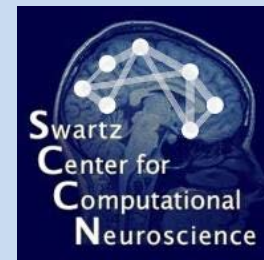


Mining Event-related Brain Dynamics II



Scott Makeig

Institute for Neural Computation
University of California San Diego

25th EEGLAB Workshop
Tokyo, Japan
September, 2017





SCCN Open Source Software Tools

List of data processing extensions

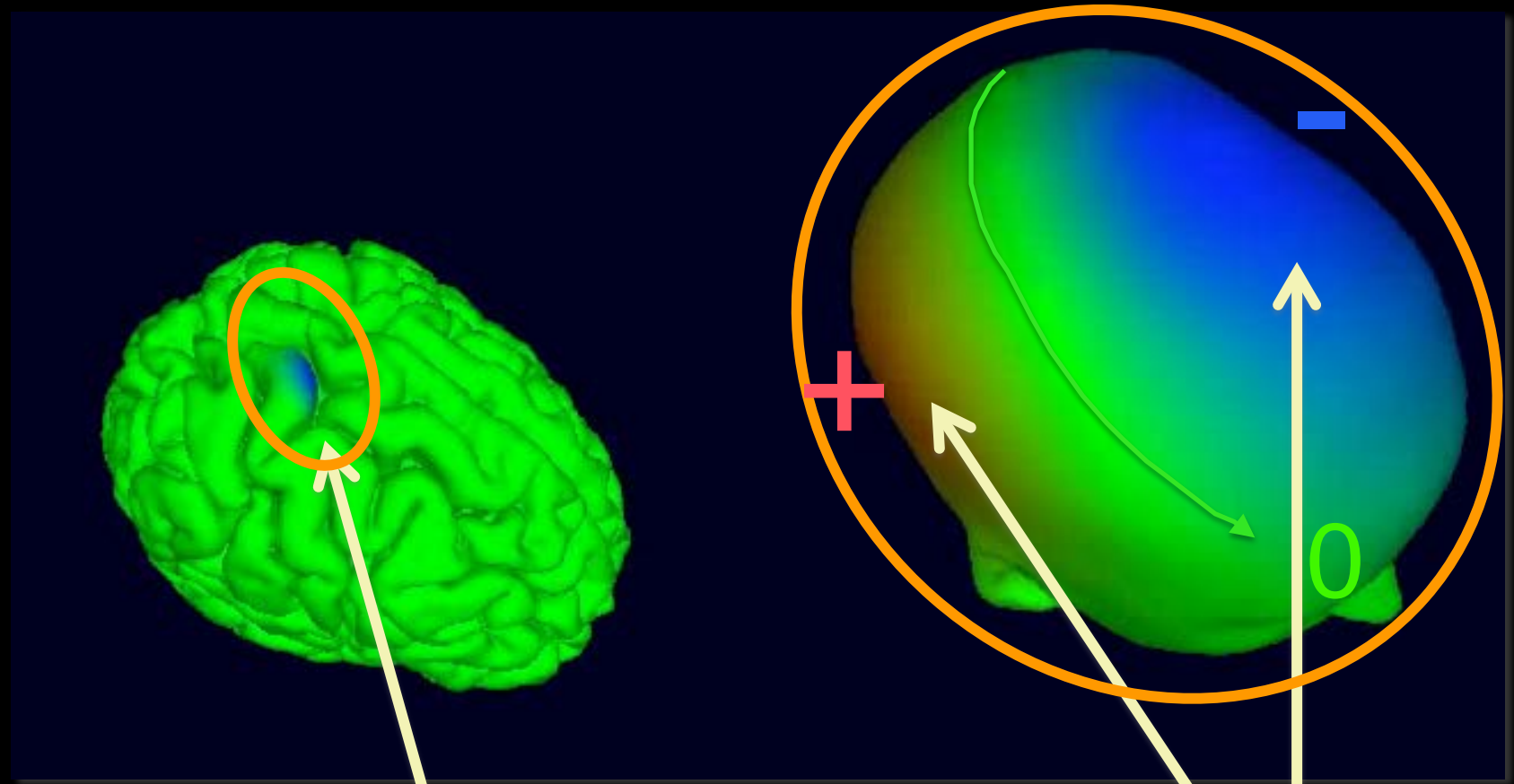
| Plug-In name | Version | Short plug-in description | Link | Contact | Comments |
|--|---------|---|--------------------------|--|-------------------------------|
| rERP | 0.4 | Estimate overlapping ERPs using multiple regression | Download | M. Burns | User comments |
| LIMO | 1.5 | Linear MODElling of EEG data | Download | C. Pernet | User comments |
| corrmap | 2.02 | Cluster ICA components using correlation of scalp maps | Download | S. Debener | User comments |
| bioelectromag | 1.01 | Uses Bioelectromagnetism toolbox for ERP peak detection | Download | D. Weber | User comments |
| VisEd | 1.05 | Add/Edit dataset events | Download | J. Desjardins | User comments |
| loreta | 1.10 | Export and import data to and from LORETA software | Download | A. Delorme | User comments |
| iirfilt | 1.02 | Non linear filtering using IIR filter | Download | M. Pozdin | User comments |
| std_envtopo | 2.39 | Plot STUDY ICA cluster contribution to ERP | Download | M. Miyakoshi | User comments |
| std_selectCsByCluster | 0.10 | Forward-project clustered ICs to channels (beta) | Download | M. Miyakoshi | User comments |
| std_dipoleDensity | 0.23 | Plot STUDY ICA cluster dipole density (beta) | Download | M. Miyakoshi | User comments |
| std_ErpCalc | 0.11 | Test and visualize simple effects on ERP (beta) | Download | M. Miyakoshi | User comments |
| pvaftopo | 0.10 | Plot topography of percent variance accounted for (beta) | Download | M. Miyakoshi | User comments |
| trimOutlier | 0.16 | Trim outlier channels and datapoints interactively (beta) | Download | M. Miyakoshi | User comments |
| clean_rawdata | 0.31 | Cleans continuous data using Artifact Subspace Reconstruction | Download | Miyakoshi and Kothe | User comments |
| ARfitStudio | 0.10 | Cleans spiky artifacts using AARfit (beta) | Download | Miyakoshi and Mullen | User comments |
| Mutual_Info_Clustering | 1.00 | Group single dataset ICA components by Mutual Information | Download | N. Bigdely | User comments |
| mass_univ | 130502 | Mass Univariate ERP Toolbox | Download | D. Groppe | User comments |
| REGICA | 1.00 | ICA regression based EOG removal | Download | M. Klados | User comments |
| MARA | 1.1 | Multiple Artifact Rejection Algorithm | Download | I. Winkler | User comments |
| firfilt | 1.6.1 | Routines for designing linear filters | Download | A. Widmann | User comments |
| PACT | 0.17 | Computes phase-amplitude coupling for continuous data | Download | M. Miyakoshi | User comments |
| fMRib | 2.00 | Remove fMRI artifacts from EEG | Download | J. Dien & R. Niazy | User comments |

Many tools now available -- but still(?) a **two-cultures** problem.

What is EEG?

- Brain electrical activity
- A small portion of *cortical* brain electrical activity
- An even smaller portion of *total* brain electrical activity
- **But *which* portion?**
- **Triggered and modulated *how*?**
- **With *what* functional significance?**

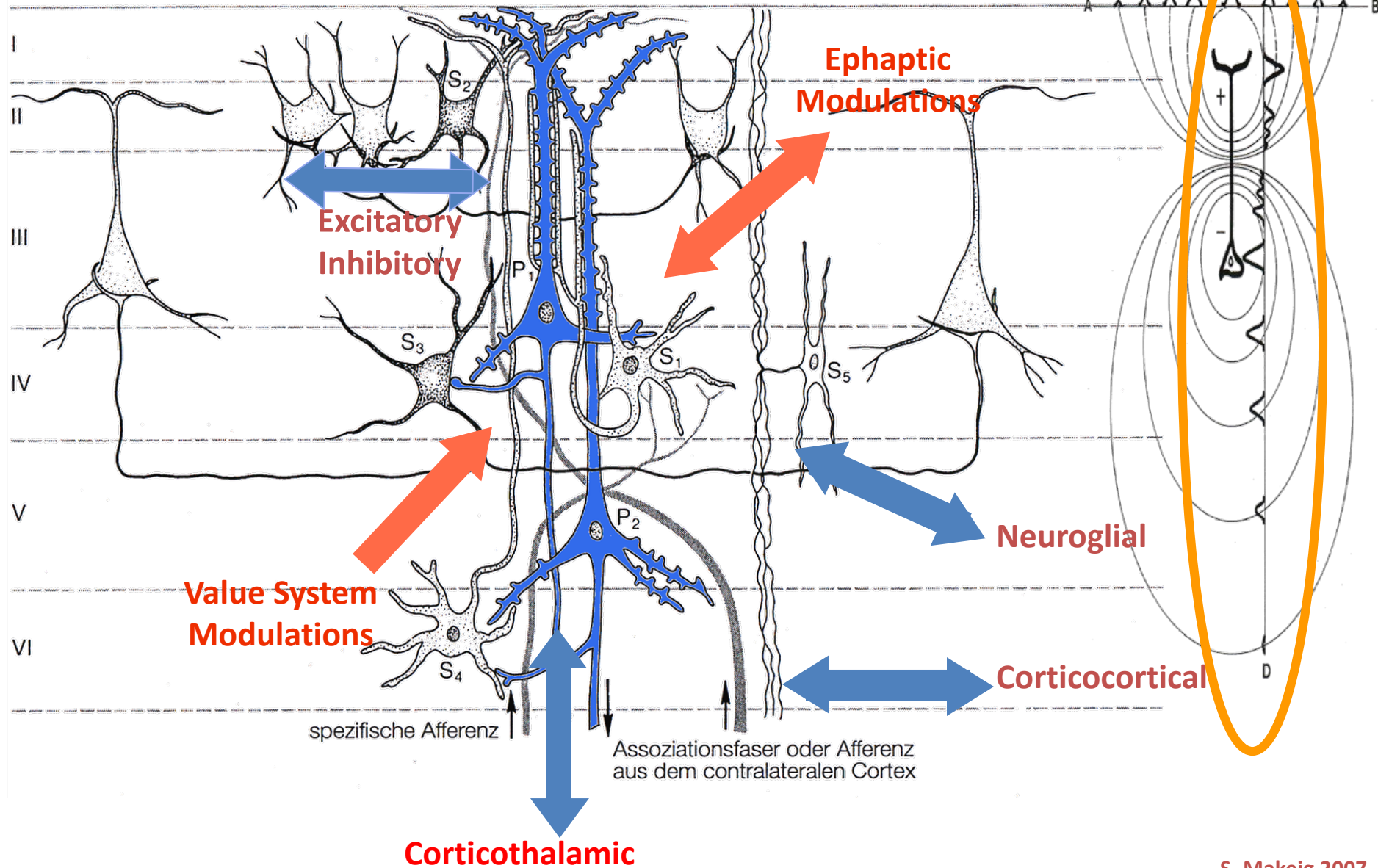
The very broad EEG point-spread function



Simulated parietal effective source

Very broad projected scalp potentials

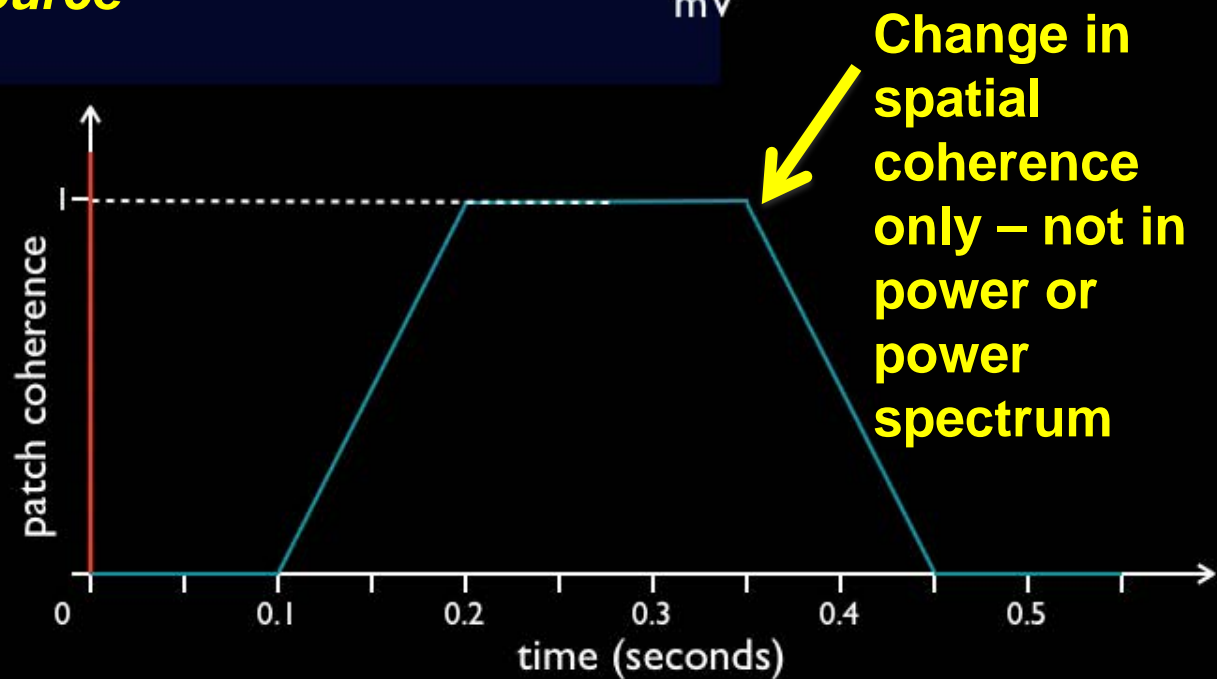
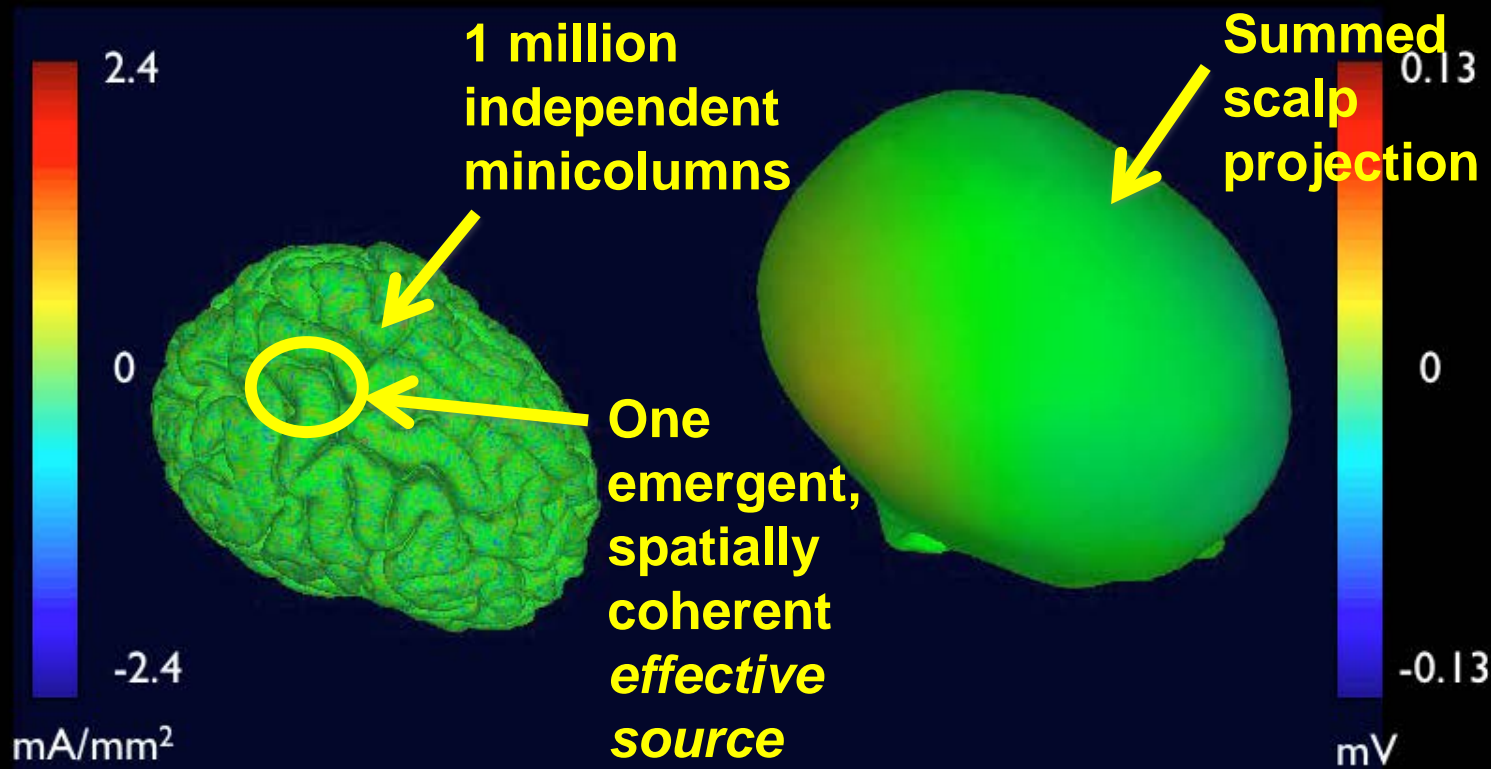
The generation and modulation of EEG is COMPLEX and not well studied

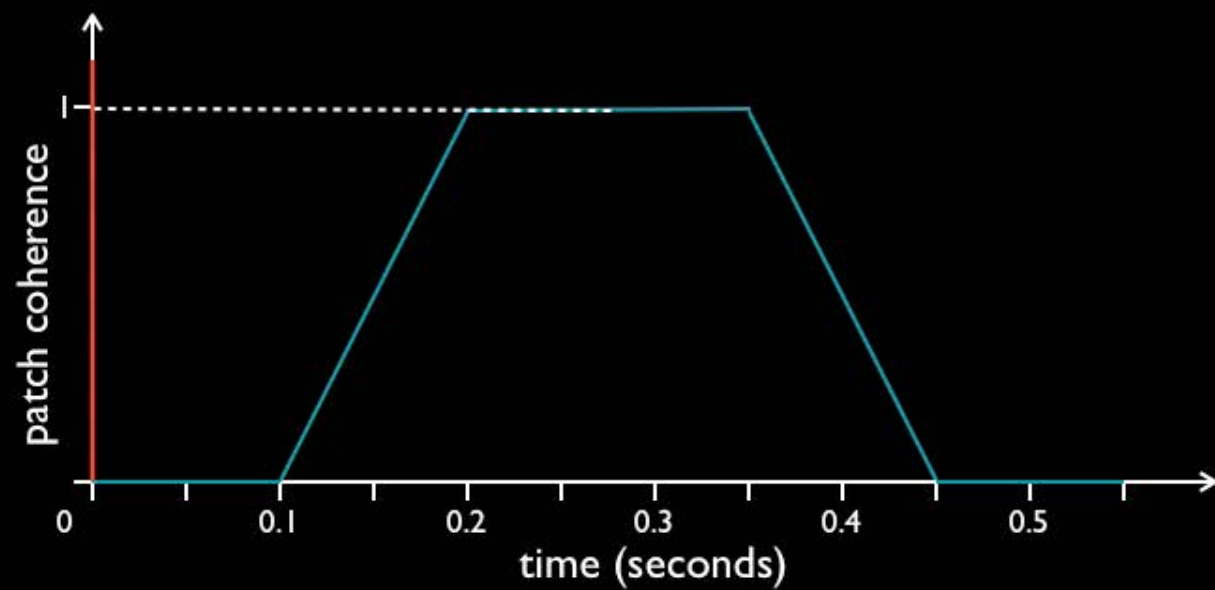
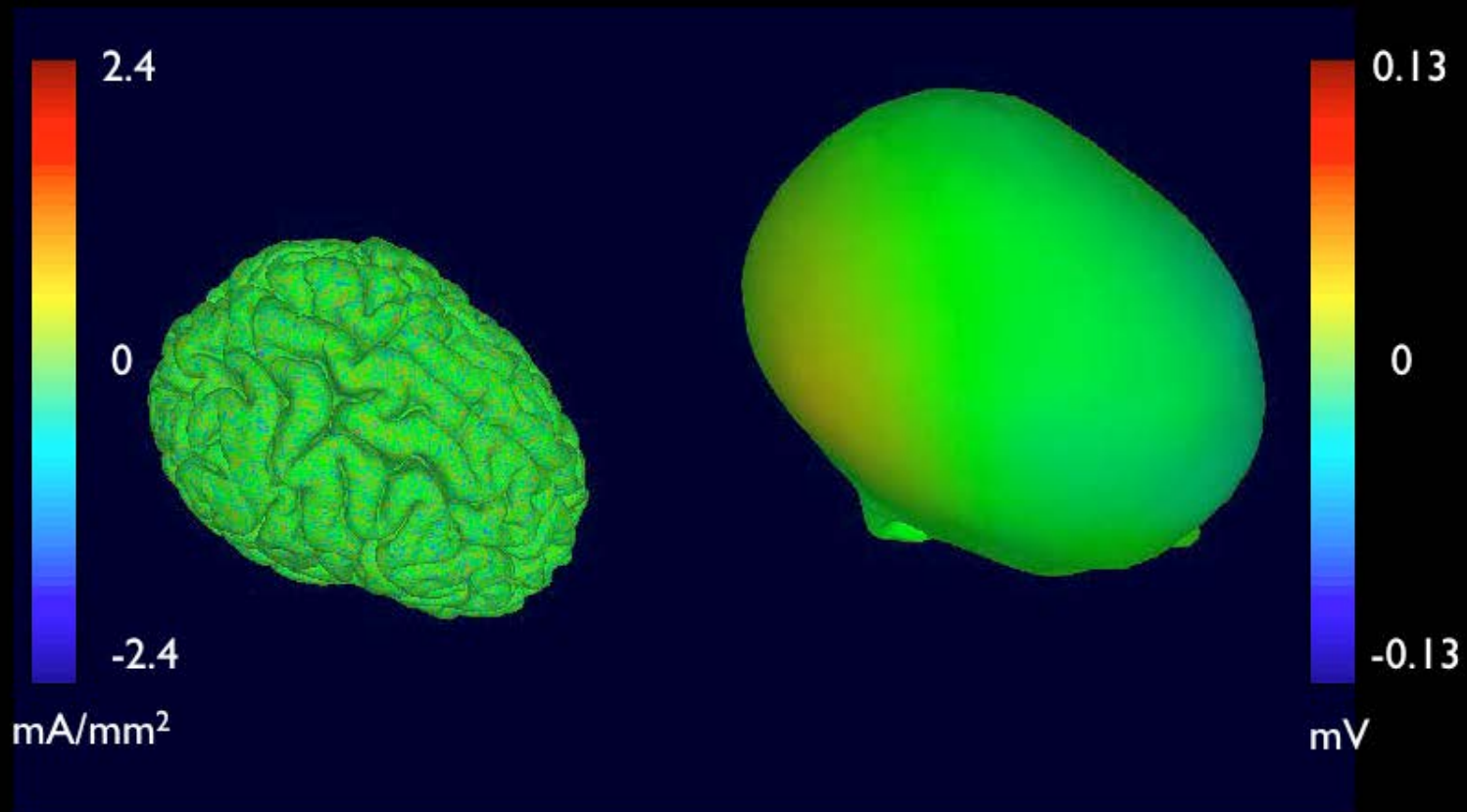


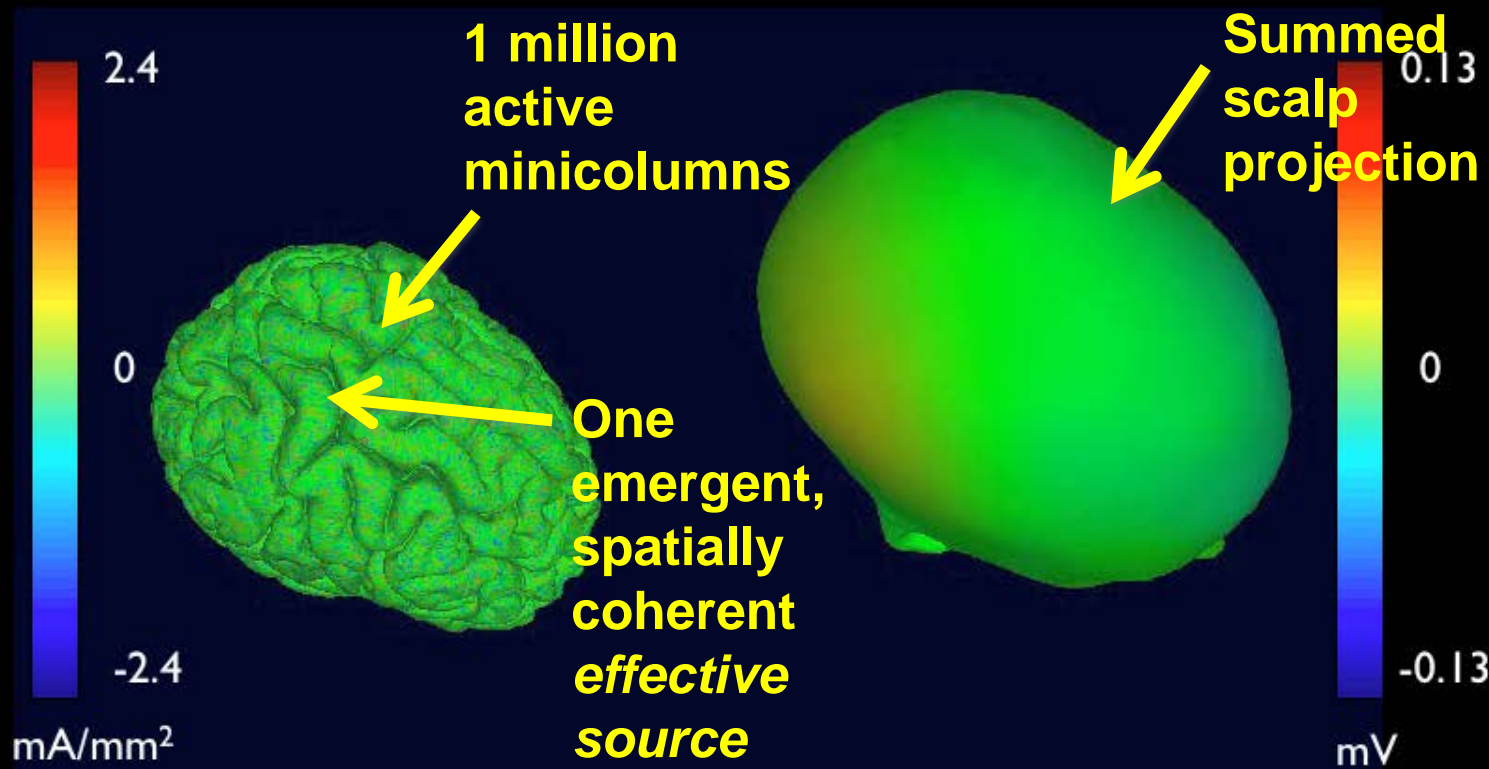
Phase cones (Freeman)

Avalanches (Plenz)

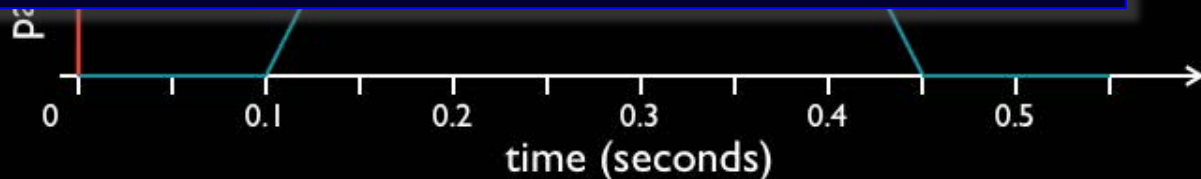




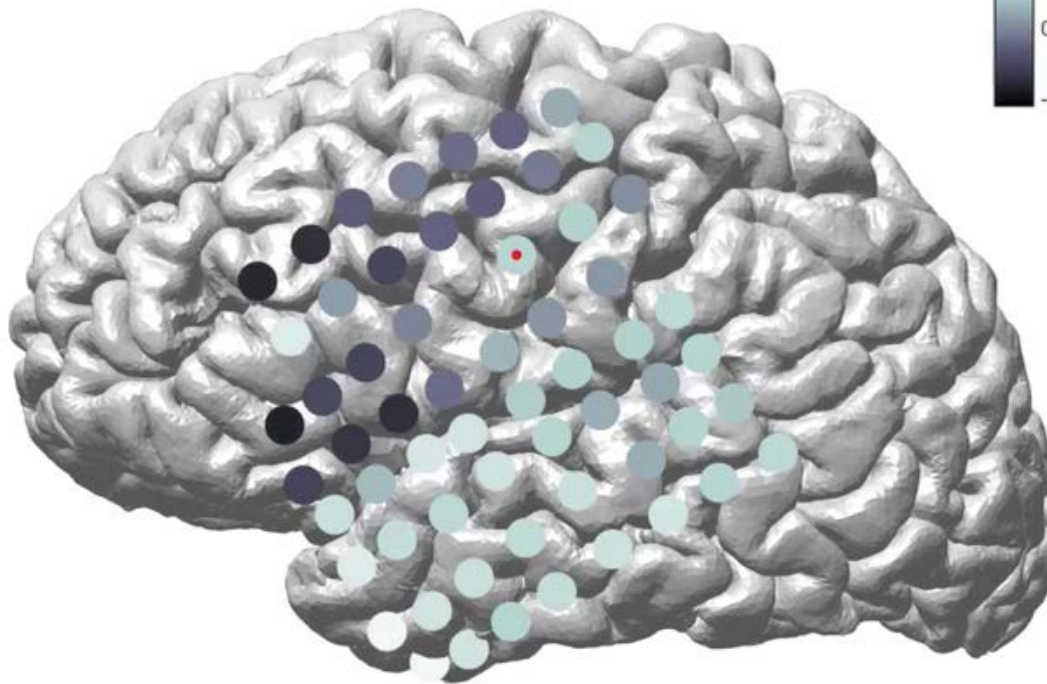
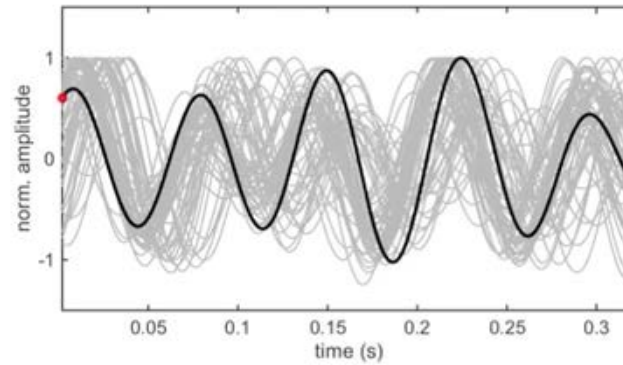


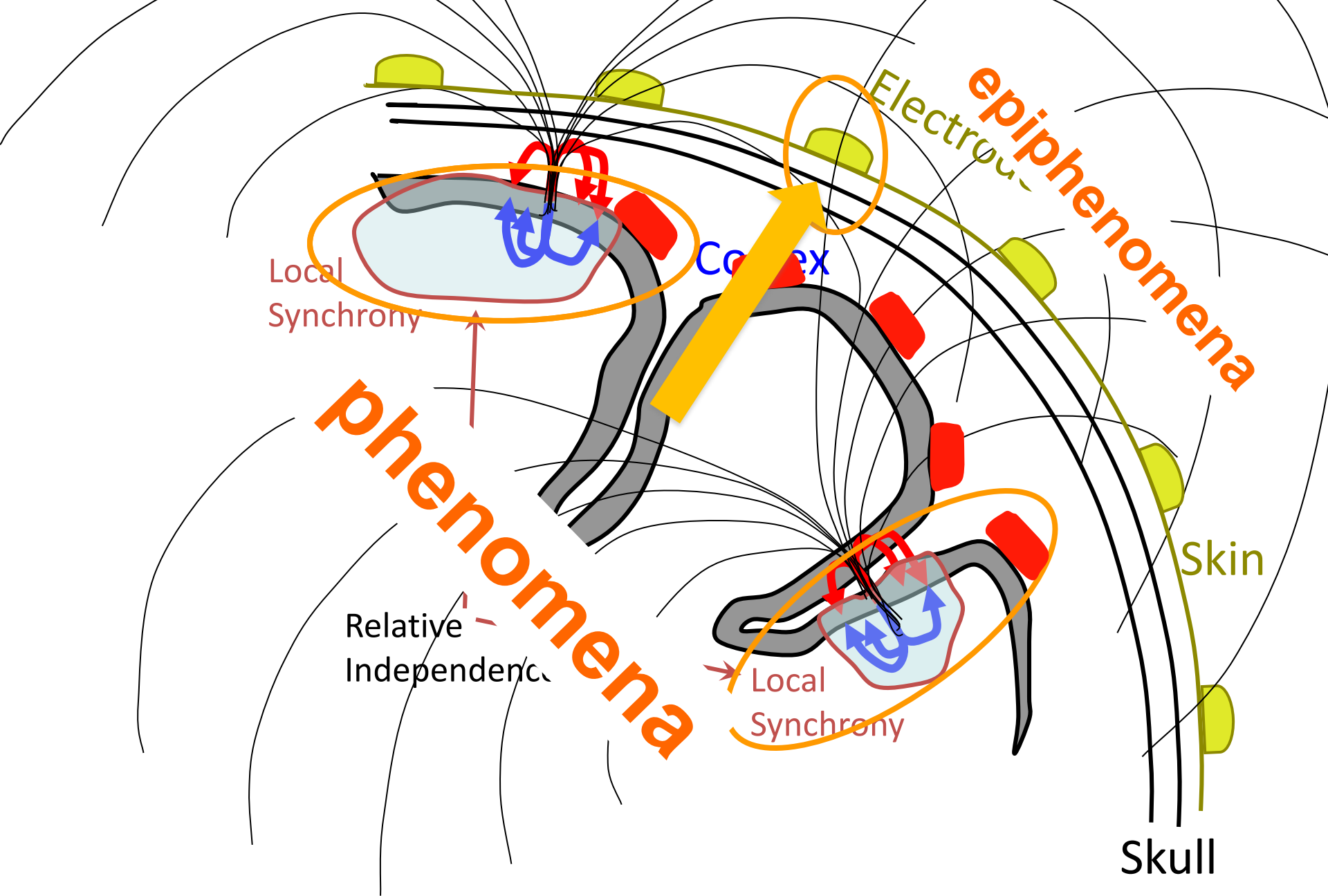


The *effective sources* of the scalp EEG & MEG are emergent islands of local synchrony / near-synchrony.



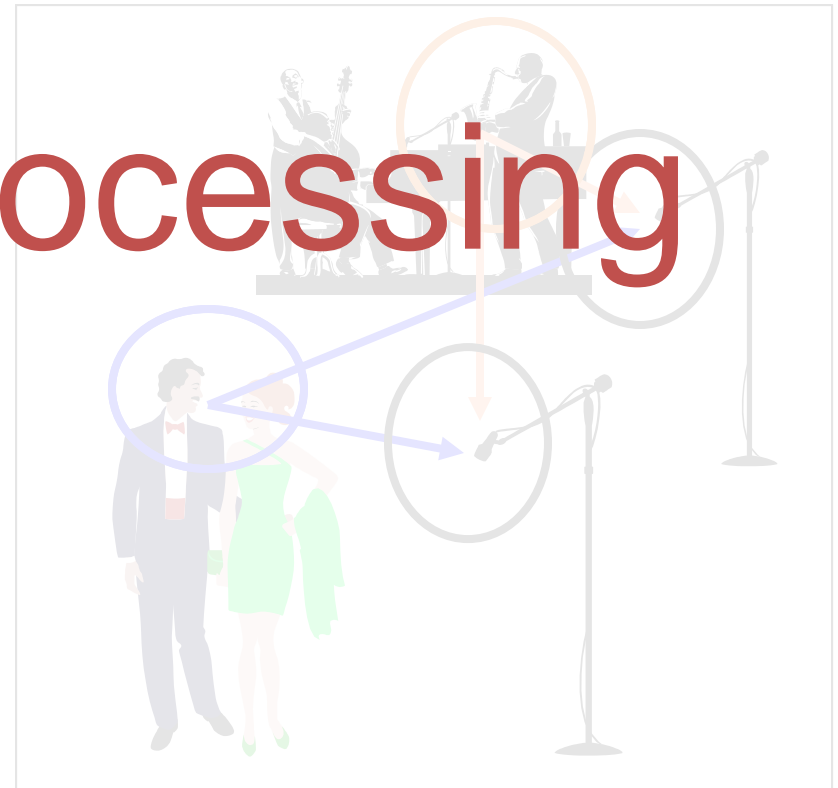
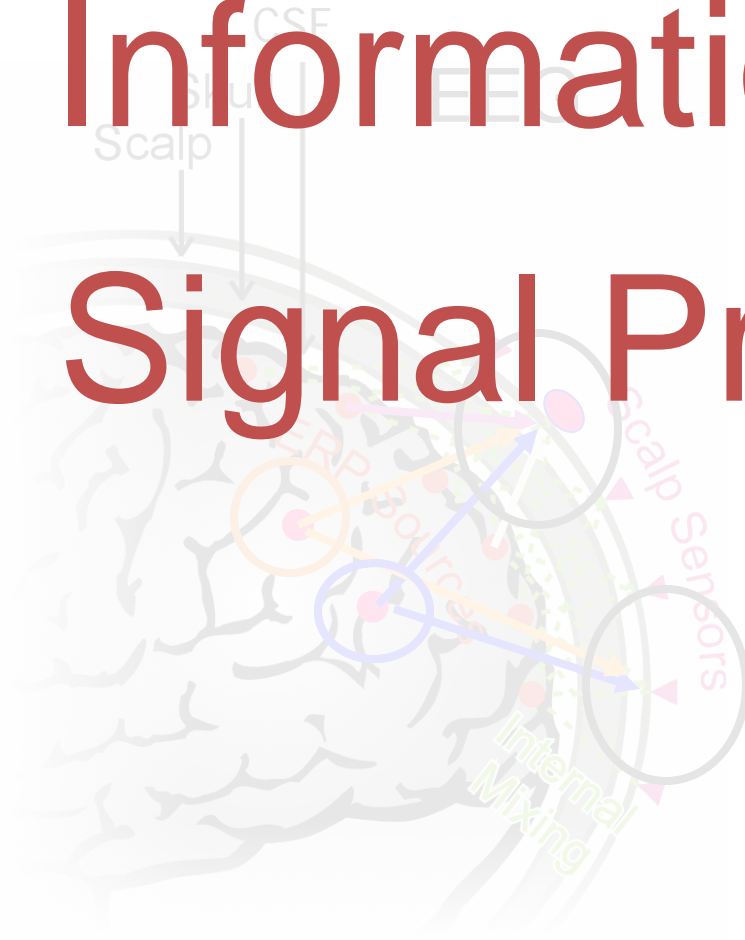
Sleep spindles



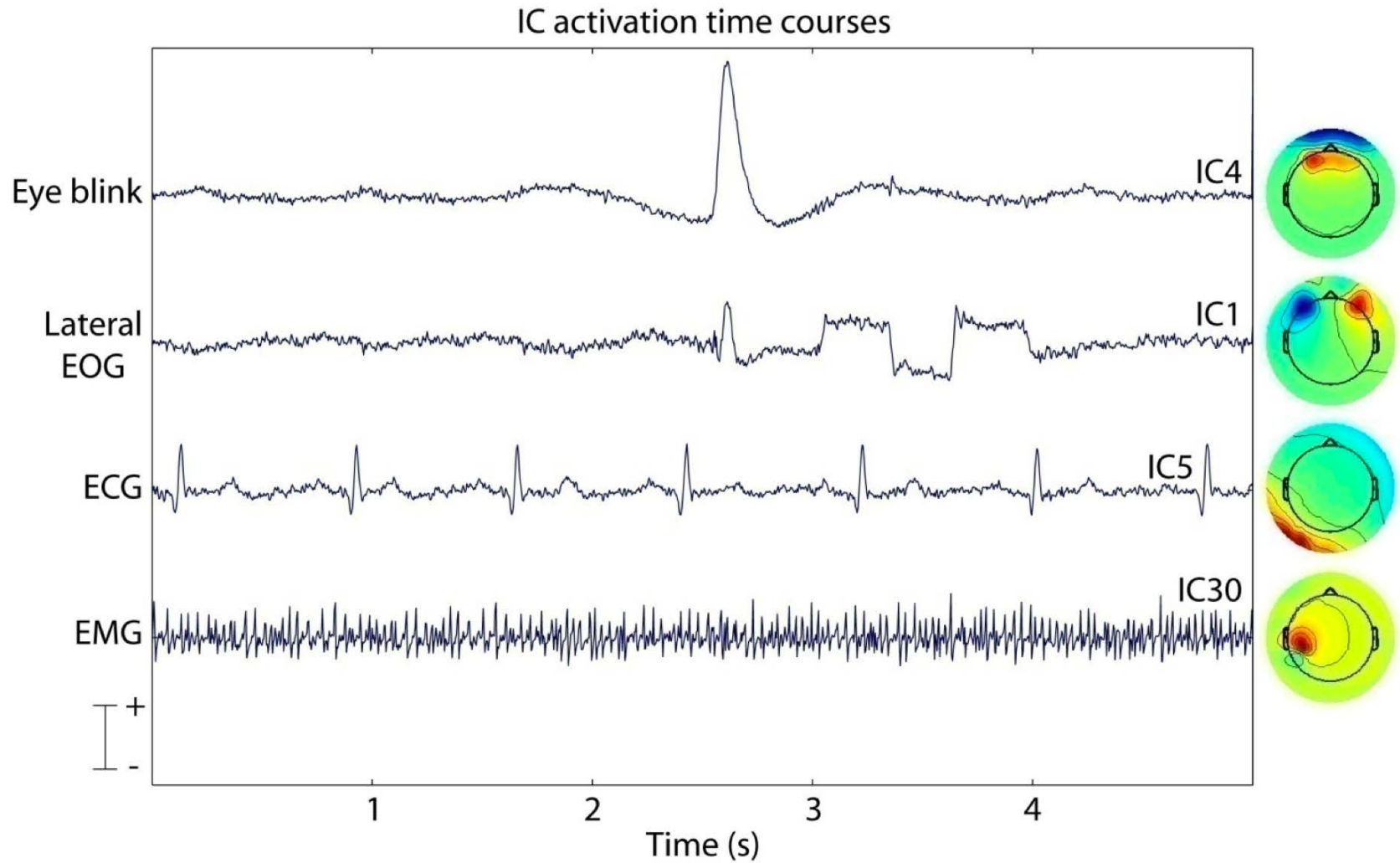


Blind EEG Source Separation by ICA

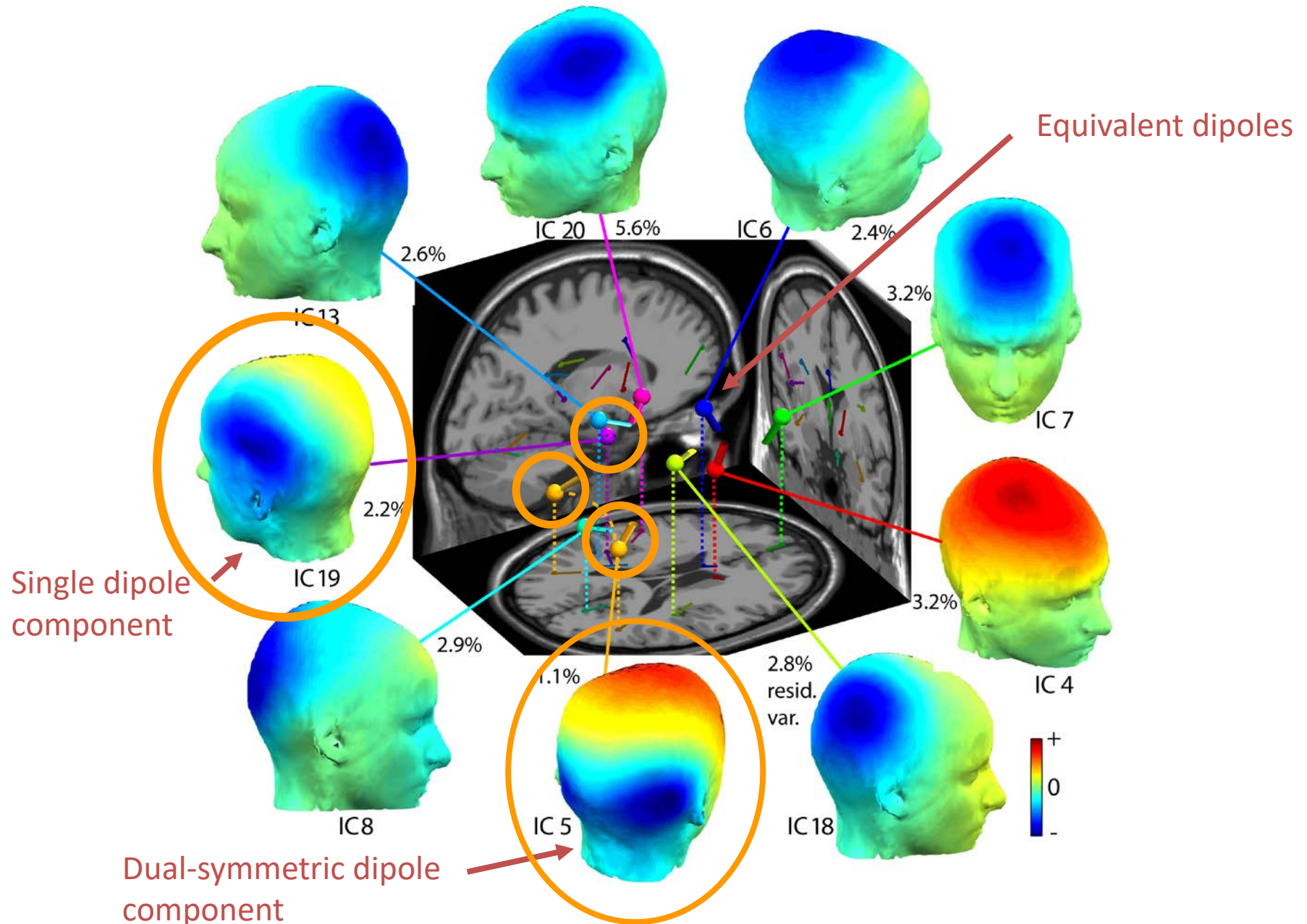
Information-based Signal Processing



ICA separates *non-brain* effective source processes

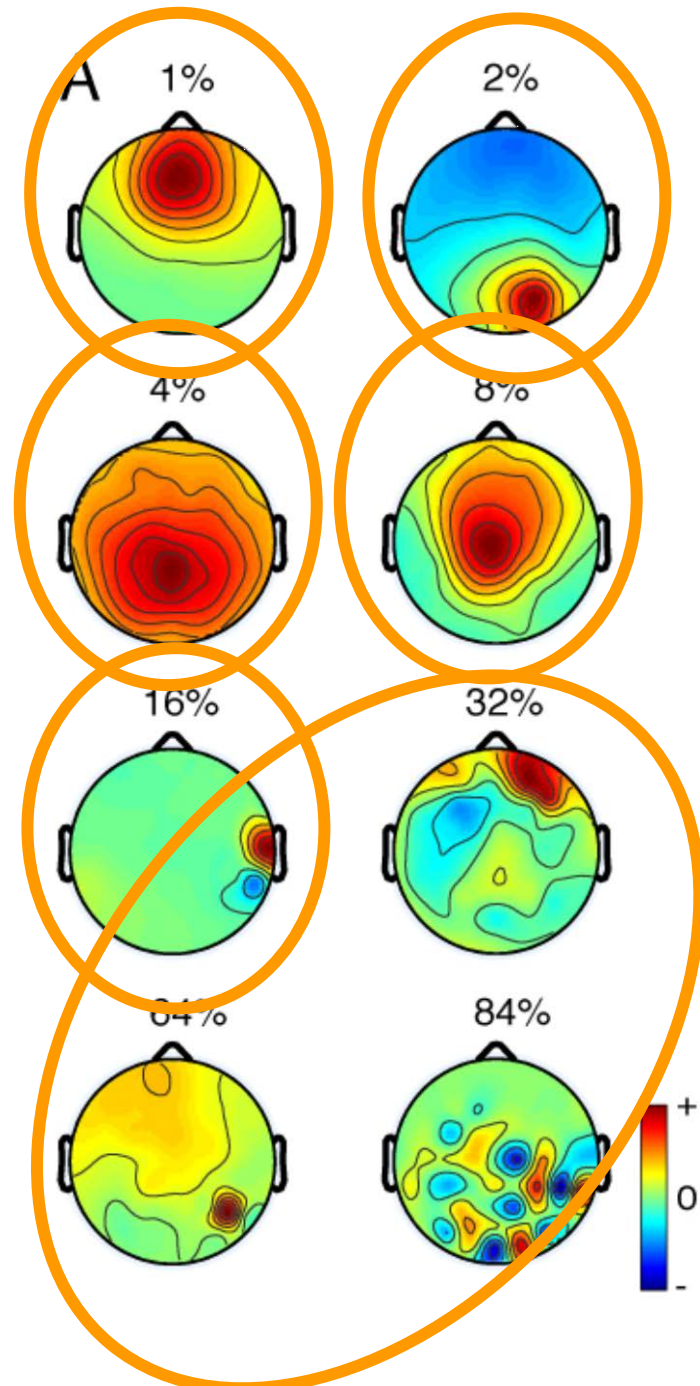
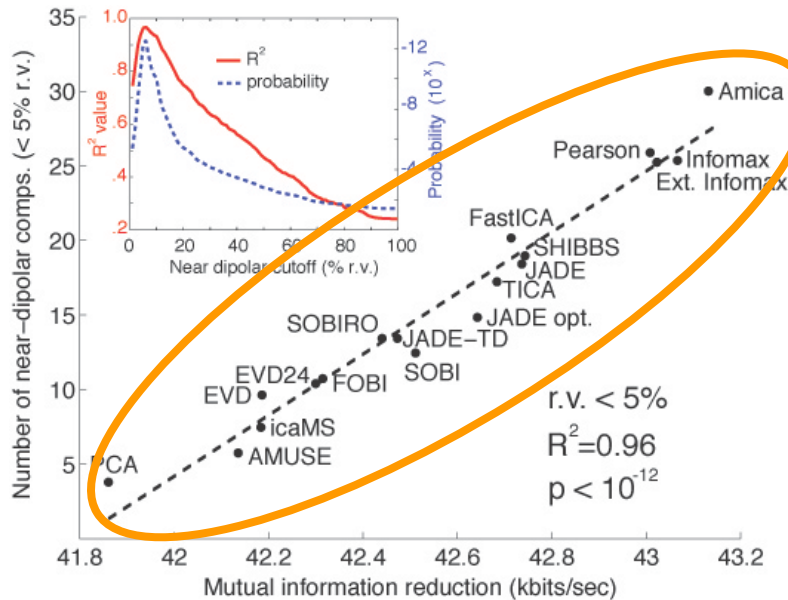


... and *also* separates cortical *brain* IC processes

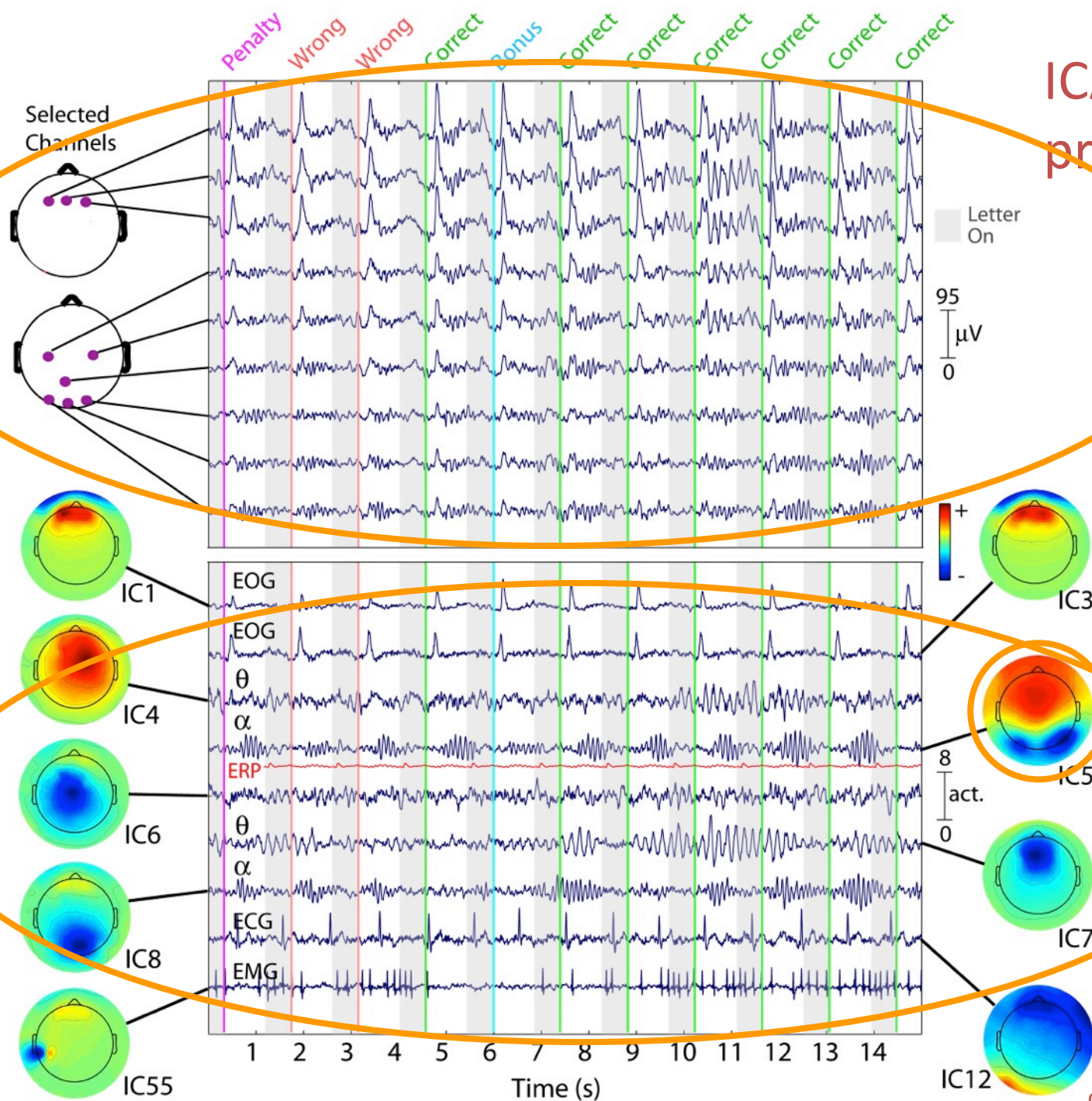


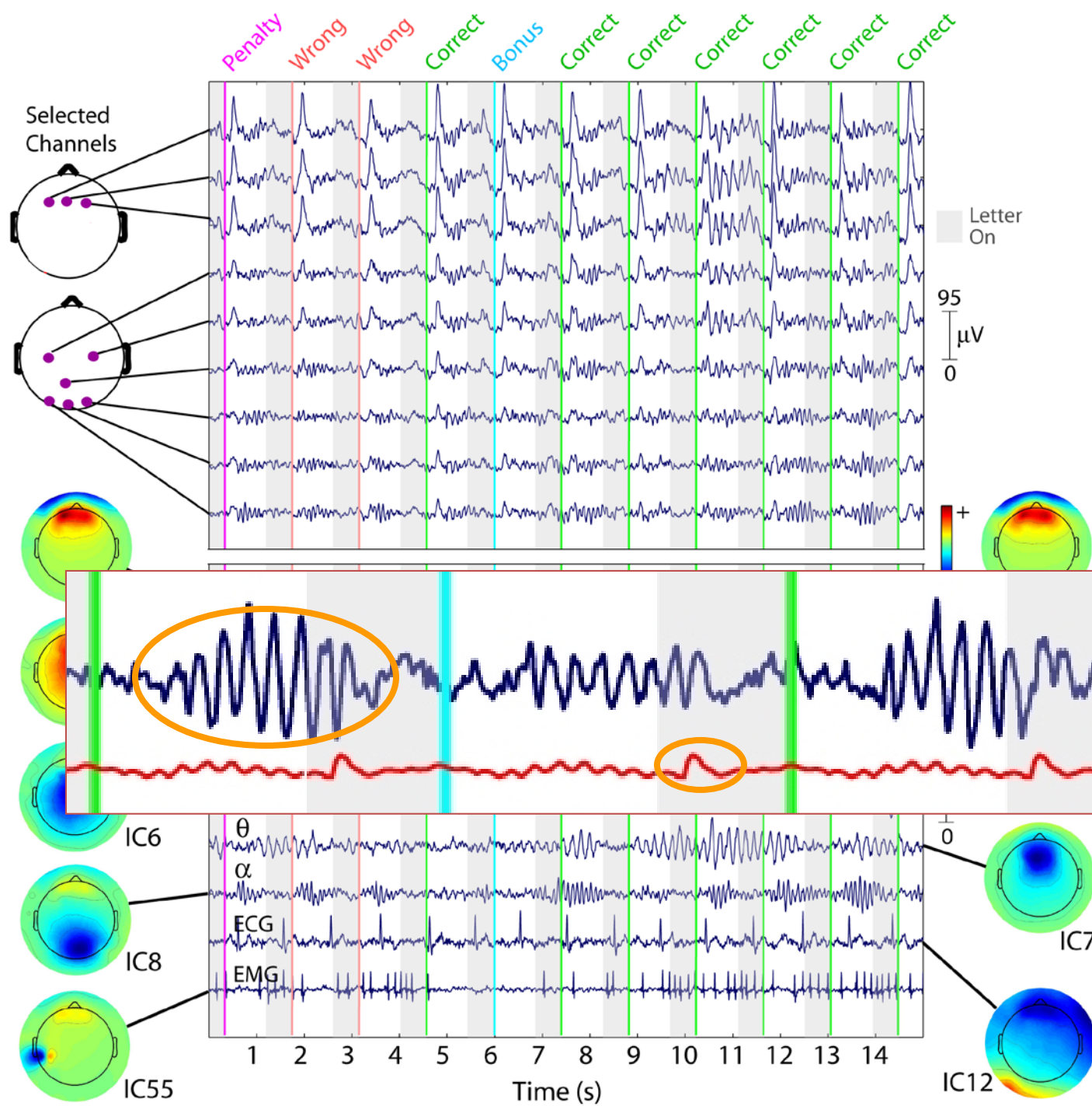
Independent Component Dipolarity

Measured by residual variance
not accounted for by the best fitting single
 (or dual) equivalent dipole model.



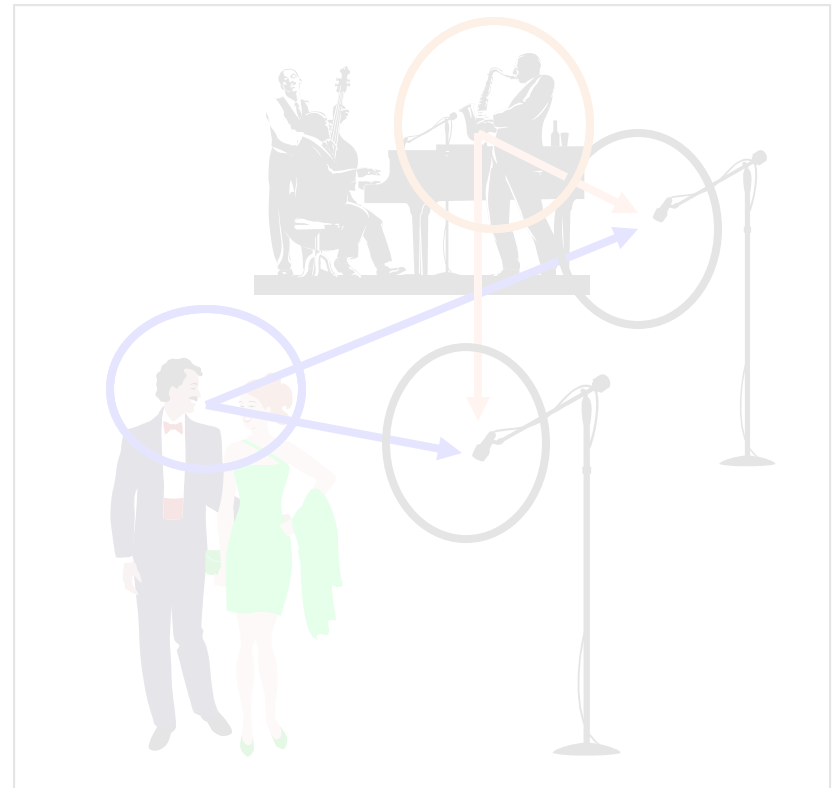
ICA in practice

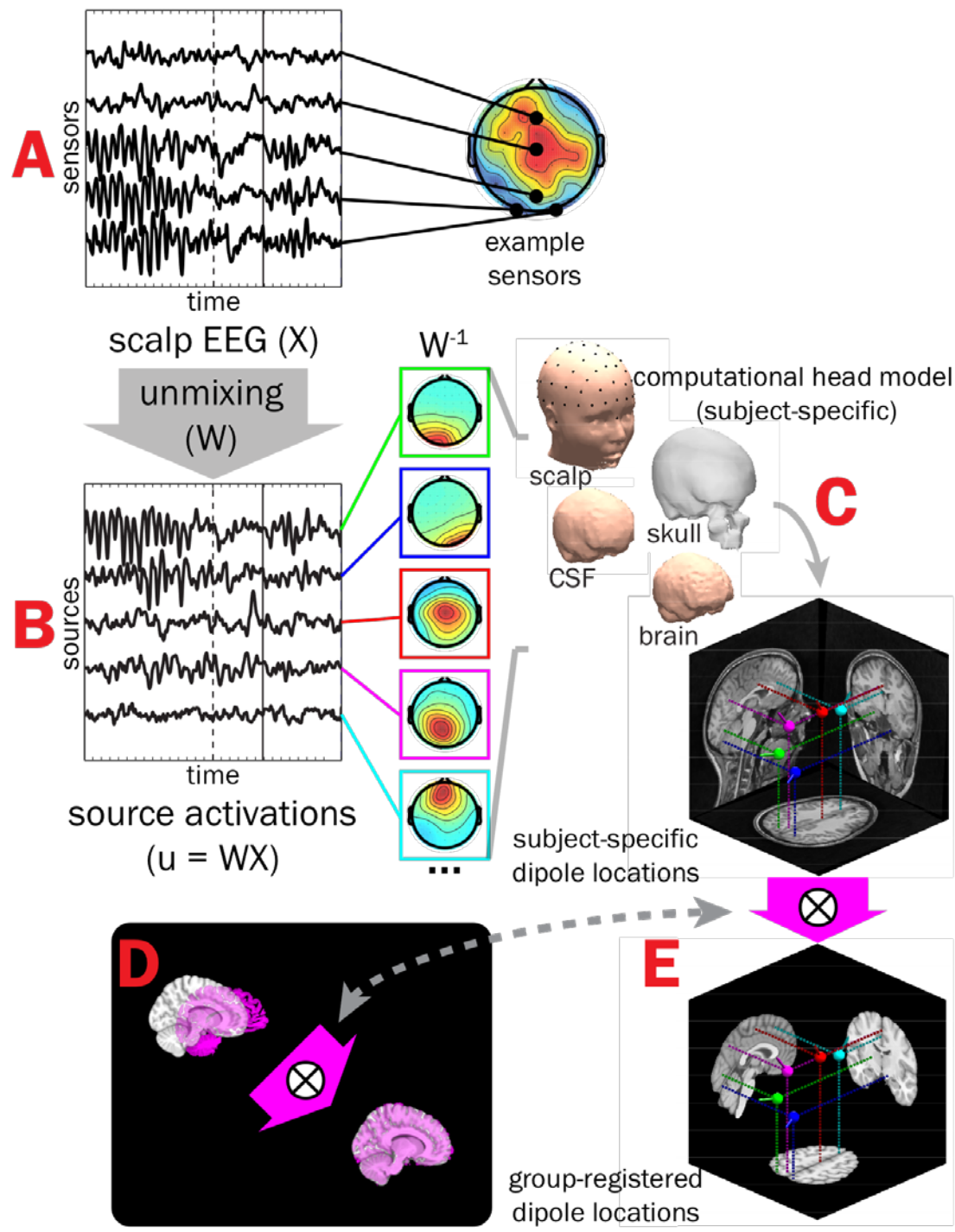




Blind EEG Source Separation by ICA

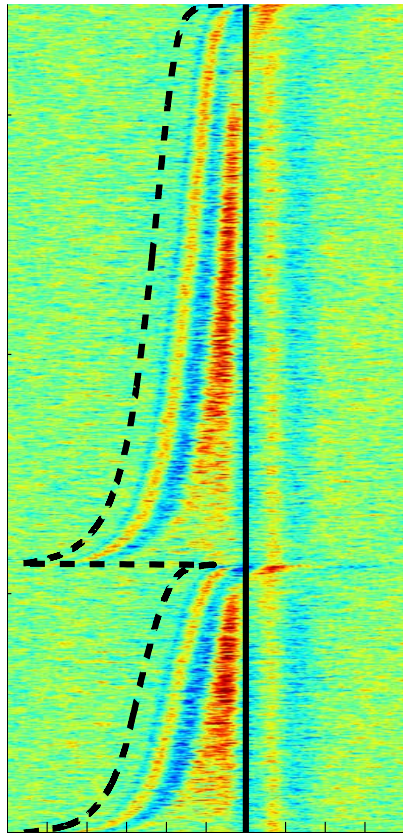
Flanker Task



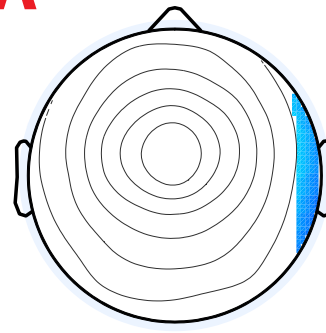


Trial-by-Trial Analysis

erpimage()
regression



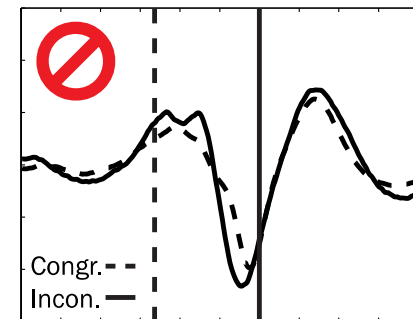
A



B

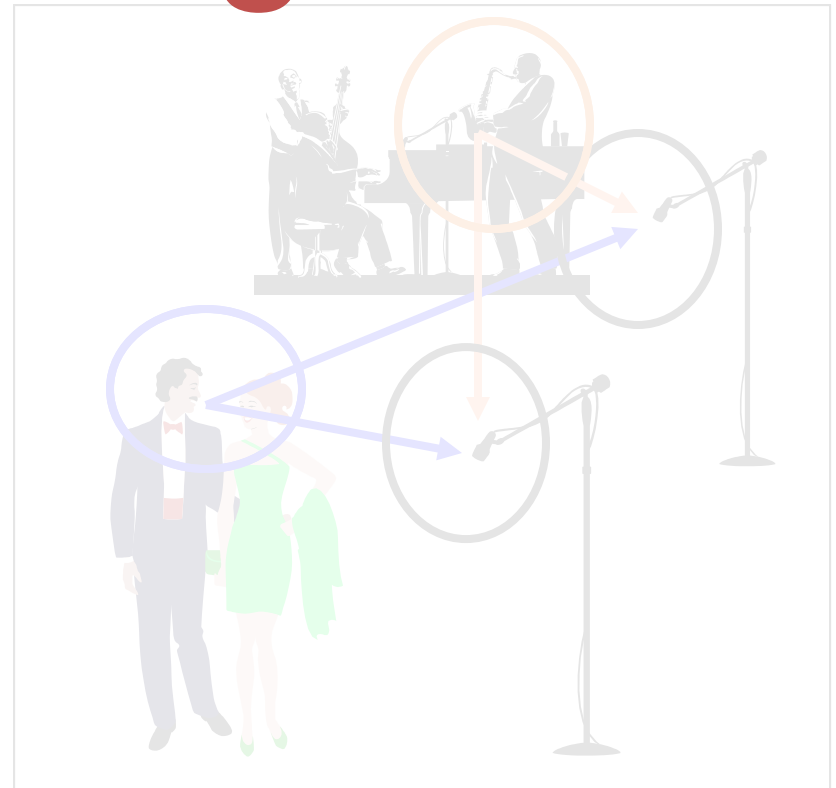
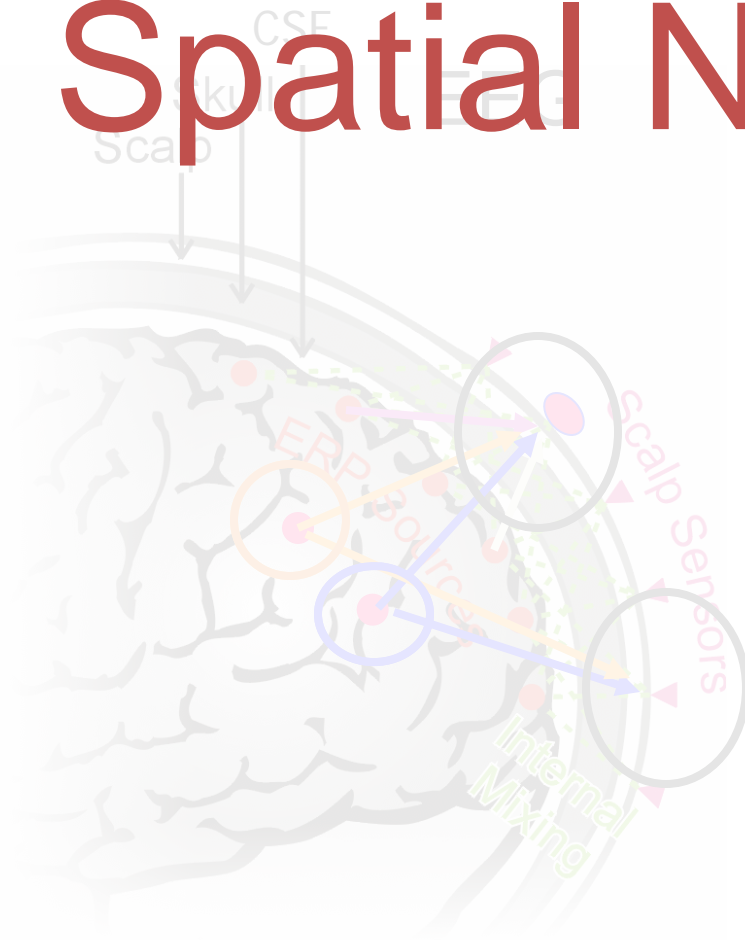


aw minus regression



Blind EEG Source Separation by ICA

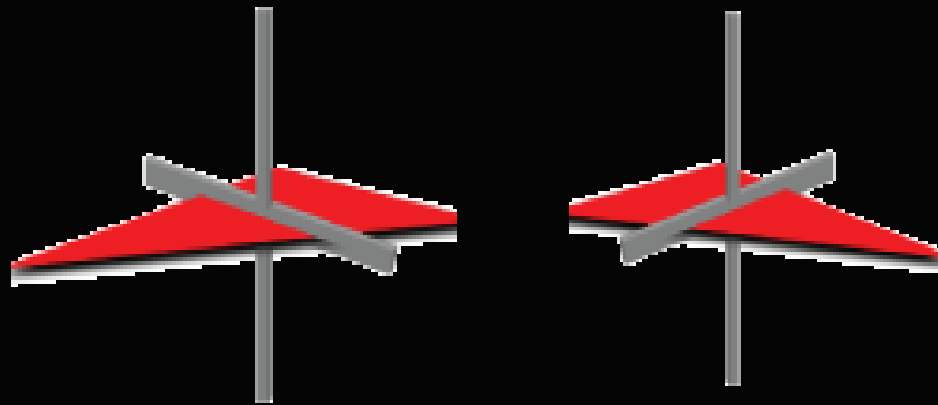
Spatial Navigation



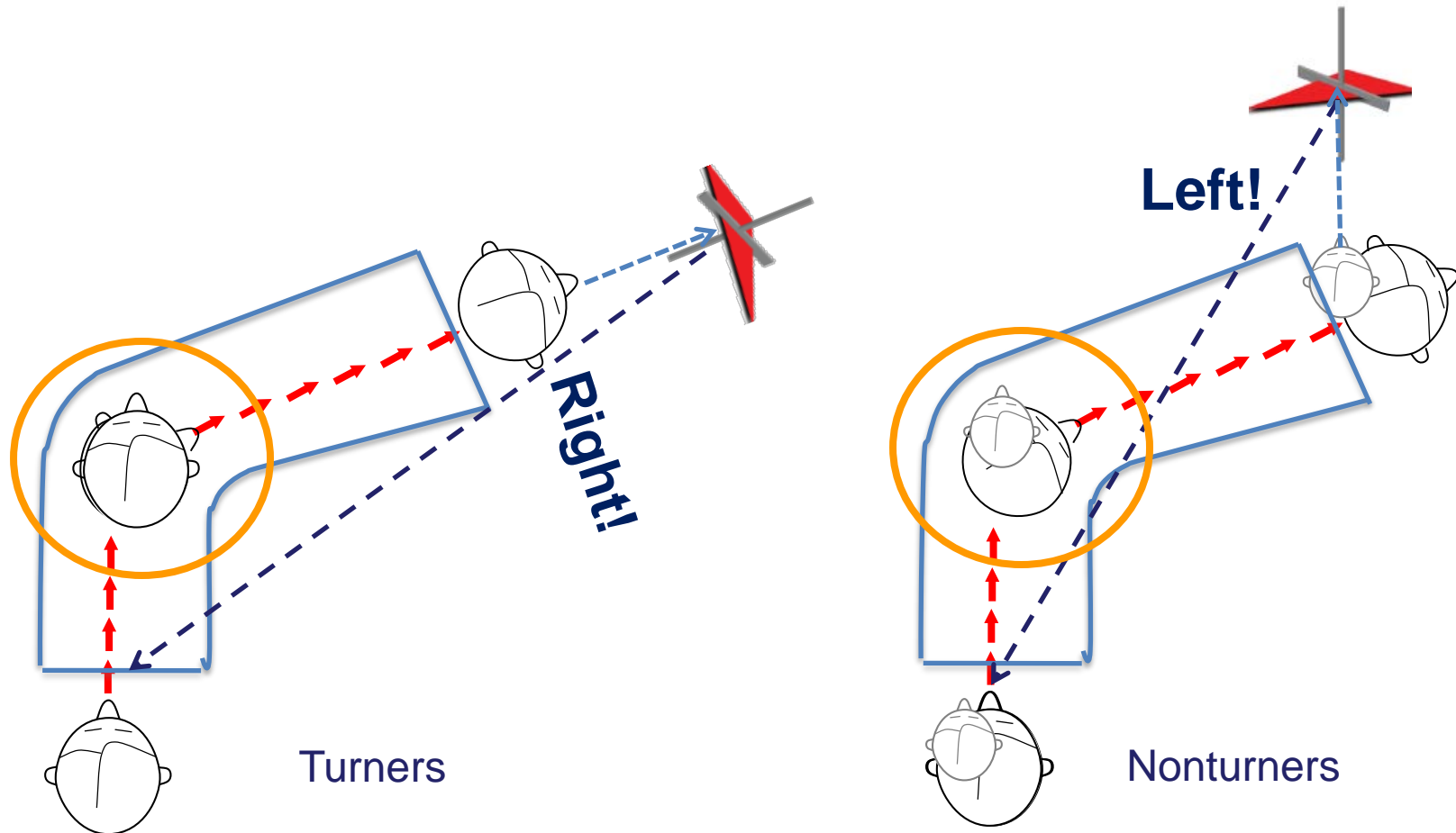
Tunnel Task – A Passive Spatial Navigation Paradigm

Tunnel Task – A Passive Spatial Navigation Paradigm

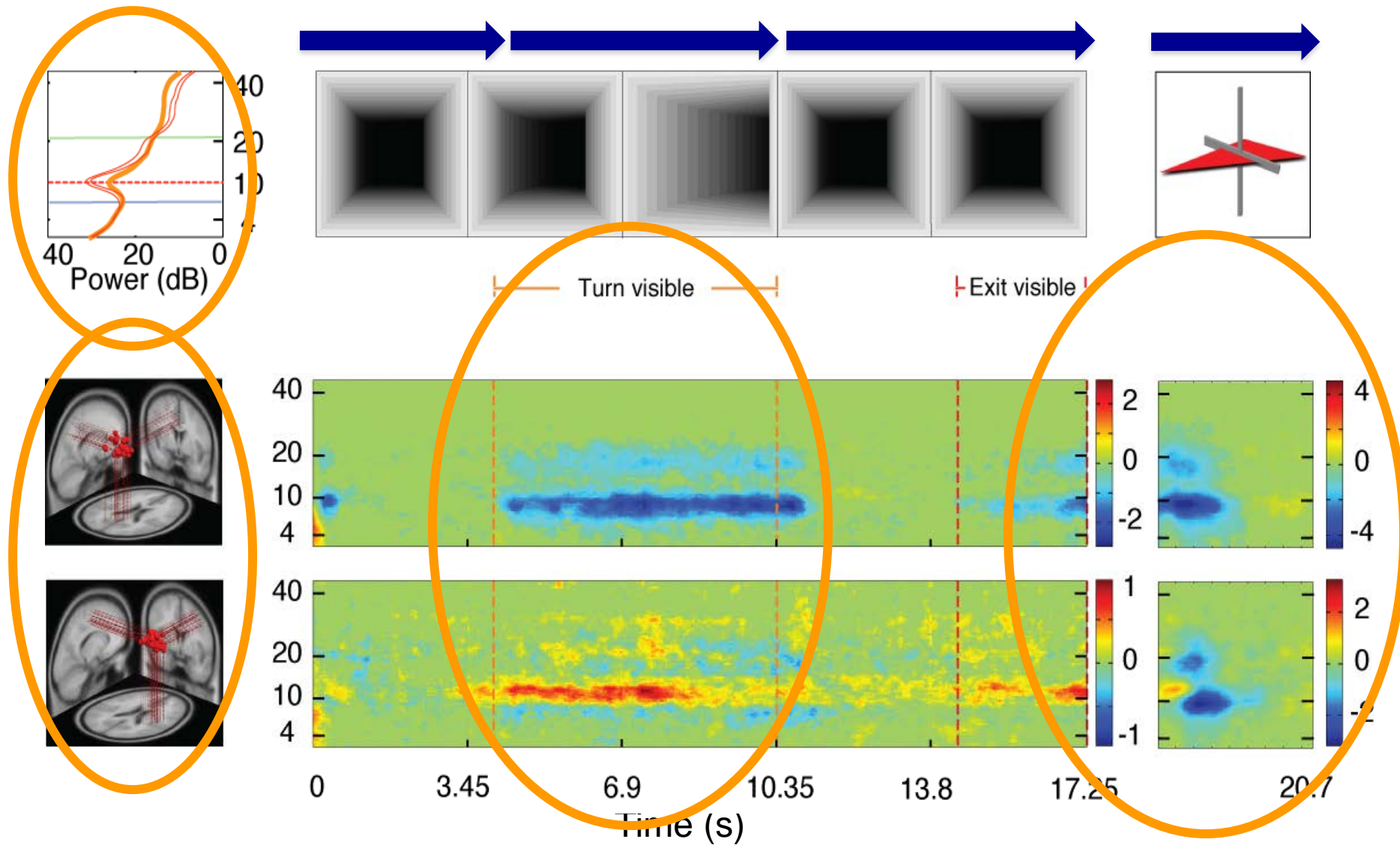
Tunnel Task – A Passive Spatial Navigation Paradigm



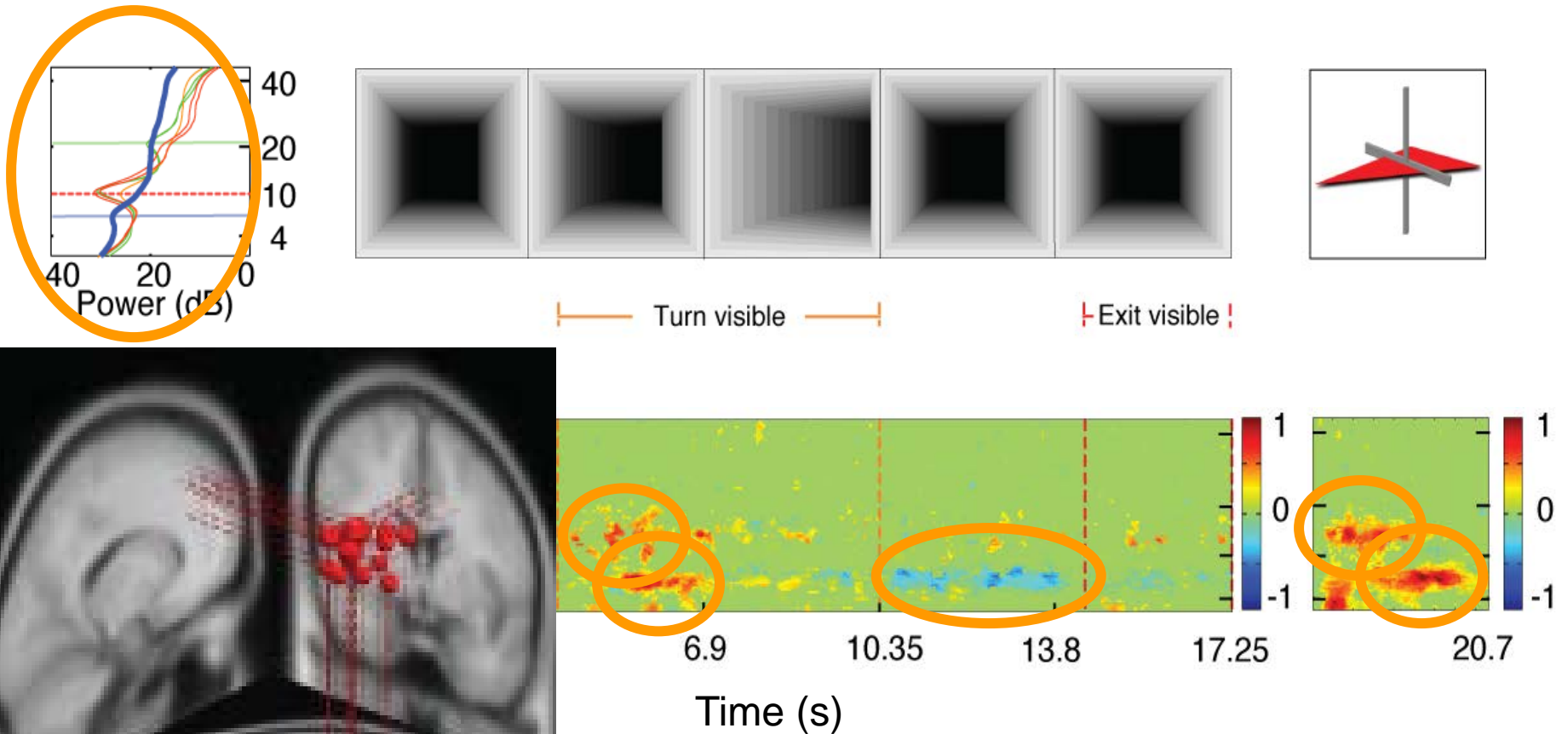
‘Turner’ and ‘Nonturner’ subjects use different spatial orienting styles



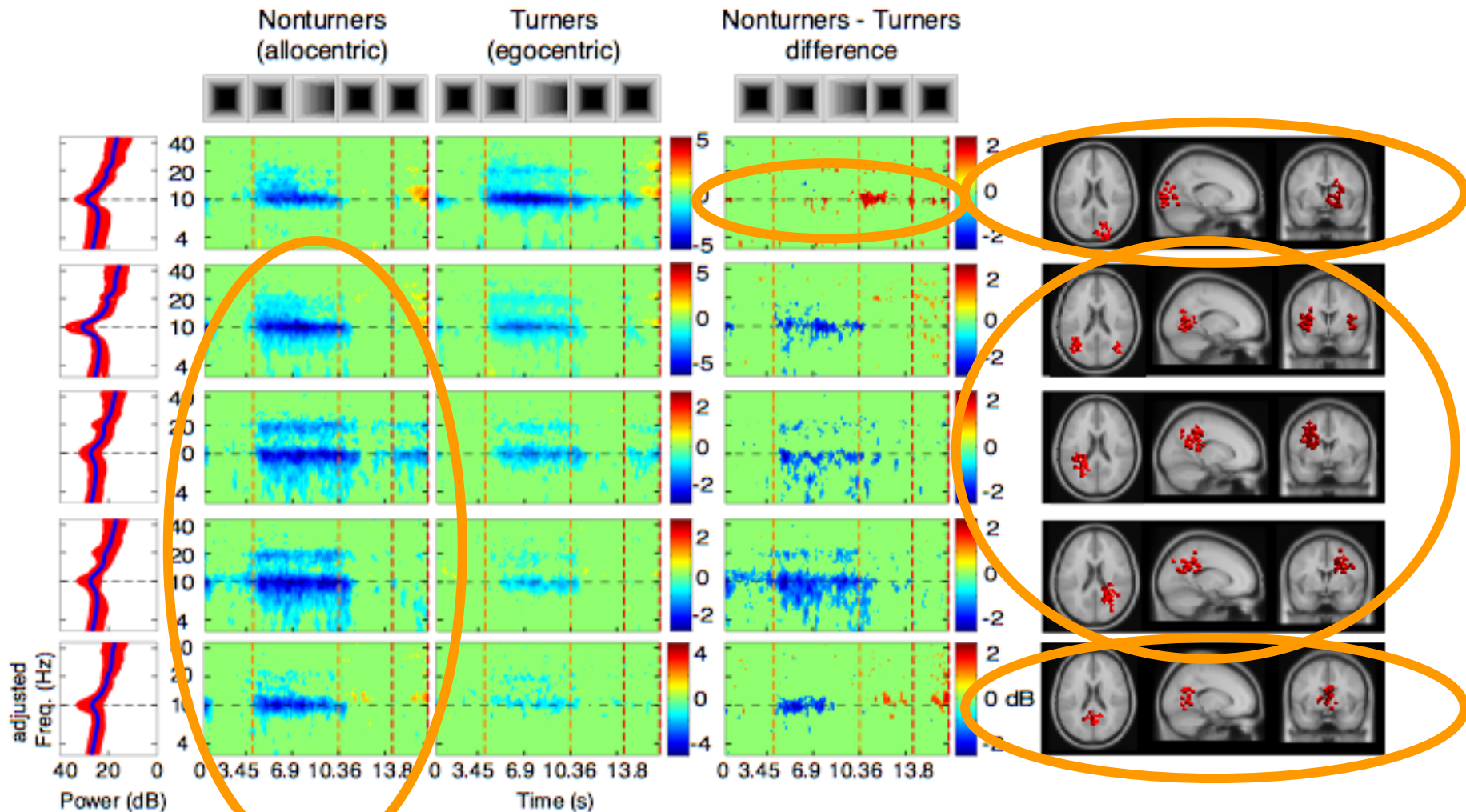
Two parietal component clusters



Medial prefrontal component cluster



Clusters distinguishing Turners & Nonturners



Blind EEG Source Separation by ICA

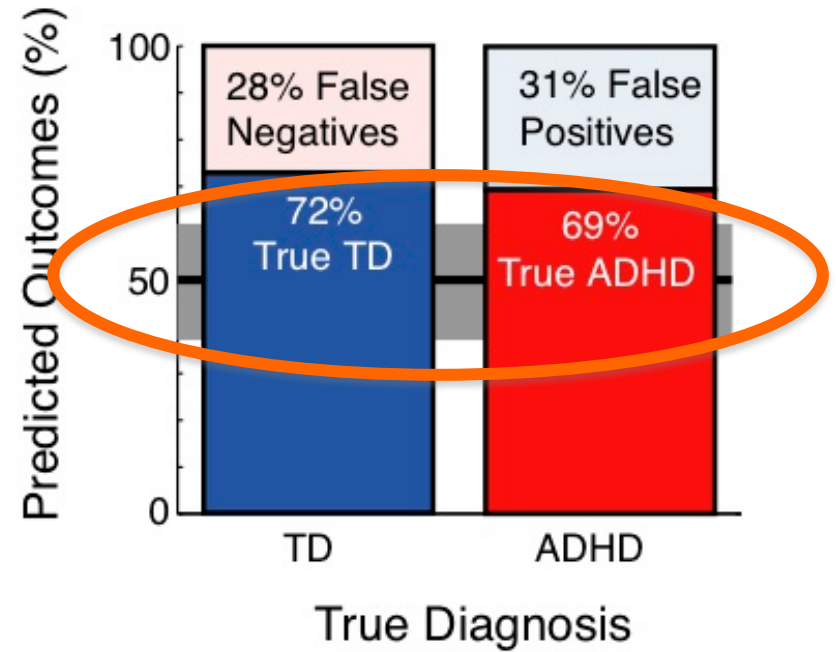
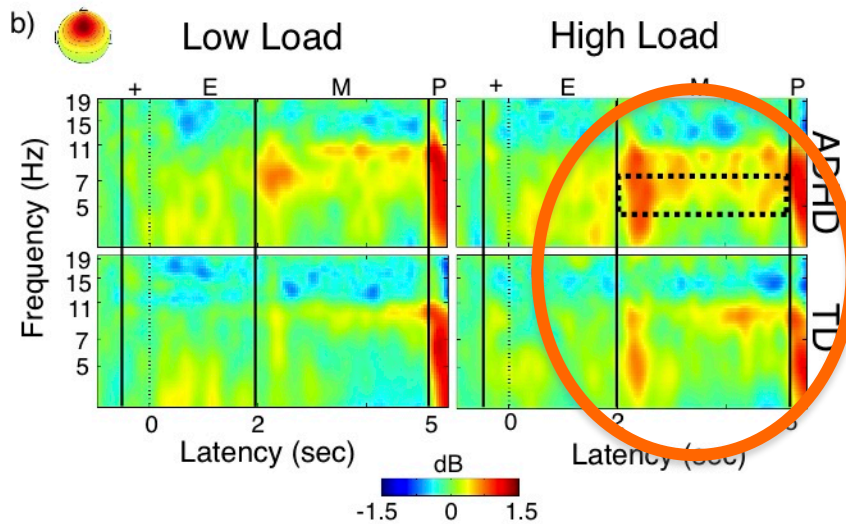
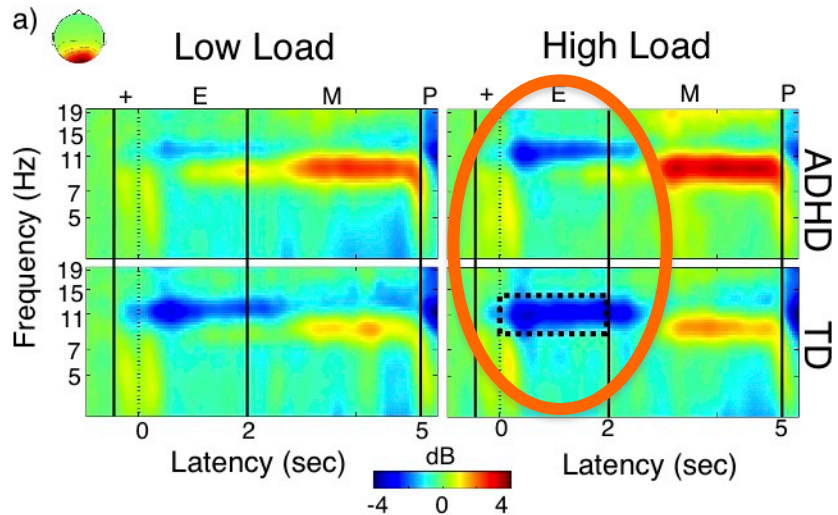
Clinical Research

Data Analysis

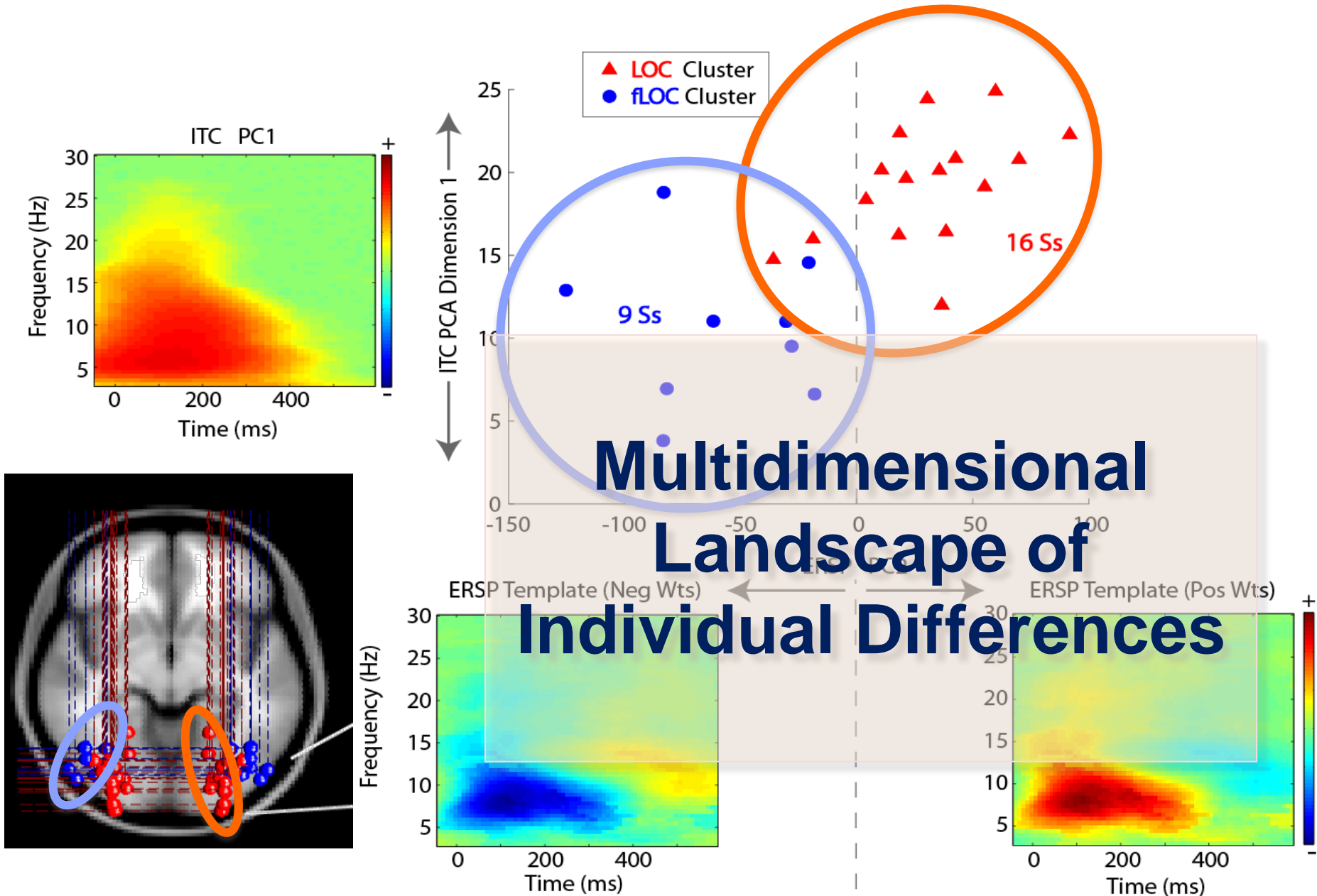


ADHD Working Memory

)



Can ICA reveal subject differences?



Blind EEG Source Separation by ICA

High-Resolution

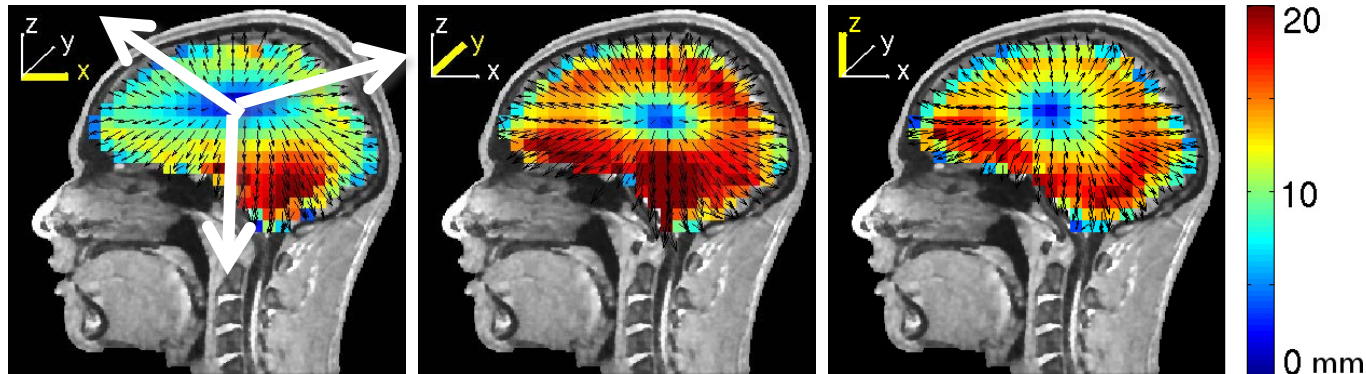
EEG Source Imaging



BSCR
Simulate 25

↑ RLS_{25-4}
↓ RLS_{80-4}

Assume 80

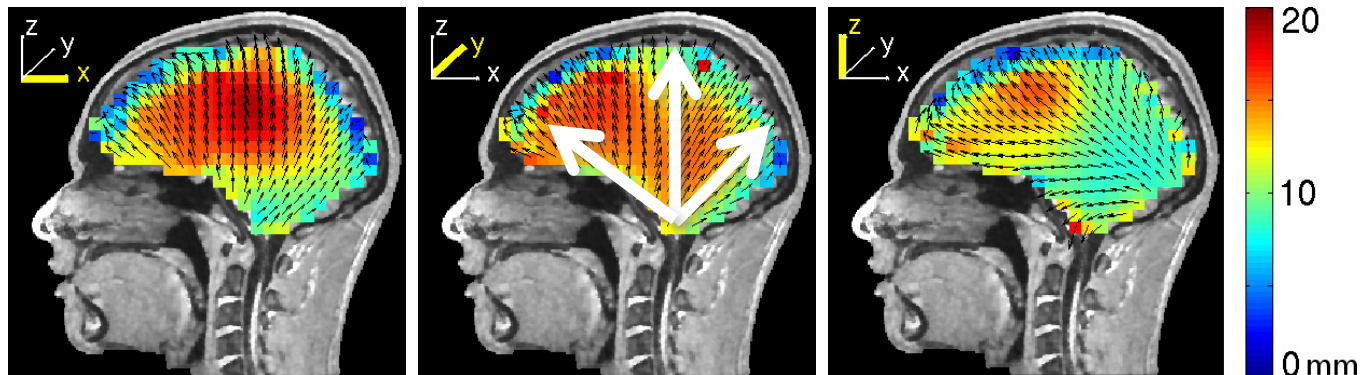


Simulate 25

↑ RLS_{25-4}
↓ $wMNI_{80-4}$

Assume 80

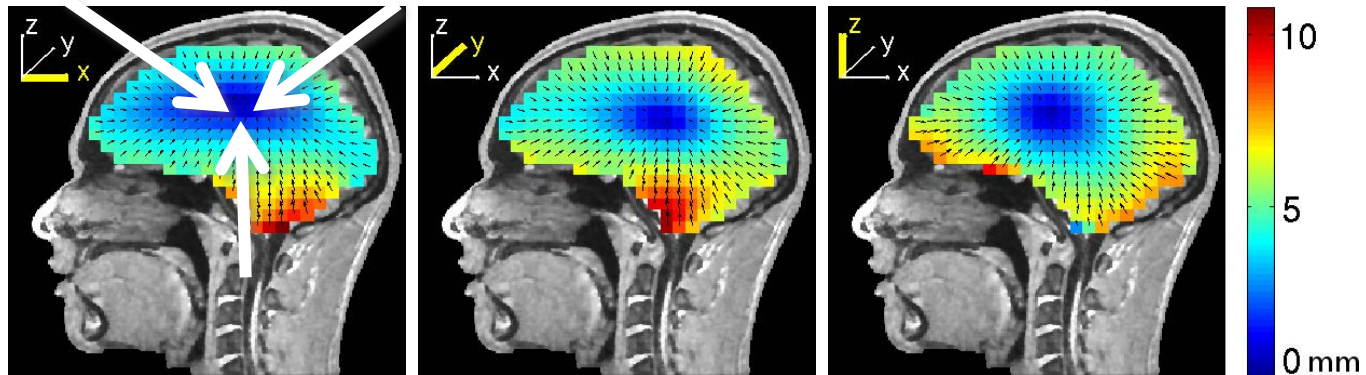
Template head



Simulate 25

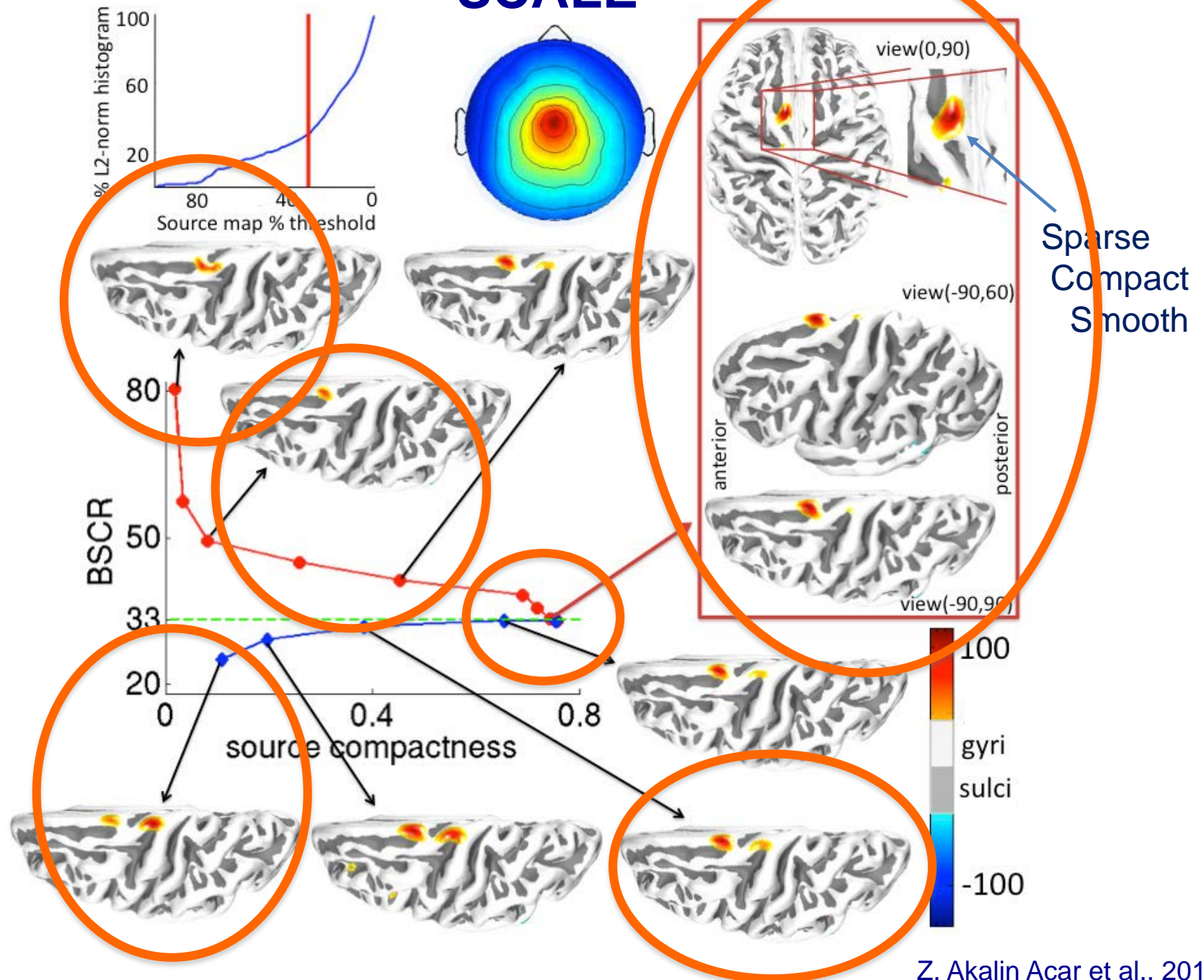
↑ RLS_{25-4}
↓ RLS_{15-4}

Assume 15



Effects of Mis-Estimating Skull Conductivity

SCALE



SCALE-returned BSCR values for 9 subjects

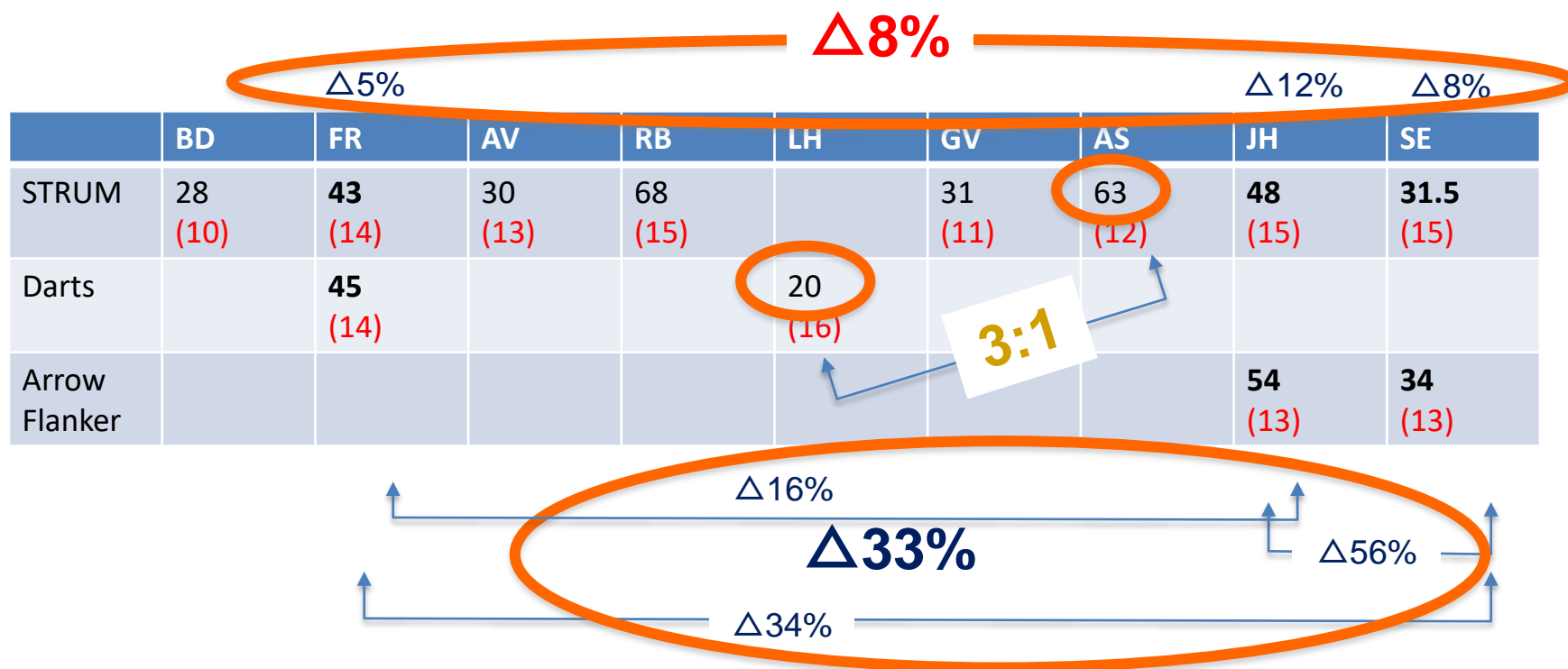
SCALE applied to data from 9 subjects between 18-25 years old. Four-layer head models (scalp, skull, CSF, and brain) were derived from whole head MR images.

Assumed conductivities: Scalp: 0.33S/m, CSF:1.79S/m, Brain: 0.33S/m

The numbers of ICs used to run SCALE are shown in parentheses.

Skull conductivity and *brain source patch distributions* were learned from the data.

Skull conductivities are expressed as Brain/Skull Conductivity Ratio (BSCR):





Brain imaging during movement – How?

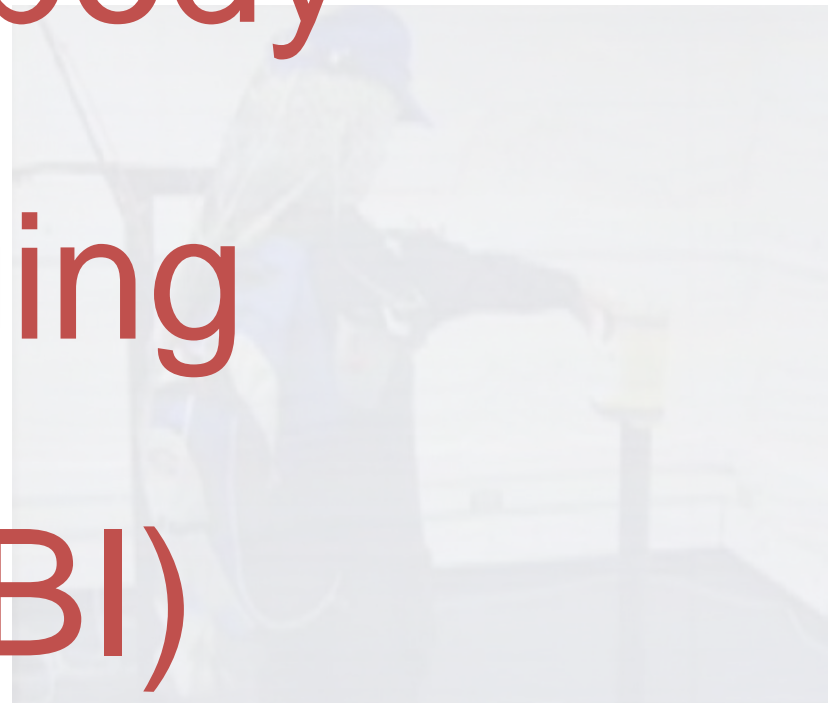
- Current advances in miniaturization, computer power, and information-based signal processing make possible a new imaging modality:

→ **Mobile Brain/Body Imaging (MoBI)**

**Brain/body
Imaging
(MoBI)**

Concept:

Combine whole-head EEG, eye gaze tracking, and whole-body motion capture recording in a real-world 3-D environment.



M
I
C
R
O

MOBI

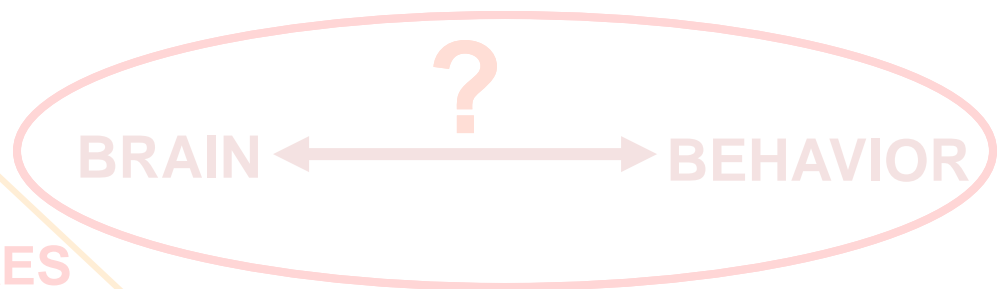
SPIKES

LFP

ECOG

MEG

MAG



Recorded !?

Average



RT

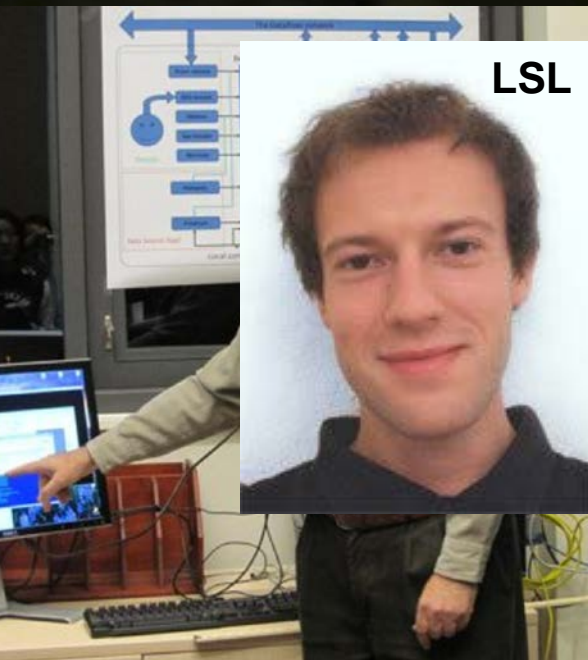
~1 Hz

~1,000,000 GHz

Mobile Brain/Body Imaging

Record what the brain does,
What the brain experiences,
And what the brain organizes.

MoBI Lab at SCCN, UCSD



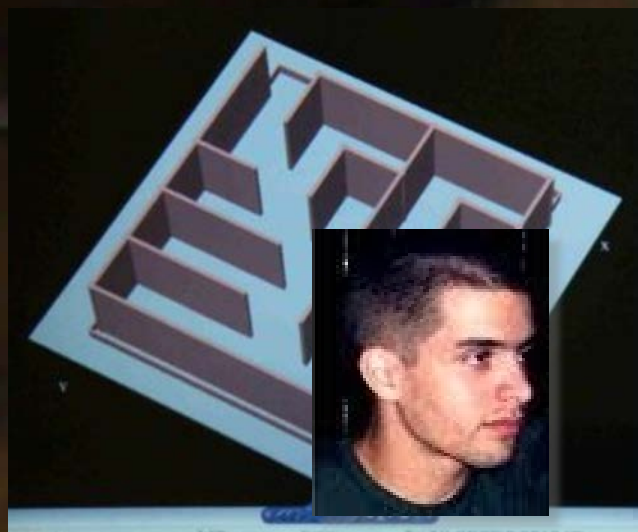
Lab Streaming Layer software for synchronous multi-stream, multi-platform recording and feedback — freely available online (paper in progress):

github.com/labstreaminglayer

Extensible Data Format (xdf) for multimodal data collection and storage.

SNAP — a python-based framework running on Unity for control of simple or complex MoBI experiments.

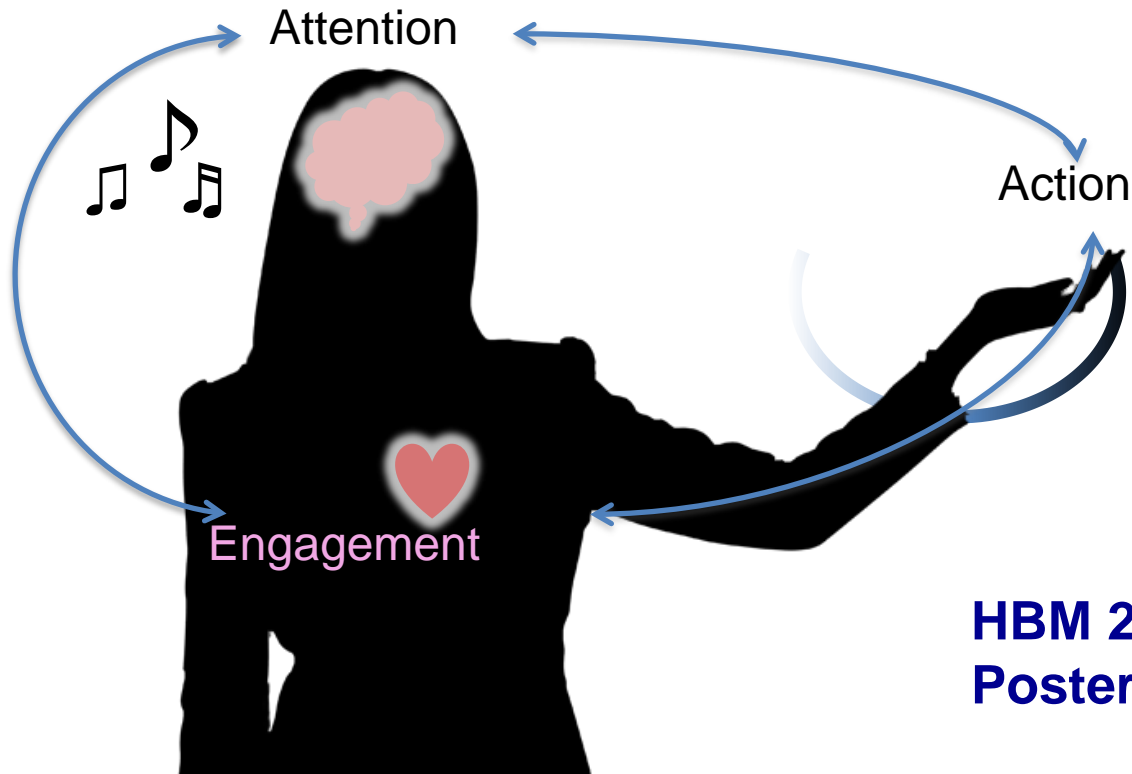
MoBILAB — a Matlab-based multimodal data browser and pre-processing app.





Measuring Musical Engagement Through Expressive Rhythm

How can we measure listeners' engagement?

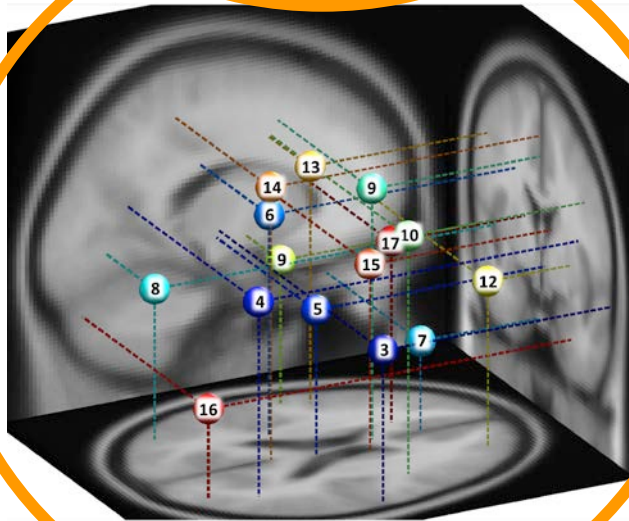
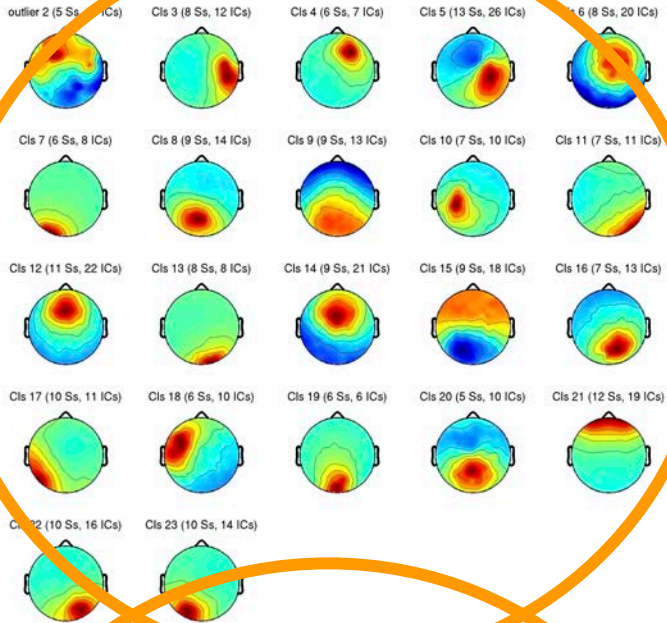


HBM 2014
Poster #1538 online

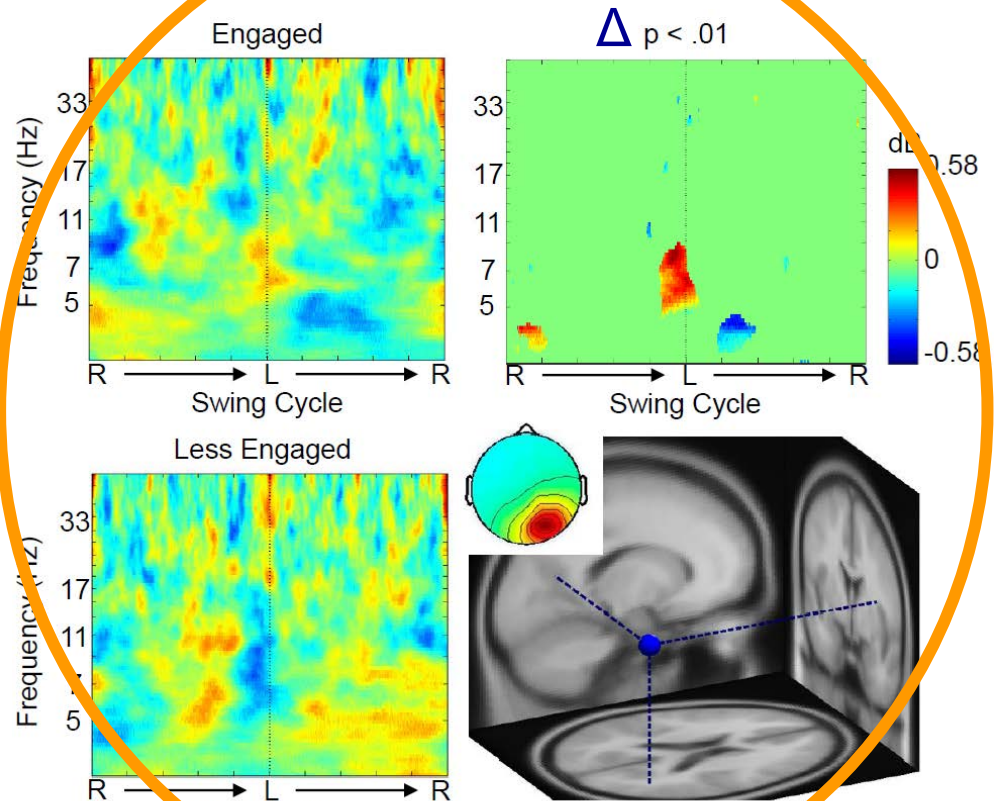
EEG Result

Right TPJ

- Theory of Mind
- Sense of Agency
- both Action & Emotion Inhibition

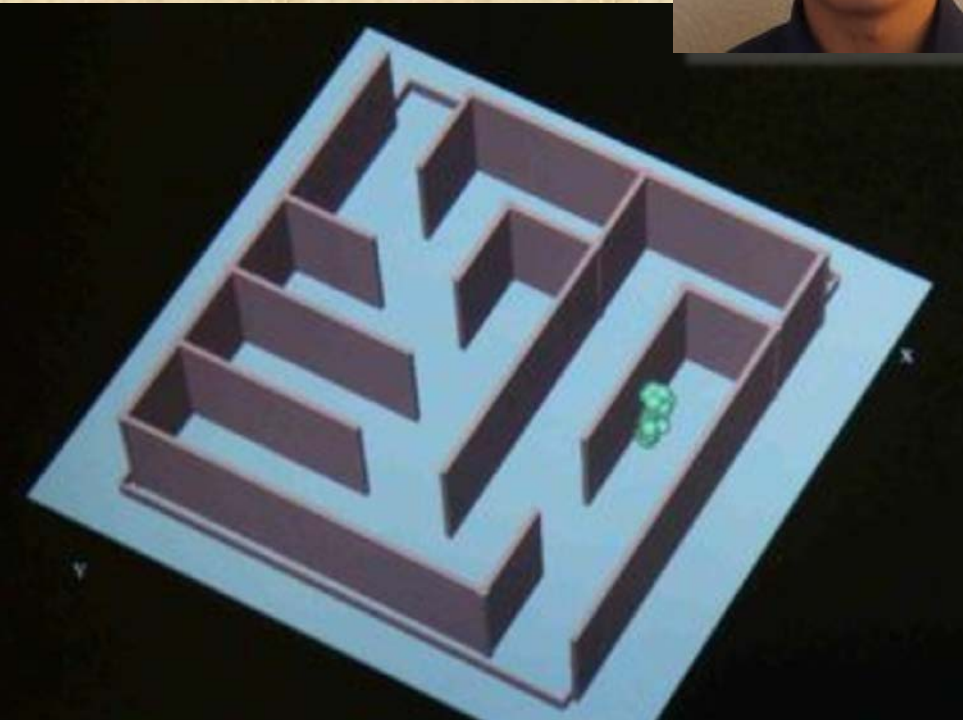
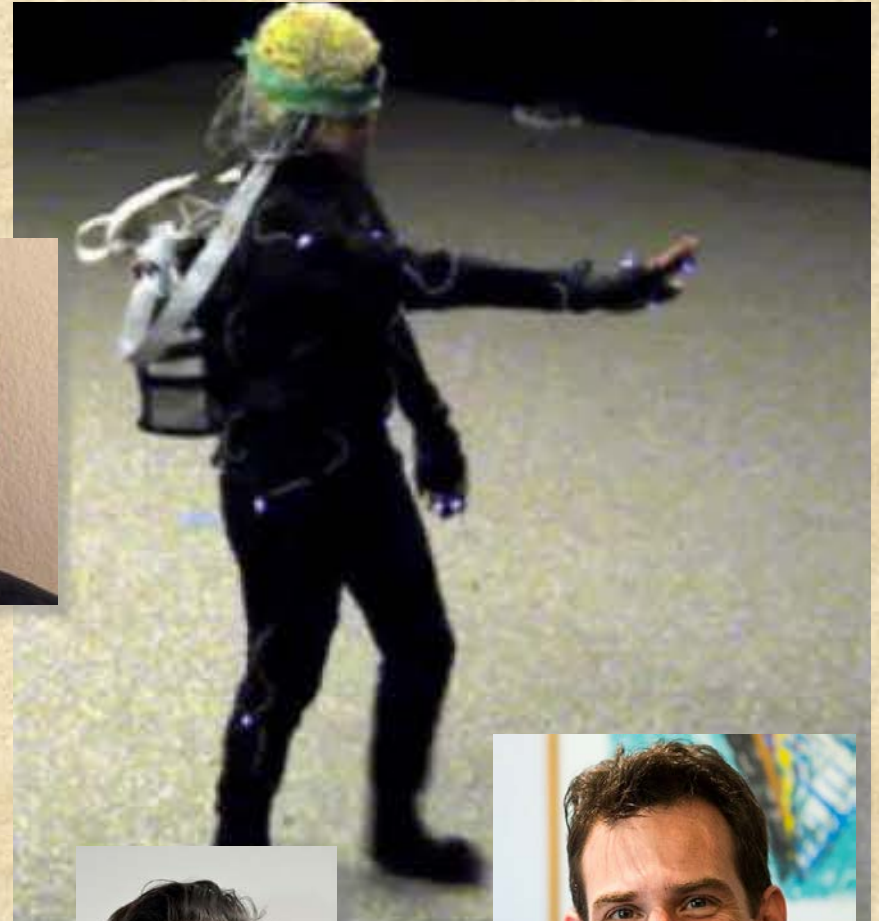
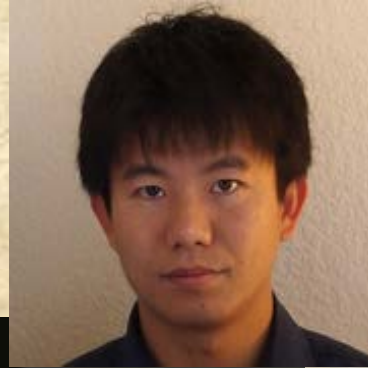


Frequency (Hz)

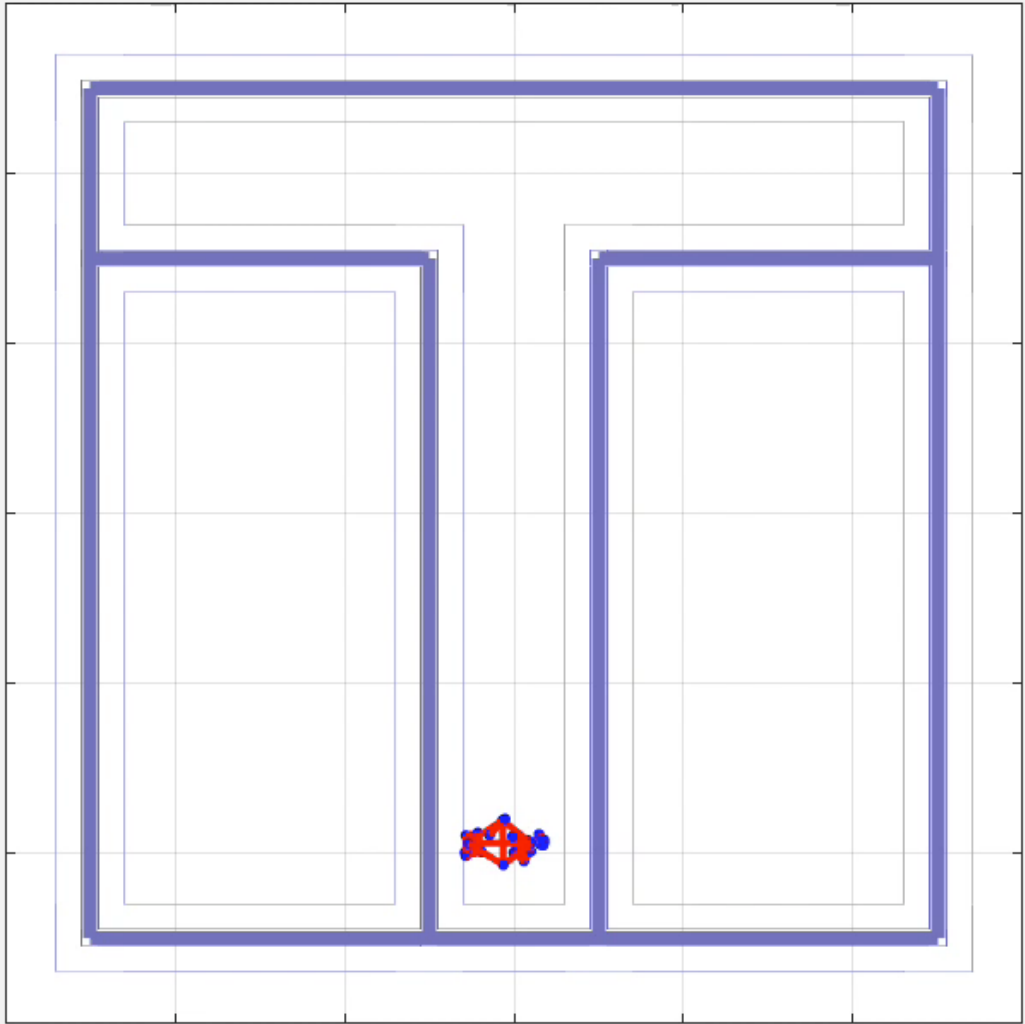


Swing Cycle

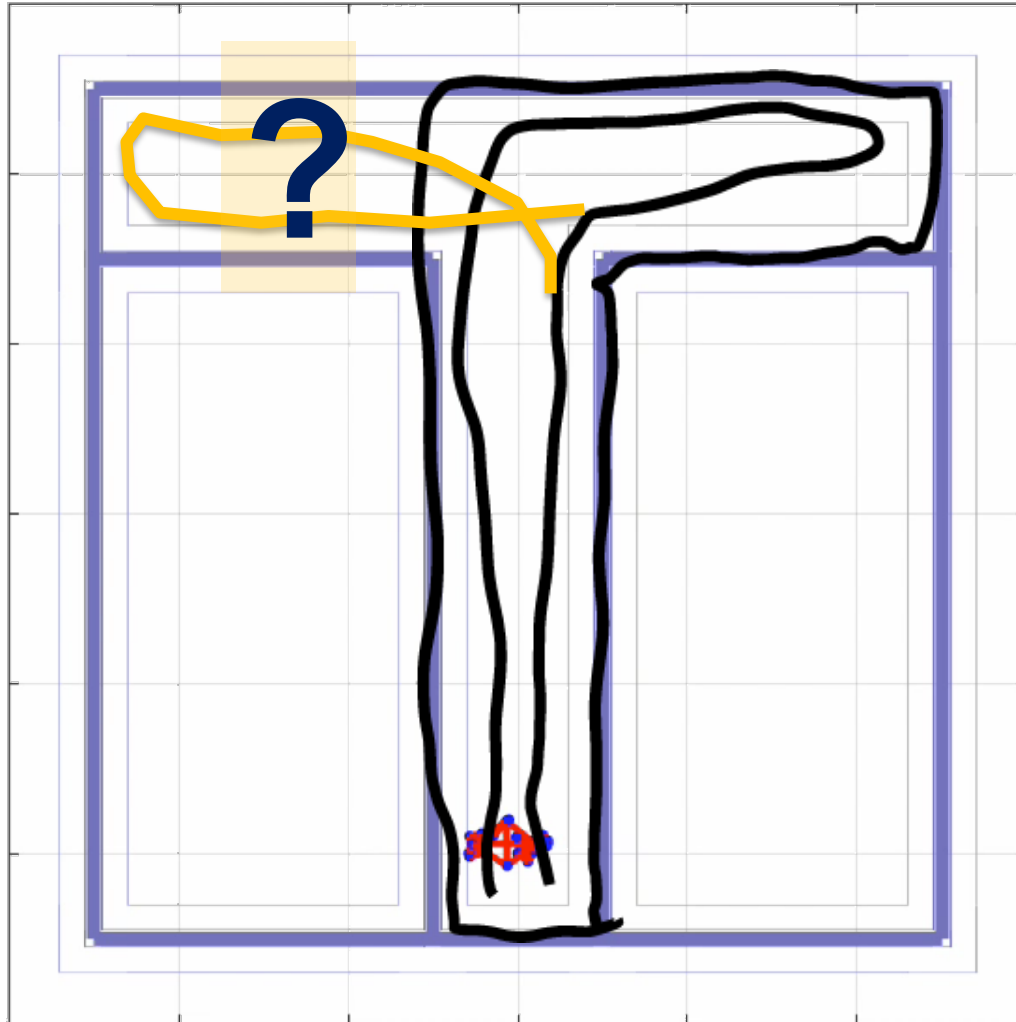
Spatial Navigation Experiment – the *Audiomaze*



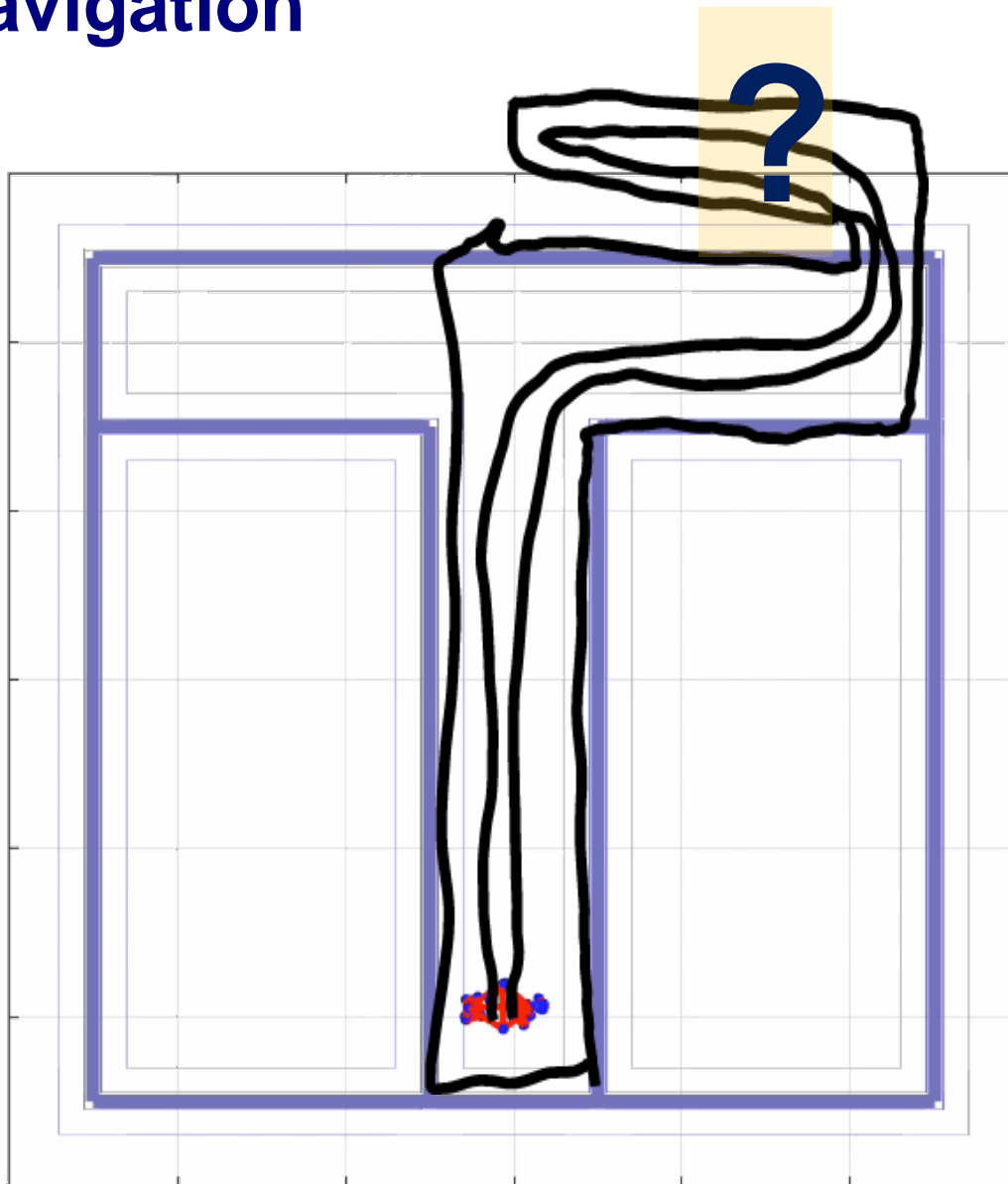
1st Pass Navigation



1st Pass Navigation

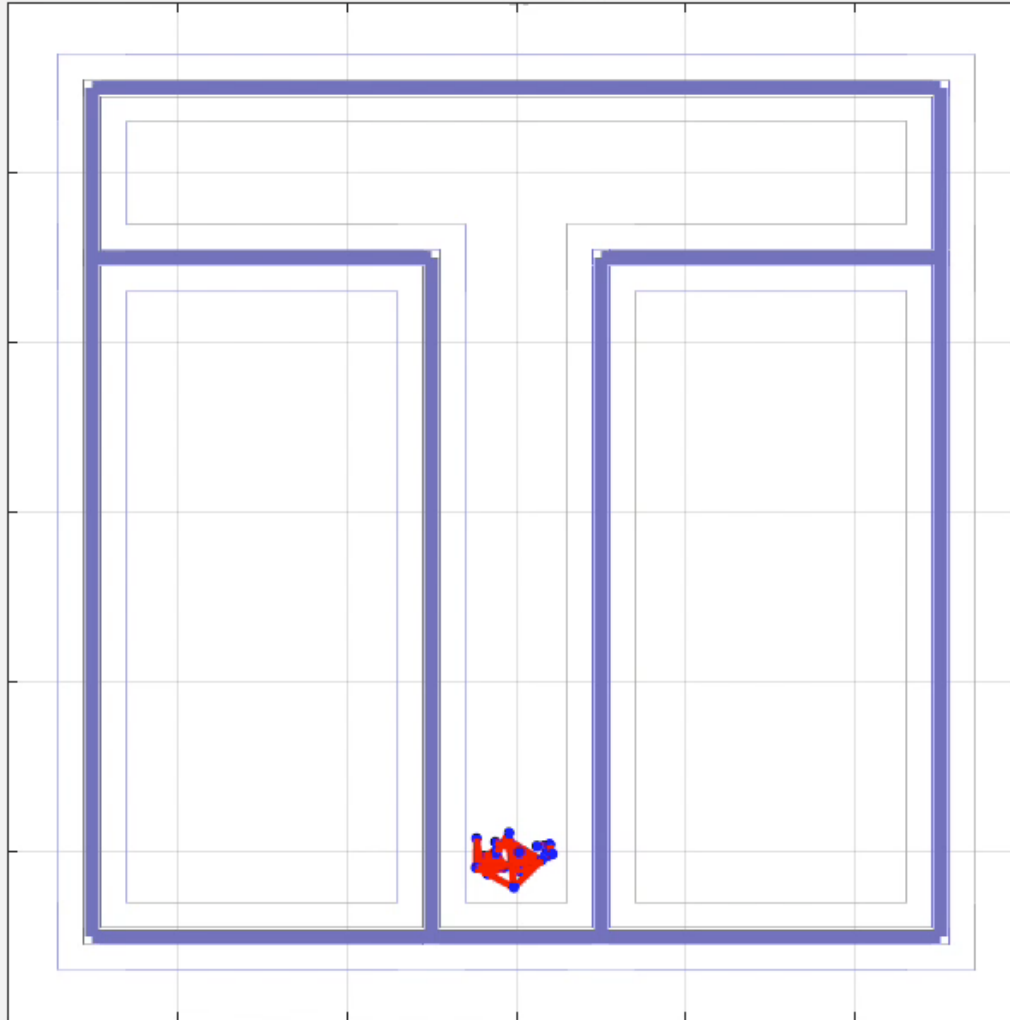


2nd Pass Navigation

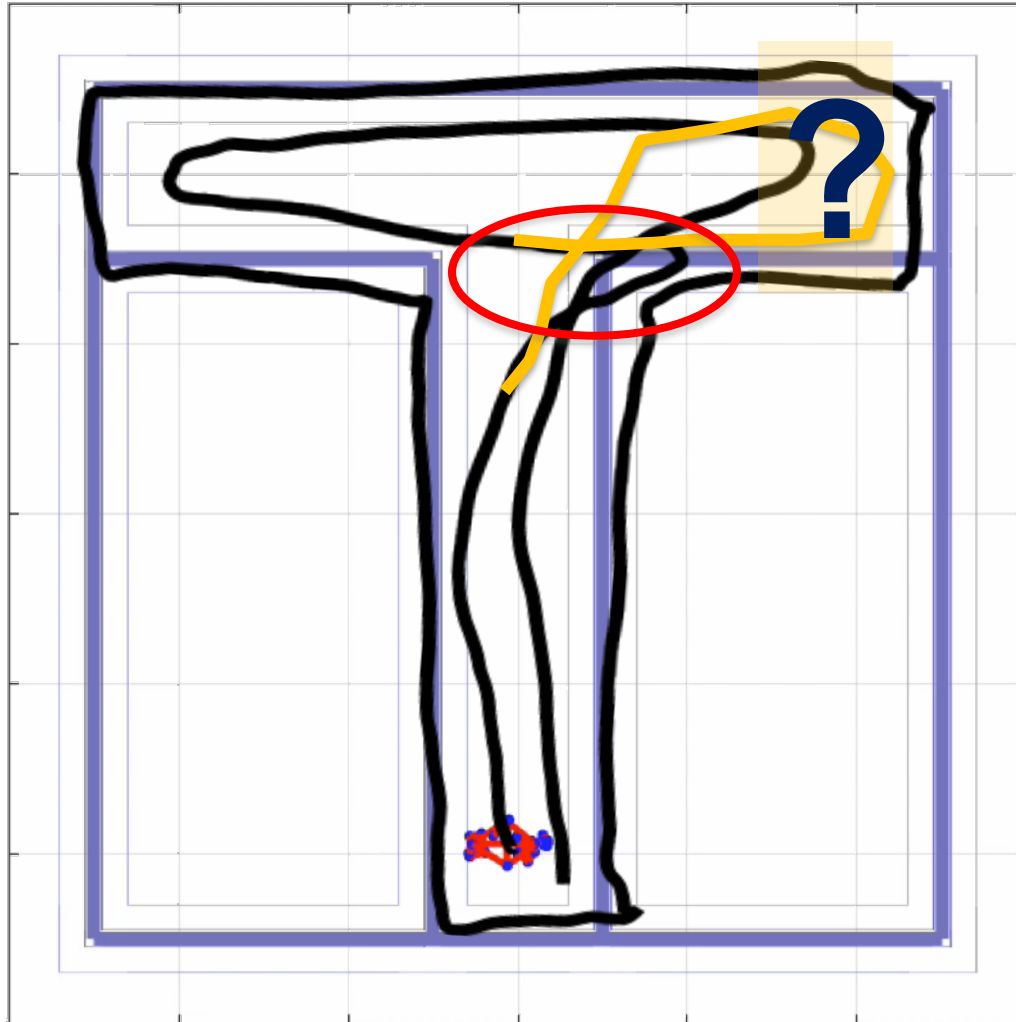


3rd Pass Navigation

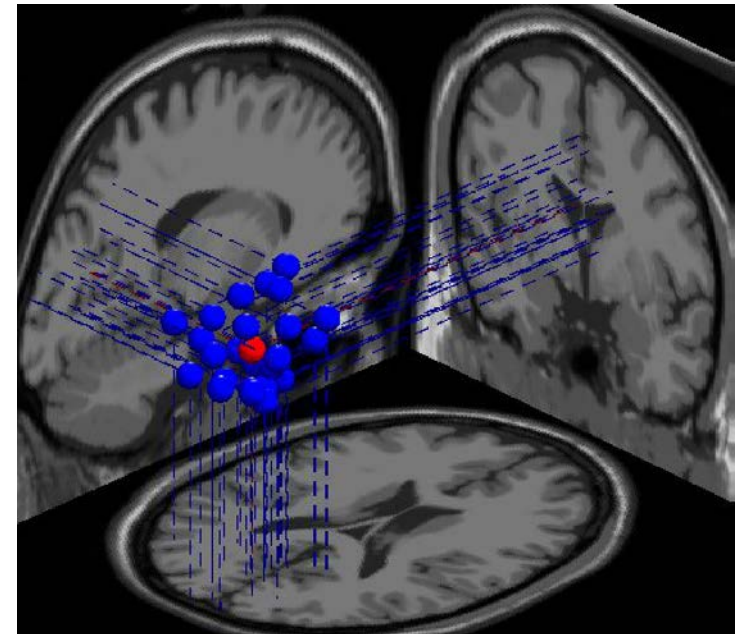
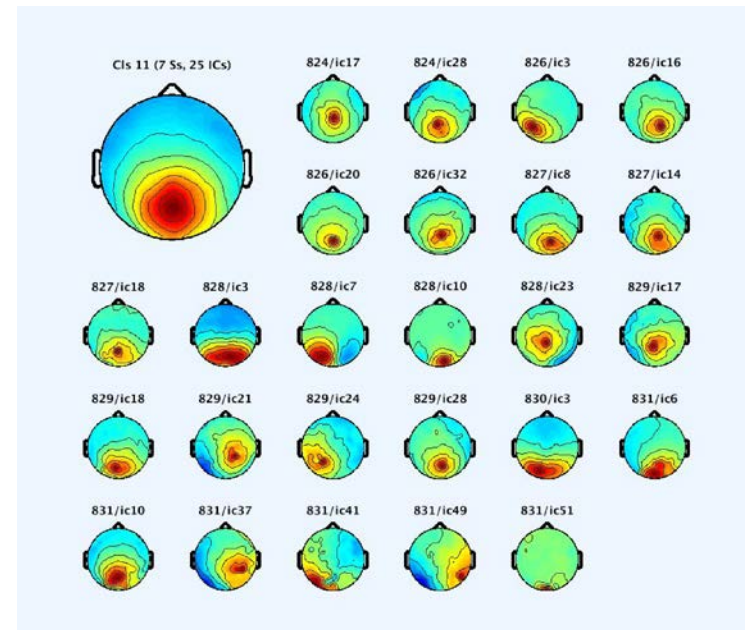
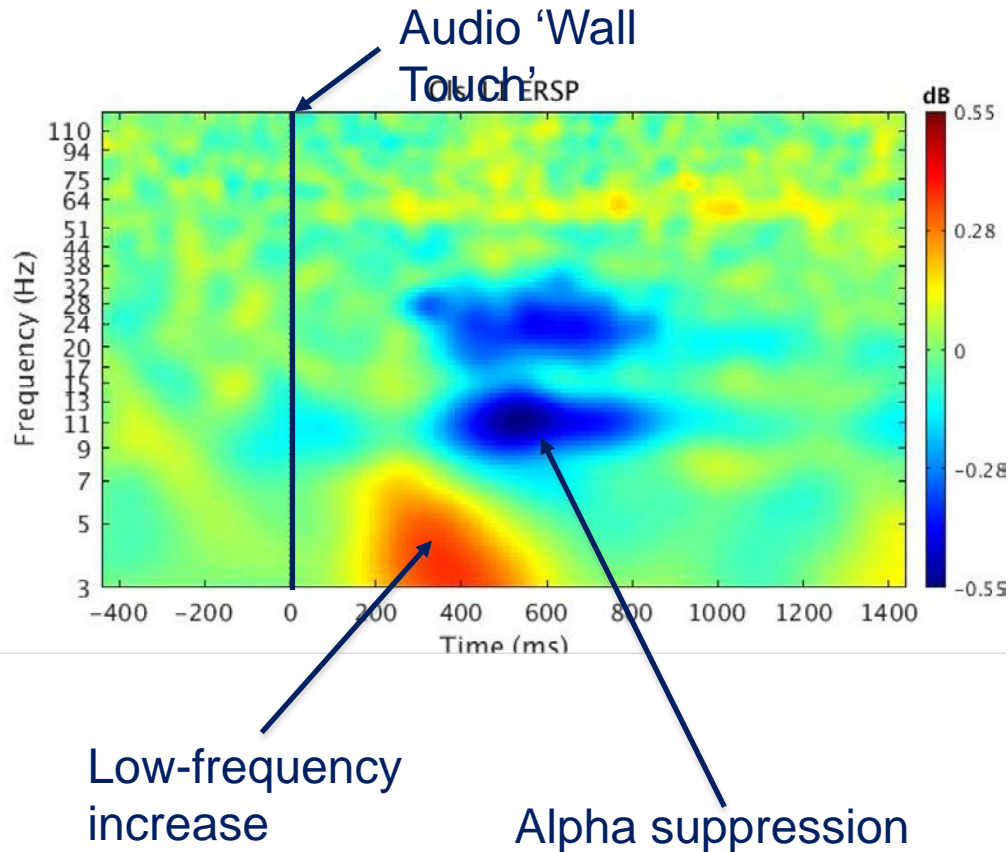
Run 3 2.5

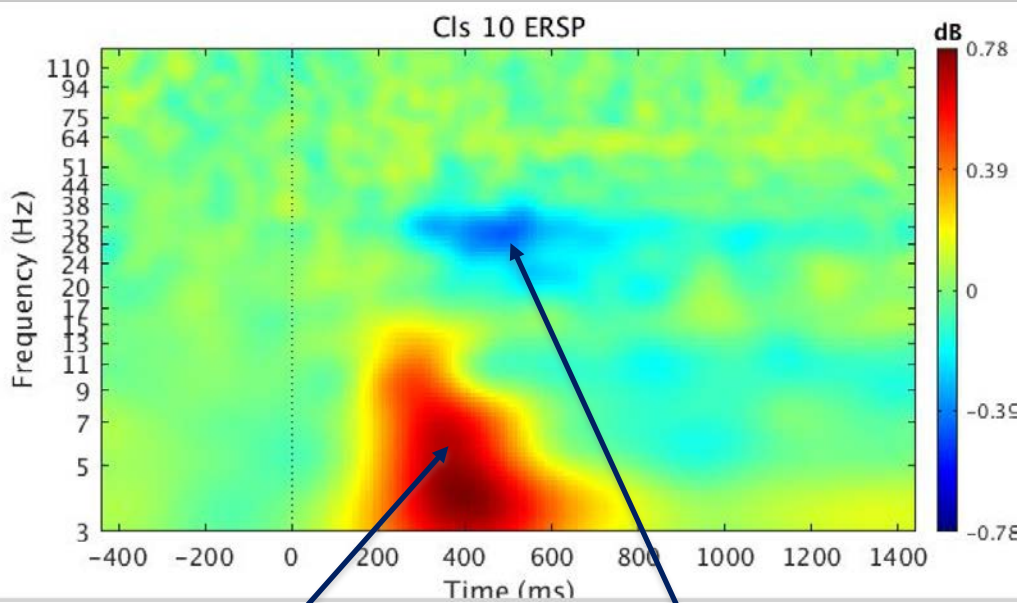


3rd Pass Navigation



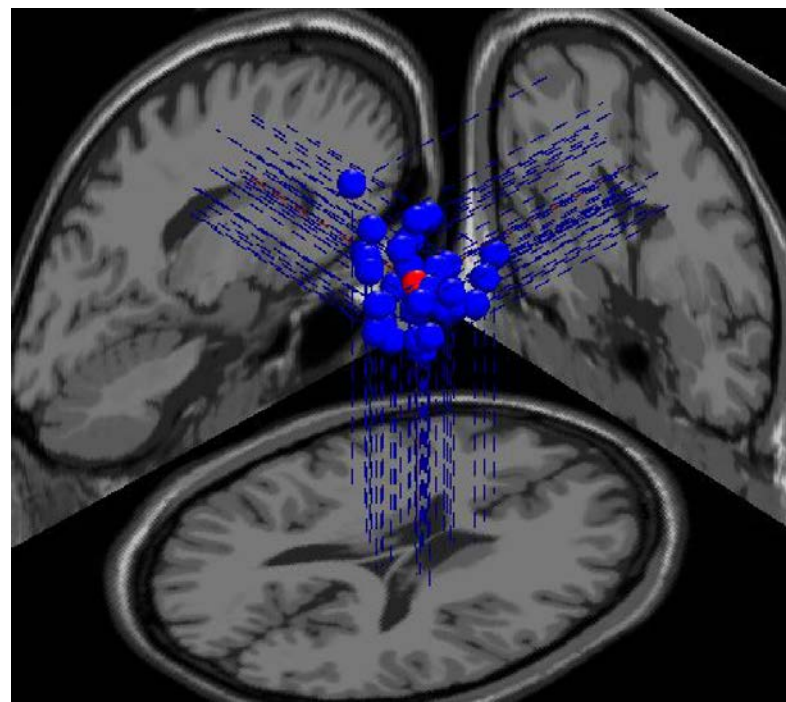
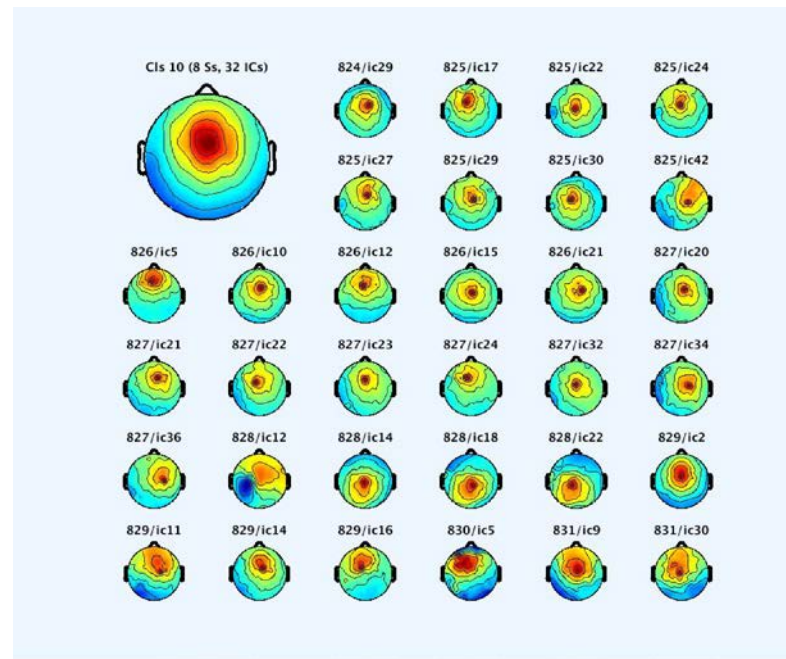
Central Posterior Independent Component Effective Source Cluster





Alpha/theta increase

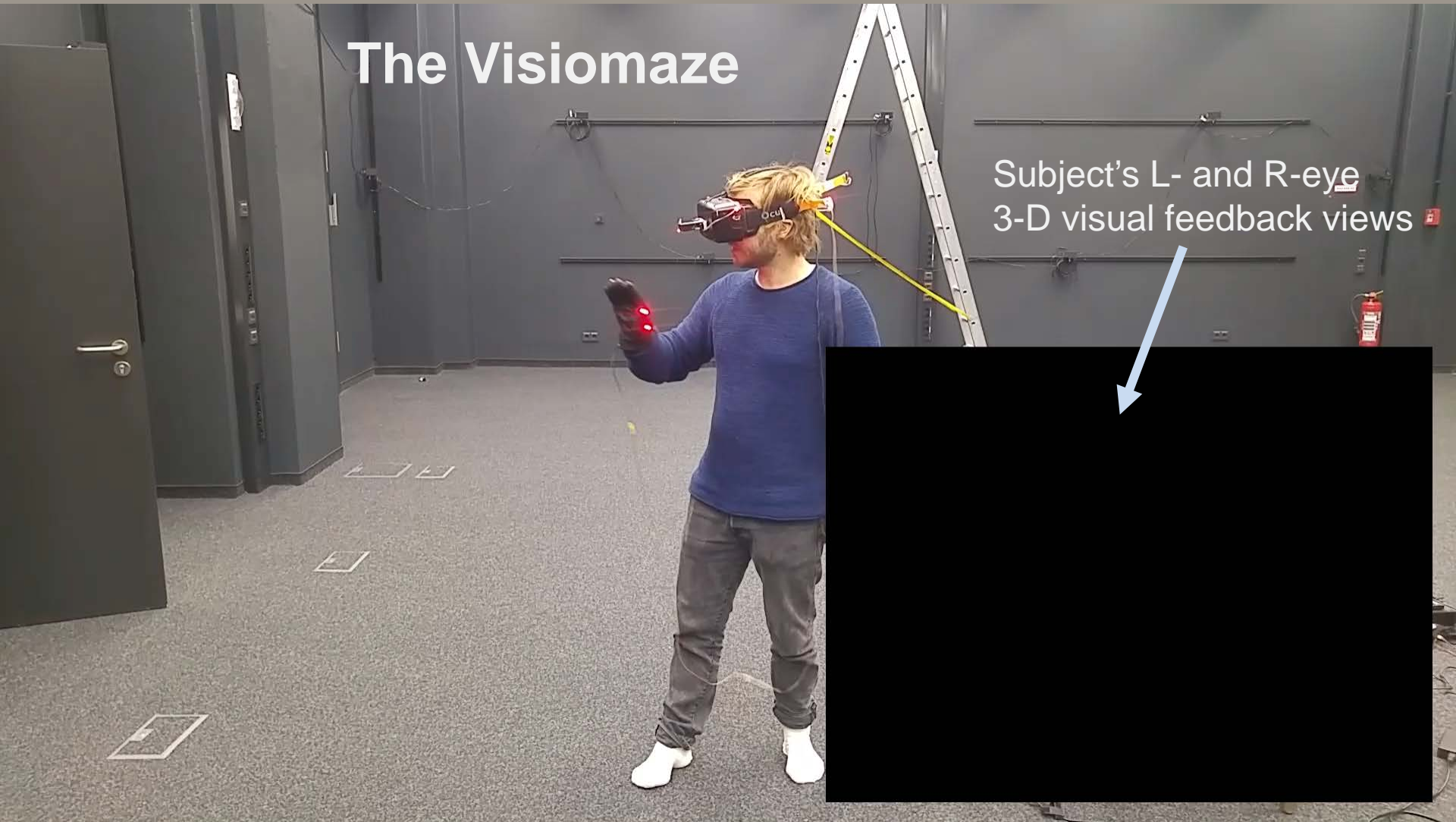
High beta suppression



Biological Psychology and Neuroergonomics Lab
of Klaus Gramann
@ Berlin Technical University

The Visiomaze

Subject's L- and R-eye
3-D visual feedback views





DEPARTMENT OF
**BIOLOGICAL PSYCHOLOGY
AND NEUROERGONOMICS**

Spatial Cognition MoBI Experiment



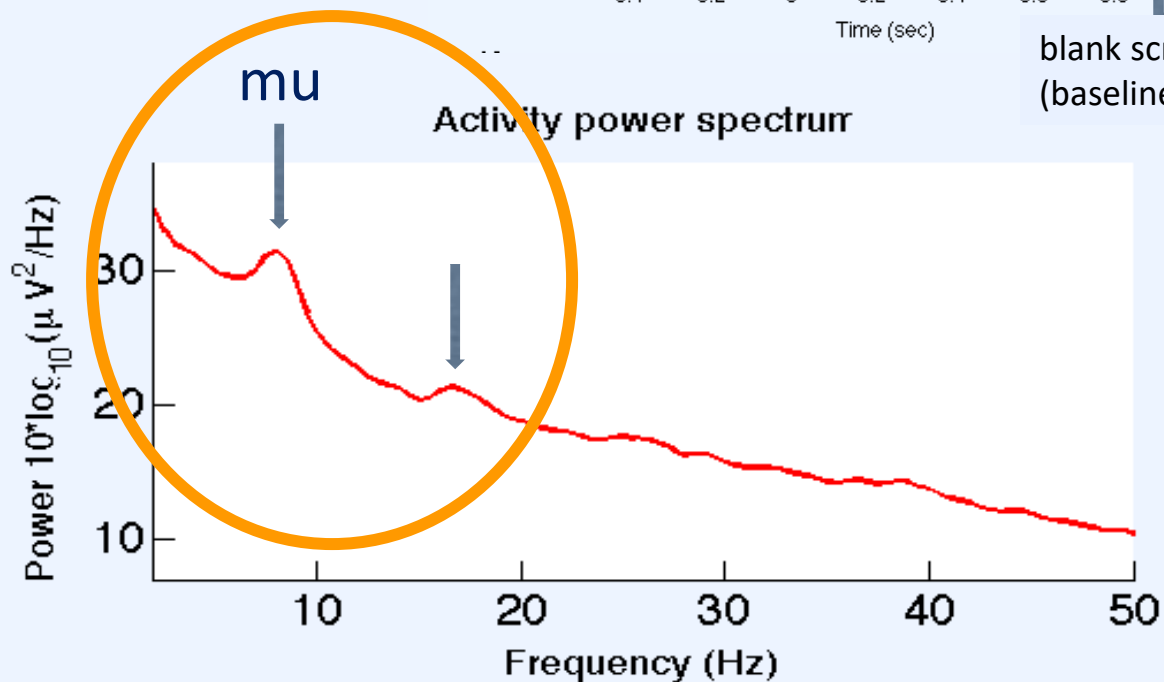
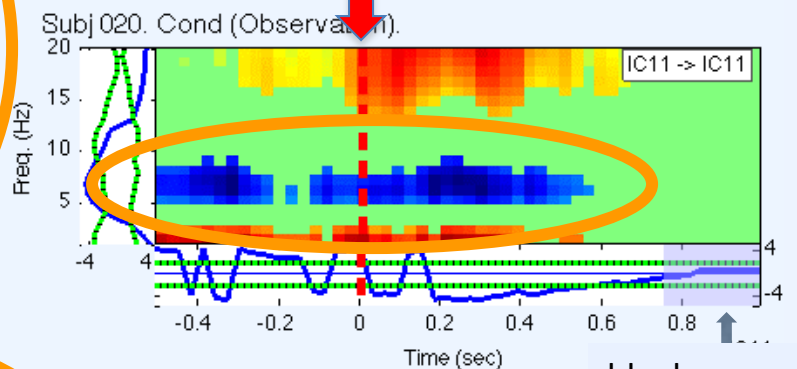
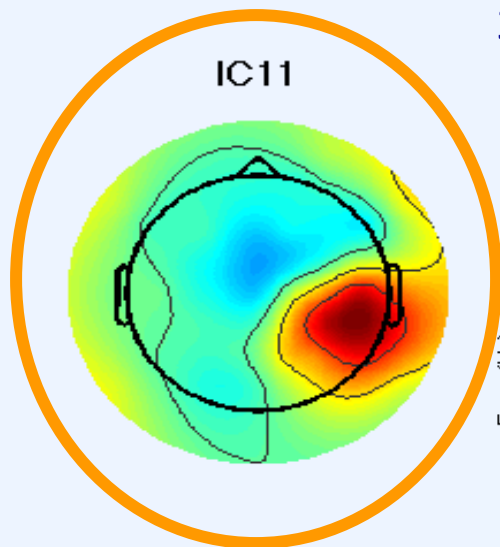
**Imaging Human Agency
and Social Interactions**

Gedeon Deak Lab @ UCSD Cognitive Science
“Development of Shared Attention” –
A Mother and Toddler MoBI Experiment



3-yr old child – Reward Observation

Mother Pops the Bubble!



Now feasible – Low-cost MoBI Systems

Low-Cost MoBI

Any EEG System

< \$500

Emotiv Neuroheadset

< \$500

Kinect motion capture

< \$500

Touchscreen

< \$1000

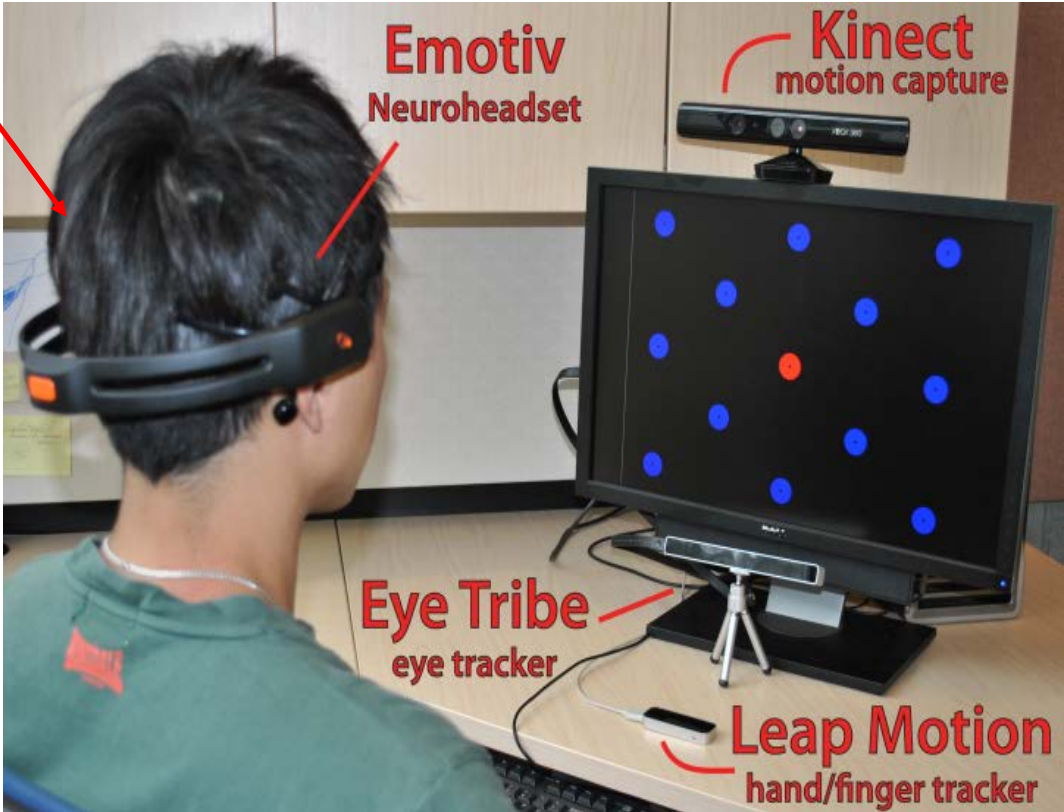
Full Body Wireless Inertial Motion Capture

Eye Tribe eye tracker

< \$100

Leap Motion hand/finger tracker

< \$100



**LSL software drivers exist for all these
(and more) devices**



New EEGLAB Portal project

- 1. Add multimodal data processing capabilities to the core EEGLAB environment** by adding support for joint processing of other time series information collected concurrently with EEG signals including appropriate data preprocessing for several modalities to allow direct comparisons to source-resolved EEG measures. We will also extend the EEGLAB General Linear Model framework to allow hypothesis testing on multimodal data.
- 2. Make available high-performance computing within EEGLAB through the Neuroscience Gateway.** The Neuroscience Gateway (nsgportal.org) now provides public HPC access for eight popular neuroscience software environments. Adding an Open EEGLAB Portal will hasten the development of human 3-D electrophysiological brain imaging, and will also allow researchers to run custom EEGLAB processing pipelines for the first time on collections of datasets for *meta-analysis* purposes.

Embodied Cognition & Agency


Brain processes
have evolved and function
to optimize the outcome
of *behavior*

the brain organizes

in response to

perceived challenges

and opportunities.


evaluation

action *perception*

am

**Brains seize the opportunity
of the moment!**

I?





The Beginning

fEEG, BCI, MoBI,
NFB, BrainStim ...