Donders Institute
for Brain, Cognition and Behaviour

Multivariate analysis of electrophysiological data

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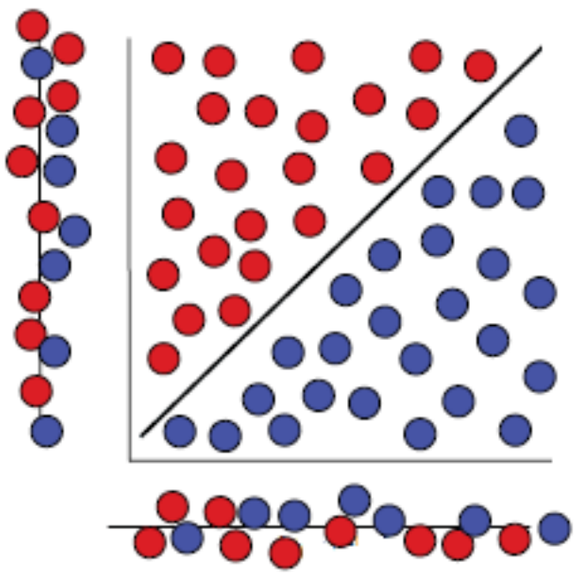
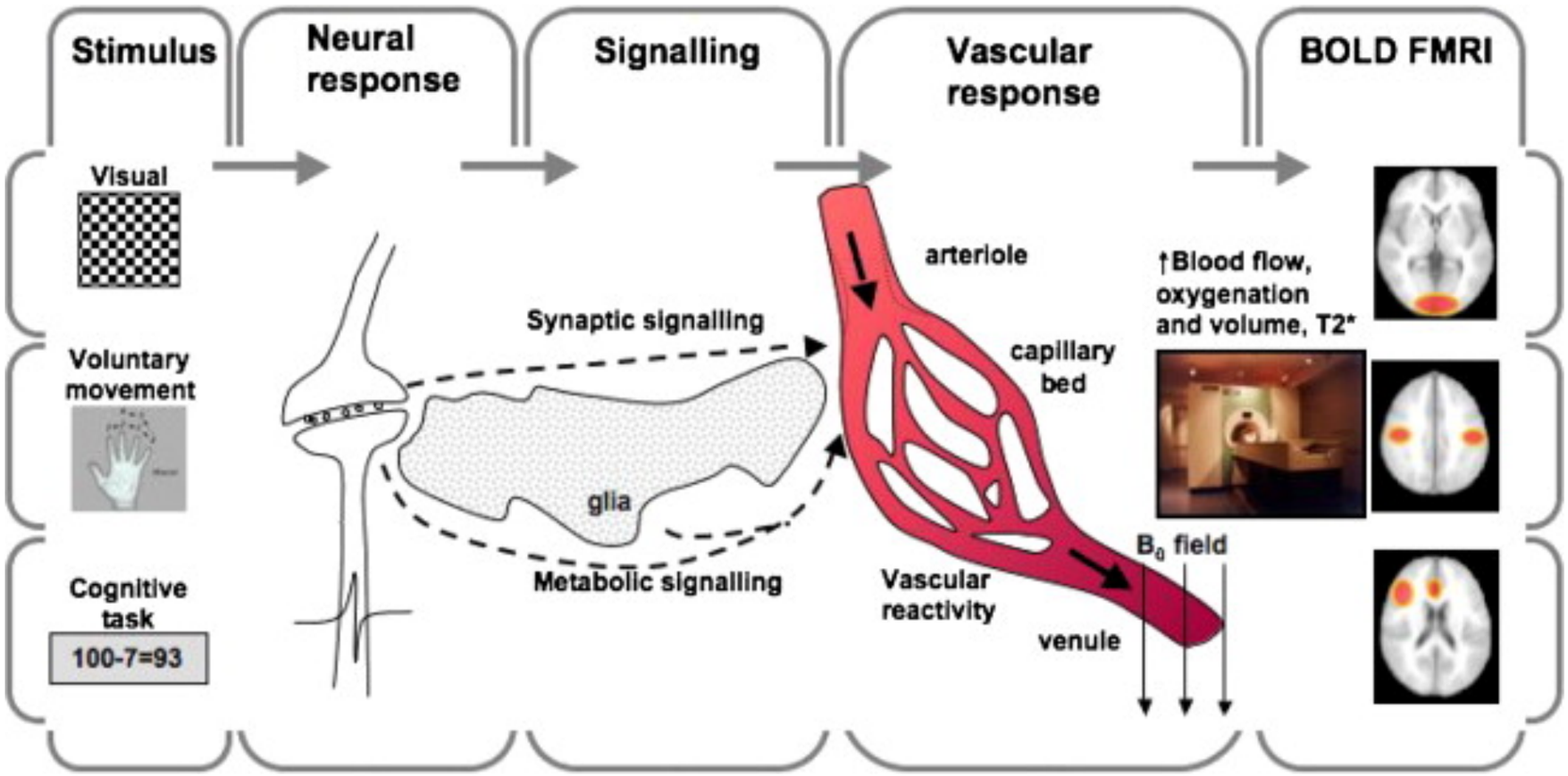
Previously in Brain Reading:

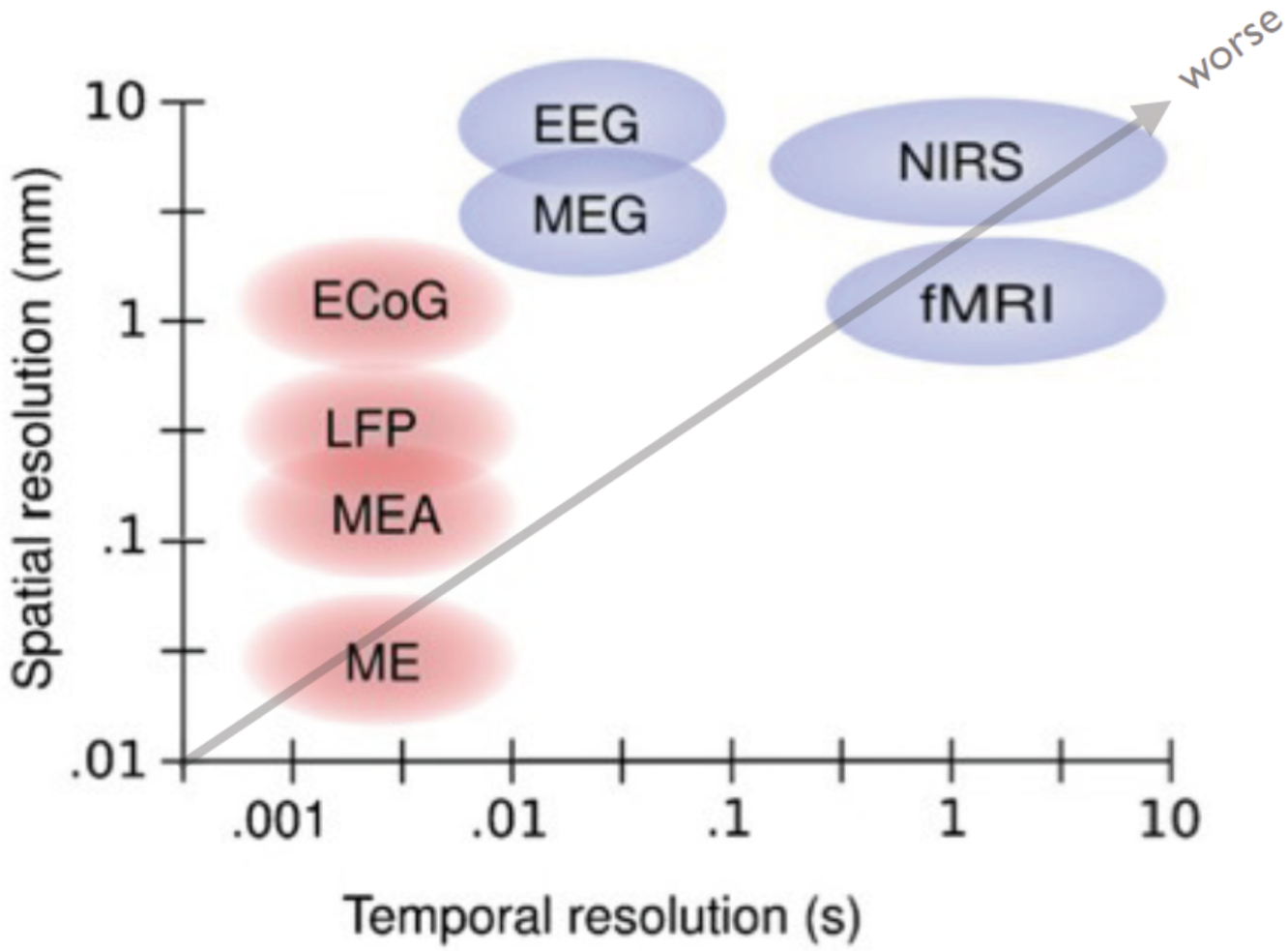
$$\hat{\beta} = (X^T X)^{-1} X^T y$$



Problem 1: BOLD is an indirect measure of brain activity



Problem 2: BOLD has a coarse temporal resolution

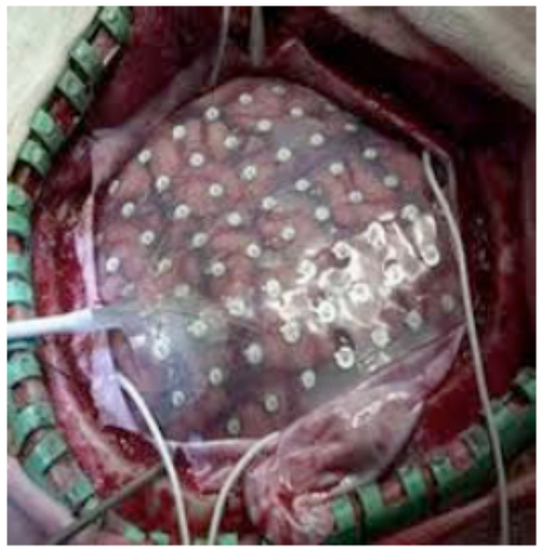


Electrophysiological methods: different flavours

EEG

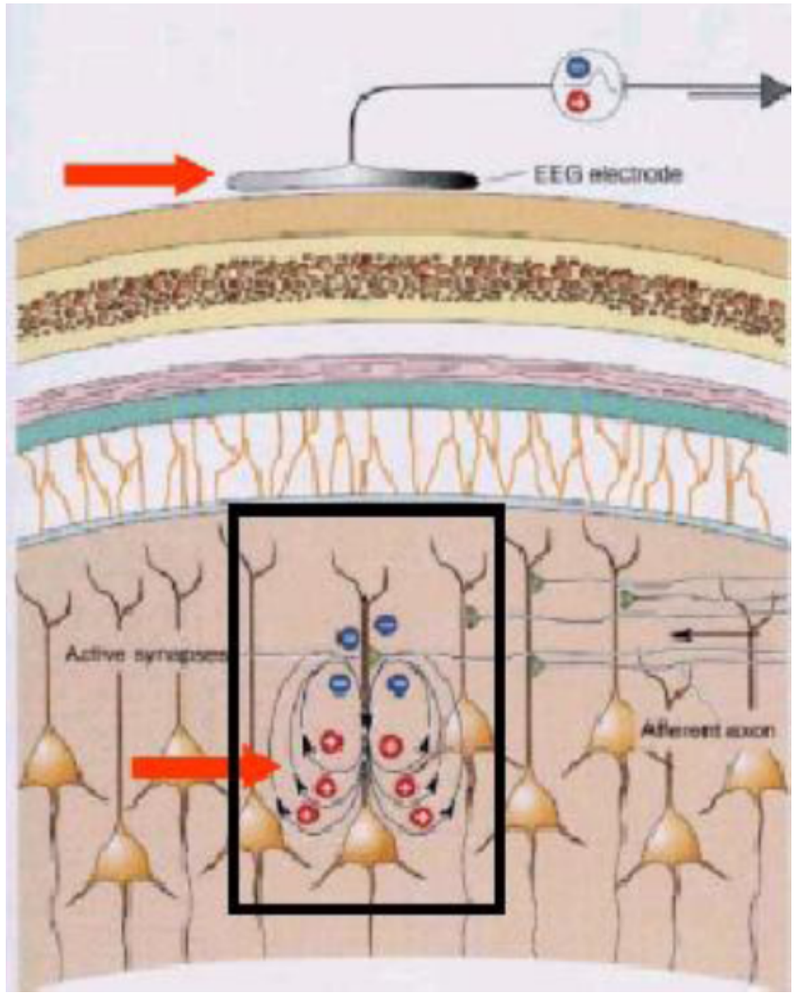
MEG

ECoG

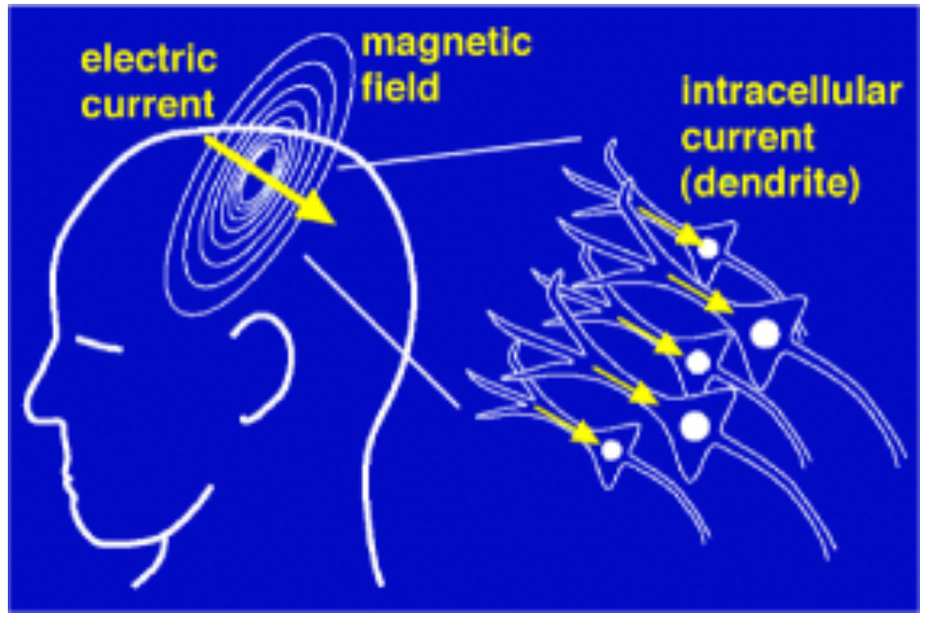


Electrophysiological methods: signal origin

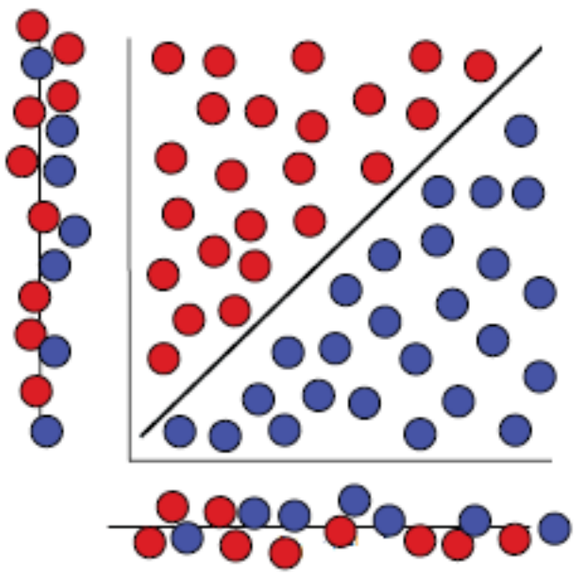
EEG & ECoG: Potential differences



MEG: Magnetic fields



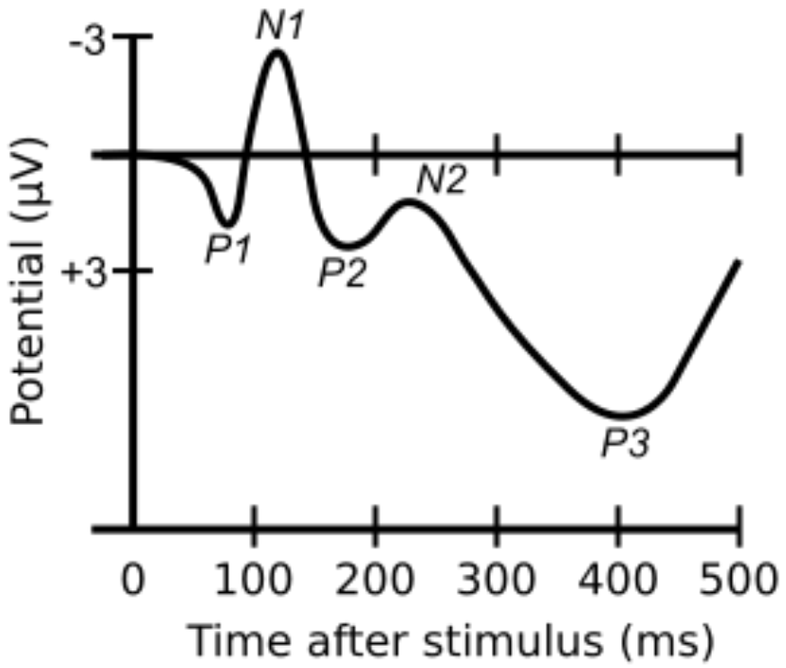
$$\hat{\beta} = (X^T X)^{-1} X^T y$$



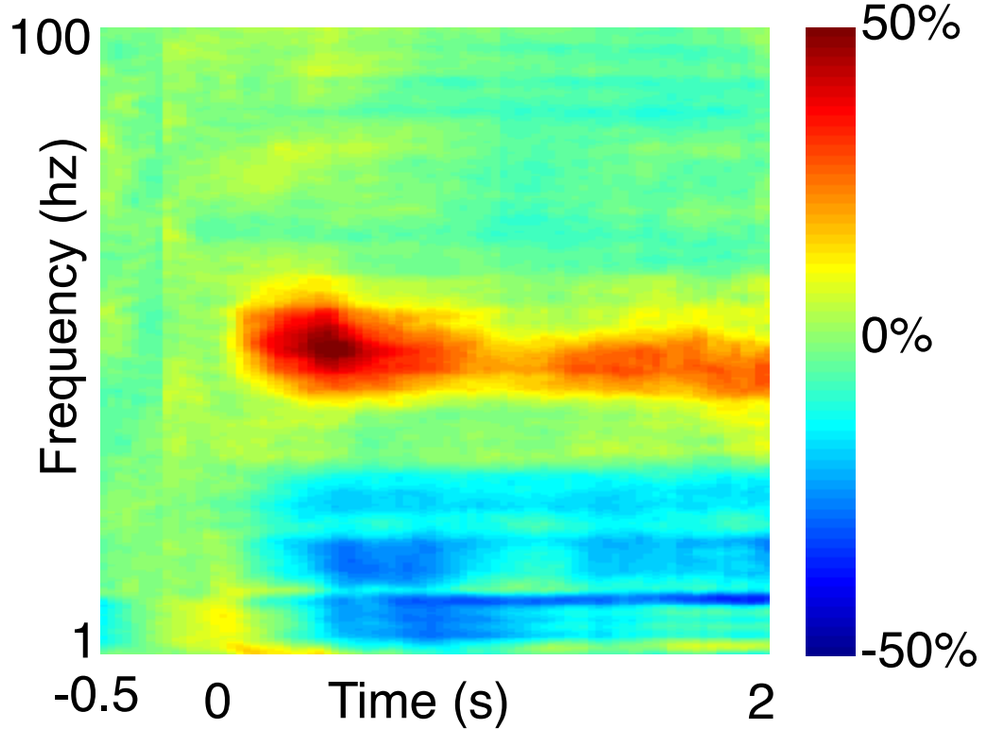
Electrophysiological methods: different features

Etc. etc. etc.

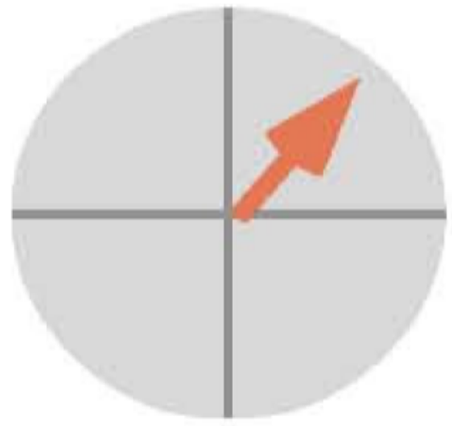
Event related potentials (time domain)



Frequency domain



Phase



Electrophysiological methods: feature space

Time domain

→ Number of Channels * number of time points

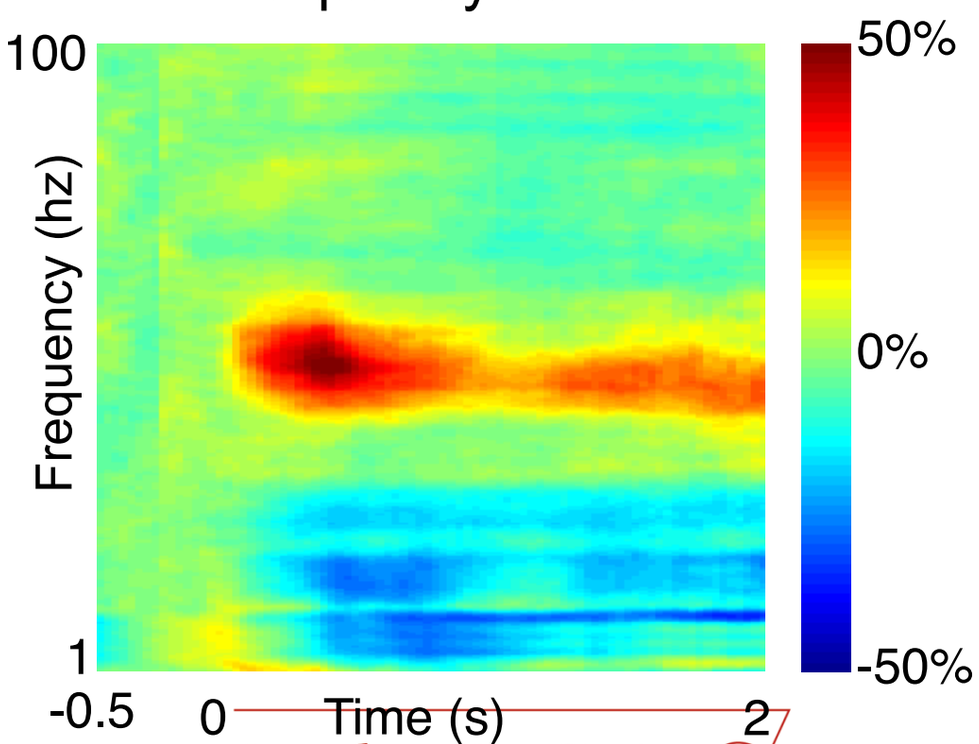
275 * 150 = 41250 features

Number of channels: 275 (MEG)

Number of time points: 150 (500 ms, 300Hz)

Number of frequency bins: 80 (40-80 Hz, 0.5 Hz steps)

Frequency domain



→ Number of frequency bins * number of time points

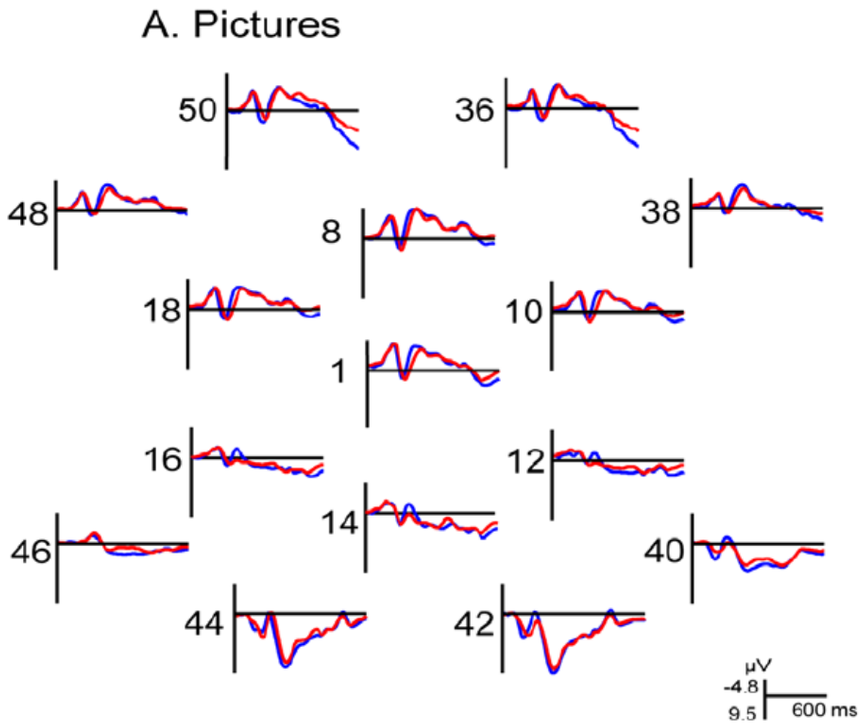
80 * 150 = 12000 features

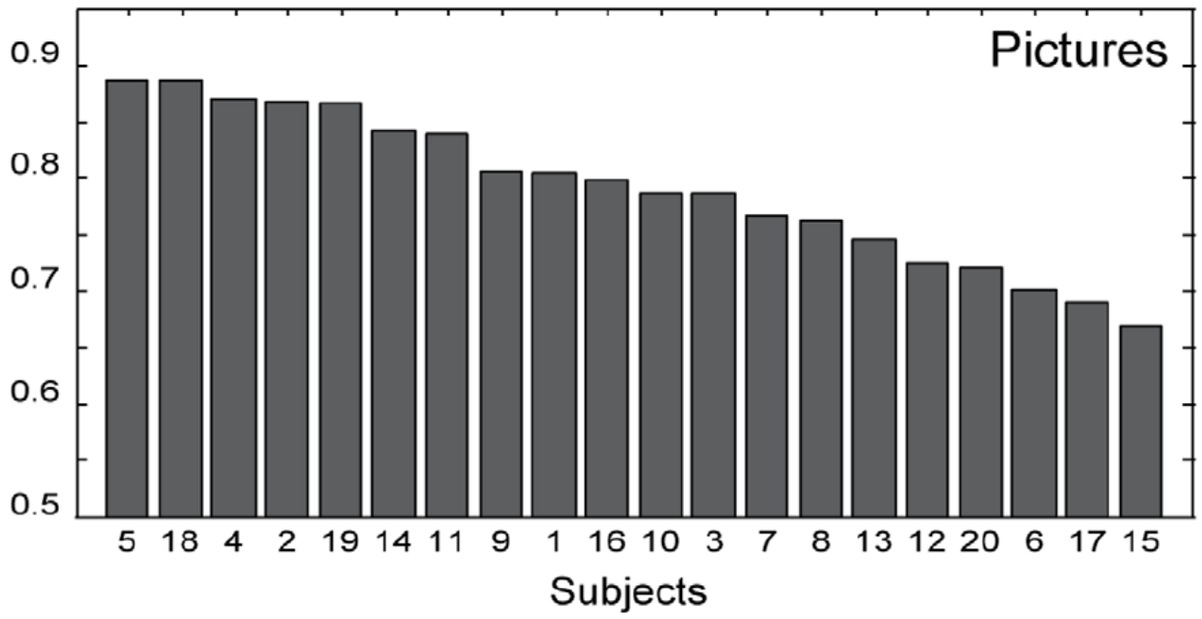
Feature reduction

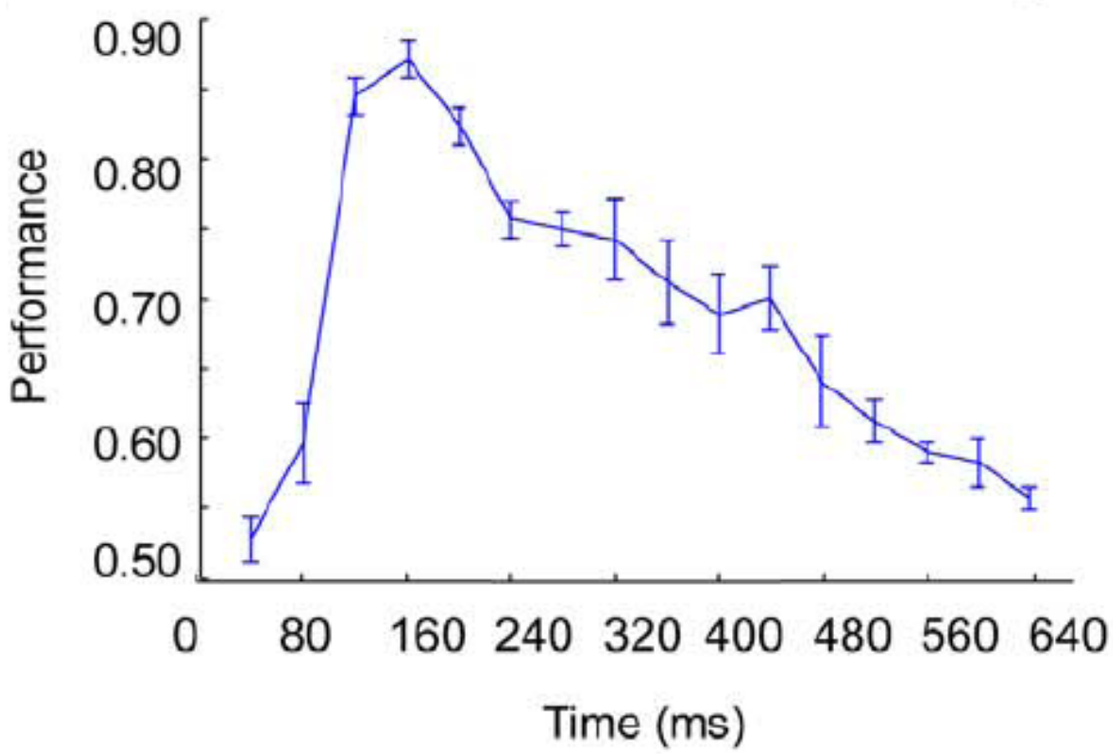
- fMRI localizer
- Univariate analysis
- Multivariate algorithm with feature selection

Classification in the time domain: ERPs

animals
tools

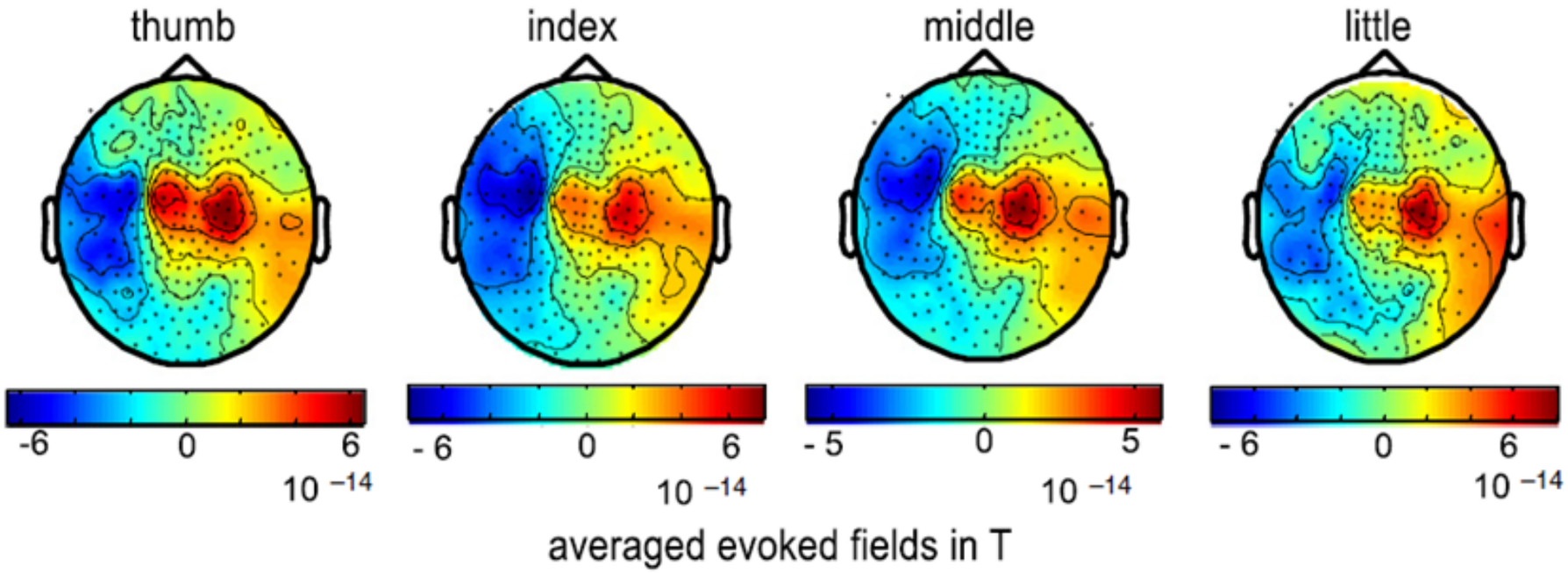


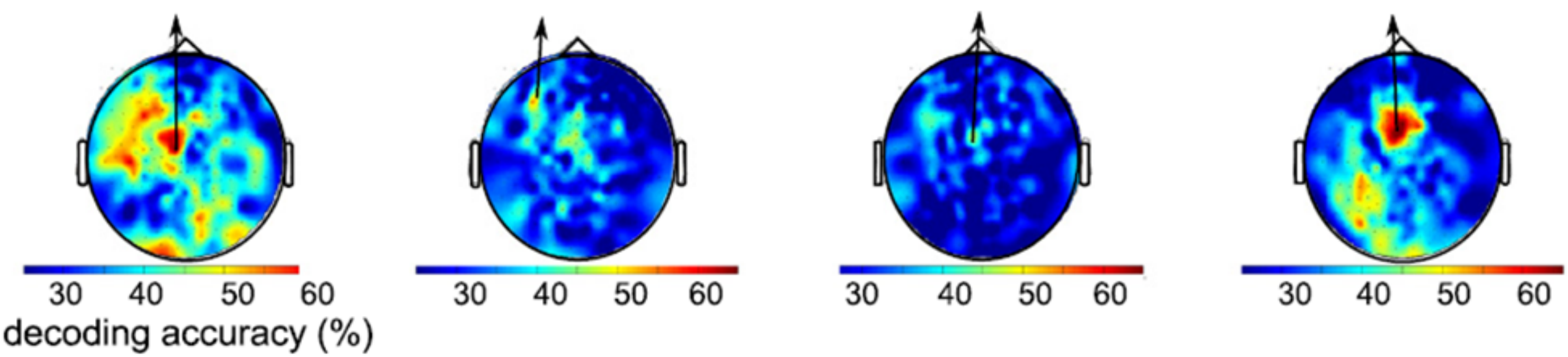




Simanova et al., 2010

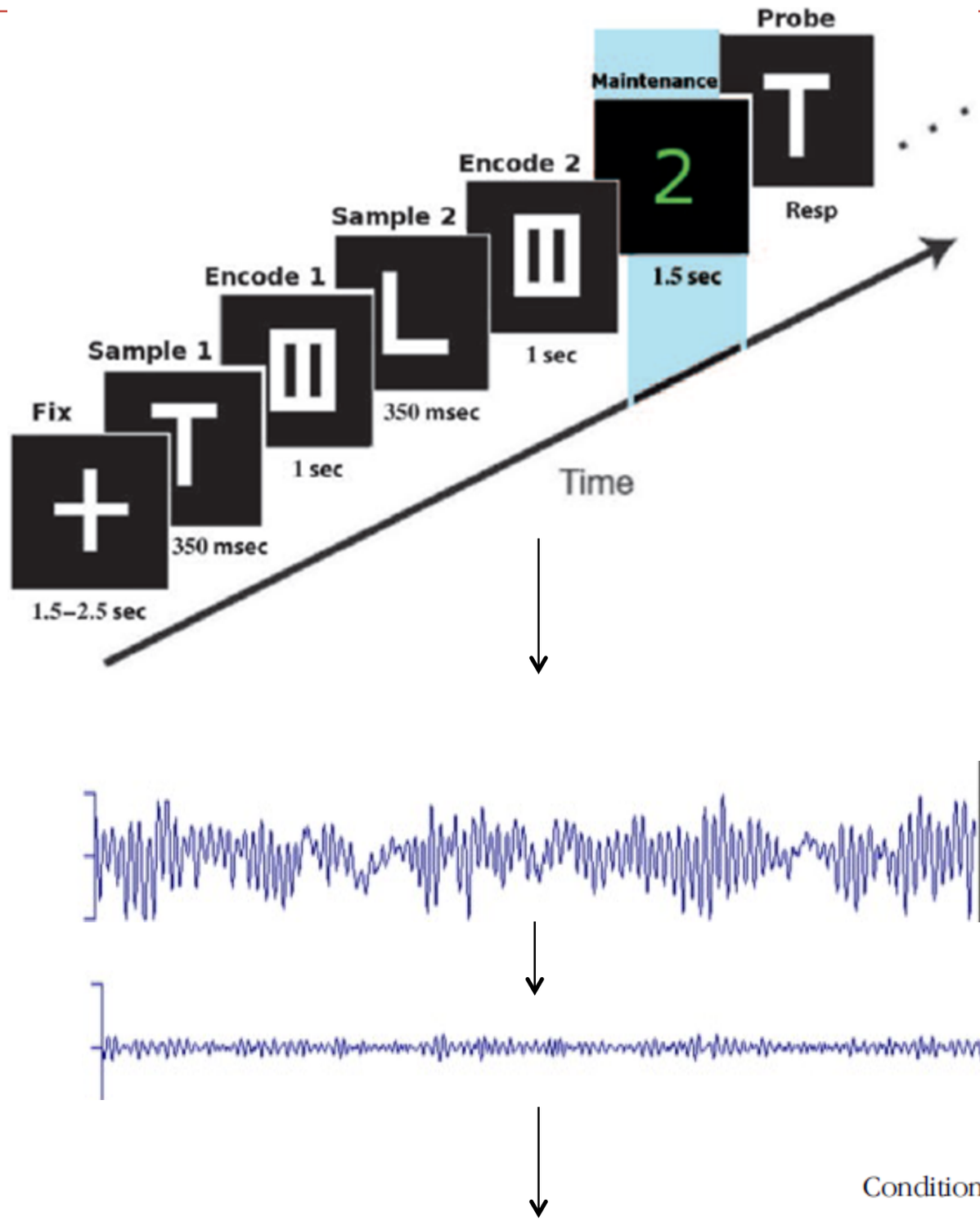
Multivariate methods boost MEG results





Quandt et al., 2012

Decoding working memory from EEG



Polanía et al., 2011

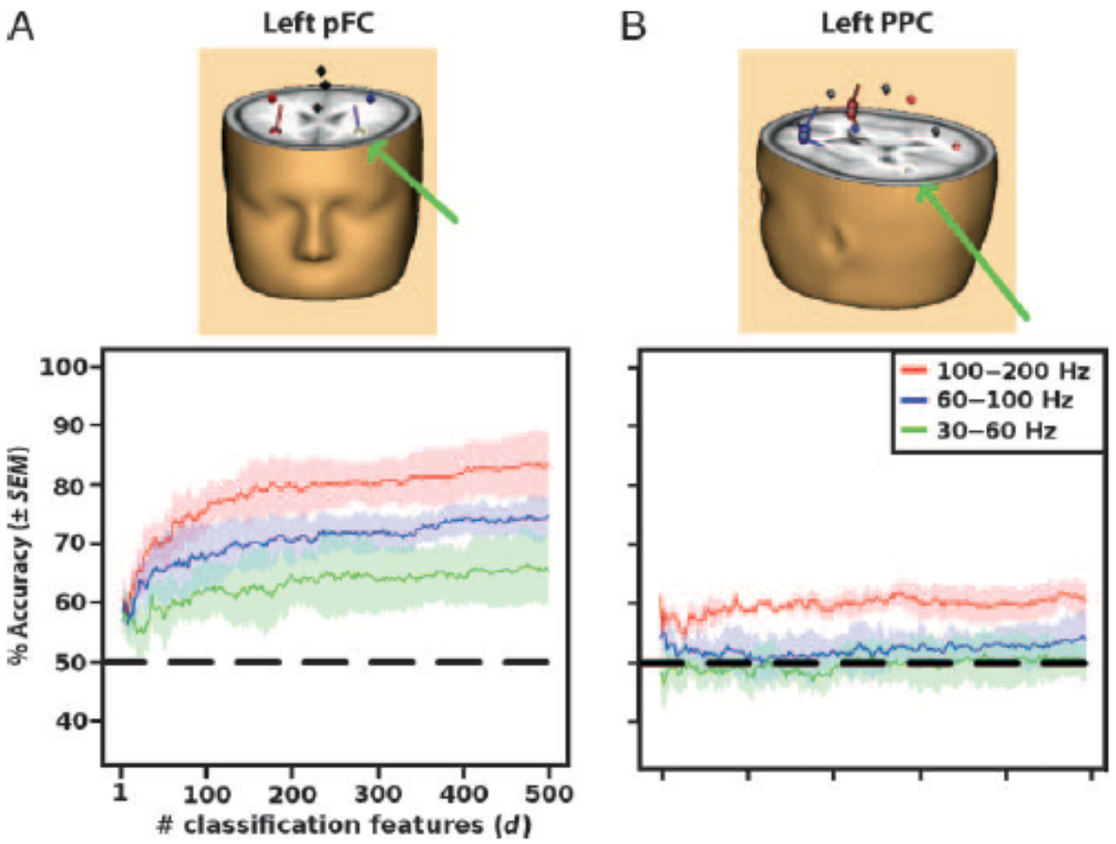
Discriminant function

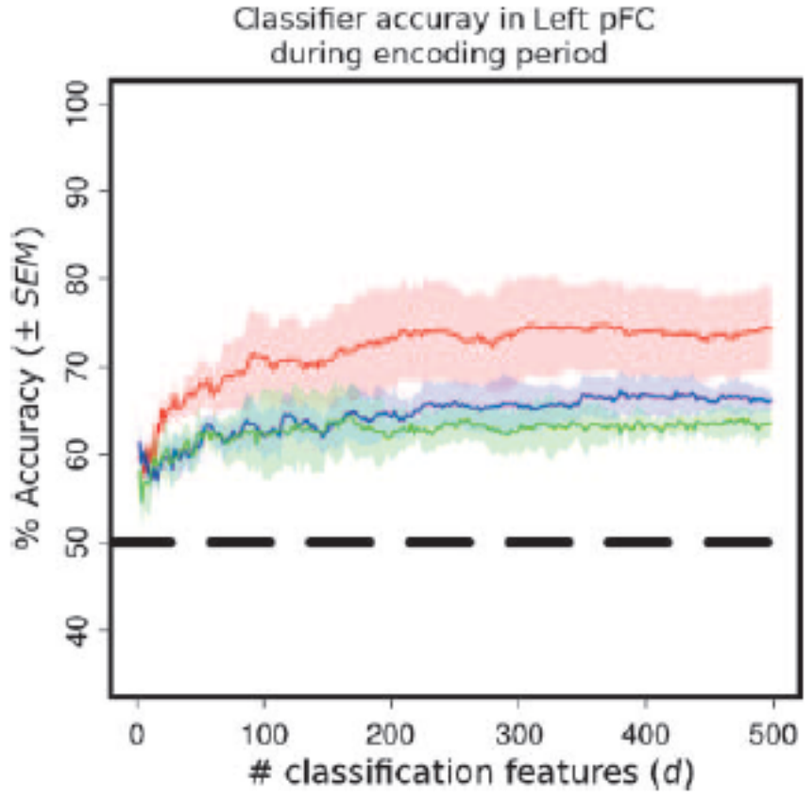
$$\text{Condition 1} : (S_{L(ij)} > (T * N_L)) \wedge (S_{T(ij)} < (0.5 * N_T)) \quad (8)$$

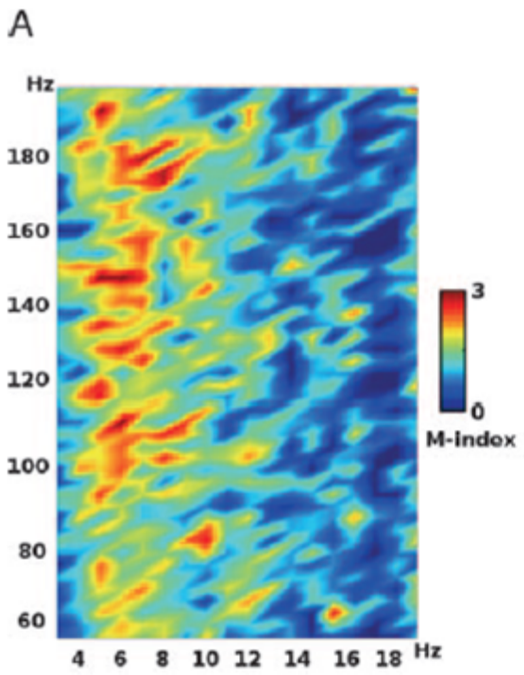
or

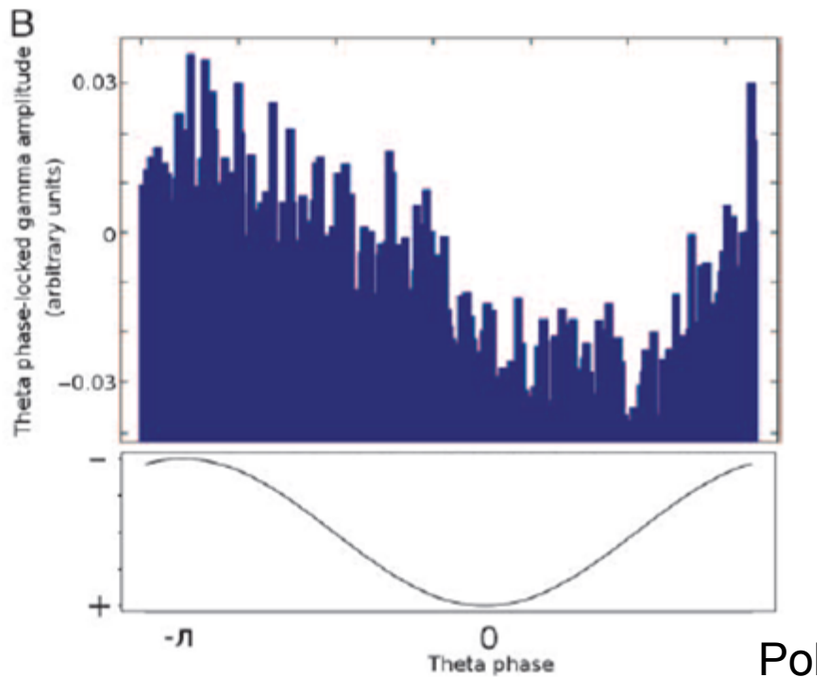
$$\text{Condition 2} : (S_{T(ij)} > (T * N_T)) \wedge (S_{L(ij)} < (0.5 * N_L)) \quad (9)$$

Decoding working memory from EEG



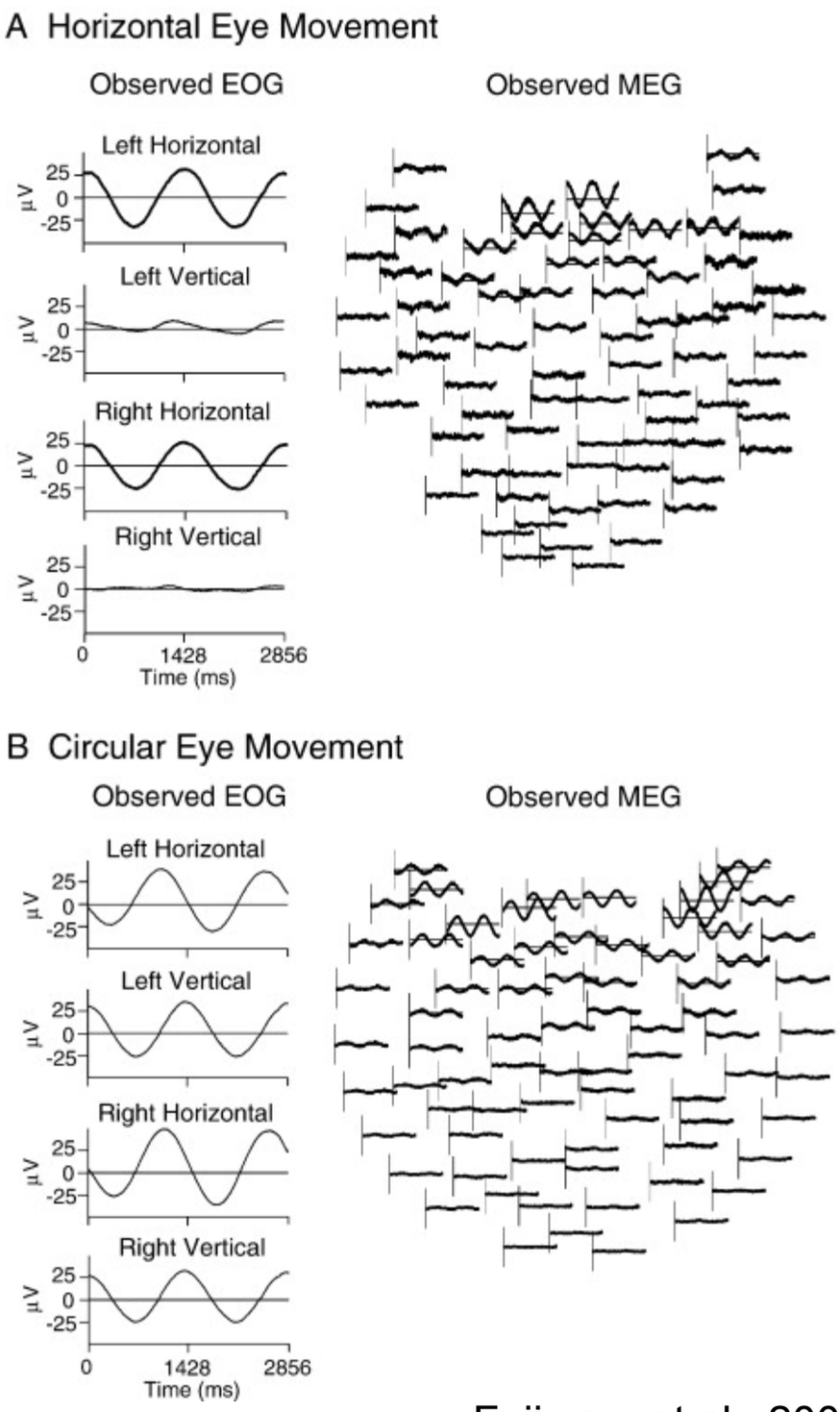






Polanía et al., 2011

Electrophysiological methods are not perfect either: eye motion artefacts



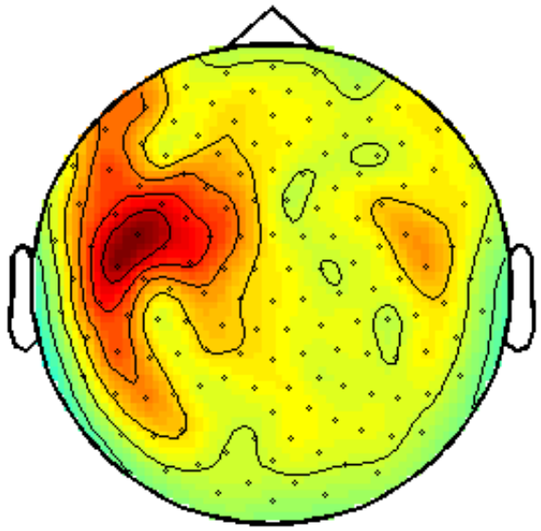
Problem: selective eye movements can be picked up by the classifier instead of real brain data.

Solution: measure EOG and train and test a classifier on this signal.

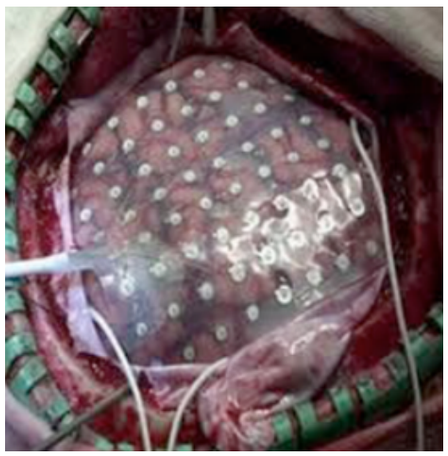
Fujiwara et al., 2005

Electrophysiological methods are not perfect either: bad spatial resolution

– Bad spatial resolution due to:
  – Smearing
  – Head motion
  – Mixing of the signal



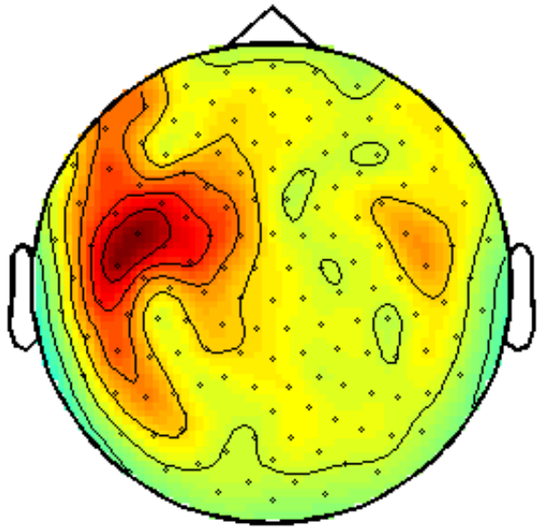
– ECoG
  – No smearing, measure directly from cortex
  – Problem 1: Invasive
  – Problem 2: Limited coverage



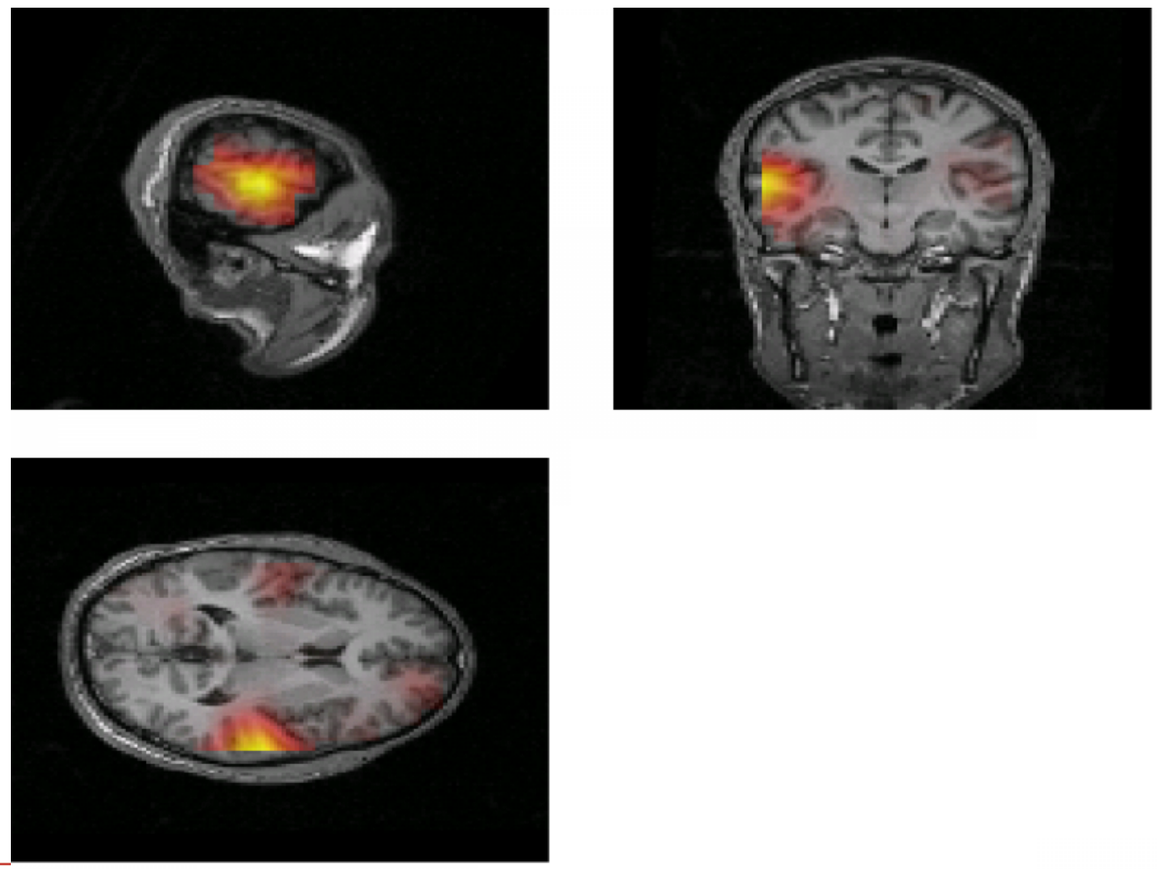
– Source reconstruction

Two spaces

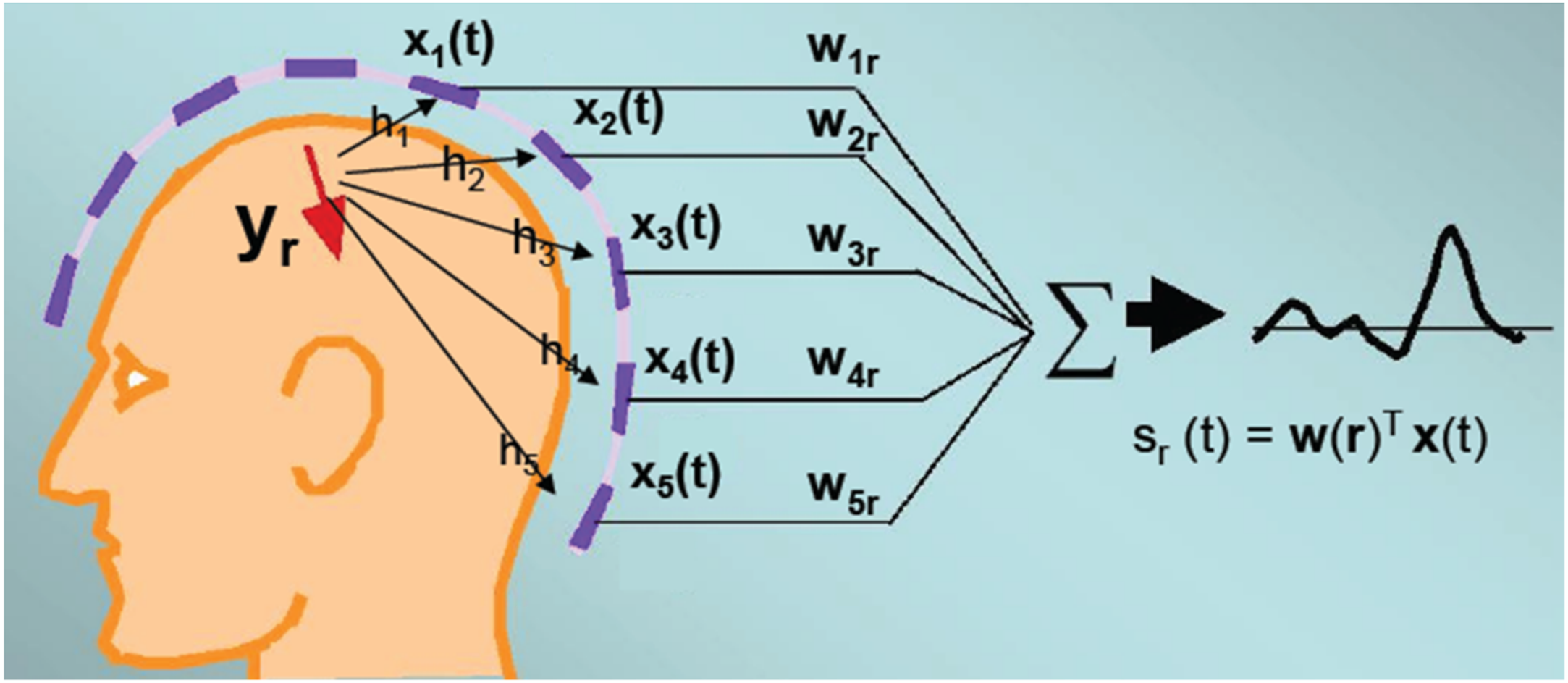
Sensor space



Source space

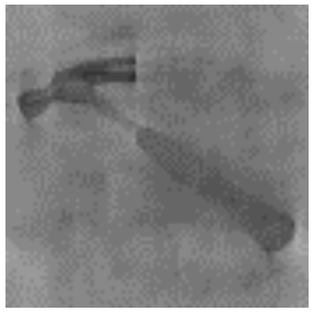


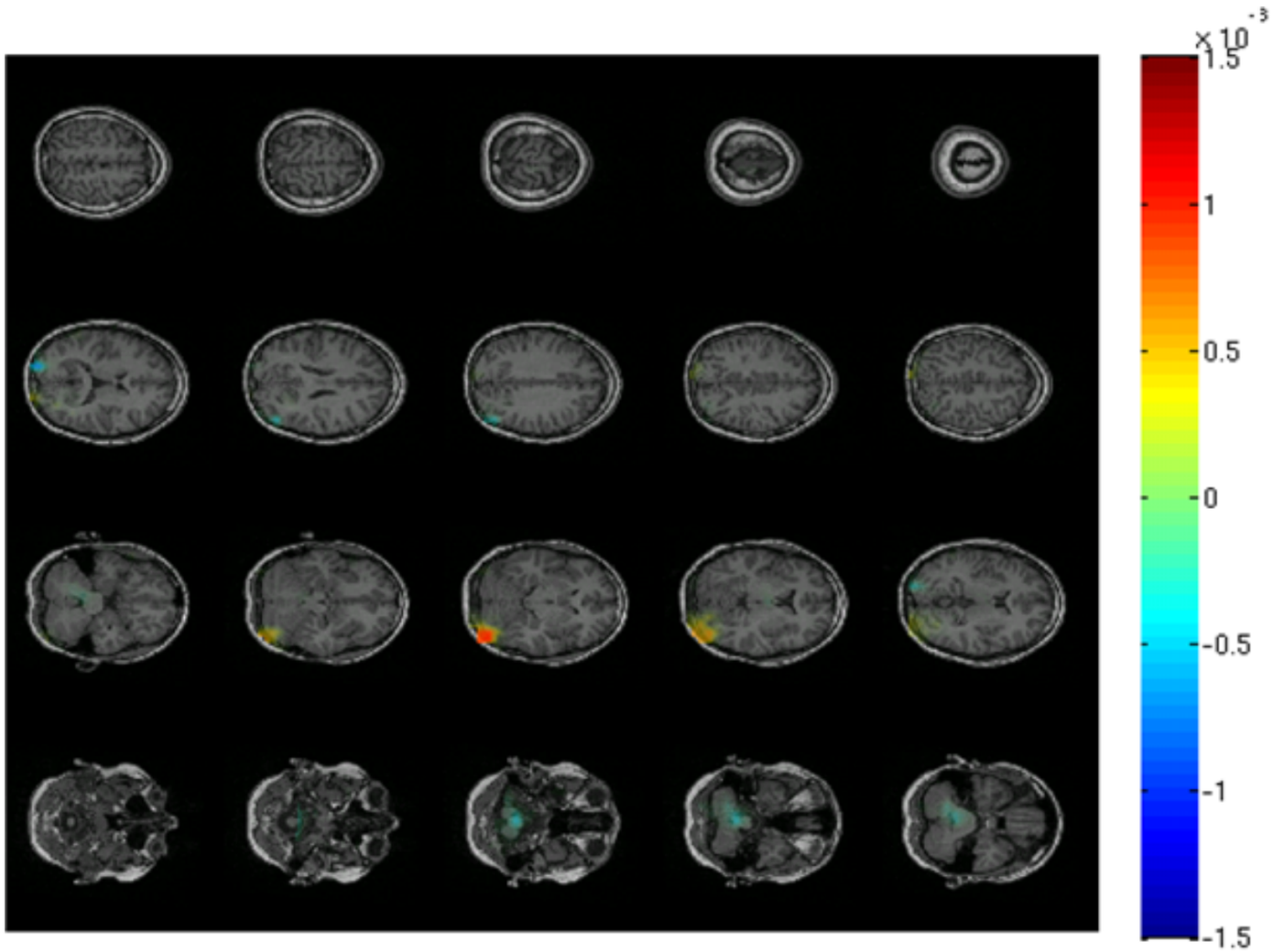
Crash course source reconstruction



Applying the elastic net algorithm to source space data gives focal sources…

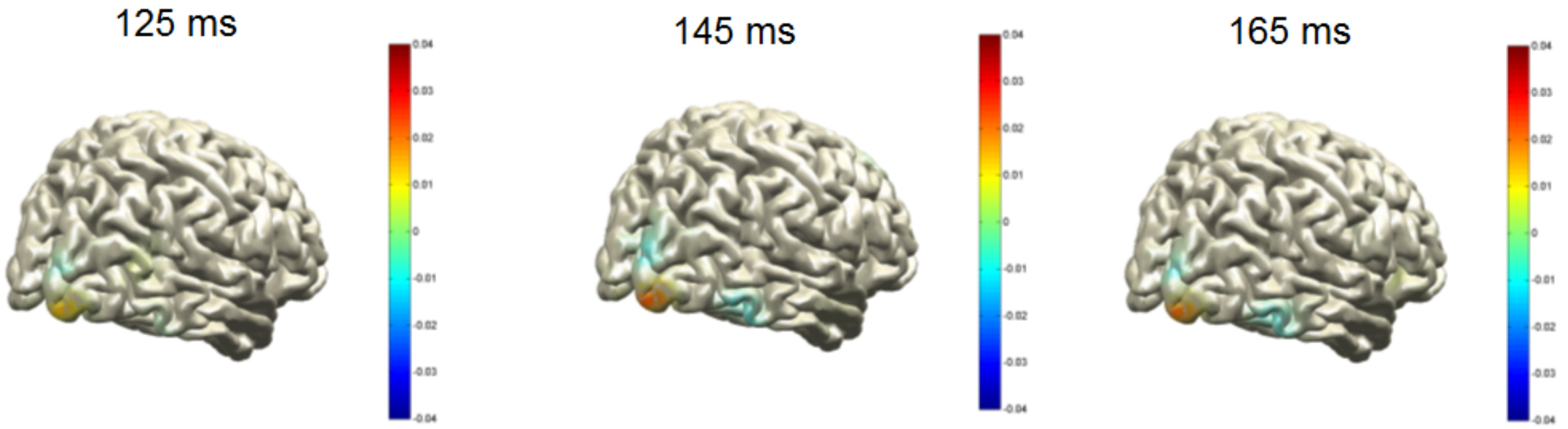
vs





Van de Nieuwenhuijzen et al. (in prep.)

… as well as specific localization at each time point



Van de Nieuwenhuijzen et al. (in prep.)

Problems of going to source space

– Inflation of feature space
  – EEG: up to 128 electrodes
  – MEG: 275 sensors
  – Source space: 2711 grid points (beamforming)

– Computationally heavy

- Beamforming requires an anatomical MRI scan

Take home messages

- Electrophysiological methods have a very good temporal resolution
- As well as many different features to feed into classification algorithms (time domain, frequency domain, …)
- Applying multivariate techniques to these methods allow decoding of, among others, visual perception, finger motion, working memory content
- Note that the number of features can inflate strongly (especially when going to source space)
- Be aware of the possible confound of selective artefacts (e.g. eye movement artefacts)
- Spatial resolution can be improved by going to source space