

Introduction to simultaneous EEG-fMRI

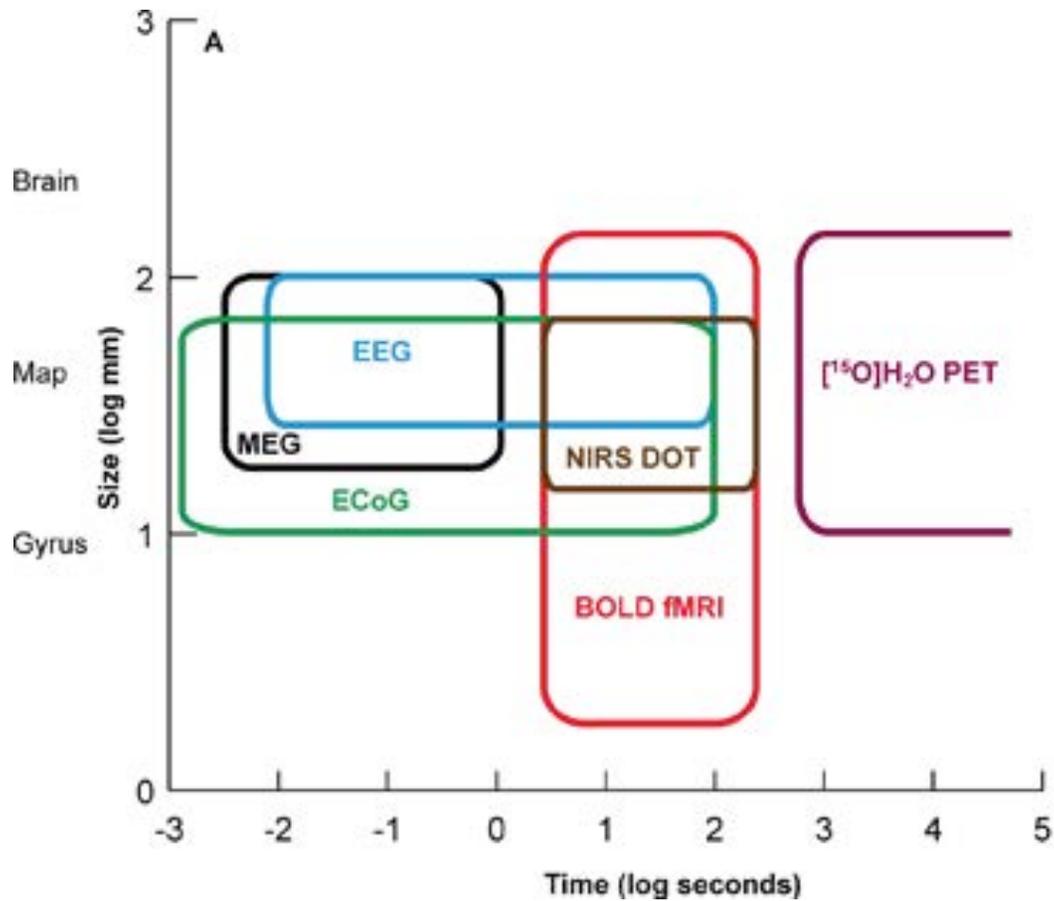


Laura Lewis, Martinos Center Why and How, March 2018

Outline

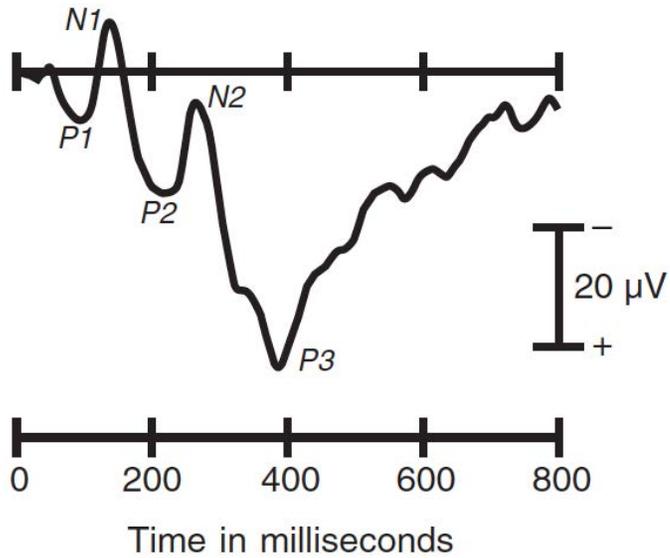
- Advantages of EEG-fMRI
- Disadvantages of EEG-fMRI
- How to do it
- Neuroscience and clinical applications

High temporal and spatial resolution

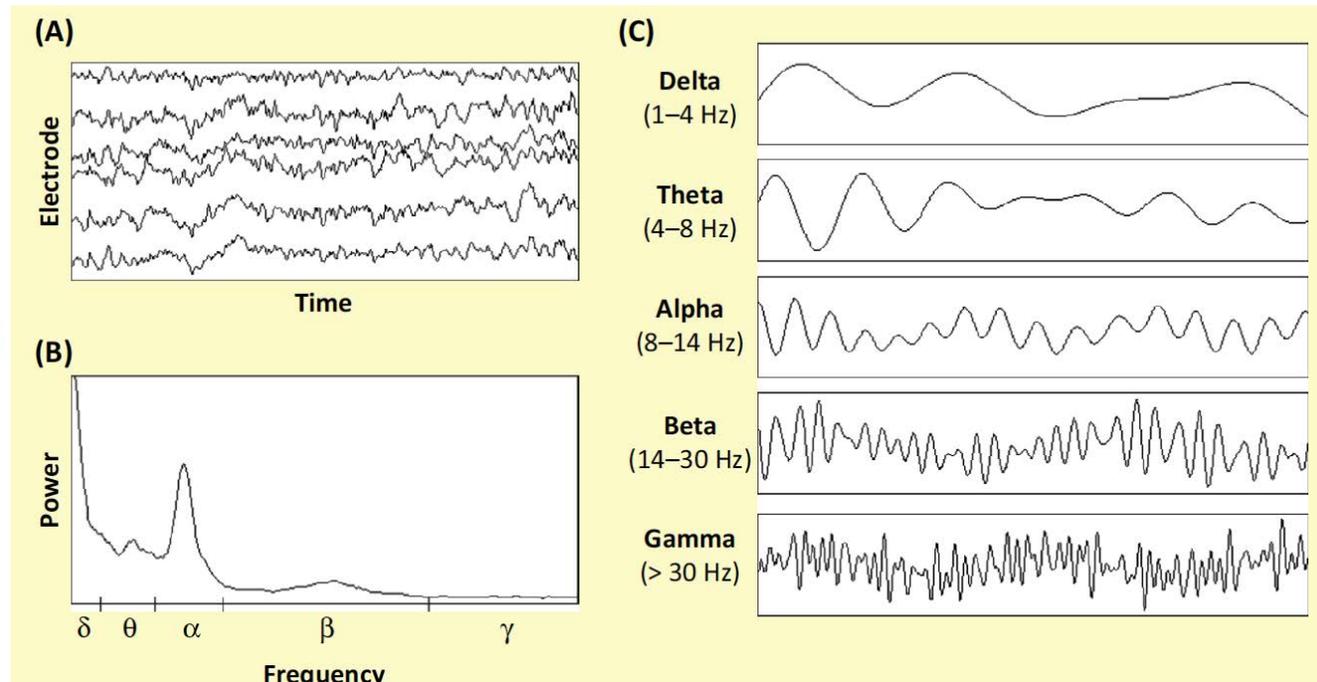


Snyder and Raichle, 2010

EEG resolution

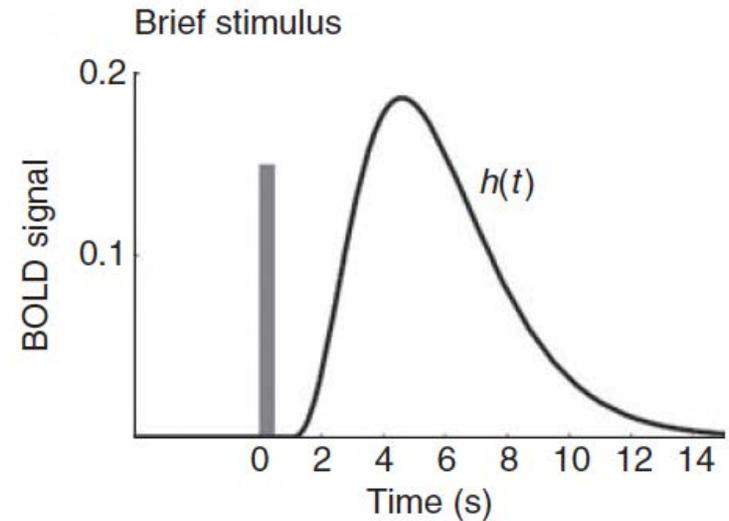
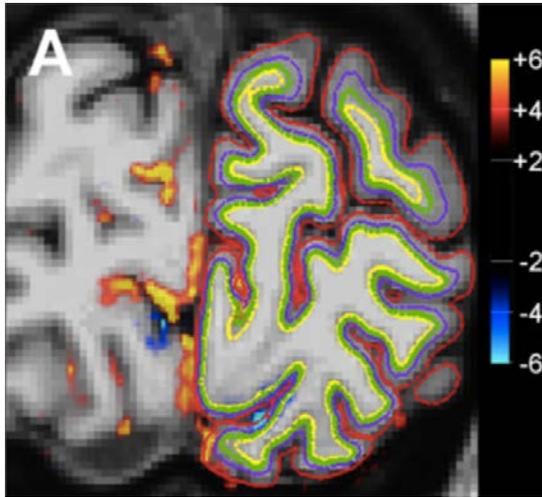


Luck, 2005

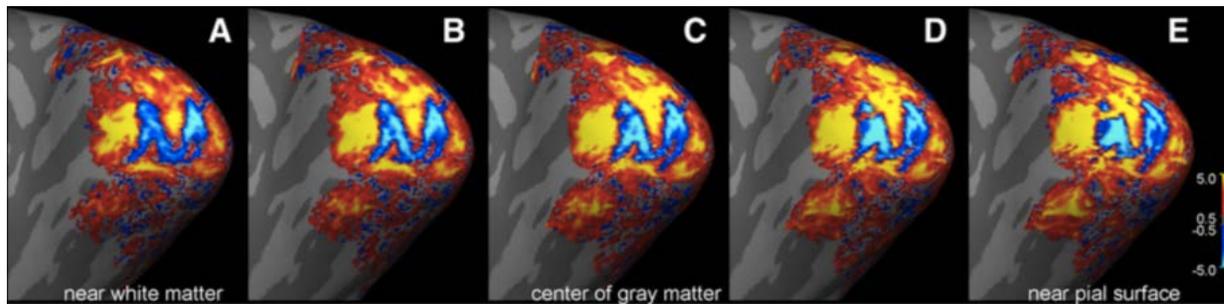


Clayton et al., 2015

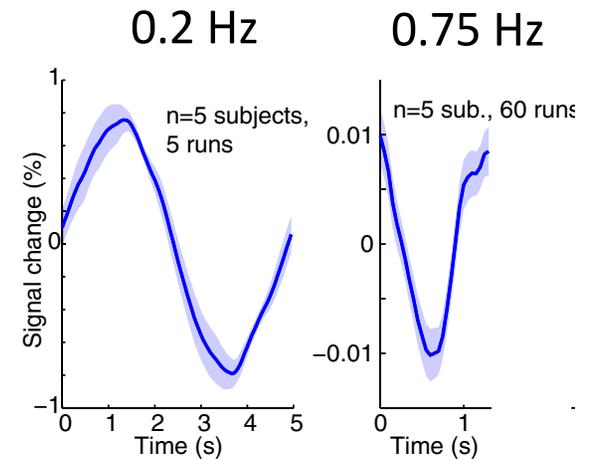
fMRI resolution



Buxton 2009



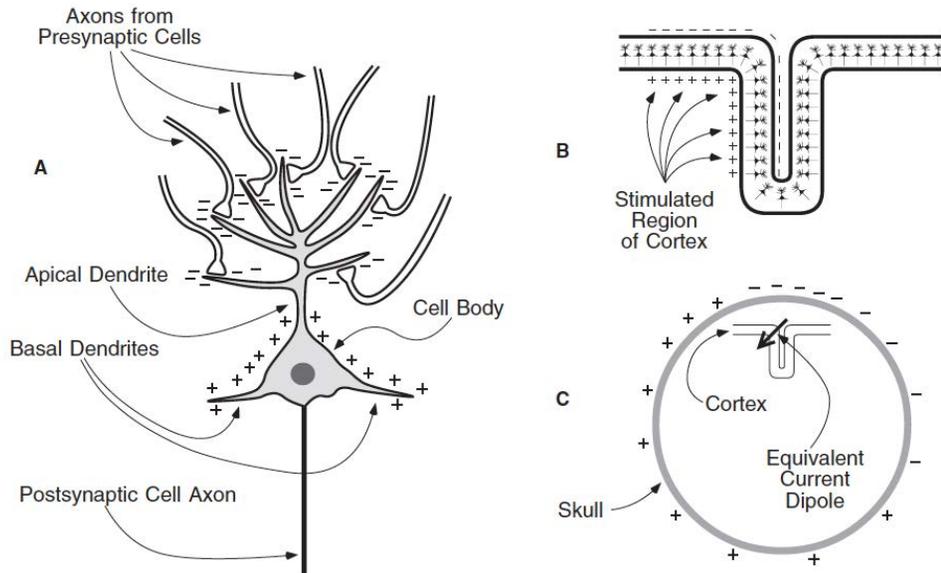
Polimeni et al., 2010



Lewis et al., 2016

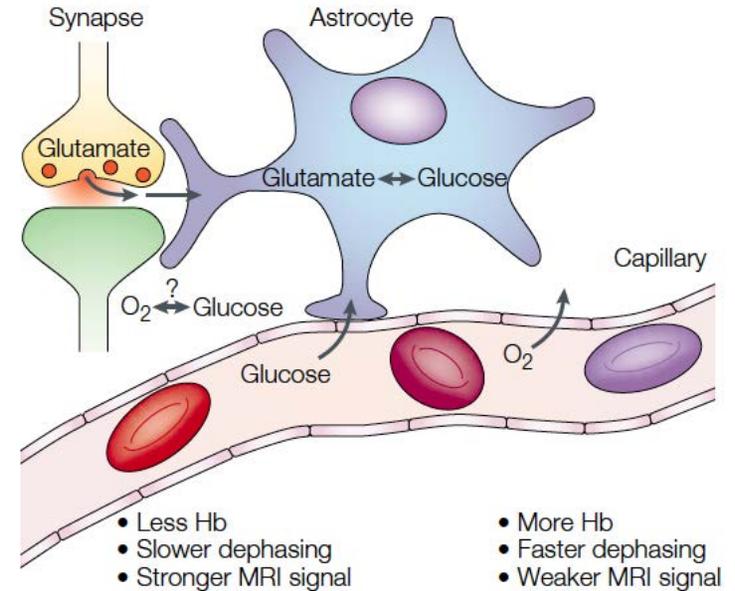
Sampling different properties of neural activity

EEG



Luck, 2005

fMRI



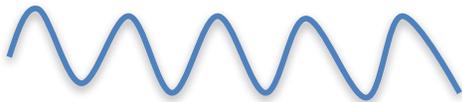
Heeger and Ress, 2002

Sampling different properties of neural activity

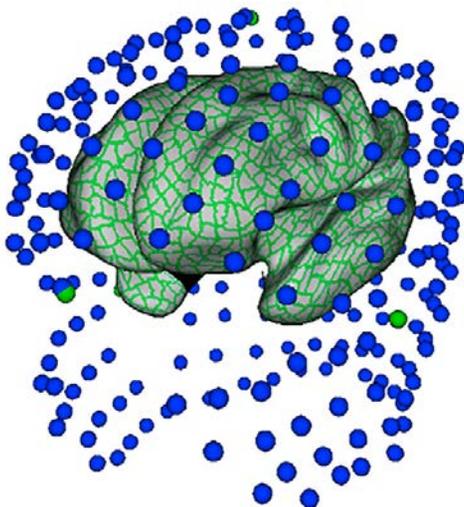
EEG

Synchrony

oscillation:



Surface



Song et al.,
2015

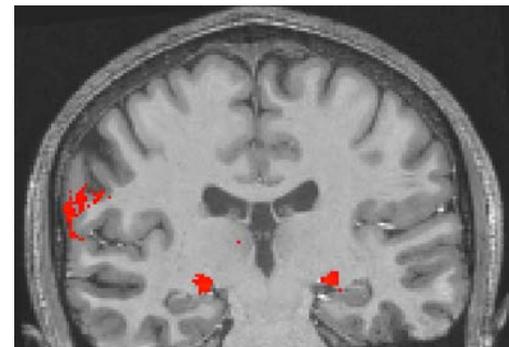
fMRI

Metabolic activity

mean firing:



Whole-brain



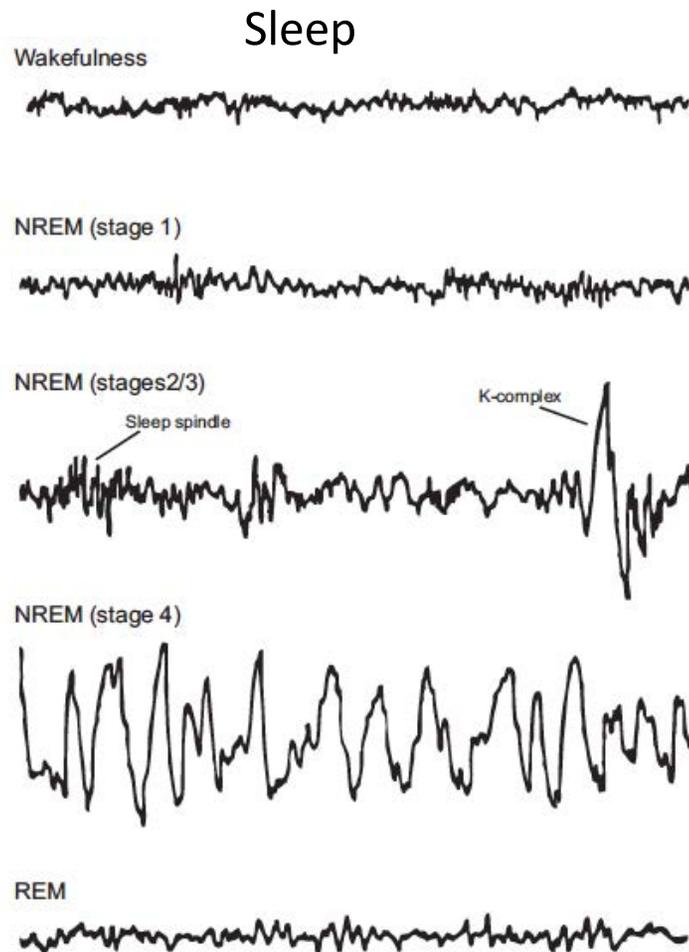
Experimental consistency

- Perfectly replicating task conditions is difficult
- Novelty/training effects of task may vary
- Brain state and daily variation affect responses

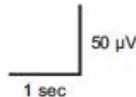
Single-trial analyses

- Variable vigilance
- Bistable perception
- Attention
- Linking neural activation to ERP components

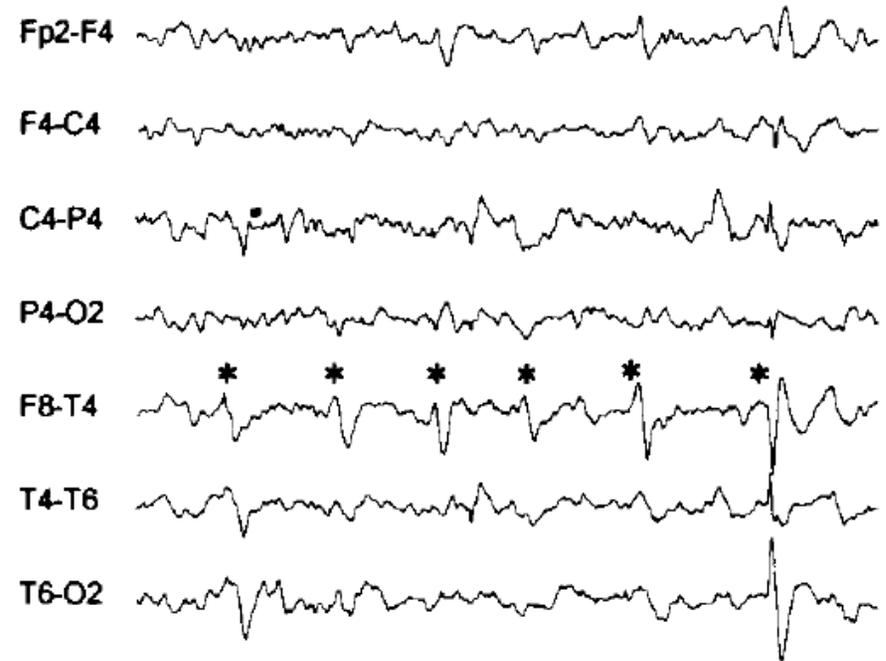
Linking ongoing neural dynamics to activation patterns



Brown et al., 2012



Epilepsy



de Curtis and Avanzini, 2001

Why would we not do EEG-fMRI?

- Increased setup time
- Degraded EEG quality
- Experimental design may not suit both modalities
- Many studies can be run as separate, non-simultaneous EEG and fMRI experiments
- Integrating these data types is not straightforward

Setting up



- 256 channel sensor net
- ECG
- Amplifier setup and baseline recording

Setting up



- In-bore amplifier system
- 64-channel traditional caps

Geodesic photogrammetry system



Safety considerations

- MR-Conditional – tested for MPRAGE and EPI
- RF heating in wire loops



Locating a looped wire.



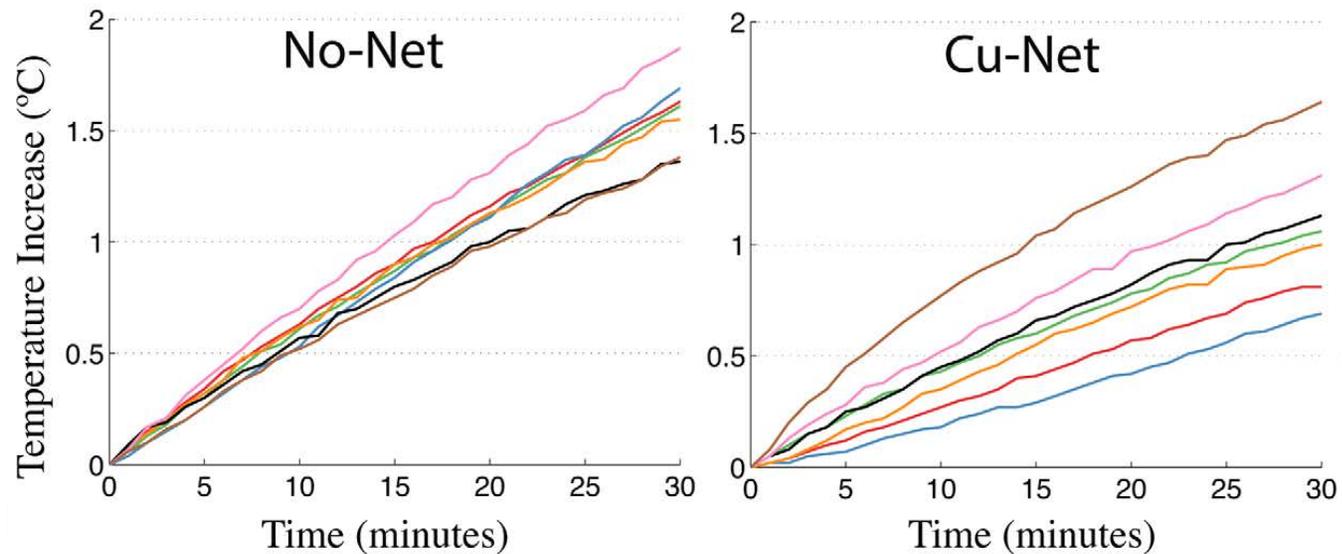
Gently fixing a wire loop.



Looped wire is fixed.

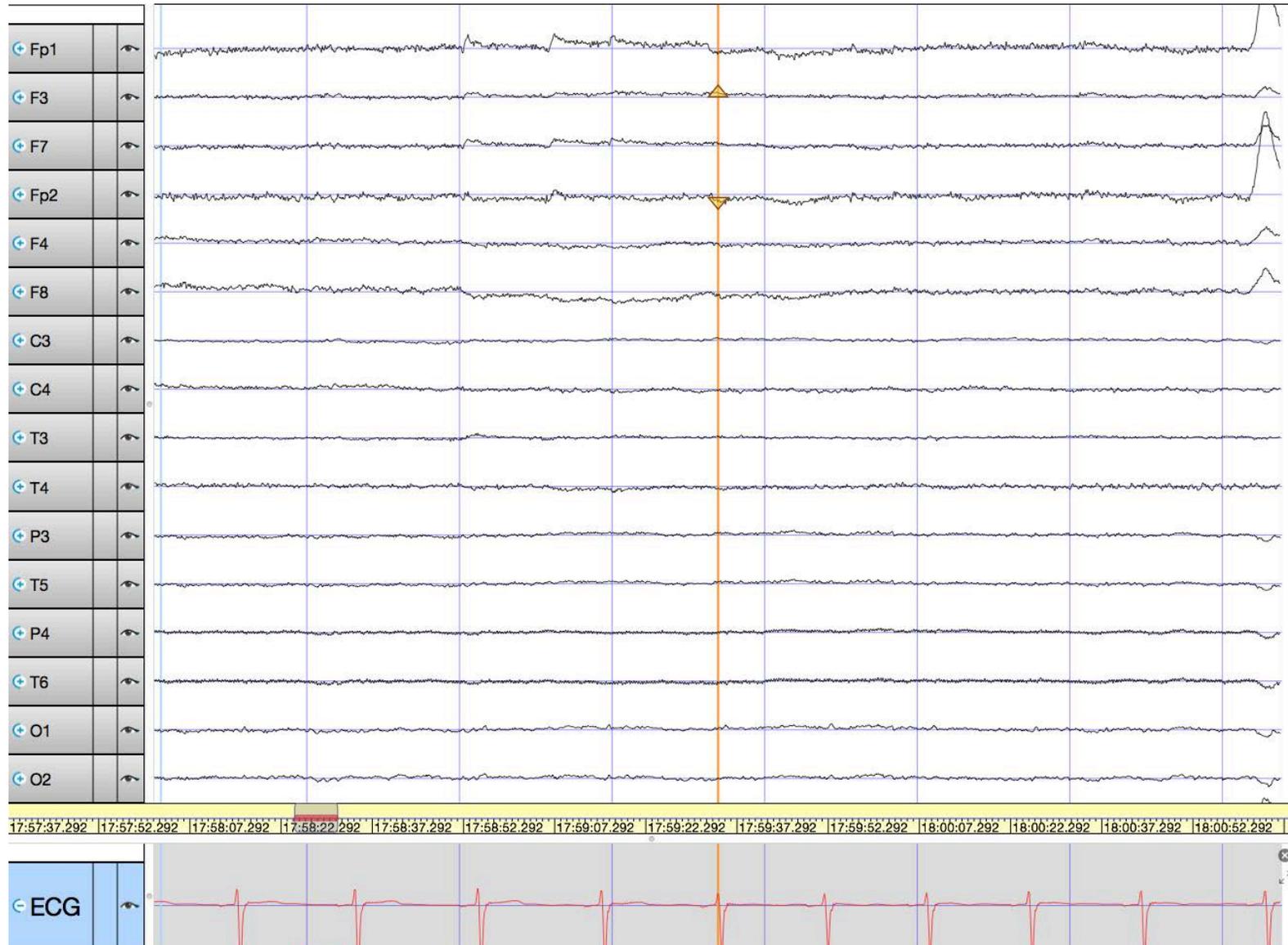
Safety considerations

- Measure temperature changes empirically

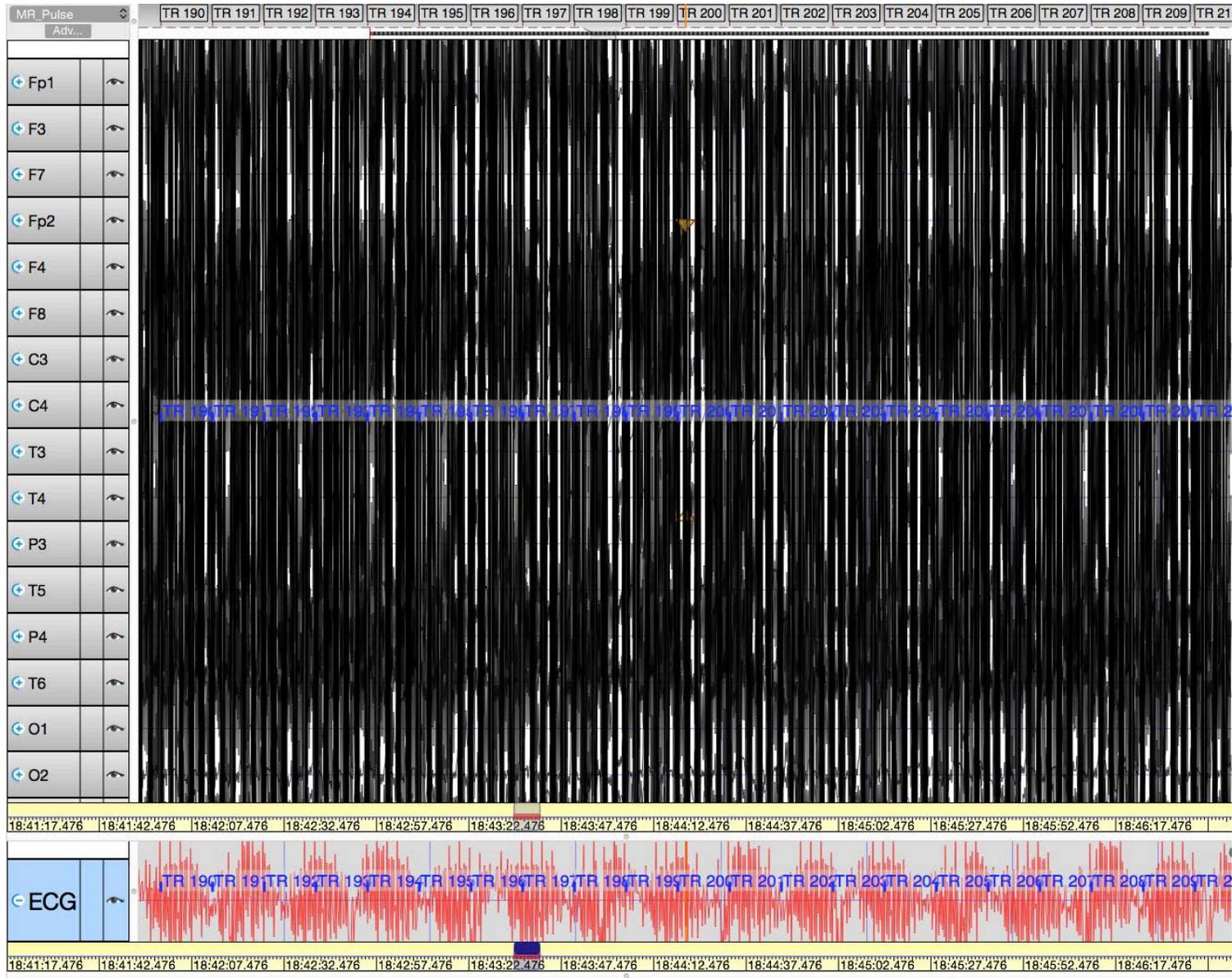


Poulsen et al., 2017

EEG cleaning – gradient artifacts

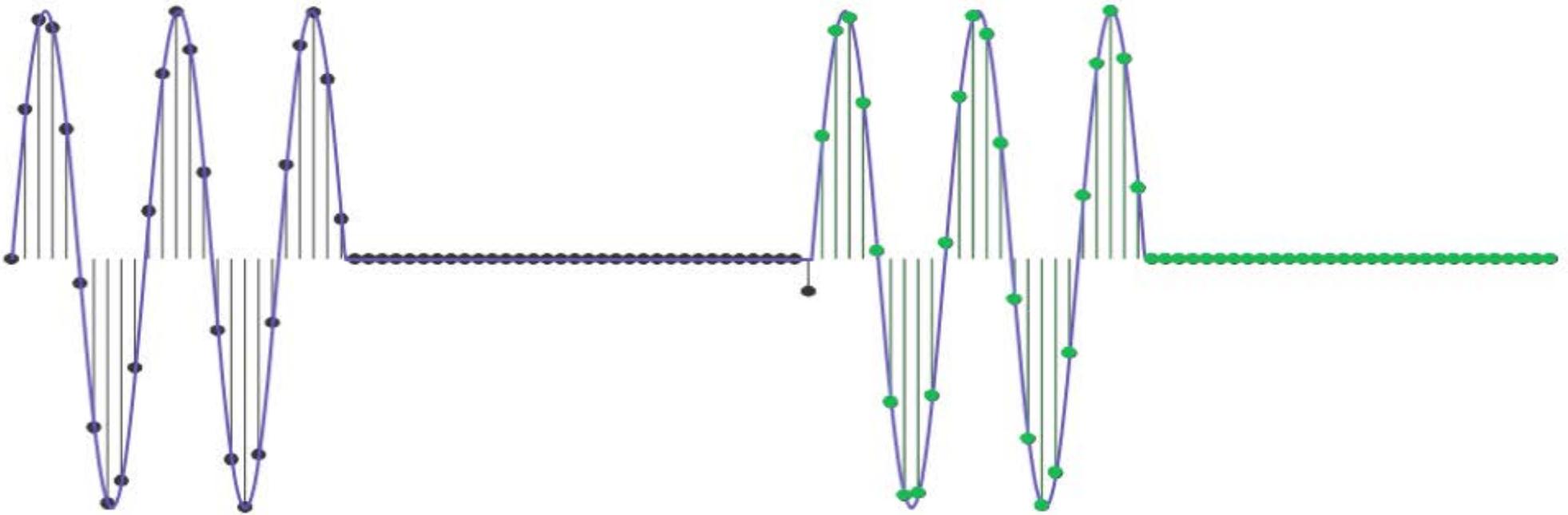


EEG cleaning – gradient artifacts



Gradient artifact template subtraction

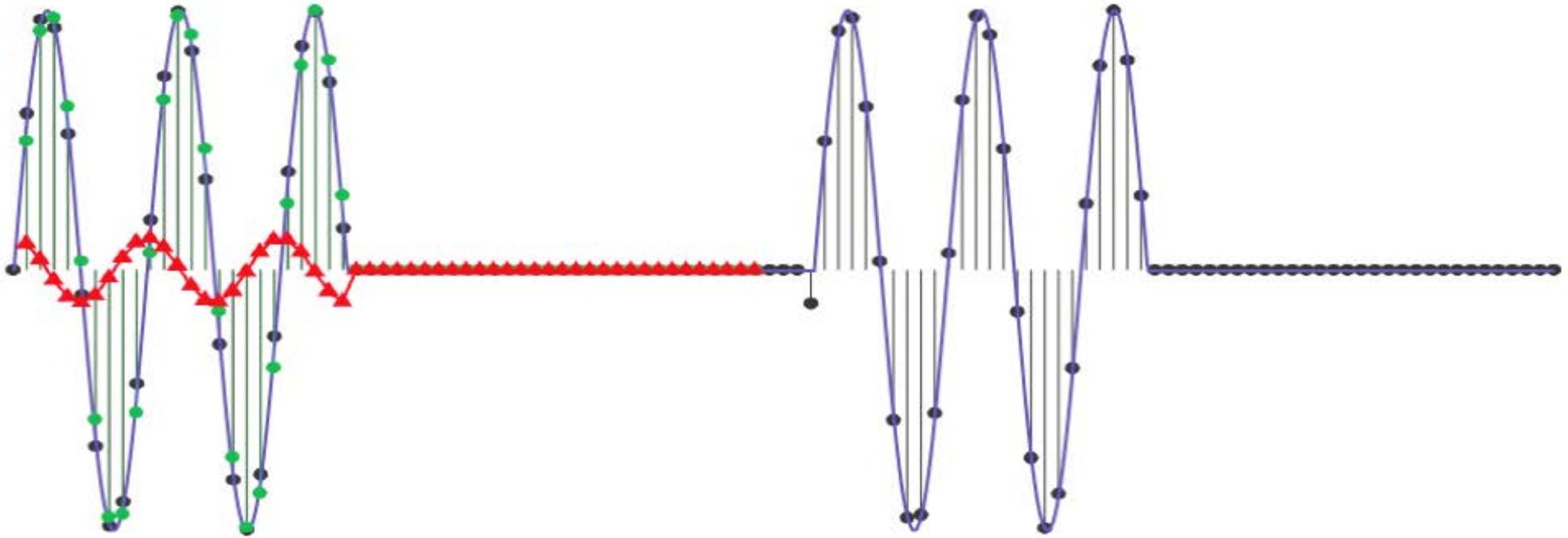
Non-synchronized sampling



Taken from EGI slides

Gradient artifact template subtraction

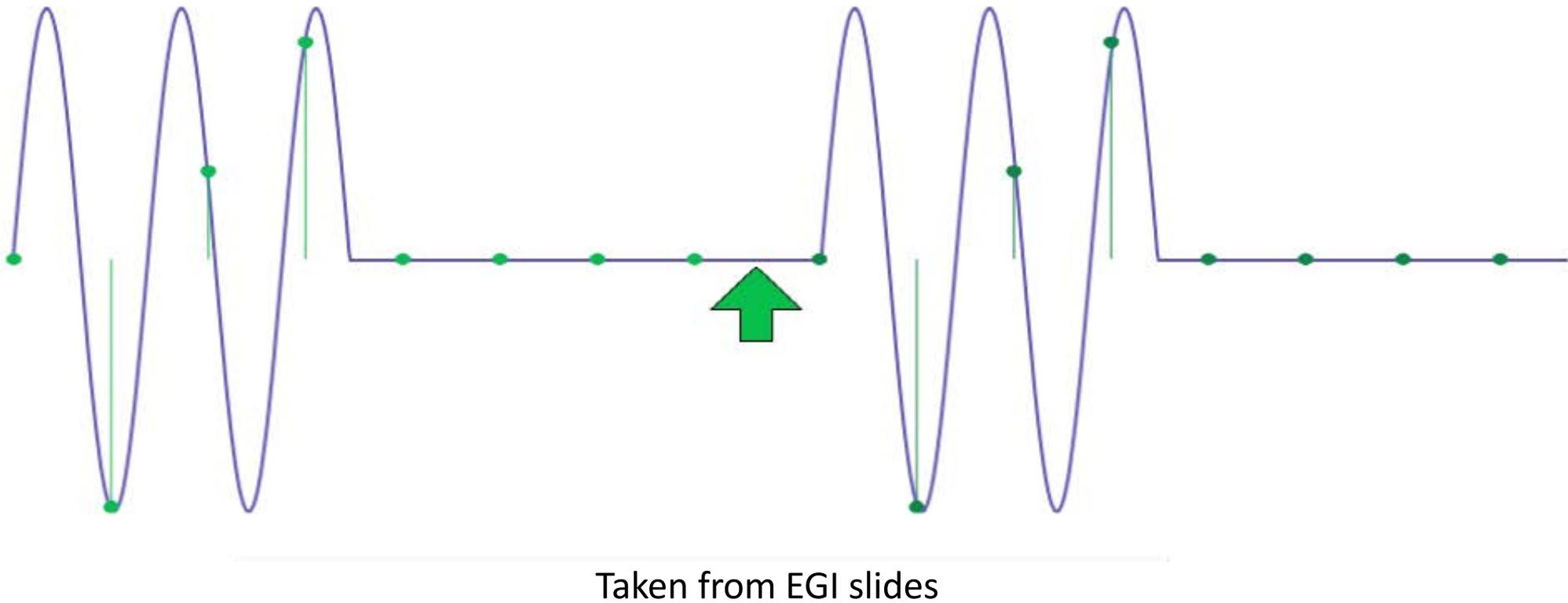
Non-synchronized sampling



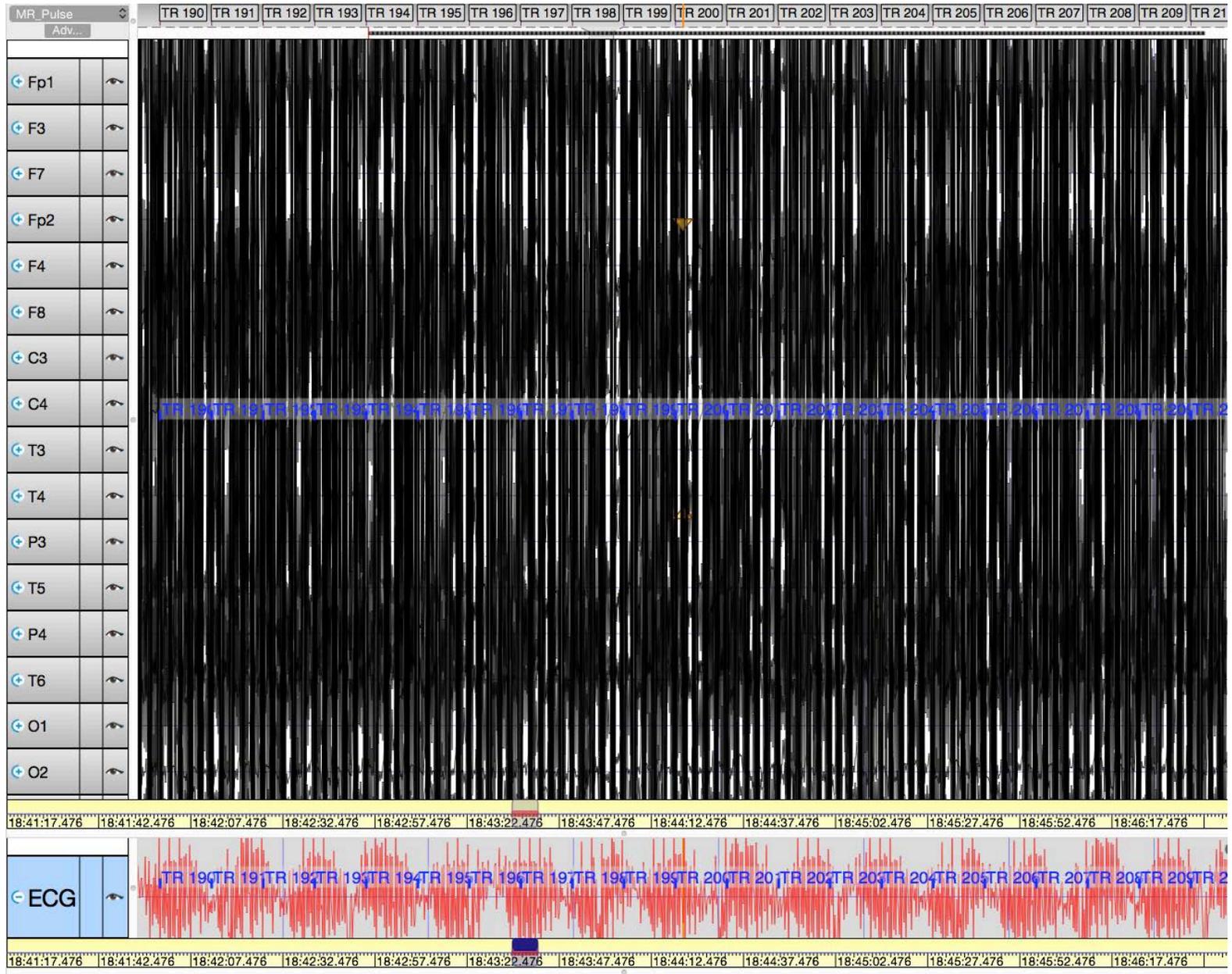
Taken from EGI slides

Gradient artifact template subtraction

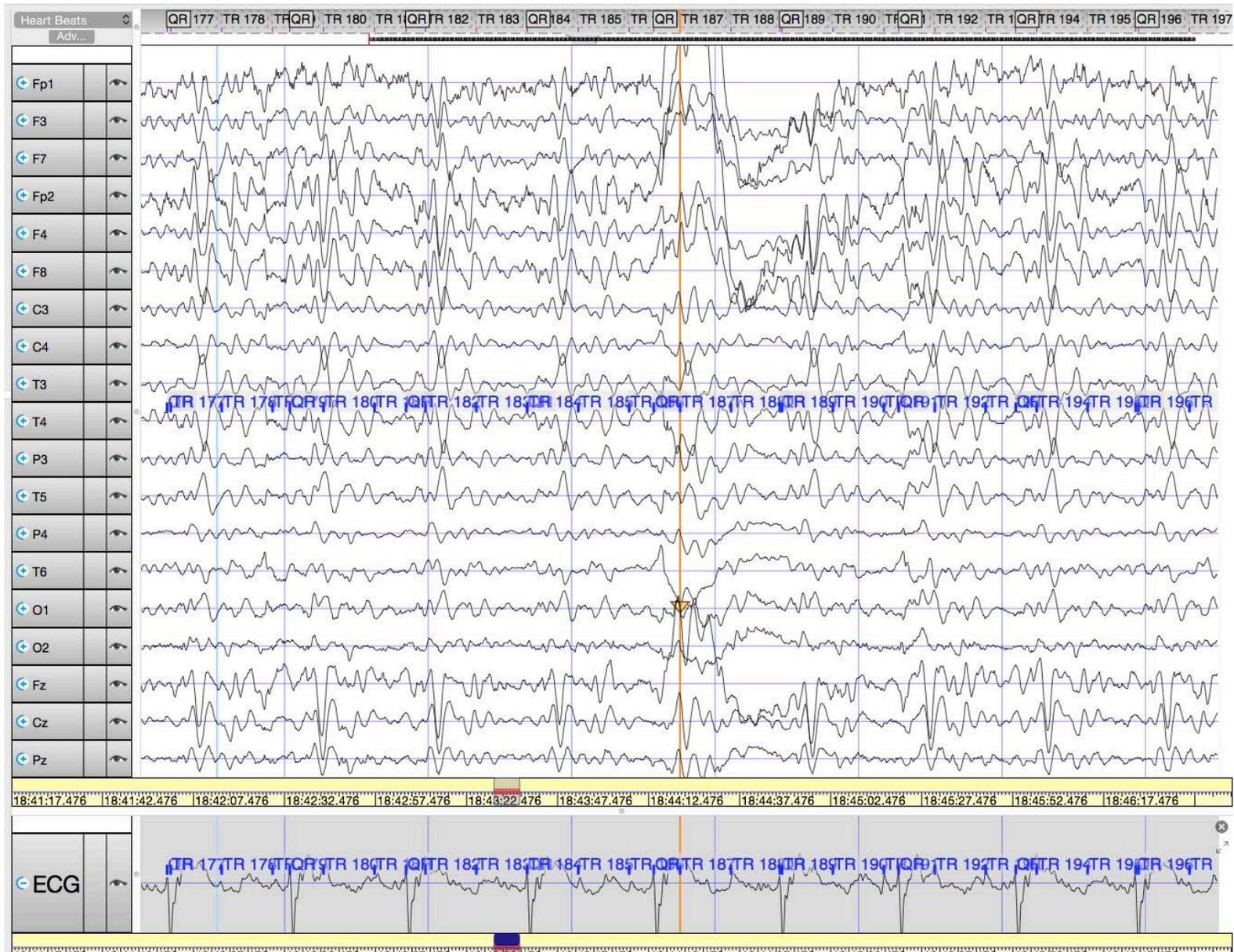
Synchronized sampling



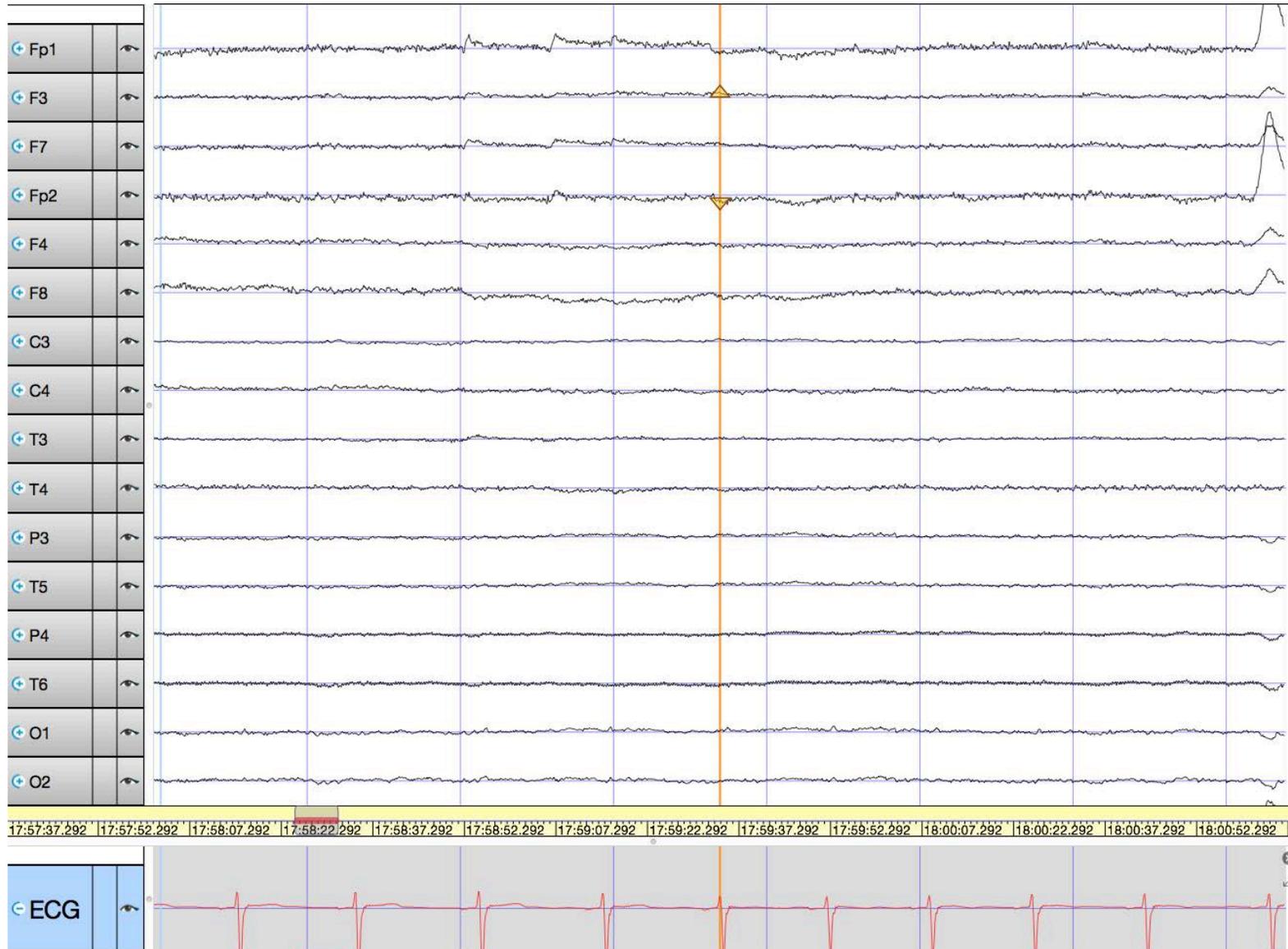
EEG cleaning – gradient artifacts



EEG – cleaned gradient artifact



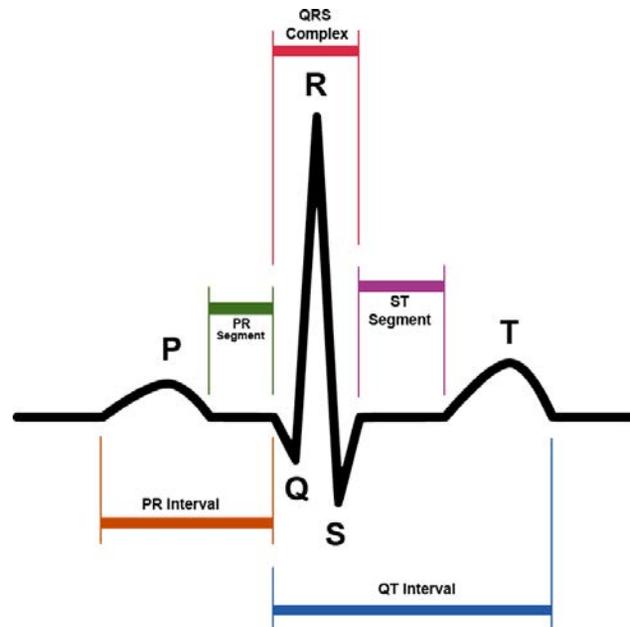
EEG cleaning – outside scanner



BCG – optimal basis sets

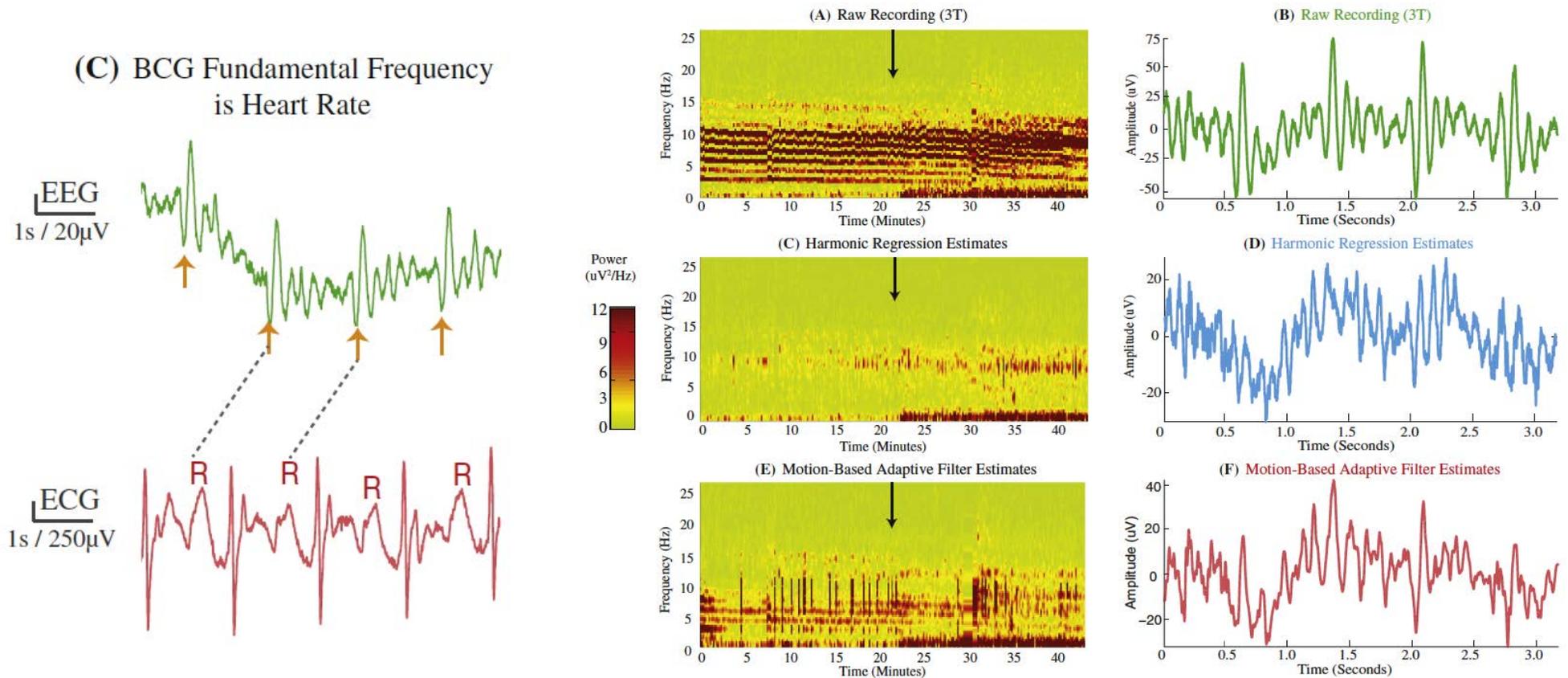
Niazy et al., 2005:

QRS Detection → PCA → Fit to each QR peak



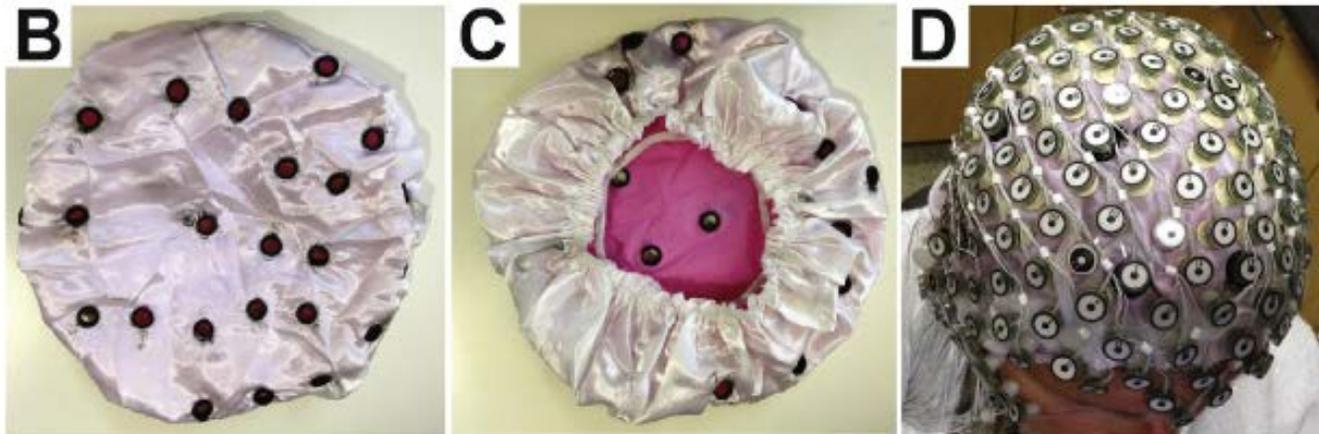
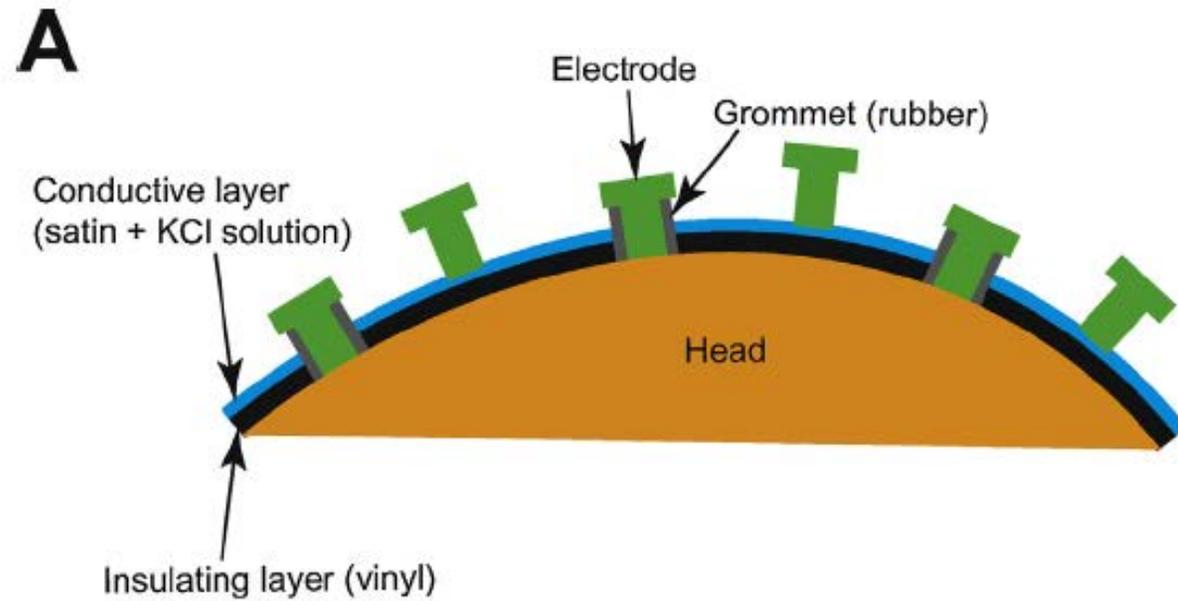
BCG – harmonic regression

Reference-free



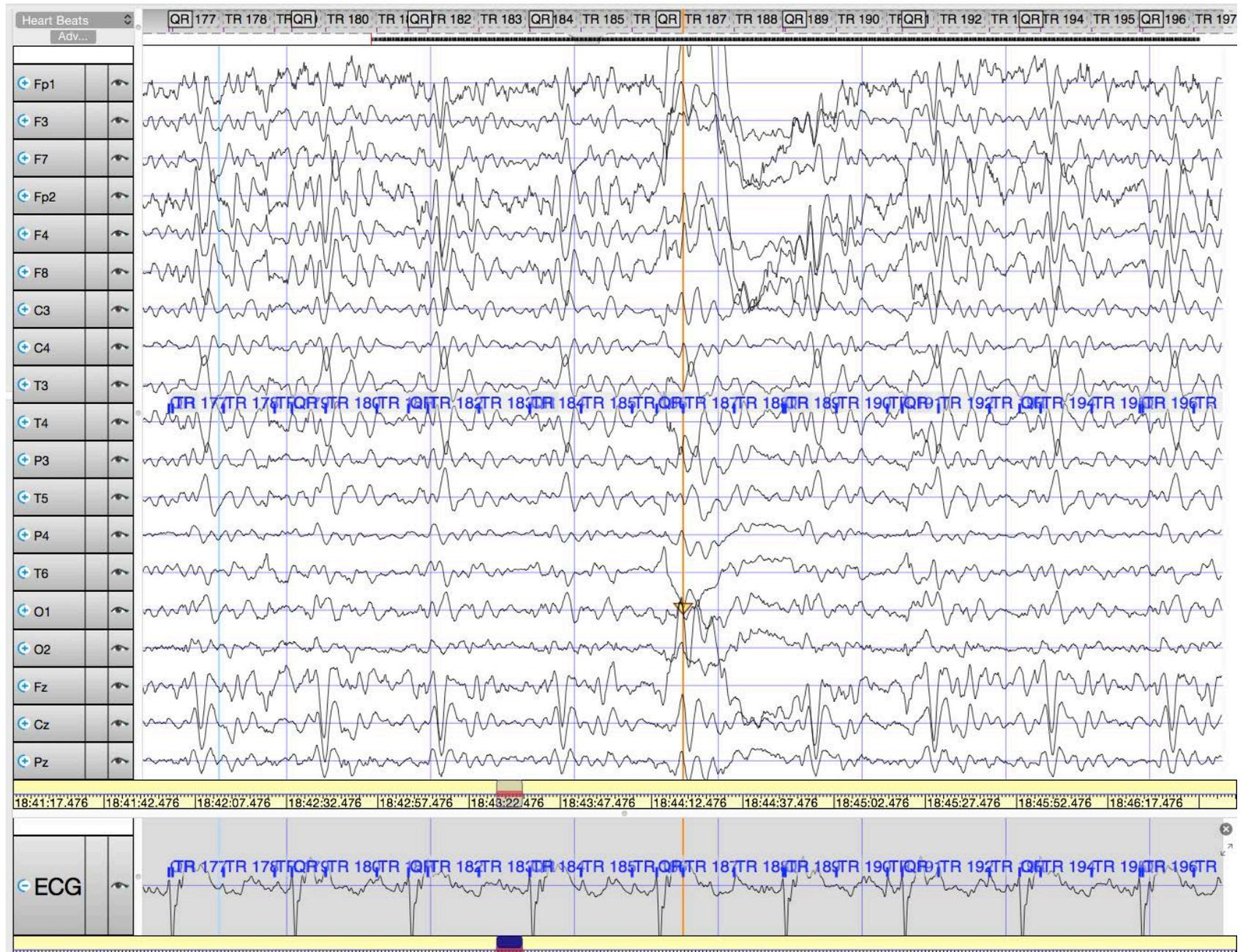
Krishnaswamy et al., 2016

BCG – reference layer

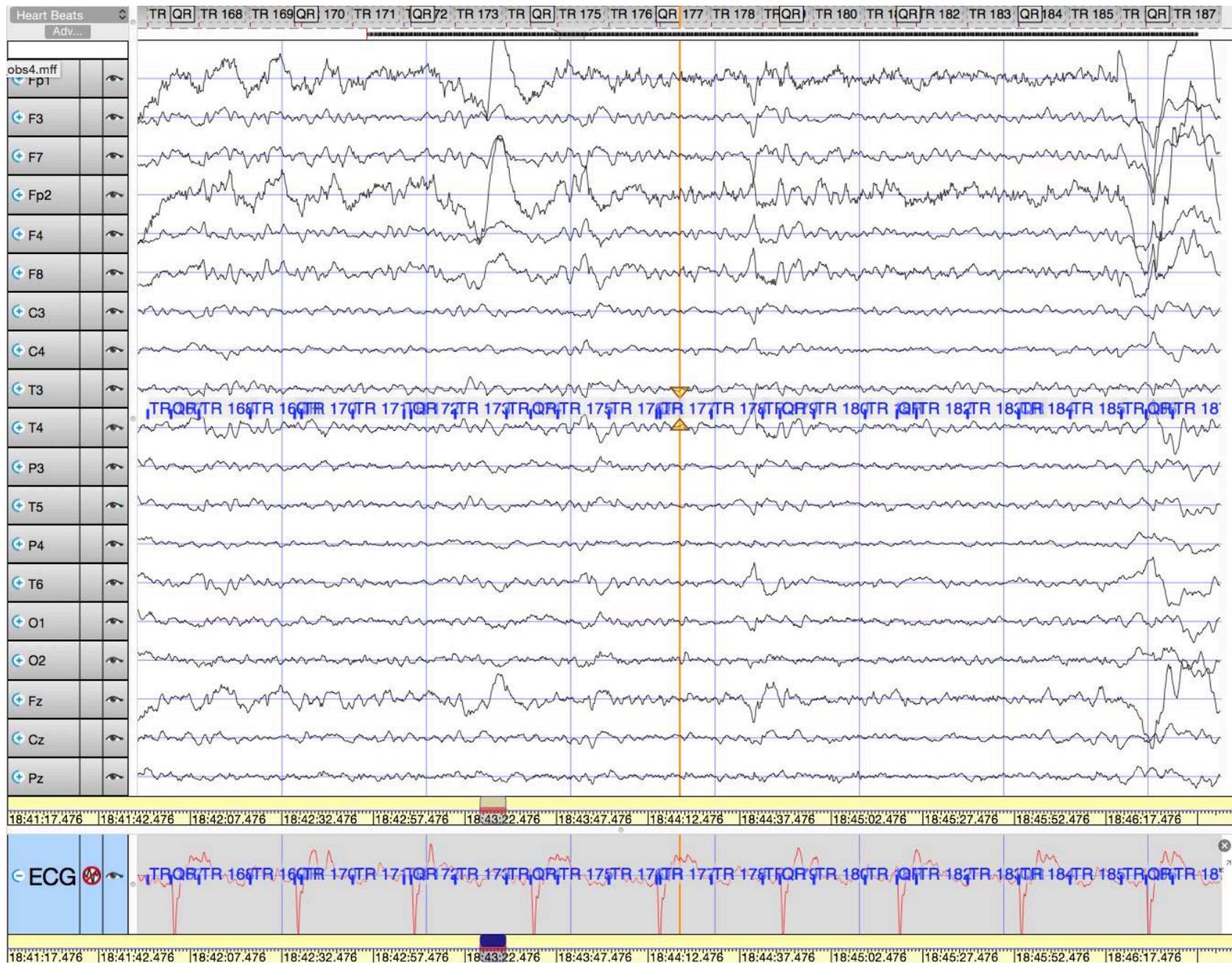


Luo et al., 2014

Ballistocardiogram artifacts



Ballistocardiogram artifacts

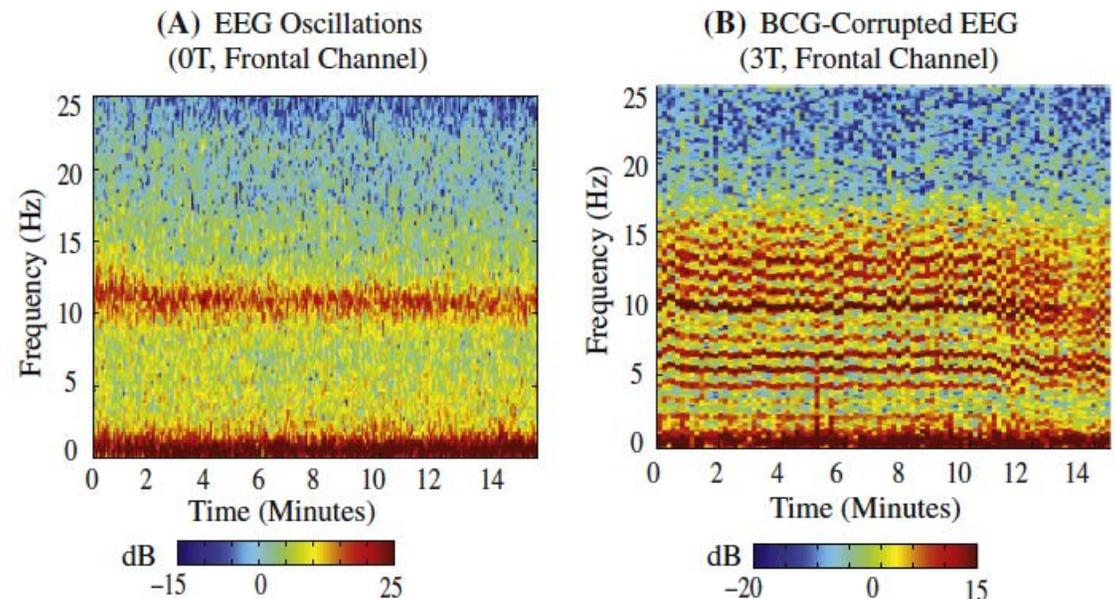


Residual artifacts

Spikes



Harmonic noise

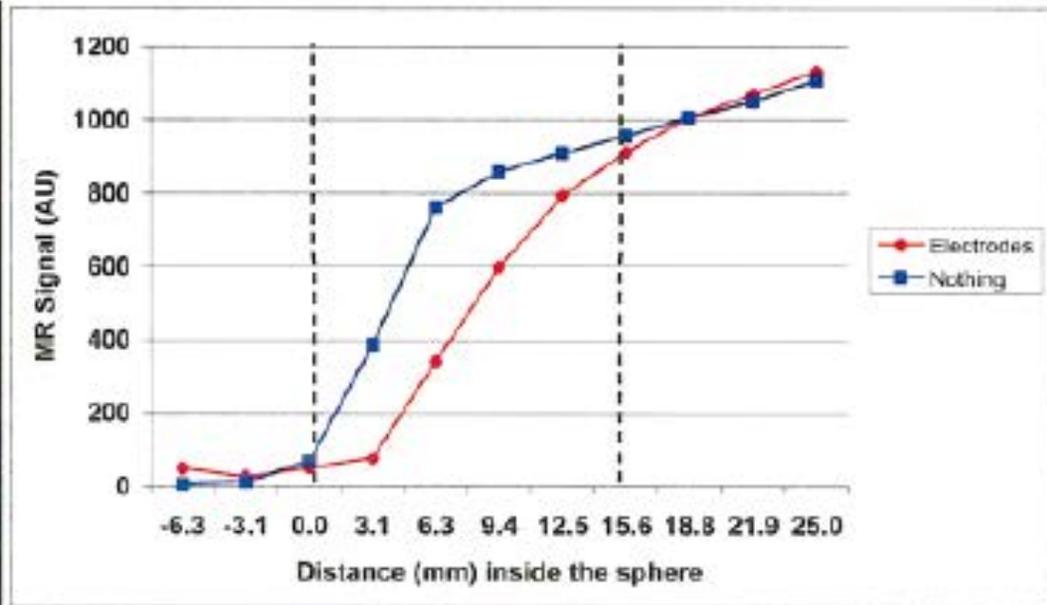
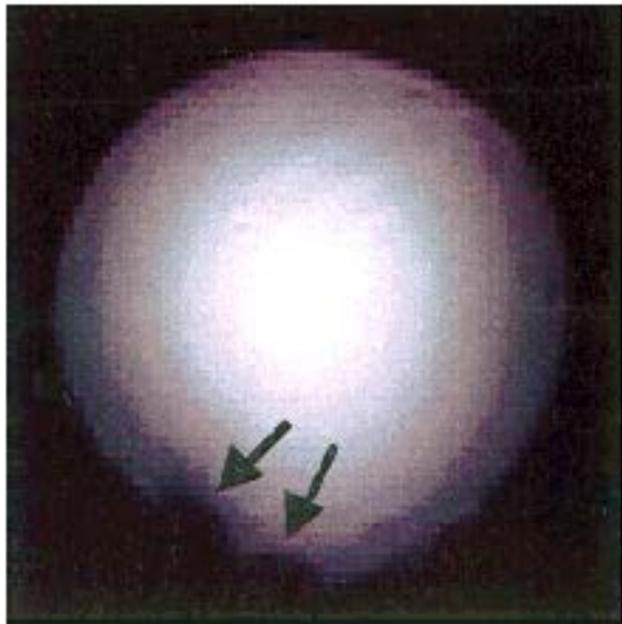


Krishnaswamy et al., 2016

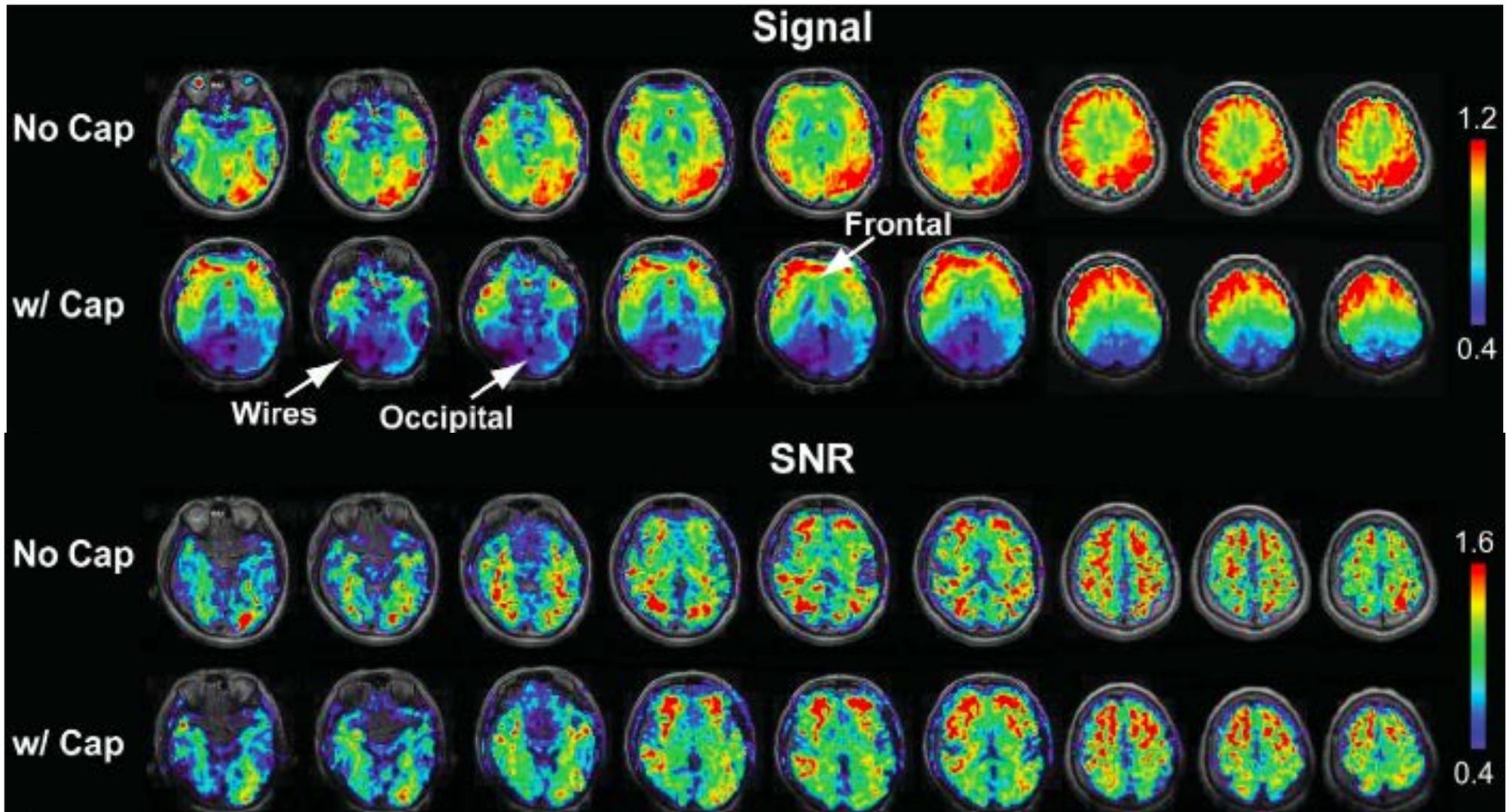
Any other source of
movement/vibration

MR image quality

- Magnetic field inhomogeneity
- RF interference



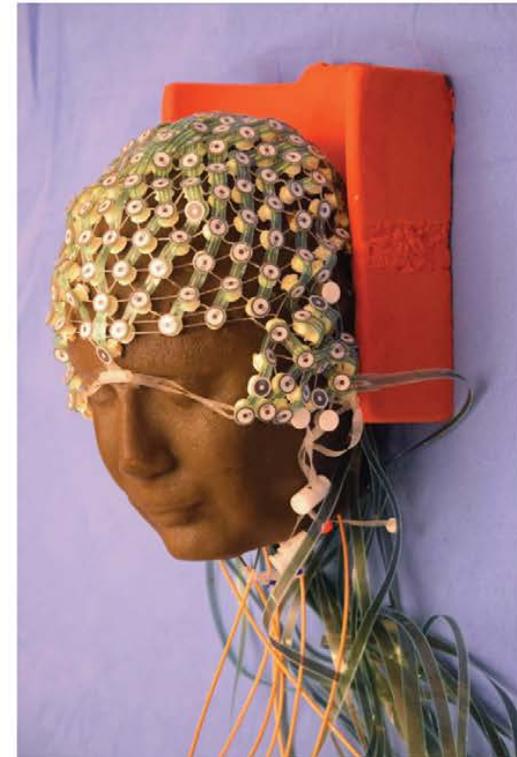
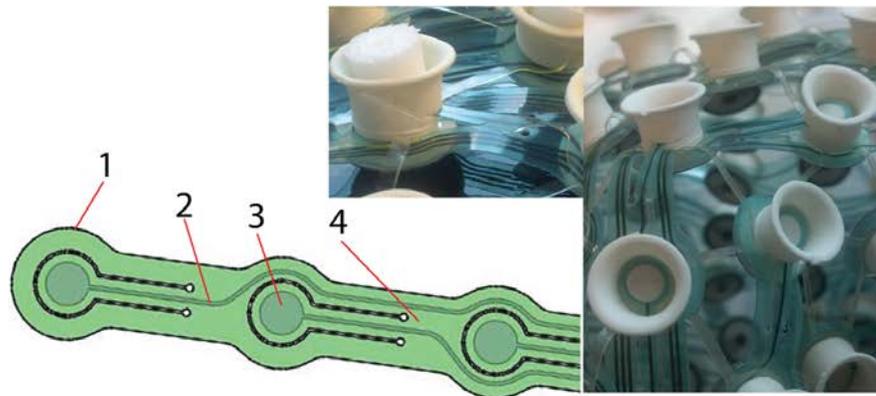
MR image quality



Luo and Glover, *MRM* 2011

Novel technologies for EEG-fMRI

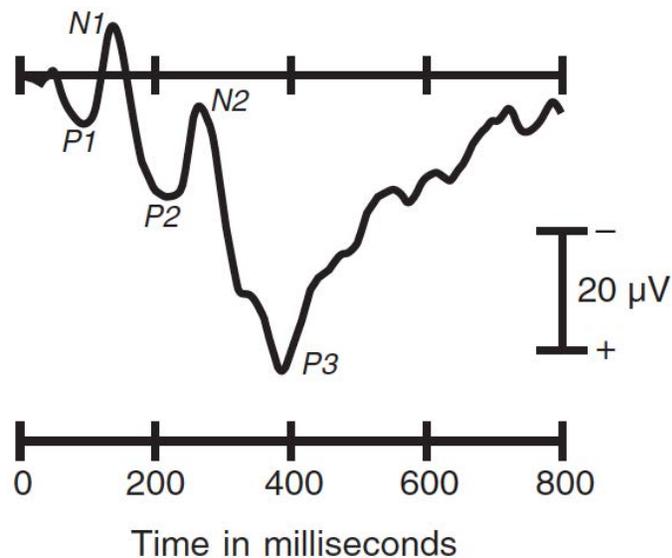
InkNet:



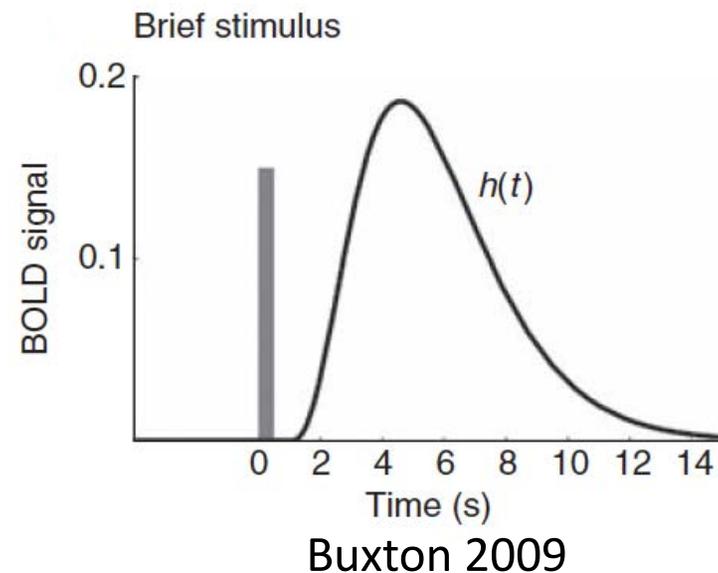
Poulsen et al., 2017

Experimental design for EEG-fMRI

Primary issue: Timing



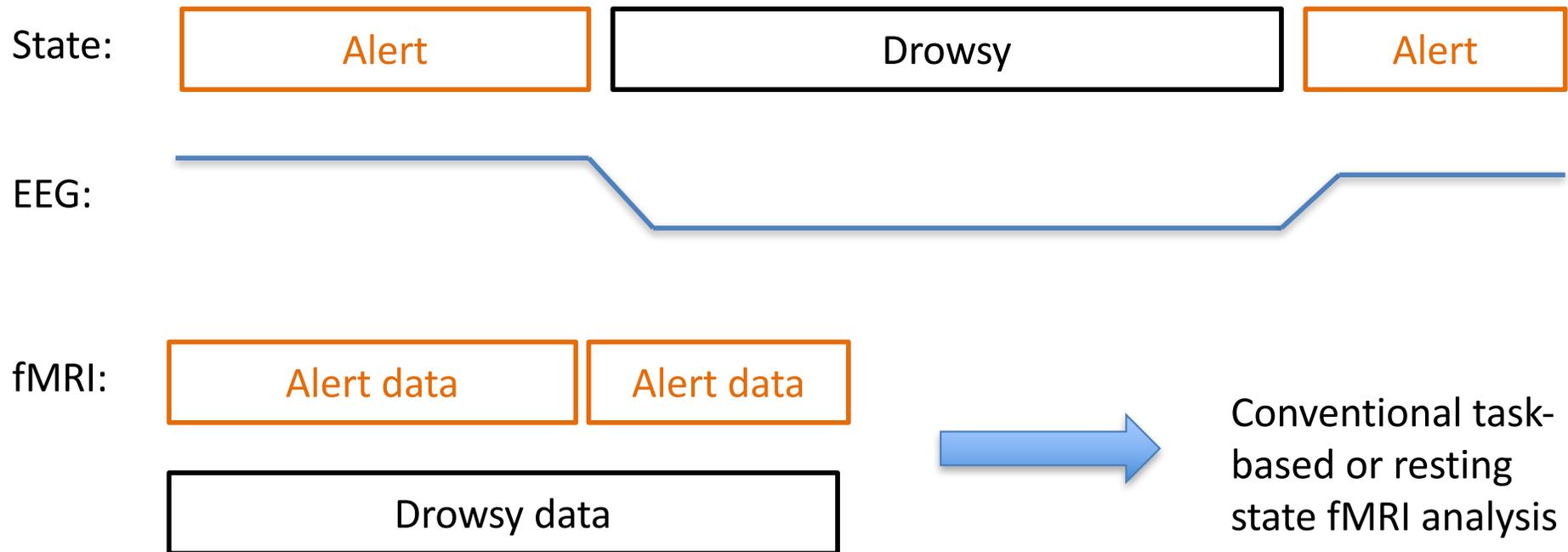
Luck, 2005



Buxton 2009

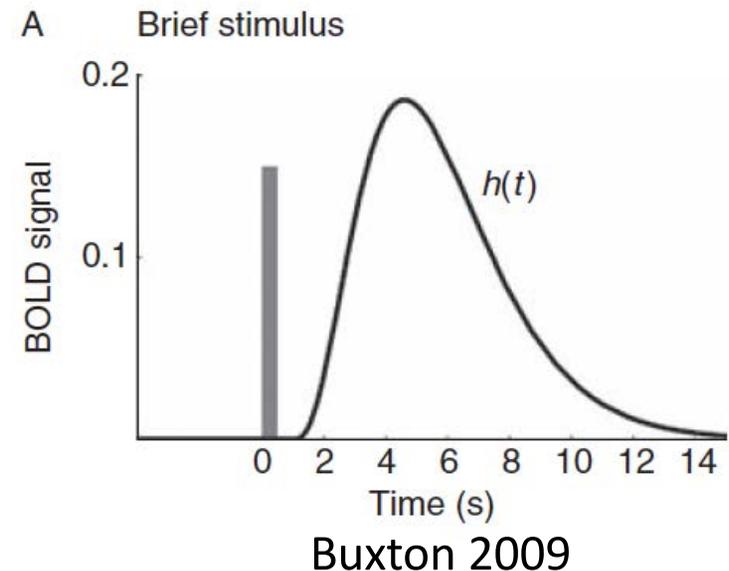
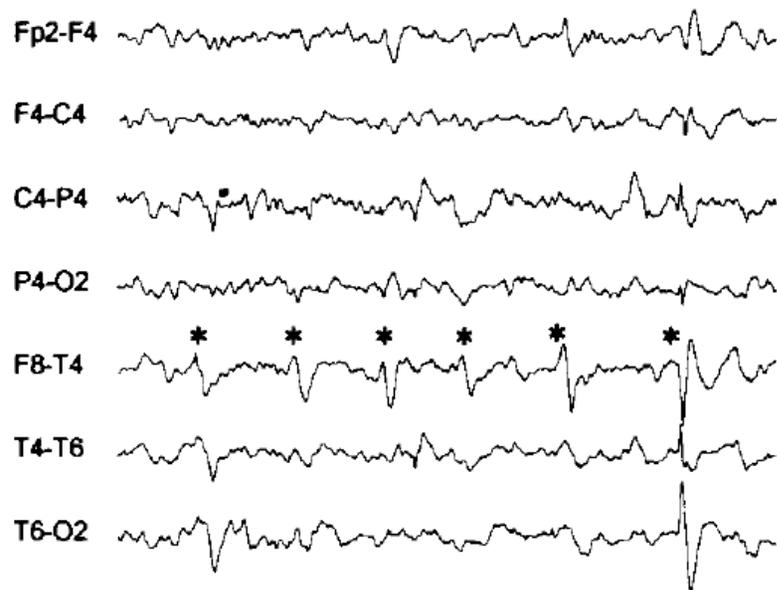
Analyzing EEG-fMRI data

Use EEG to select fMRI epochs:



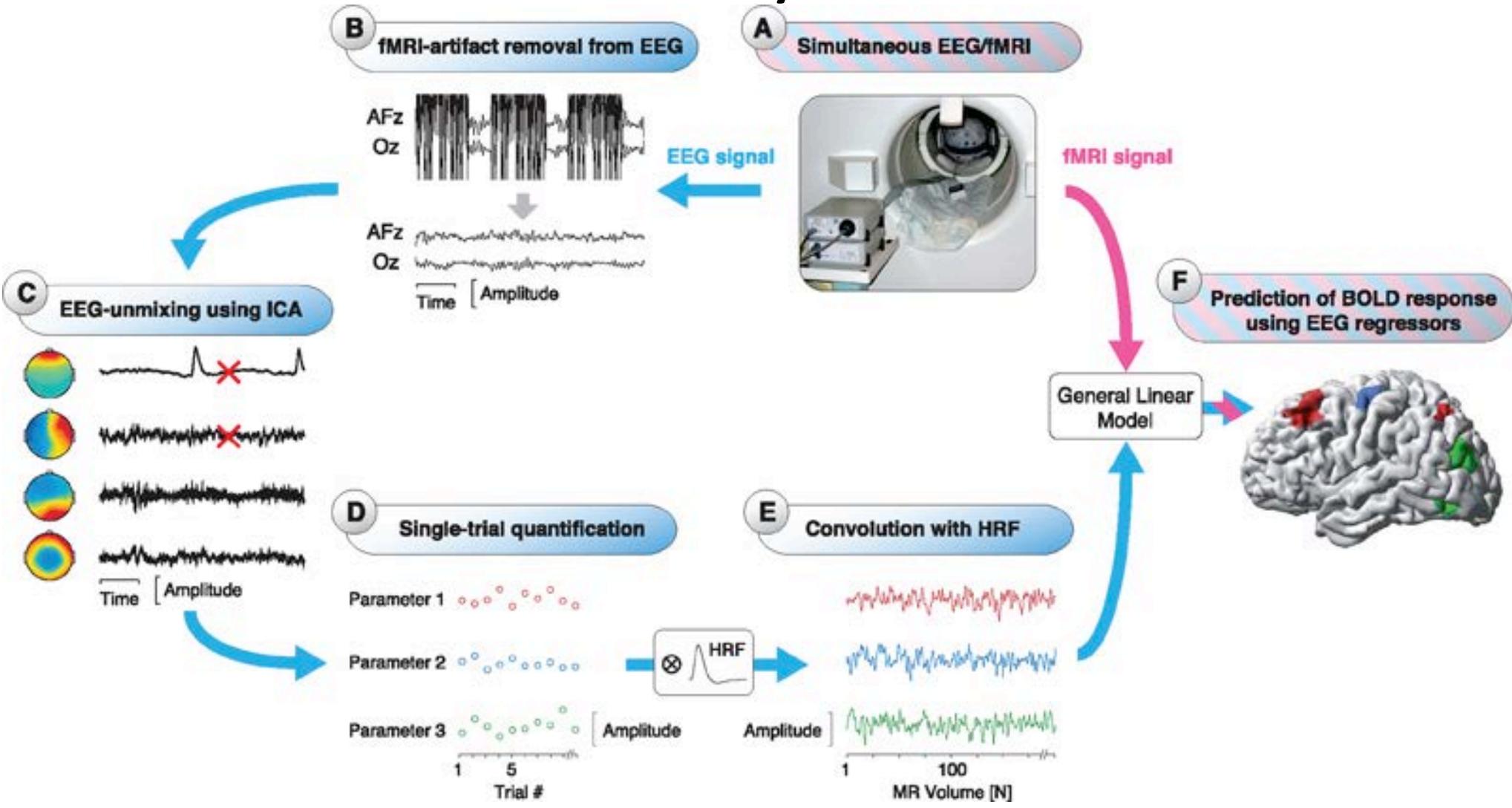
Analyzing EEG-fMRI data

Use EEG to create 'stimulus design' matrix:



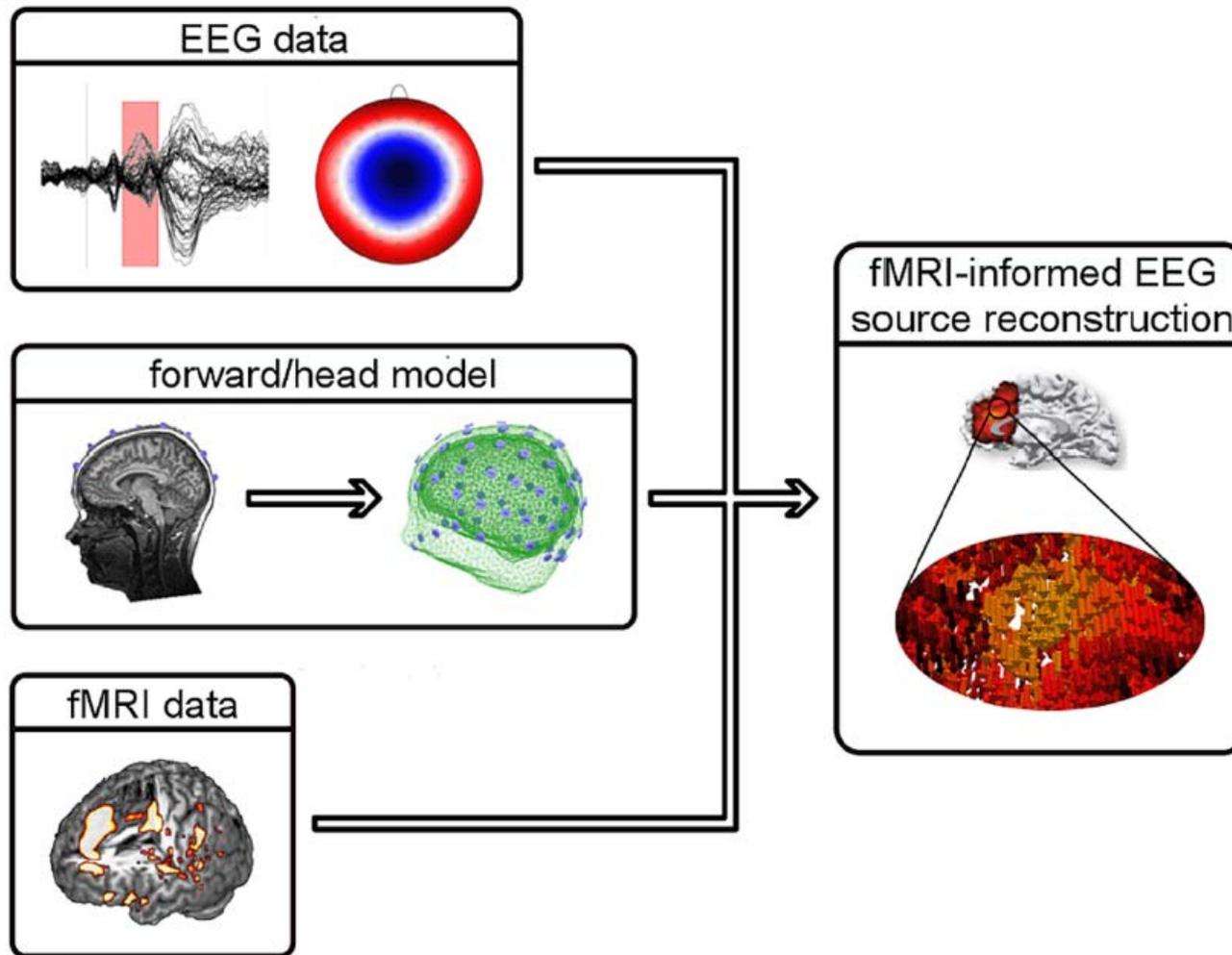
de Curtis and Avanzini, 2001

Integrating data: EEG-informed fMRI analysis



Debener et al., 2006

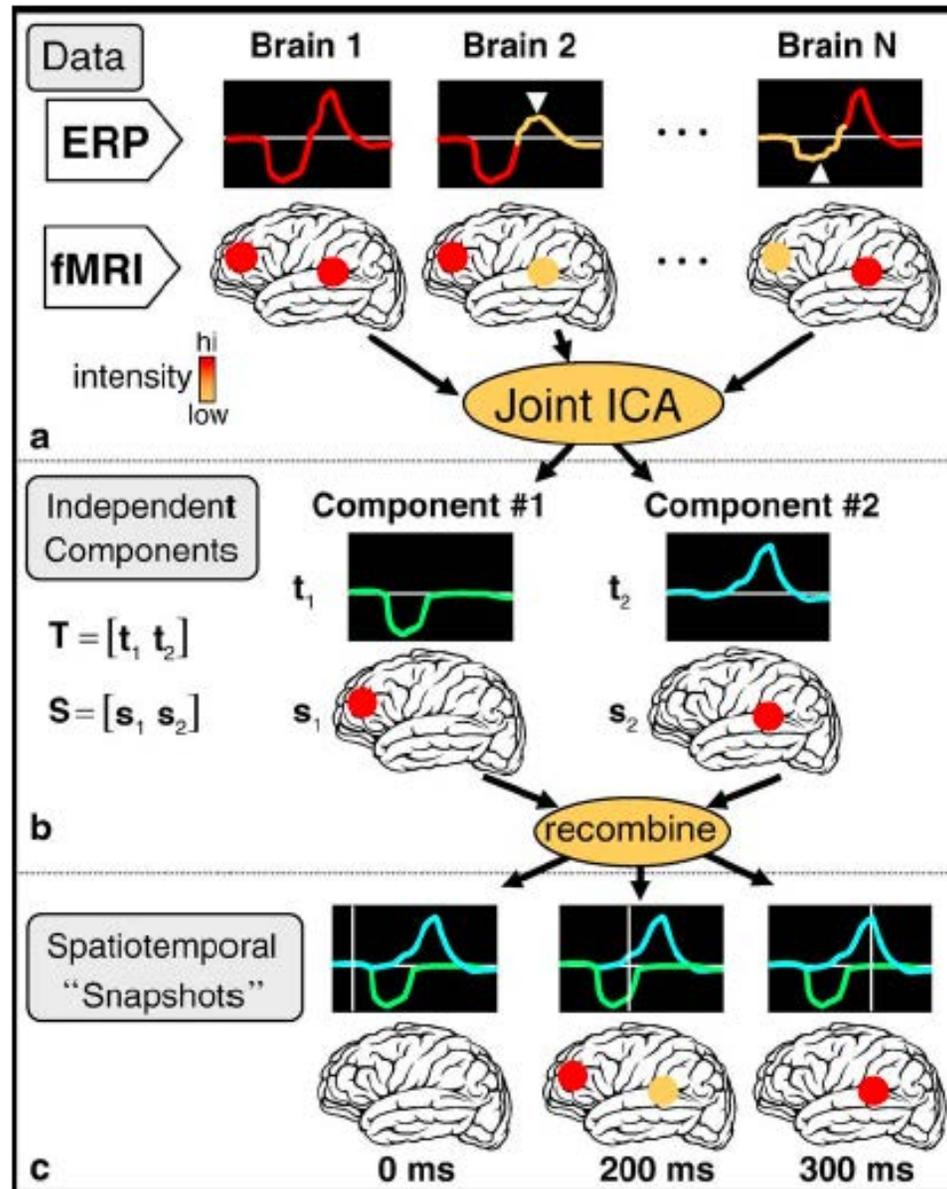
fMRI-informed EEG analysis



Huster et al., 2012

Joint ICA

Calhoun
et al., 2006:



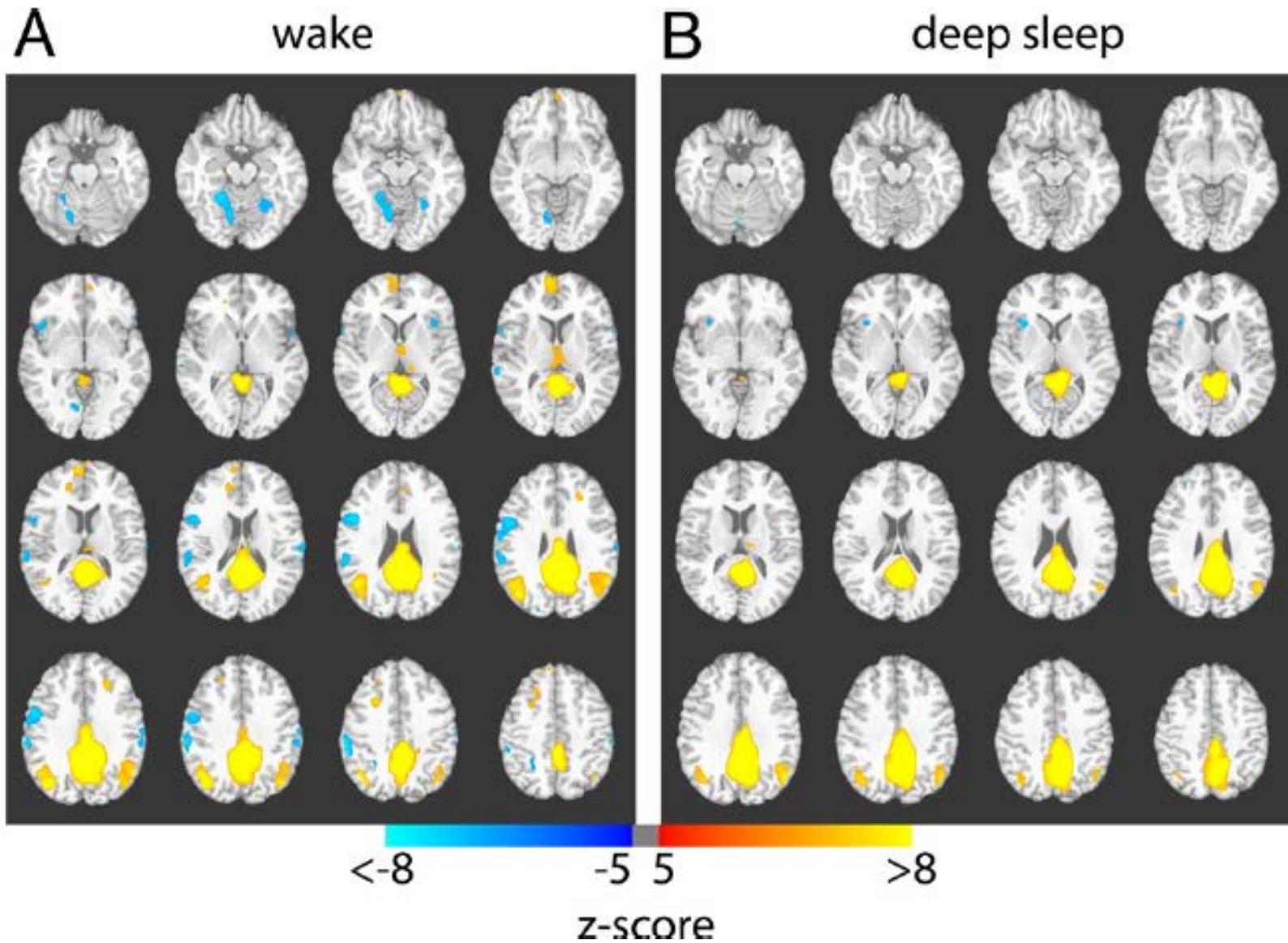
Applications of EEG-fMRI

At its best when your phenomenon of interest is:

- *Spontaneous*
- *Variable across trials*
- *Coupling mechanisms*

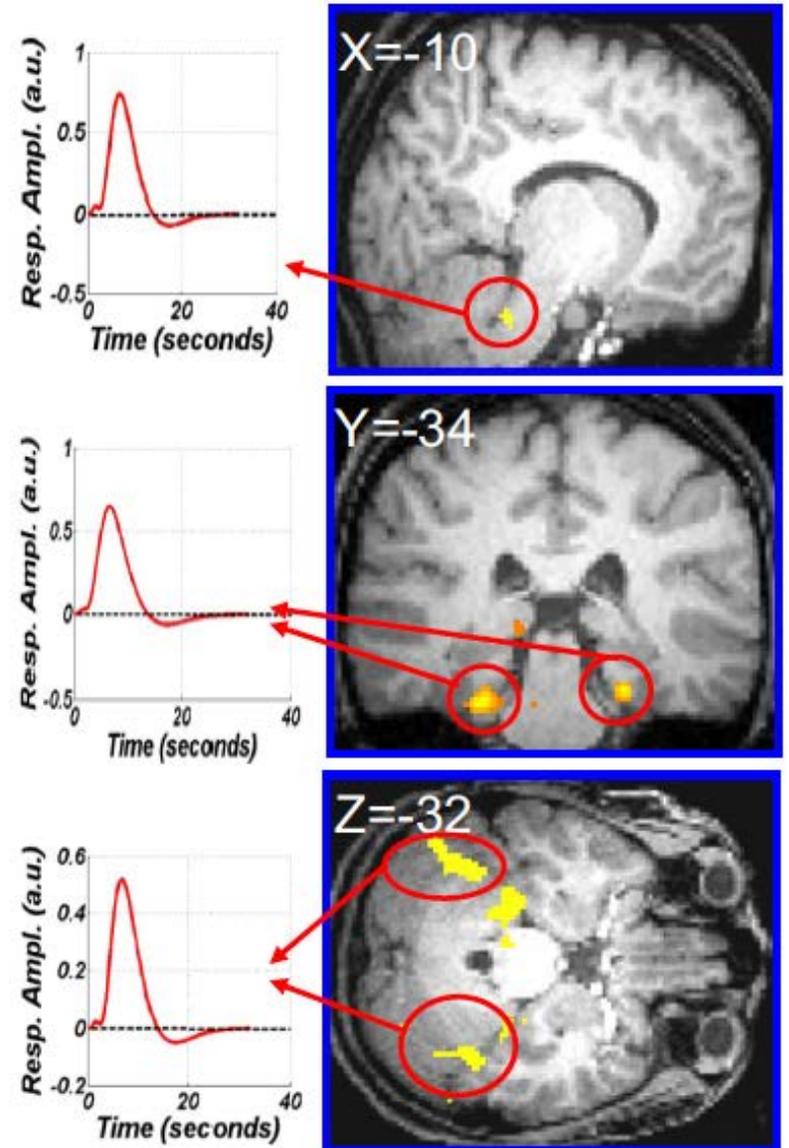
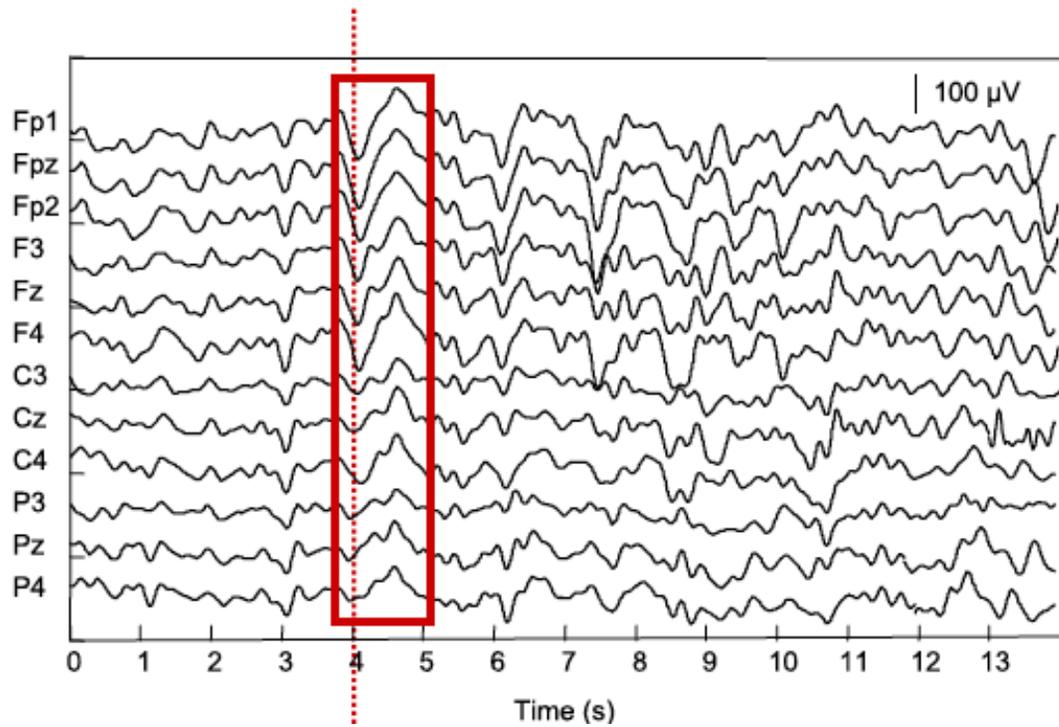
Sleep

Horovitz et al., 2009:



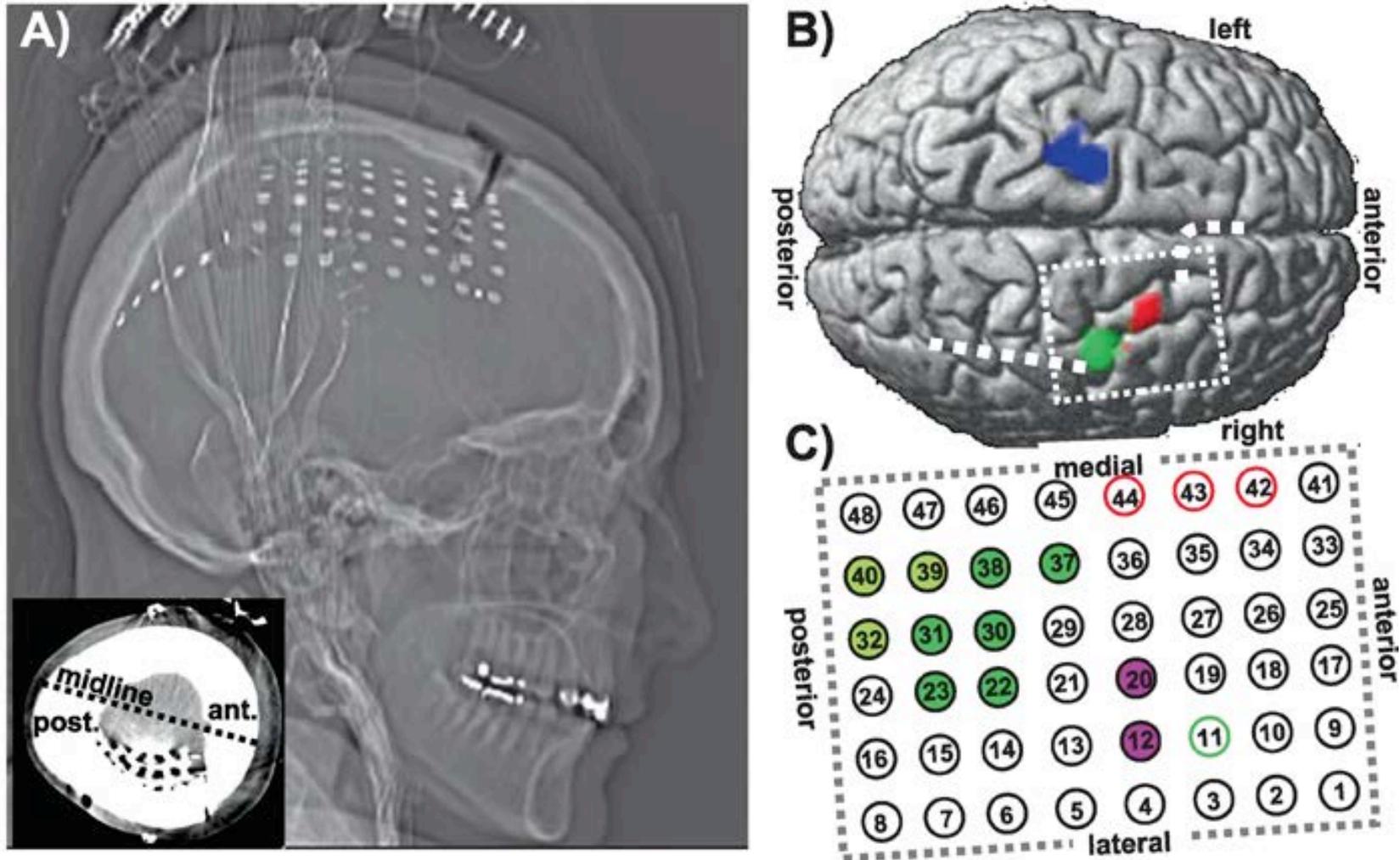
Sleep

Dang-Vu et al., 2008:



Epilepsy

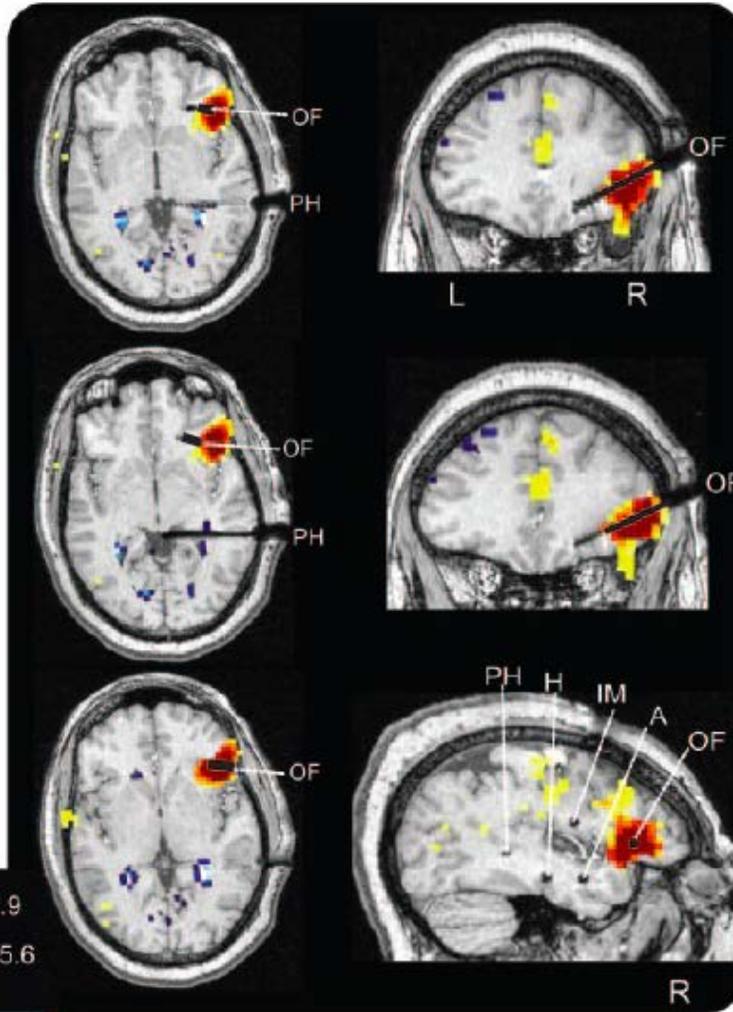
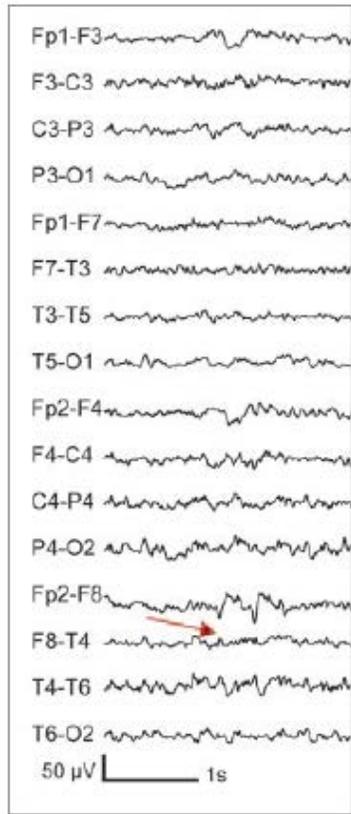
Multimodal assessment of a patient with focal epilepsy



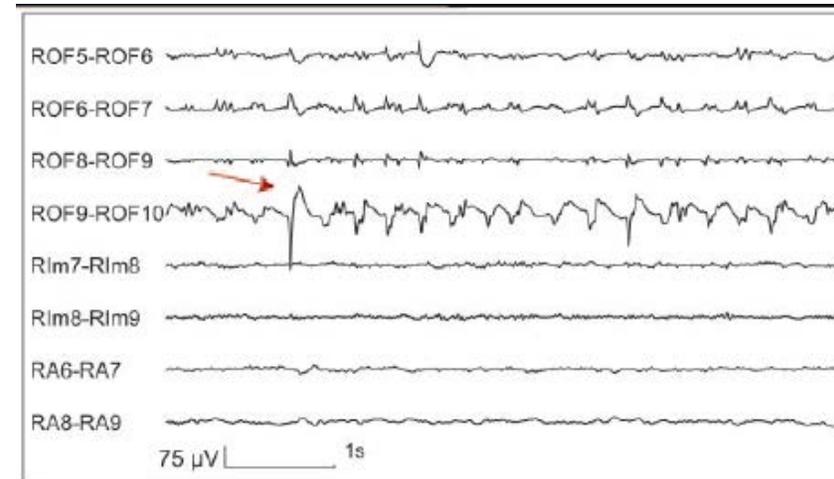
Reprinted from Magnetic Resonance Imaging, 24/4, Laufs, H., Hamandi, K., Walker, M. C., Scott, C., Smith, S., Duncan, J. S., Lemieux, L., EEG-fMRI mapping of asymmetrical delta activity in a patient with refractory epilepsy is concordant with the epileptogenic region determined by intracranial EEG, pp. 367-371, Copyright (2006), with permission from Elsevier.

Epilepsy

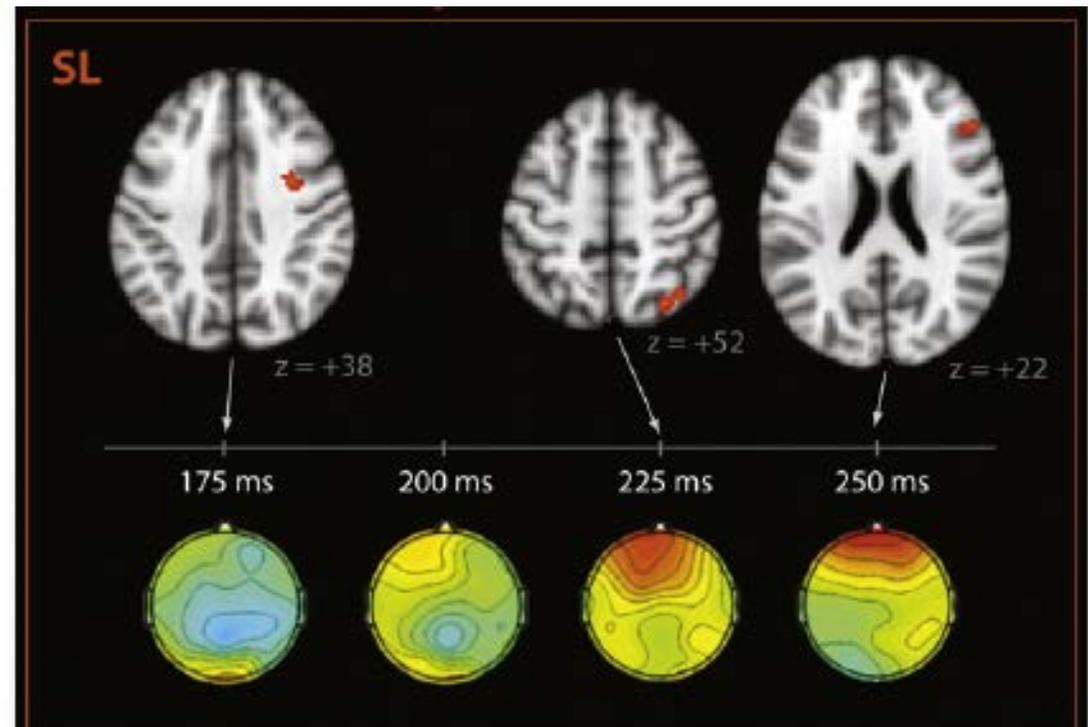
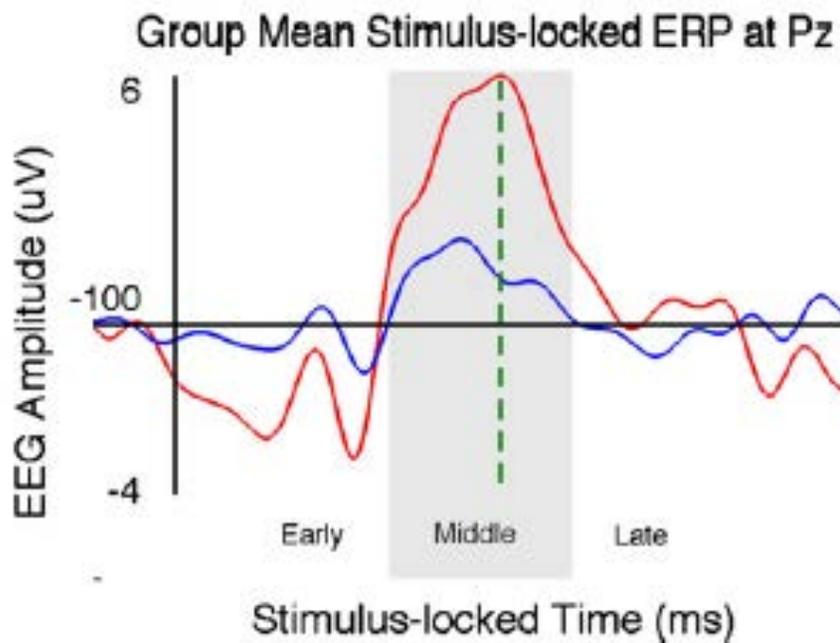
EEG-fMRI



Intracranial EEG



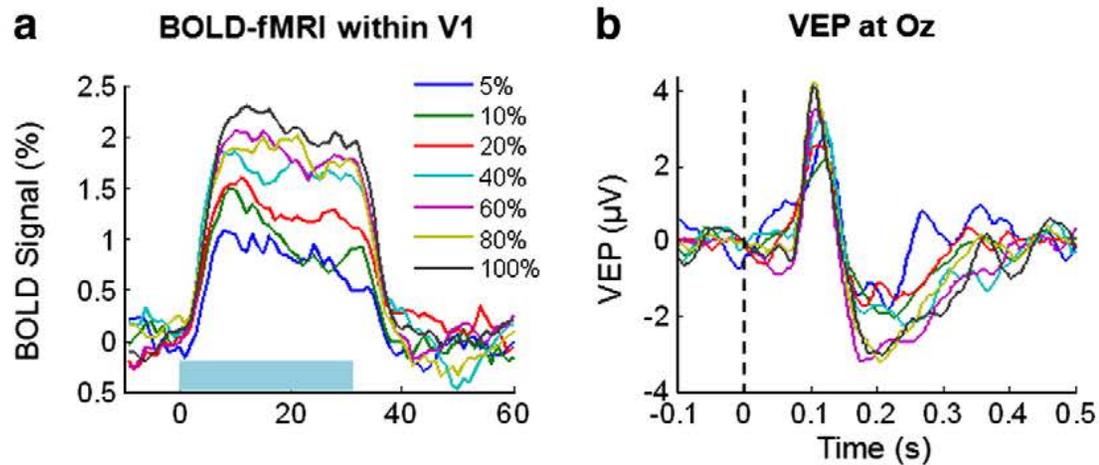
Single-trial analysis to track effects of fluctuating attention



Walz et al., 2014

Neural basis of BOLD dynamics

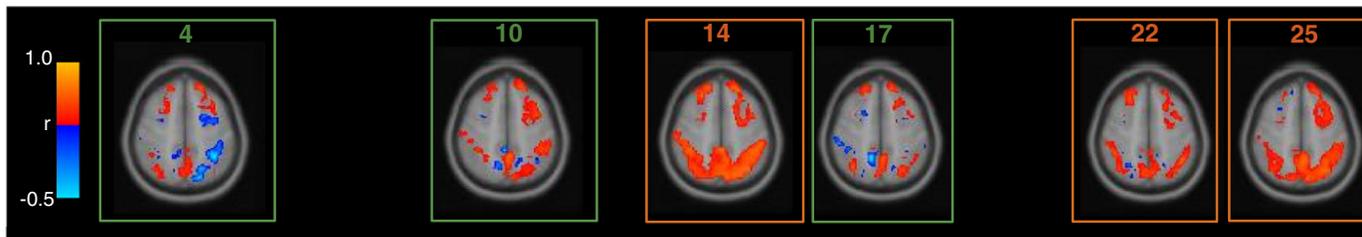
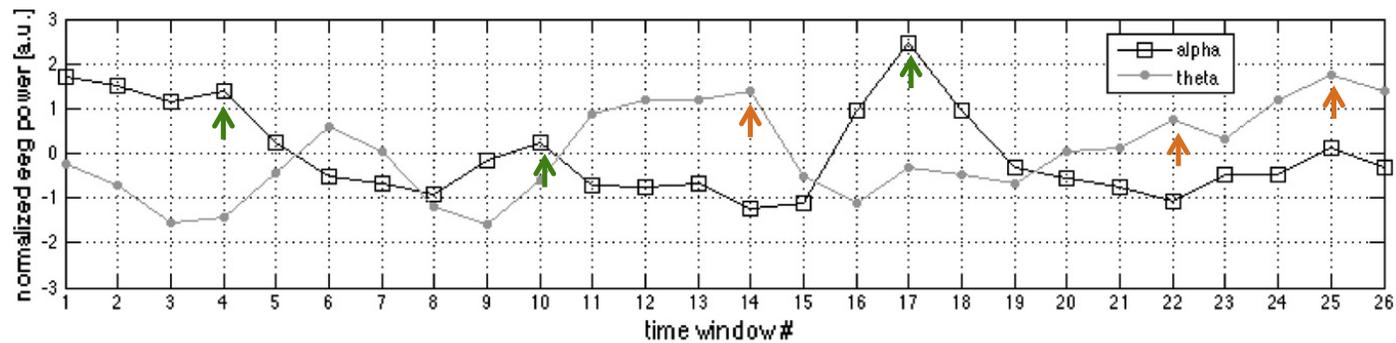
Nonlinear BOLD responses when accounting for neural activity



Liu et al., 2010

Neural basis of BOLD dynamics

Dynamic functional connectivity associated with EEG fluctuations:



Chang et al., 2013

Conclusions

- EEG-fMRI offers high spatiotemporal resolution and measures multiple aspects of neural activity
- However, loss of signal quality means it is best suited to specific types of scientific questions
- Joint inference for EEG-fMRI remains a new and evolving field