LIÈGE université
GIGA
Consciousness

Neurophysiology Demo/Workshop

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Brain computer interface

Content

- What and how do we measure with EEG?
- Pro's and Con's of EEG

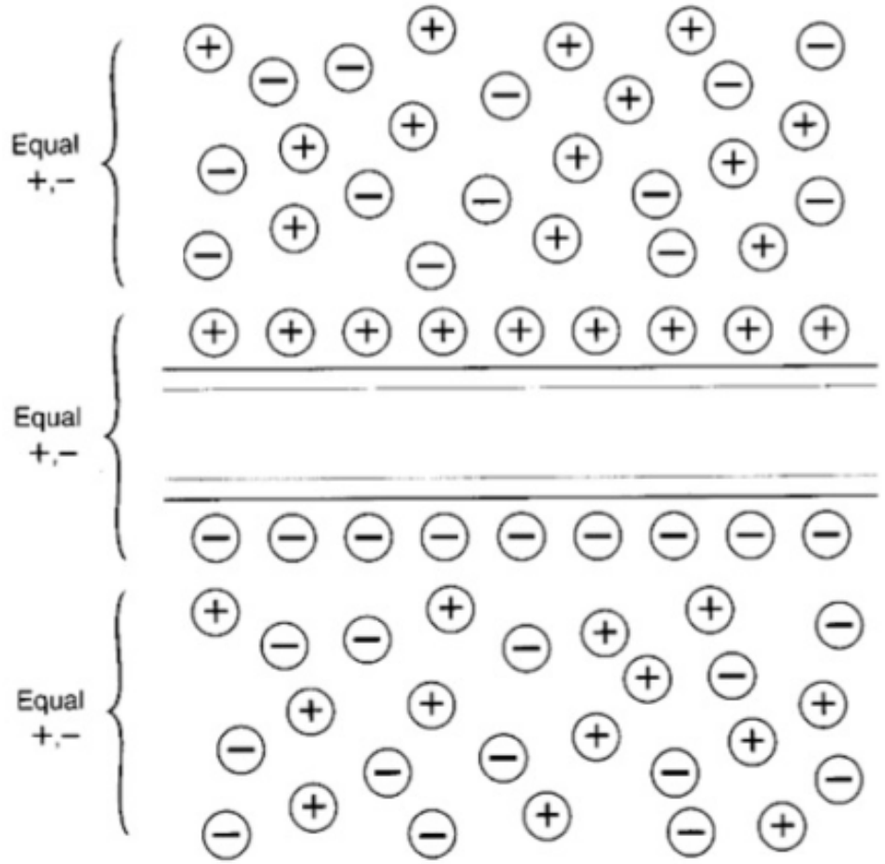
- **Utilities of EEG**
- Clinical EEG
- Quantitative task-free EEG
  - Power
  - Connectivity
  - Sleep EEG
- Evoked responses
  - Oddball paradigm
  - TMS-EEG
  - Heartbeat-evoked responses
  - BCI applications
- State fluctuations & treatment

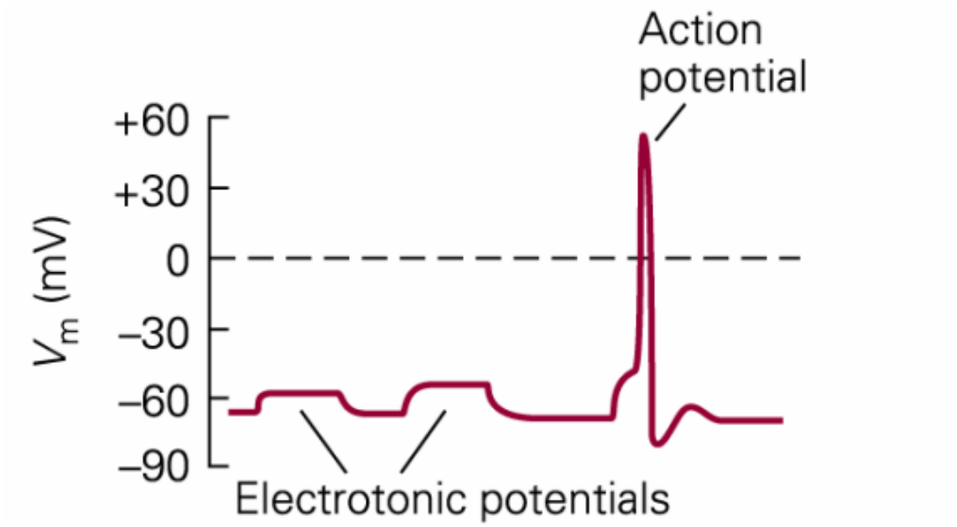
- Advanced methods examples
  - Source reconstruction → increase spatial resolution and avoid volume conduction
  - Phase amplitude coupling → Interaction between different frequencies
  - Microstates → dynamical view of how the spatial distribution of the electric potential on the scalp changes over time

EEG: What do we measure?

Outside

Inside

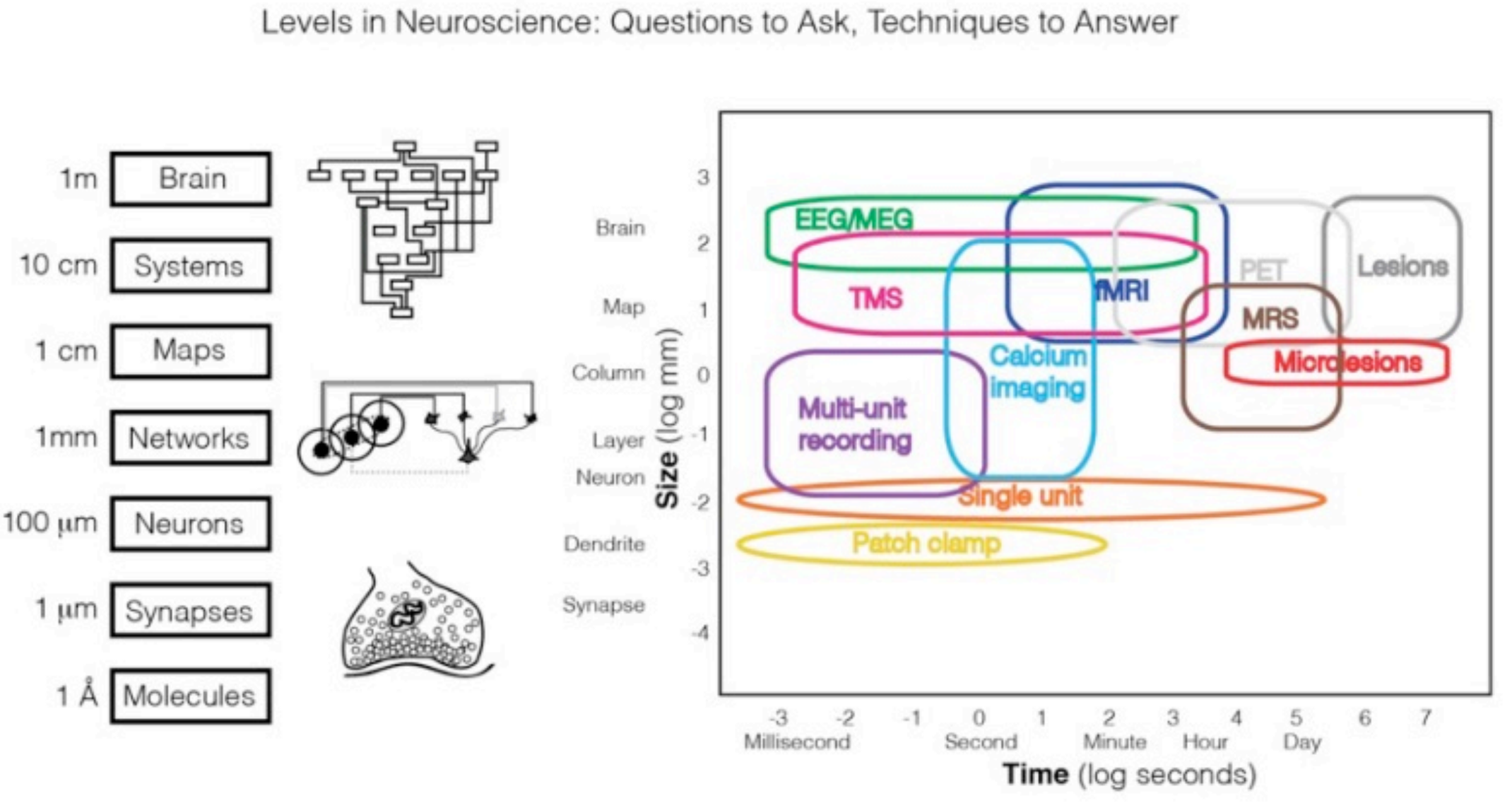




Polarization = any potential difference (>0) between intra- and extracellular space. Polarization is normally negative

De-polarization = loss of (negative) polarization, bringing the cell closer to an action potential → **a neuron transports electrical signals**

EEG: What do we measure?



How to set up an EEG acquisition

- Measure the head circumference
- Measure CZ

How to set up an EEG acquisition

- Check impedences
- Check data quality

Advantages of EEG as compared to other neuroimaging modalities

- Cheap
- Portable
- LOT of analyses possibilities
- No/little contraindications
- High temporal resolution
- Etc..

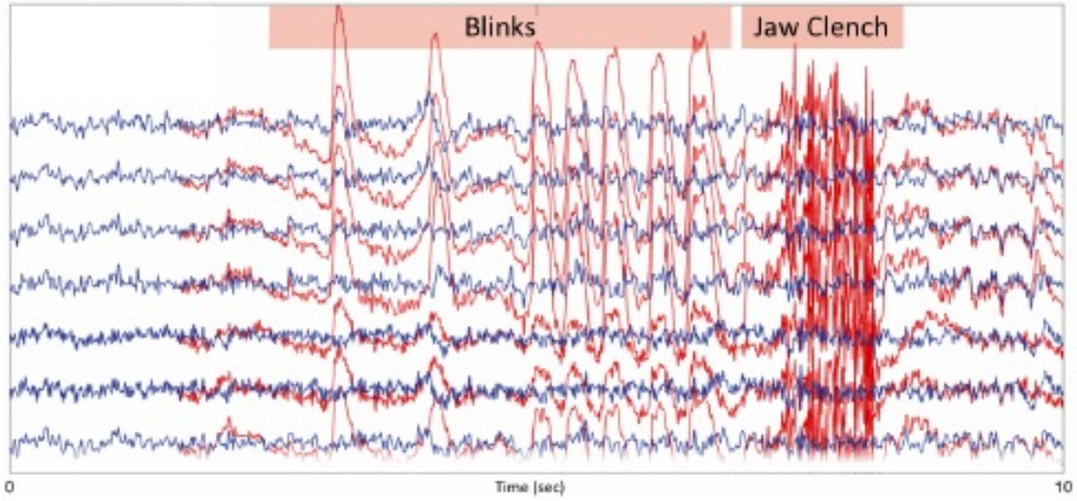
Disadvantages of EEG as compared to other neuroimaging modalities

- Prone to noise
- Setting up might take time
- No/little standardization
  (PREP pipeline)
- Low spatial resolution
- Etc..

Basic data preprocessing steps

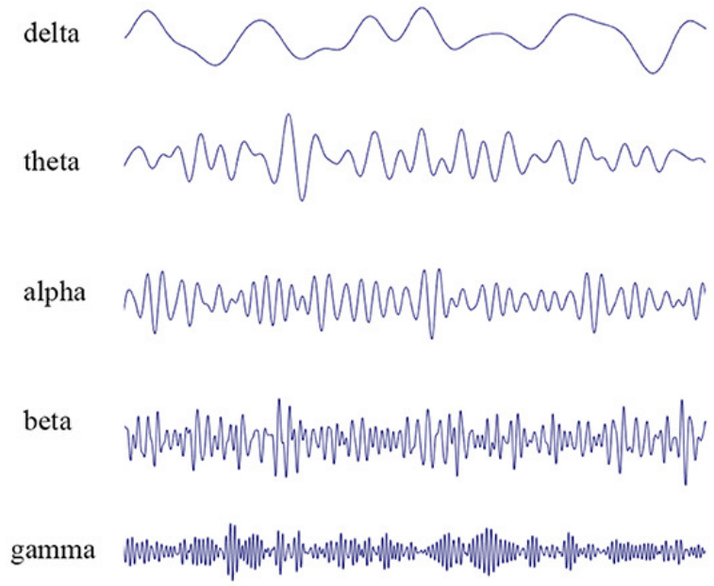
- Exact pipeline depends strongly on the analysis envisioned

- ±General steps
  - Downsample data
  - Filter (low-, highpass & notch)
  - Identify bad electrodes
  - Identify bad segments
  - ICA
  - Re-reference
    - › Feature extraction

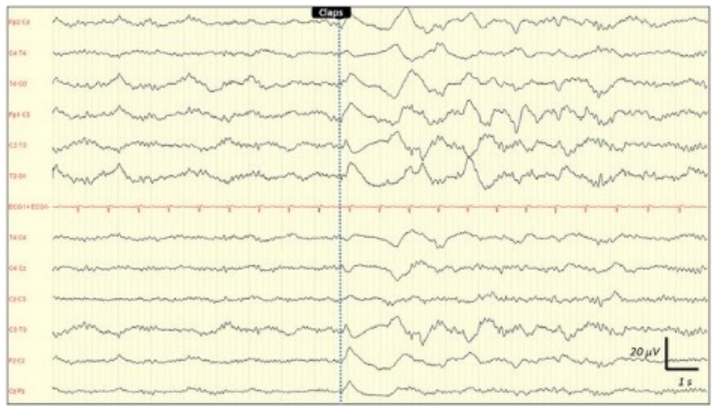


Clinical EEG

- Background activity



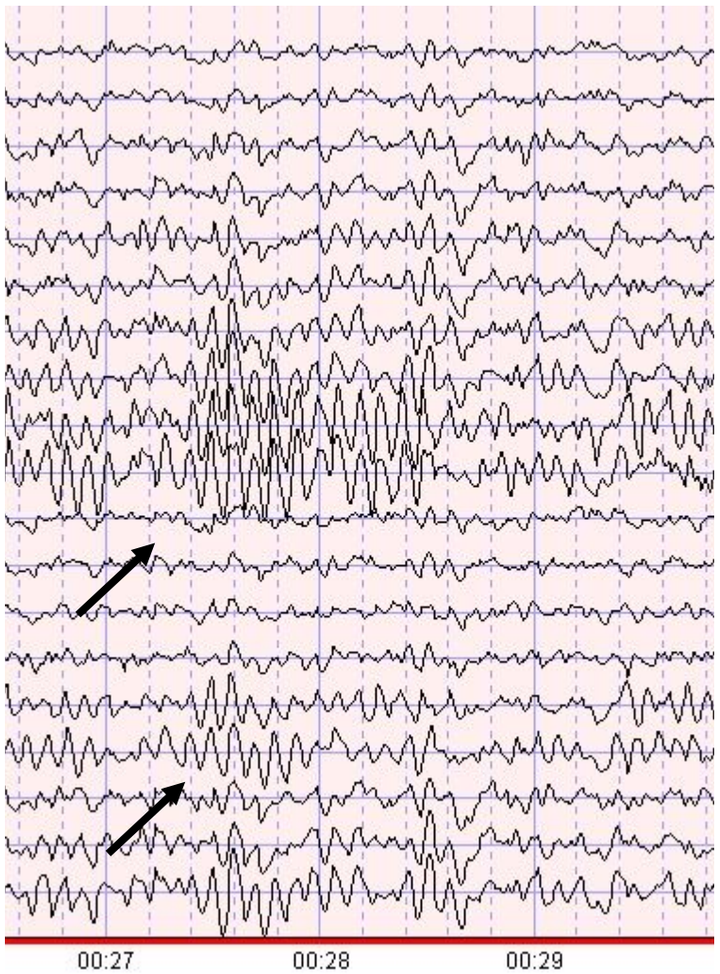
- Reactivity



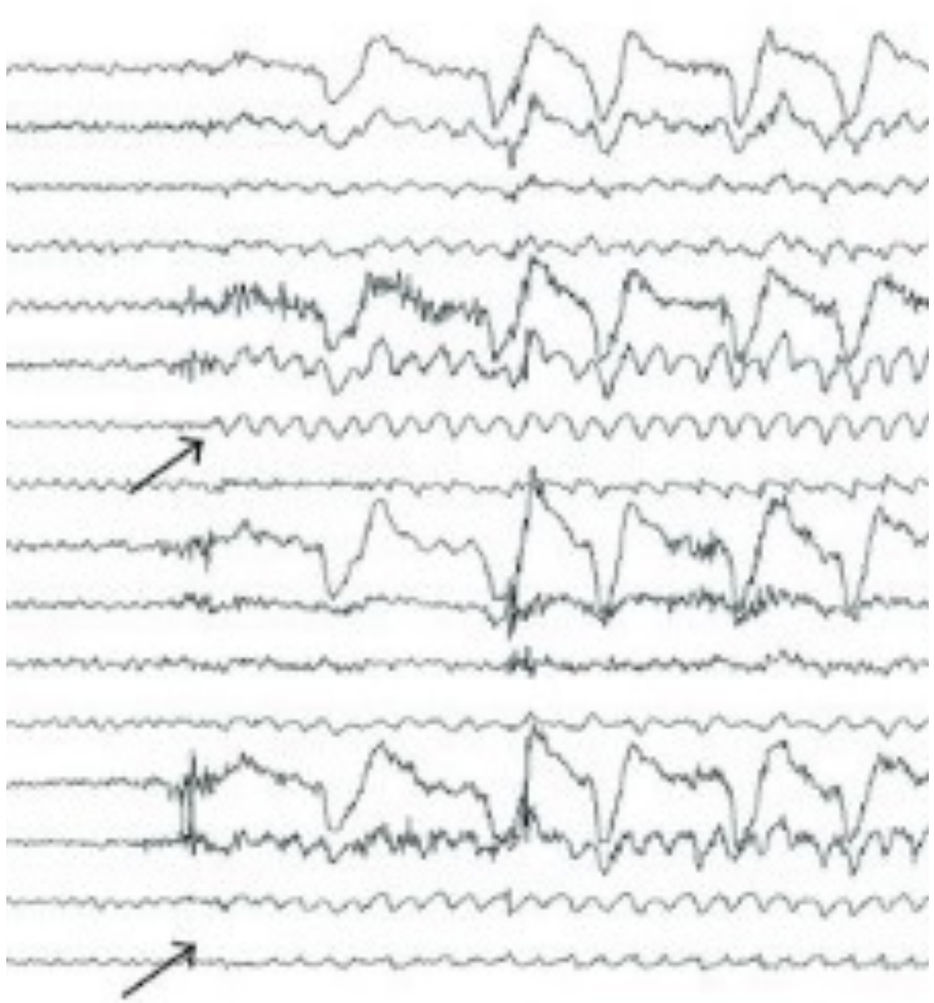
- Epileptic activity

Quiz question: Which EEG traces show abnormal electrical activity?

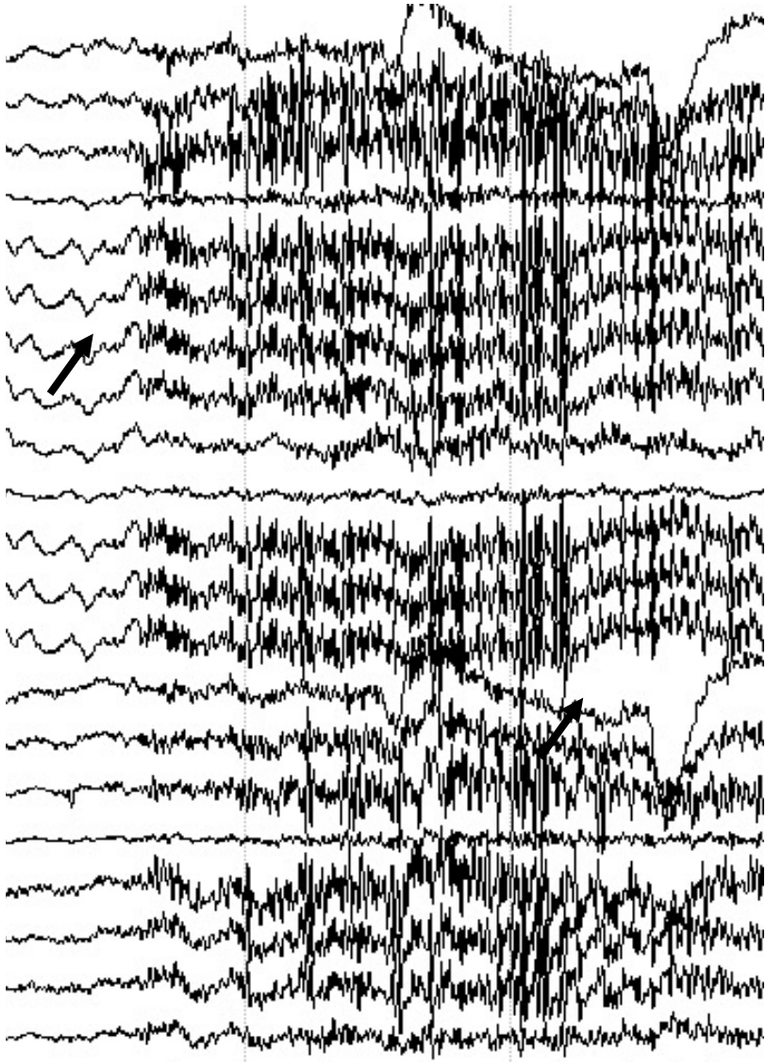
A



B

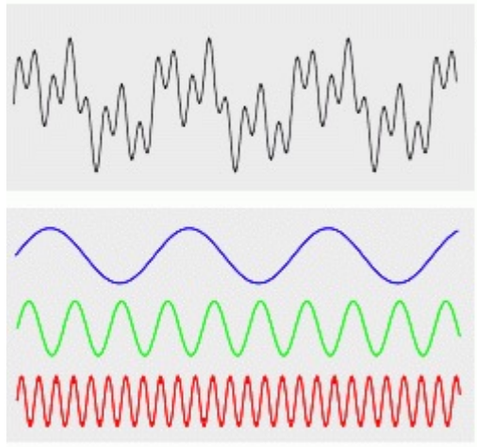


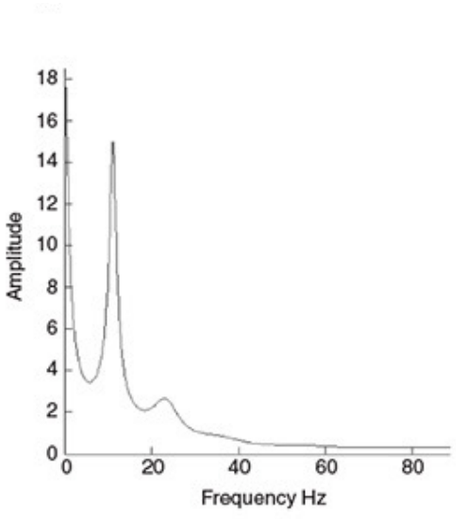
C



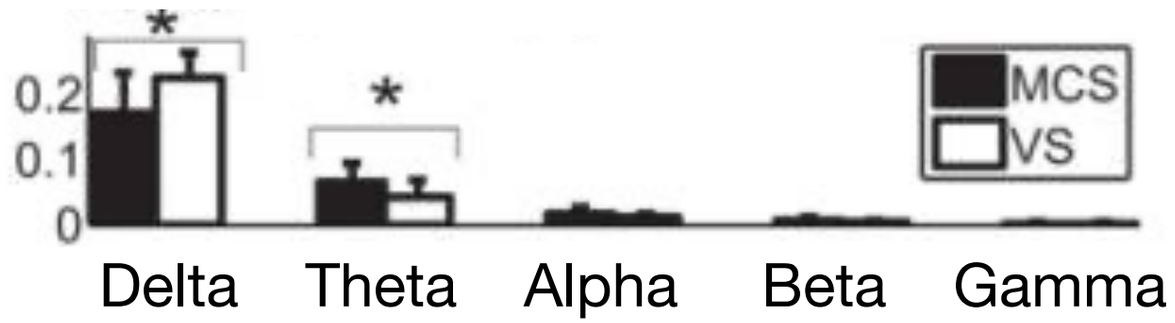
Quantitative EEG: Power

- Calculate spectral density
  - E.g. Fourier transform
    - The complex signal can be composed by the sum of simple signals





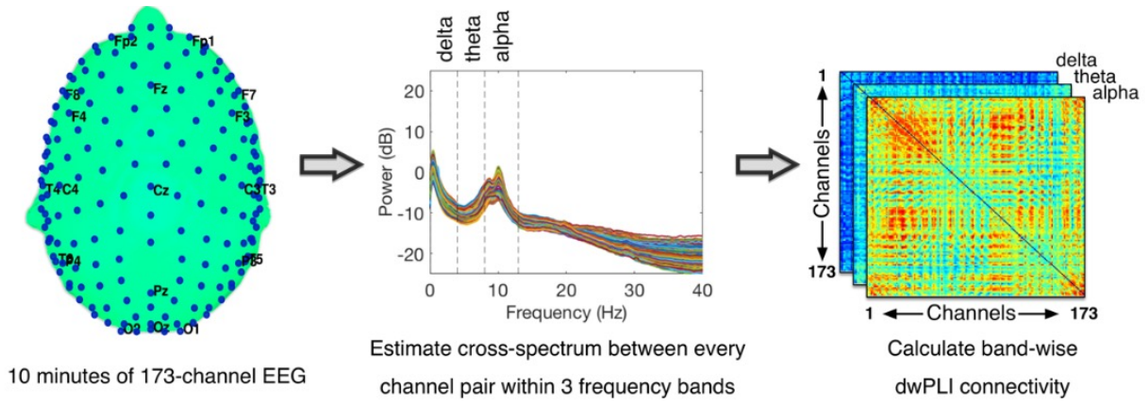
- Low frequencies characterize states of unconsciousness

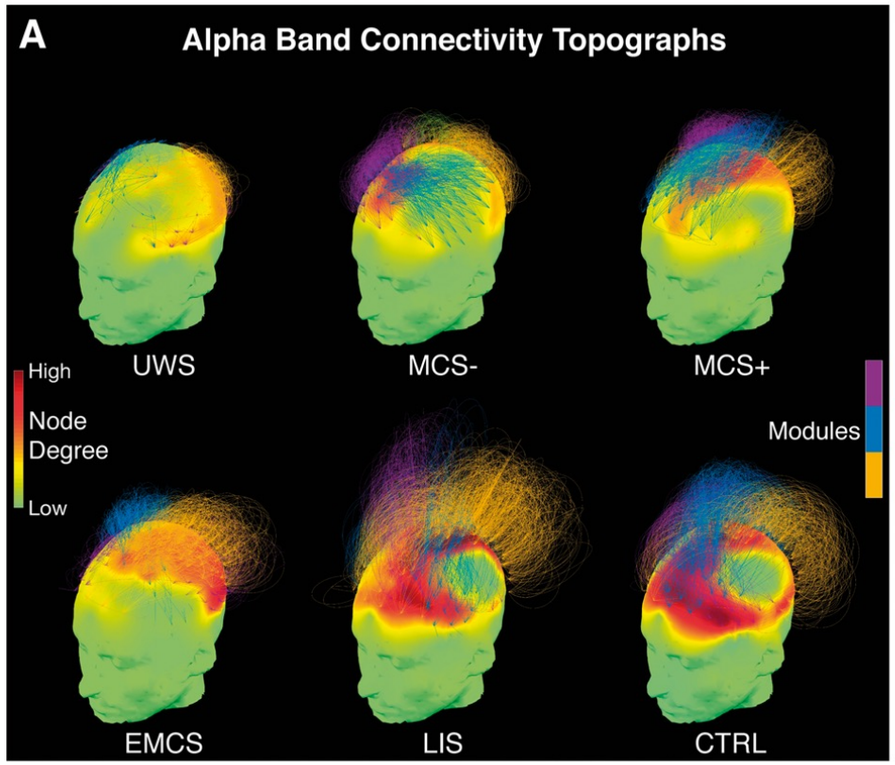


Lehembre et al., 2012

Quantitative EEG: Connectivity

- Covariation (in amplitude and phase) of two timeseries





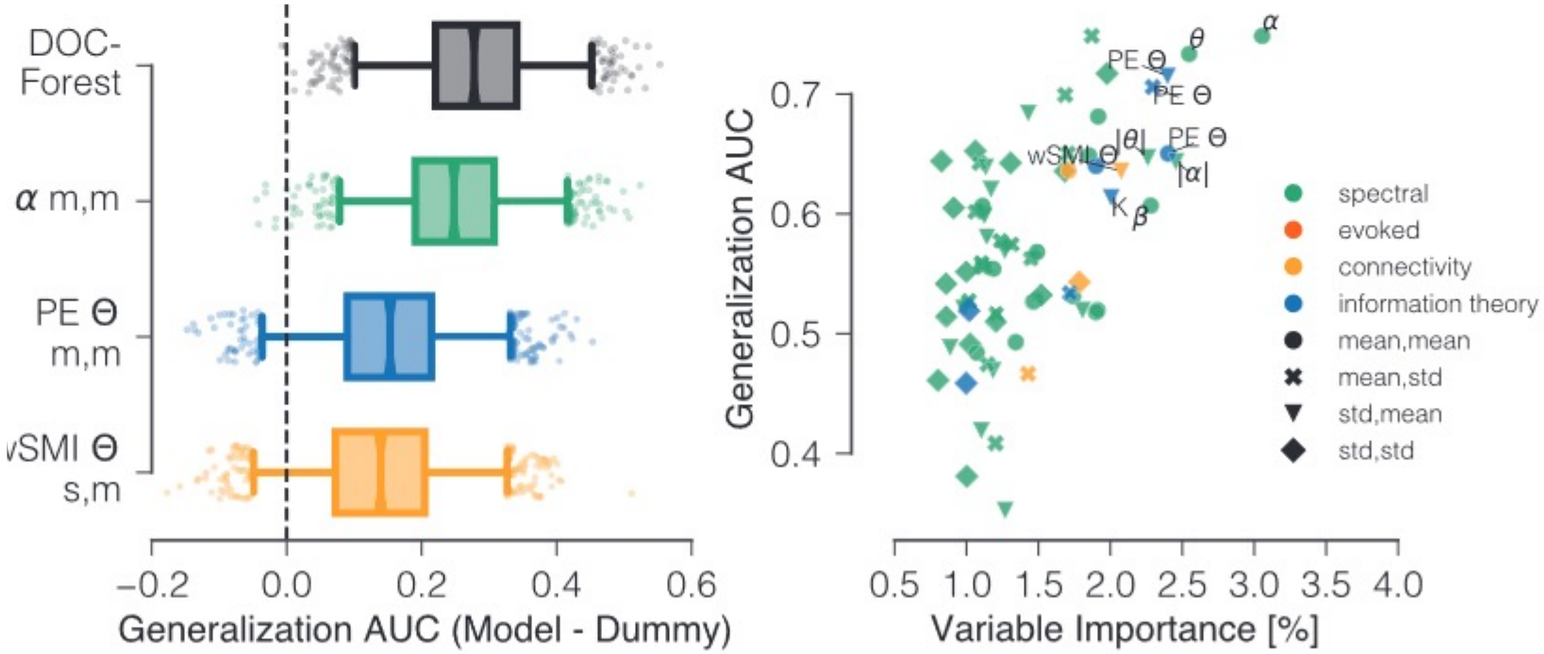
Work of Rajanikant Panda: characterize dynamic network organization using graph theory and computational modelling in EEG and fMRI

- Thesis in 180 seconds

Chennu et al., 2017

Quiz question: Which measure do you think is more informative to distinguish UWS and MCS patients?

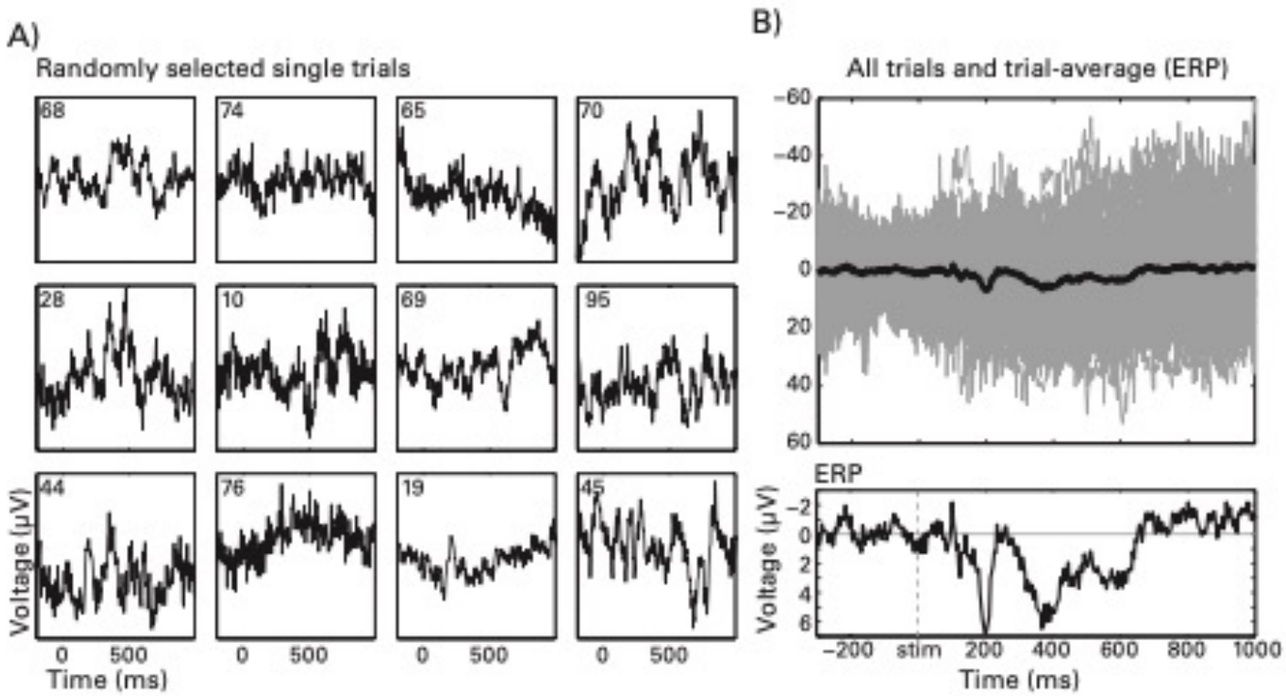
- Not easy to answer question
- Machine learning approach combining many univariate markers



- Robust between centers, electrode configuration and protocols

Engeman et al., 2018

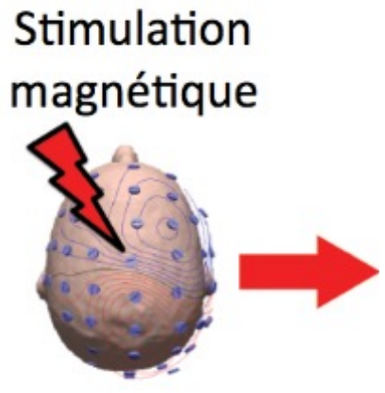
Evoked Responses: The principle of event related potentials

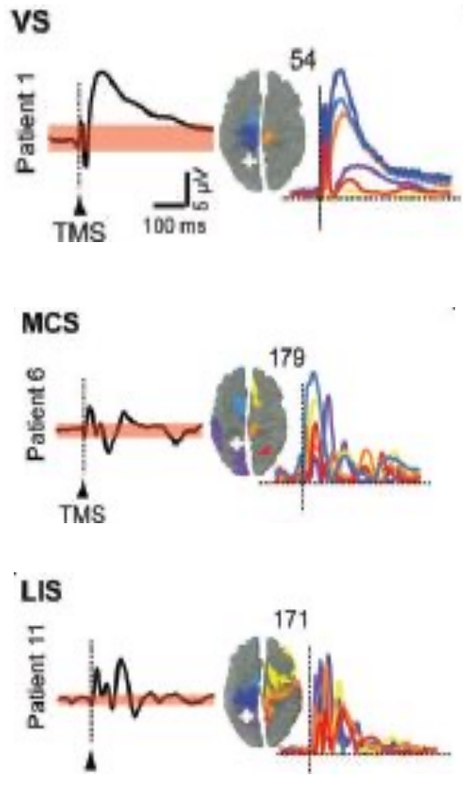


- Time-locked average response
  - Average out random fluctuations
- Based on stimuli (e.g. sounds)
- In case of oddball paradigm:
  - Creates *expectancy* based on short-term (within trial) regularities and long-term (across-trial) regularities
  - Depends on attention

Cohen, *Analyzing Neural Time Series Data: Theory and Practice*.

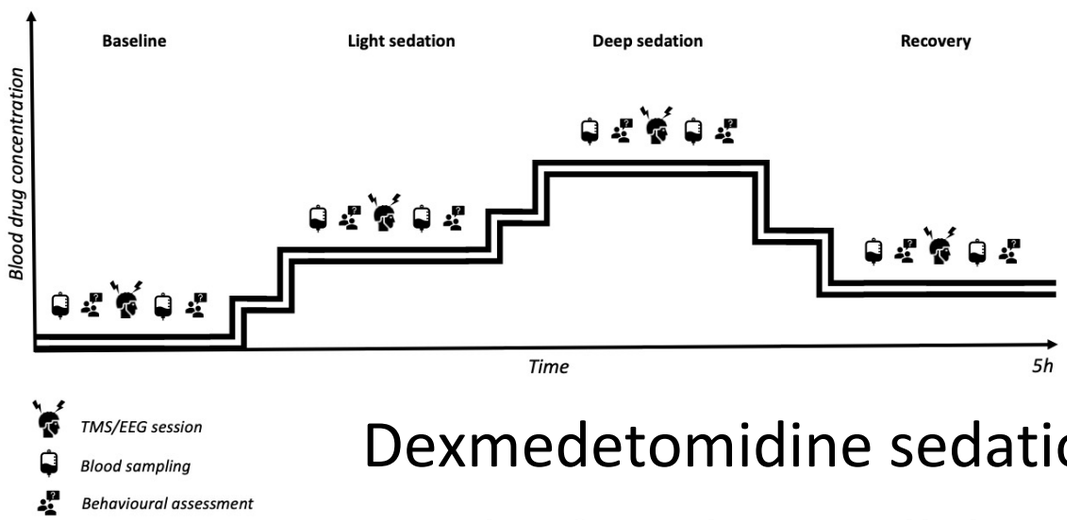
Evoked responses: TMS-EEG

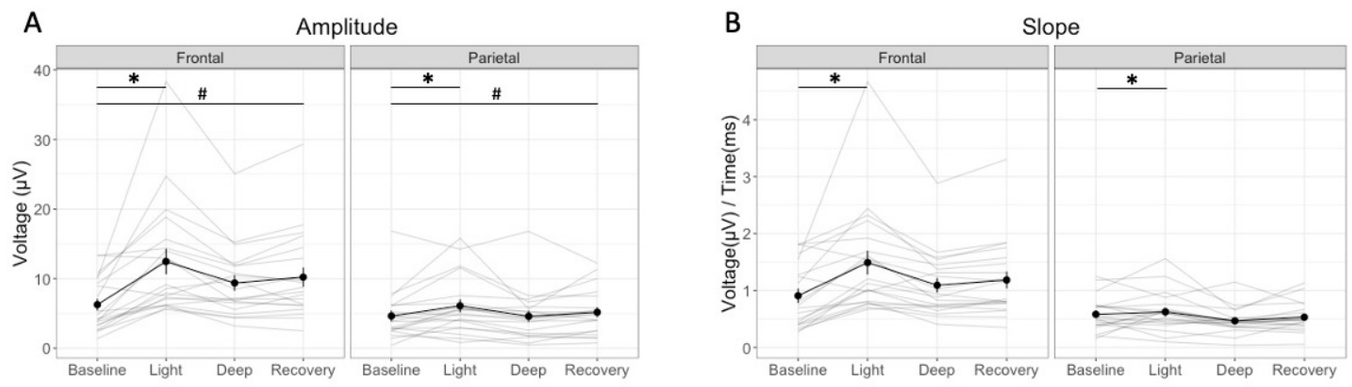




Gosseries & Casali et al., *Science Transl Med*
Rosanova and Gosseries et al, *Brain*

- Independent from the subjects' participation/ attention level!





Dexmedetomidine sedation in healthy controls.

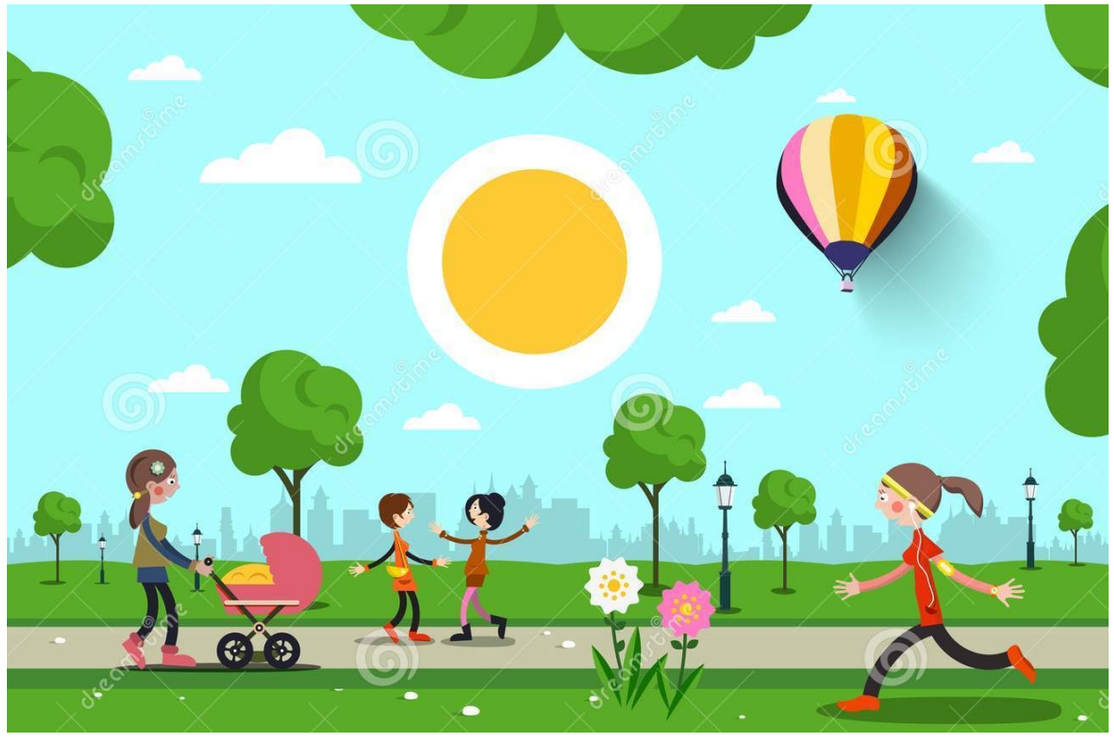
Work of Paolo in collaboration with GIGA Consciousness

Cardone et al., in Preparation

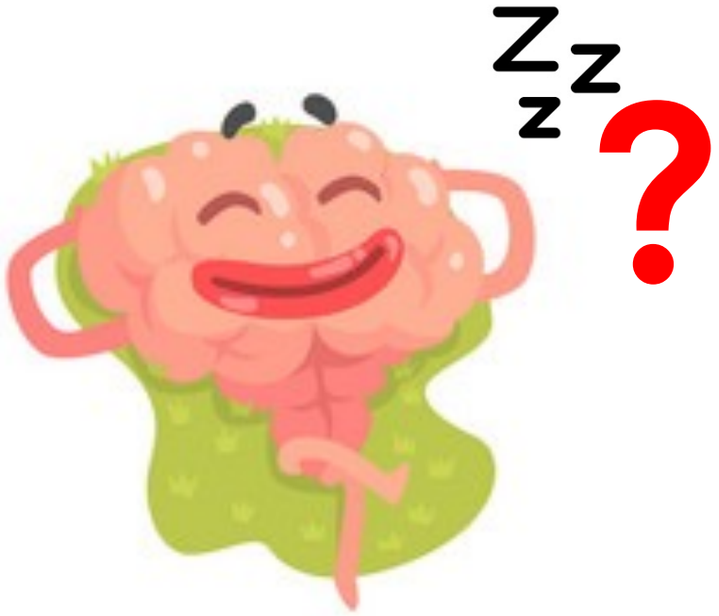
Disconnected consciousness

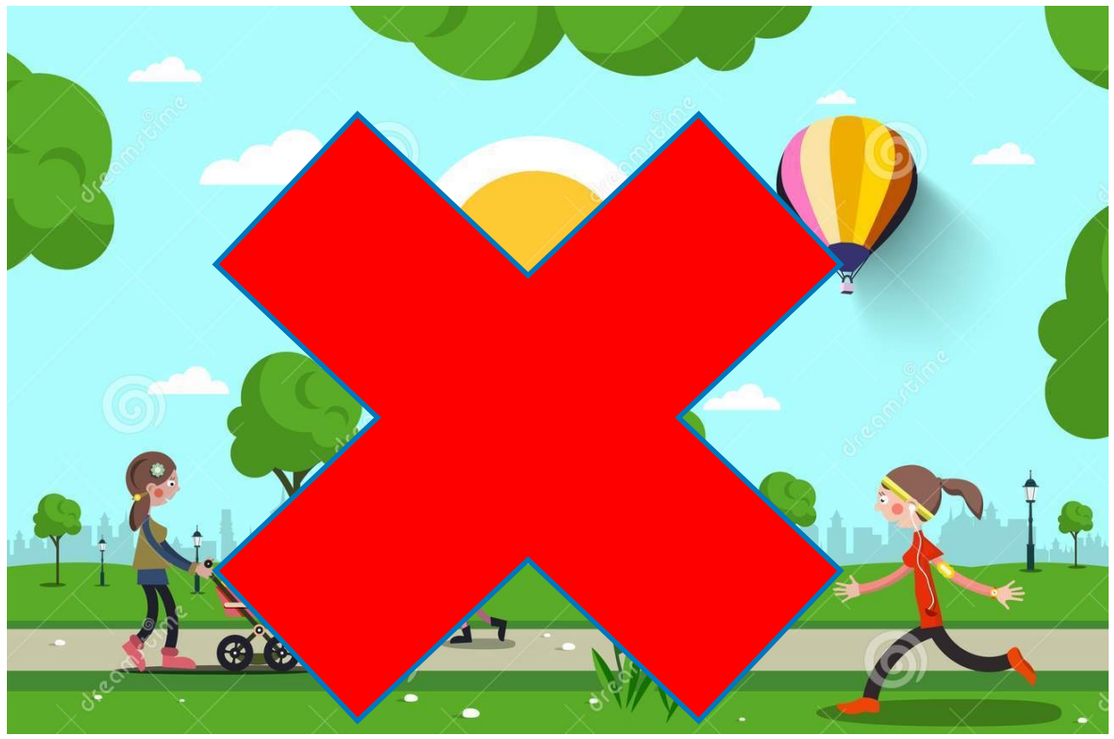
Connectedness

Omgeving



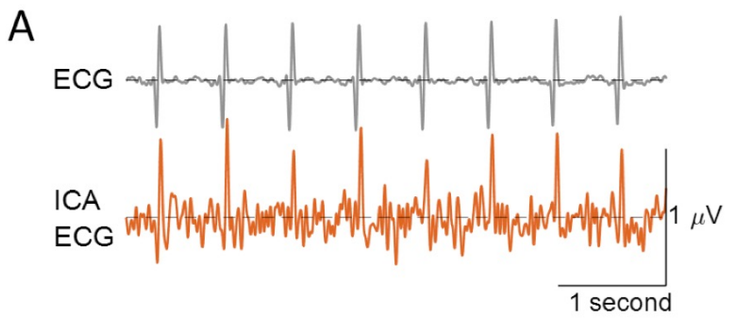
Disconnectedness

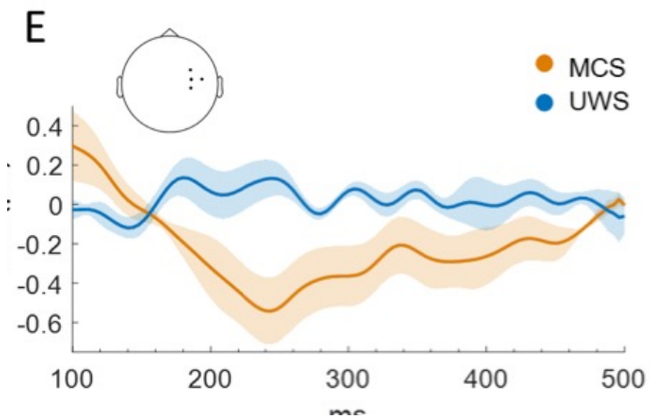


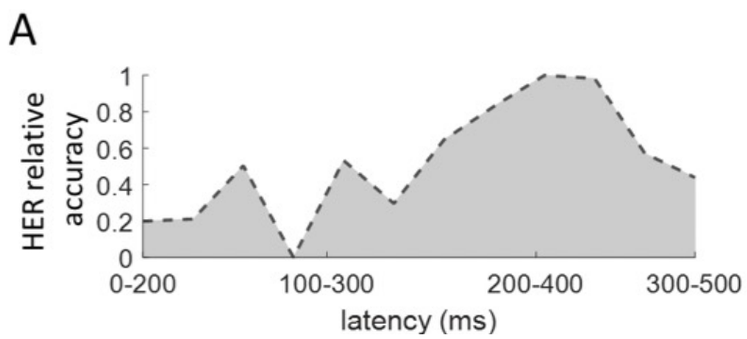


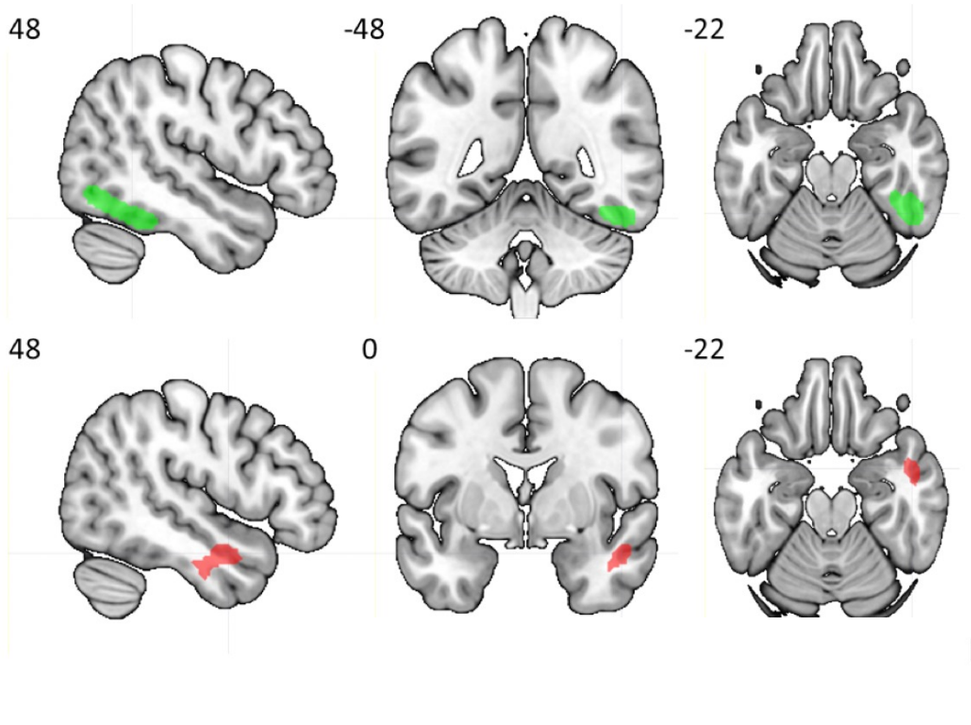
Heartbeat evoked reponses

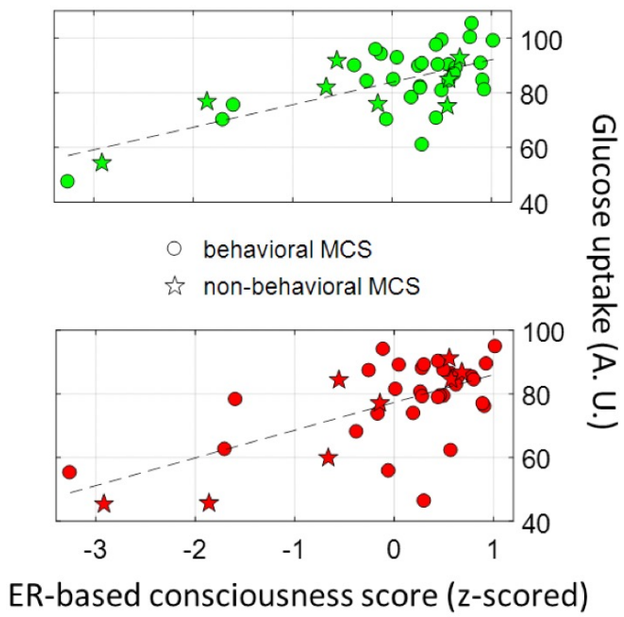
Heartbeat evoked potential
- Visceral information in brain
- Influences cognition







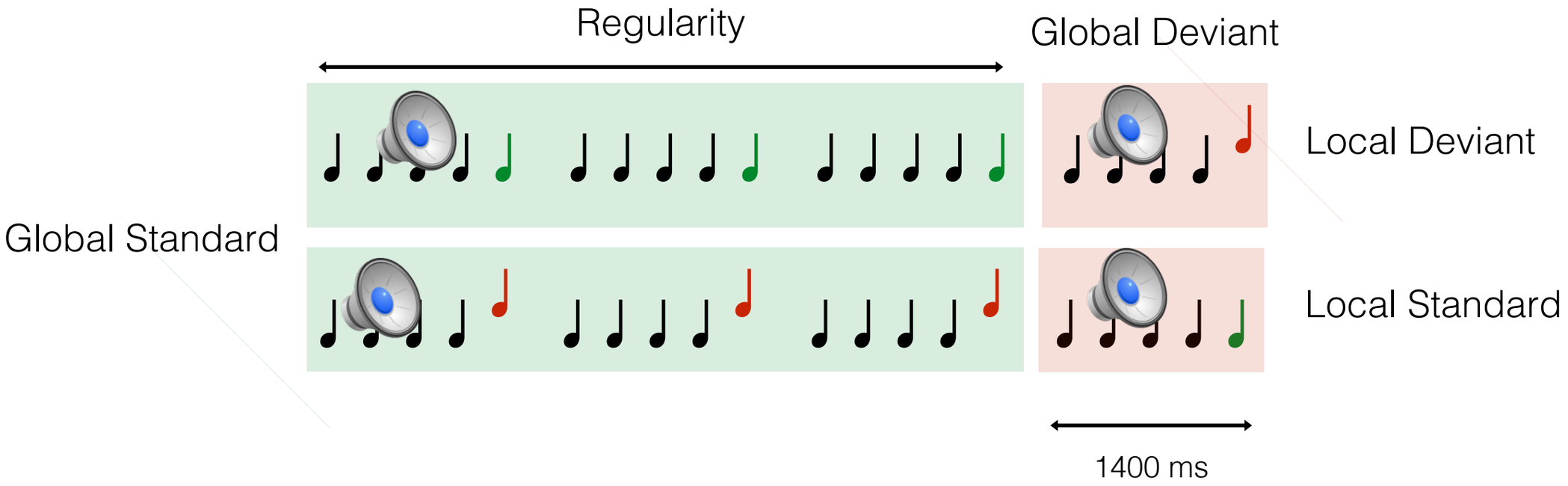


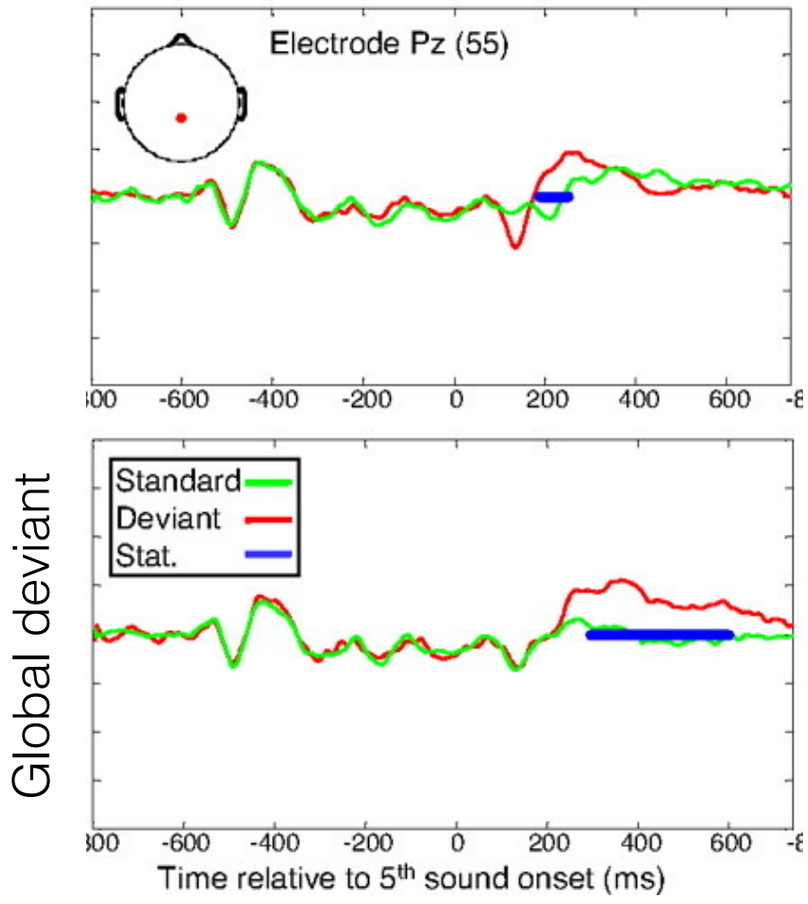


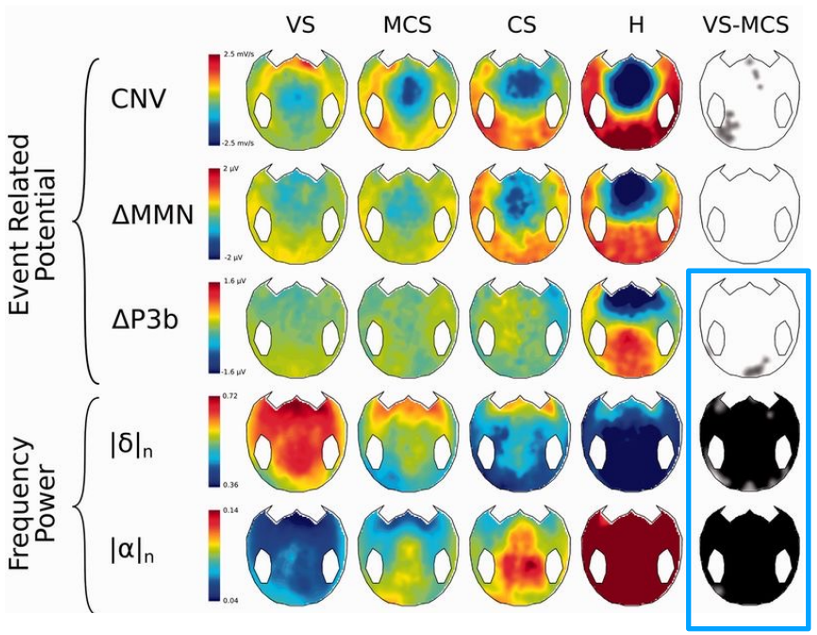
Heartbeat evoked potential
- Diagnostic accuracy of 87%
- Better than random EEG
- More accurate for PET-diagnosis than CRS-R diagnose (77% accuraat)
- Correlation with DMN

Candia-Rivera & Annen et al,. *Journal of Neuroscience* (2021)

Evoked Responses: the P300



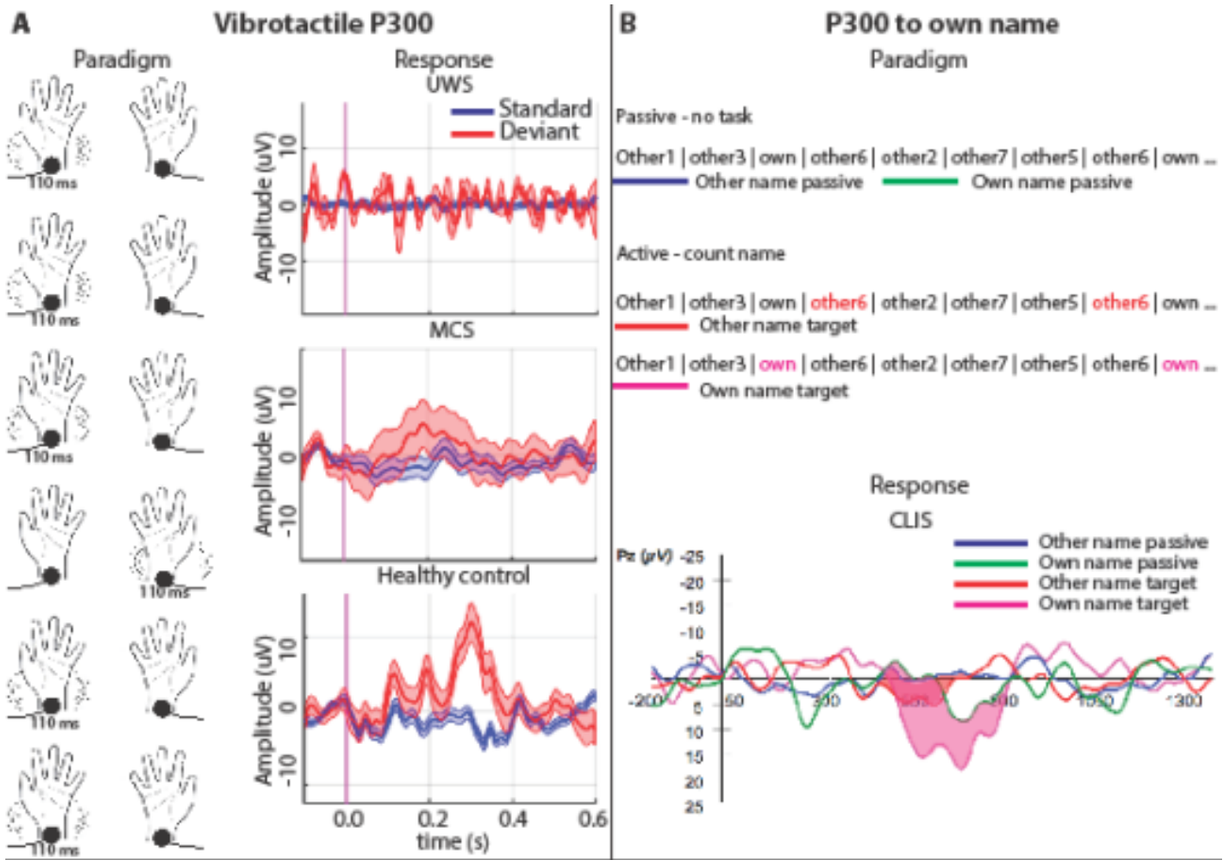




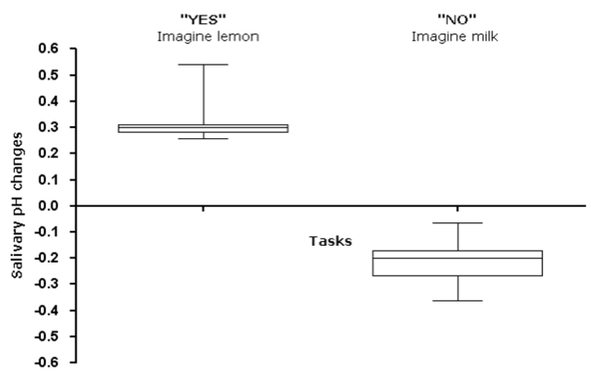
- Work of Benedetta Cecconi (GIGA DS):
  - How is stimulus processing altered in disconnected consciousness

→ Obtained FNRS fund and mind science grant! ☺

Evoked responses: BCI applications

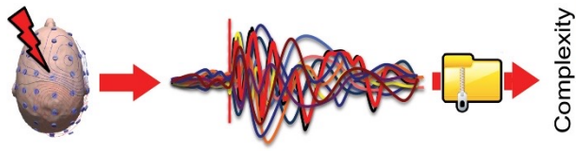


- Several BCI approaches
- 1st step: command following
- 2nd step: Communication
- Could potentially be used for assistive technology
  - E.g. speller
- Other communication devices
  - E.g. pH of saliva



Wilhelm et al *JNNP 2006*

European Academy of Neurology (EAN) recommendations



Recommendation: consider TMS-EEG to differentiate unresponsive from minimally conscious

6 publications

Recommendation: consider quantitative high density

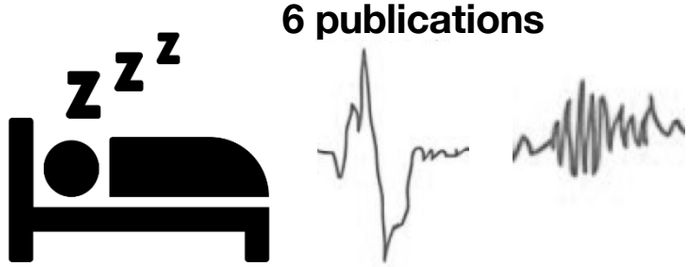
6 publications

Recommendation: Visual analysis of clinical EEG (high specificity, low sensitivity)

2 publications

Recommendation: Use sleep EEG

6 publications



Tracking state fluctuations with EEG

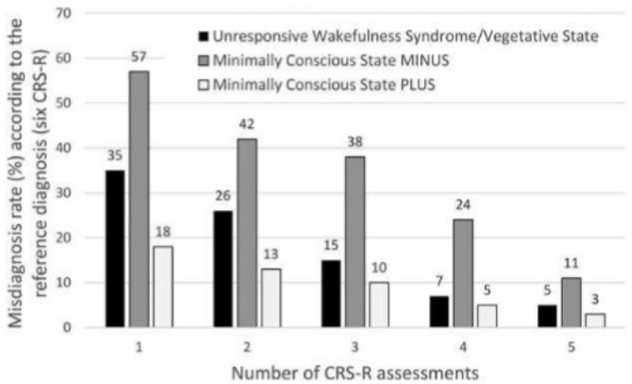
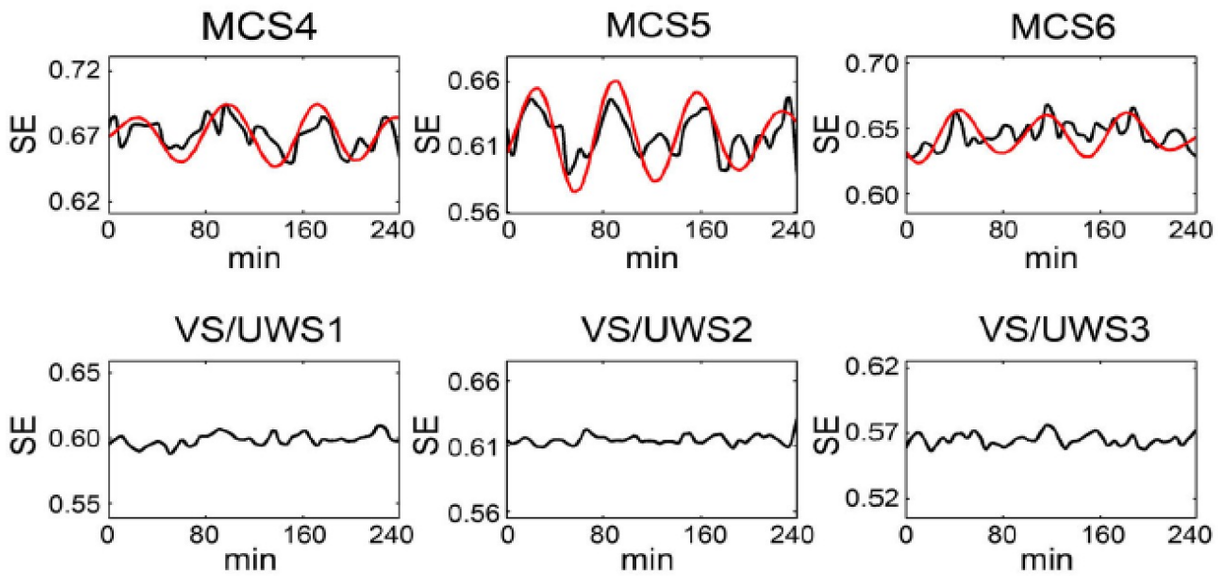
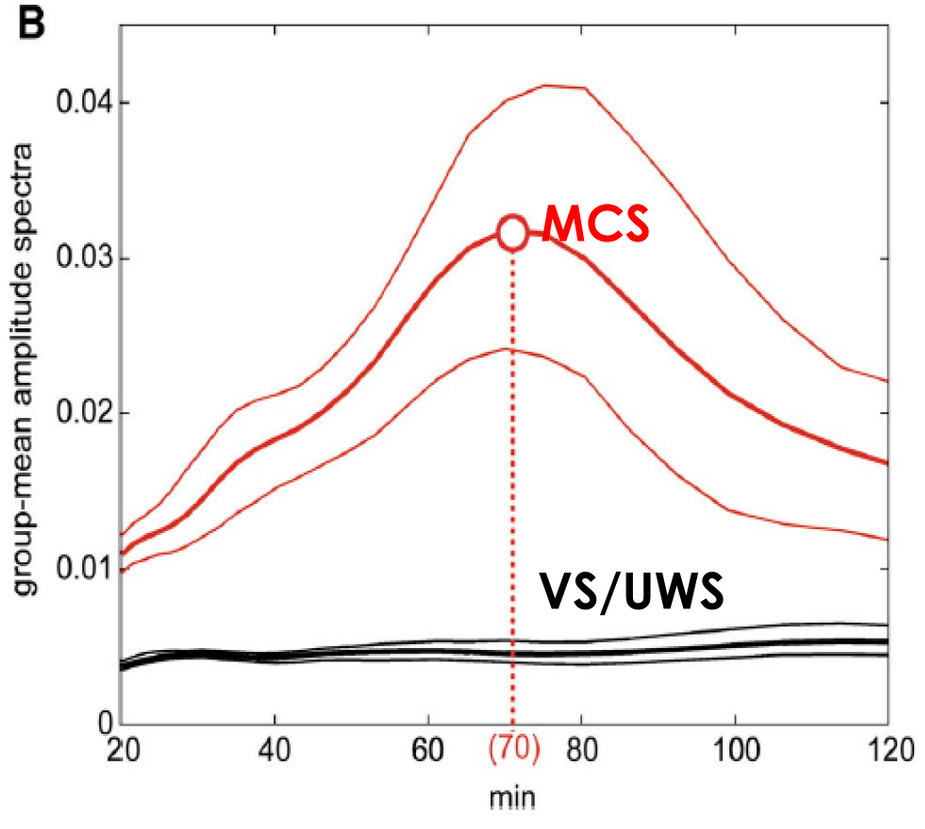


FIGURE 1: Misdiagnosis rates (%) of patients after *n* CRS-R assessments according to the diagnosis. CRS-R = Coma Recovery Scale-Revised.

Wannez et al., *Annals of Neurology* 2017



- Work of Glenn van der Lande:
  - Track state fluctuations using actigraphy
  - Does and how does tDCS induce state fluctuations?

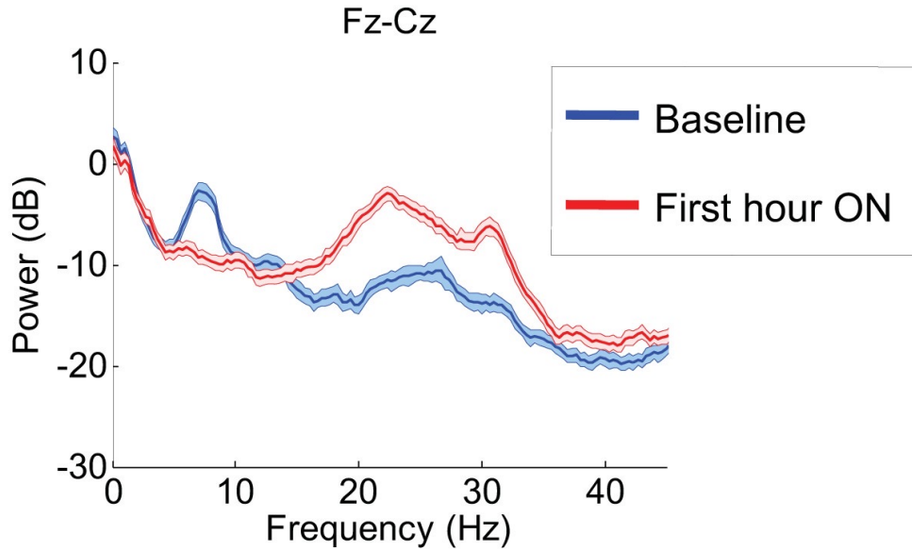


Piarulli et al, *J Neurol*, 2016

Measuring effects of Zolpidem with EEG

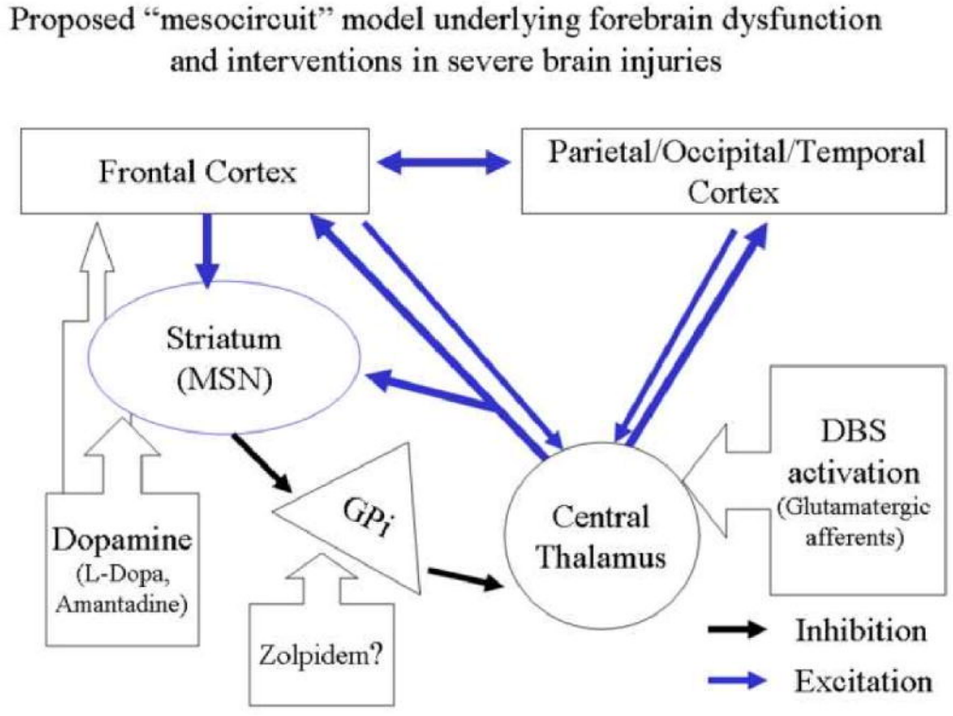
Before Zolpidem

After Zolpidem



Williams et al, 2013

- Resting EEG power spectra in the baseline state revealed an abnormal peak at ~6–10 Hz
- Might reflect layer V neocortical pyramidal activity due to de-affertiation
- Potential mechanism of action of zolpidem: Mesocircuit hypothesis



Schiff 2010

Take home messages

- EEG is a VERY broad topic
  - can be used to study neuronal function at several levels
  - can characterize several aspects of neuronal function

- In DOC patients specifically
  - Used for diagnosis, simple measures seem reasonably effective
  - Identify state changes, treatment effects
  - Potentially used for communication purposes

Questions?

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