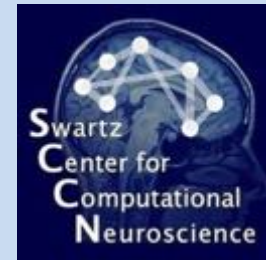


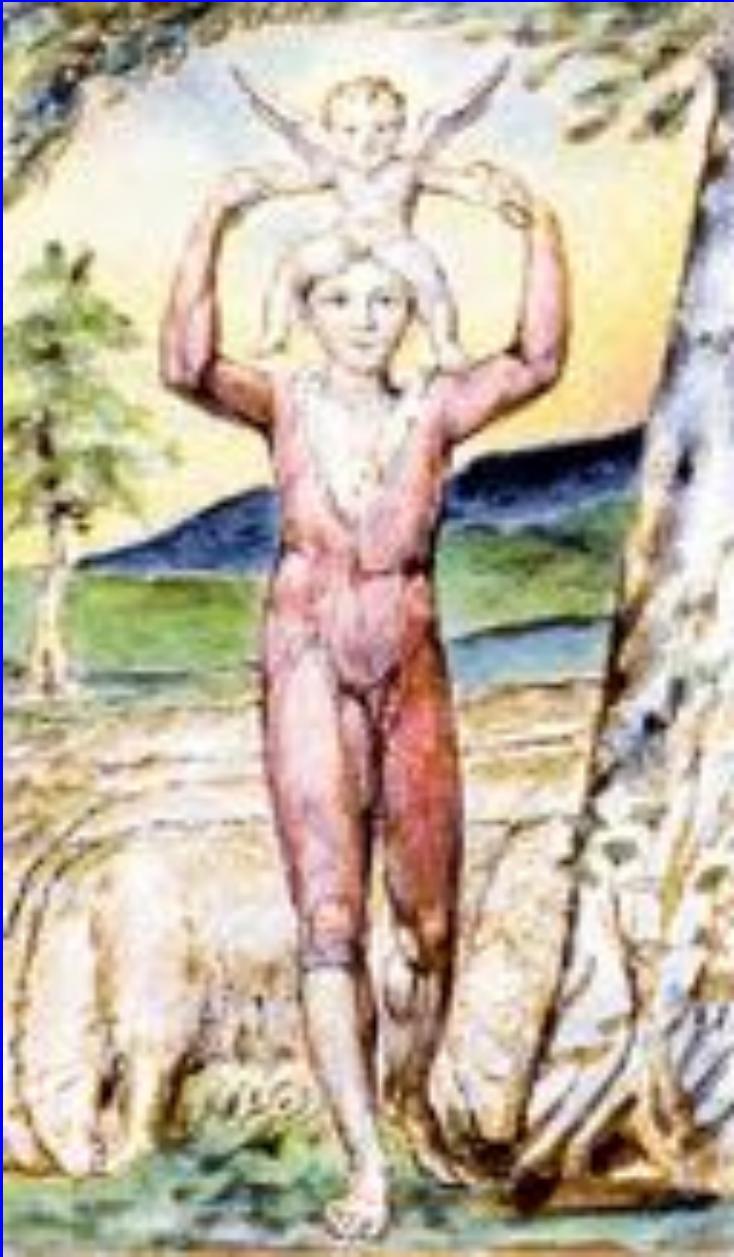
# Mining Event-related Brain Dynamics II



**Scott Makeig**

Institute for Neural Computation  
University of California San Diego

29<sup>th</sup> EEGLAB Workshop  
Bois Perché, Aspet, France  
June 21, 2019





# SCCN Open Source Software Tools

List of data processing extensions

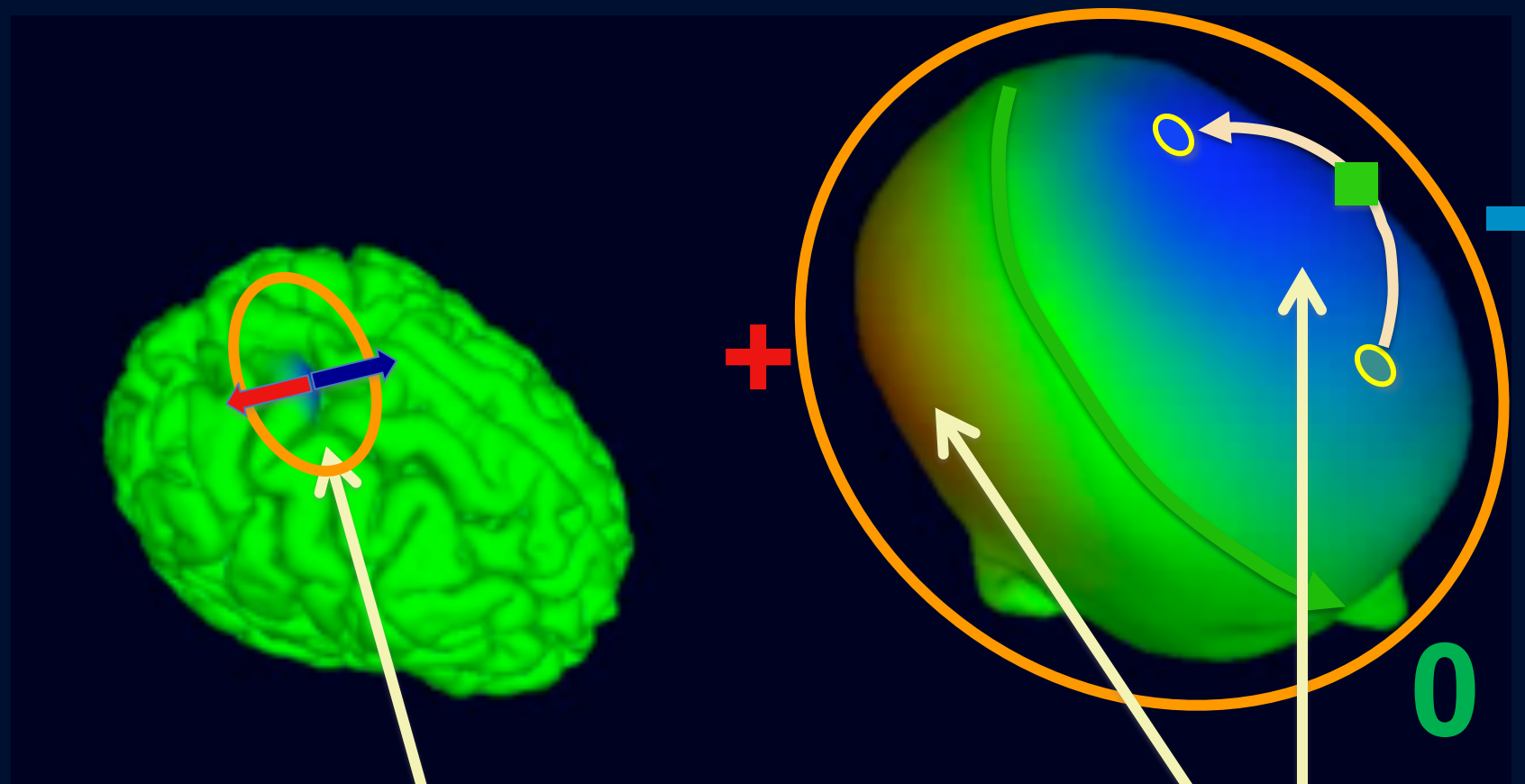
Plug-in name	Version	Short plug-in description	Link	Contact	Comments
<a href="#">rERP</a>	0.4	Estimate overlapping ERPs using multiple regression	<a href="#">Download</a>	<a href="#">M. Burns</a>	<a href="#">User comments</a>
<a href="#">LIMO</a>	1.5	Linear MODElling of EEG data	<a href="#">Download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

Many tools now available -- but still (?) a **multicultural** problem.  
 Psychology.                      Biology.                      Physics/Math.

# What is EEG?

- Brain electrical activity
- A small portion of *cortical* brain electrical activity
- An even smaller portion of *total* brain electrical activity
- **But a *particular* portion.**
- **Triggered and modulated *in complex ways*.**
- **With *not well-understood* functional significance.**

# The very broad EEG point-spread function

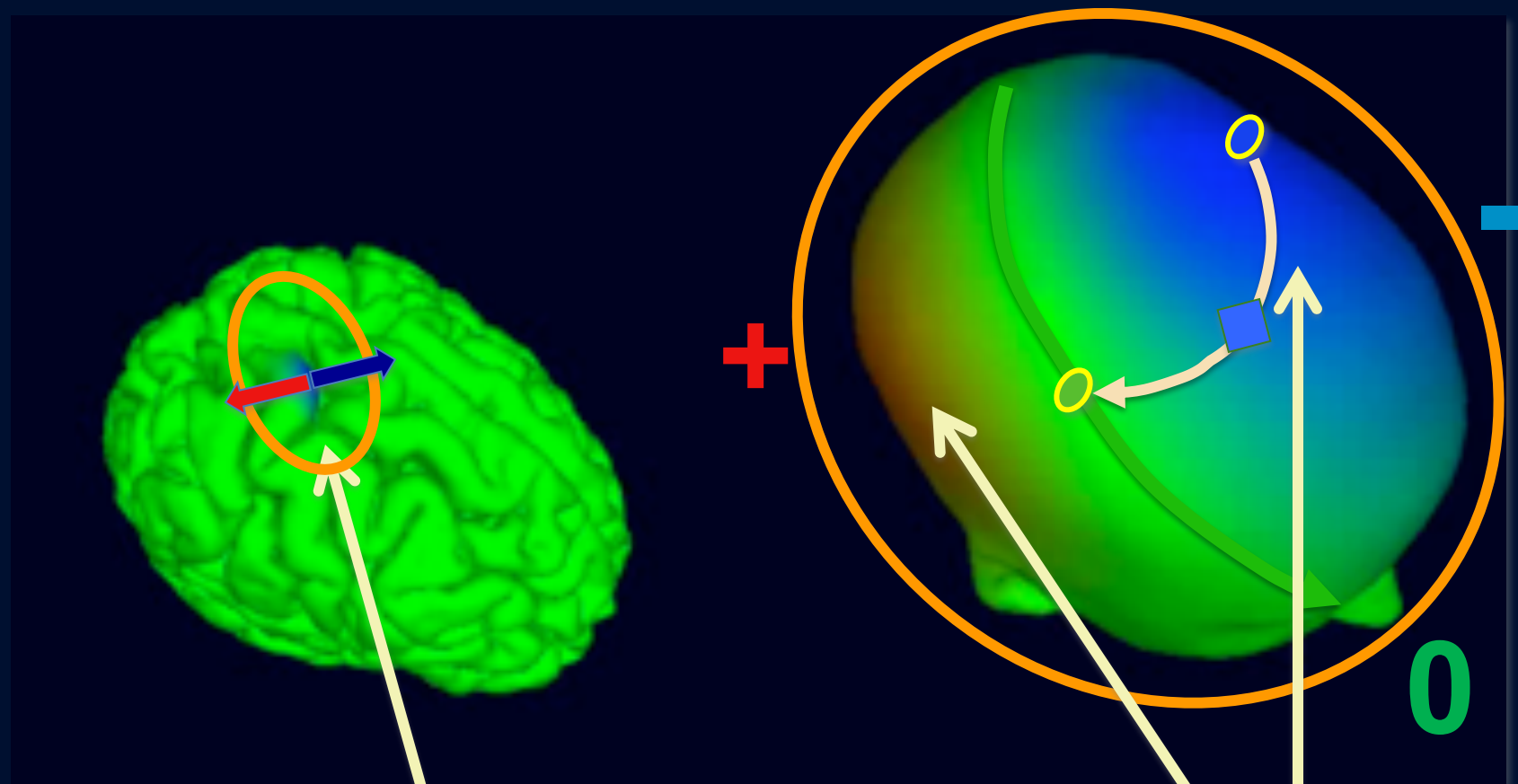


Single simulated parietal source →

Very broad projected scalp potentials



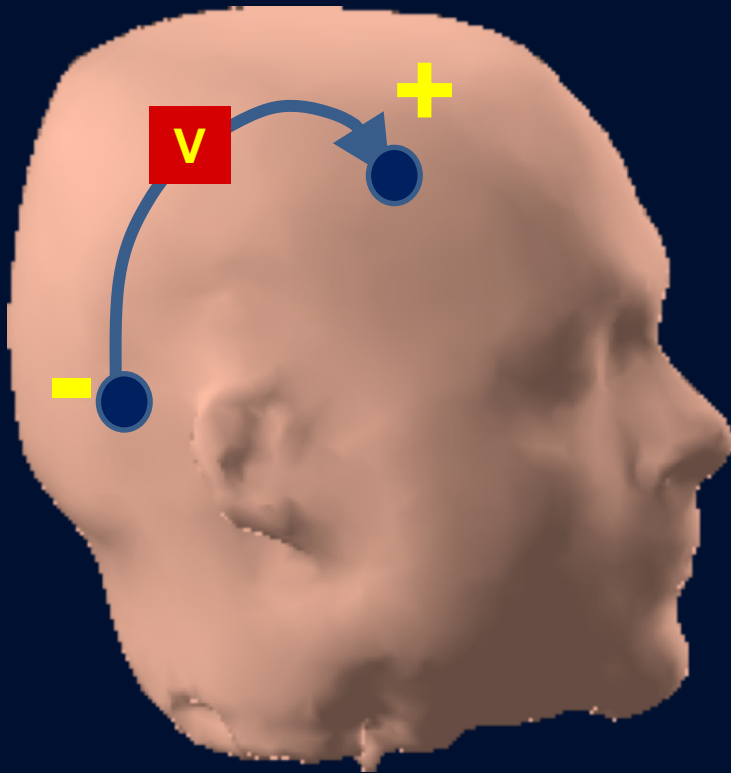
# The very broad EEG point-spread function



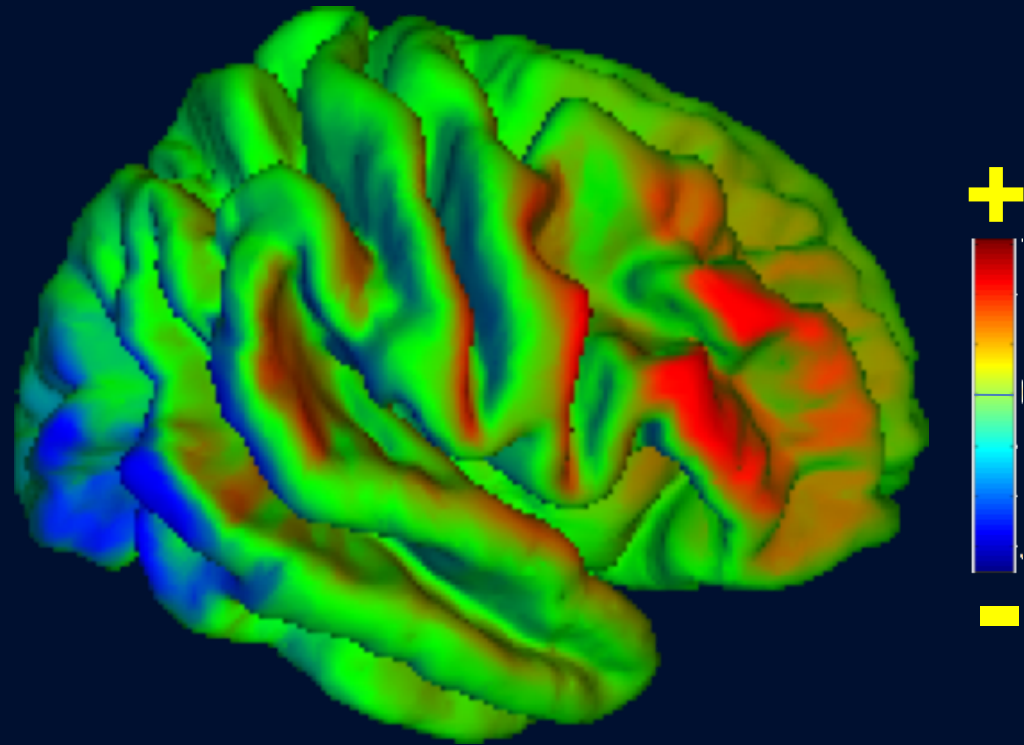
Single simulated parietal source →

Very broad projected scalp potentials

# The 'receptive field' of a bipolar EEG channel

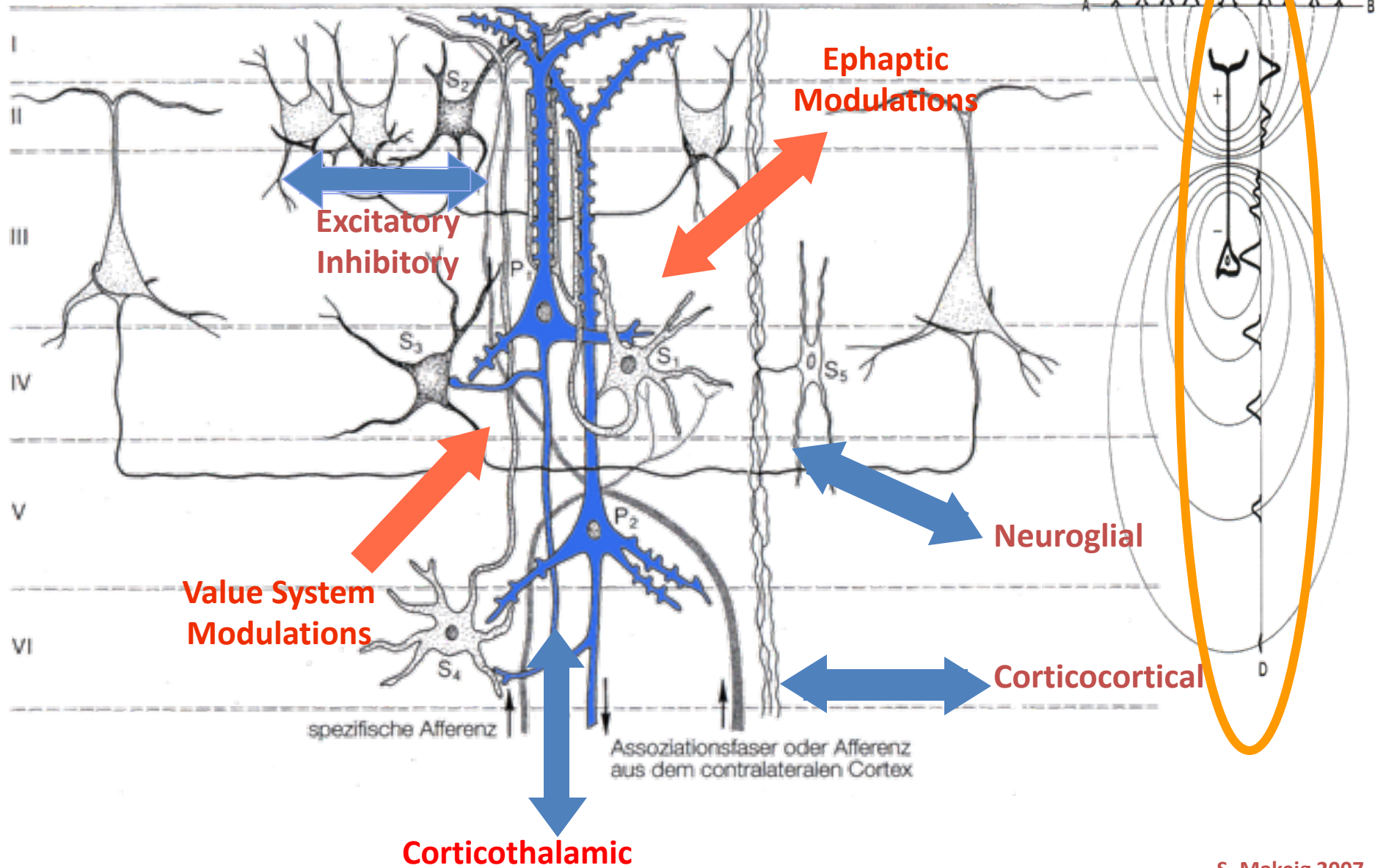


Scalp EEG channel



Its cortical 'receptive field'

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



Phase cones (Freeman)

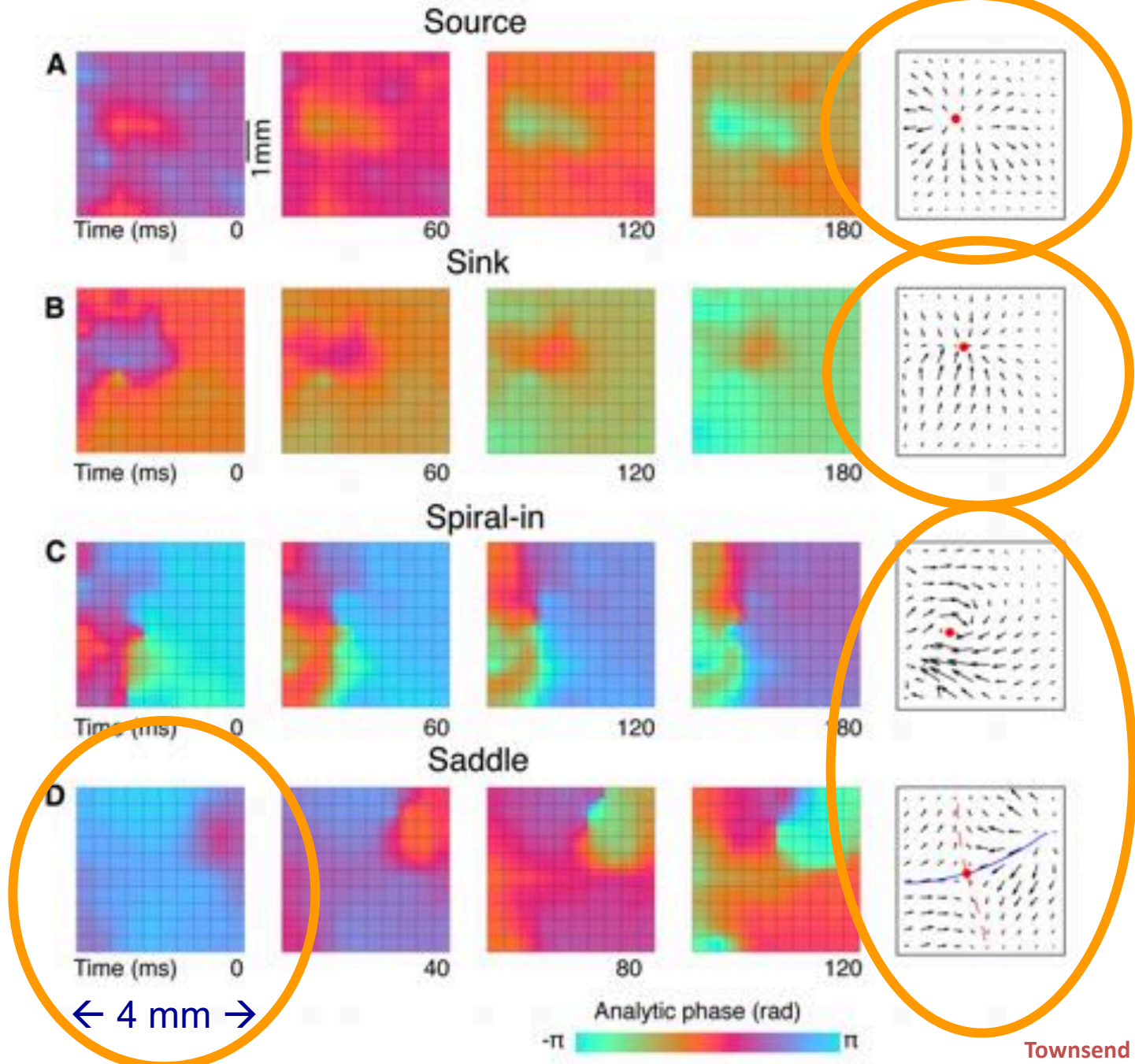
Avalanches (Plenz)

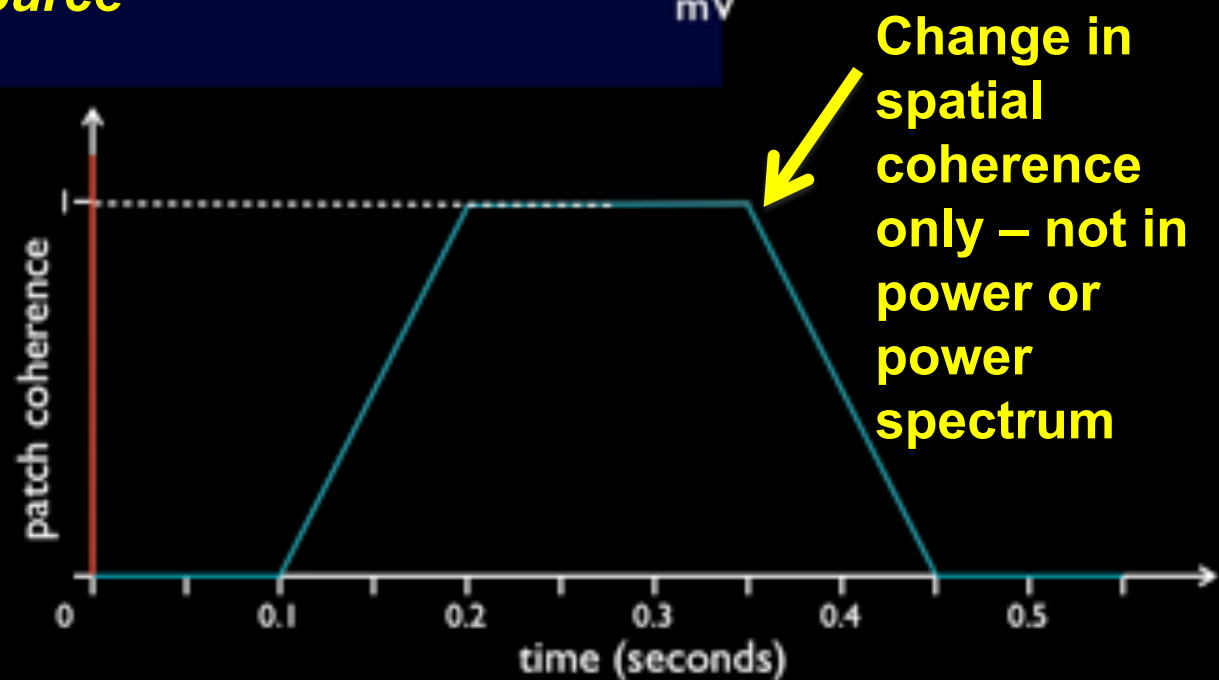
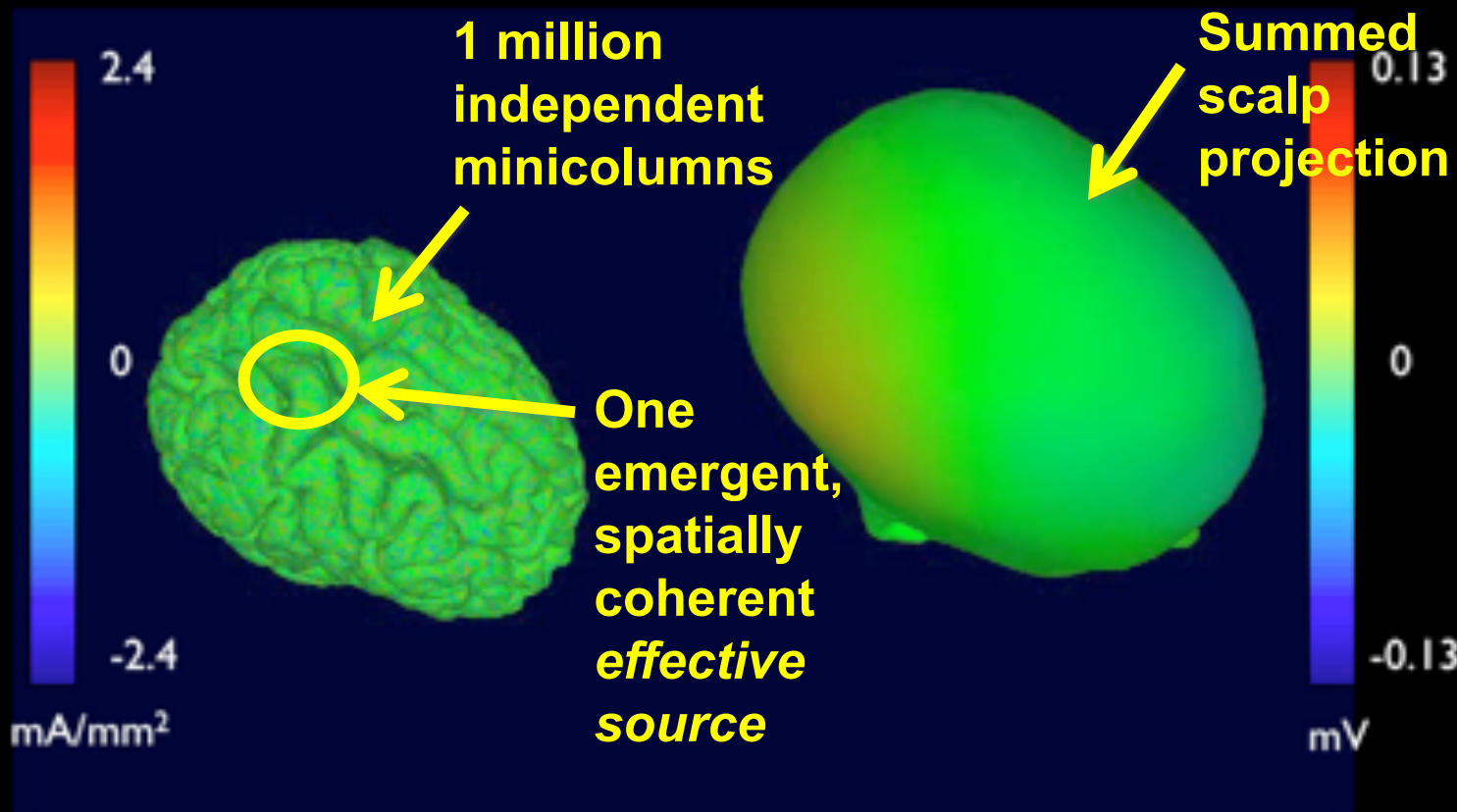


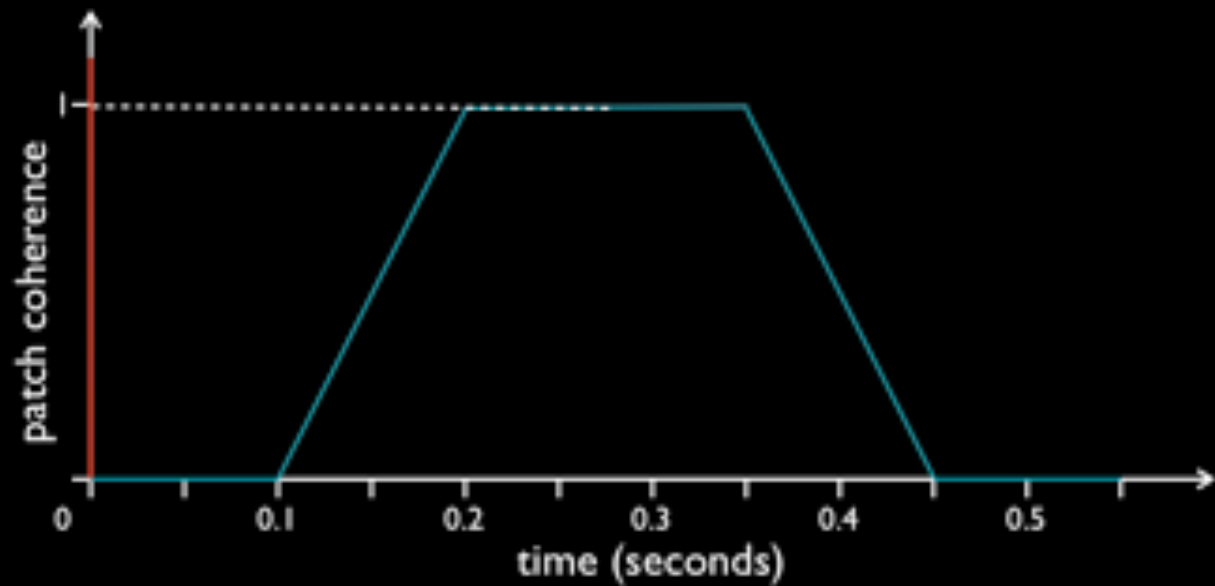
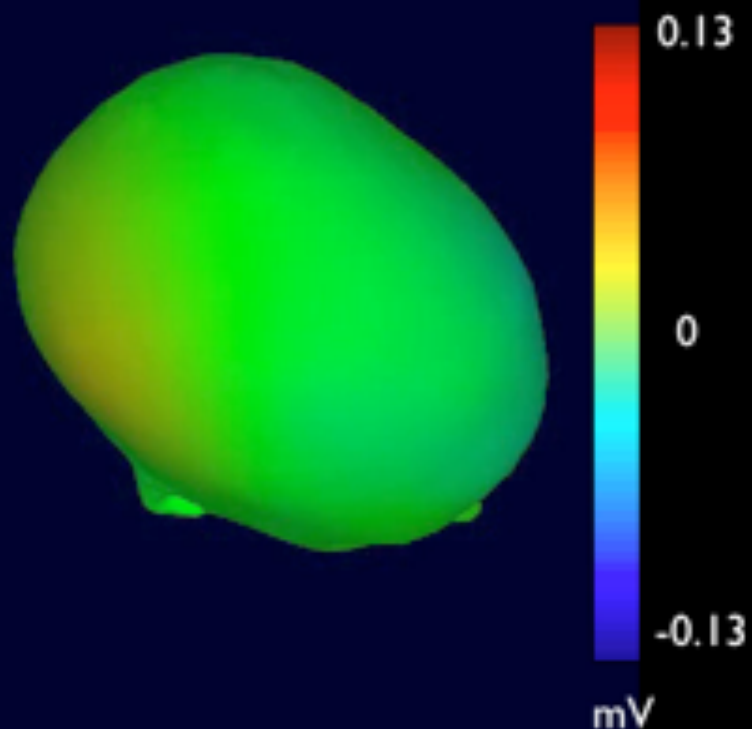
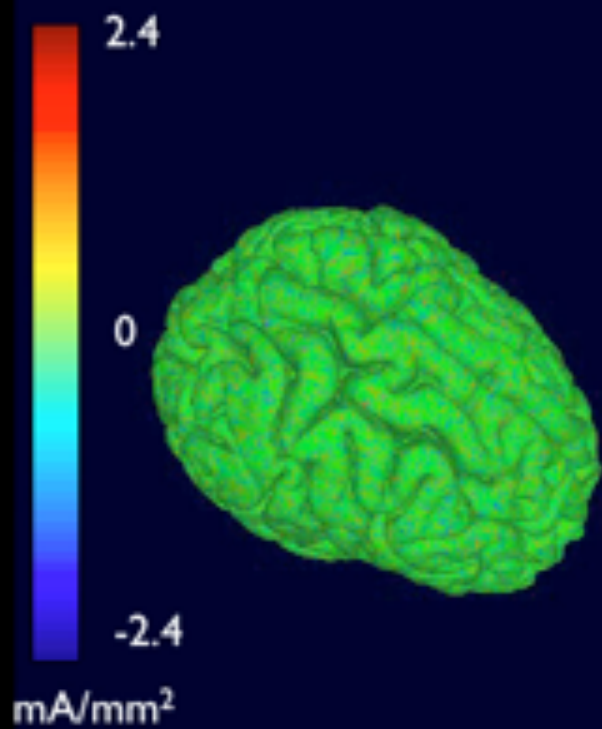


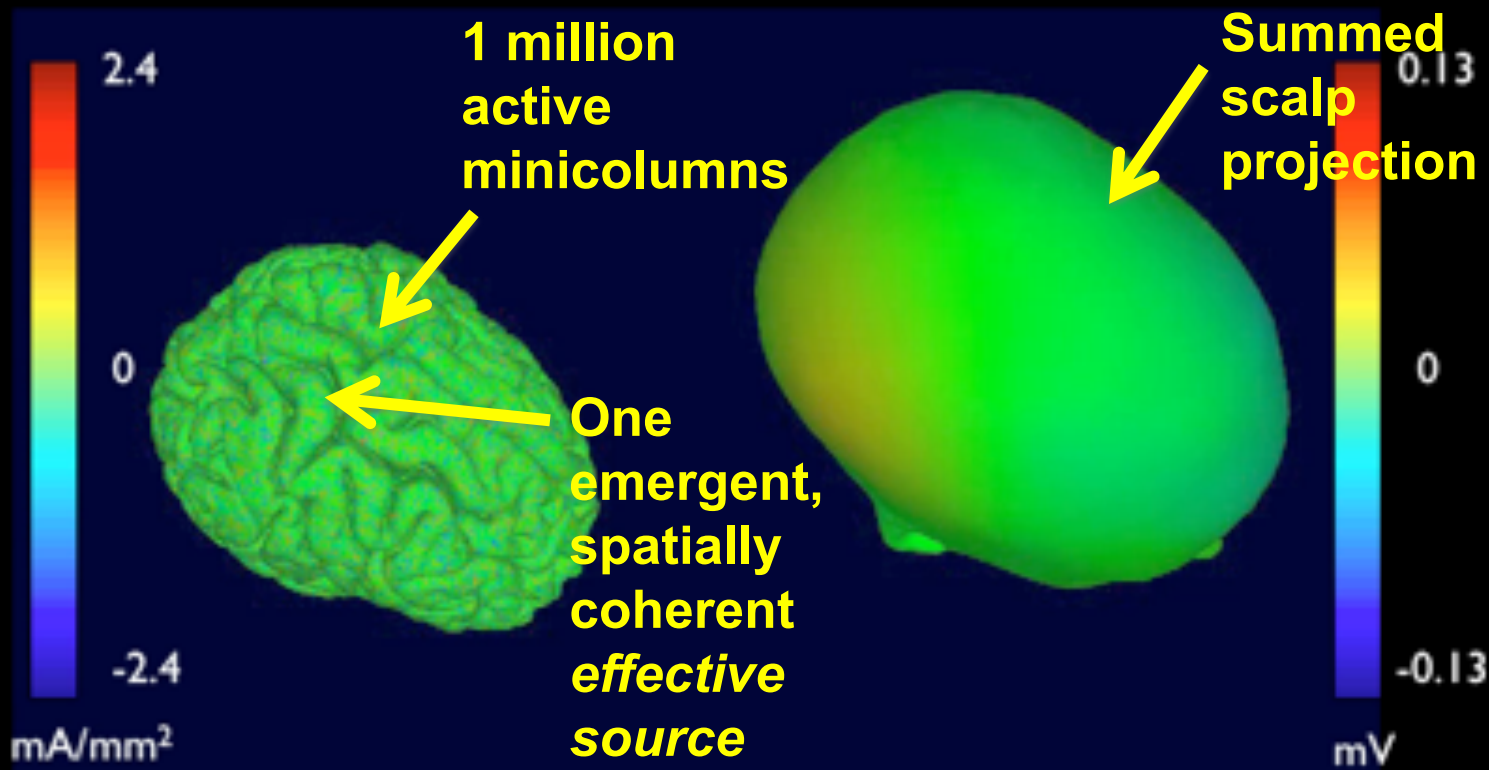
Simple patterns

Complex patterns

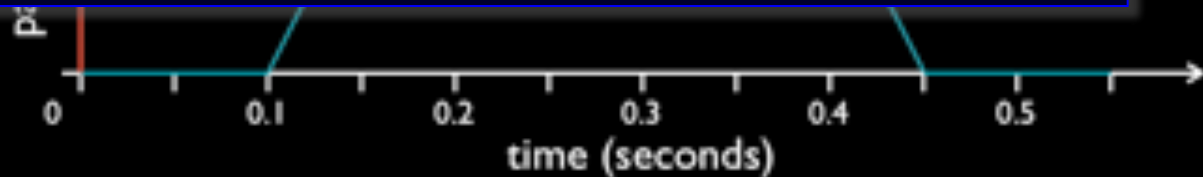
Delta band  
(1-4 Hz)  
in  
anesth.  
animals



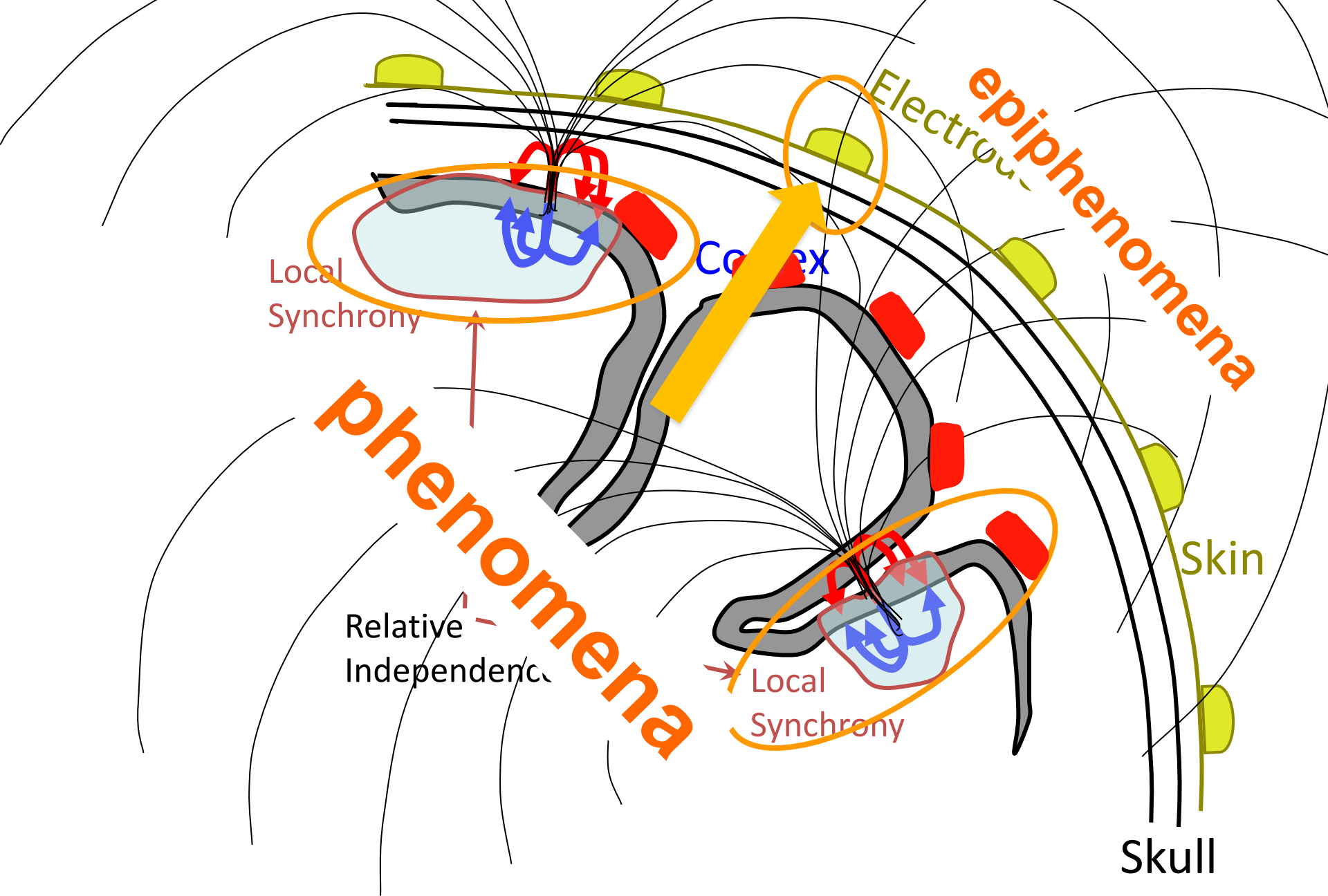




**The *effective sources* of the scalp EEG & MEG are emergent islands of local synchrony / near-synchrony.**

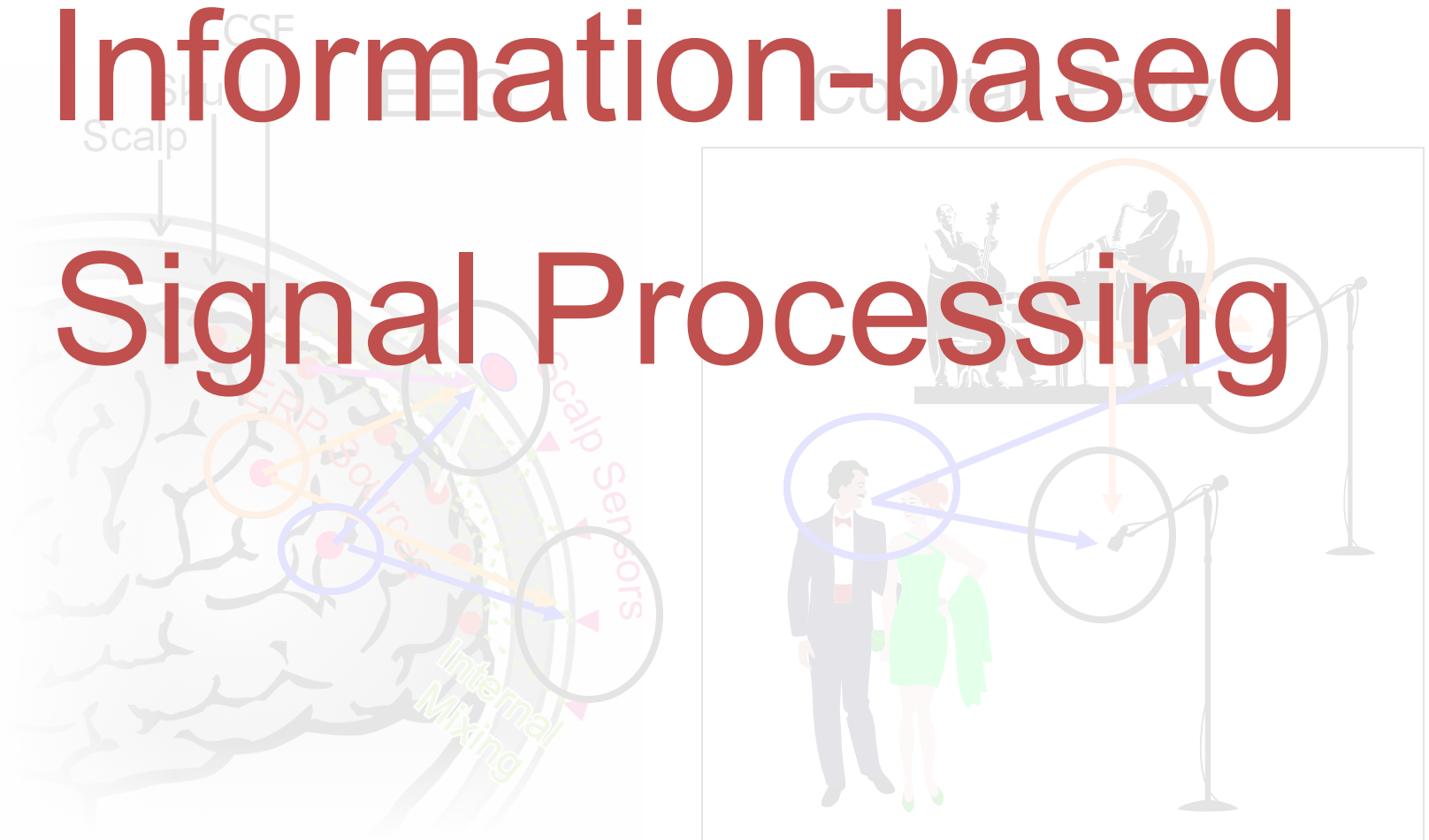






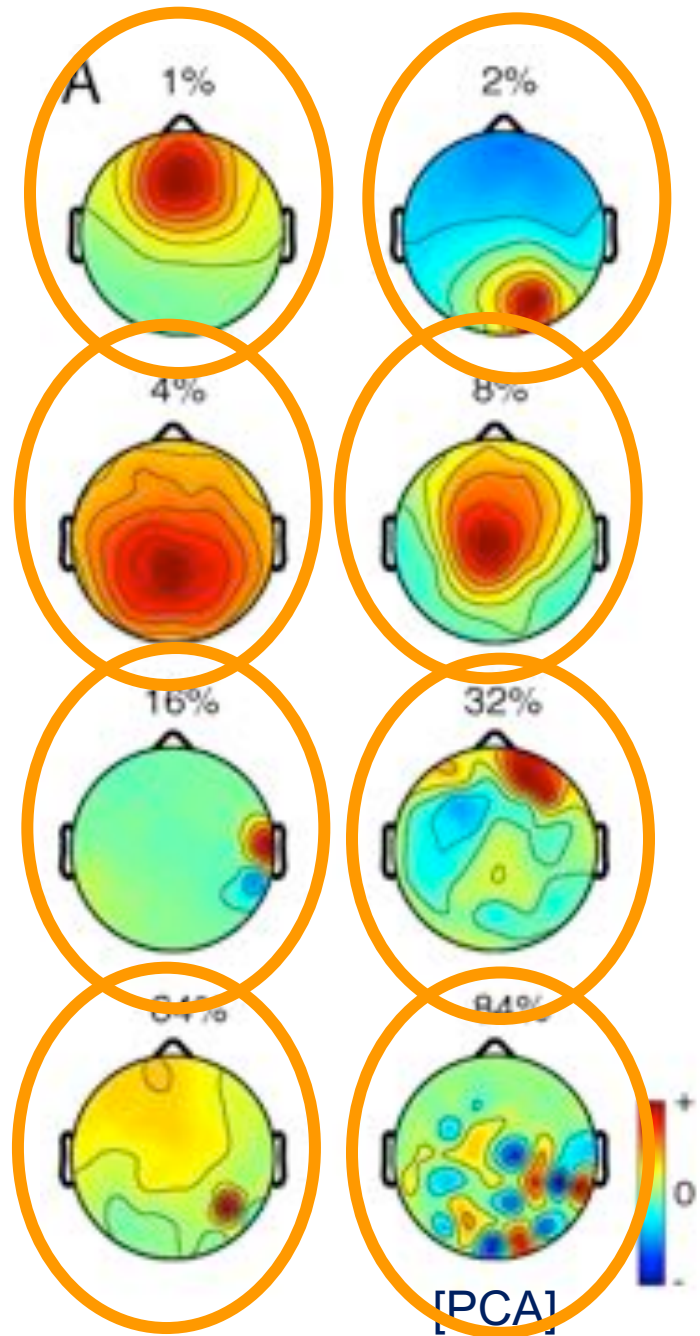
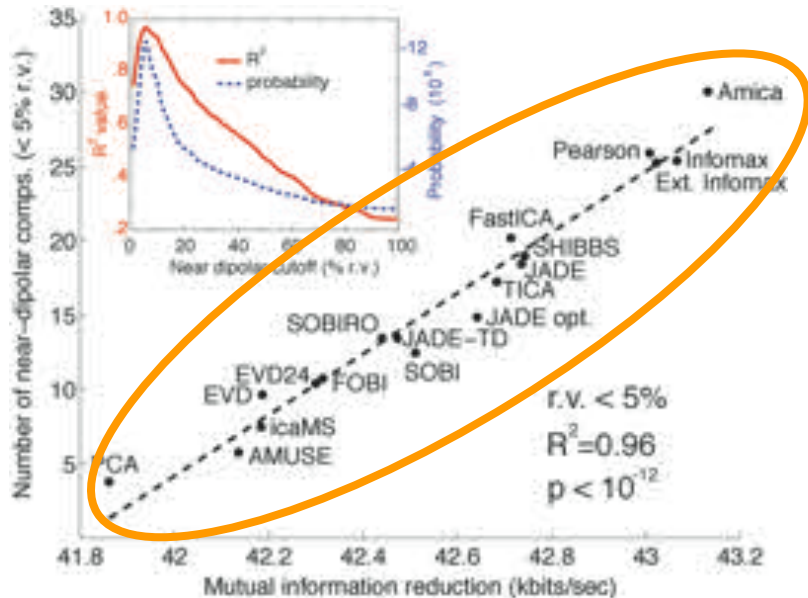
# Blind EEG Source Separation by ICA

## Information-based Signal Processing

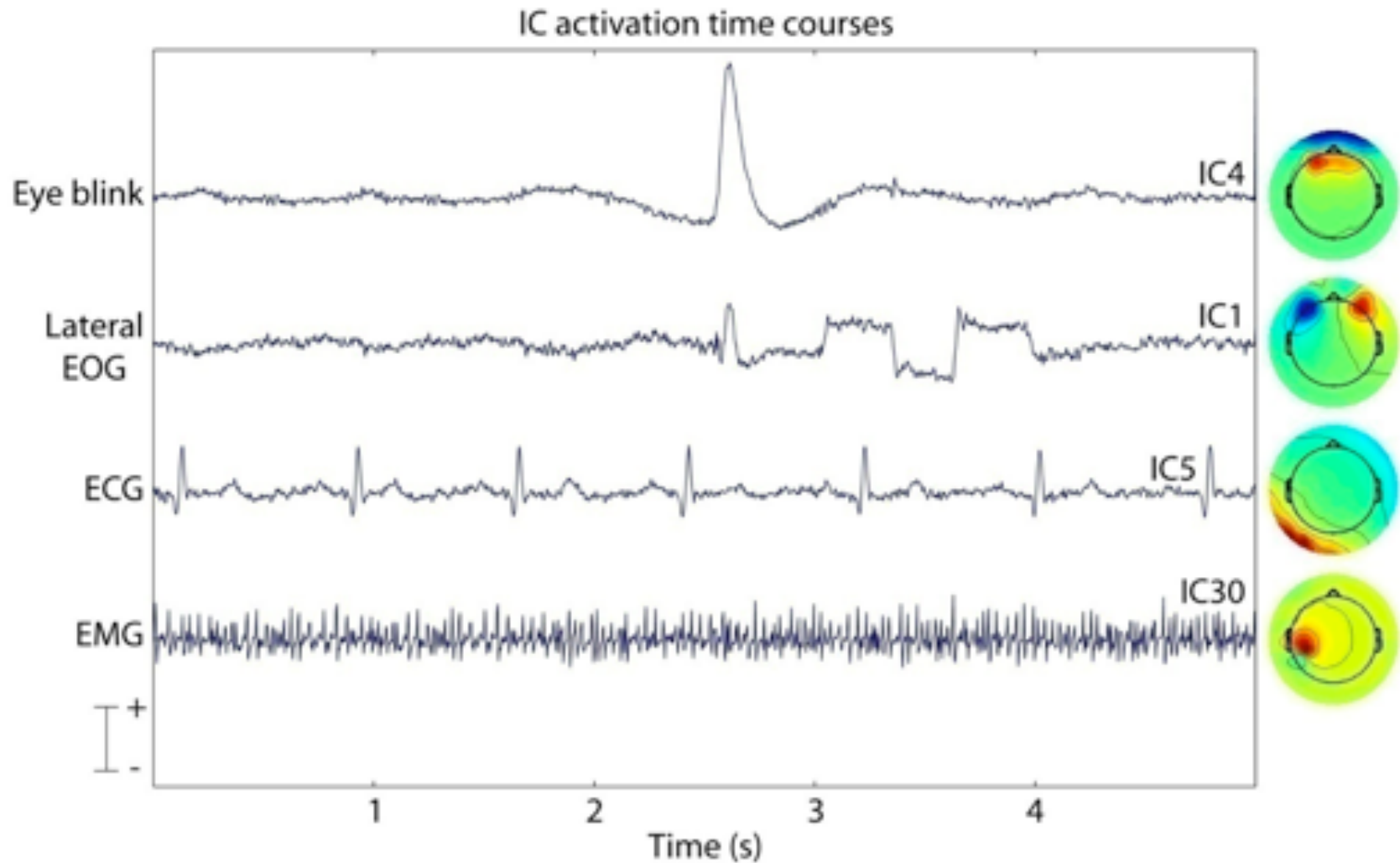


# Surprising 'dipolarity' of Independent Component scalp projections

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

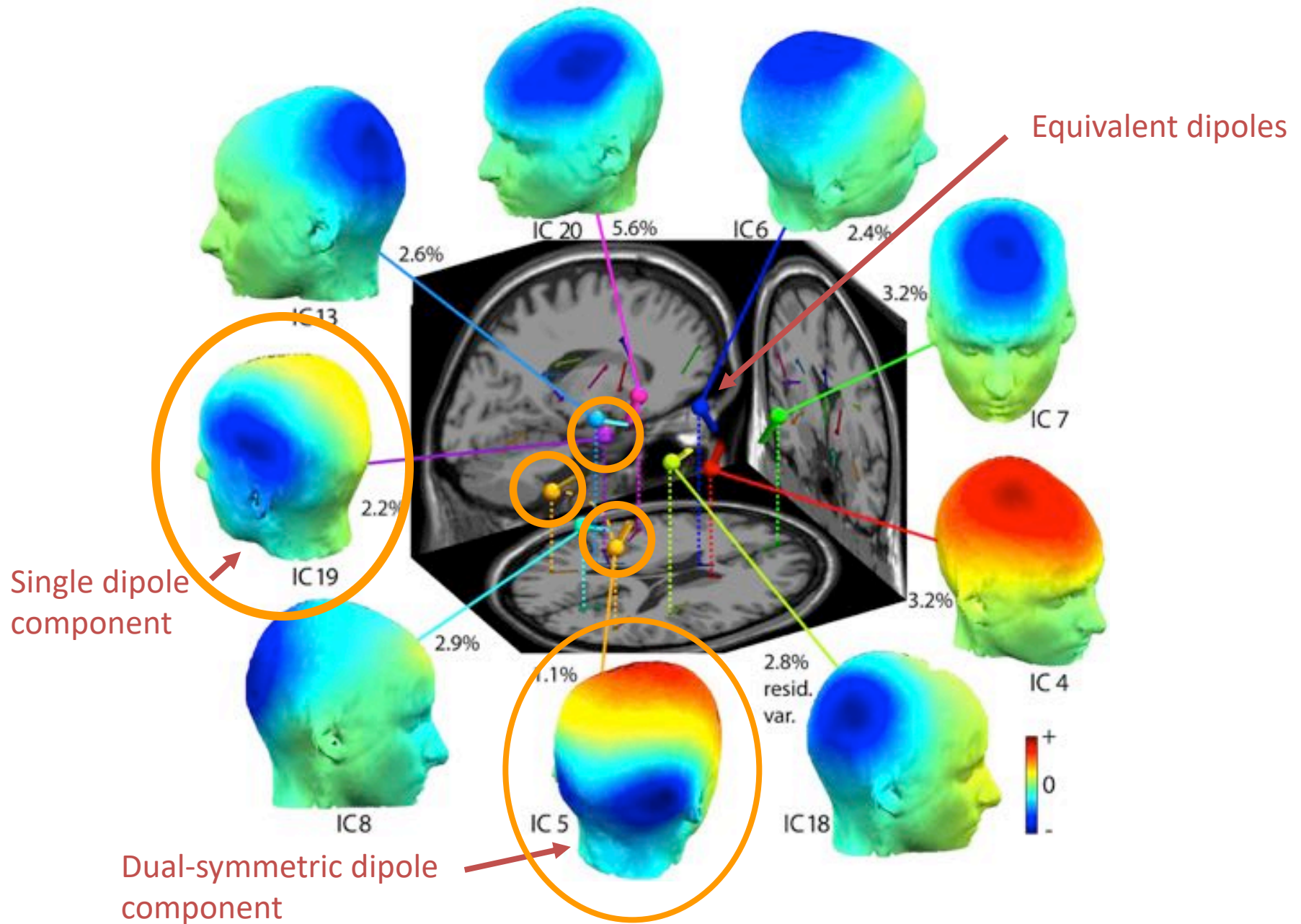


# ICA separates *non-brain* effective source processes

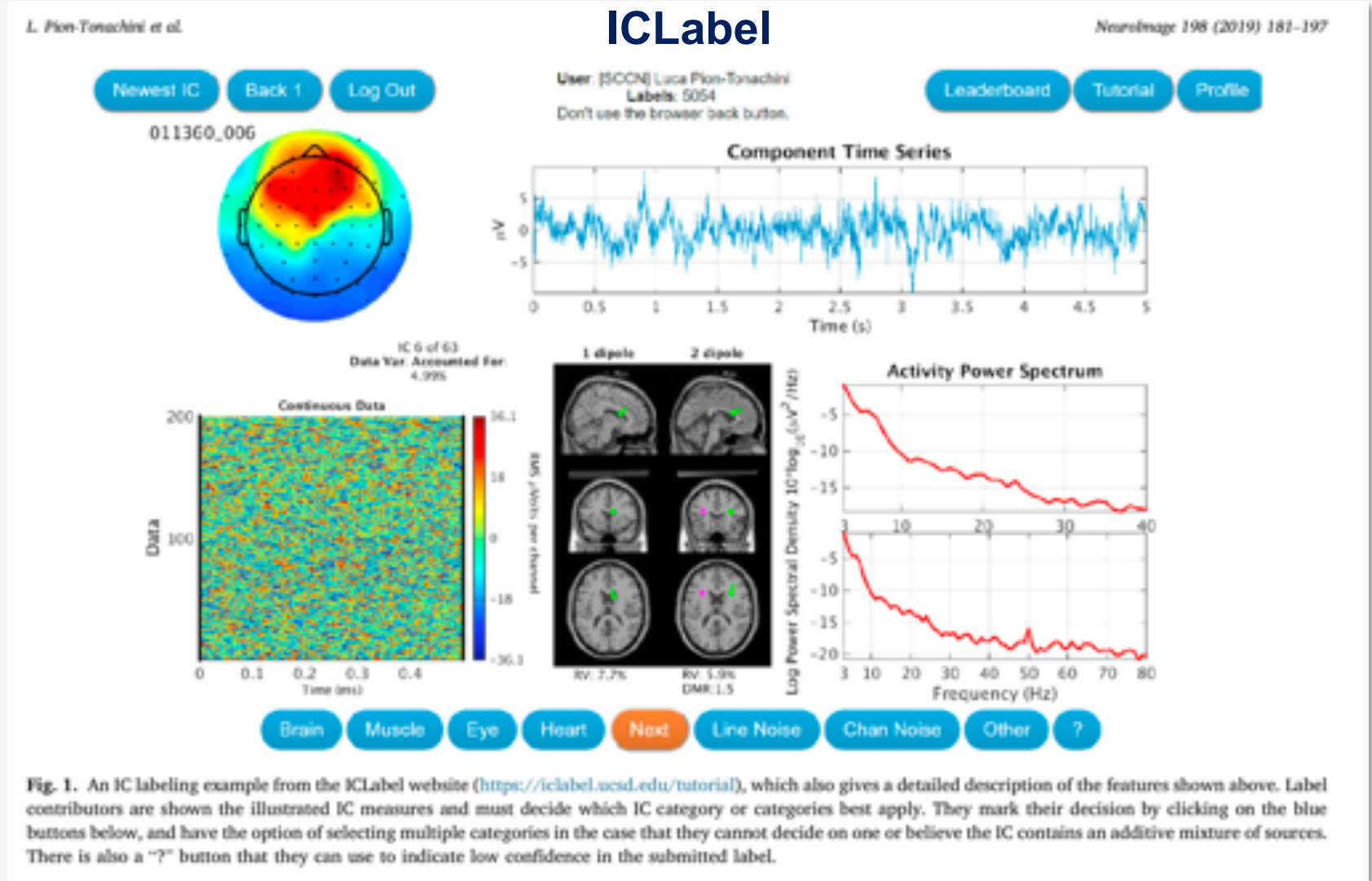




# ... and *also* separates cortical *brain* IC processes



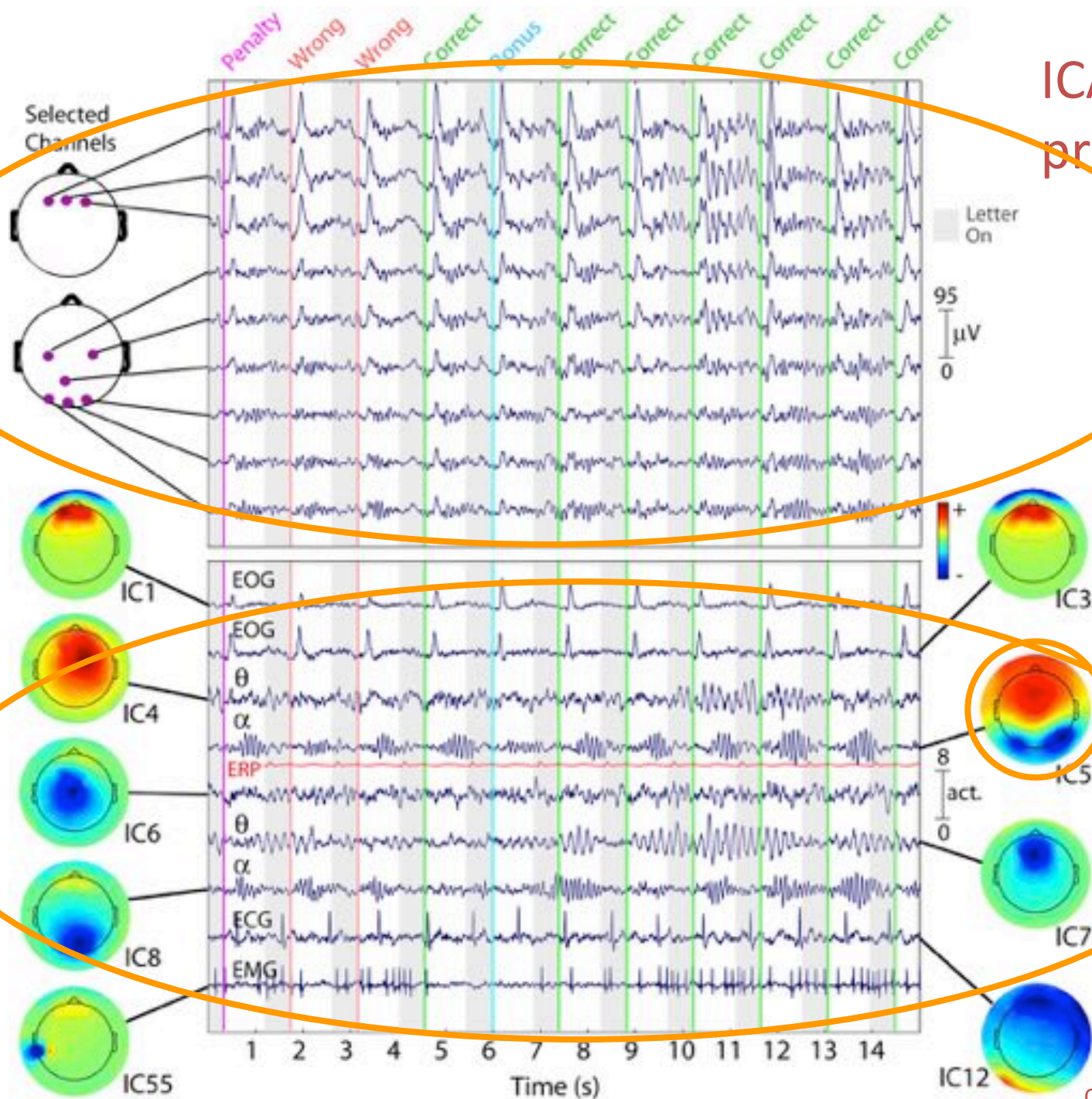
# ICLabel: A crowd-sourced AI independent component classifier

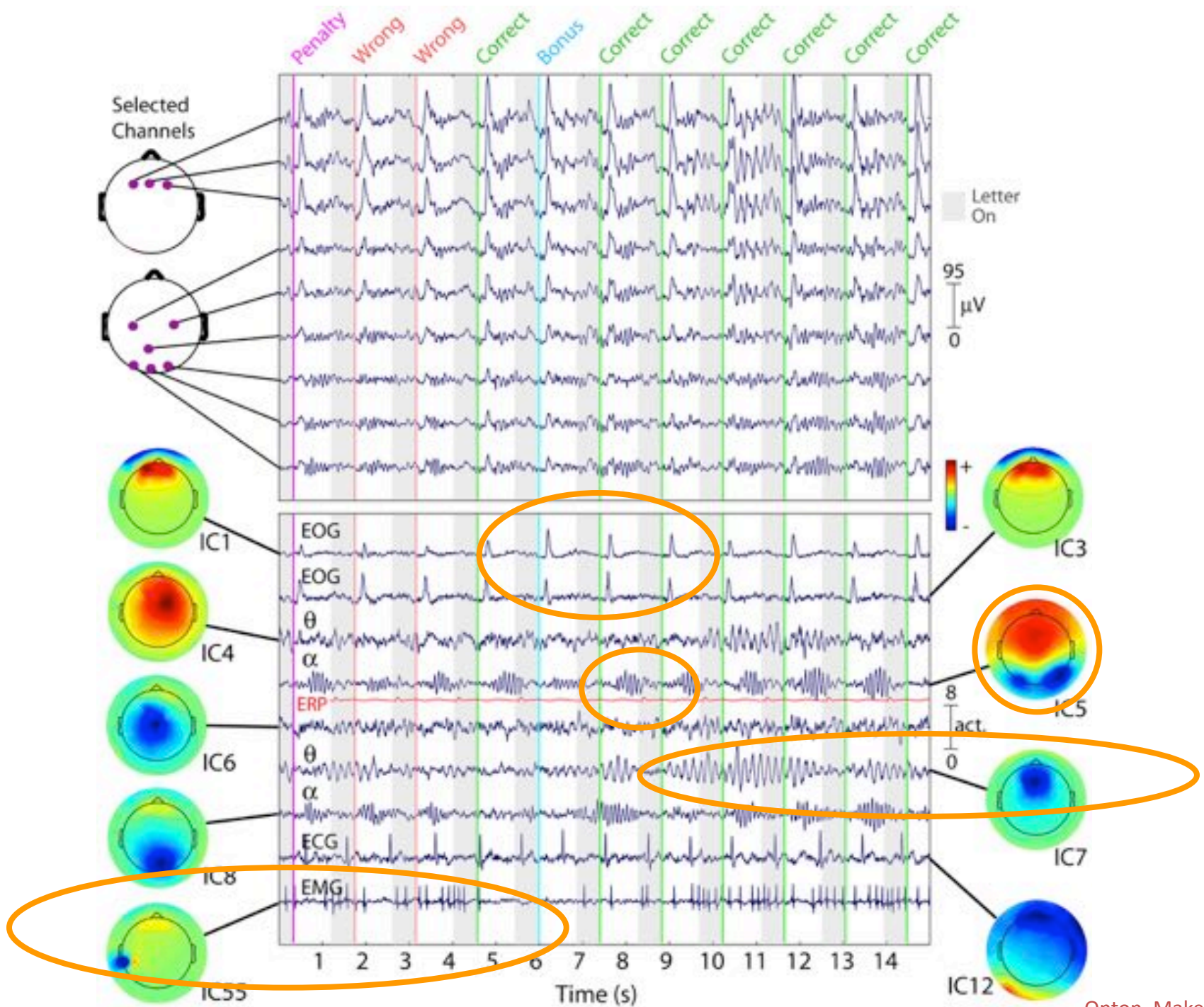


[iclabeling.ucsd.edu/tutorial](https://iclabel.ucsd.edu/tutorial)



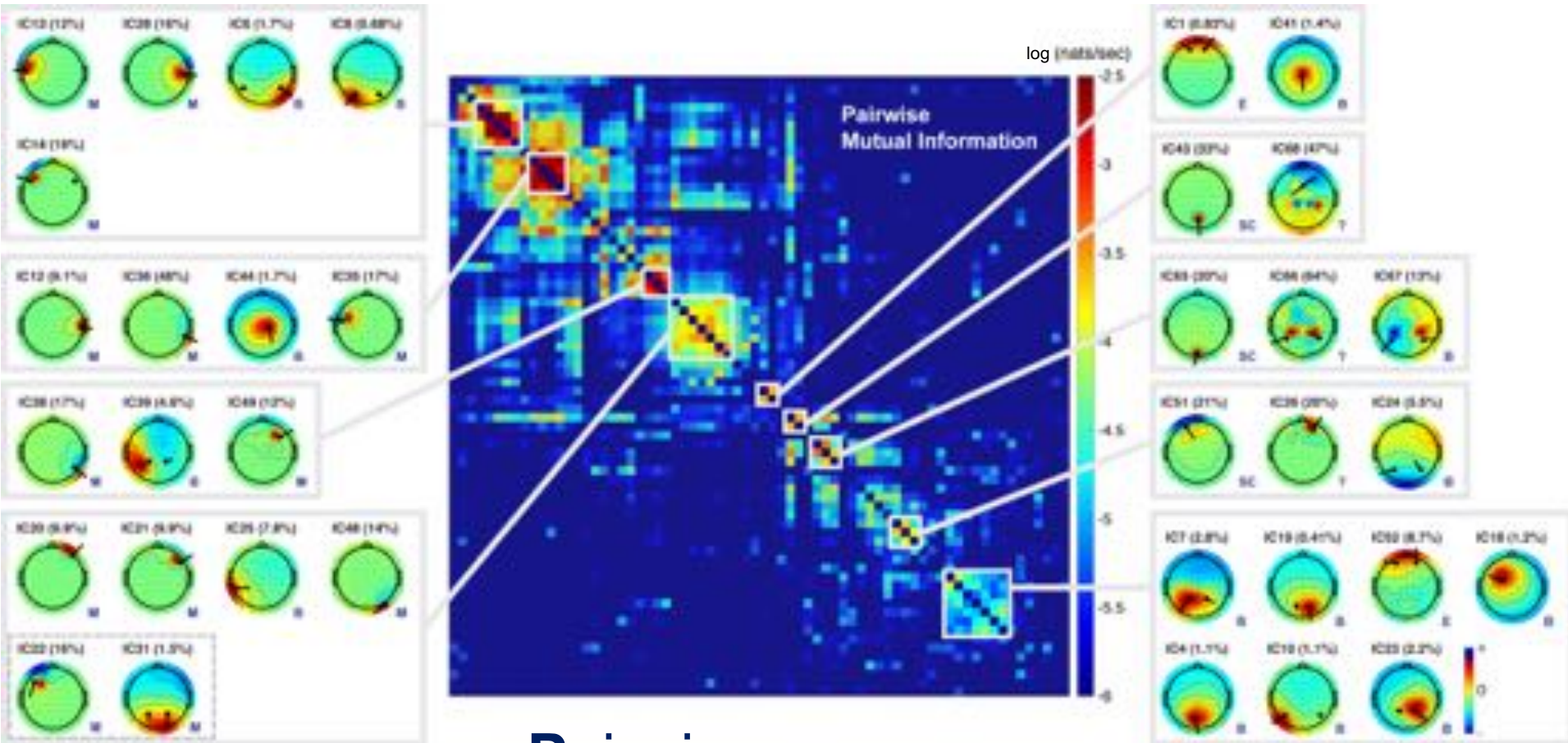
# ICA in practice







# ICA decomposition finds dependent subspaces



B = brain  
M = muscle  
E = eye  
? = other  
SC = channel

Pairwise  
Mutual  
Information

# Blind EEG Source Separation by ICA

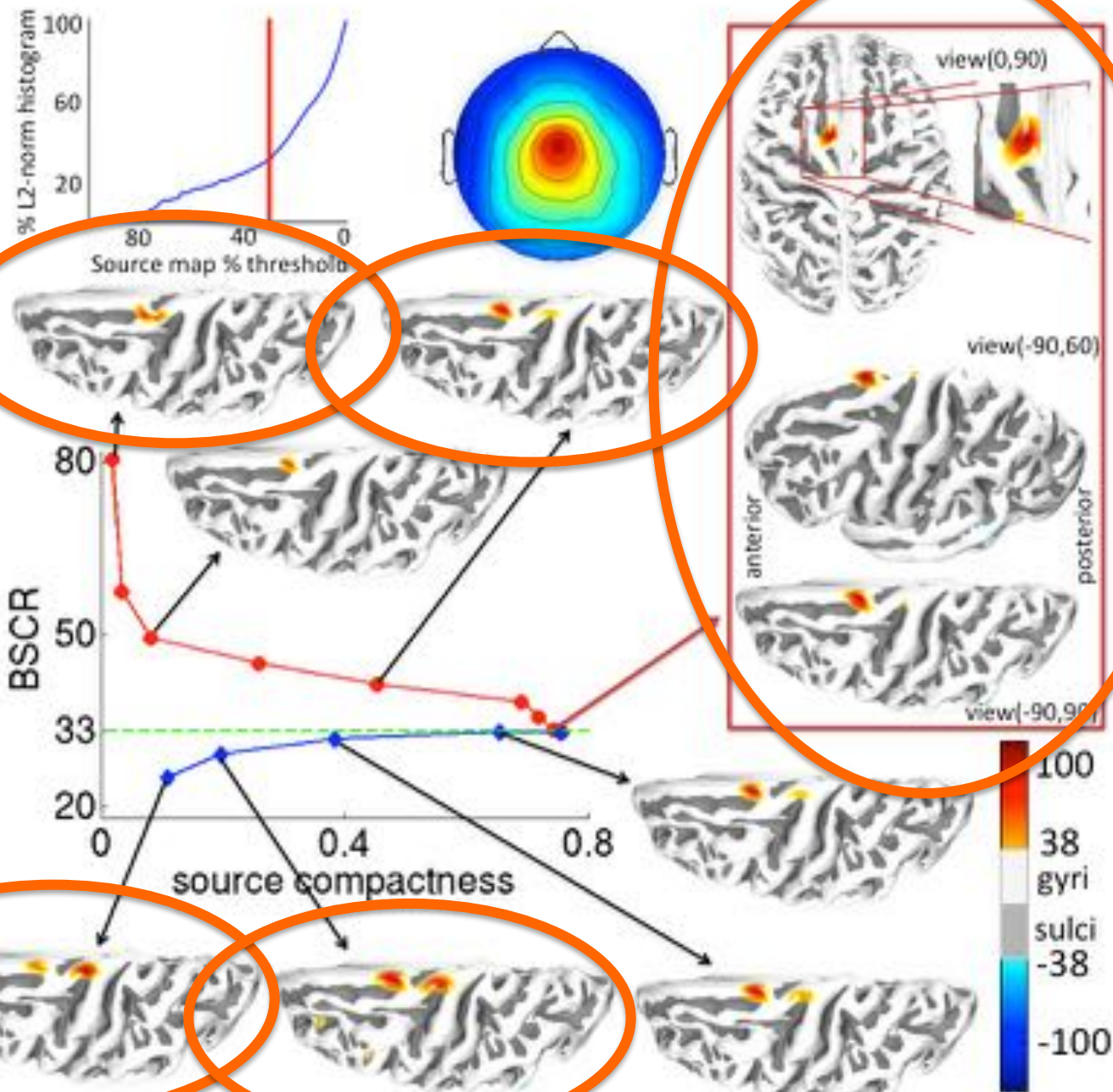
## High-Resolution

## EEG Source Imaging



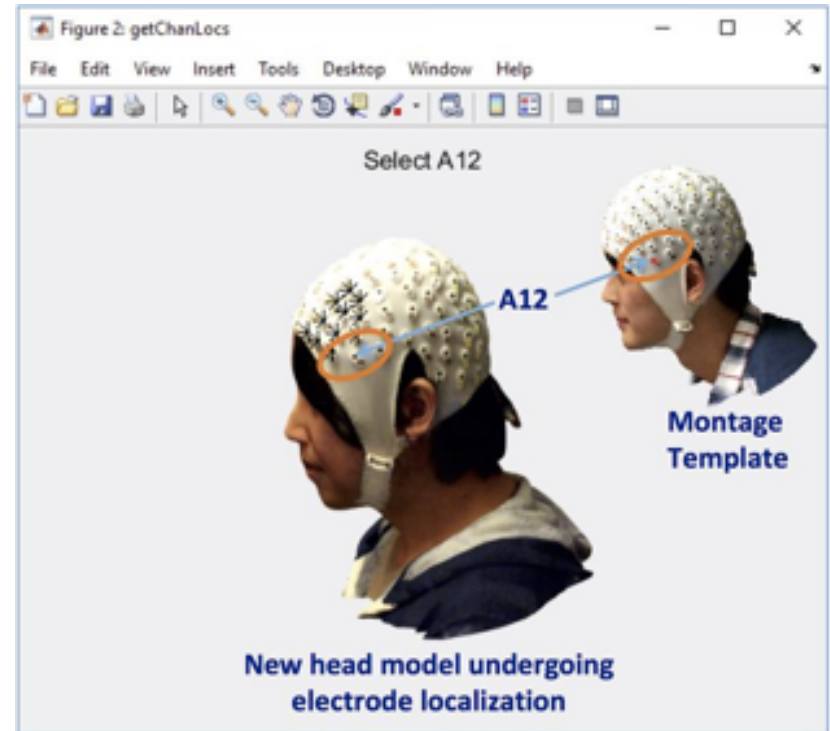


# SCALE





# get\_chanlocs – handheld 3-D electrode position recording



Clement Lee & S. Makeig, 2018

**get\_chanlocs()**  
*post hoc* 3-D electrode  
location recording from  
a subject 3-D head image.

Brain dynamics are inherently multi-scale

EEG (scalp surface fields)

ECOG (larger cortical surface fields)

# Imaging Brain Support for

# Three Aspects of Consciousness

At each spatial recording scale, the coherence of distributed activities at the next smaller scale.

**knowing**

Cross-scale coherence is bi-directional!

Intracellular and extracellular fields

Synaptic and other trans-membrane potentials

Larger



Smaller

**feeling**

**willing**





# EEG & *feeling*



# EEG Dynamics of Emotion Imagination

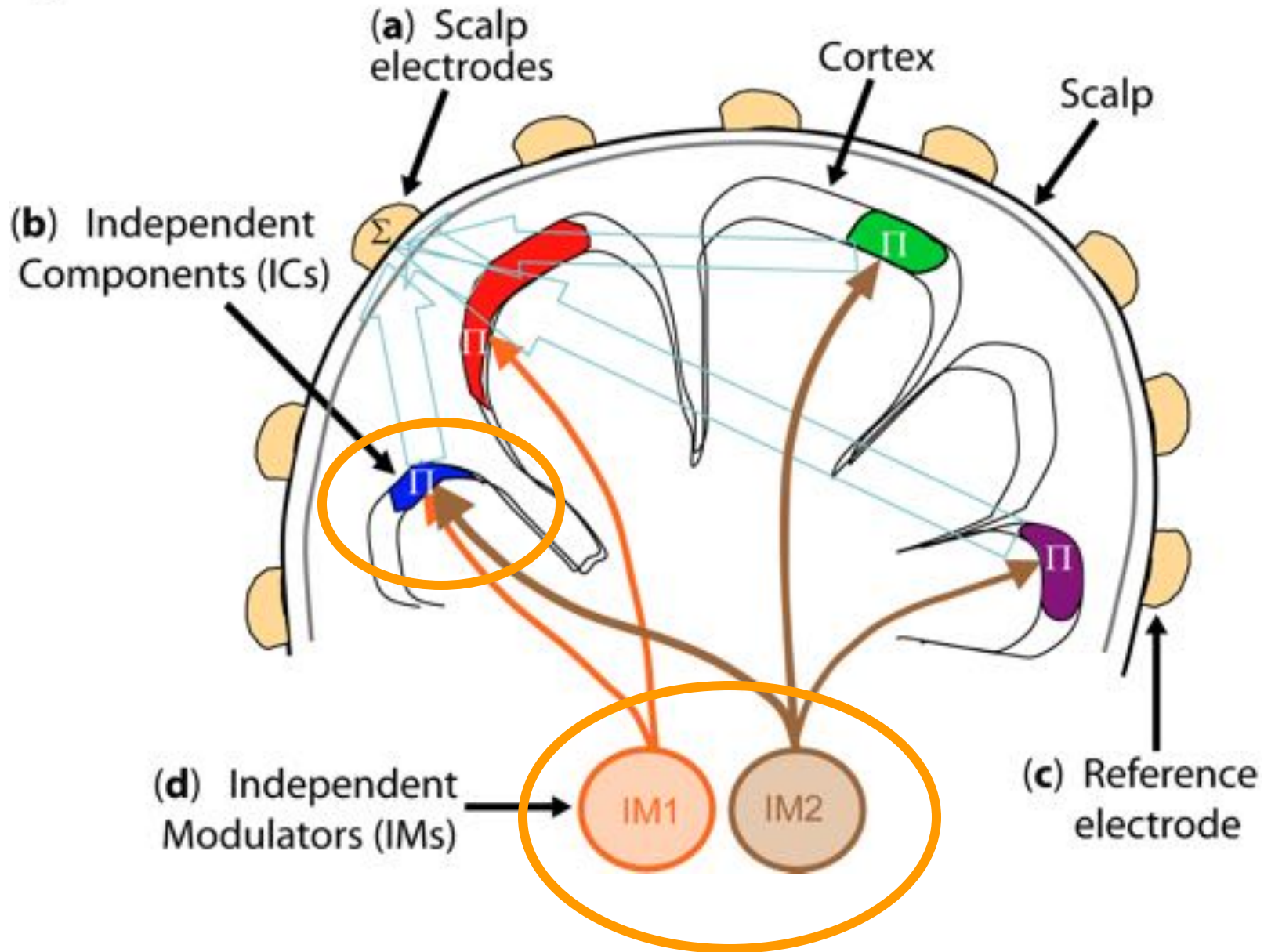
## Suggest the imaginative experience of 15 emotions:

- after Helen Bonny
- initial relaxation instruction
- alternate suggestions to imagine scenes engendering positive and negative emotions
- relaxation instructions between emotion episodes
- **obtained 1-5 min periods of eyes-closed spontaneous EEG** for each emotion from 33 subjects.

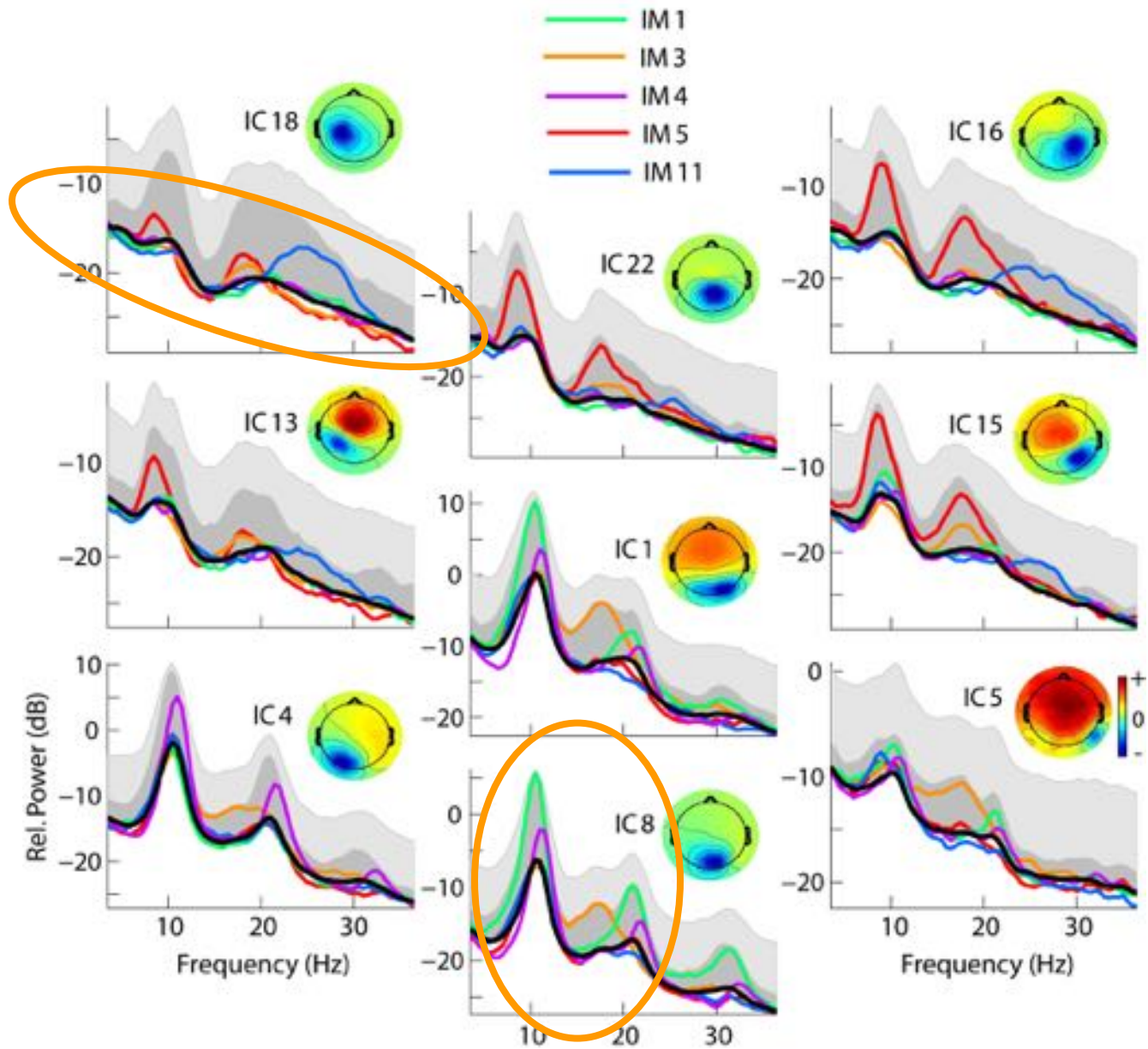


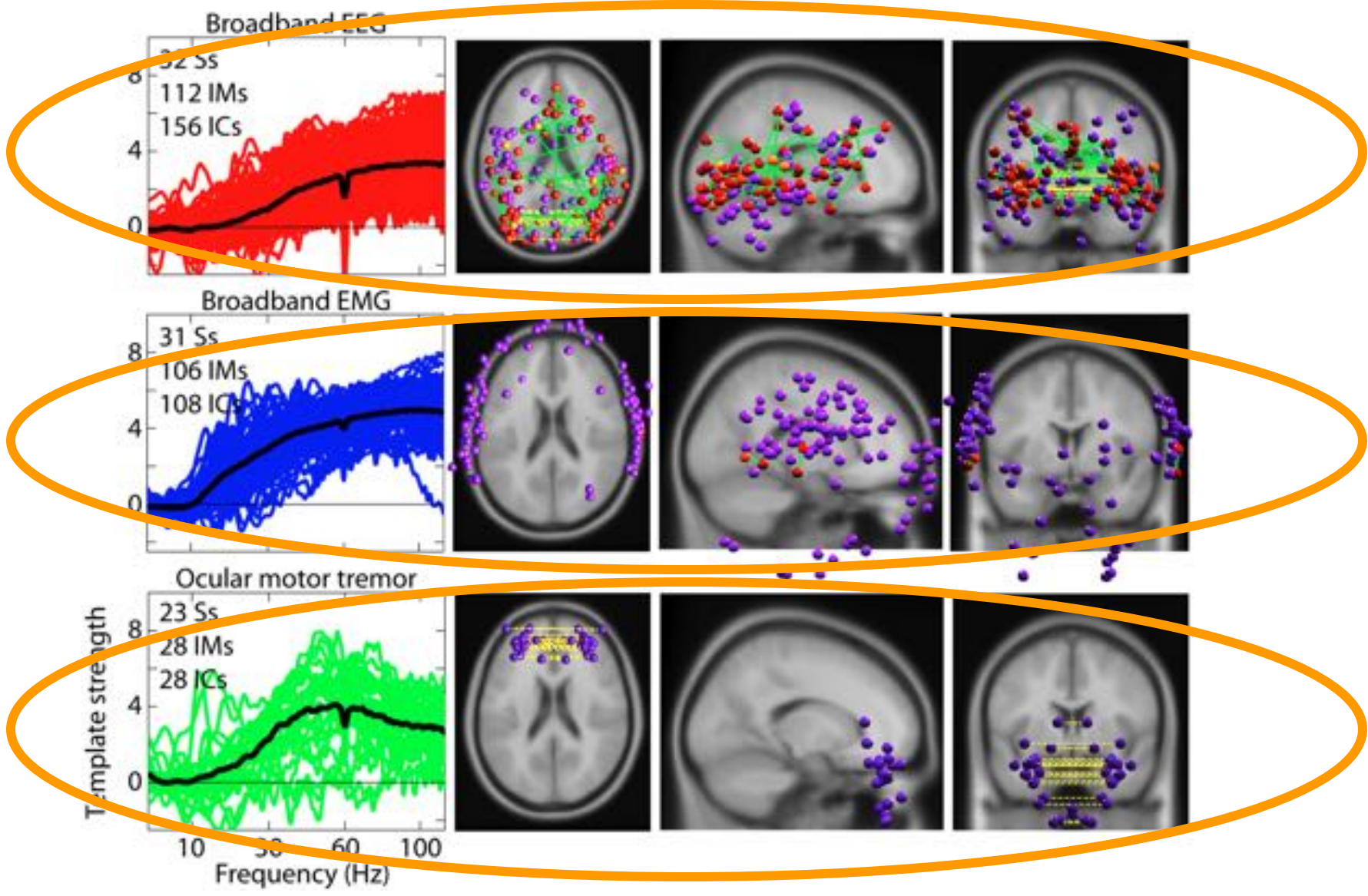


# Independent Modulators



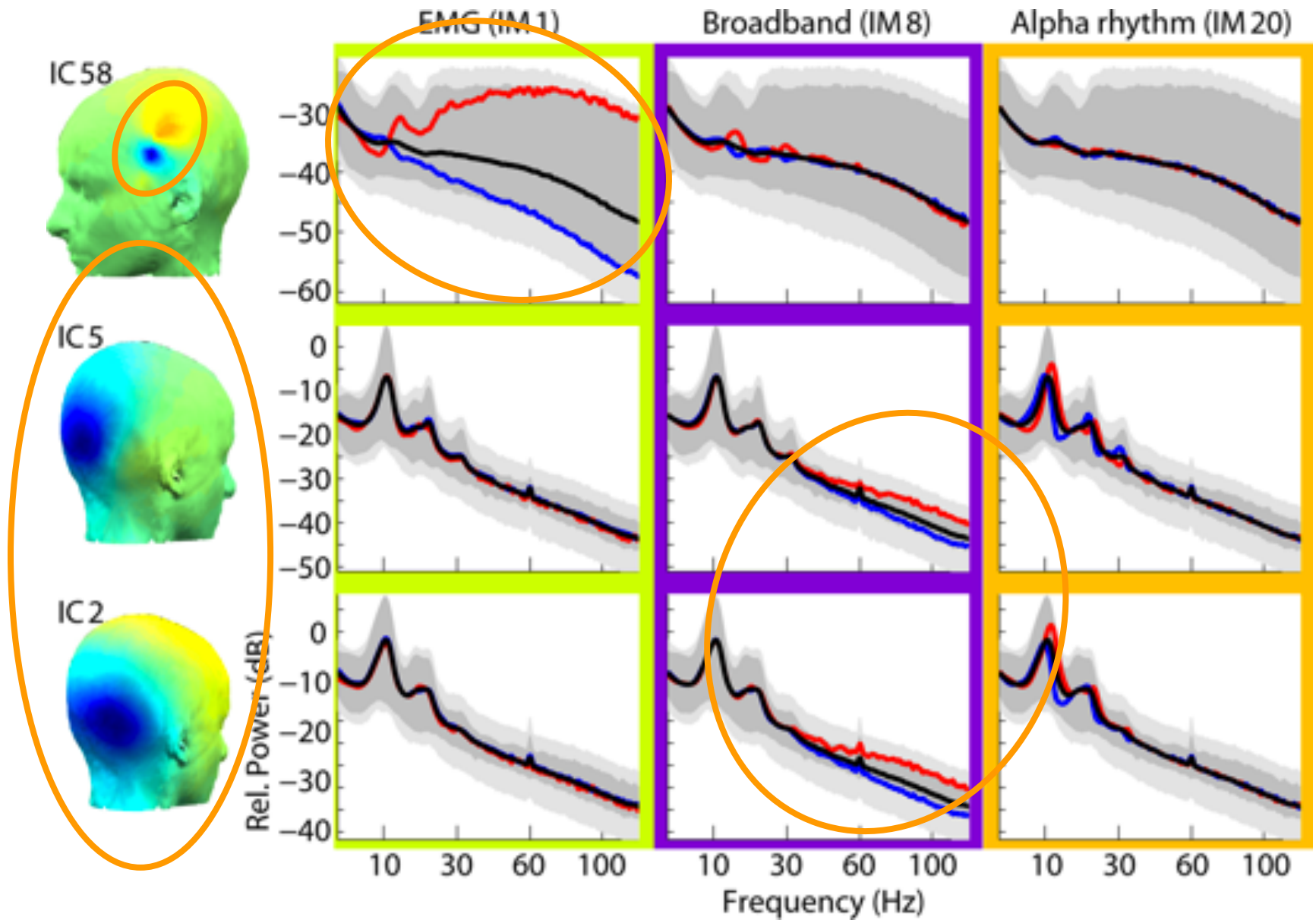
# Independent Modulators



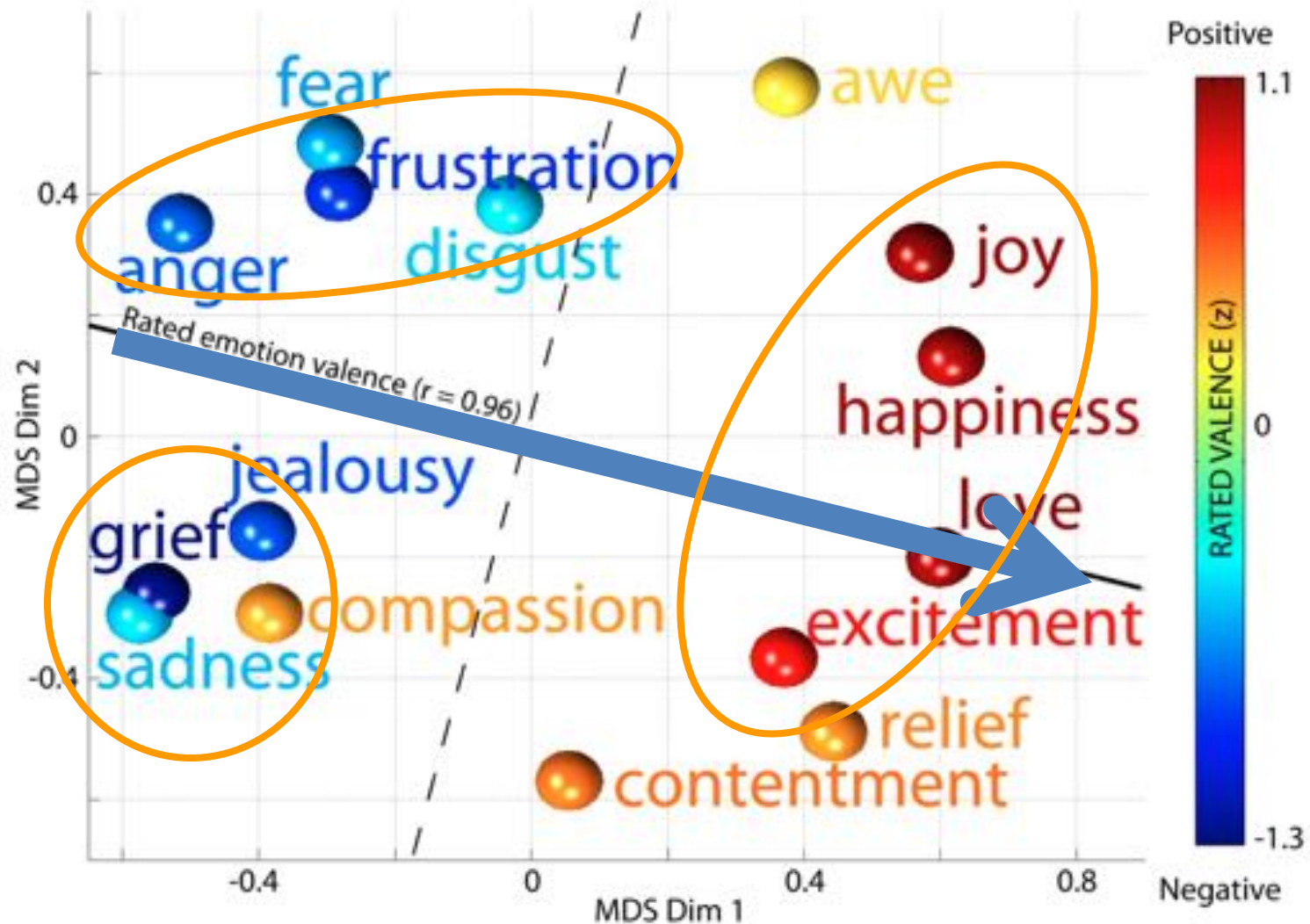


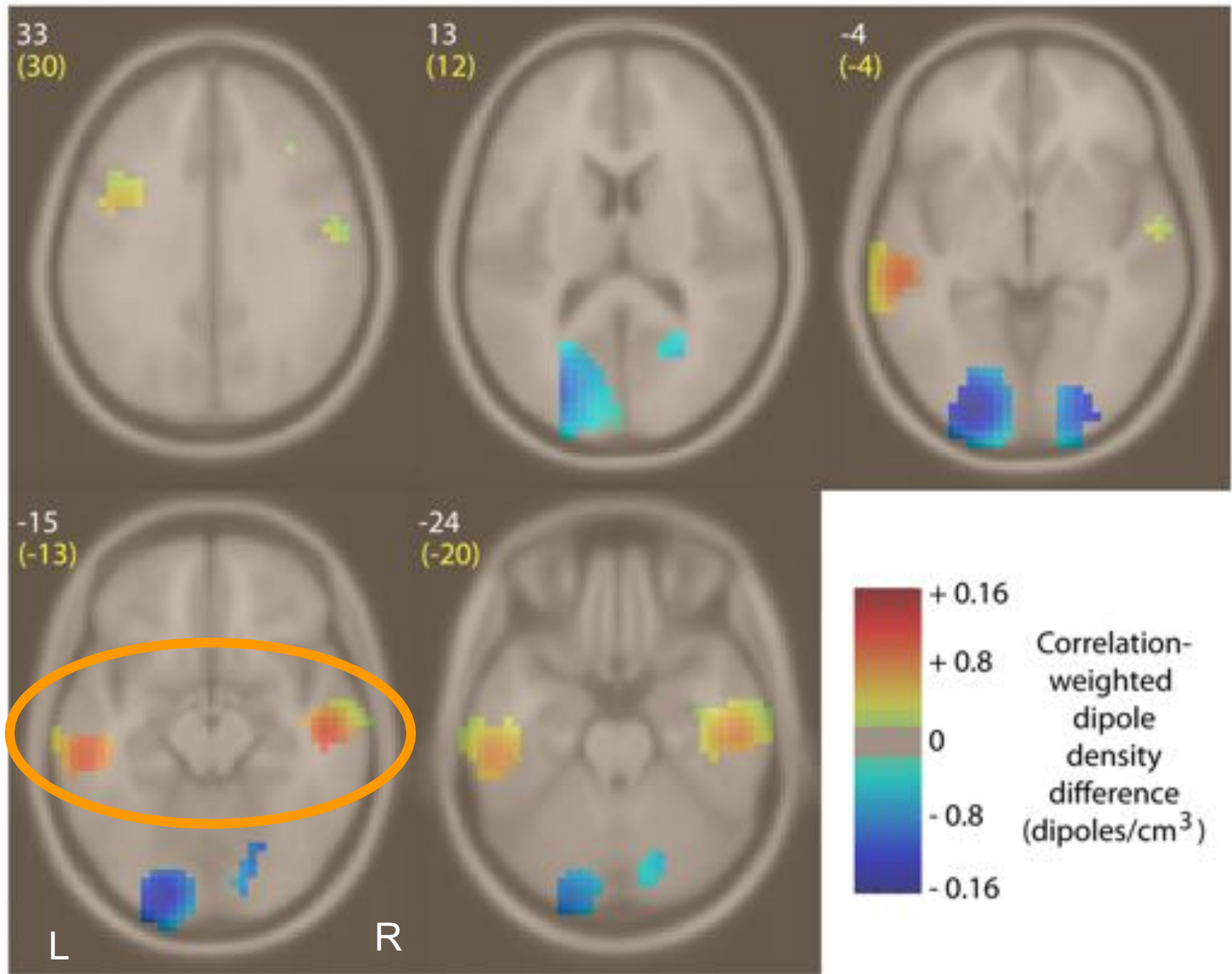


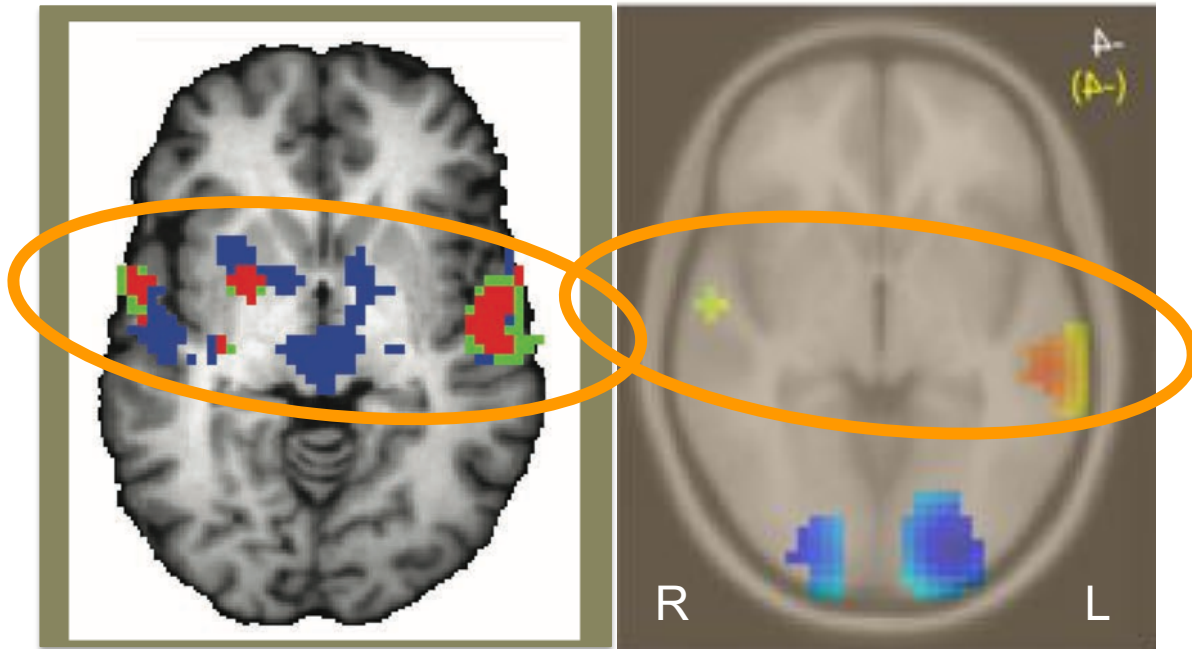
# Independent Modulators



# Changes in distribution of *broadband high-frequency* EEG power with imagined emotion





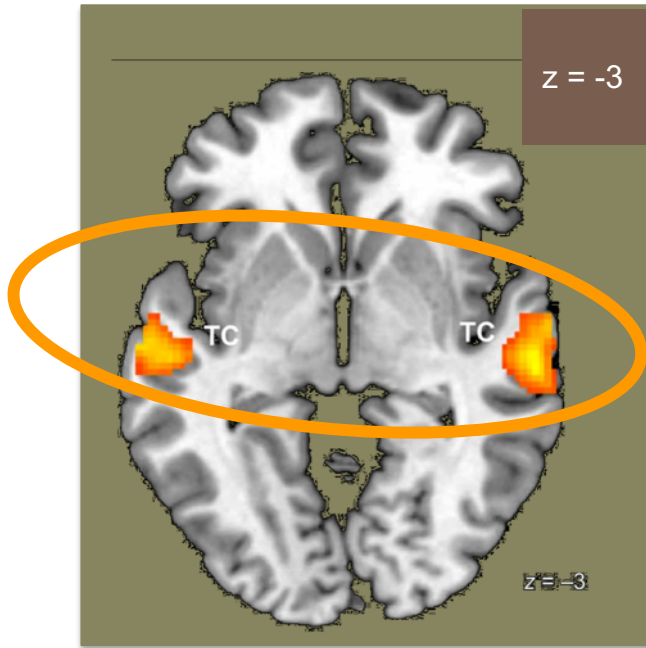


T. Fritz, 2009

Onton & Makeig, 2009

**fMRI BOLD**

**EEG**



Mona Park et al., 2015

**fMRI BOLD**



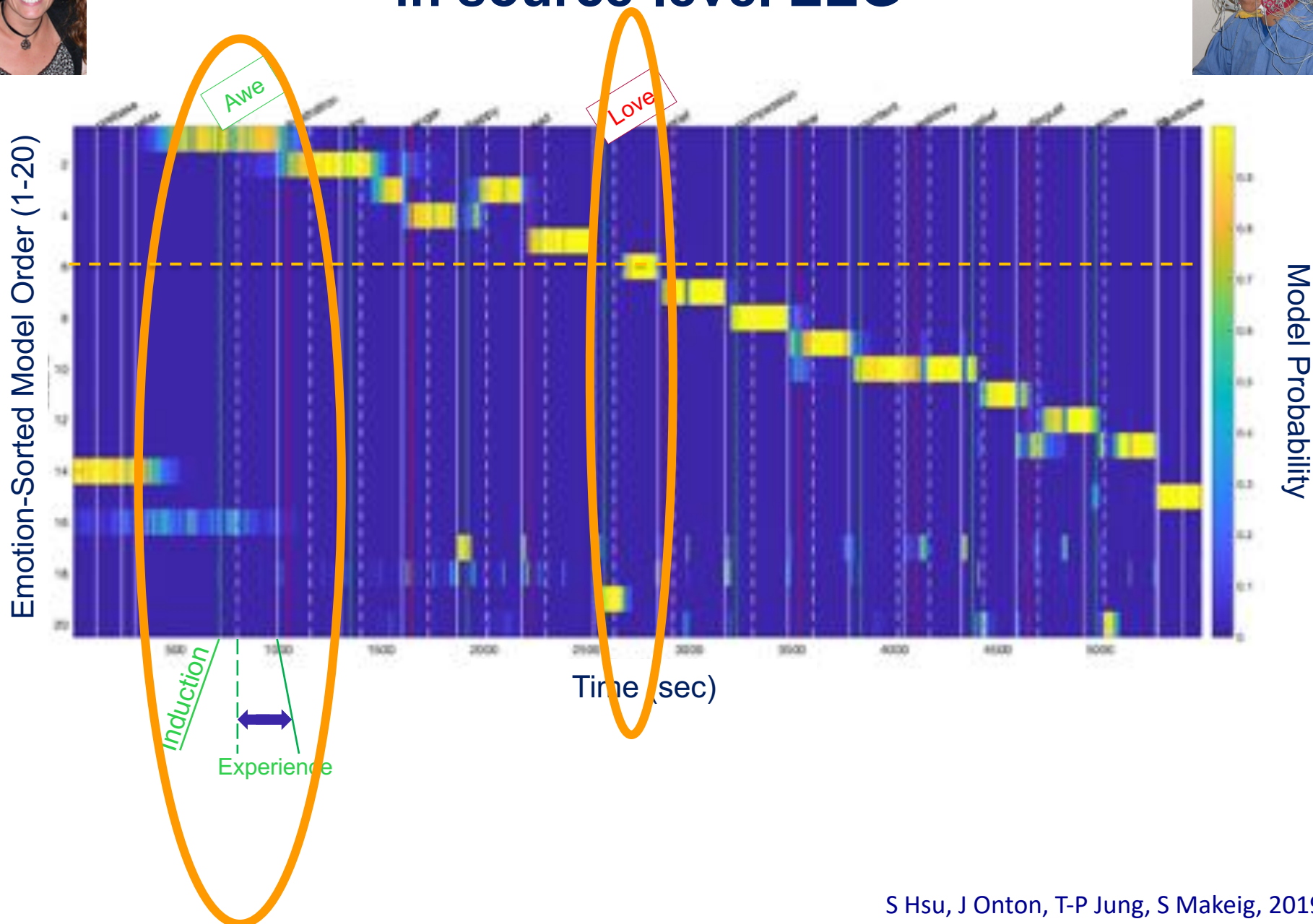
Onton & Makeig 2009

**EEG  
HFB**





# Multi-model AMICA detects non-stationarity in source-level EEG



# EEG & Willing



**Imaging Human Agency**

## Brain imaging during movement – How?

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

# Mobile

→ Mobile Brain/Body Imaging (MoBI)

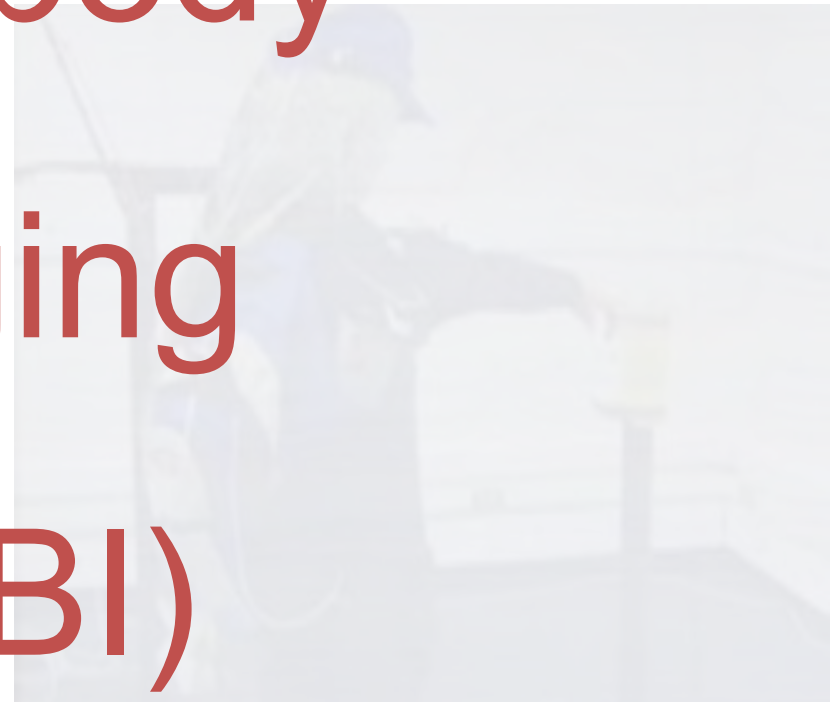
# Brain/body

Concept:

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

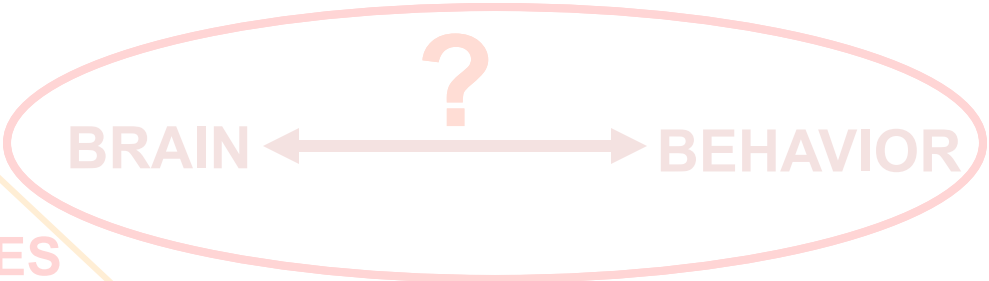
# Imaging

(MoBI)



M  
I  
C  
R  
O

# M O B I B I



SPIKES

LFP

ECOG

MA (D)

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](https://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.

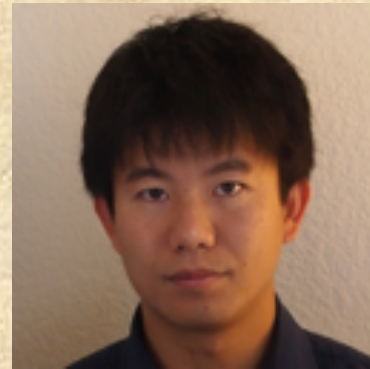
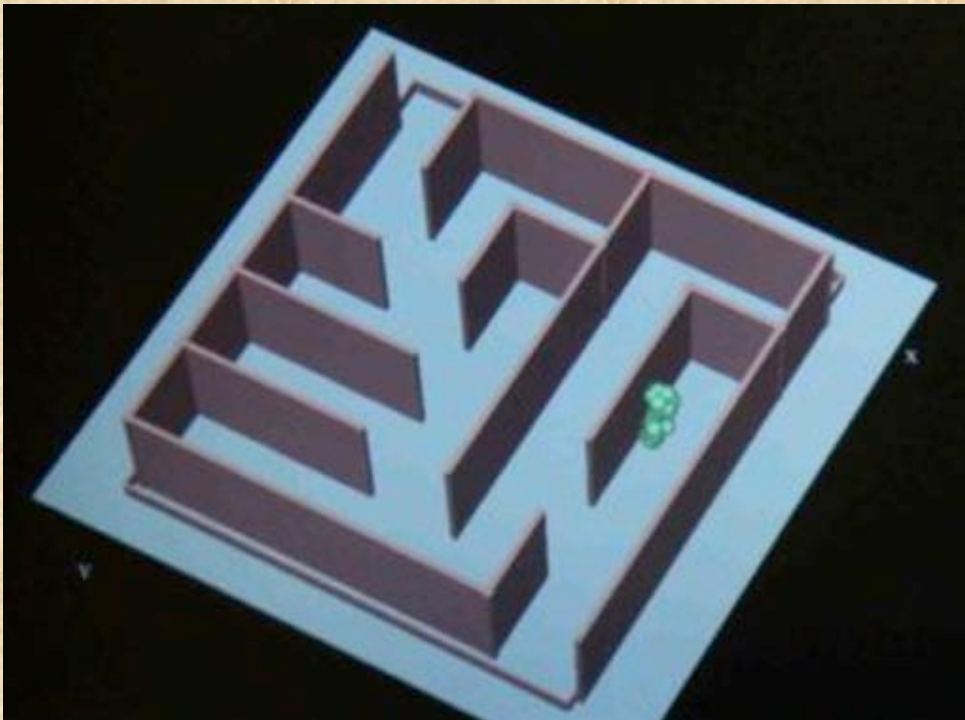
**MoBILAB** – a Matlab-based multimodal data browser and pre-processing app.



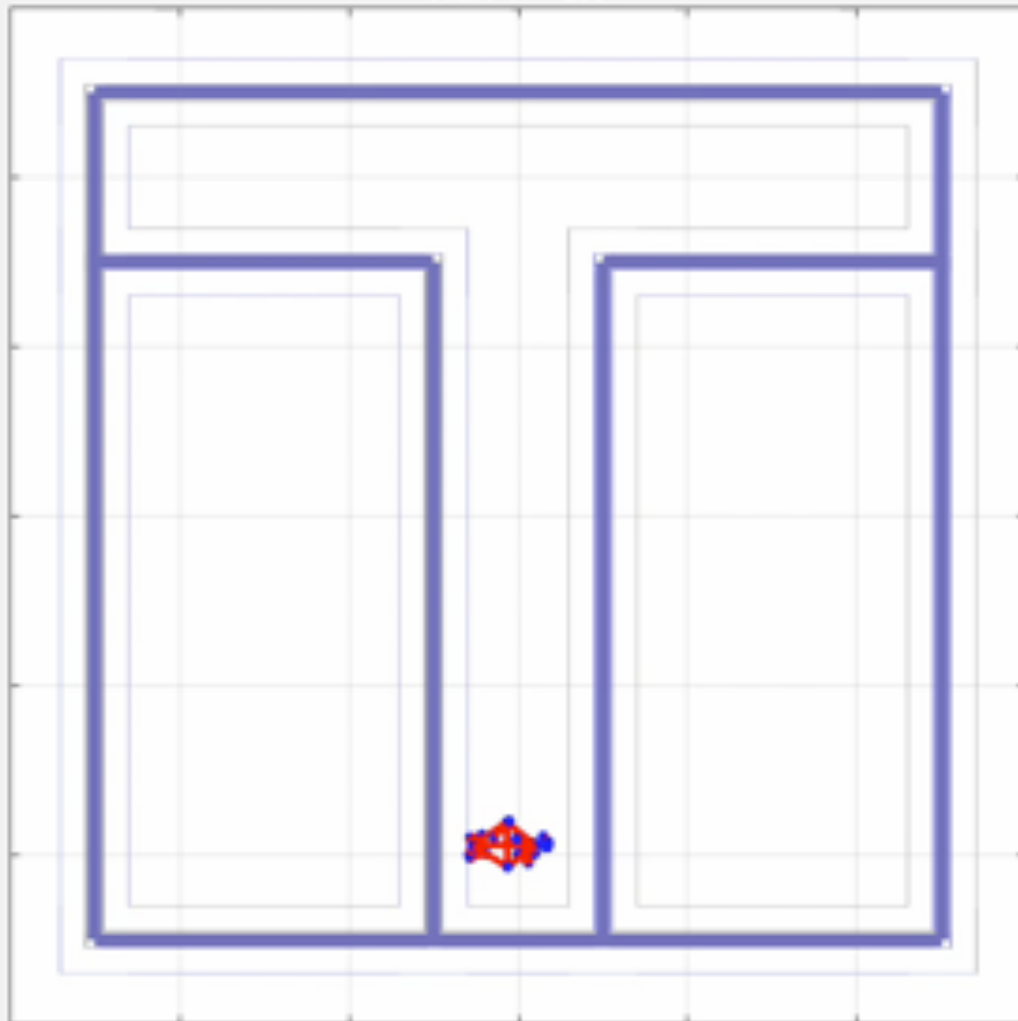


# Spatial Navigation Experiment – the *Audiomaze*

- Navigate an ‘invisible’ maze in the dark.
- Receive directional audio feedback, not tactile feedback.
- Task: Explore the maze and learn its configuration.
- Test: Draw the maze.

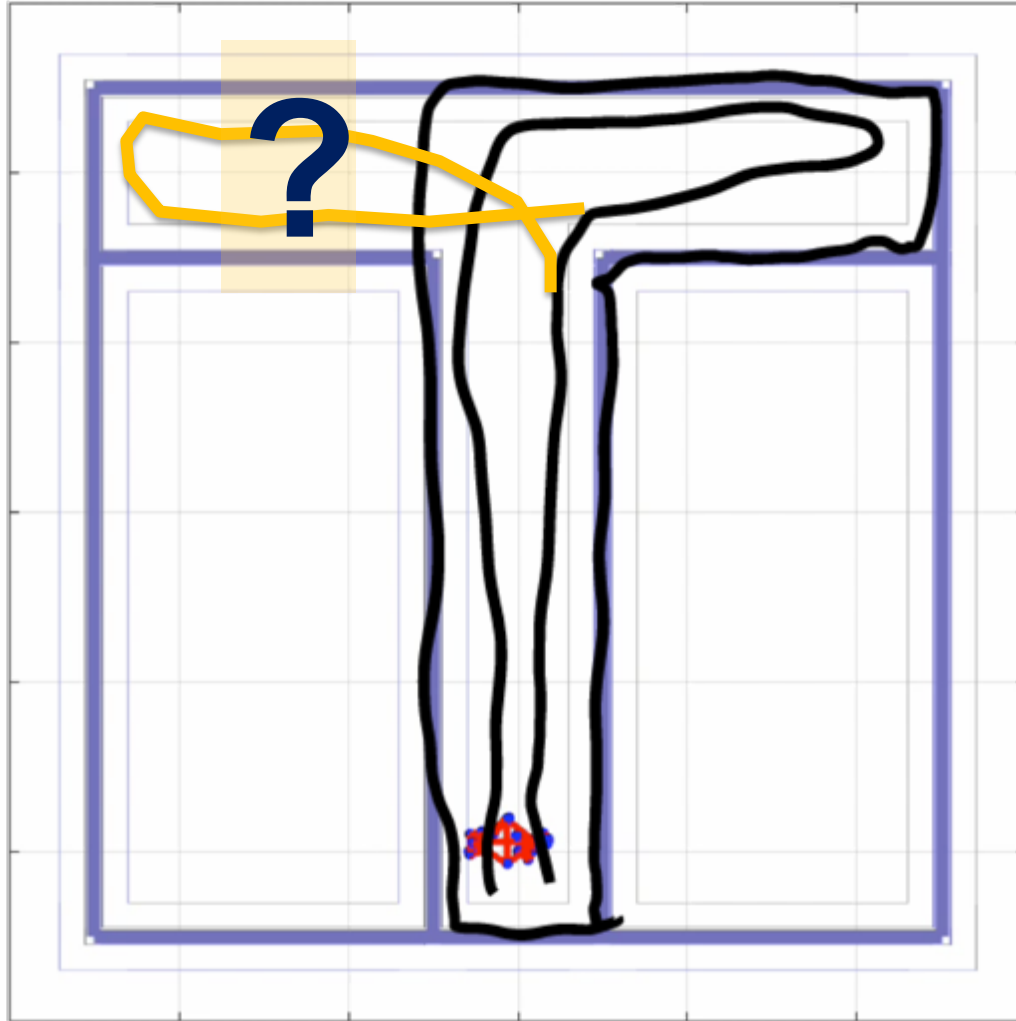


Run 1 0.1

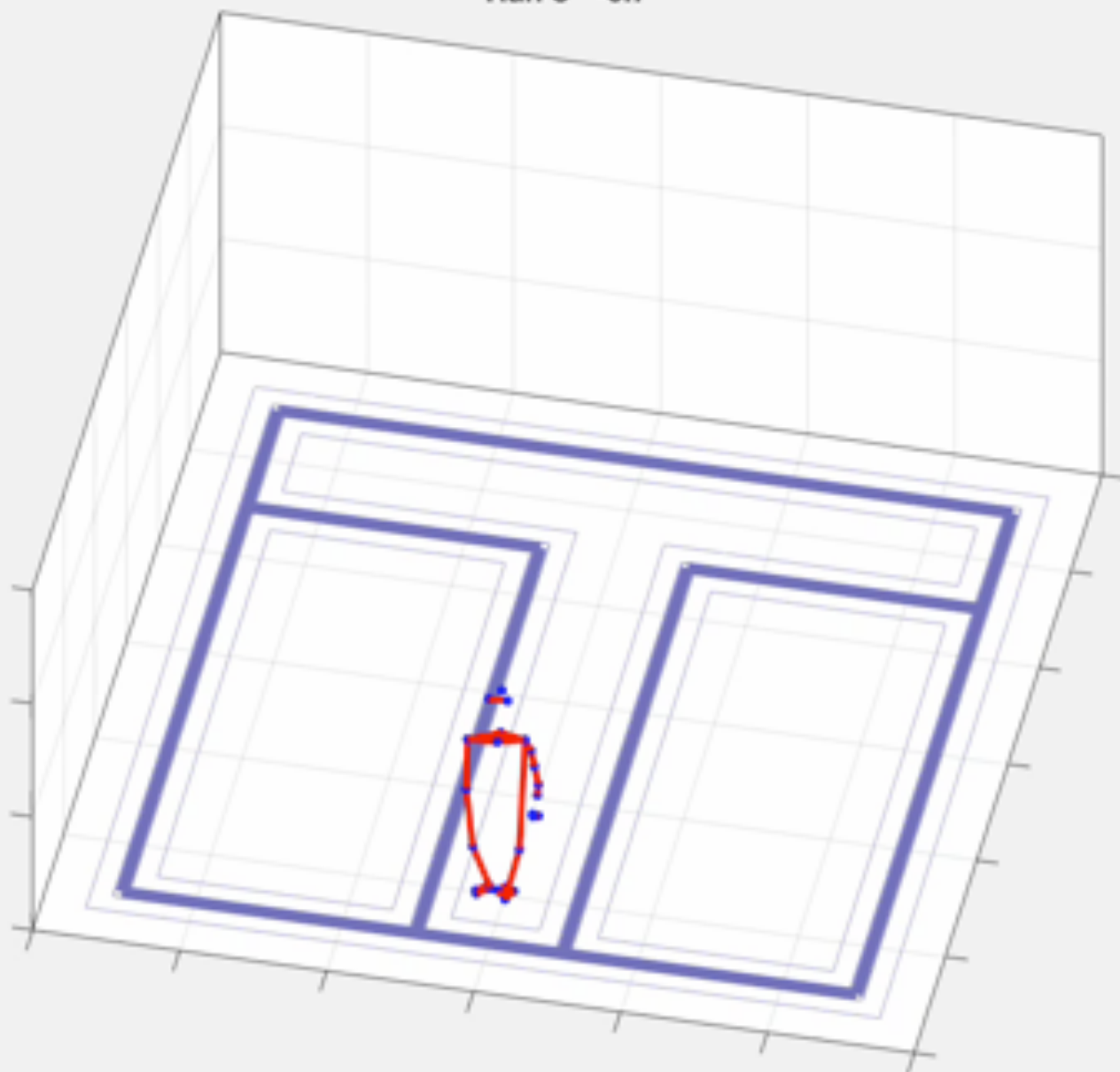




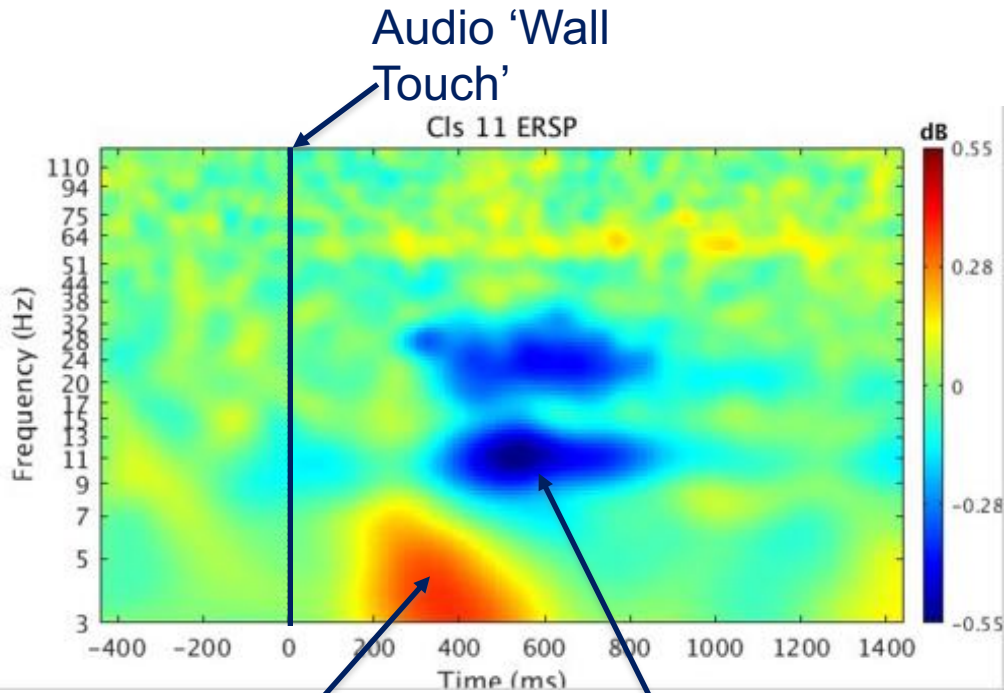
# 1<sup>st</sup> Pass Navigation



Run 3 -0.7

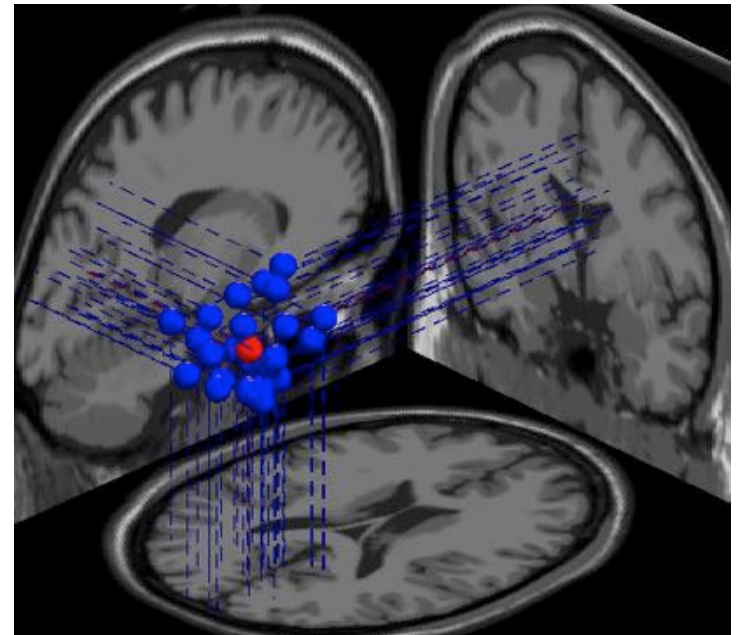
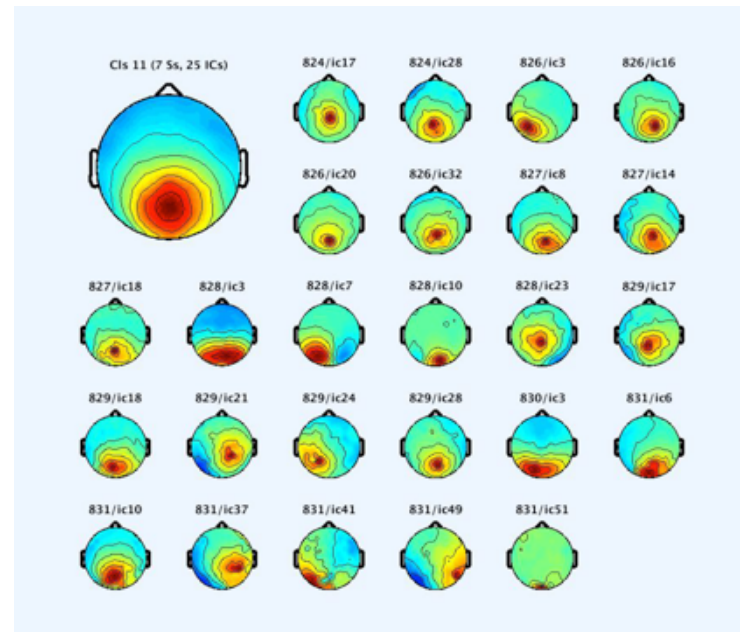


# Central Posterior Independent Component Effective Source Cluster

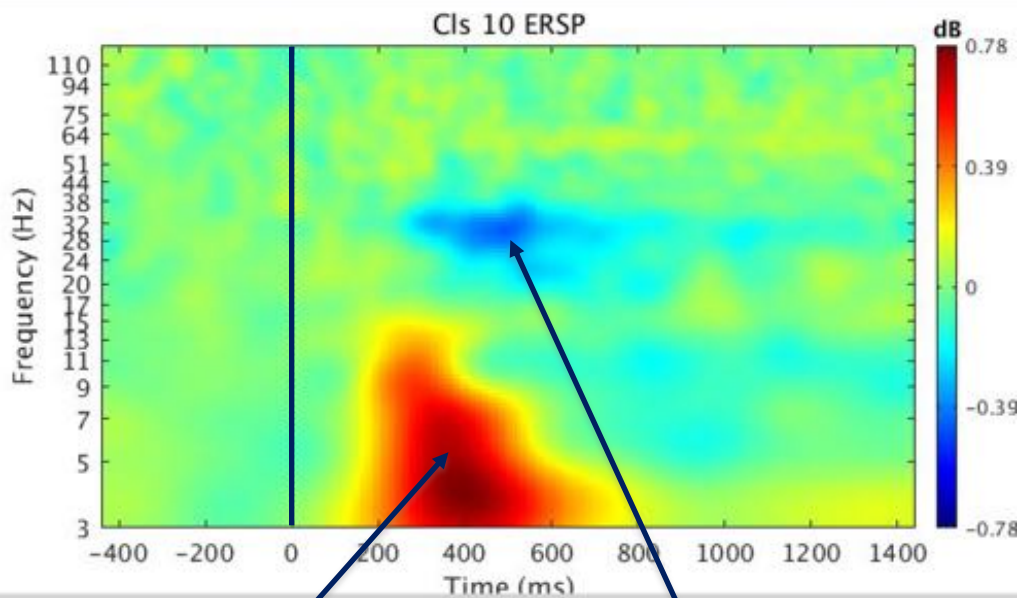


Low-frequency  
increase

Alpha suppression

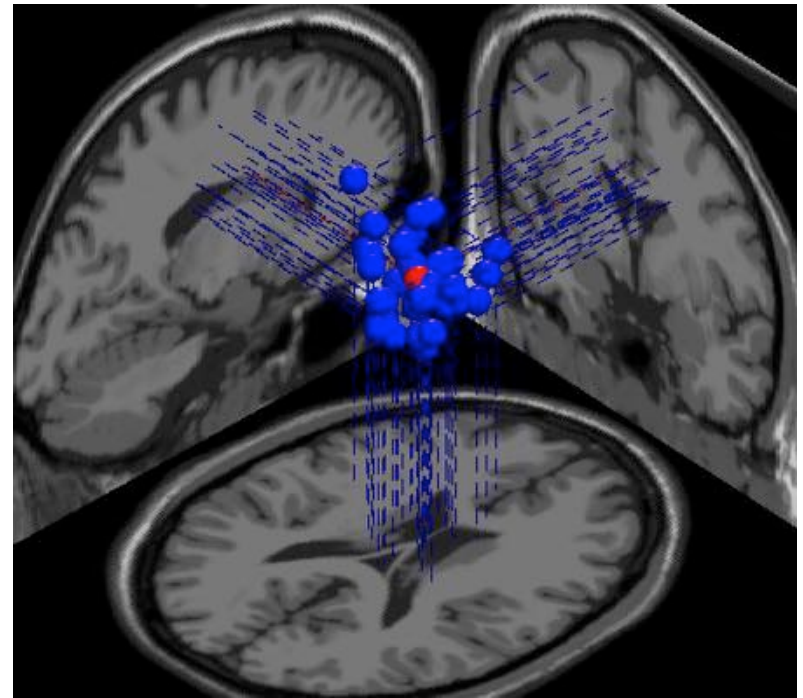
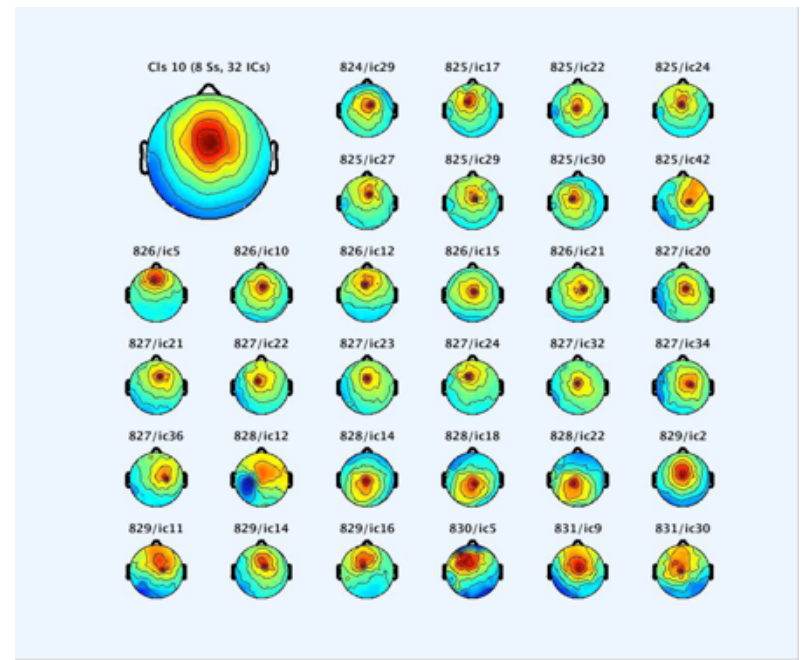


# Frontal Midline Independent Component Effective Source Cluster



Alpha/theta increase

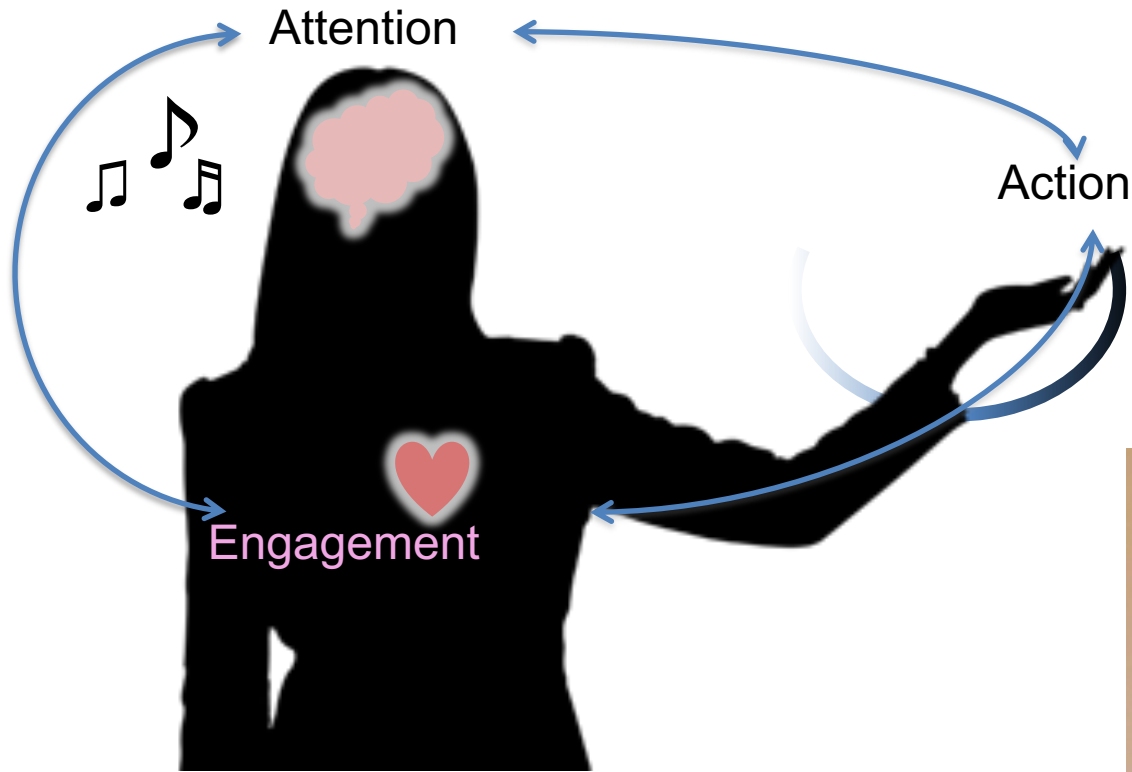
High beta  
suppression





# Measuring Musical Engagement Through Expressive Rhythm

How can we measure listeners' engagement?



# Expressive gesturing task

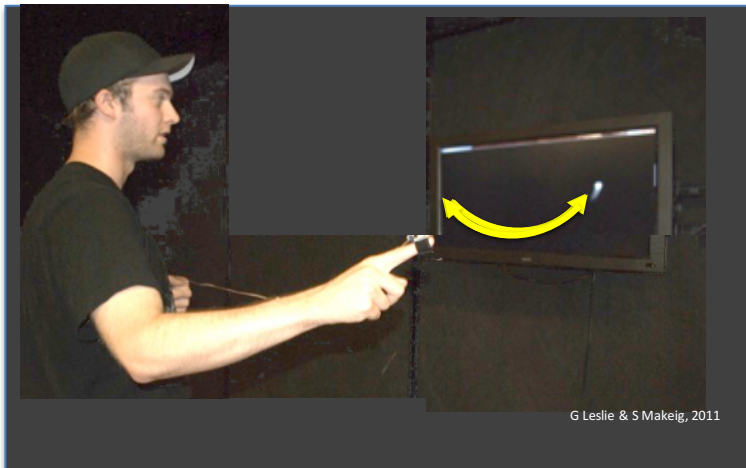
The Heart is a  
Lonely Hunter (1968)



**Two conditions:**

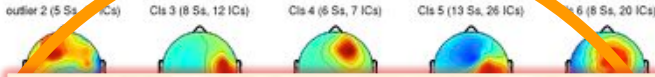
- Fully engaged
- Less engaged

Conducting Experiment (2013)



Grace Leslie & S Makeig, 2013

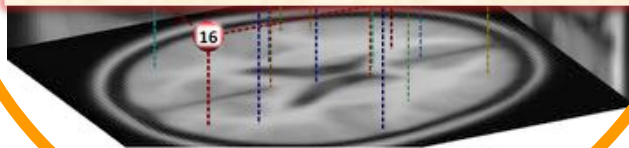
# EEG Result



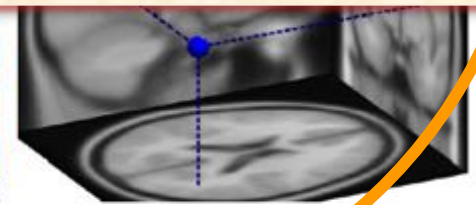
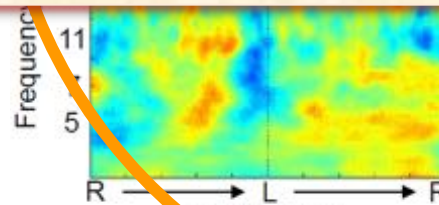
The **TPJ** controls **representations of the self or of another individual** across a variety of low-level and high-level and socio-cognitive processes (mentalizing, empathy, agency discrimination, visual perspective taking, imitation) ...

The **right TPJ** is a key cortical structure for both motor and emotional control – particularly of hand control.

**rTPJ volume predicts level of emotional awareness of others** (in autistics) ...

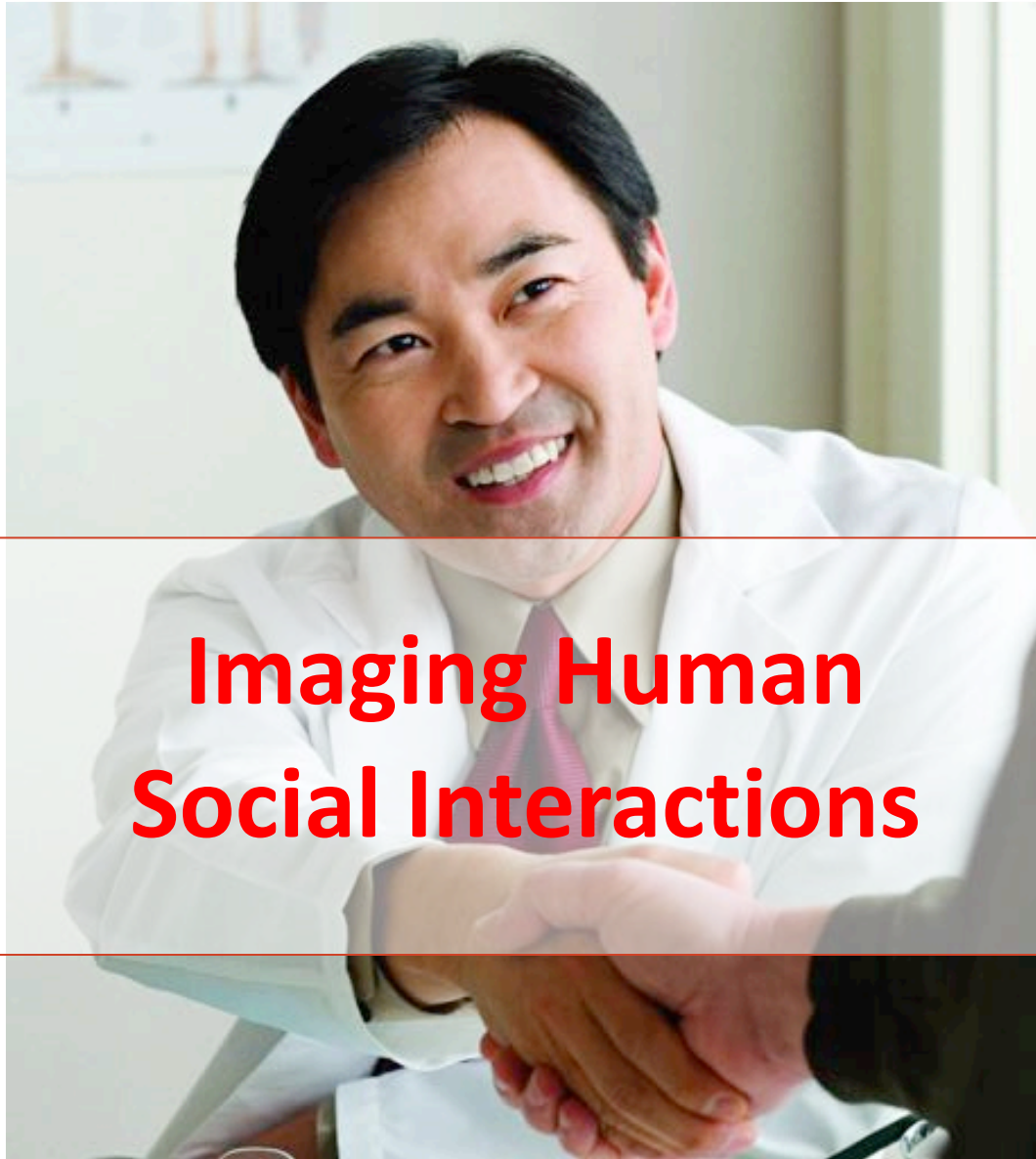


Fre



**Swing Cycle**

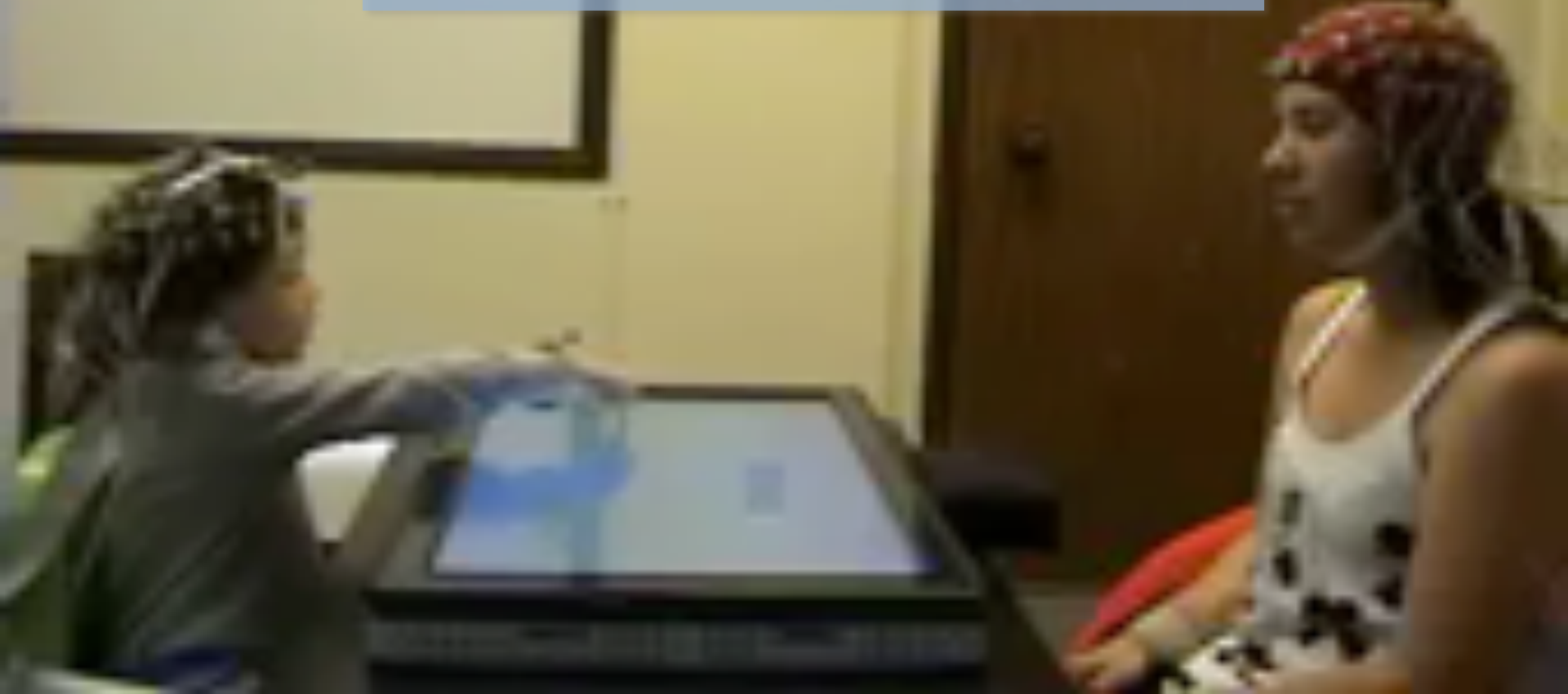
*Brain imaging natural cognition -- actions & interactions*



**Imaging Human  
Social Interactions**

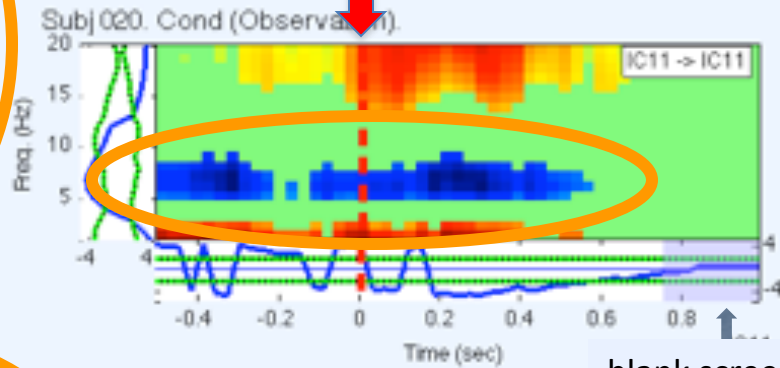
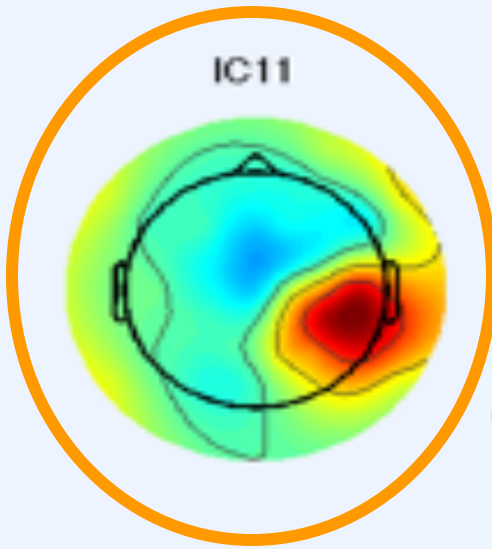


Gedeon Deak Lab @ UCSD Cognitive Science  
“Development of Shared Attention” –  
**A Mother and Toddler MoBI Experiment**

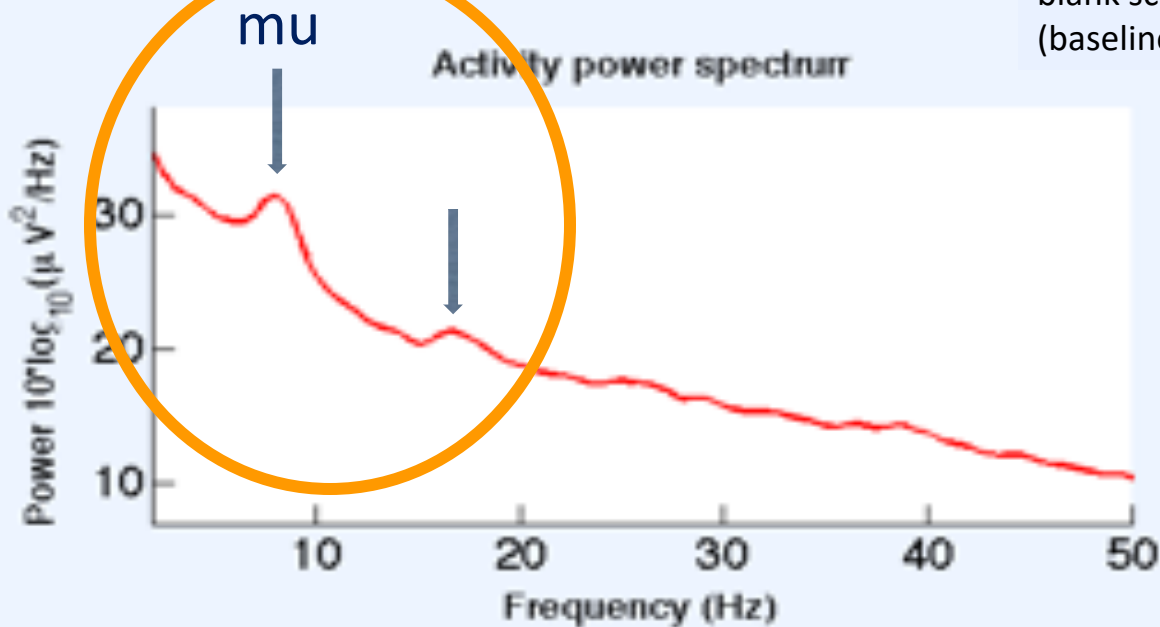


3-yr old child – Reward Observation

**Mother Pops the Bubble!**



blank screen  
(baseline)

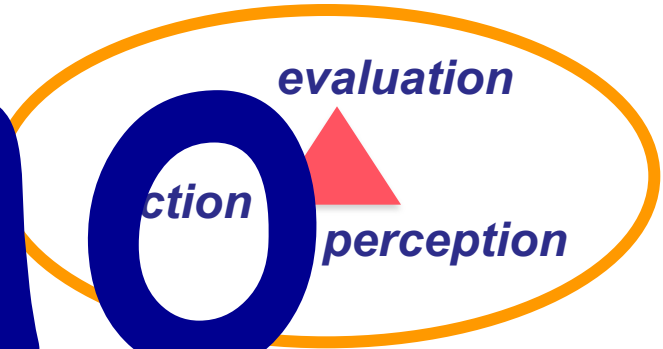


# Embodied Cognition & Agency

Brain processes  
have evolved a function  
to optimize the outcome  
of behavior.

the brain organizes  
in response to  
*perceived challenges*  
*and opportunities.*

who



am

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



# The Beginning

fEEG, BCI, MoBI,

NFB, BrainStim ...