Microstate EEGLAB toolbox

Andreas Pedroni, Andreas Poulsen, Nicolas Langer, Lars Kai Hansen

Methods of Plasticity Research, University of Zurich

Department of Applied Mathematics and Computer Science, Technical University of Denmark

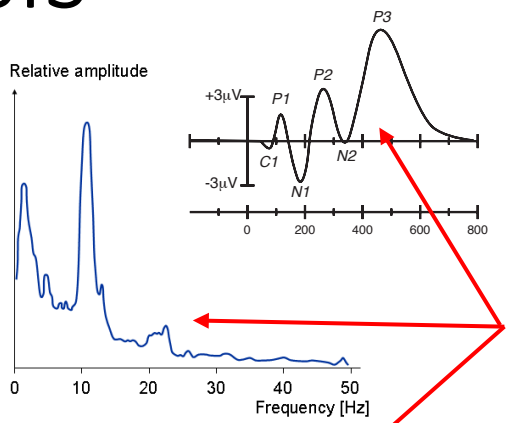
University of Zurich[UZH]

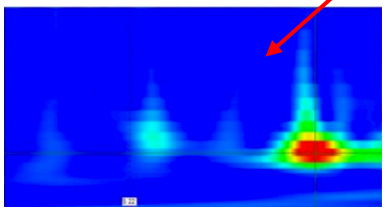
Technical University of Denmark

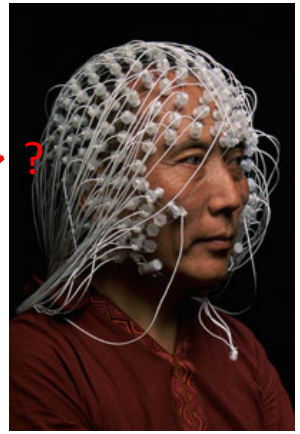
Classical EEG analysis

EEG

- Time (ERP)
- Frequency (FFT)
- Time-Frequency (Wavelet)







Typically many electrodes

Which electrode(s) should I analyze?

→Problem I: multiple testing, cherry picking,

→Problem II: missing out on information

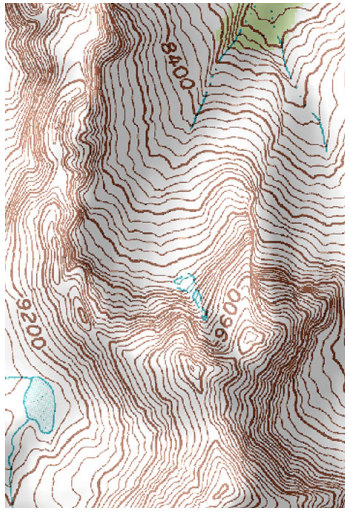
A state-dynamics view of EEG signals

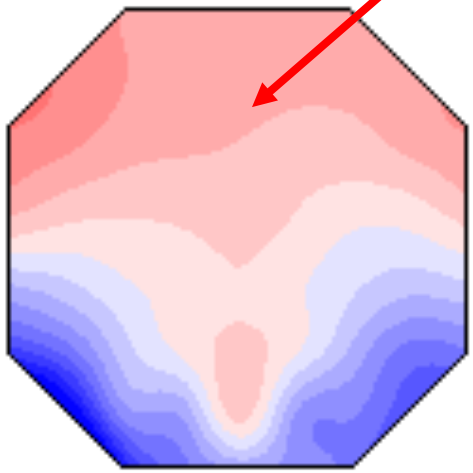
One approach for analyzing EEG-signals in a more holistic fashion is to view it as **states** with **dynamics**

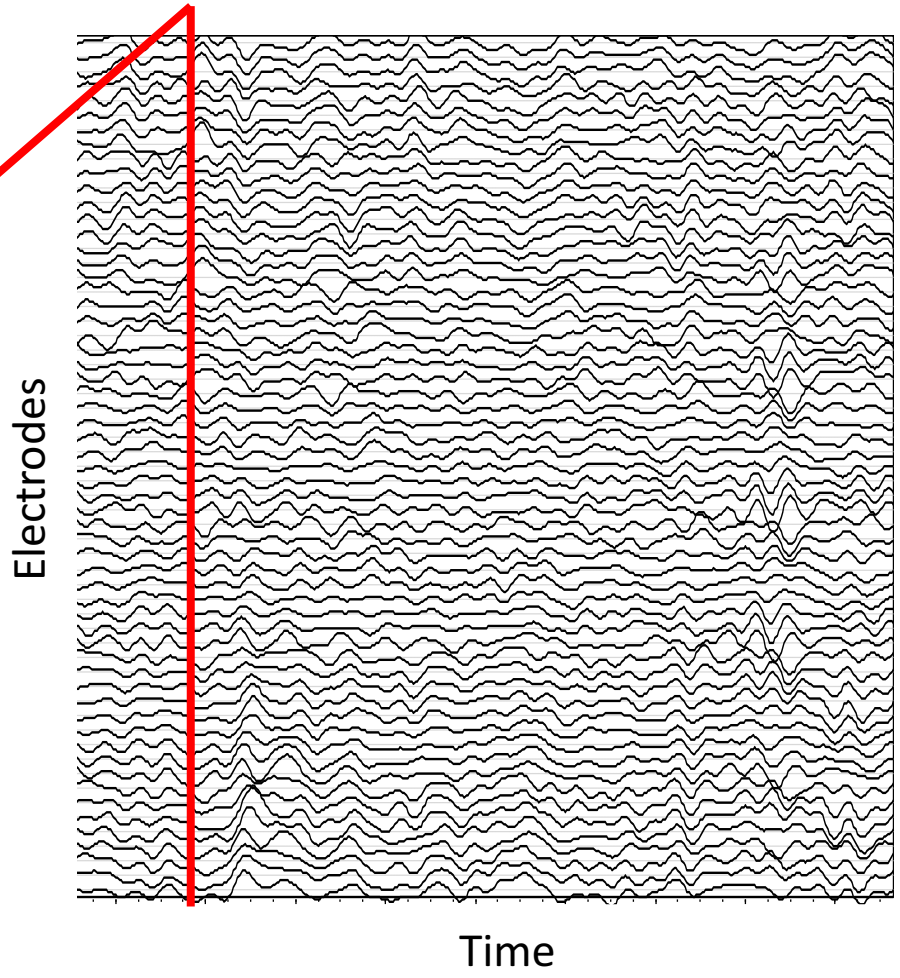
- **States** = Description of the EEG-signal at any time *t* (complexity, synchronicity, etc.)
- **Dynamics** = How do the states behave over time (duration, frequency of occurrence, sequence)

A topographical view on EEG

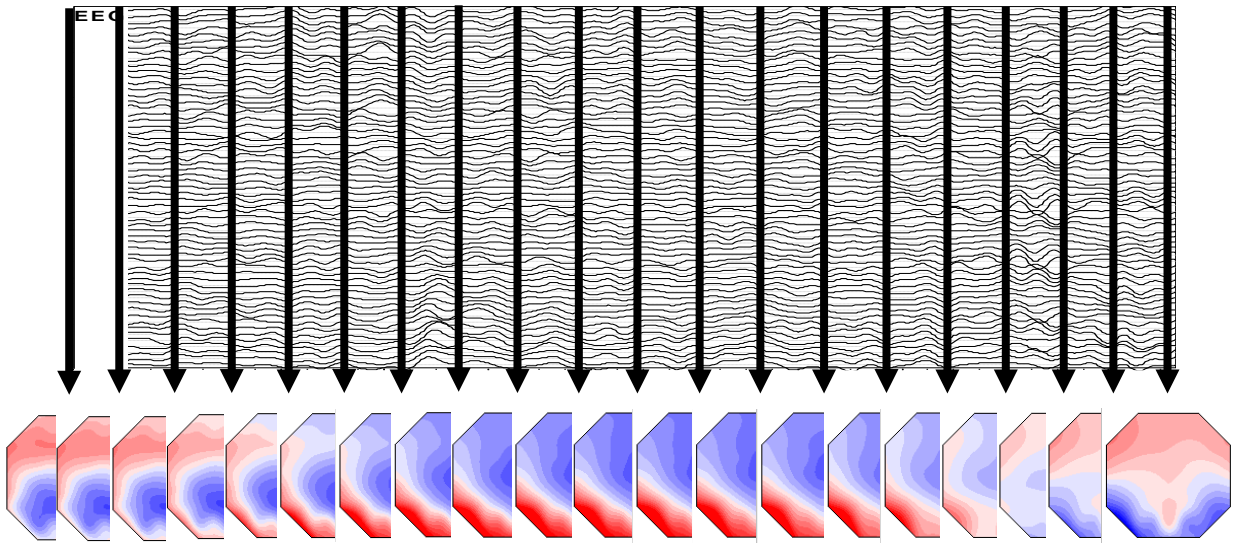
Coherent firing of a large number of neurons produces a defined voltage field on the scalp (=topography)







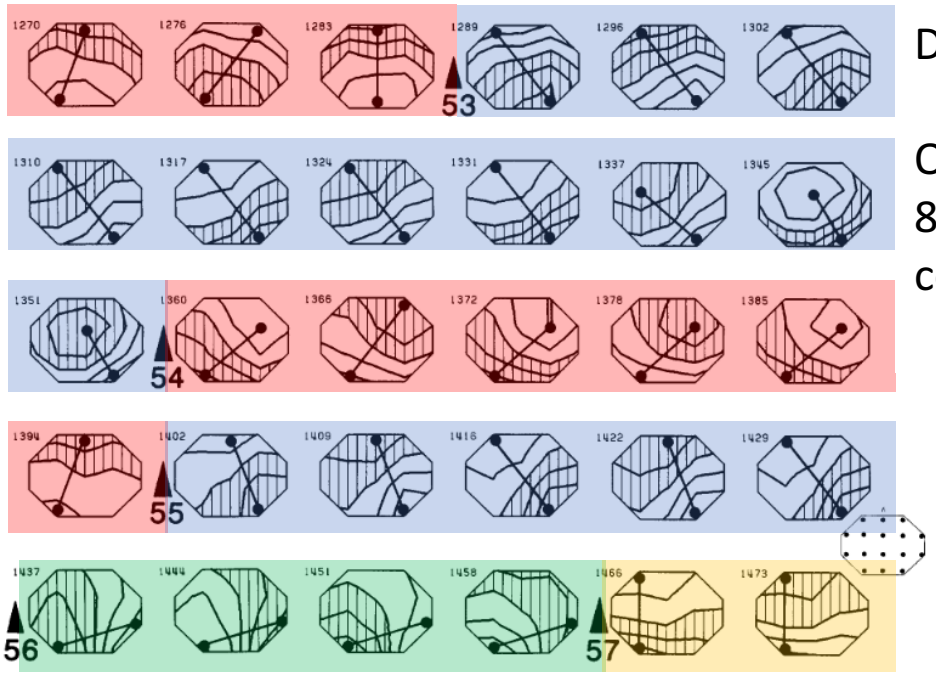
A topographical view on EEG



- **Change of the topography** indicates change in activation of networks
- **Change of the amplitude** indicates change in the number of coherently active neurons

Topographical analysis describes the **dynamics** of the functional **states** of neuronal networks

The birth of EEG microstates: EEG topographies are „quasi-stable“ over time



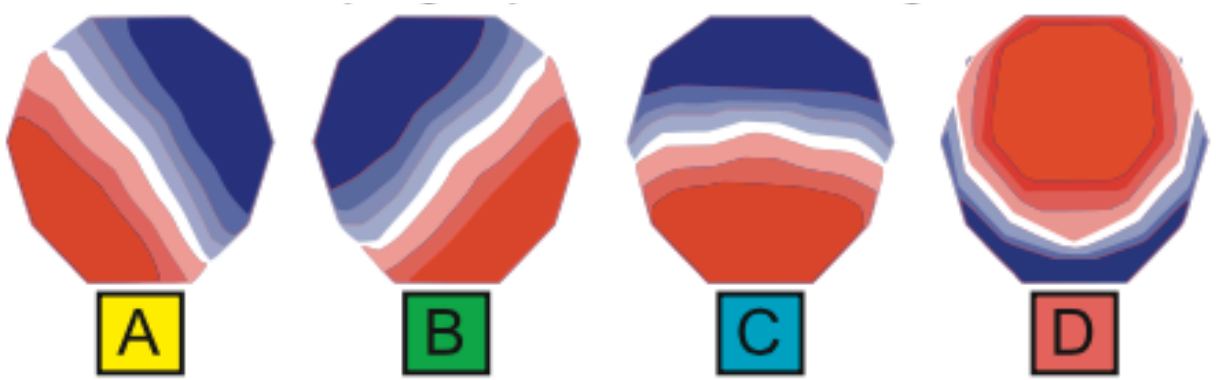
Data: 1500ms, topographies at GFP peaks

Observation:
80 – 150ms, quasi-stable topographical configurations

„The spatially stationary segments might be basic building blocks of brain information processing, possibly operationalizing consciousness time and offering a common phenomenology for spontaneous activity and event-related potentials“ (Lehmann et al., 1987)

EEG Microstates in spontaneous data

- During resting (closed eyes):
- Typically 4 microstate class topographies (explain ~80 % of the topographical variance in the EEG)
- Microstates last on average between 80 – 120ms

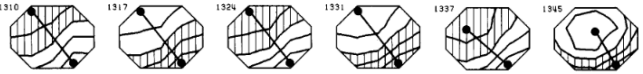


The basic steps of a EEG microstates Analysis

1. Preprocessing
2. **Microstates segmentation** *(pop_micro_segment)*
   Goal: Find the prototypical topographies (=microstate-classes, prototype maps)
3. **Back-fitting** *(pop_micro_fit)*
   Goal: Label the data of interest with respect to the best fitting Microstate-class
4. **Microstates statistics** *(pop_micro_stats)*
   Goal: Calculate for the EEG segments of a respective MS-class the parameters of interest
5. Inferential statistical analysis of parameters

Microstates analysis in spontaneous vs. event-related data

- **Spontaneous data (e.g. resting data):**
- Ignore polarity of topography



- Modified K-means (Pascual-Marqui et al., 1995)
- Global Field Power (GFP) peaks
  - topographies with high signal-to-noise ratio
  - topographies tend to be stable around GFP peaks

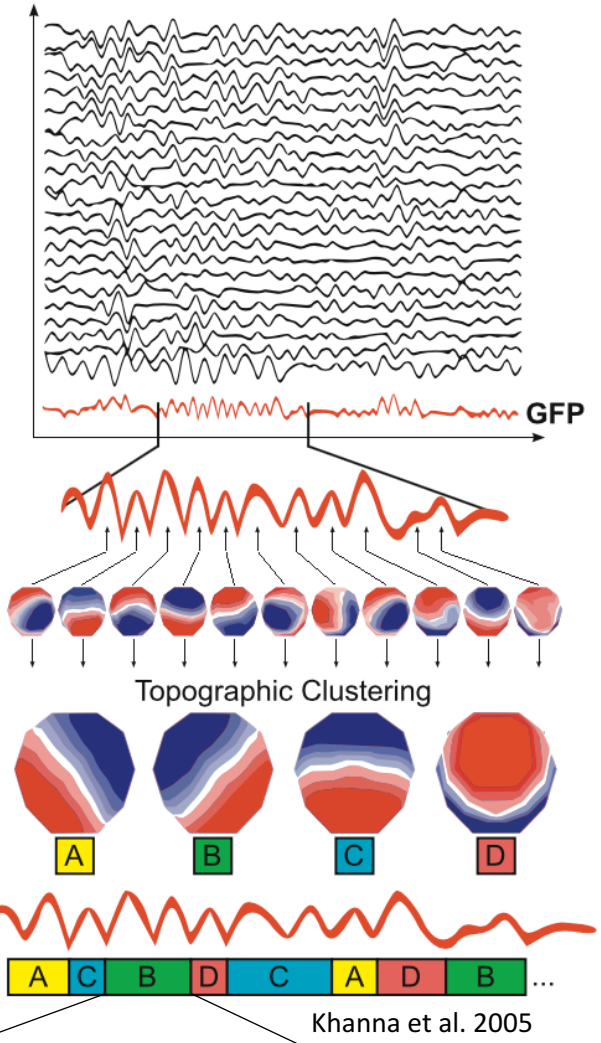
- **Event related data:**
- Account for polarity of topography
- K-means
- Use (grand)averaged data for segmentation

Microstates segmentation and back-fitting

Segmentation:
The segmentation aims to find the most prototypical topographies (=microstate-classes, prototype maps) of the data

→ use GFP peaks
→ Modified k-means clustering
→ How many clusters? Cross validation, other criteria…

Back-fitting:
Assign the microstate-class with highest spatial correlation to each timeframe of EEG (with minimum segment duration)



without min duration:

The Output: EEG microstates statistics

- Average duration
- Mean number of occurrences per second
- Percentage time covered by each state
- Global explained variance of each state
- Average GFP during a state
- Transition probabilities between states

Functional significance of EEG microstates

Emergence of microstates:

Improbable: A microstate is produced by a small, local group of neurons that are transiently active together (Only small number of MS, well defined temporal structure)

Probable: A microstate is produced by a large network of activity, spanning over the large parts of the cortex

Connection to fMRI resting state networks:

- When the microstate time series is convoluted with the resting-state fMRI BOLD signal, individual **microstate maps correlate with the activity of particular resting state networks** (Britz et al., 2010; Musso et al., 2010; Yuan et al., 2012).
- MS time series are linked to fMRI signal via scale free dynamics, suggesting that resting-state brain activity at the **EEG and fMRI timescales reflect the same underlying neurophysiological processes** (Van de Ville et al., 2010)

Now to the practice…

- Resting EEG data of children
- Filtered from 2 to 20 Hz
- Preprocessed with Automagic 💫
- Plugin: https://github.com/atpoulsen/Microstate-EEGlab-toolbox
- https://github.com/DynAge/brainhack-zh/blob/master/misc/MicrostateBrainHackSingle.m
- Data: the same as in Automagic.

Further reading...

Topographic ERP Analyses: A Step-by-Step Tutorial Review by Murray et al., 2008

Microstates in resting-state EEG: Current status and future directions by Khanna et al., 2015

Electrical Neuroimaging by Michel et al., 2009

Email: andreas.pedroni@uzh.ch