Automated Sleep Analysis

Peter Achermann, *Member, IEEE*, Alexander Malafeev, Jelena Skorucak, and Leila Tarokh

***Abstract*— Automated sleep analysis can be based on simple quantitative analysis of EEG, EOG and EMG and provides a good overview of different vigilance stages. For example, the density of large slow waves reflects NREM sleep, while the absence of such oscillations coupled with low EMG and eye movements are indicative of REM sleep.**

I. Introduction

Typical patterns in the electroencephalogram (EEG) in conjunction with changes in the electrooculogram (EOG) and the electromyogram (EMG) serve to discriminate rapid-eye-movement (REM) sleep, non-REM sleep and waking. Sleep stage scoring according to standardized criteria is achieved by visual inspection of the signal, is cumbersome and time consuming. Such scoring is to some degree subjective and thus, inter-rater reliability may be low, in particular for scoring of patients. Therefore, numerous attempts have been made to automatically score sleep stages. However, the sleep community has not accepted an algorithm as the gold standard thus far.

Here we demonstrate that automated sleep analysis based on some simple quantitative measures of EEG, EOG and EMG may provide a good summary of sleep structure.

II. Results and Discussion

Fig. 1 illustrates the visually scored sleep profile (hypnogram), spectrogram of the EEG (color-coded power density spectra), slow-wave activity (SWA; power in the 0.75 - 4.5 Hz range), number of slow waves (SW; >75 µV peak-peak; 0.5 - 2 Hz), occurrence of eye movements (ratio of delta power in the EOG and EEG), and EMG activity (power in the 15 - 30 Hz range). Subjective scoring of stages and quantitative measures were determined for consecutive 20-s epochs. The hypnogram is provided to compare the quantitative measures with the classical sleep staging. Spectral activity is modulated by the NREM-REM sleep cycle. SWA, spindle frequency activity (12 - 14 Hz), and alpha activity (8 – 12 Hz) in the first two NREM sleep episodes can be identified in the color plot by the presence of warm colors. SWA and the number of SW are also modulated by the NREM-REM sleep cycle and exhibit a declining trend in the course of the night. REM sleep is characterized by the absence of large SWs, the occurrence of eye movements (high values of the EOG/EEG power ratio) and low EMG power (muscle tone).

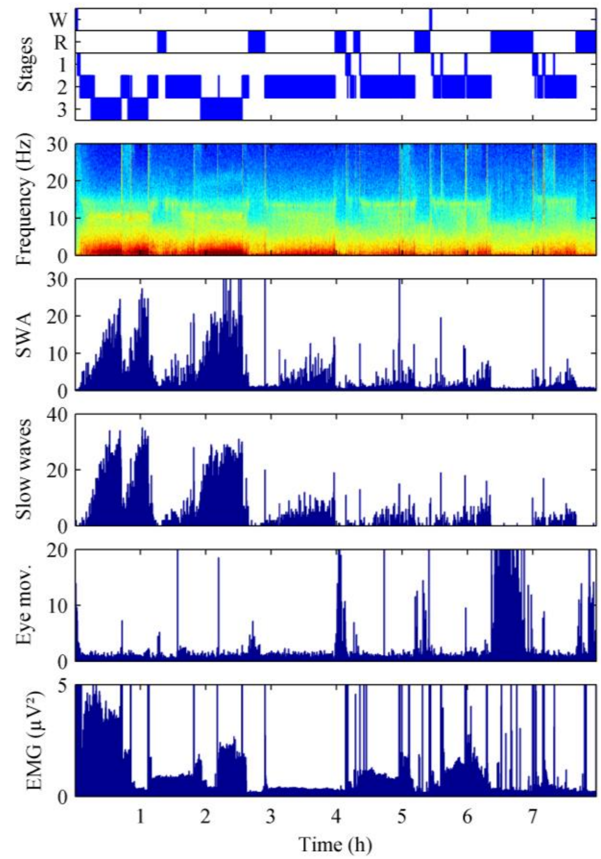

Figure 1. Example of automated sleep analysis. *(Hypnogram, spectrogram of EEG [-20 - 30 dB], slow-wave activity [SWA, in $\mu V^2/10$], number of slow waves per 20-s epoch [density], eye movements [ratio of delta power in the EOG and EEG], and EMG activity. No artifacts were removed)*

SWA and the density of large SWs are highly correlated and reflect the depth or intensity of sleep. Their absence seems to reliably indicate REM sleep episodes. In particular, if consecutive epochs with zero or 1 to 2 SWs are considered, in the absence of alpha activity, a reasonable estimation of REM sleep can be obtained. A drop in eye movements and the occurrence of spindle frequency activity can be used to identify sleep onset. We are working on a fully automated separation of waking, NREM and REM sleep based on the described measures.

We demonstrate that simple quantitative analysis of a few physiological signals has the potential to reliably reveal the structure of sleep. Such automated detection of sleep is of utility to both research and commercial applications.

*Resrach supported by the Swiss National Science Foundation (grant 32003B_146643) and nano-tera.ch (grant 20NA21_145929).

P. Achermann (phone: +41-44-635-5954; fax: +41-44-635-5707; e-mail: acherman@pharma.uzh.ch), A. Malafeev (e-mail: malafeev@pharma-.uzh.ch), J. Skorucak (e-mail: jelena.skorucak@pharma.uzh.ch), and L. Tarokh are with the University of Zurich, Institute of Pharmacology and Toxicology, CH-8057 Zurich.

L. Tarokh is also with and the University of Bern, University Hospital of Child and Adolescent Psychiatry and Psychotherapy, CH-3000 Bern (e-mail: leila.tarokh@kjp.unibe.ch).