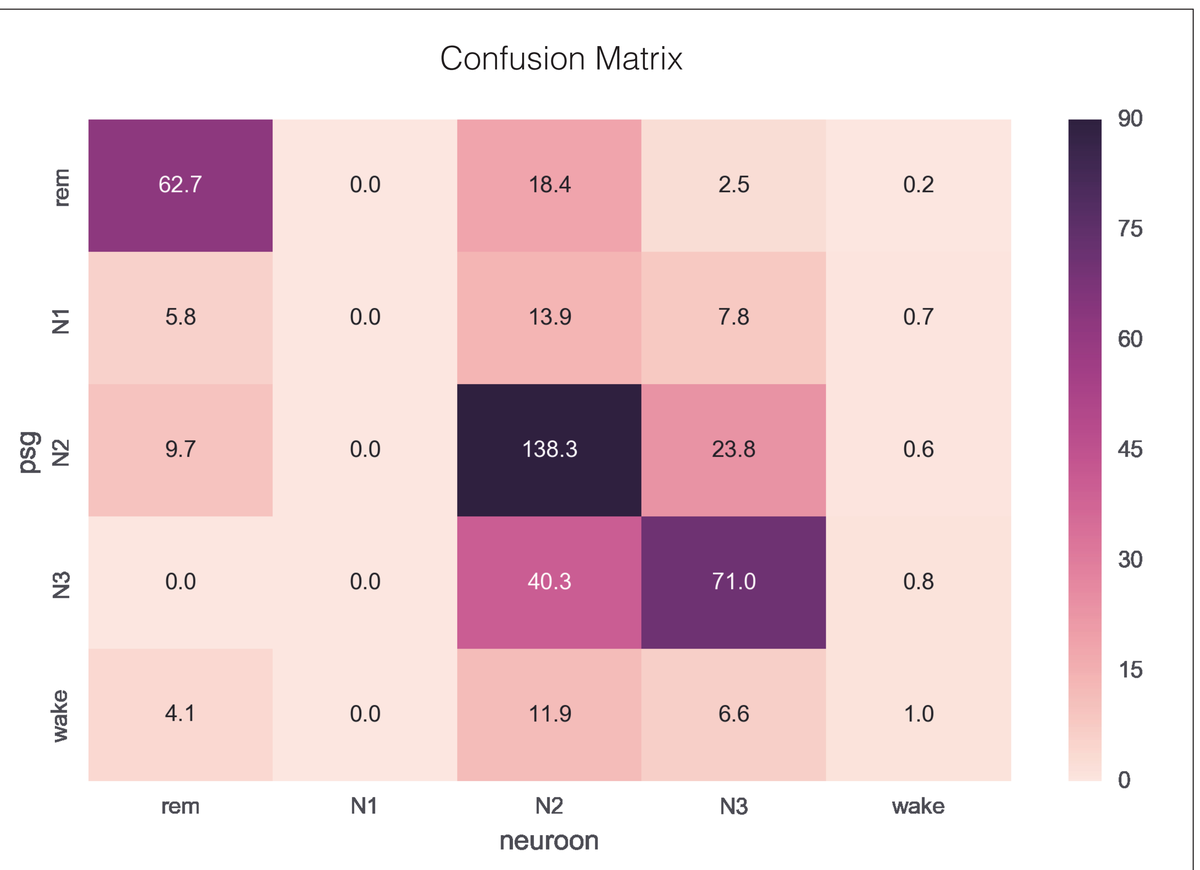

Figure 2.1: After correcting for the unsynchronized clocks we compared the sleep stage classifications produced by the PSG and Neuroon. We represent the overlap between two classifications in a confusion matrix. The values are minutes during the night when each device was indicating a sleep stage

	Precision	Recall
N1	0	0
N2	0.64	0.81
N3	0.63	0.63
REM	0.75	0.73
Wake	0.3	0.1

Figure 2.2: Table on the left displays parameters describing the confusion matrix (CM). ‘Precision’ represents the proportion of correct responses to false positive responses. ‘Recall’ represents the proportion of the class occurences that have been correctly classified.

The **accuracy score** of the CM was **0.65**. Accuracy represents the percentage of correct classifications from all responses. Graph on the right represents the permutation test for the accuracy score. Each permutation was obtained by randomly changing the class labels assinged by Neuroon.

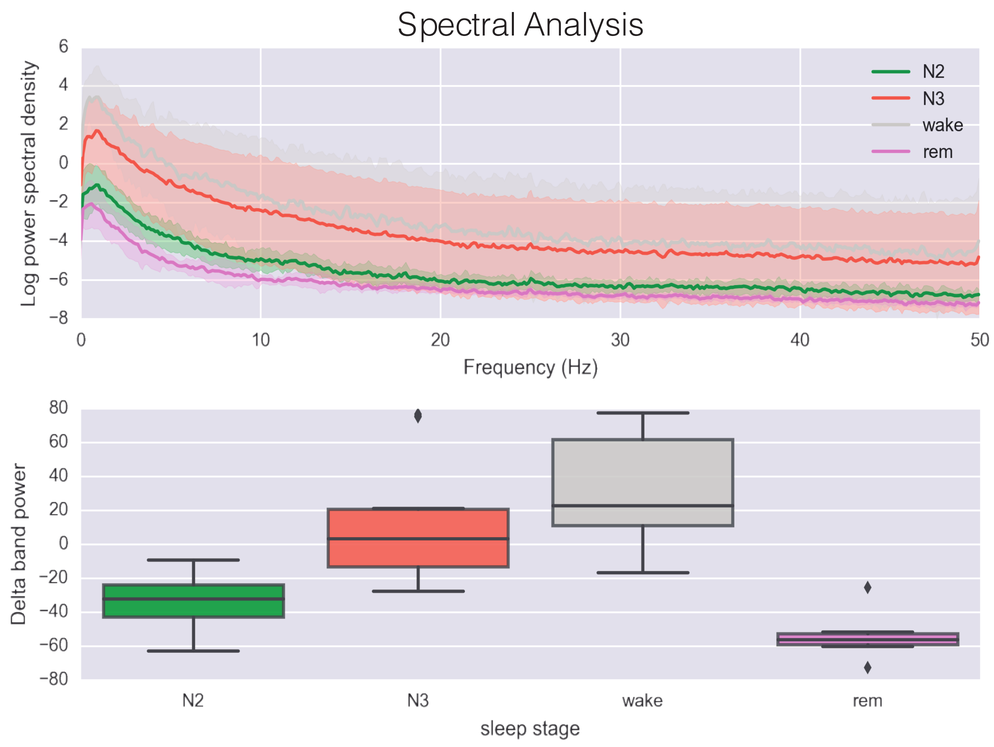

Figure 3: Comparison of PSG and Neuroon in their ability to discriminate EEG delta power in sleep stages. Delta power is an important feature for EEG based sleep staging[3].

Conclusions

- **Neuroon performs sleep stage classification with above chance accuracy.**

- **There is enough information in EEG signal to discriminate sleep tages.**

- **Neuroon precision is far from satisfactory for commercial application.**

References

1. For the story behind the project visit: https://alxd.org/neuroon-analysis-sources.html

2. PSG staging was performed by Sleep Disorders Center at the Institute of Psychiatry and Neurology in Warsaw.

3. Mukai, J., Uchida, S., Miyazaki, S., Nishihara, K., & Honda, Y. (2003). Spectral analysis of all-night human sleep EEG in narcoleptic patients and normal subjects. J Sleep Res, 12(1).