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

Polimeni et al., 2010

Lewis et al., 2016
Sampling different properties of neural activity

**EEG**

**fMRI**

Luck, 2005

Heeger and Ress, 2002
Sampling different properties of neural activity

EEG
- Synchrony
  - Oscillation:

fMRI
- Metabolic activity
  - Mean firing:

Surface

Whole-brain

Song et al., 2015
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

decurtis 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
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

Taken from EGI slides
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

Any other source of movement/vibration

Krishnaswamy et al., 2016
MR image quality

• Magnetic field inhomogeneity
• RF interference

Bonmassar et al., *HBM* 2001
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:

- State: Alert, Drowsy, Alert
- EEG: Alert data
- fMRI: Alert data, Drowsy data

Conventional task-based or resting state fMRI analysis
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:
Multimodal assessment of a patient with focal epilepsy

Epilepsy

Epilepsy

EEG-fMRI

Intracranial EEG

Pittau et al., 2012
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
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