Dynamic Imaging Science Center (DISC):
Combined MRI & EEG acquisition

Outline

What is EEG?

Combined EEG and MRI

DISC EEG system

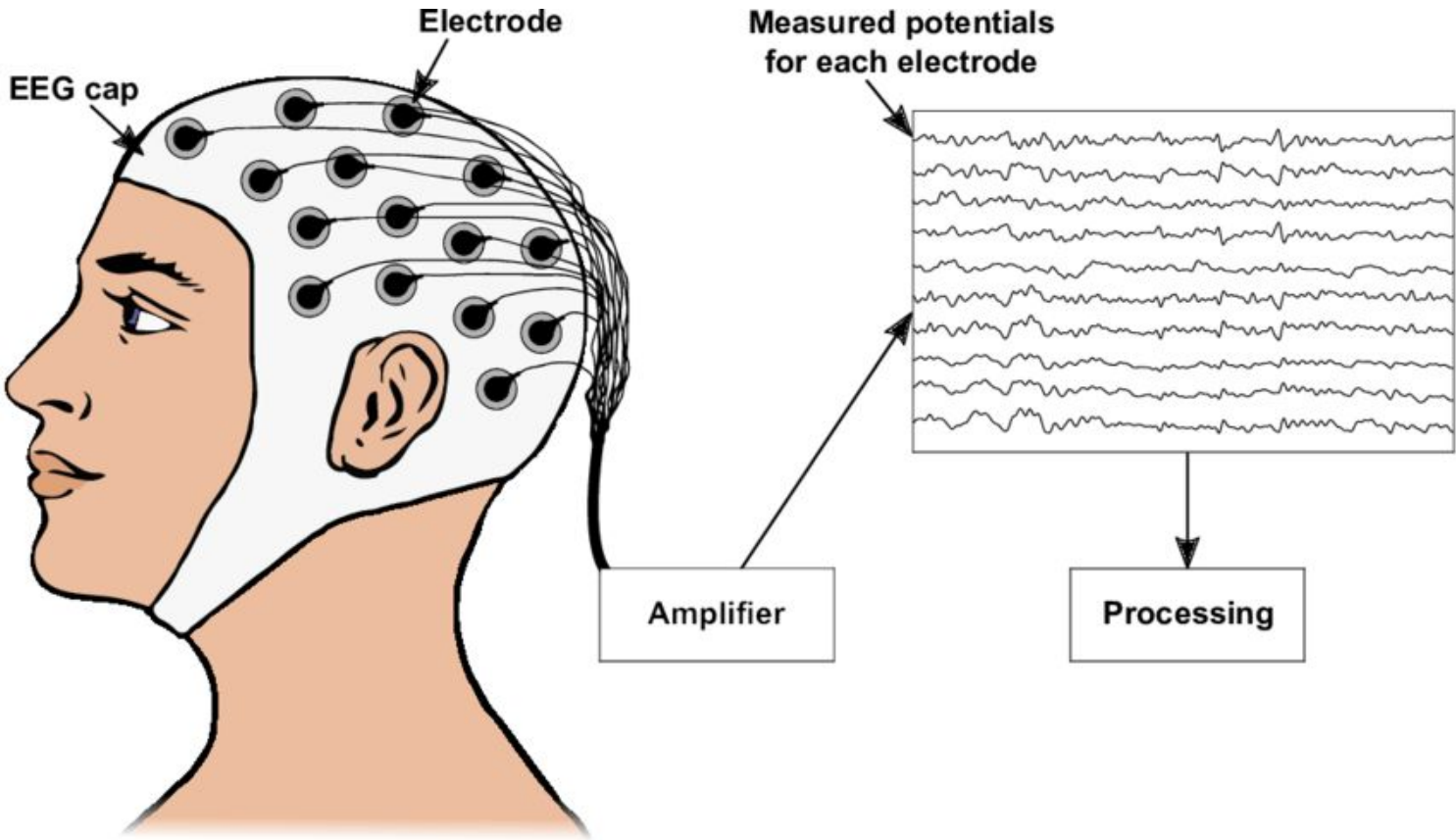
DISC EEG set up

Implemented protocol

Preliminary data acquisition and some results

What is EEG? :

EEG offering high temporal resolution (~ms)



Combined EEG & MRI:

- Complementary insights into brain function, with **EEG offering high temporal resolution** and **fMRI providing higher spatial detail**
- Most studies are conducted in high-field MRI environments
- **No studies at 0.55T yet**
- Reduced susceptibility artifacts
- Decreased acoustic noise

Combined EEG & MRI:

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Challenges:

- Gradient-induced artifacts (GA)
- Ballistocardiogram (BCG) interference
- Unique characteristics at 0.55T
- Pilot study investigates the feasibility of simultaneous EEG-fMRI recording within the 0.55T

The EEG system at DISC

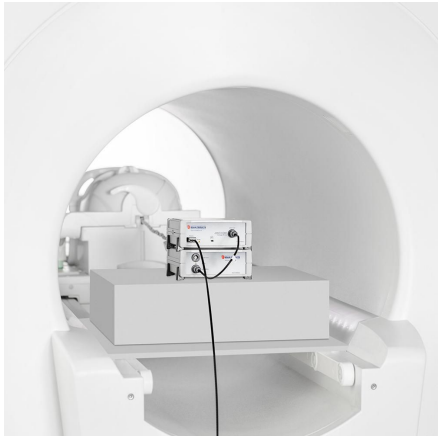
- Brainvision **BrainAMP MR**
- One amplifiers with 32 Channels with 5kHz SR
- Powered by the rechargeable PowerPack battery
- Caps, MRI Interfaces, SyncBox,
- Acquisition software included
  - (post-processing software not included)

Note: the BrainAmp MR can be combined with the BrainAmp ExG MR to add the capability to record bipolar and peripheral signals (e.g. EOG, ECG, EMG, GSR – Galvanic Skin Response, etc.)

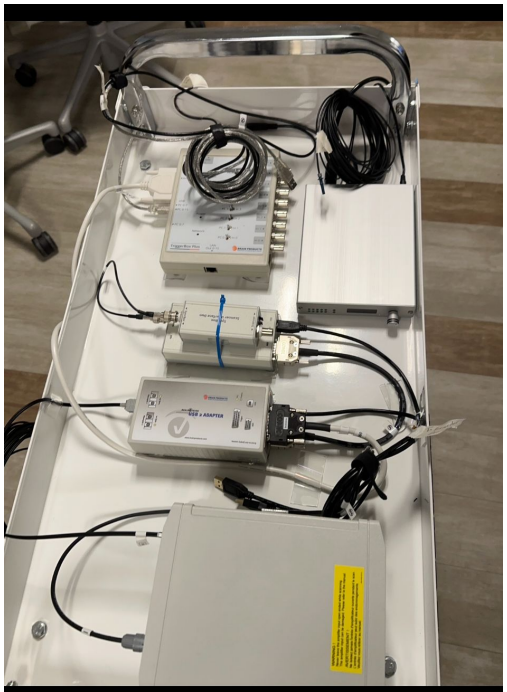
https://brainvision.com/products/brainamp-mr/

The EEG system at DISC

- The installation of the EEG system require specific training
  - The setup of the EEG requires about ~ 30 min to wire the EEG and MRI
- The preparation of the participants requires about ~30min
  - Requires specific training for EEG inside the MRI
- EEG system requires two synchronised computers
  - Stimulation computer and recording computers

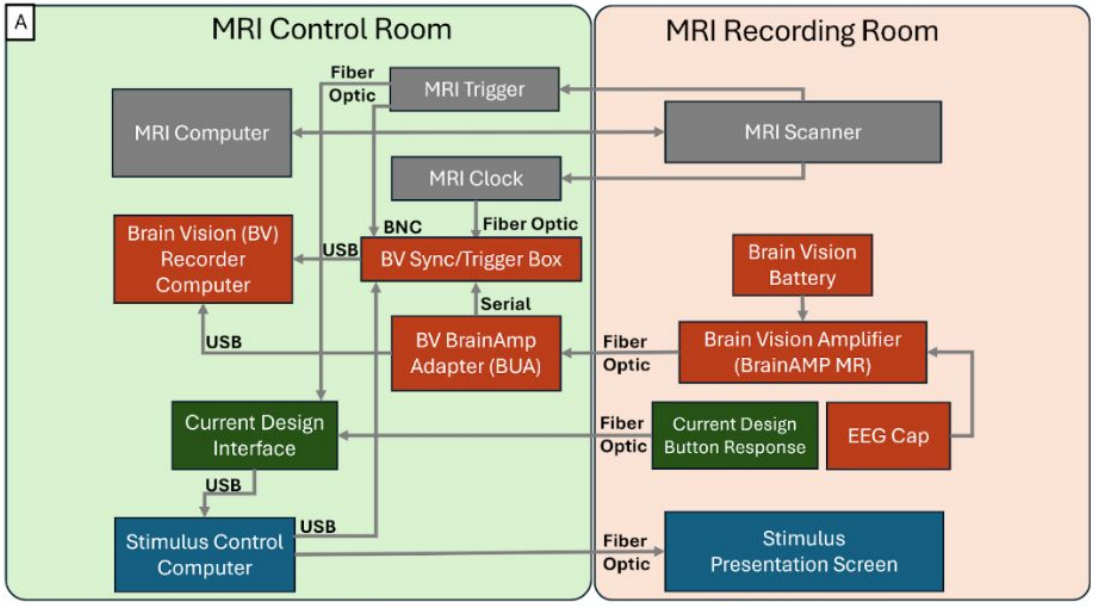


The BV EEG system at DISC : Optimized Setup



DISC Setup

Figure1:



DISC Setup

Protocols

Figure1:

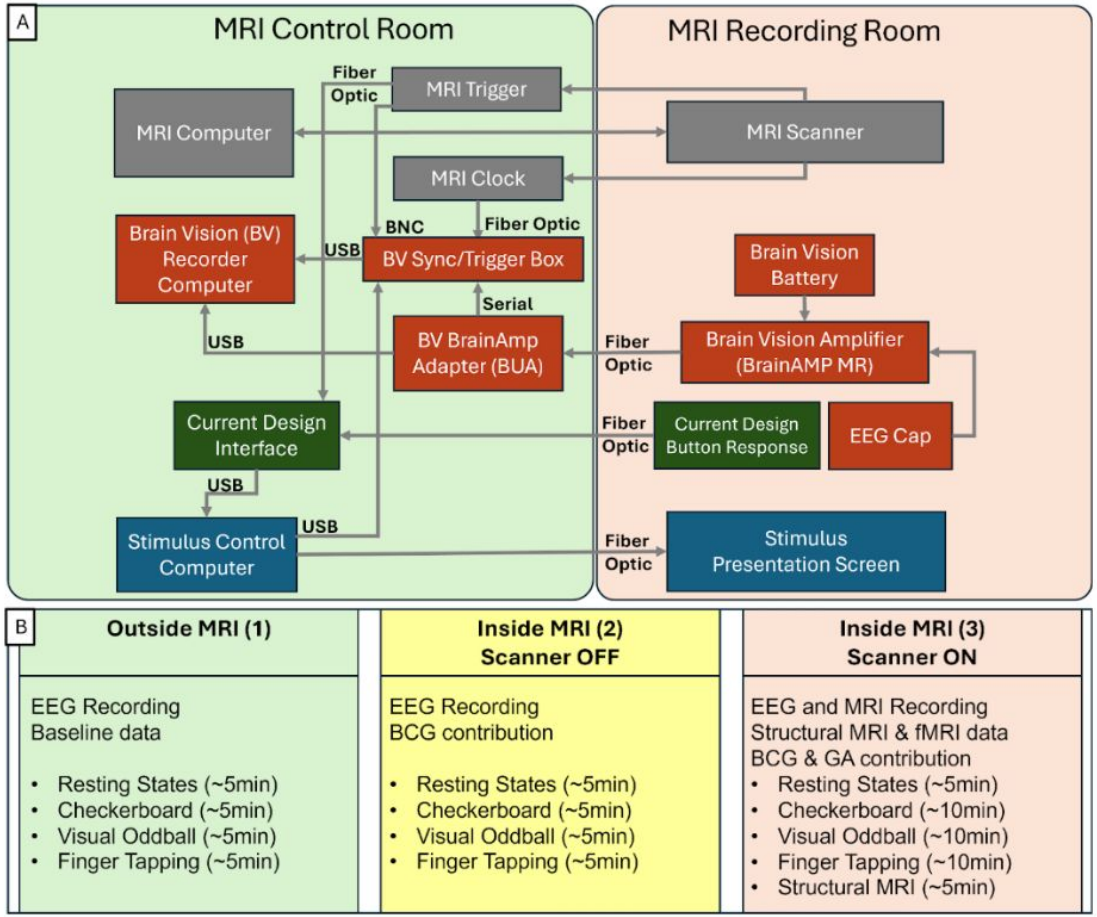
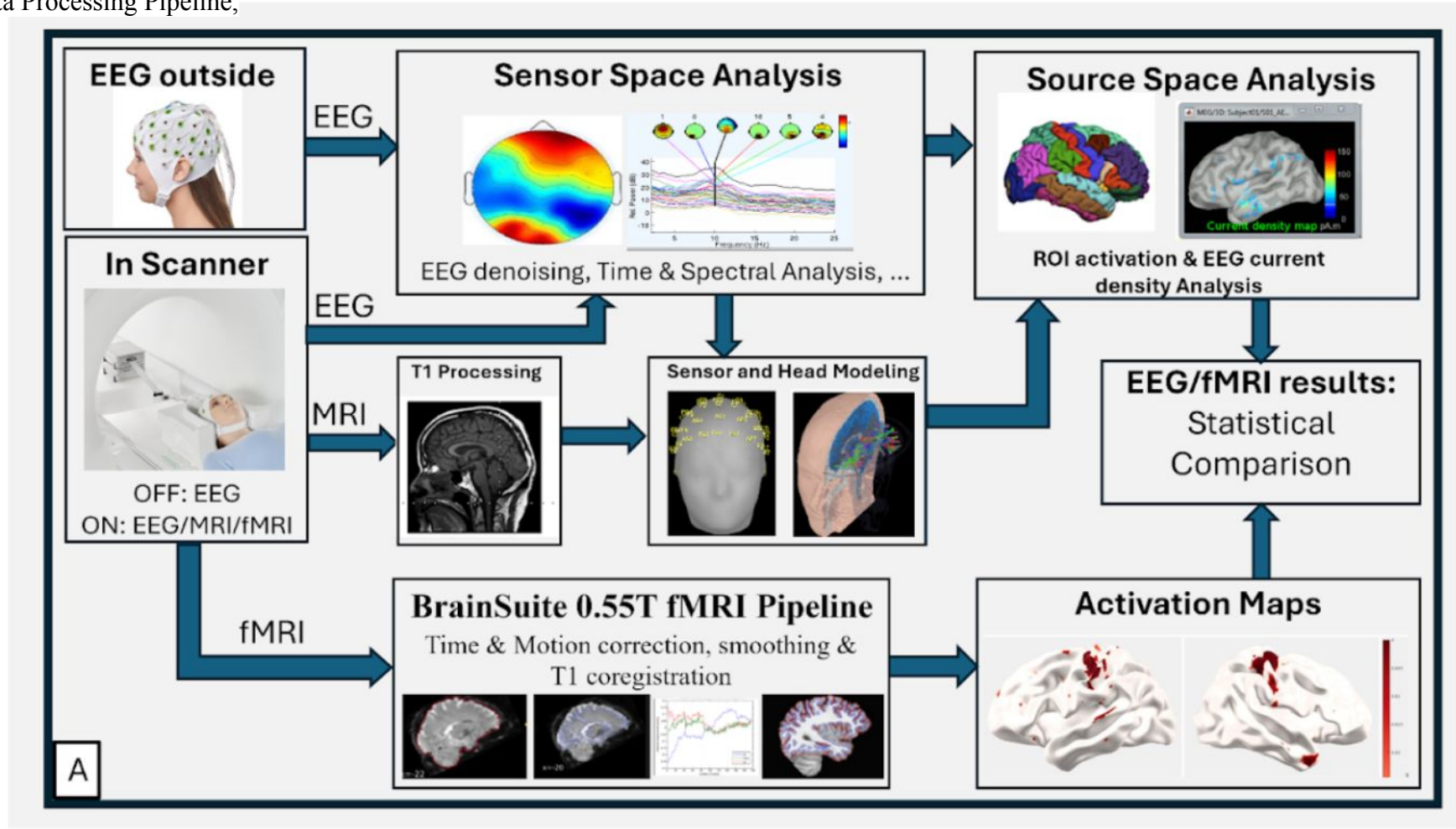


Figure 1: A: Schematic of EEG-fMRI setup, B: Overview of the EEG/fMRI data collection protocols

A: Data Processing Pipeline,



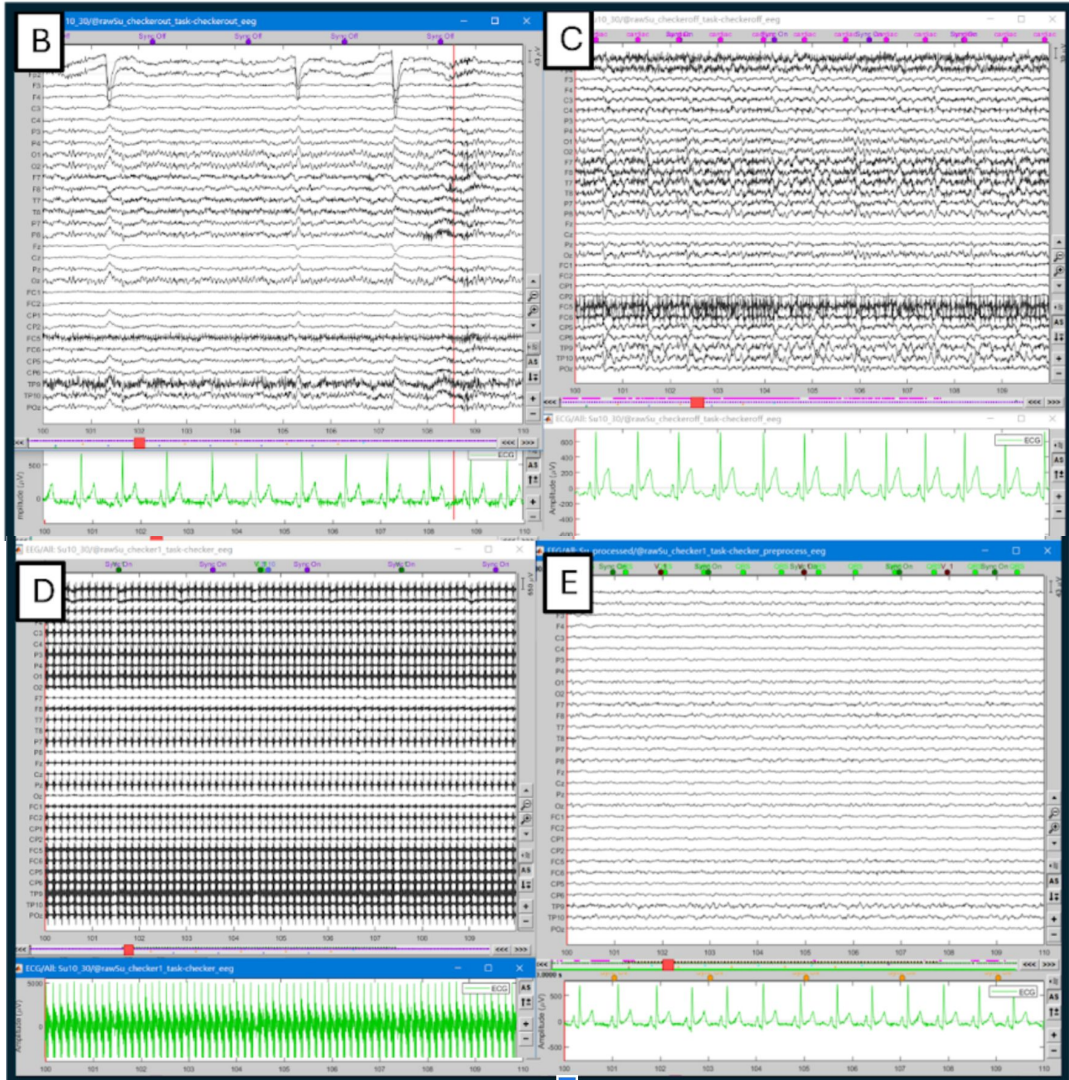


Figure 2: [B, C, D, E] Representative example of the EEG data, B: EEG outside scanner, C: inside Scanner OFF, D: inside scanner ON, E: cleaned EEG data from all artifacts

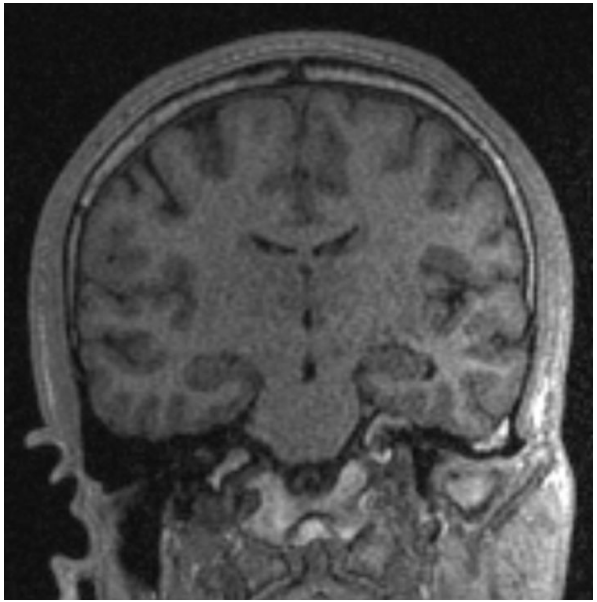
rt MRI and EEG

Ongoing preliminary investigations by Shri’s lab

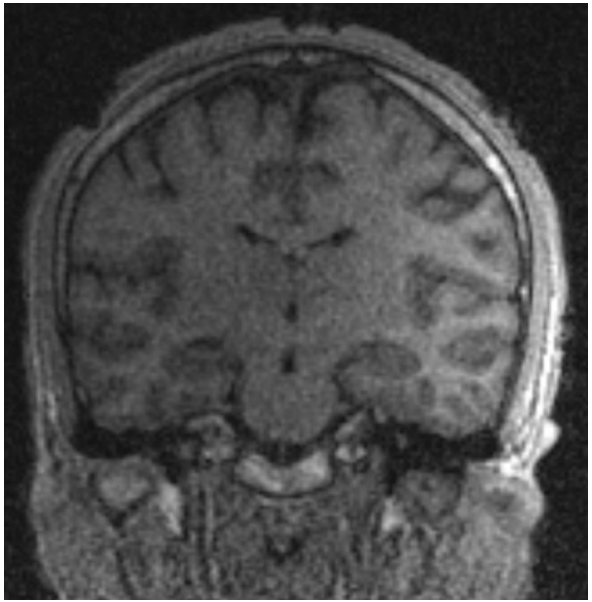
Currently consulting with the BrainVision technical team regarding setup preparation.

Preliminary Results
Combined EEG-fMRI

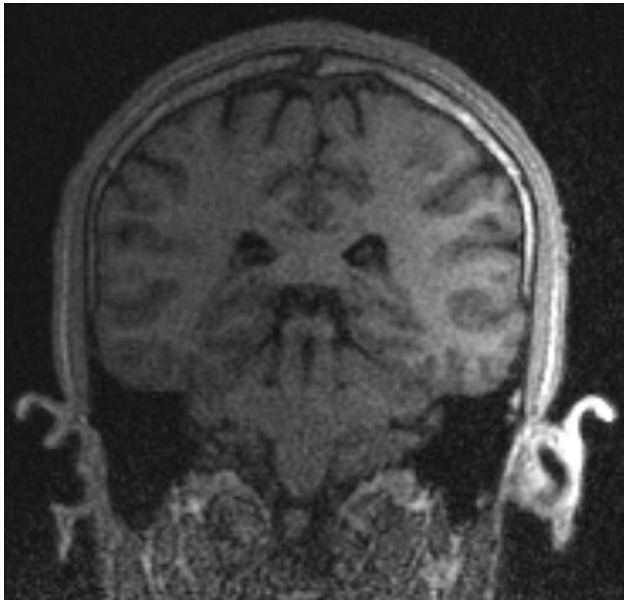
T1 Anatomical Scan (the same volunteer)



Without EEG cap

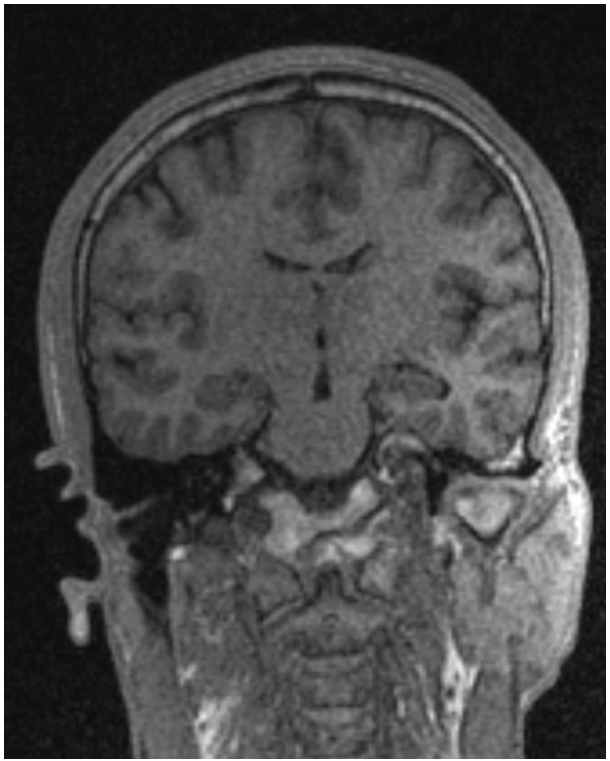


With EEG cap

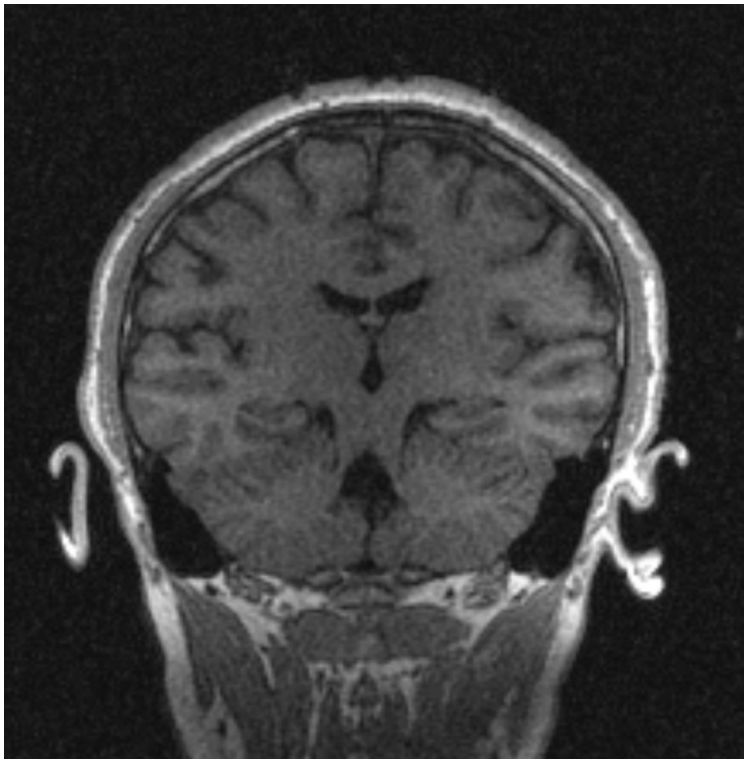


With EEG cap

T1 Anatomical Scan (two different volunteers)

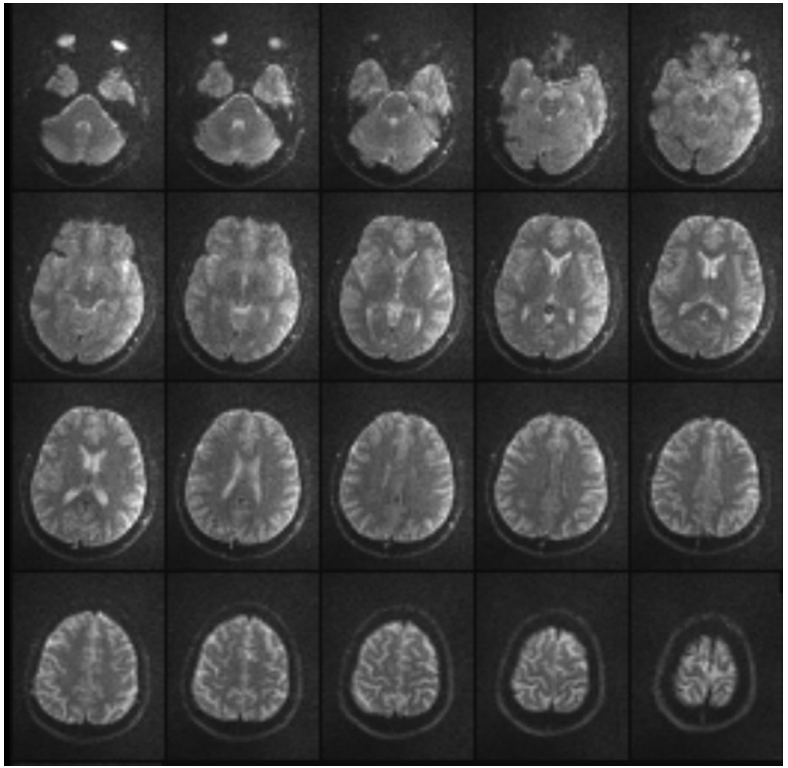


Without EEG cap
(Vol 1)

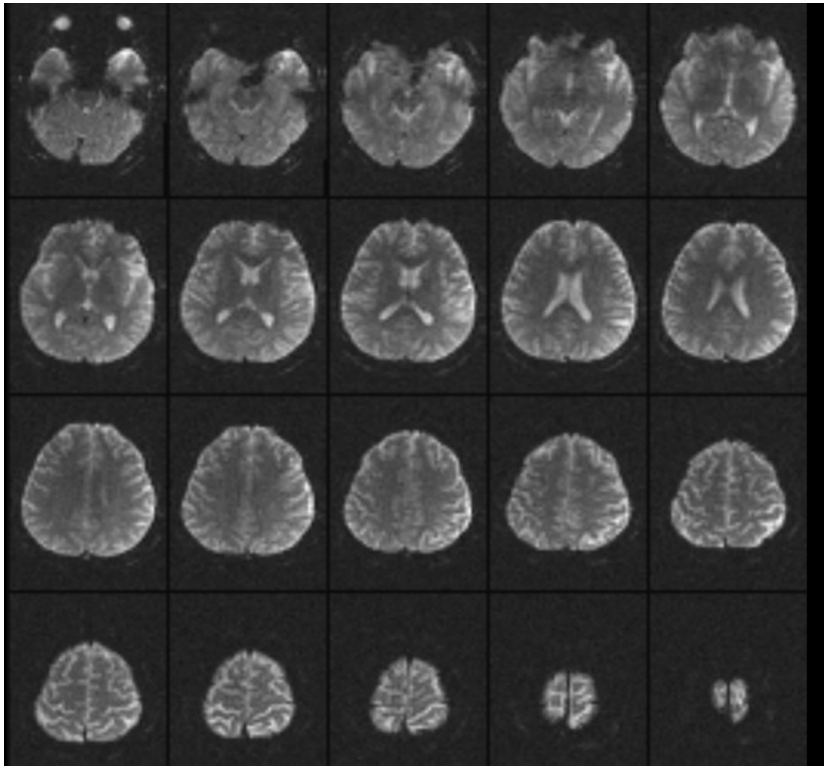


With EEG cap
(Vol 2)

Single-Shot EPI fMRI (two different volunteers)

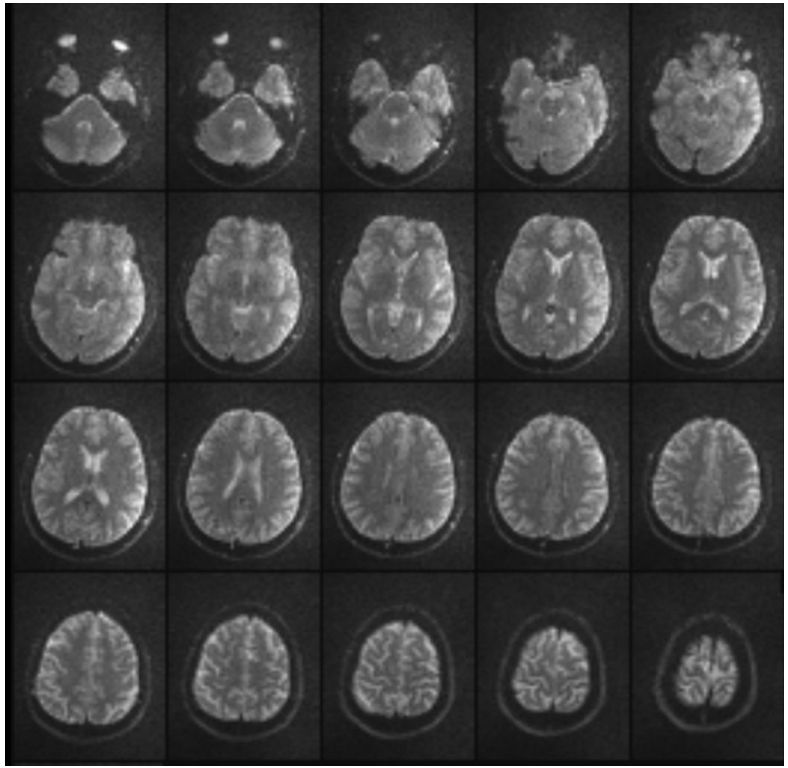


Without EEG cap
(Vol 1)

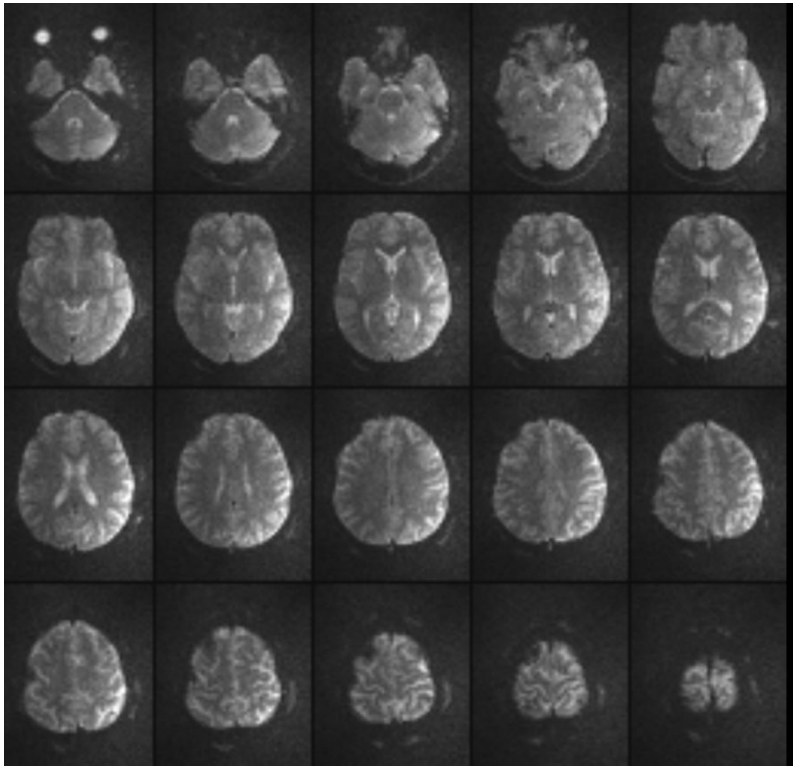


With EEG cap
(Vol 2)

Single-Shot EPI fMRI (the same volunteer)

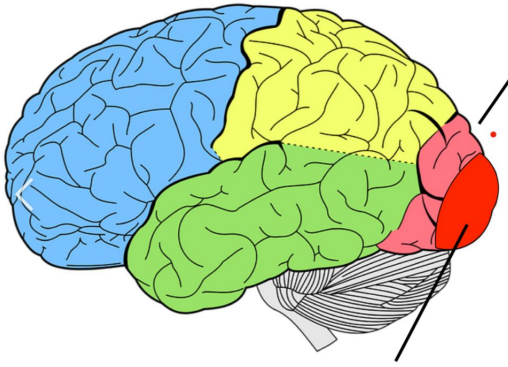


Without EEG cap



With EEG cap

fMRI results (with EEG cap)

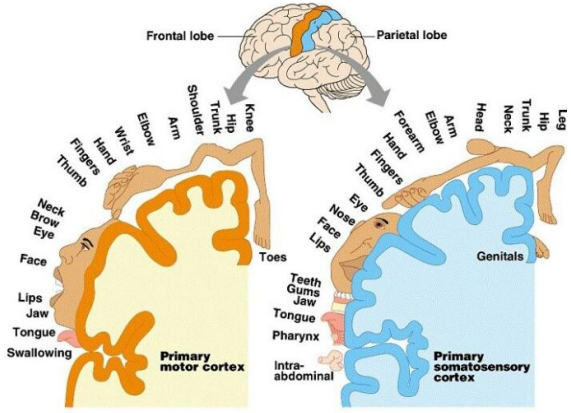


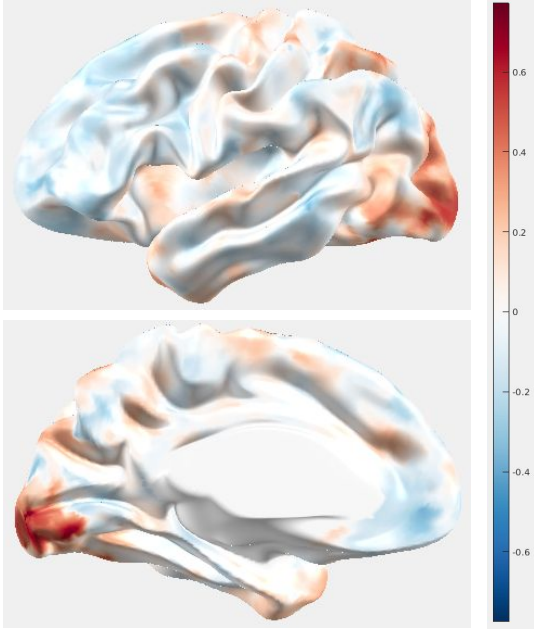
Occipital

Functional Areas

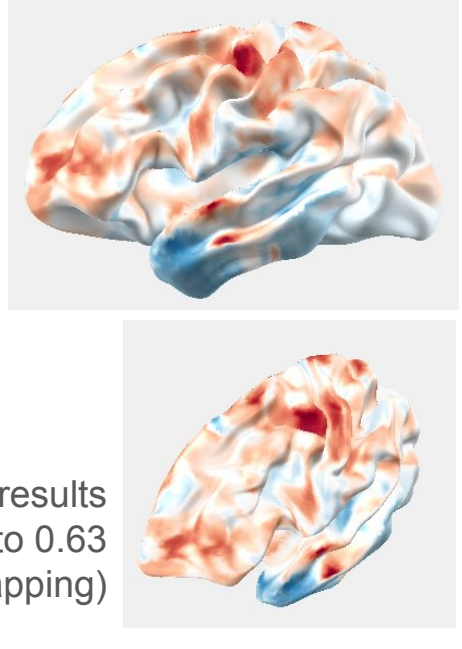
- Primary Visual Cortex
- Awareness of Visual Stimuli

Primary Visual Cortex



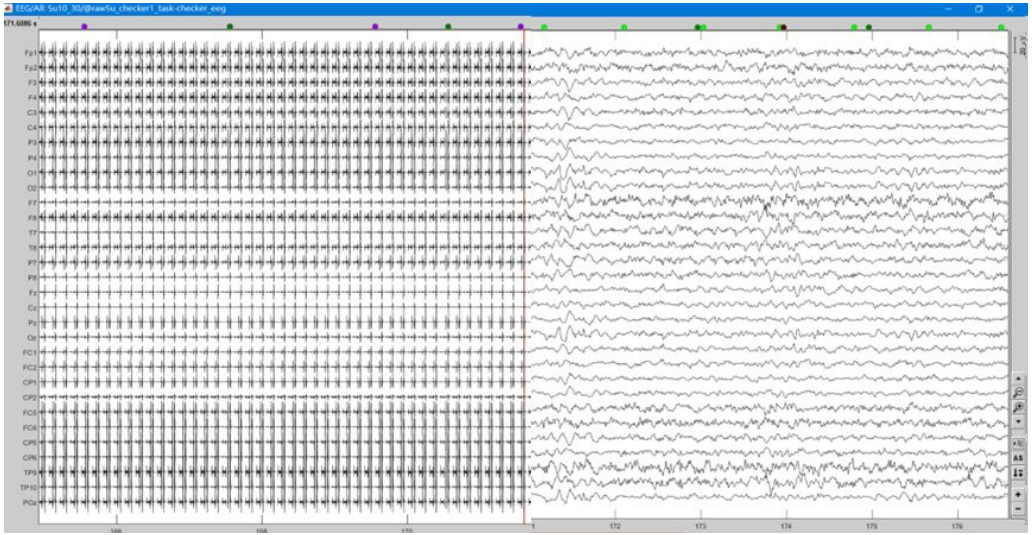


Correlation results
Up to 0.77
(Visual Task)



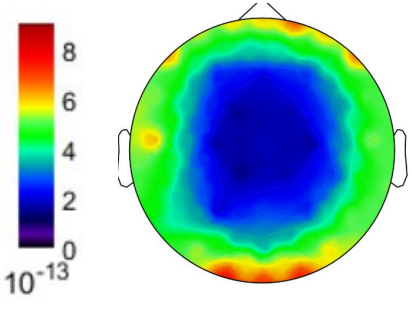
Correlation results
Up to 0.63
(Finger tapping)

Initial EEG results inside the scanner

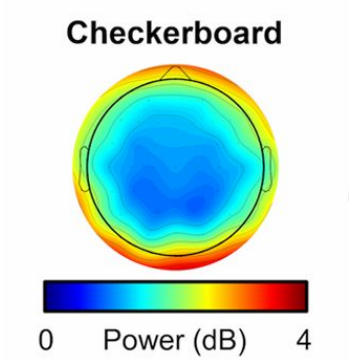


EEG data inside MRI(raw), 166-176s, amplitude scale 3000 uv

EEG data inside MRI(denoised), 166-176s, amplitude scale 20 uv



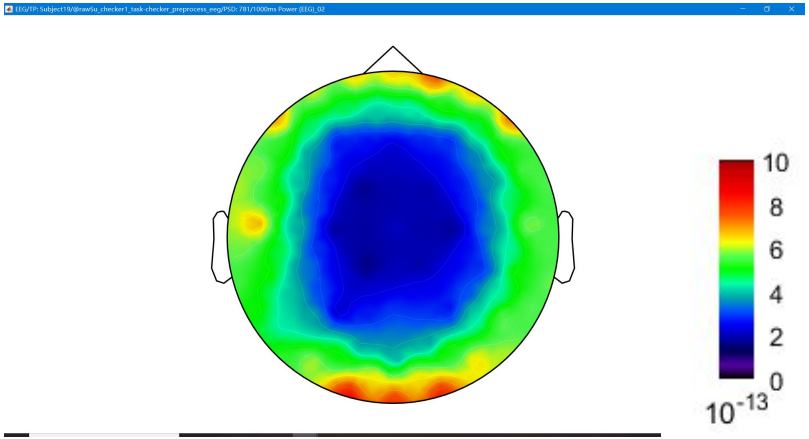
EEG data inside FMRI (ours)



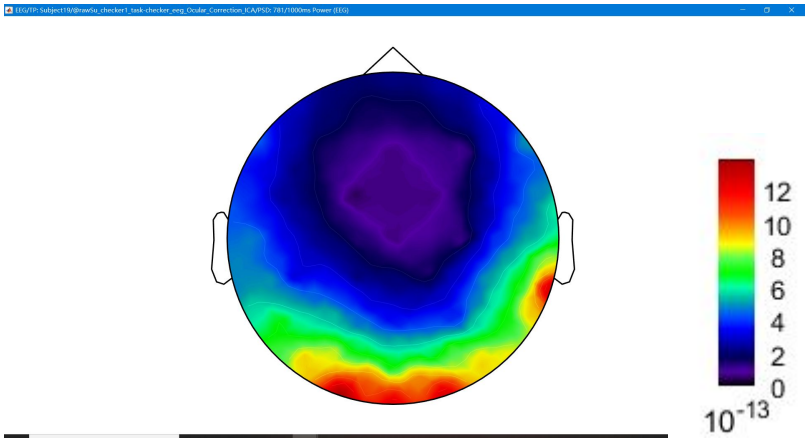
EEG data inside Nature paper [1]

Denoised EEG data inside FMRI (left), compared to nature paper [1] checkerboard result (right)

[1]Telesford,. *et al.* An open-access dataset of naturalistic viewing using simultaneous EEG-fMRI. *Sci Data* 10, 554 (2023).



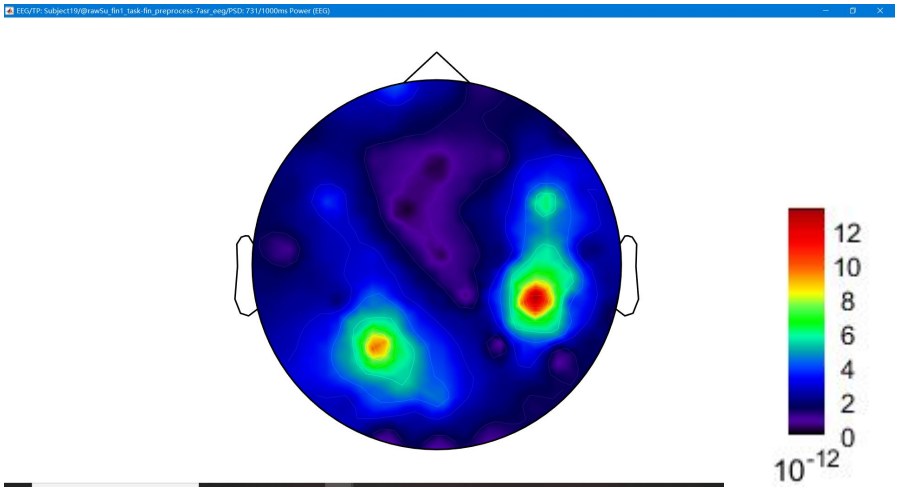
Denoised by Pipeline, 13 Hz



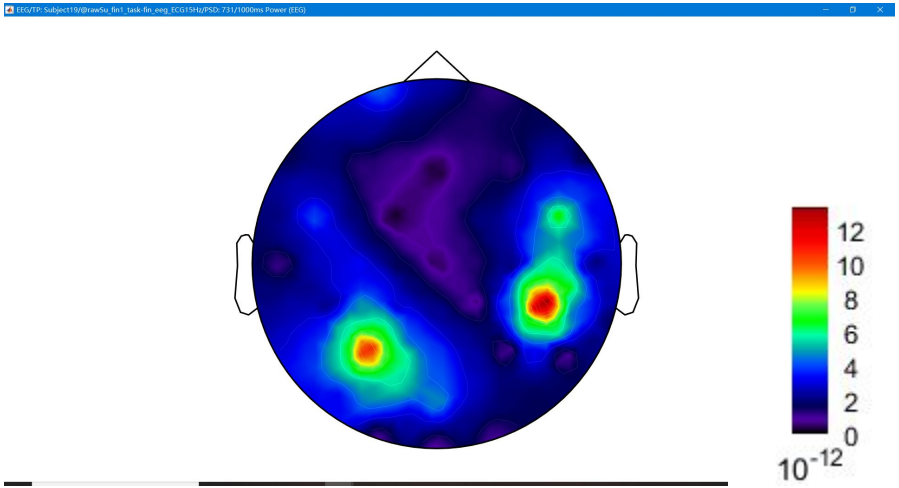
Denoised by Brainvision, 13 Hz

Comparison between Brainvision Analyzer 2 and our Denoising pipeline

- Visual task power spectrum
- Strong activation in the visual cortex



Denoised by Pipeline, 20 Hz



Denoised by Brainvision, 20 Hz

Comparison between Brainvision Analyzer 2 and our Denoising pipeline

- Finger tap experiment
- Same power spectrum scale
- Strong activation in the motor cortex C4-CP6

Next step

Optimizing Experiment Timing

Validating EEG Denoising Algorithms

Resting State Data

Event Related Visual Task

3T EEG-fMRI for validation

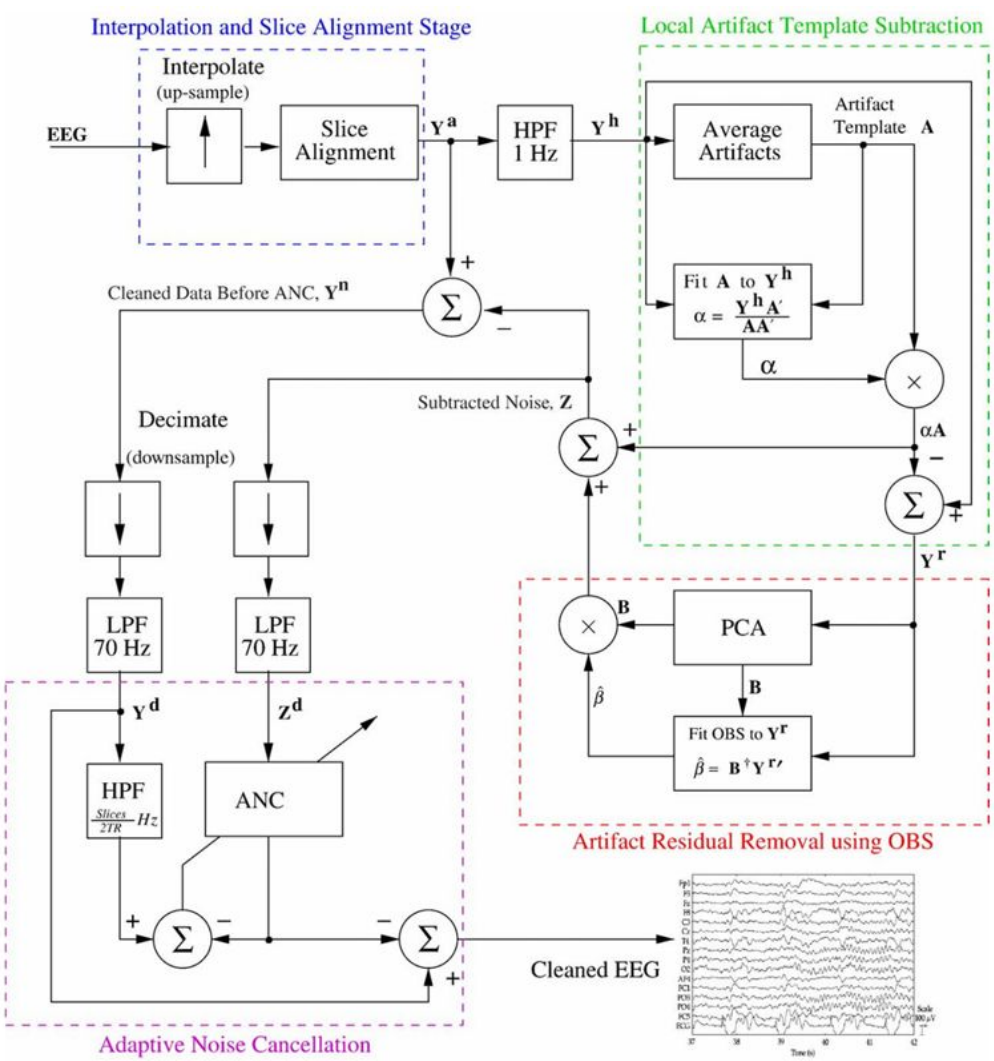
Supplemental slides

Parsa

Two main methods:

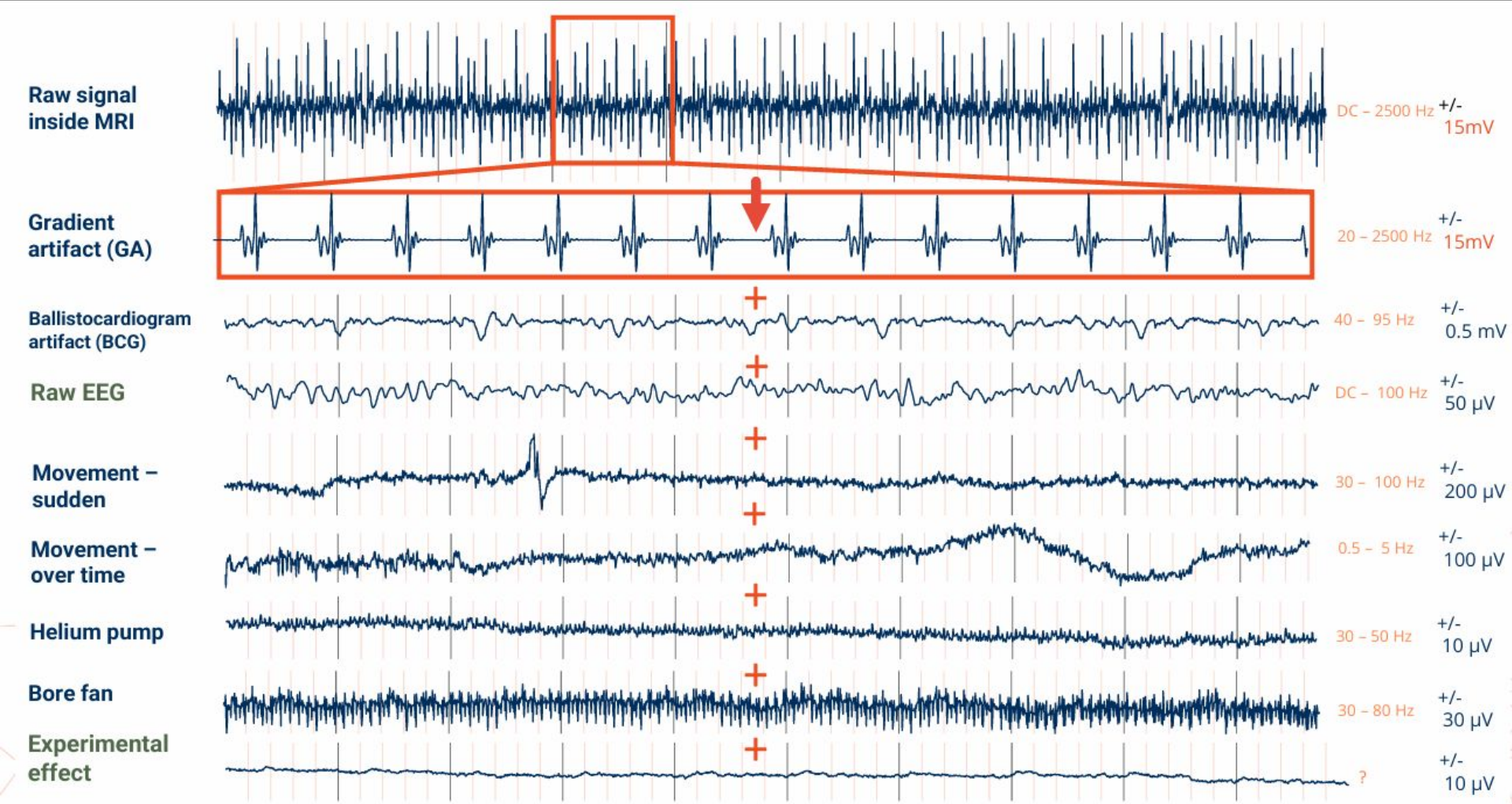
imaging artifact reduction (IAR) (2000): NO OBS step

FMRI artifact slice template removal (FASTR) (2005): the following Schematic flow chart

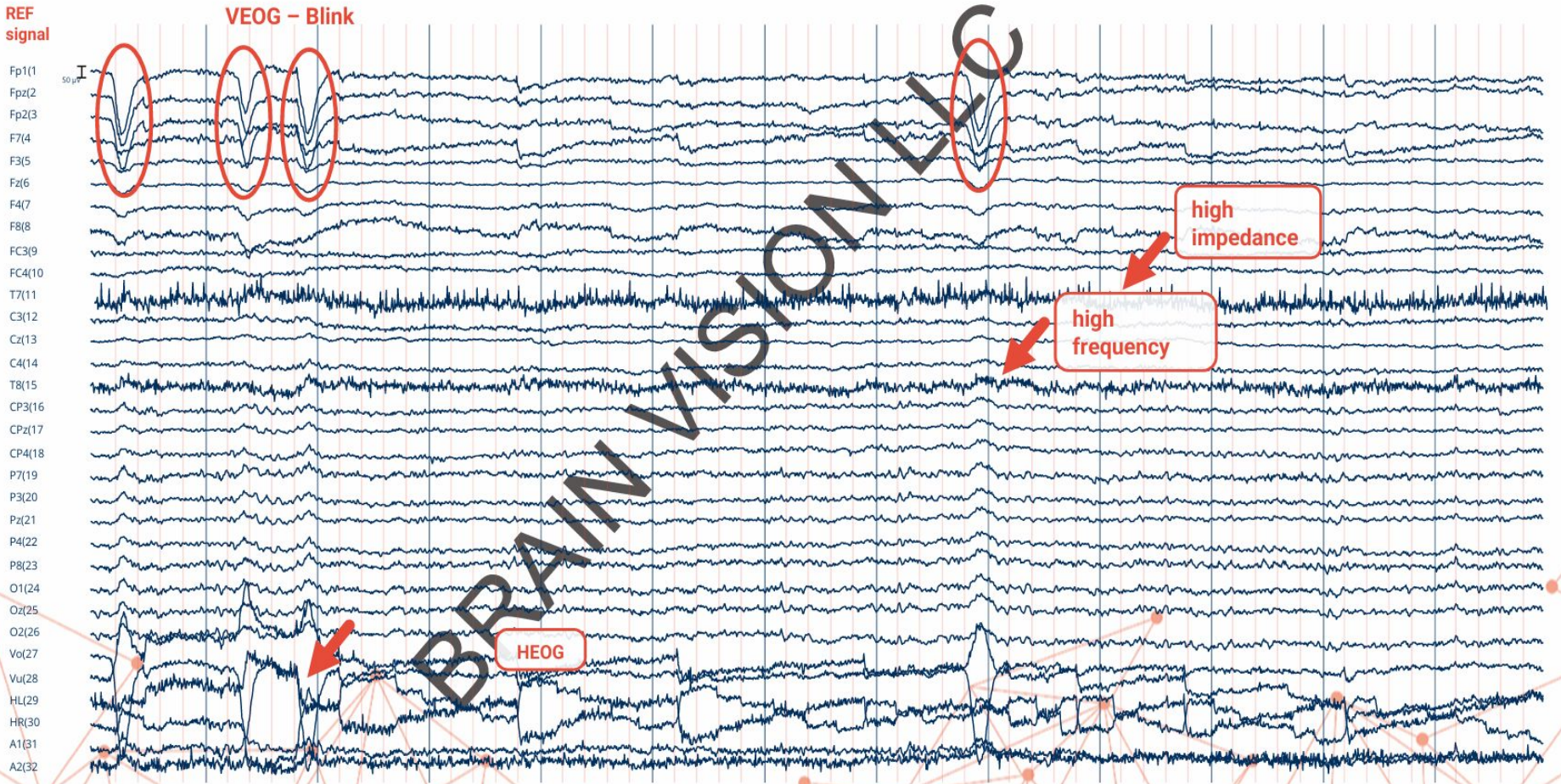


local slice artifact template subtractior

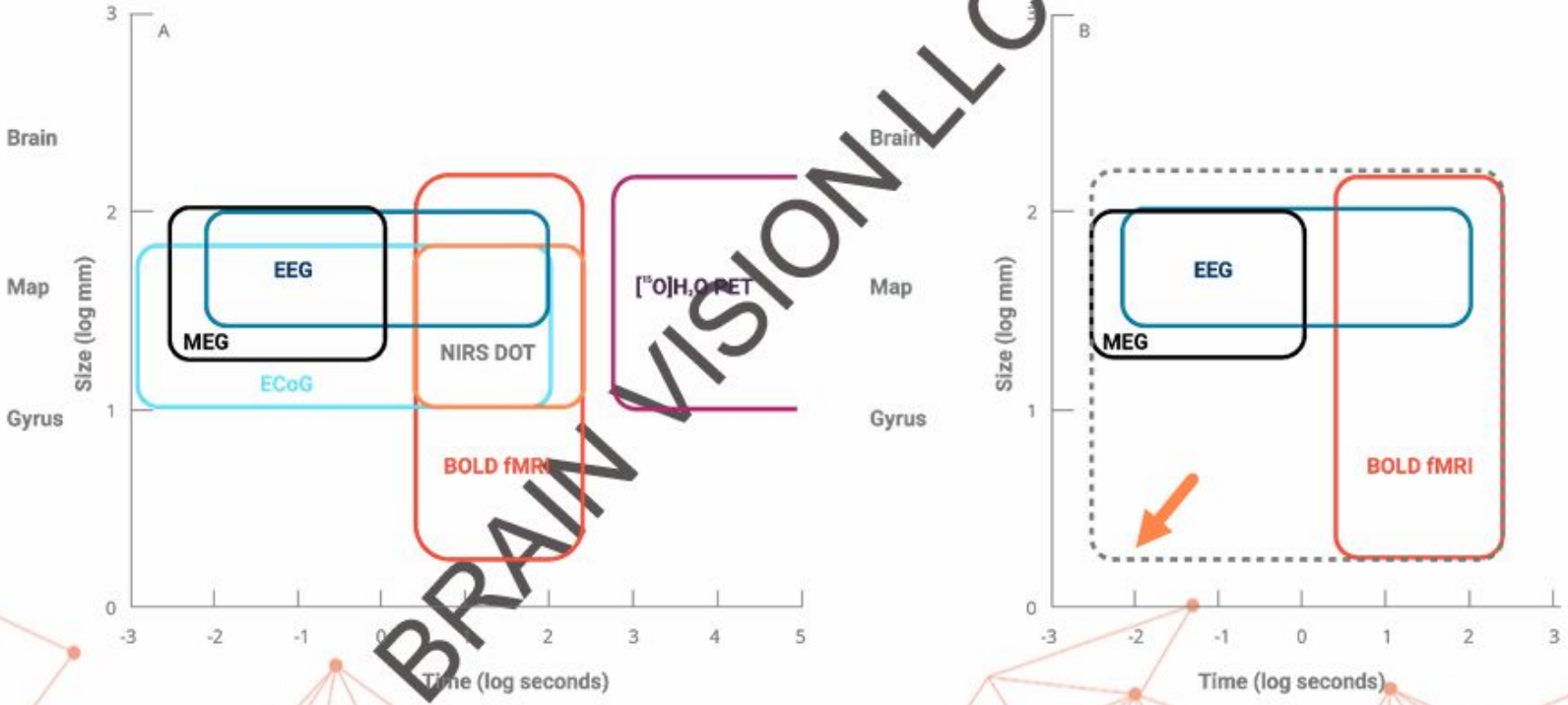
$$\mathbf{A}_j = \frac{1}{|I(j)|} \sum_{\ell \in I(j)} \mathbf{Y}_\ell^h$$


Raw signal inside MRI
DC – 2500 Hz
+/- 15mV
Gradient artifact (GA)
20 – 2500 Hz
+/- 15mV
Ballistocardiogram artifact (BCG)
40 – 95 Hz
+/- 0.5 mV
Raw EEG
DC – 100 Hz
+/- 50 µV
Movement – sudden
30 – 100 Hz
+/- 200 µV
Movement – over time
0.5 – 5 Hz
+/- 100 µV
Helium pump
30 – 50 Hz
+/- 10 µV
Bore fan
30 – 80 Hz
+/- 30 µV
Experimental effect
?
+/- 10 µV

EEG – SIGNAL (OUTSIDE SCANNER)

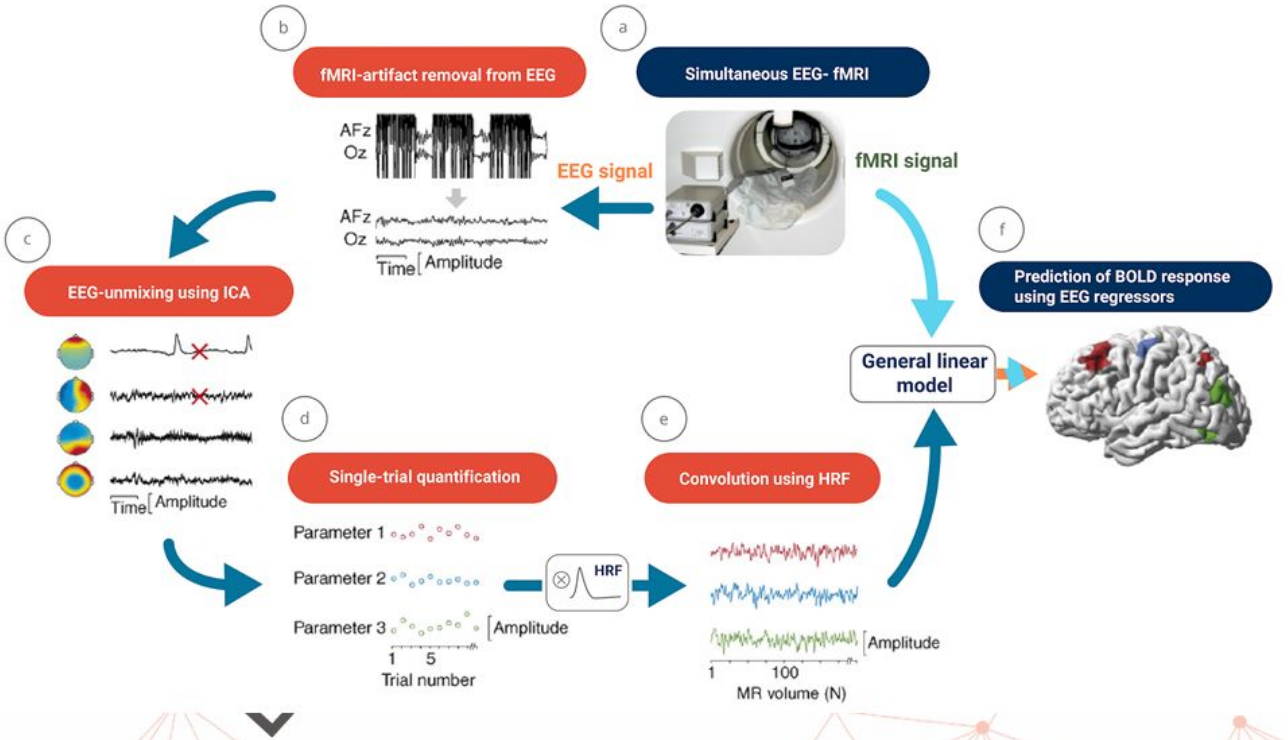


COMBINING MODALITIES



Source: Scott A. Huettel, Allen W. Song, Gregory McCarthy.
Functional Magnetic Resonance Imaging

JOINING TWO DATA STREAMS



TRENDS in Cognitive Sciences

Source: Debener, S., Ullsperger, M., Siegel, M., Engel A.K. 2006