Differences in sleep microstates curves among healthy sleepers and patients after stroke

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| Introduction

Sleep deprivation, whether from disorder or lifestyle, poses a significant risk in daytime performance. Ischemic stroke is a serious disease affecting parts of brain and resulting in possible changes in sleep structure. In the study, functional cluster analysis was used in order to identify potential sources of disturbed sleep in stroke patients.

| Data and methods

In total, 33 night records of patients after ischemic stroke were used (average age 68 years). A control sample of healthy sleepers was taken from the SIESTA database [2] .

Instead of the traditional Rechtschaffen and Kales scoring system an alternative method for sleep modelling was used. Probabilistic sleep model (PSM) describes sleep via posterior probabilities of sleep stages called sleep microstates [1]. Posterior probabilities for a given microstate of a selected subject are considered as curves.

Cluster analysis of posterior curves was chosen as a tool for detecting differences in sleep architecture influenced by ischemic stroke. Posterior curves were smoothed by smoothing covariance surface within functional principal component analysis [3]. After that, *k-means* algorithm was applied on smoothed posterior curves aligned to sleep latency. Each cluster was represented by an average posterior curve.

| Probabilistic sleep model

PSM characterizes sleep as continuous process in terms of posterior probabilities of a finite number of sleep stages called sleep microstates. We consider an updated version of the PSM trained on EEG signal obtained from 3 pairs of electrodes and a single channel EMG signal. Both signals were partitioned into non-overlapping segments of length 3 s. An autoregressive model (AR) of order 5 was then fitted with the Burg method applied for every segment, in the case of EMG signal the AR model of order 2 was used. Estimated coefficients were concatenated into a feature vector *a*. After that, the Gaussian mixture model was estimated in 3 × 5 + 2 dimensional space of the AR coefficients:

$$p(a) = \sum_{i=1}^{20} p(i)p(a \mid i) = \sum_{i=1}^{20} \pi_i N(\mu_i, \Sigma_i),$$

where $p(i)$ or π_i indicates probability of micro-state i in a given segment. Conditional probabilities $p(a \mid i)$ were modeled by normal distribution N with (unknown) parameters μ_i a Σ_i. All unknown parameters were estimated in the training process by the EM-algorithm. Derived microstates do not necessarily have a well-defined clinical or physiological interpretation. Hence for each microstate probabilities of traditional sleep stages (*wake*, *S1*, *S2*, *SWS – slow wave sleep*, *REM*) were estimated (Figure 1).
Plotting posterior probabilities for a given microstate against time produces a posterior curve.

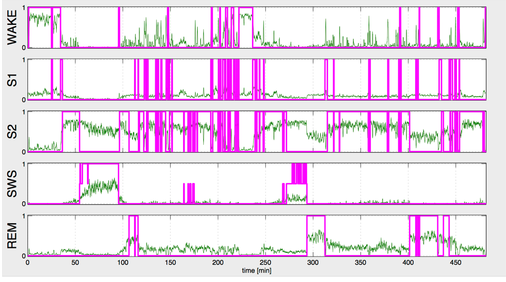

Figure 1: *Posterior probabilities (green color) transformed into classical sleep stages and compared with the Rechtschaffen & Kales scores (magenta color).*

| Sleep structure and age

First, we aimed to find a connection between sleep structure and age. In this case, only healthy sleepers were taken into account. By testing differences among clusters we found out, that within microstates related to *SWS* or *S2* stage a cluster with a higher posterior values included mostly younger, less than 40 years old subjects (Figure 2). By contrast, higher probability values of microstates related to *wake* or *S1* stages were associated with clusters formed by elderly healthy subjects (> 60 years old) and were observed during the whole night (Figure 3).

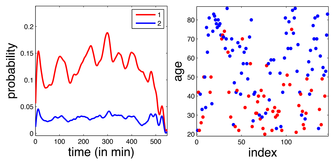

Figure 2 : *Microstate 17 (97% S2). Cluster with higher posterior values (red line) was formed by young subjects (< 40 years old, red dots).*

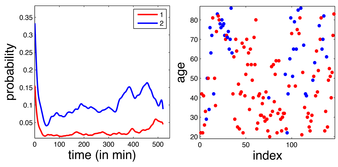

Figure 3: *Microstate 13 (44% wake, 40% S1). Higher probability values are associated with the cluster including people over 60 years (blue dots).*

| Sleep structure and subjective quality of sleep

Following the results of the functional cluster analysis we found relations between self-rating sleep quality scores and microstate posterior curves related to *wake* (Figure 4). Scores over 10 indicate poor sleep and belong to the cluster with high probability values.

Similar relations with microstate 14 related to *REM* were found for scores of Visual Analogue Scale Test for Drive and Drowsiness of healthy sleepers. Subjects in cluster with higher probability values of the microstate 14 were associated with low values of their drive and drowsiness.

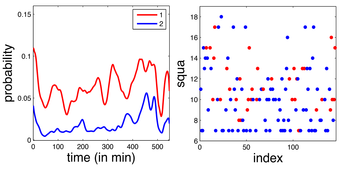

Figure 4: *Microstate 19 (87% wake). Higher probability values belong to cluster with self rating sleep quality scores over 10. In this case, values about 8 indicates good sleep ratings, high scores represents bad sleep. It seems like higher values of sleep quality scores reflect higher probability for microstate similar to wake stage.*

| Differences in sleep structure among healthy sleepers and patients after stroke

Sleep structure varies in age groups, therefore posterior curves of patients after stroke were compared only with healthy sleepers older than 60 years. Figure 5 shows clustering results within the first 16 microstates. Average posterior curves of clusters are represented by colored lines. Black curves are related to stroke patients (solid) and healthy sleepers (dashed).

- microstates 5 (76% *S2*) and 14 (80% *SWS*)
  - differences between black curves,
  - evident similarity between black curves and average posterior curves of clusters,
  - in microstate 14 during the second half of night black and coloured curves overlap,
  - the red cluster in these microstates included more healthy subjects than stroke patients, in the blue cluster dominated patients after stroke.
- microstate 12 (96% *S2*)
  - the red cluster included only healthy sleepers, in the case of stroke patient very low probability values were noticed, therefore the microstate can be associated and typical for healthy sleepers.

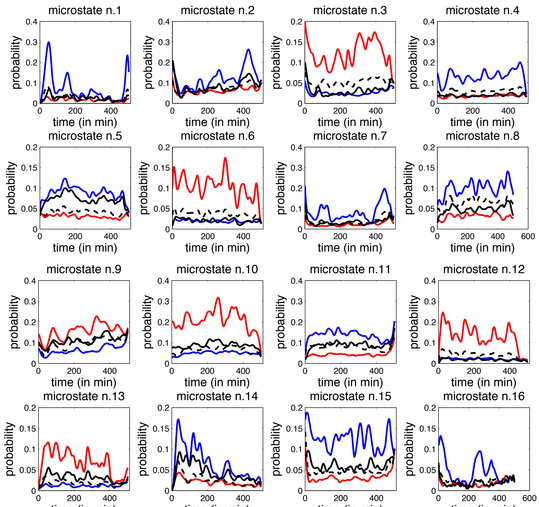

Figure 5: *Cluster analysis of posterior curves in patients after stroke and healthy sleepers for the first 16 microstates. Average posterior curves of clusters are represented by colored lines. Black curves are related to stroke patients (solid) and healthy sleepers (dashed).*

| Bibliography

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| Acknowledgement

This work was supported by MZ 2013/56-SAV-6 research grant.