

Mining Event-related Brain Dynamics

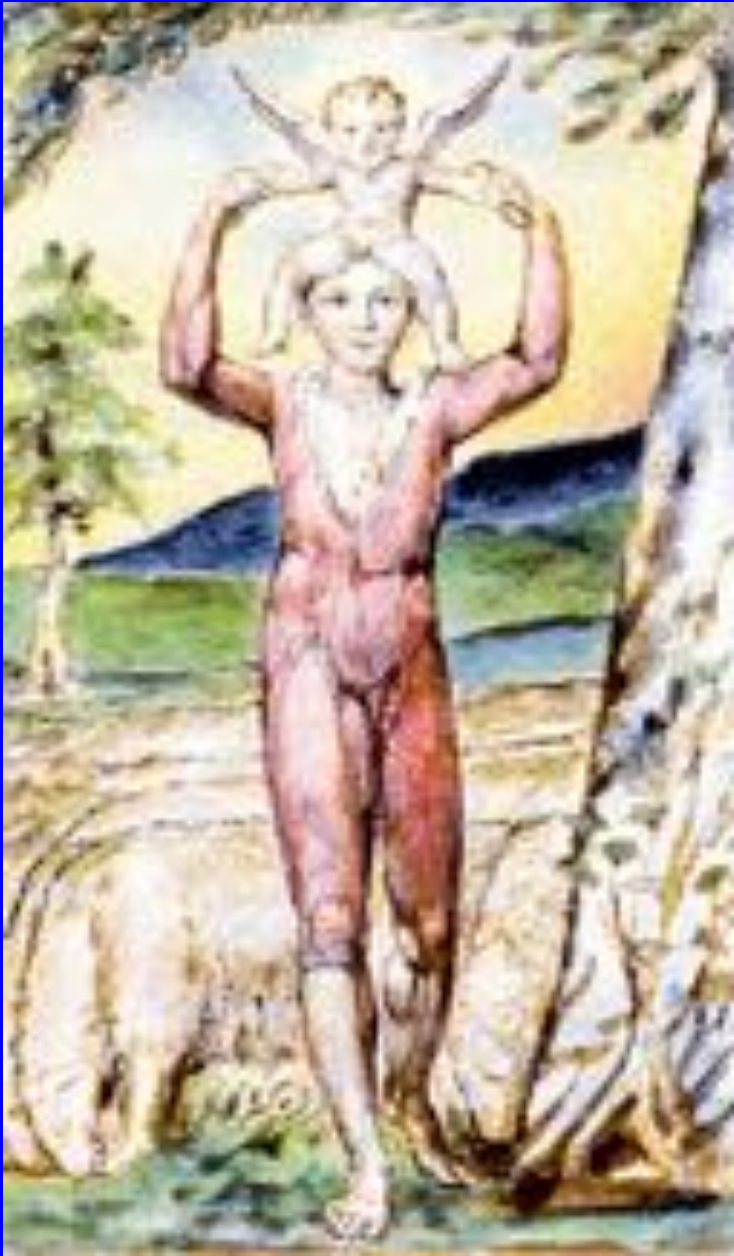
II



Scott Makeig

Institute for Neural Computation
University of California San Diego

27th EEGLAB Workshop
Pittsburgh, Pennsylvania
September, 2018





SCCN Open Source Software Tools

List of data processing extensions

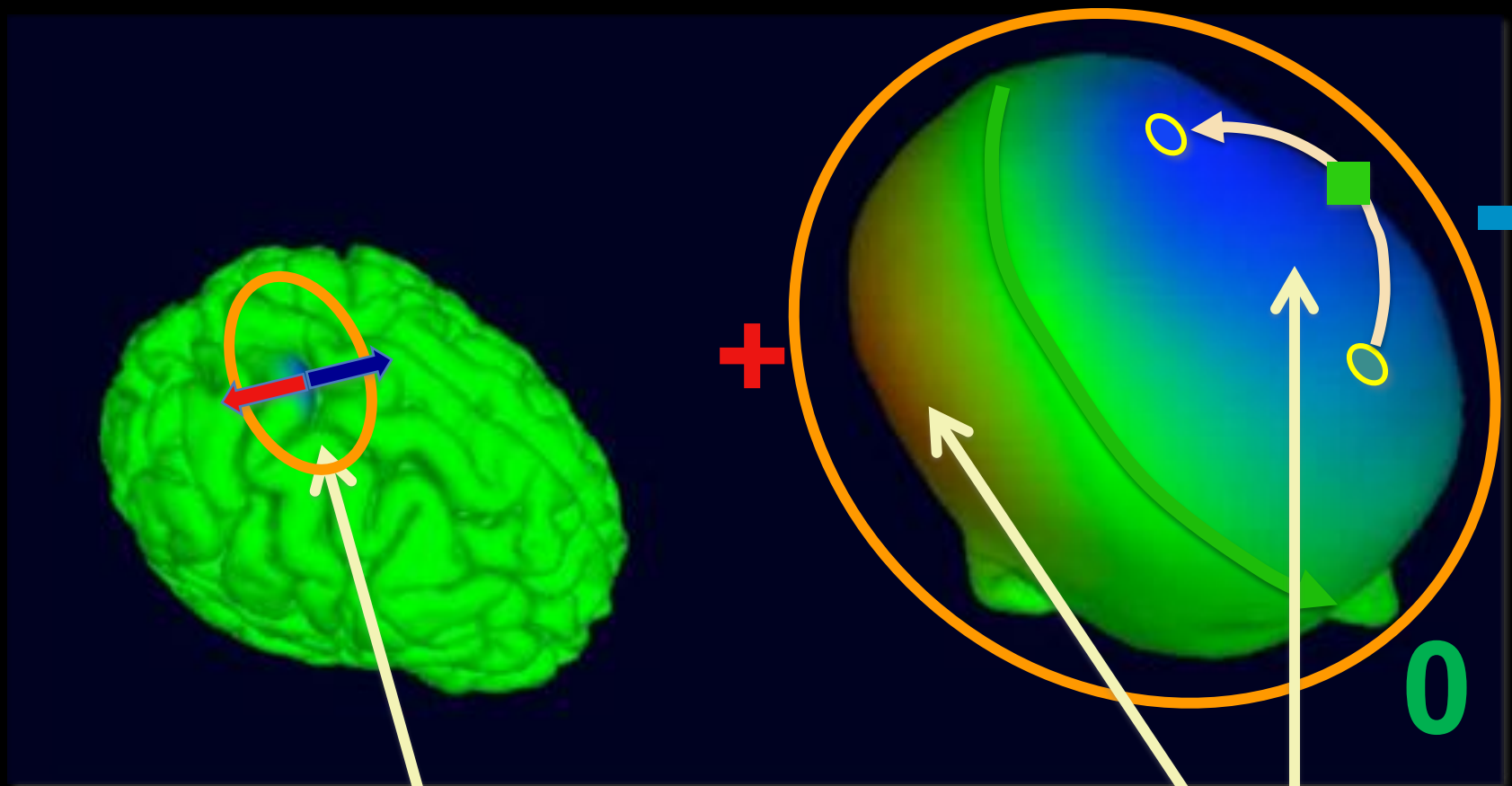
Plug-in name	Version	Short plug-in description	Link	Contact	Comments
rERP	0.4	Estimate overlapping ERPs using multiple regression	Download	M. Burns	User comments
LIMO	1.5	Linear MODElling of EEG data	Download	C. Pernet	User comments
corrmap	2.02	Cluster ICA components using correlation of scalp maps	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
irfilt	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
pvstftopo	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
AfitStudio	0.10	Cleans spiky artifacts using Afit (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. Groppa	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
irfilt	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 **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.**

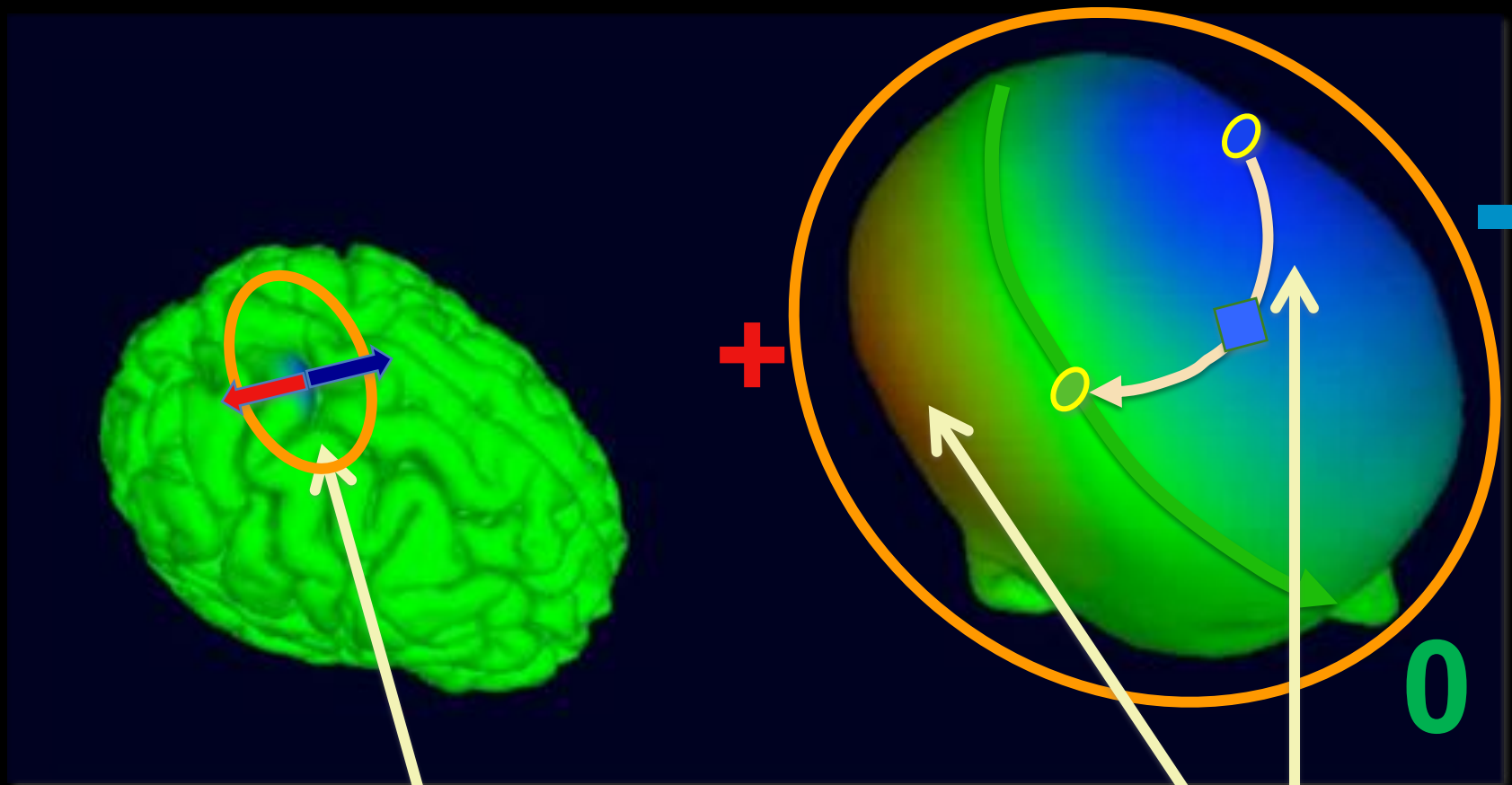
The very broad EEG point-spread function



Single simulated parietal source →

Very broad projected scalp potentials

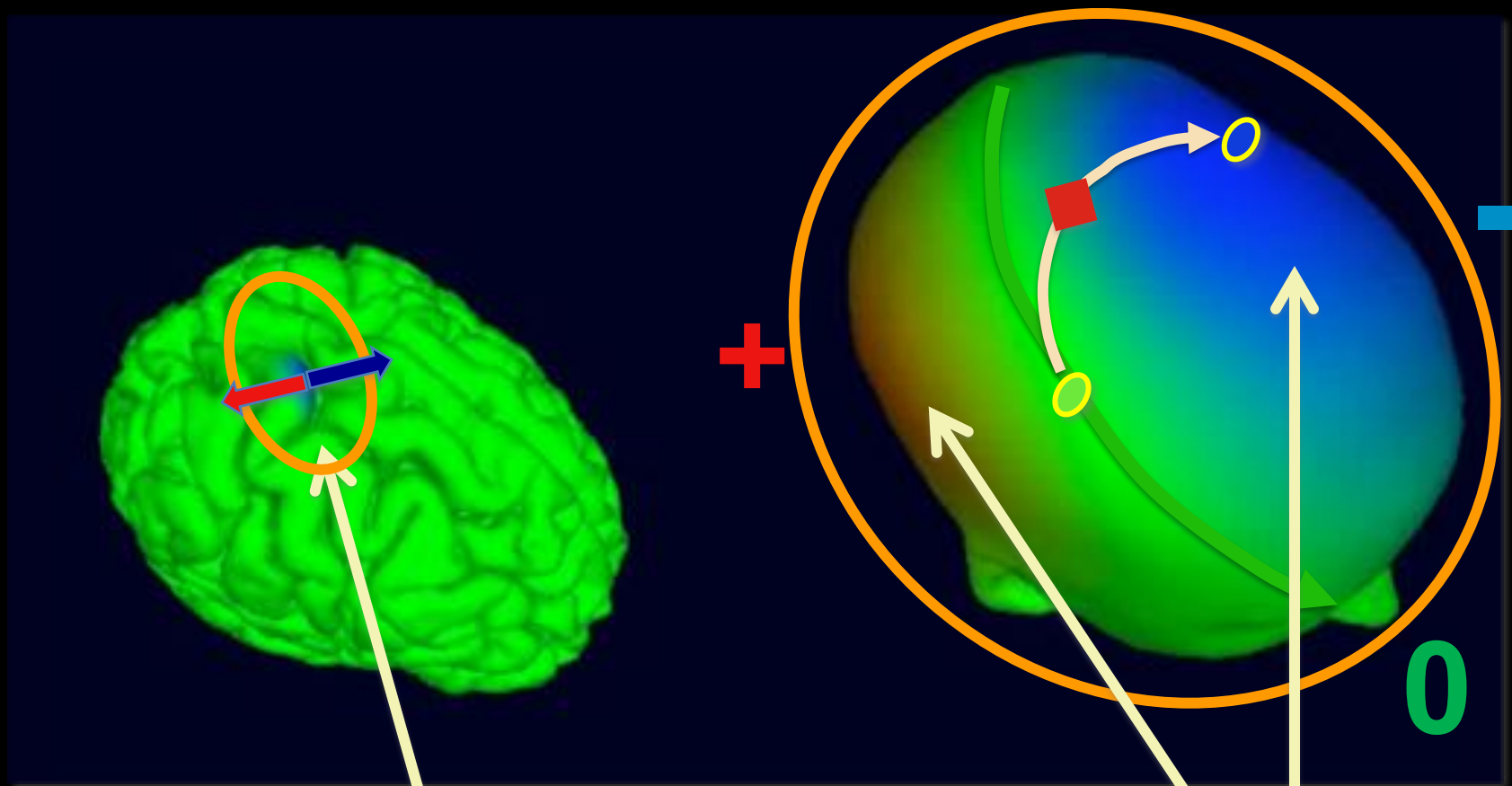
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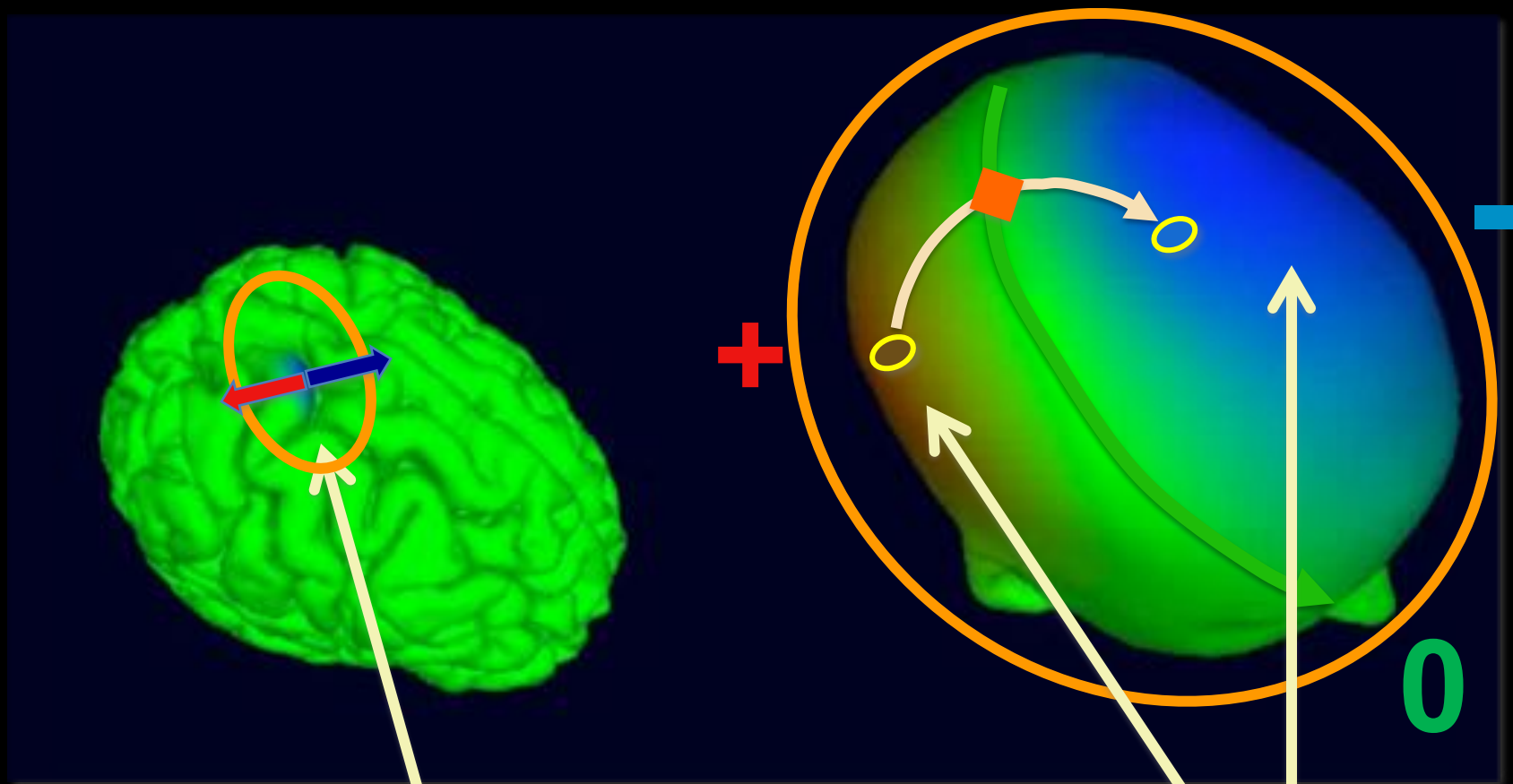
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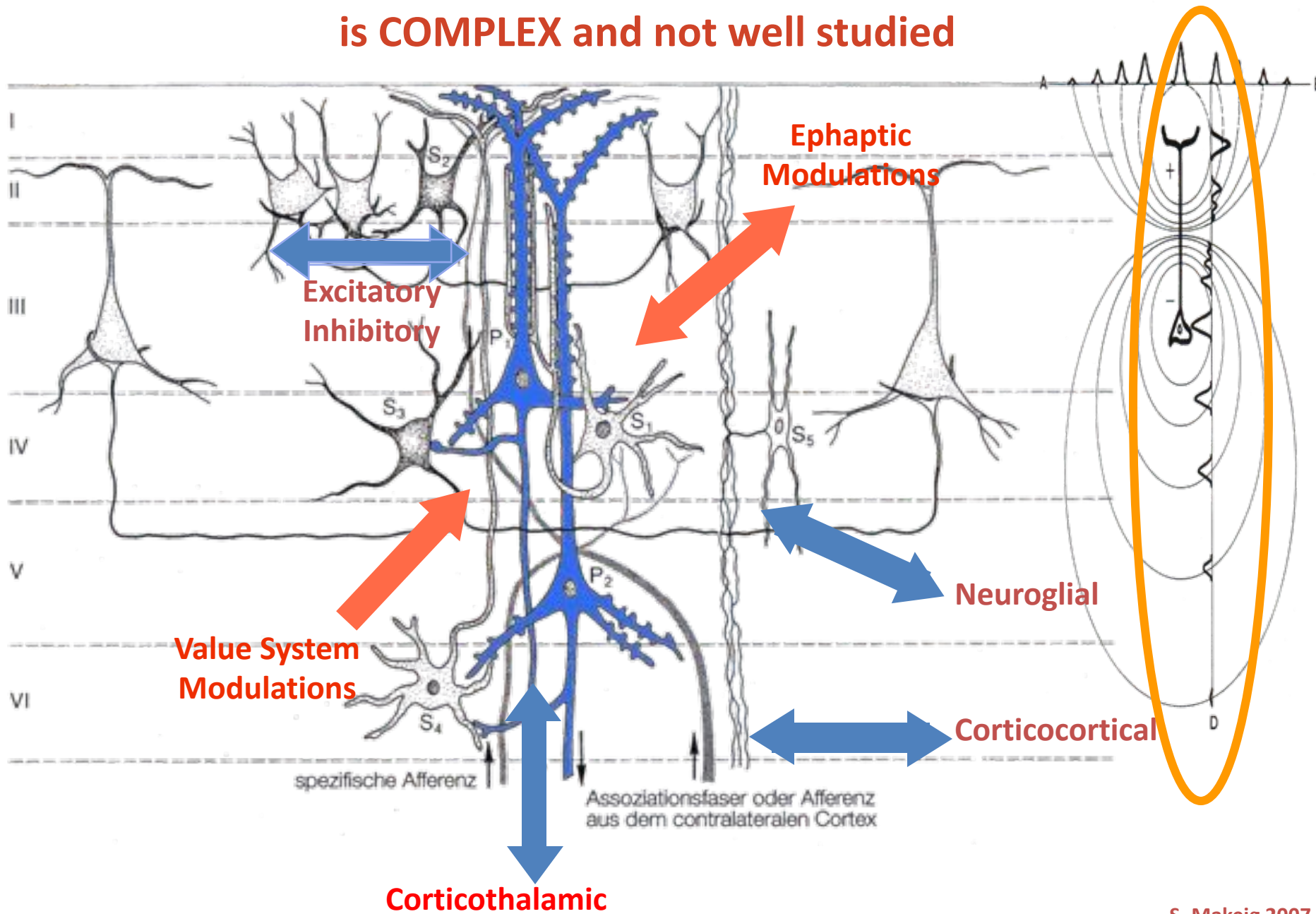
The very broad EEG point-spread function



Single simulated parietal source →

Very broad projected scalp potentials

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

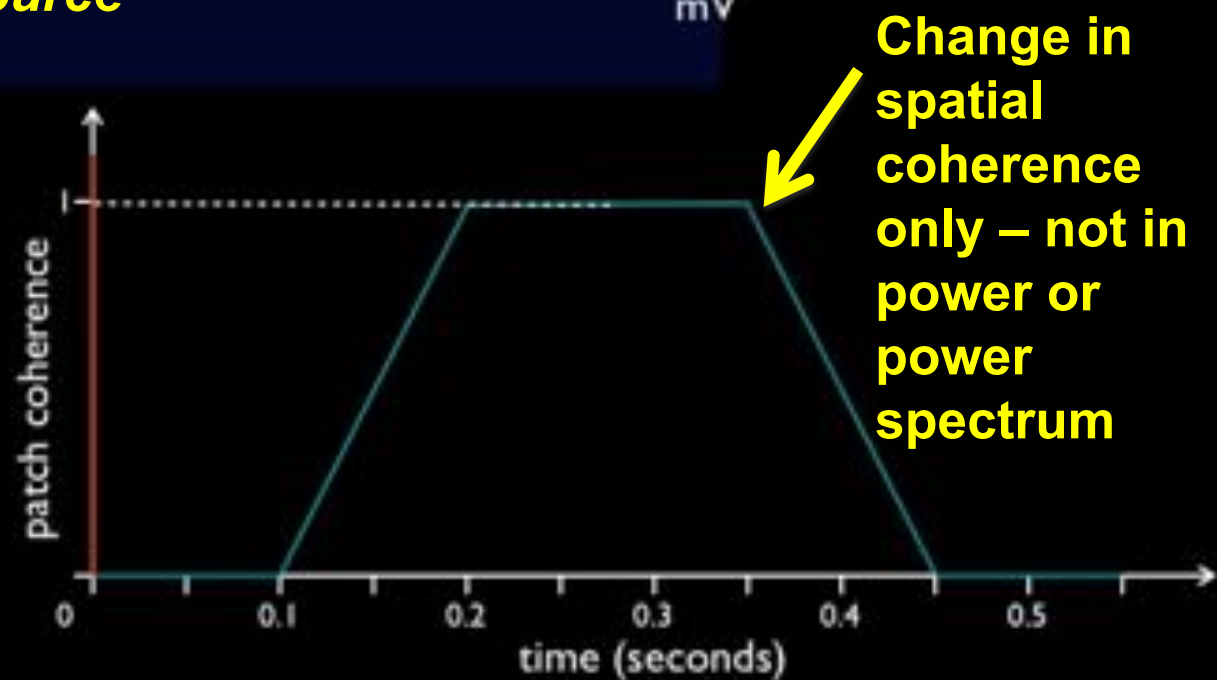
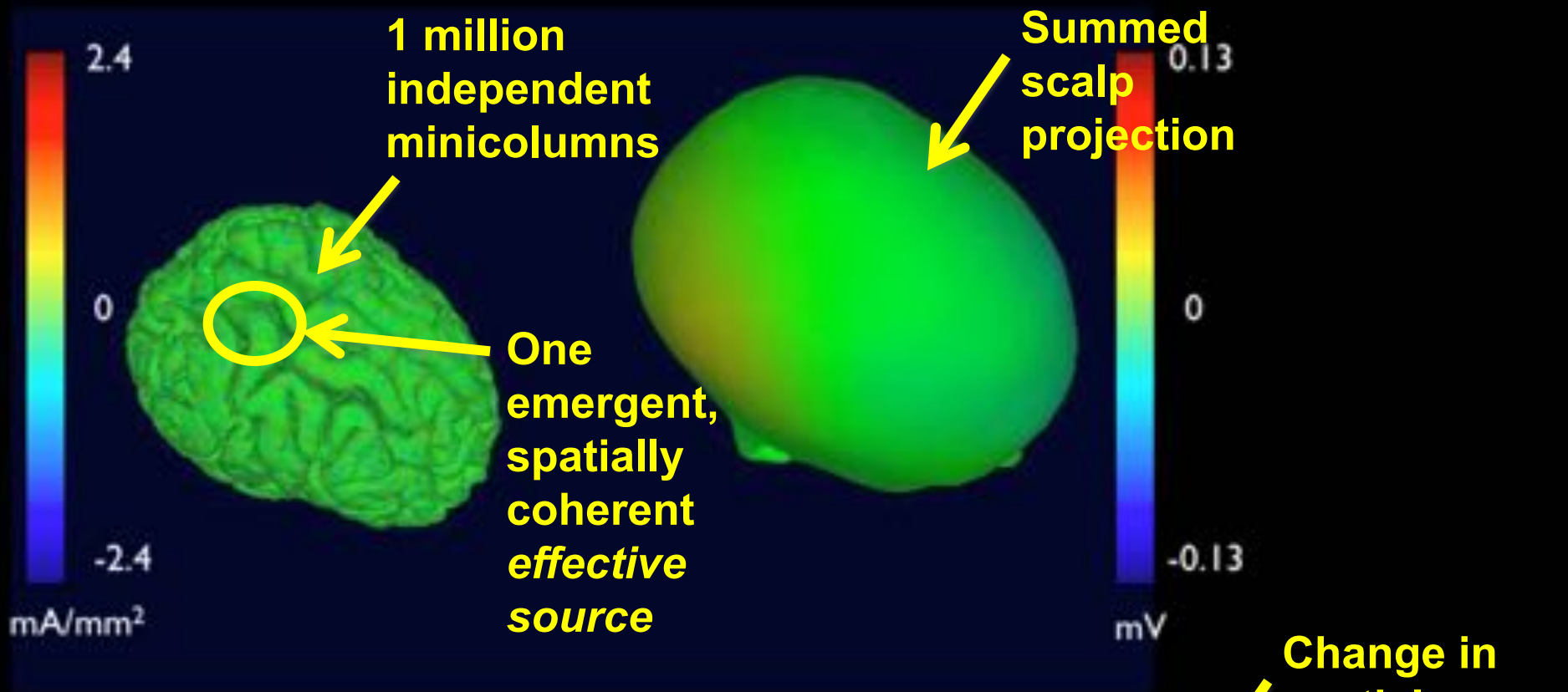


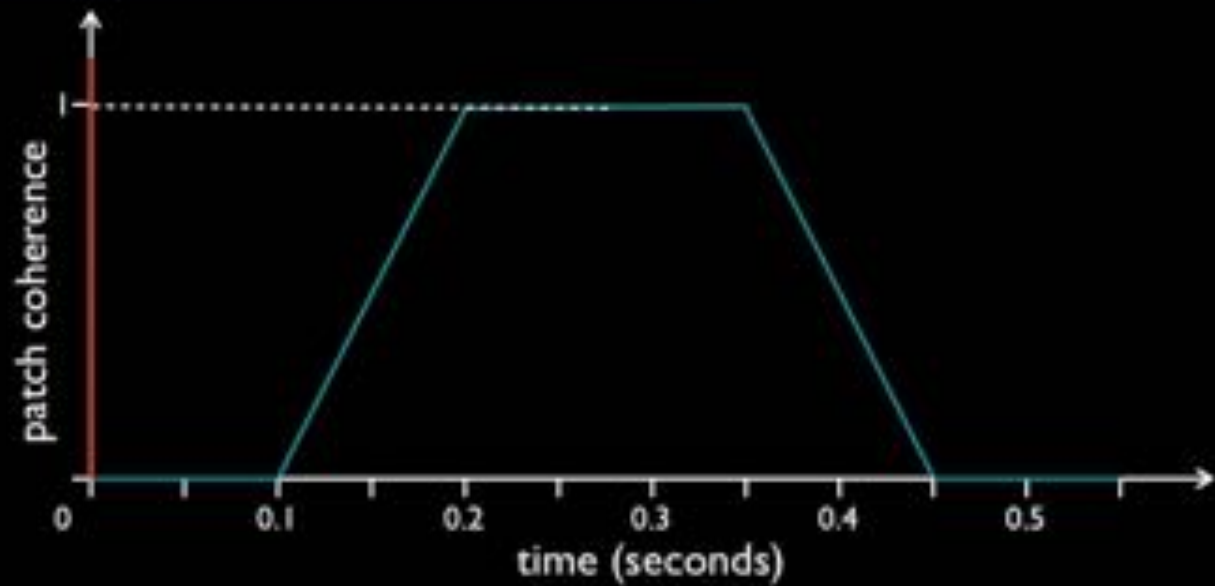
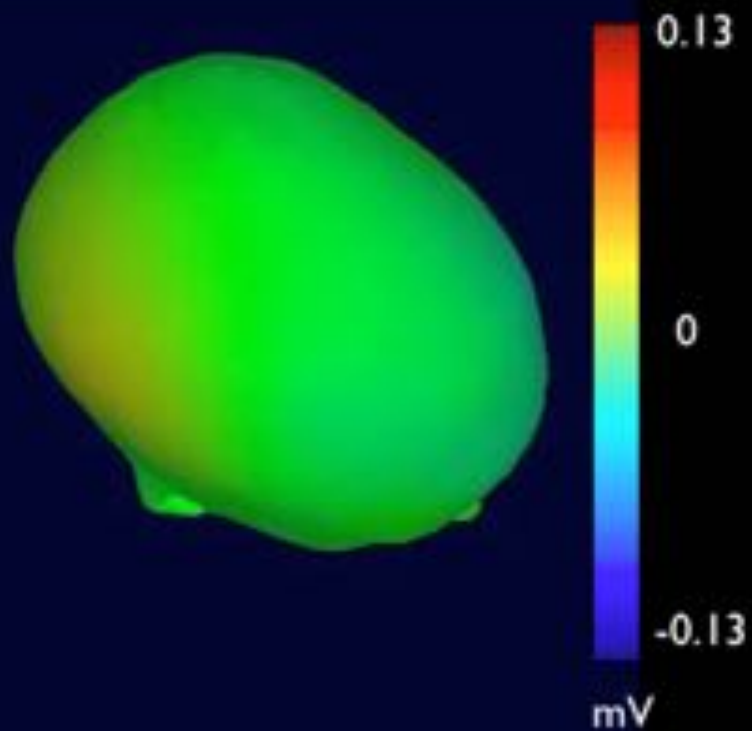
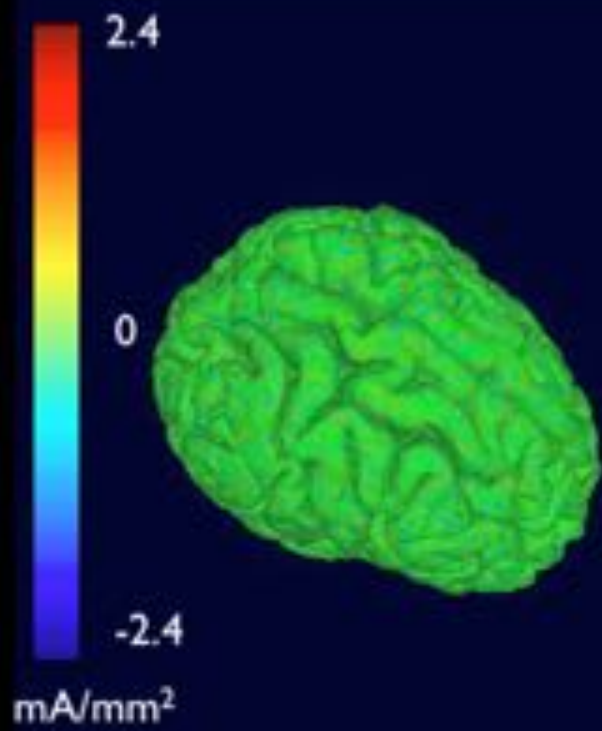


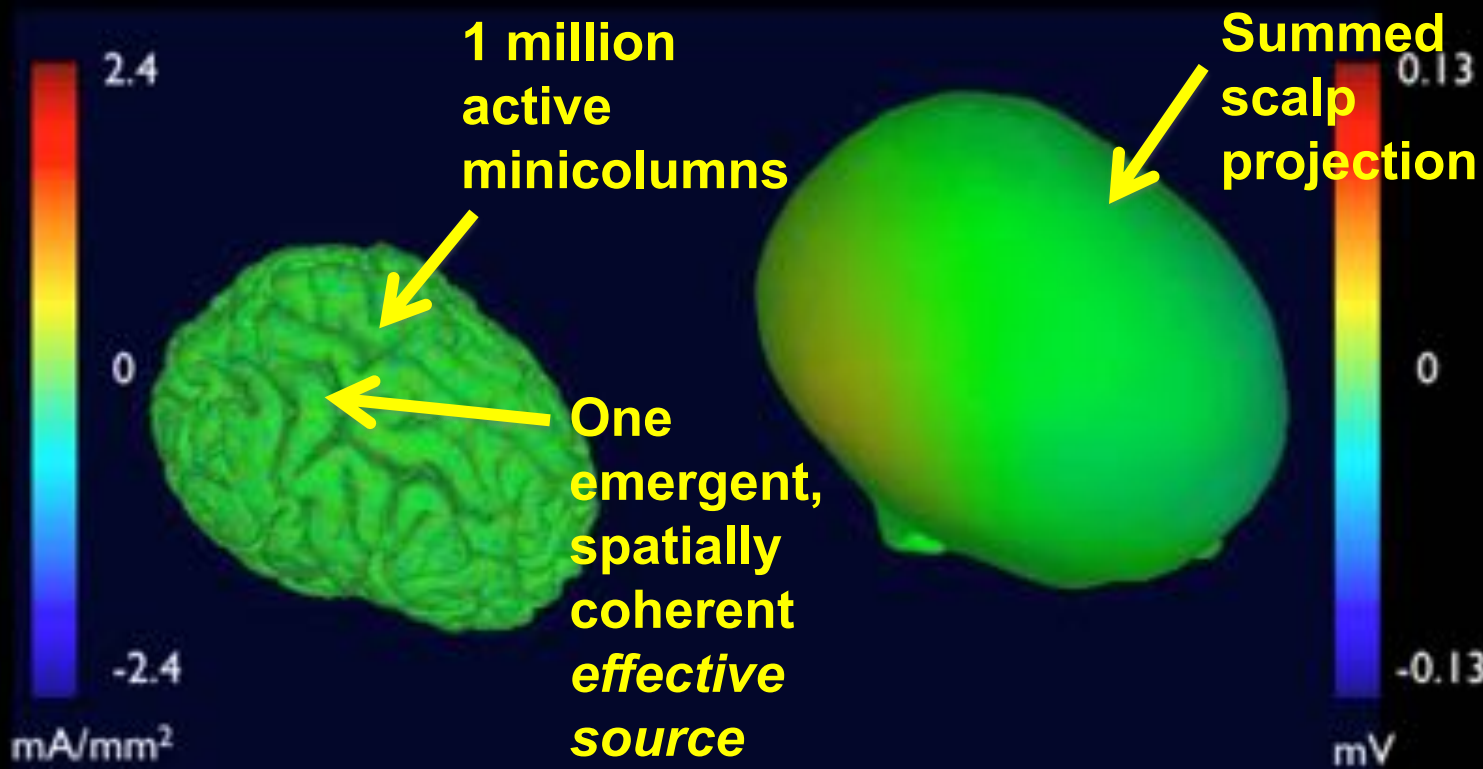
Phase cones (Freeman)

Avalanches (Plenz)



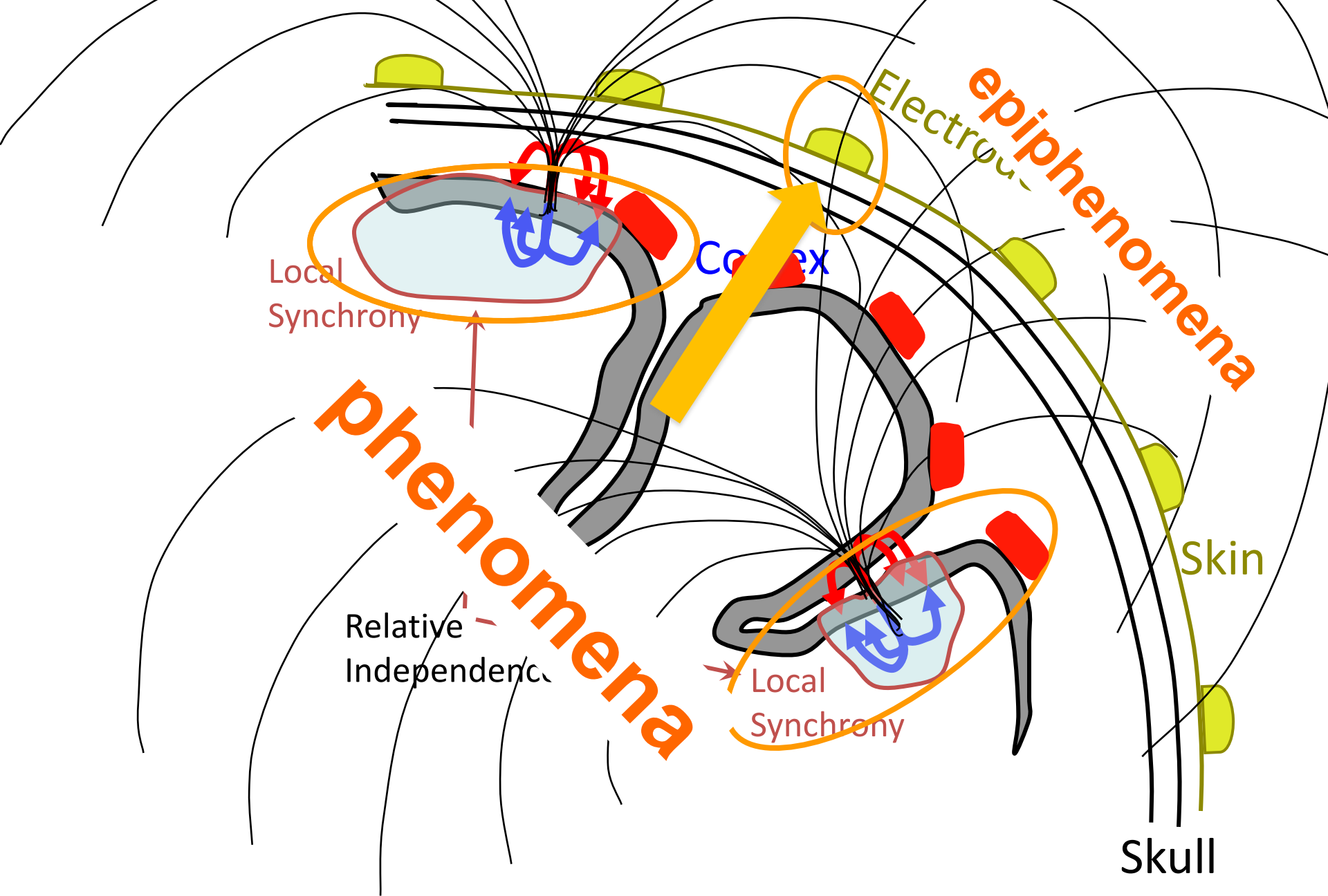






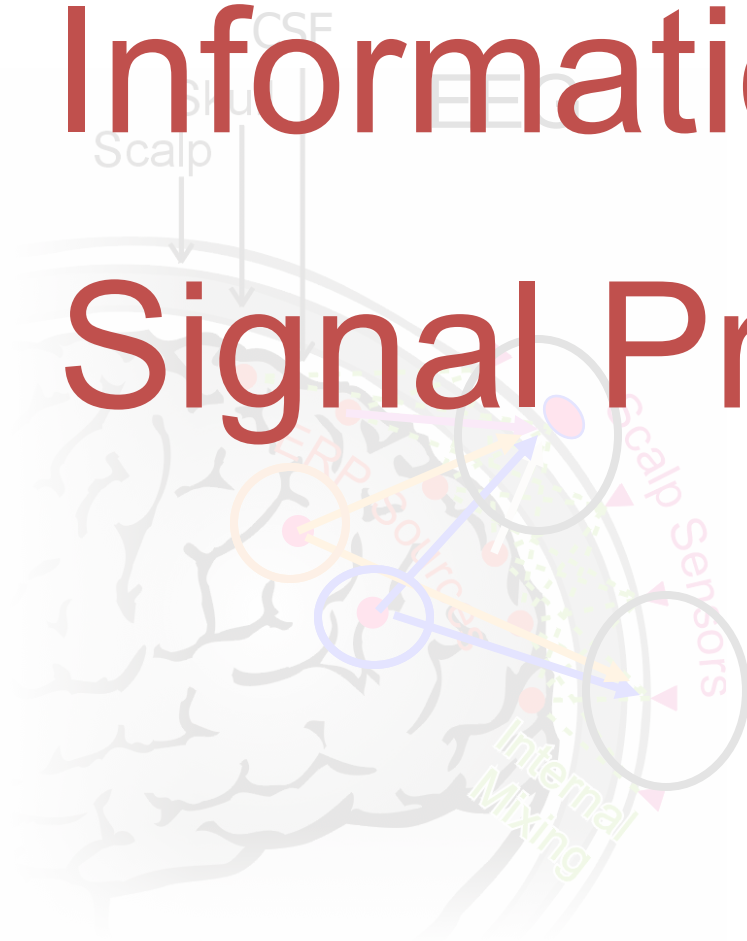
The *effective sources* of the scalp EEG & MEG are emergent islands of local synchrony / near-synchrony.





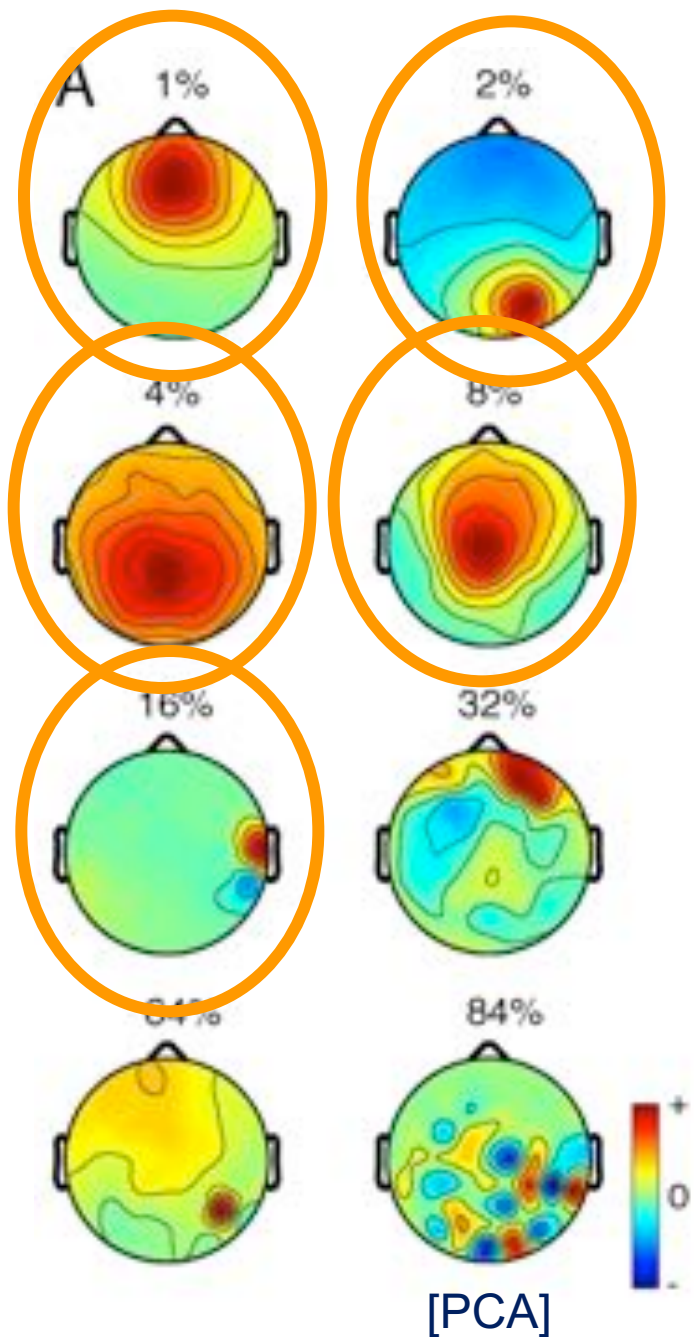
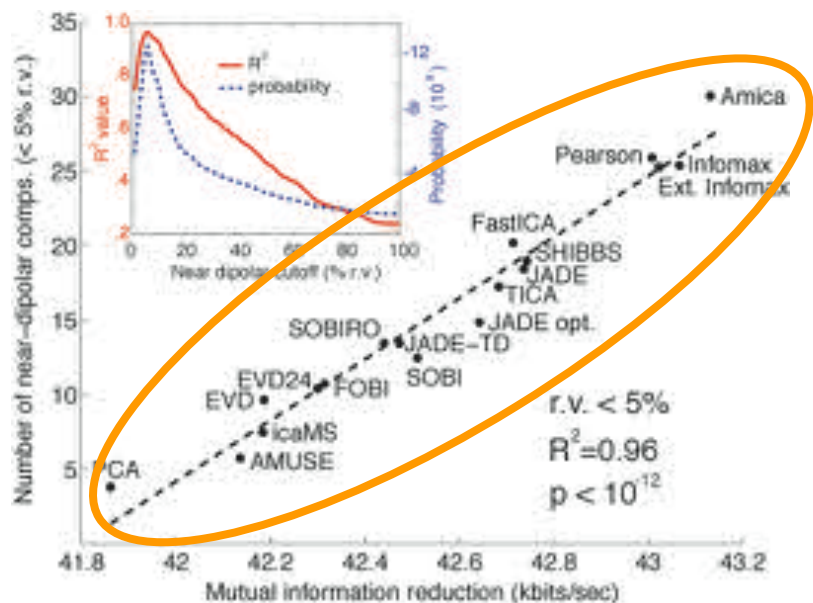
Blind EEG Source Separation by ICA

Information-based Signal Processing

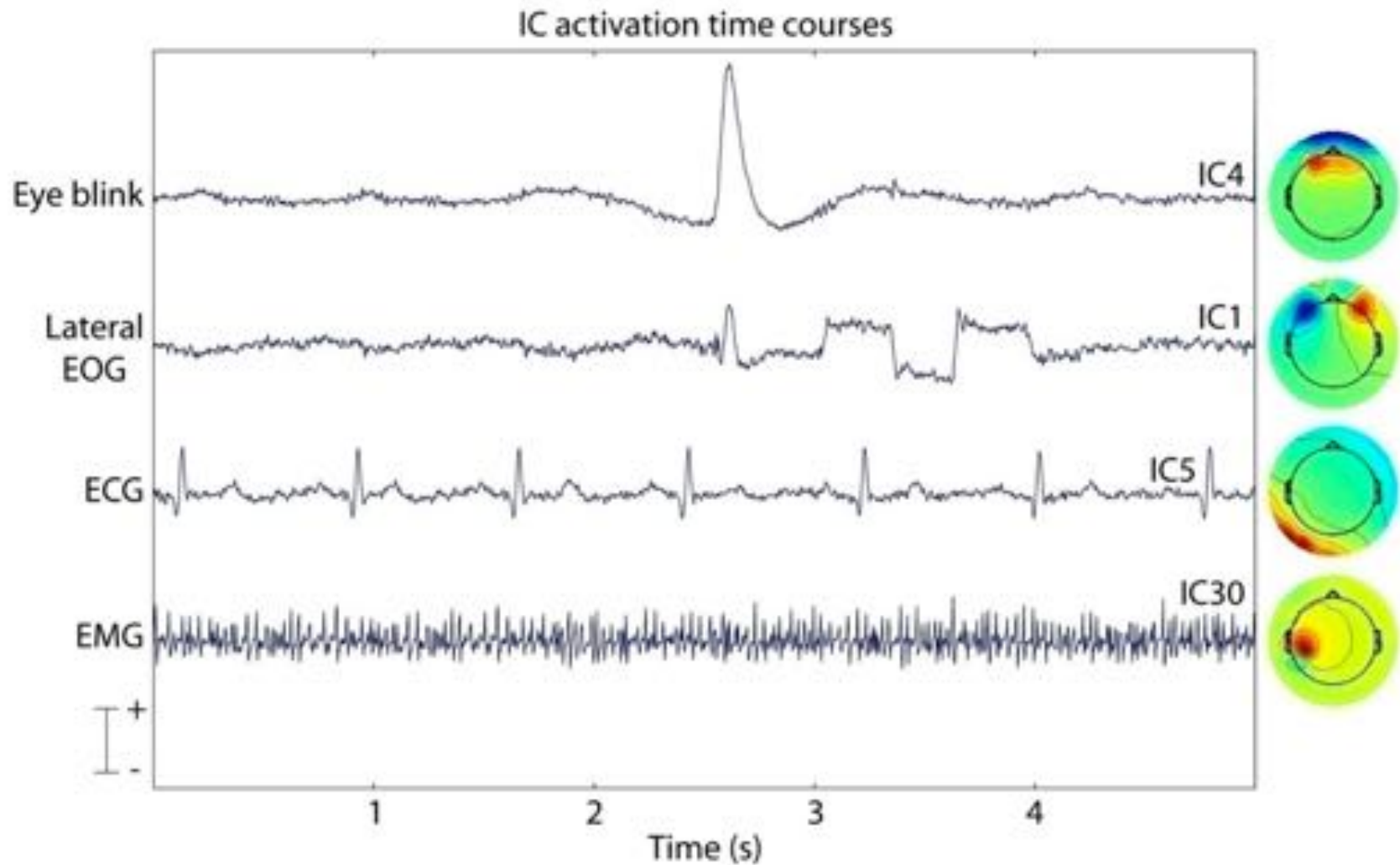


Independent Component Dipolarity

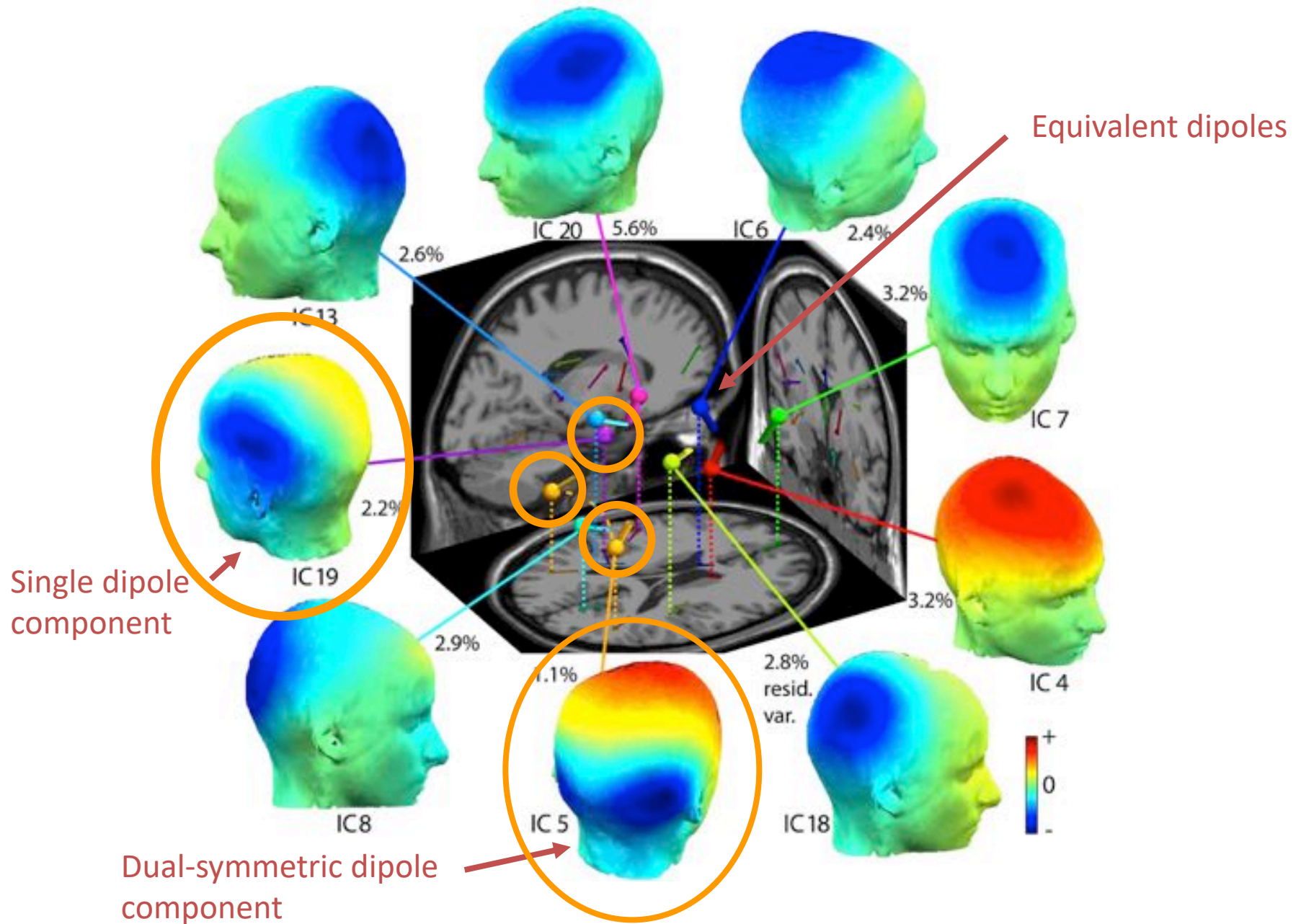
Measured by residual variance
not accounted for by the best fitting single
 (or dual) equivalent dipole model.



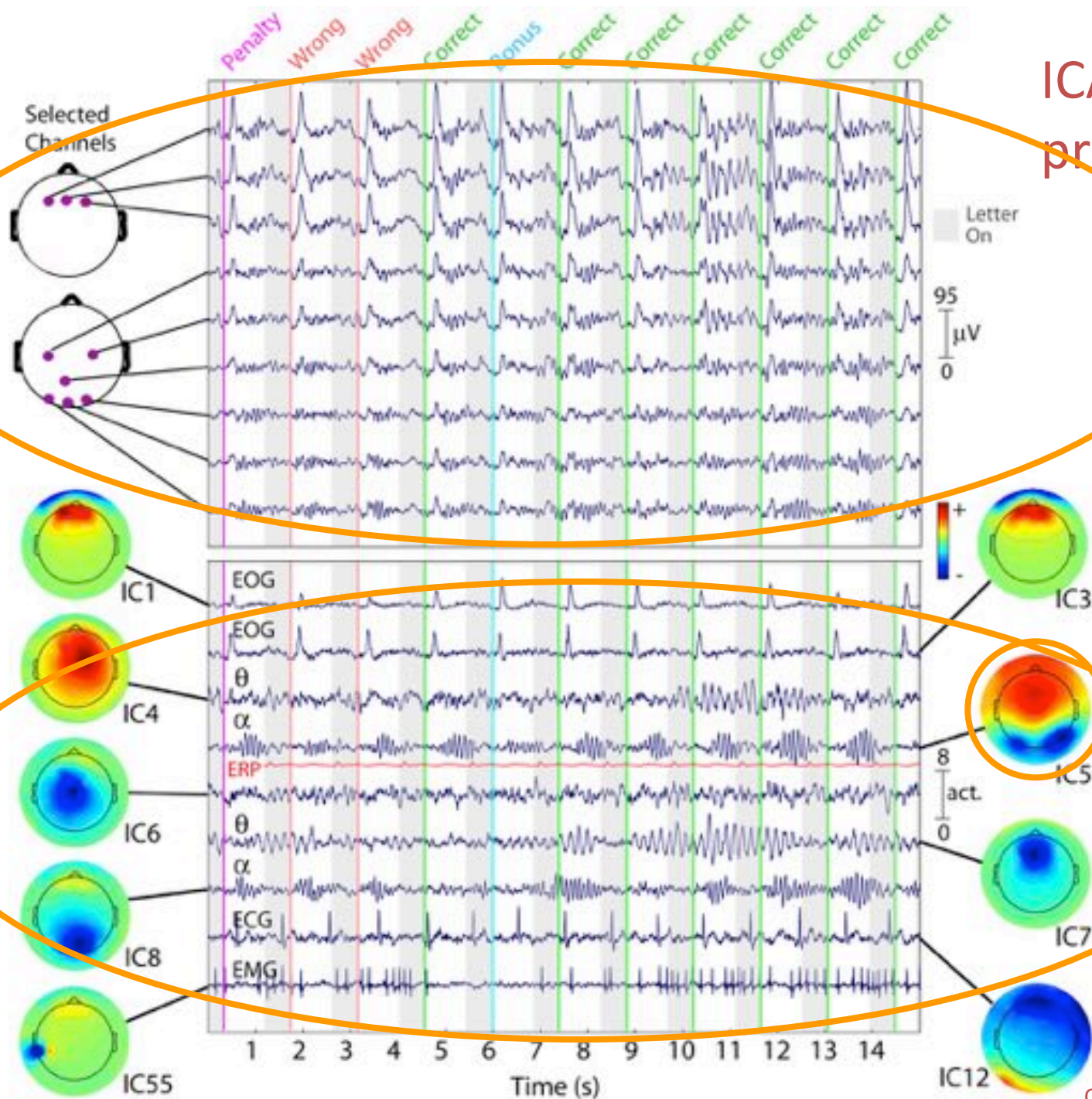
ICA separates *non-brain* effective source processes

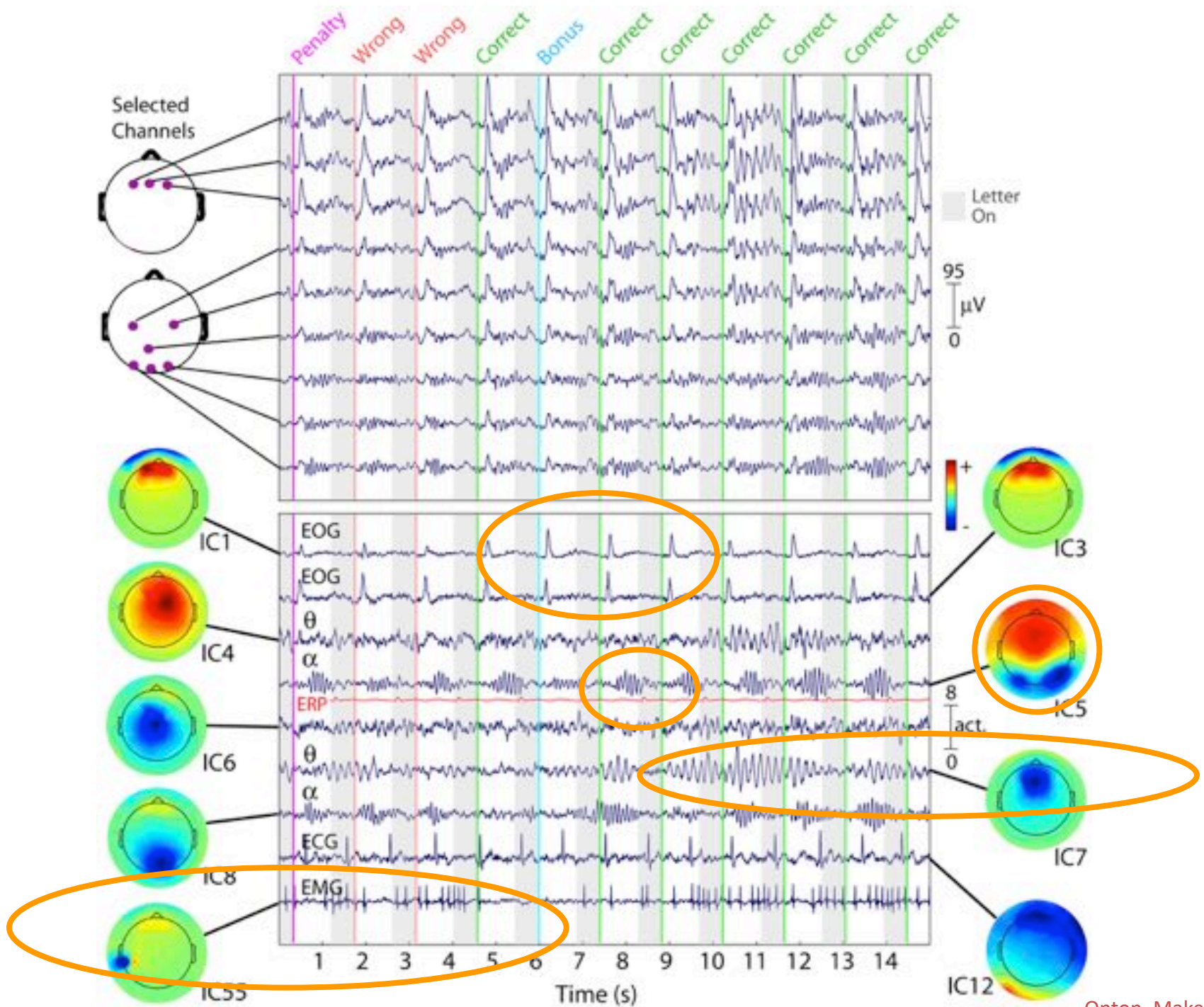


... and *also* separates cortical *brain* IC processes

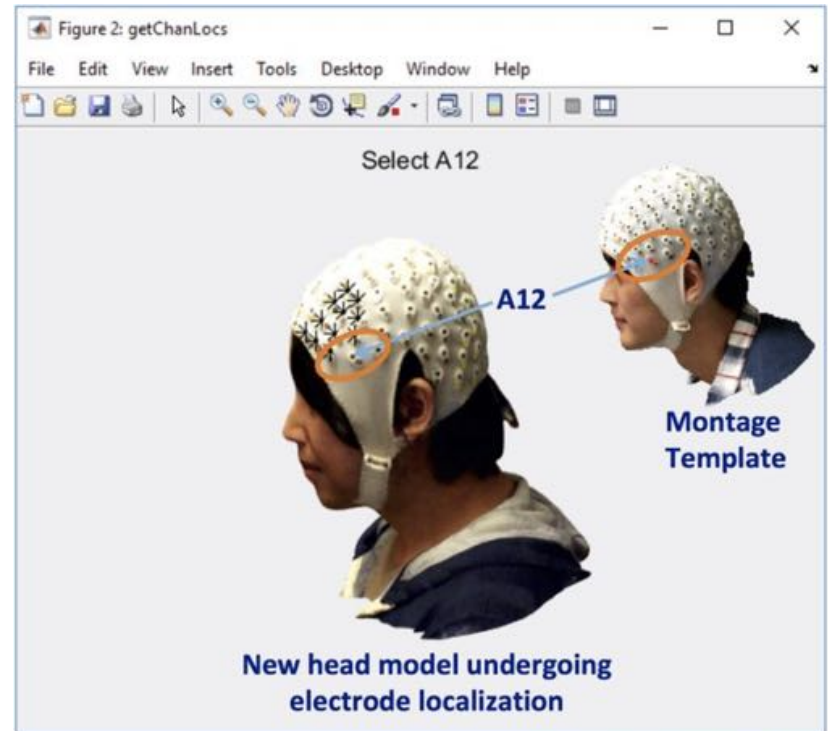


ICA in practice





NEW! Handheld 3-D electrode position recording (aka 'digitizing' the electrode montage)



Clement Lee & S. Makeig, 2018

`get_chanlocs()` interface –
post hoc 3-D electrode
location recording from
a subject 3-D head image.

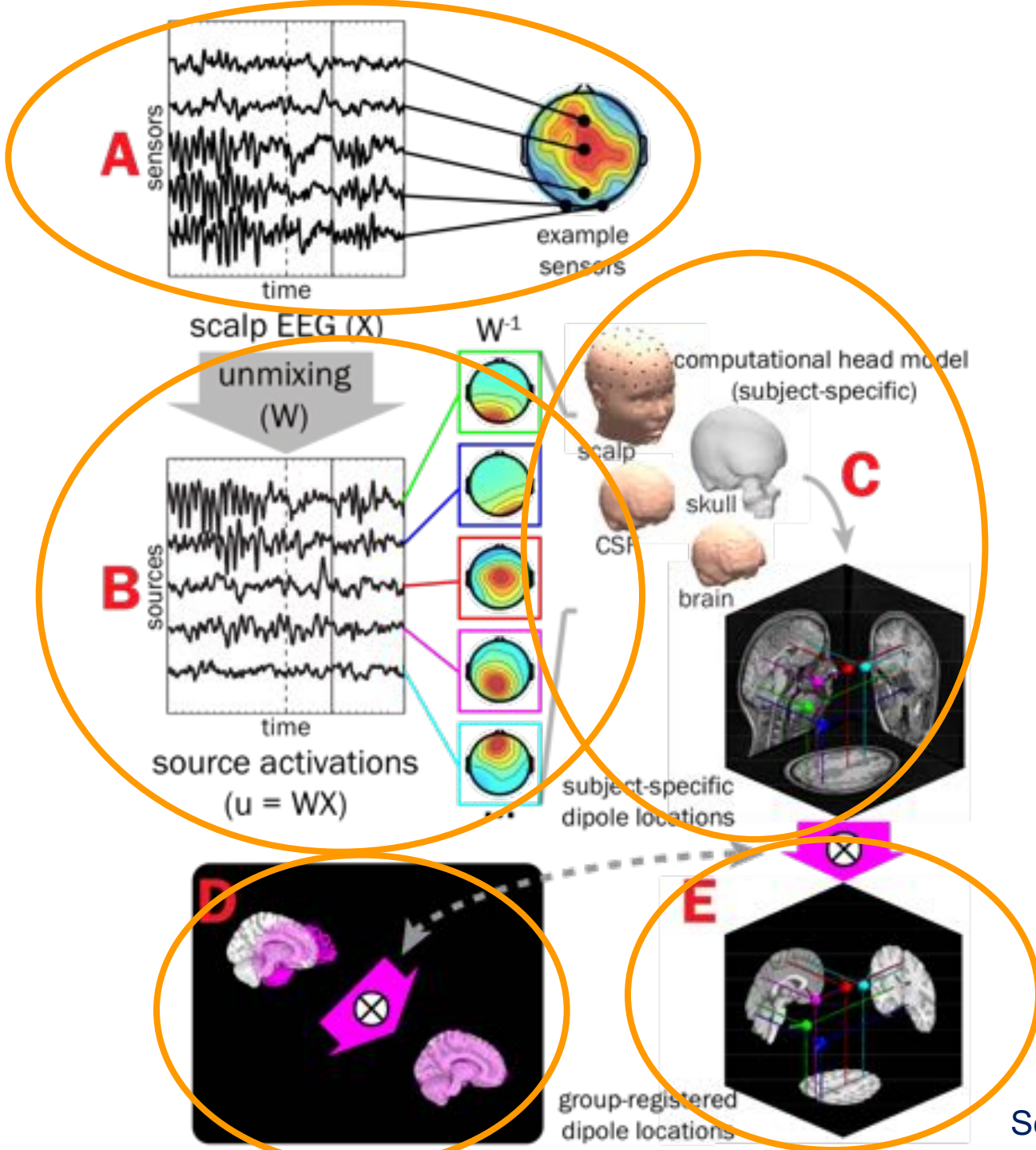
Blind EEG Source Separation by ICA

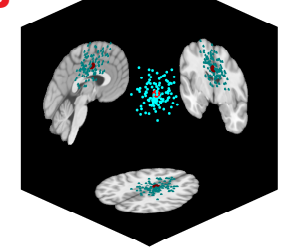
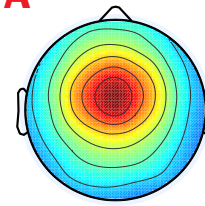
Regress

Overlapping

Event Responses

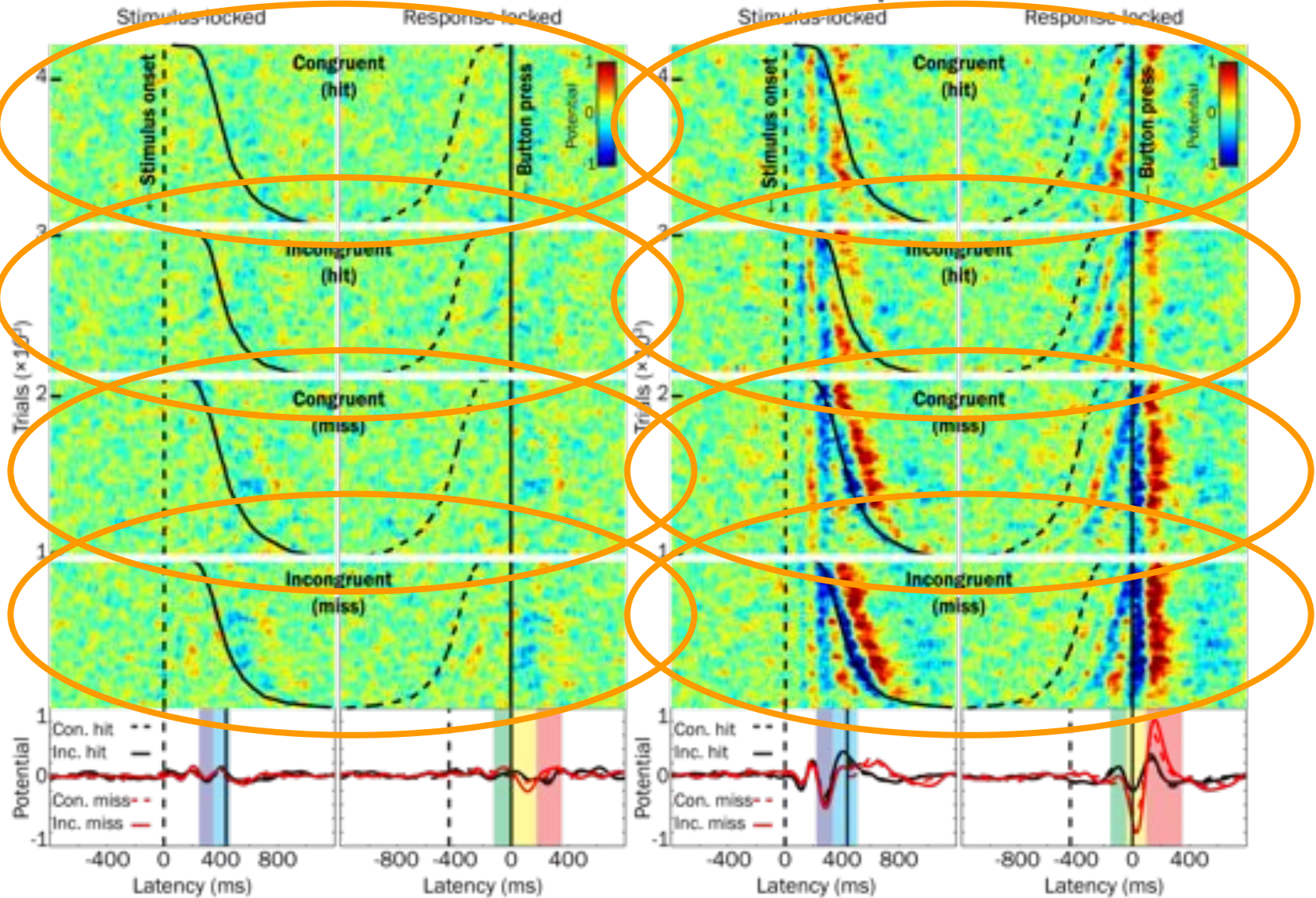






aMFC-IC

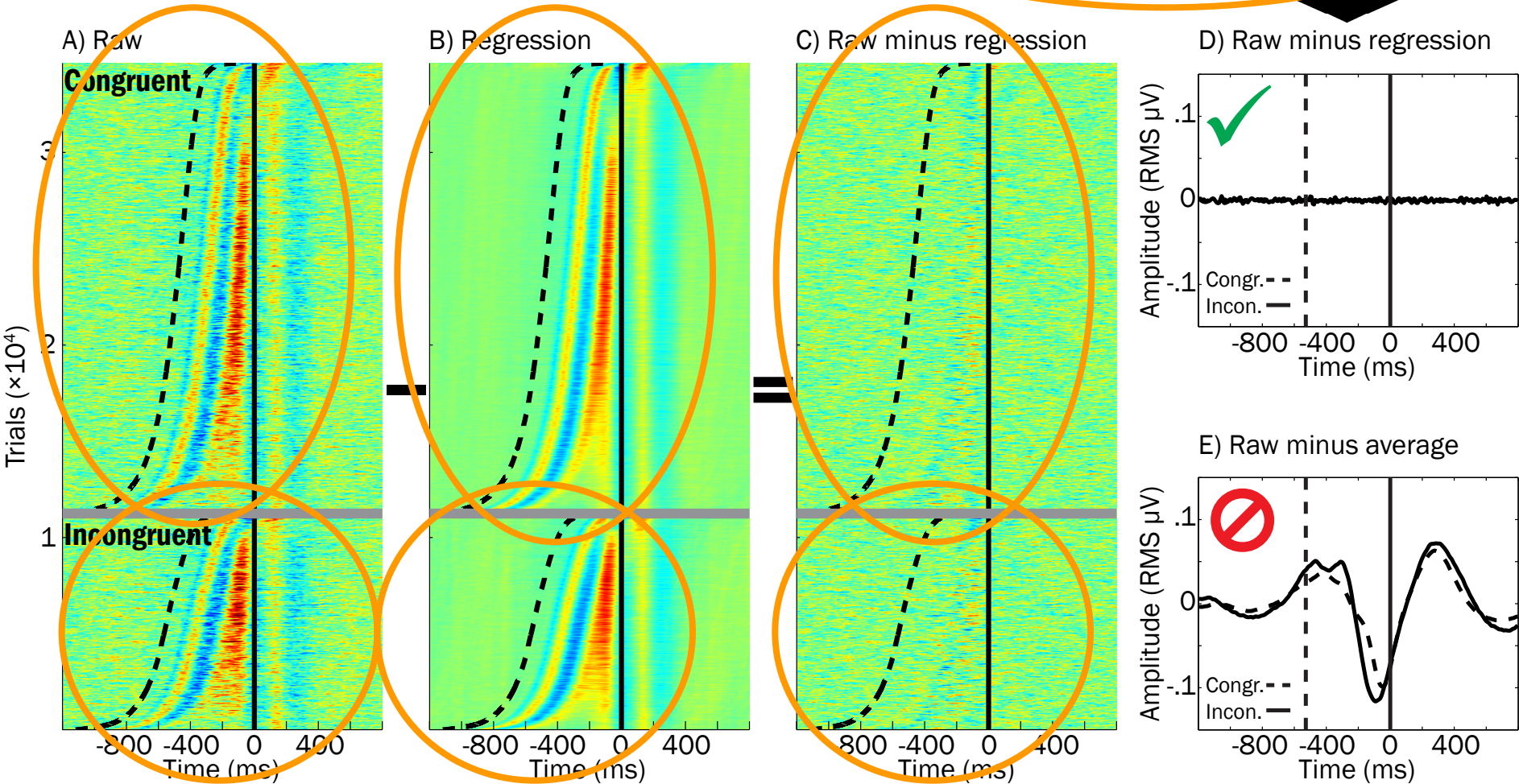
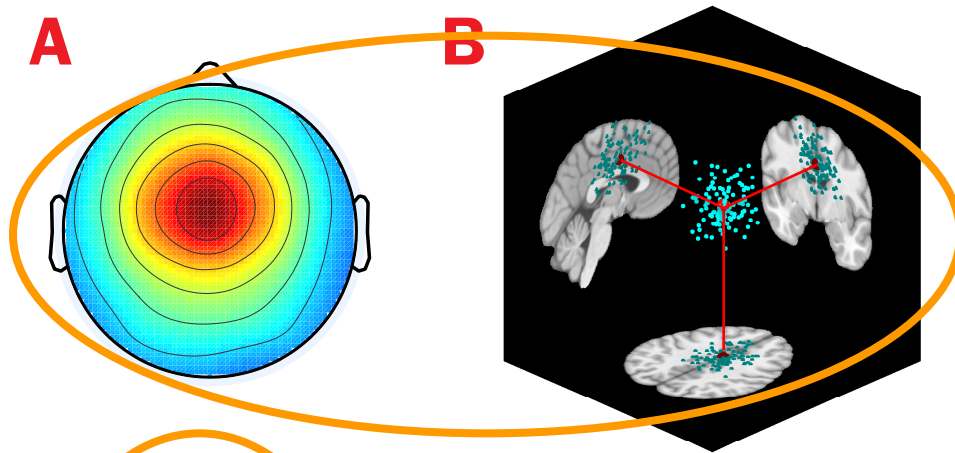
pMFC-IC



Trial-by-Trial Analysis

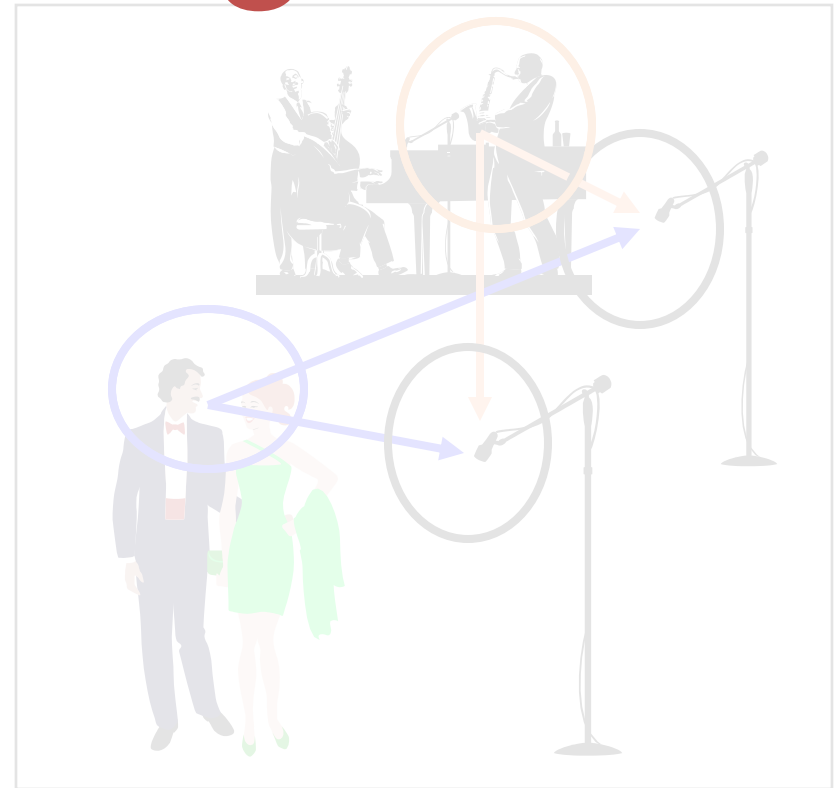
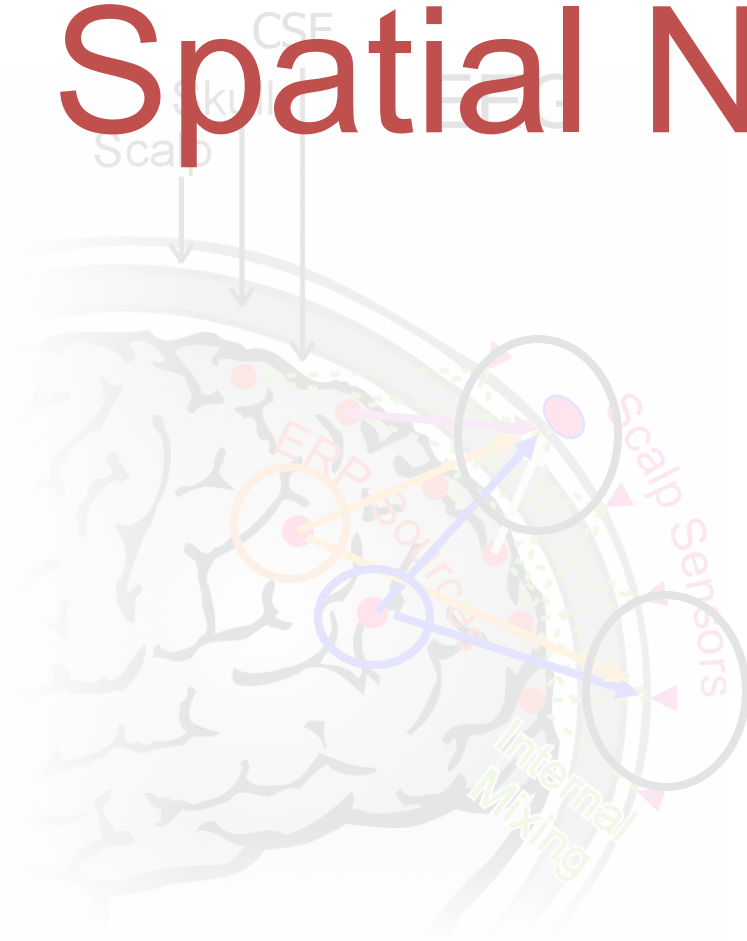
erpimage()

regression -- pMFC cluster

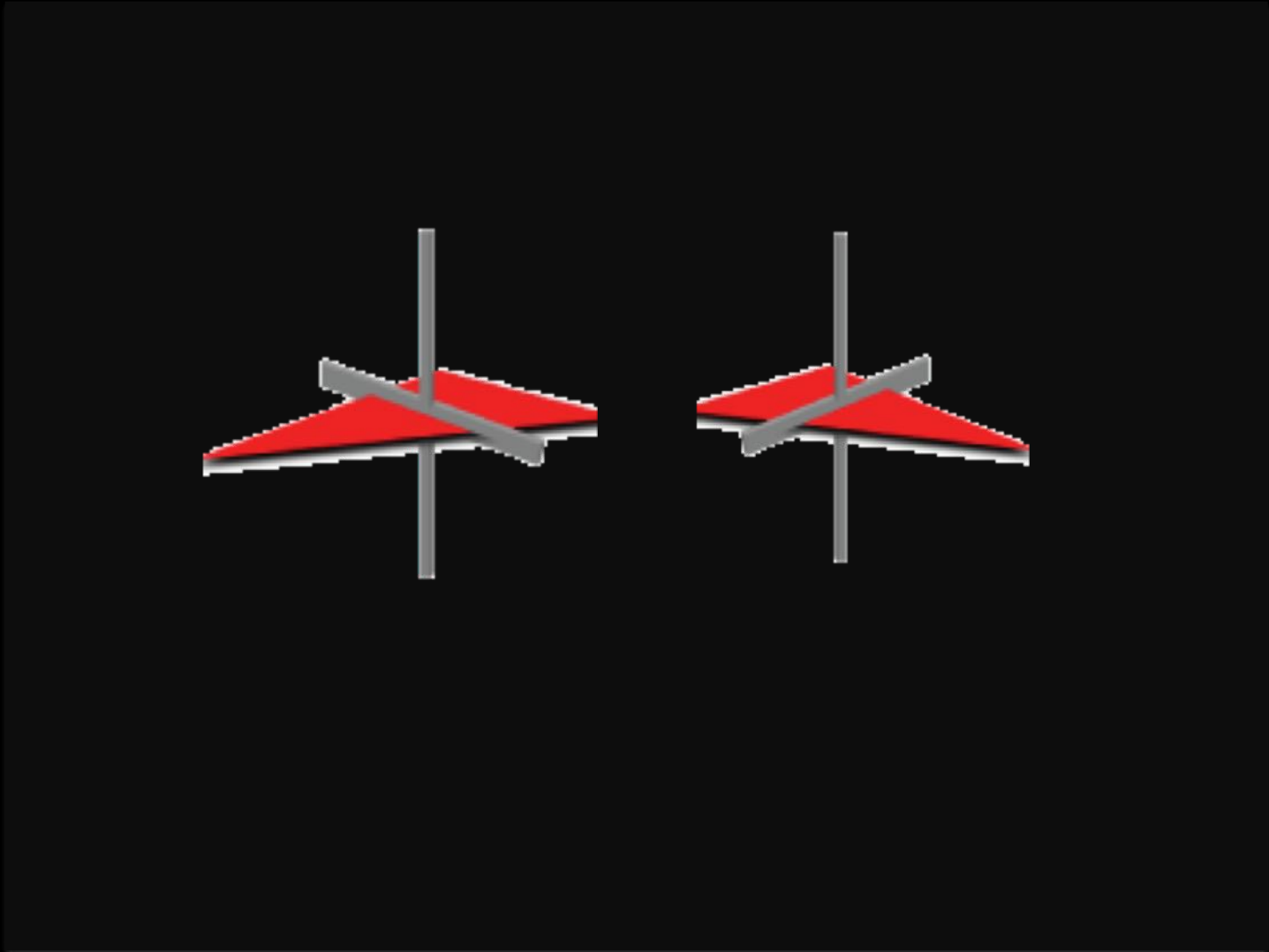


Blind EEG Source Separation by ICA

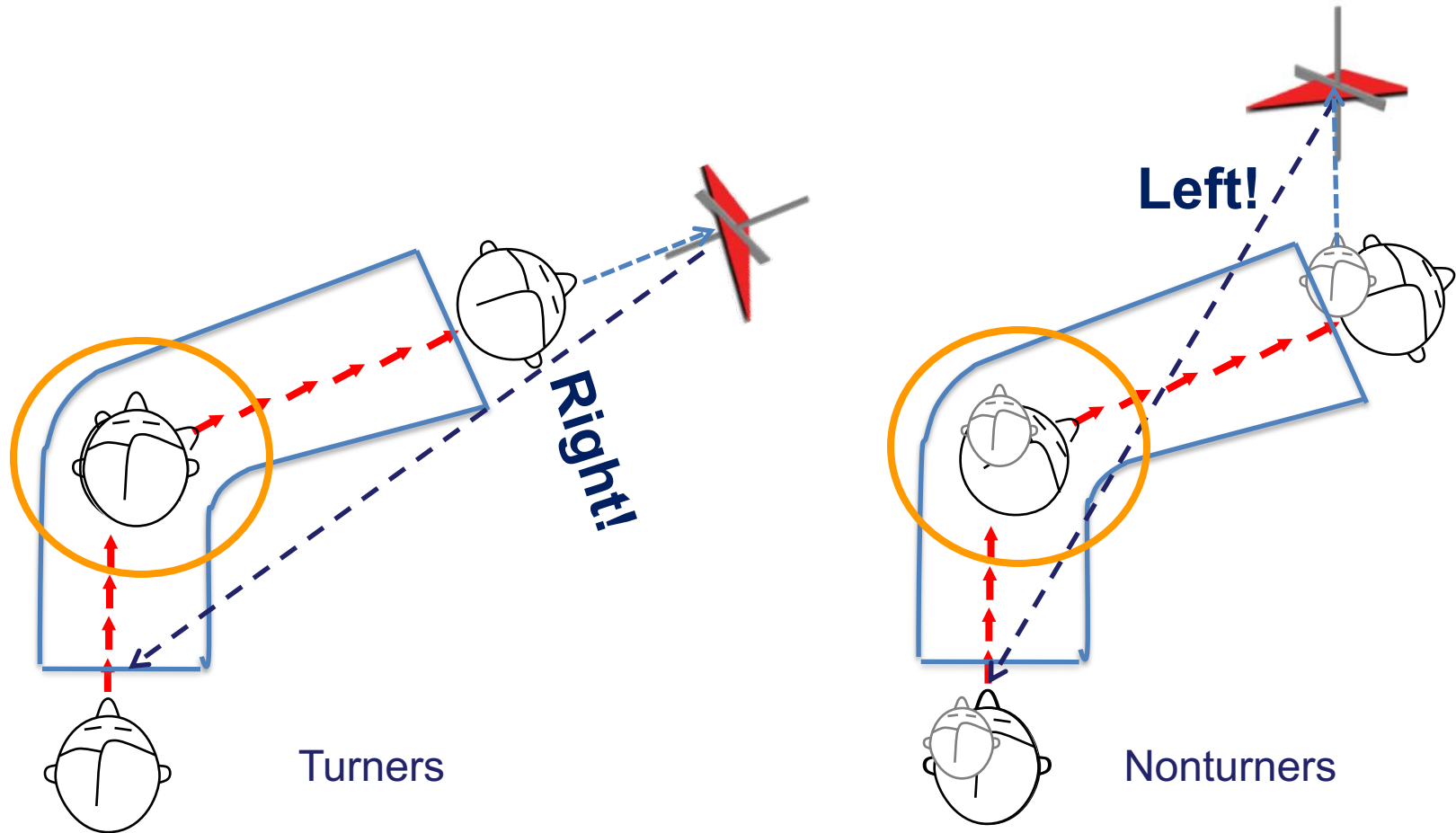
Spatial Navigation



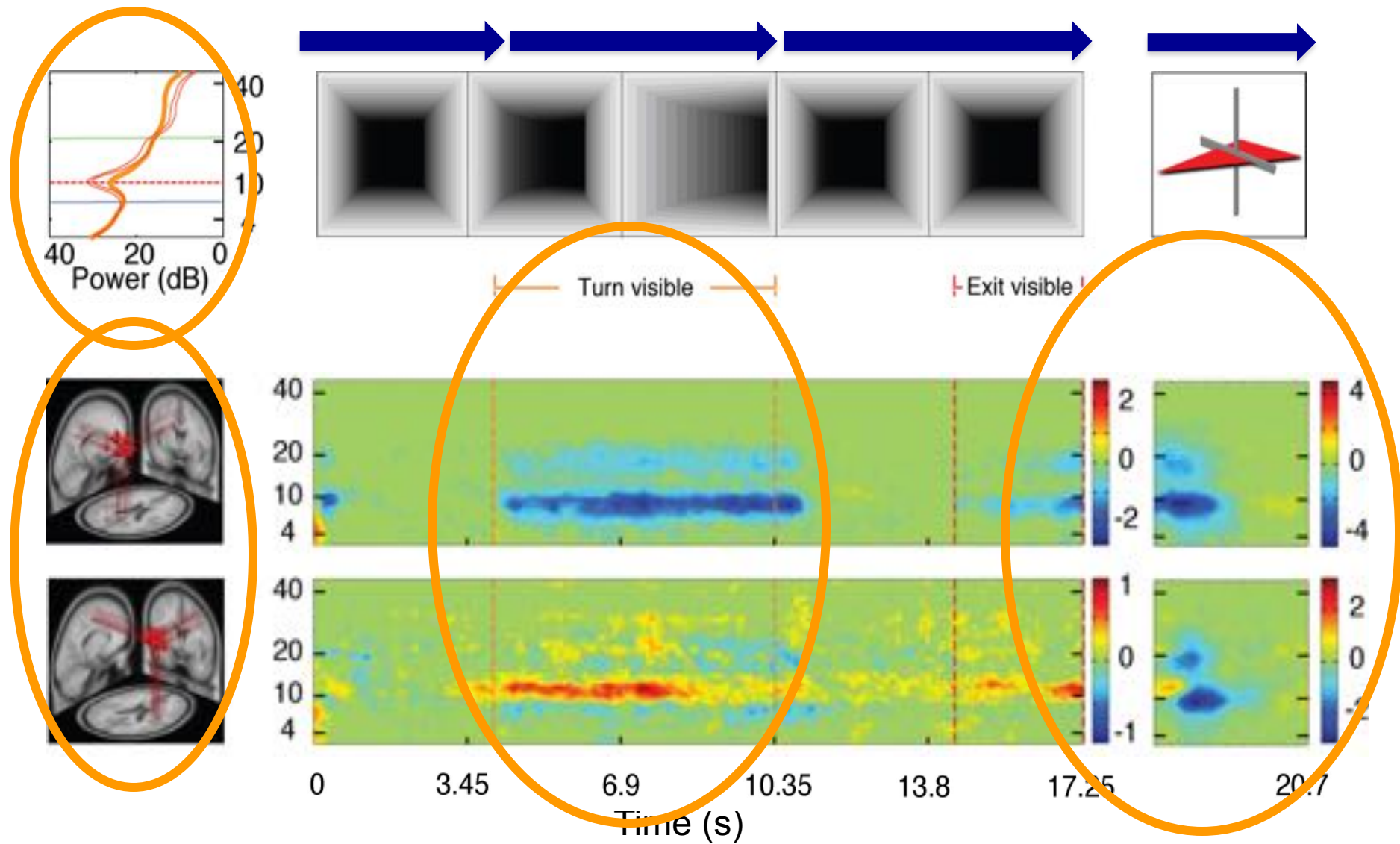
Tunnel Task – A Passive Spatial Navigation Paradigm



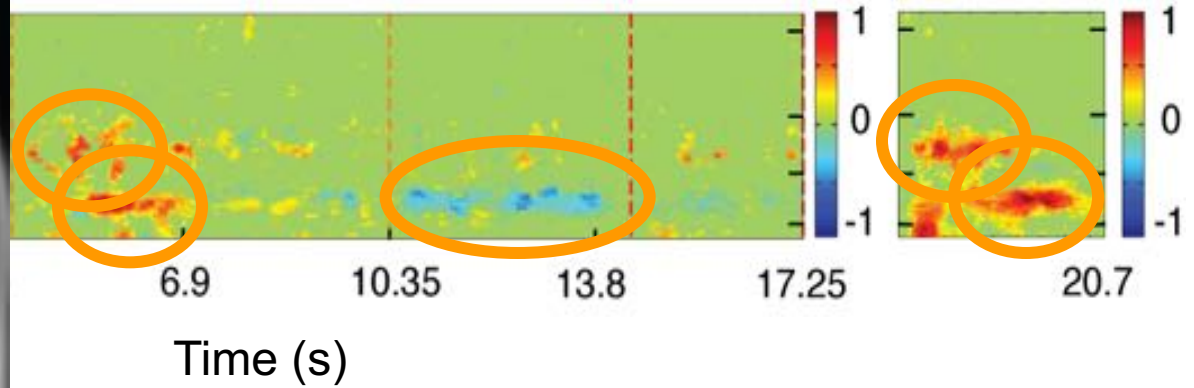
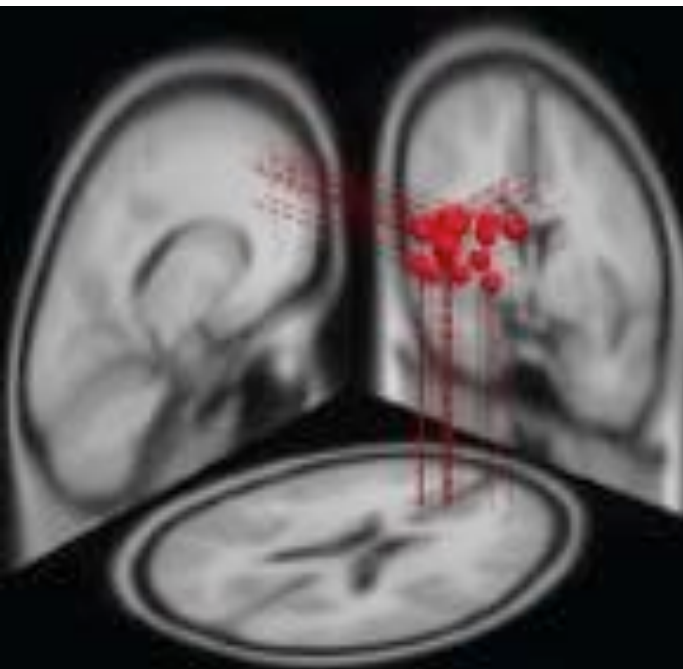
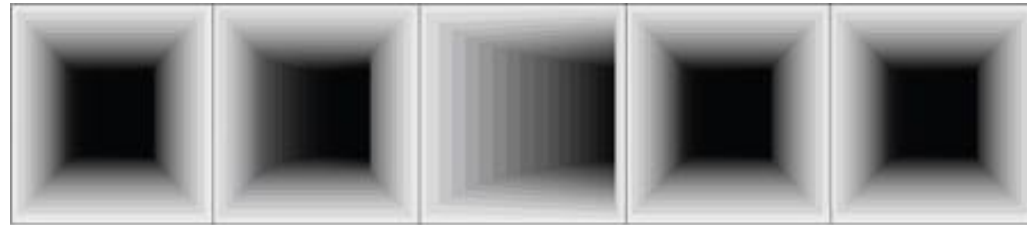
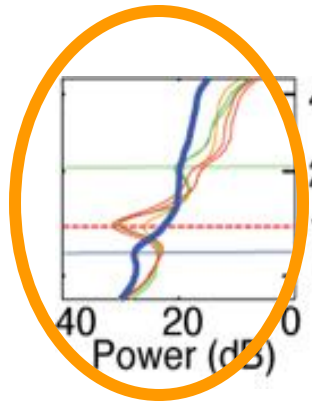
‘Turner’ and ‘Nonturner’ subjects use different spatial orienting styles



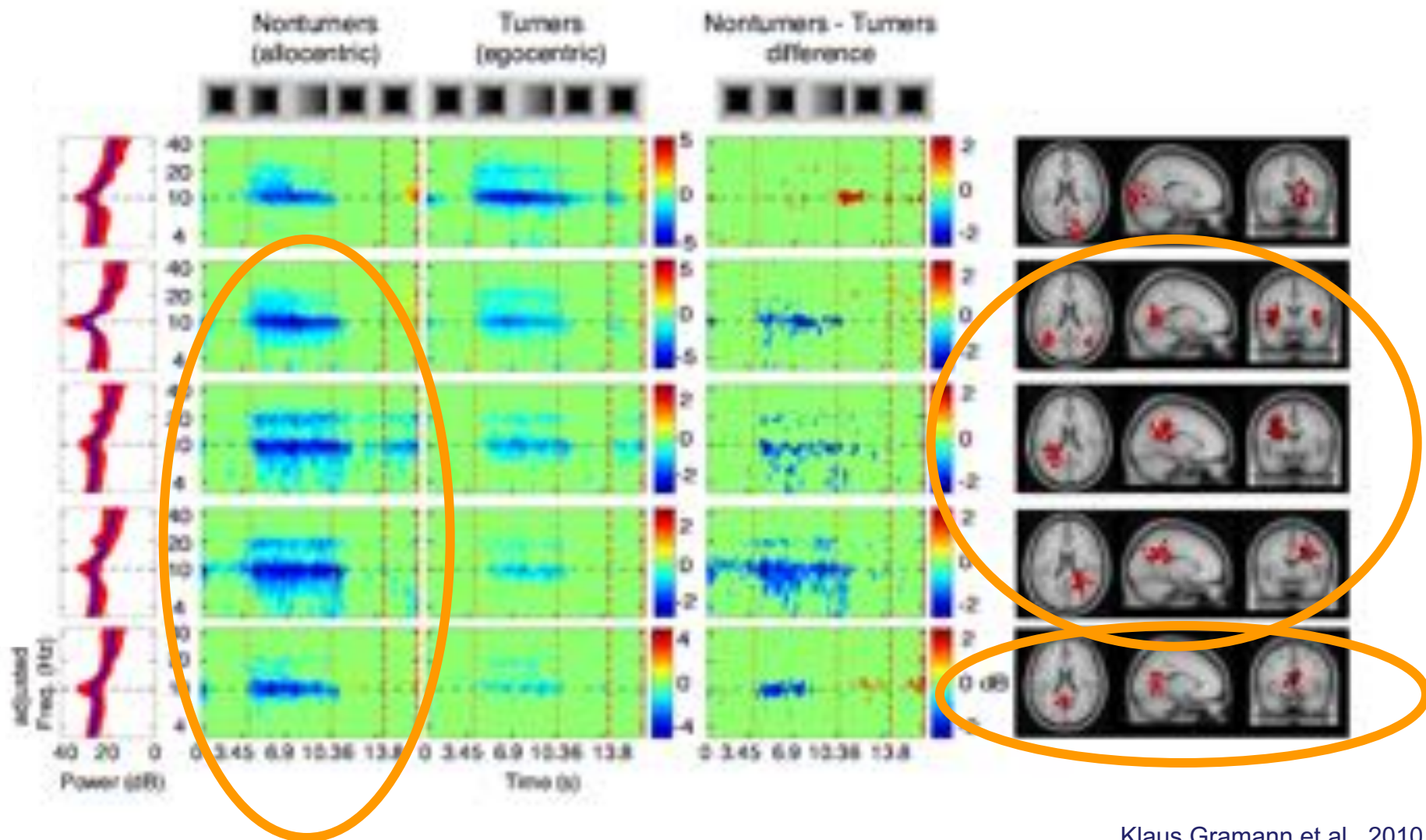
Two parietal component clusters



Medial prefrontal component cluster



Clusters distinguishing Turners & Nonturners



Blind EEG Source Separation by ICA

Clinical Research

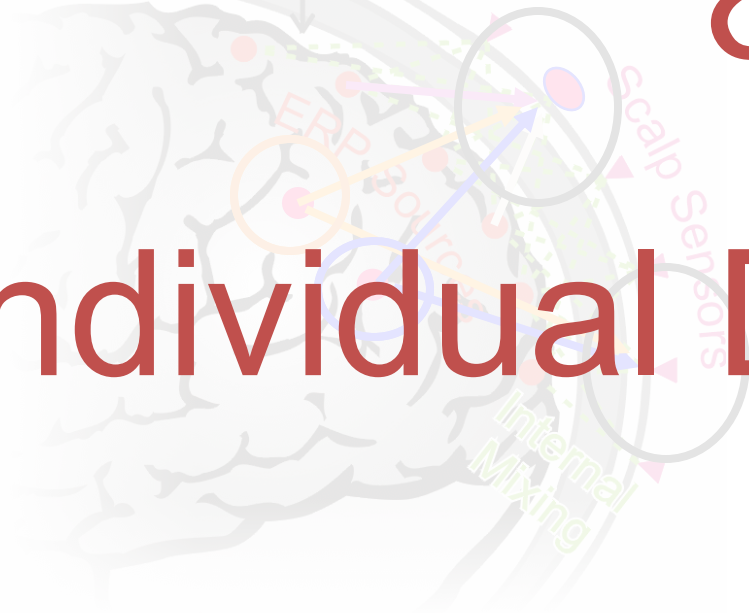


Cocktail Party

&



Individual Differences

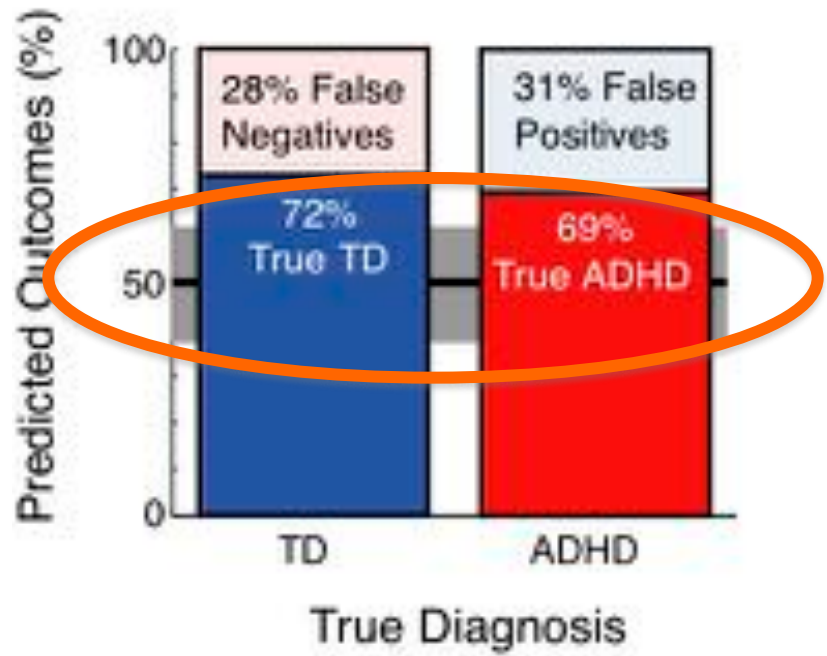
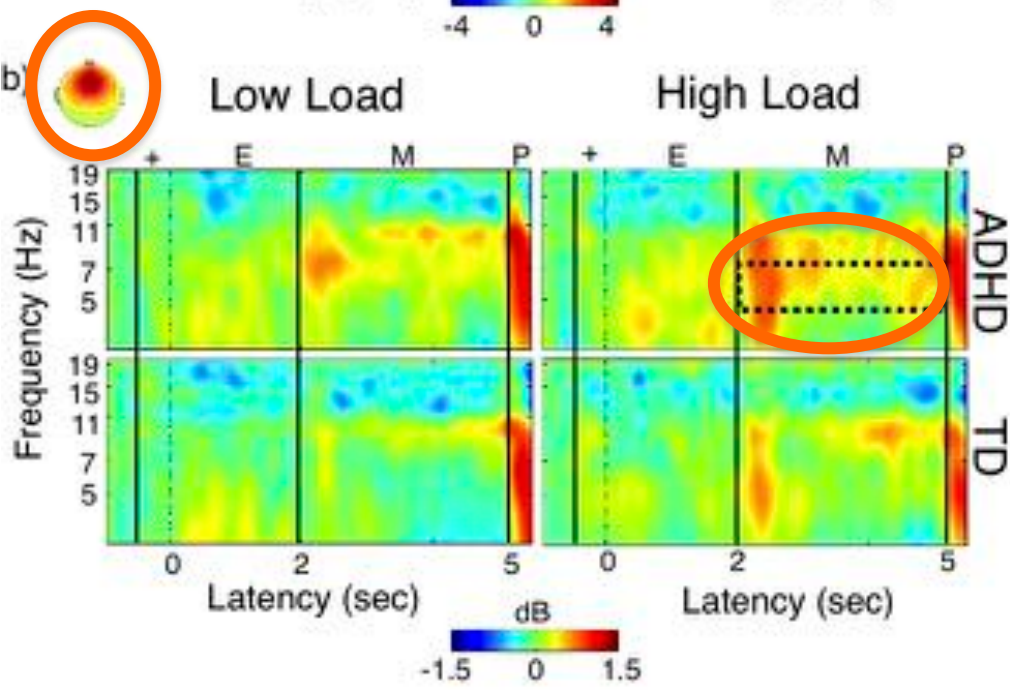
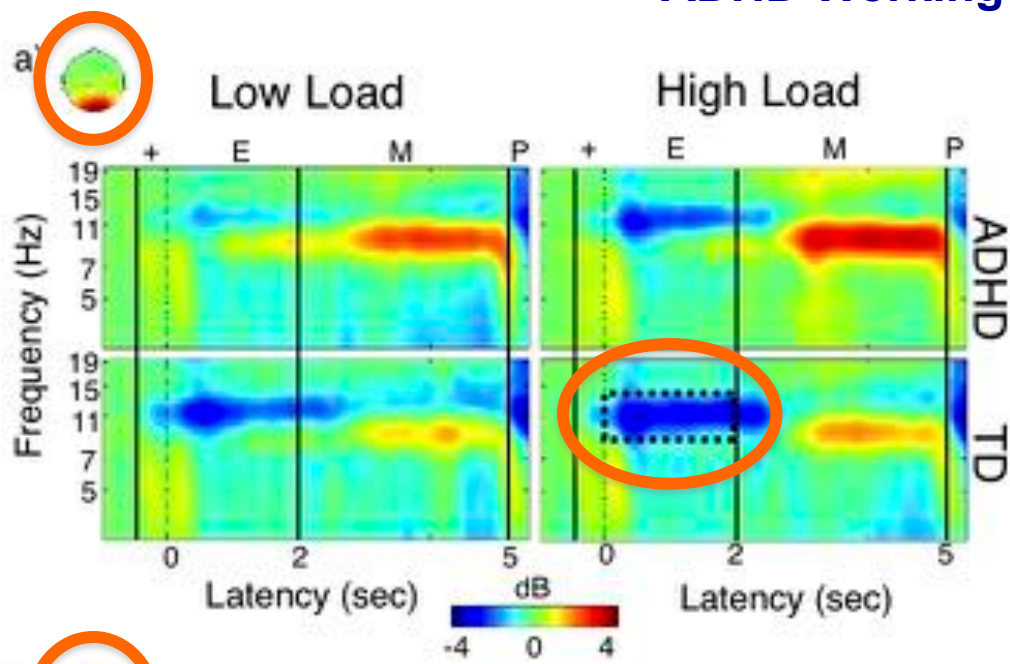


Visual Working Memory Task – Trial Summary



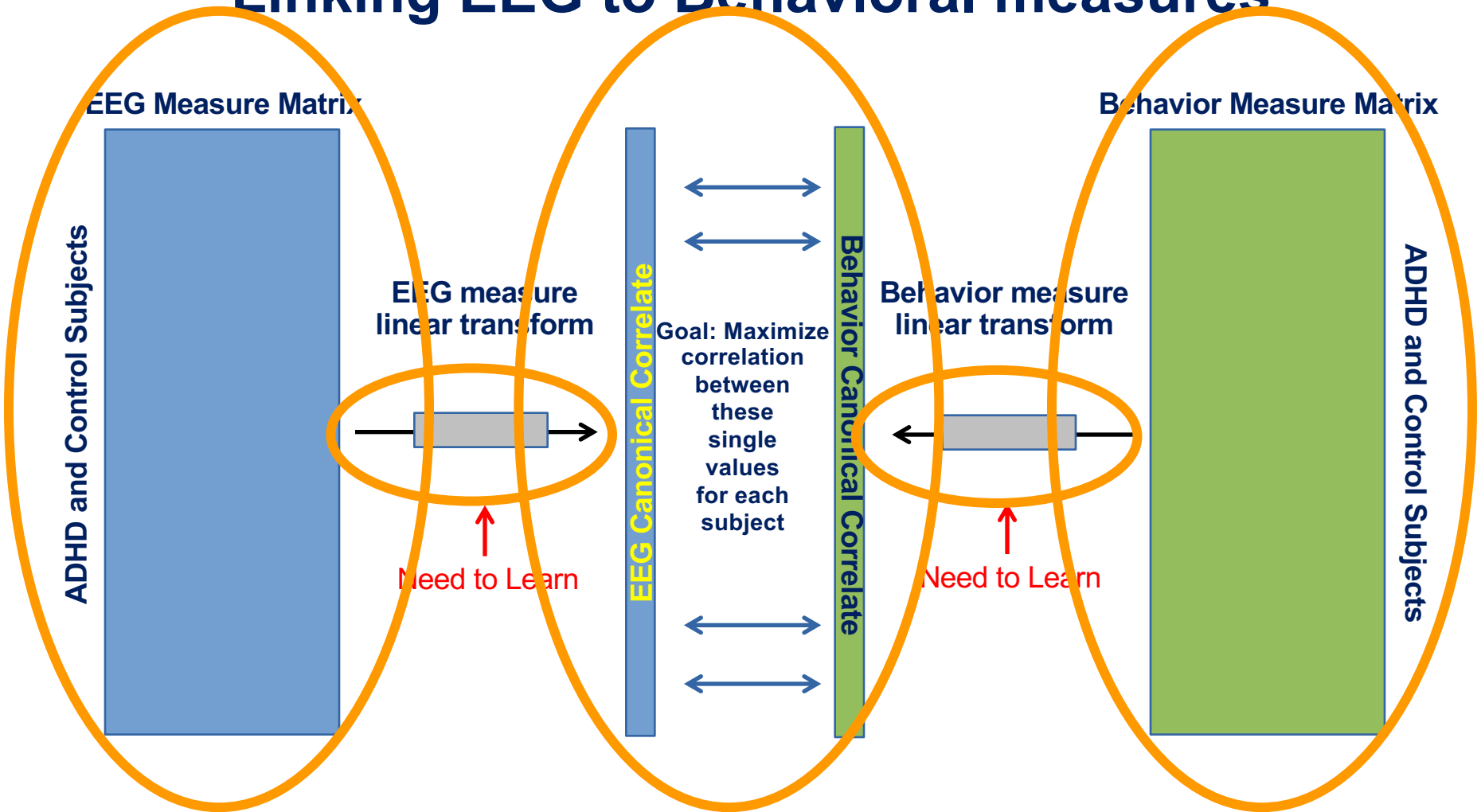
Figure 1. Participants performed a Sternberg visual working memory task during EEG recordings. In each trial, appearance of an alerting fixation-cross cued trial onset. Participants then viewed an encoding stimulus containing either 1 or 3 dots (low-load), or 5 or 7 dots (high-load), attending the spatial positions of the dots for 2 s. The dots then disappeared from screen, beginning a 3 s maintenance period. Upon presentation of the probe stimulus, participants were asked to indicate, by button press, whether or not the location of the probe disc matched the location of any of the encoding stimulus discs. During the ensuing intertrial interval (ITI) the screen was blank.

ADHD Working Memory



Canonical Correlation Analysis (CCA)

Linking EEG to Behavioral measures



15 IC Clusters

Cl 1 (114 vox, 365 vox)



Cl 3 (108 vox, 357 vox)



Cl 4 (152 vox, 493 vox)



Cl 5 (191 vox, 619 vox)



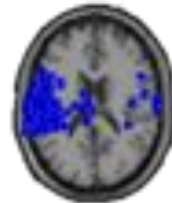
Cl 6 (180 vox, 589 vox)



Cl 7 (181 vox, 587 vox)



Cl 8 (138 vox, 489 vox)



Cl 9 (121 vox, 392 vox)



Cl 10 (177 vox, 589 vox)



Cl 11 (130 vox, 436 vox)



Cl 12 (164 vox, 508 vox)



Cl 13 (187 vox, 591 vox)



Cl 14 (176 vox, 587 vox)



Cl 15 (218 vox, 671 vox)

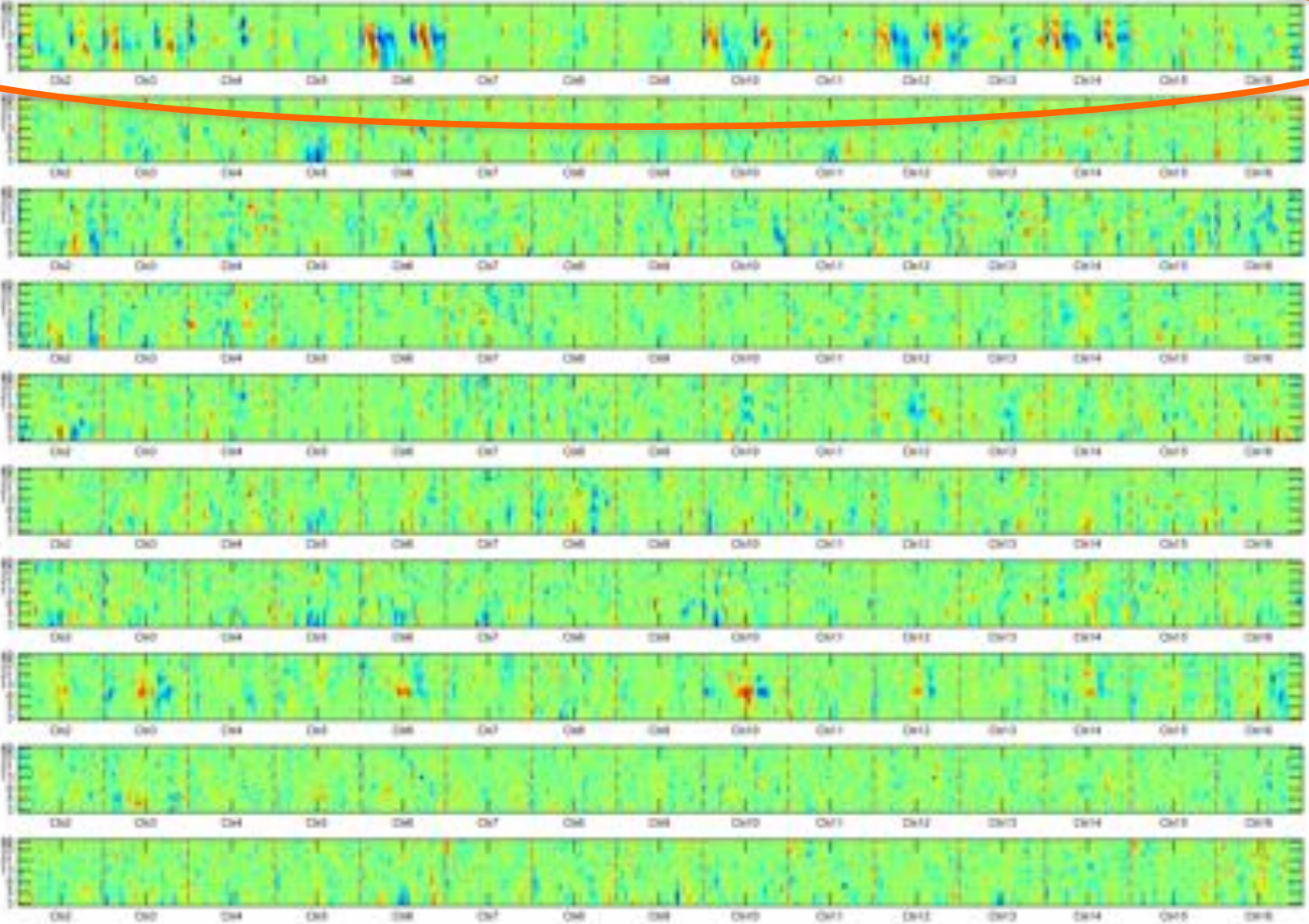


Cl 16 (264 vox, 791 vox)



10 ERSP Canonical Correlation Filters

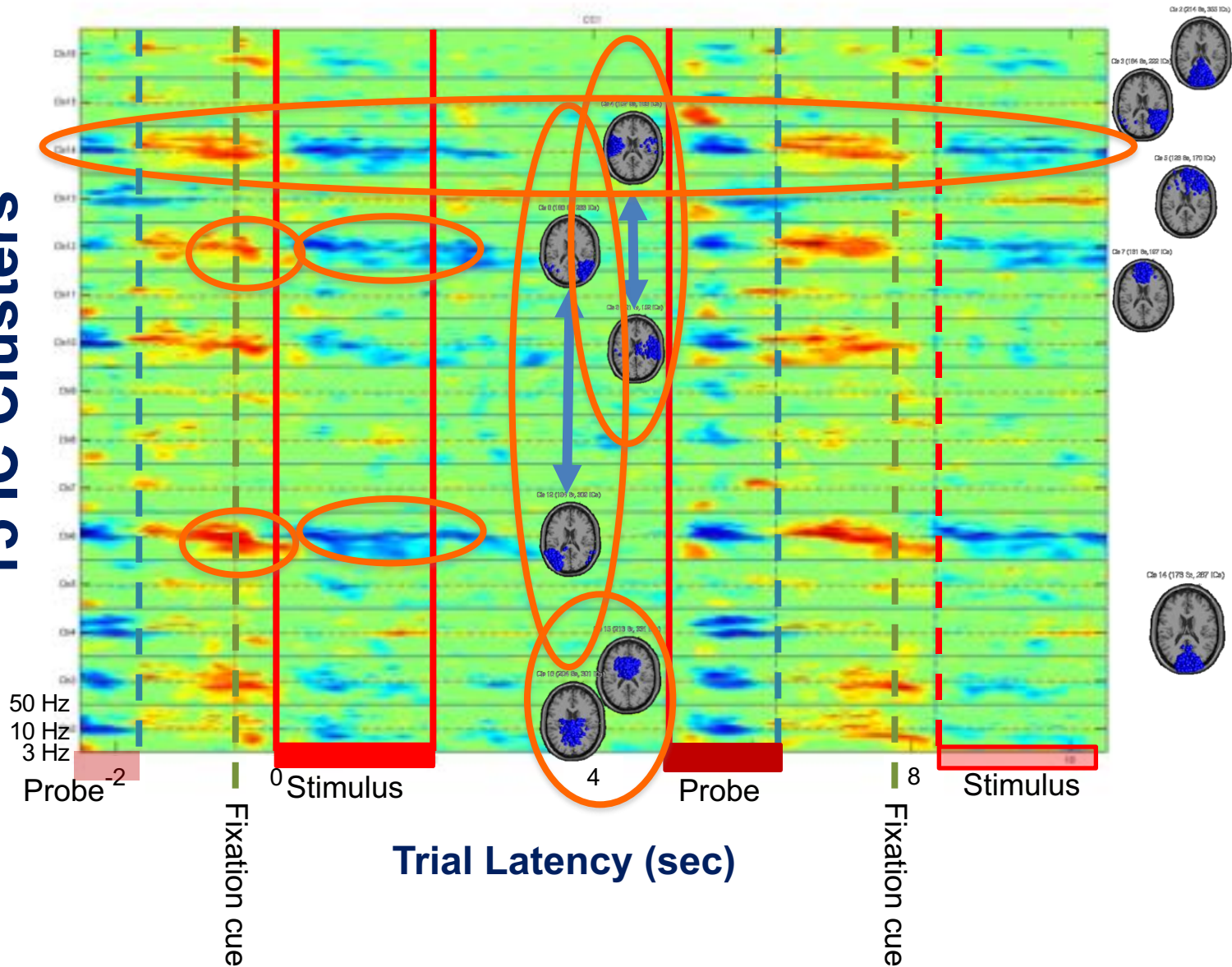
#1



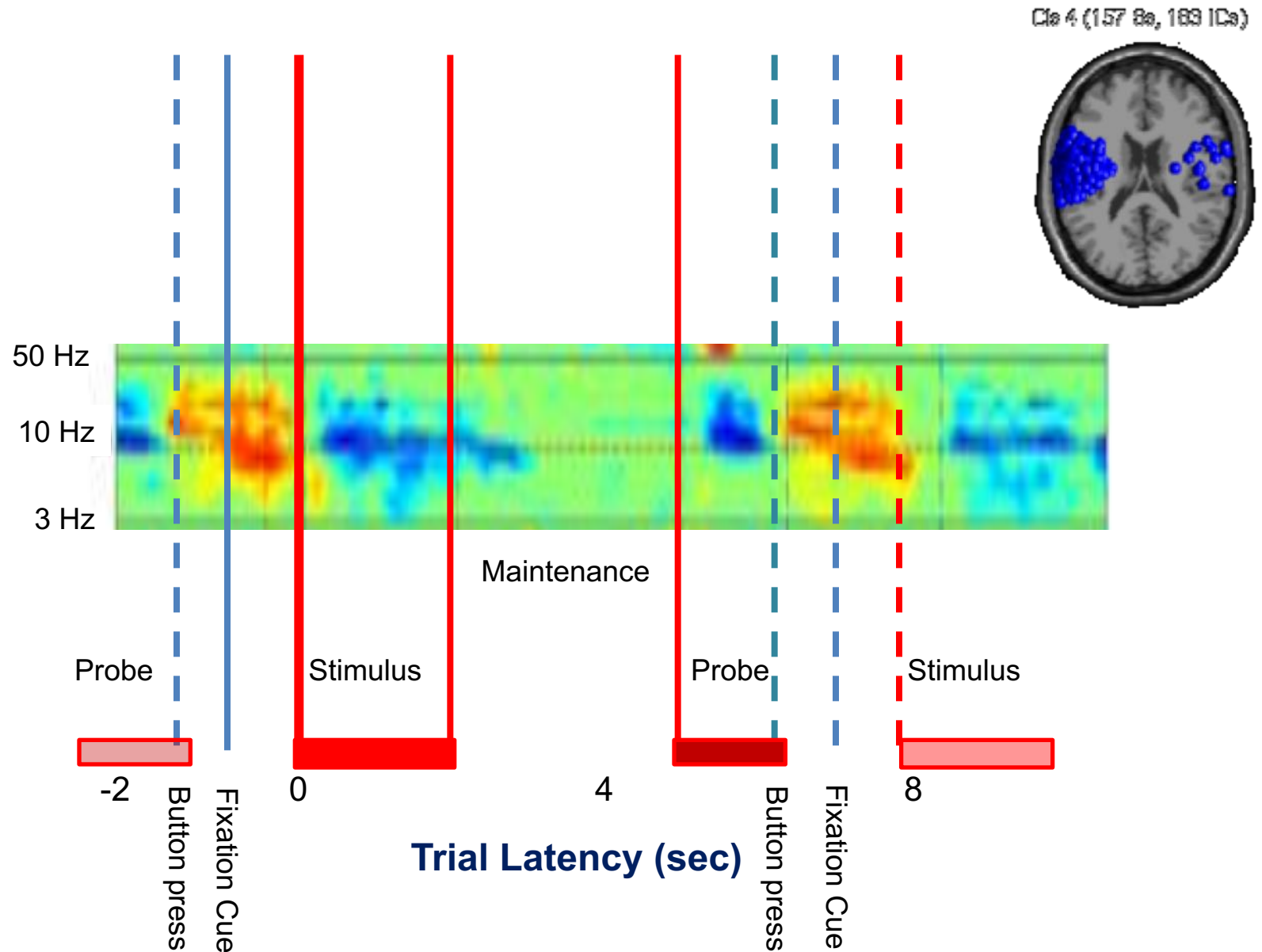
#8

First Canonical Component, ERSP Filter

15 IC Clusters



First Canonical Component, ERSP Filter



Blind EEG Source Separation by ICA

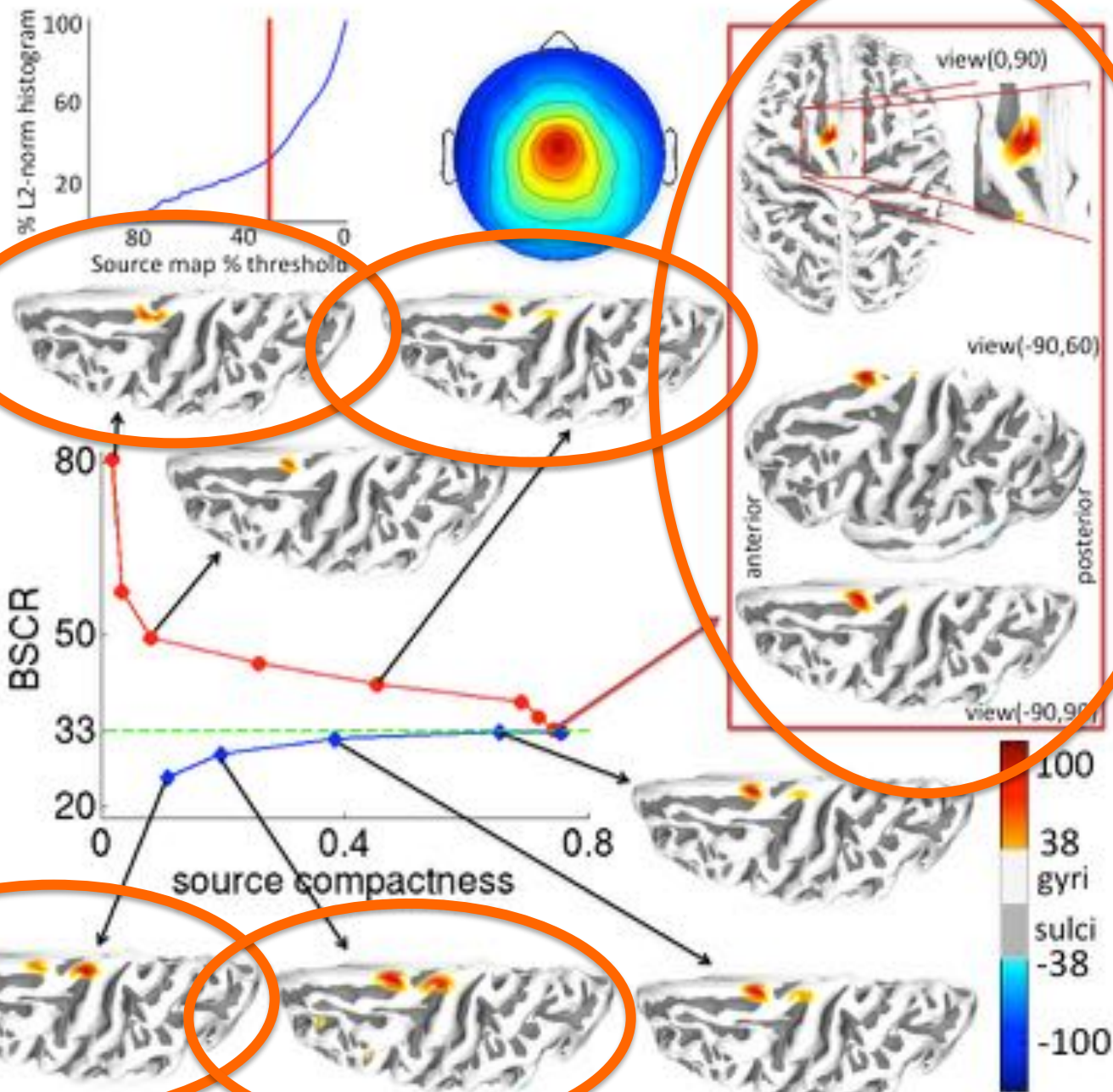
High-Resolution

EEG Source Imaging





SCALE



SCALE-returned BSCR values for 9 subjects

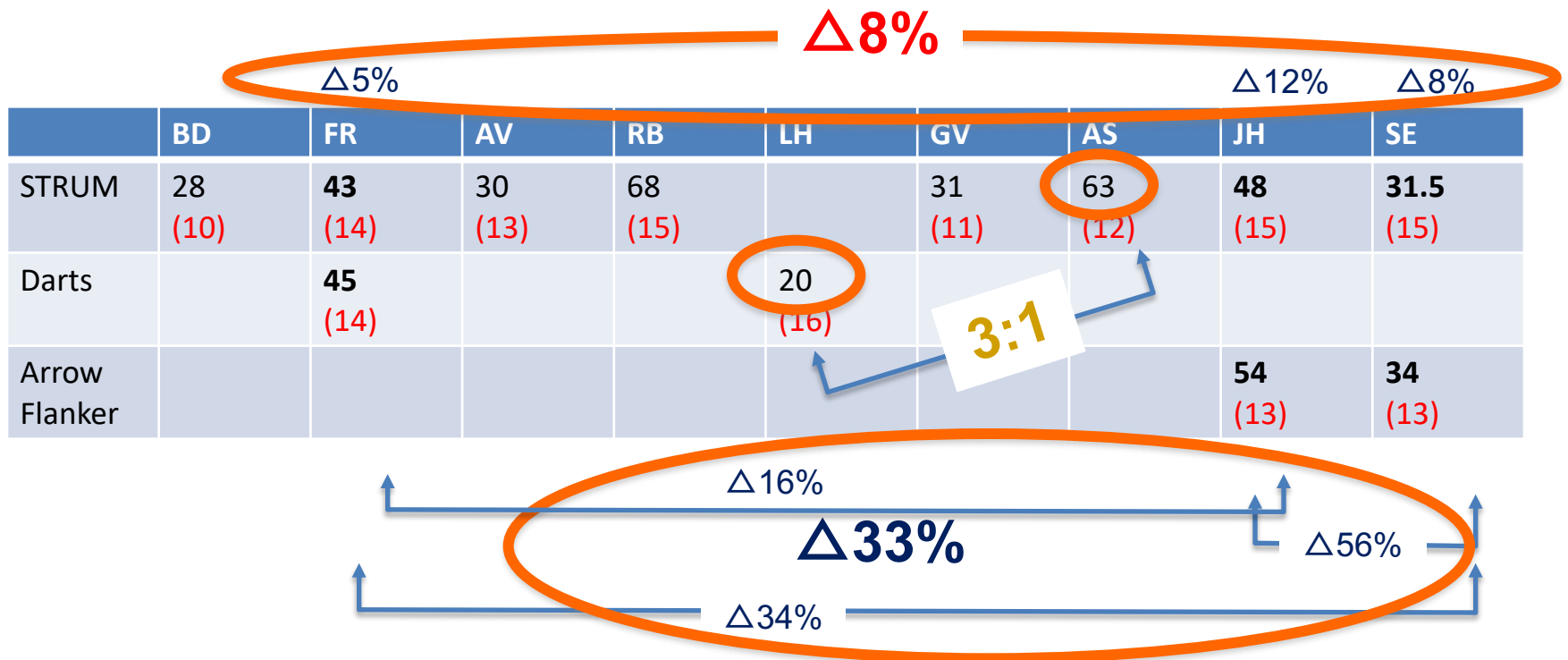
SCALE applied to data from 9 subjects between 18-25 years old. Four-layer head models (scalp, skull, CSF, and brain) were derived from whole head MR images.

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

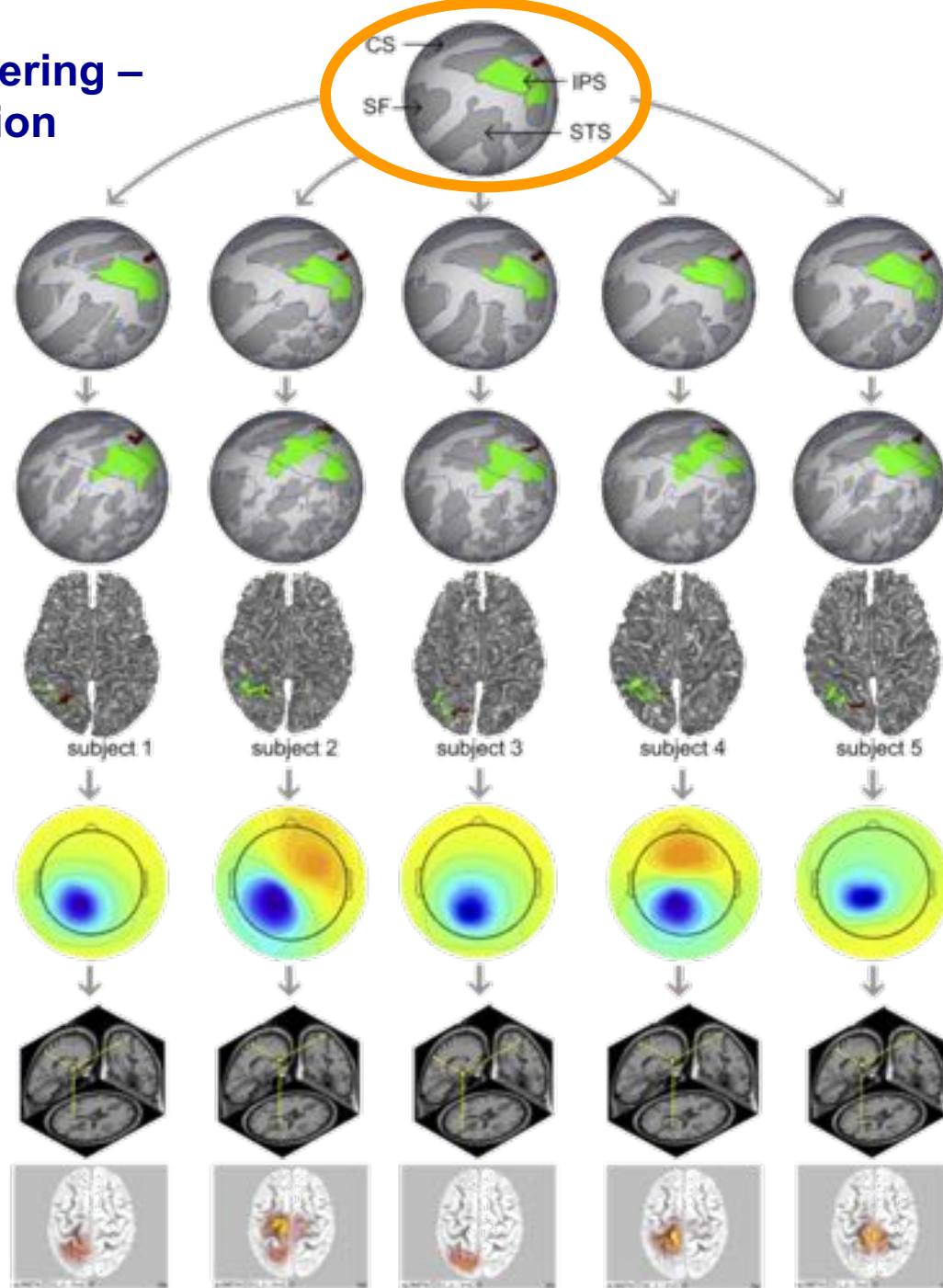
The numbers of ICs used to run SCALE are shown in parentheses.

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

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



Topological source clustering – 2-D measure projection



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)

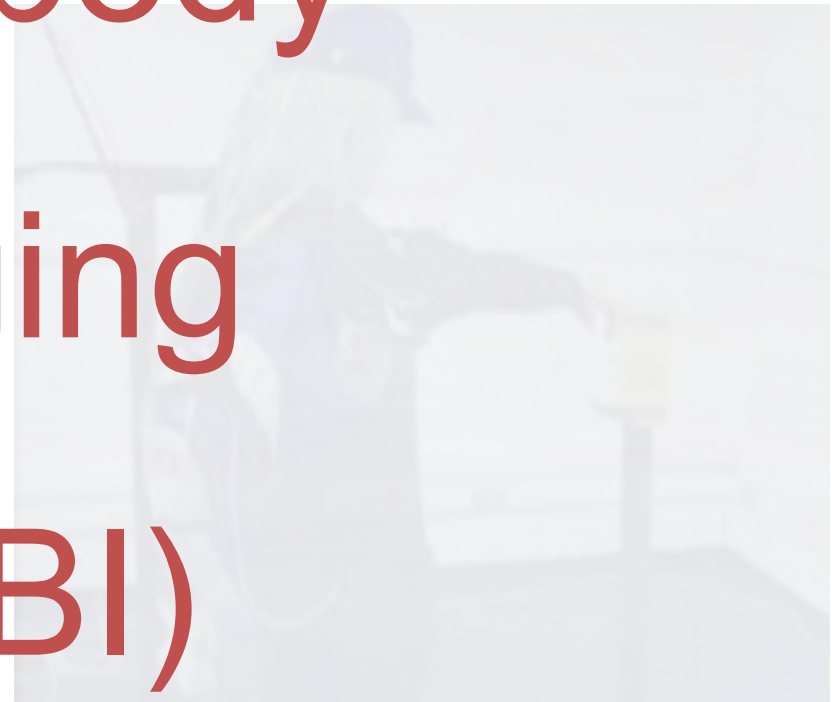
Brain/body

Concept:

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

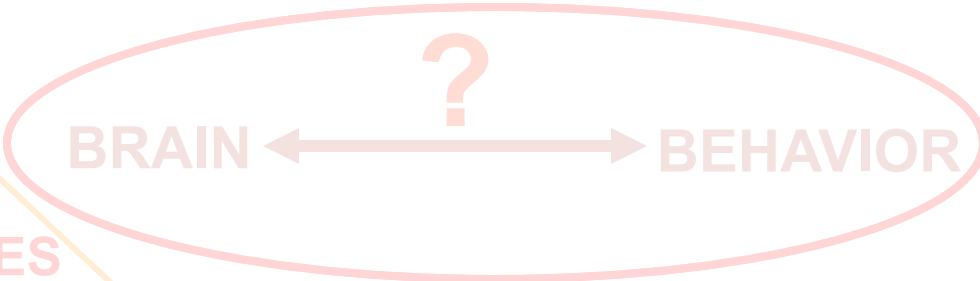
Imaging

(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

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.

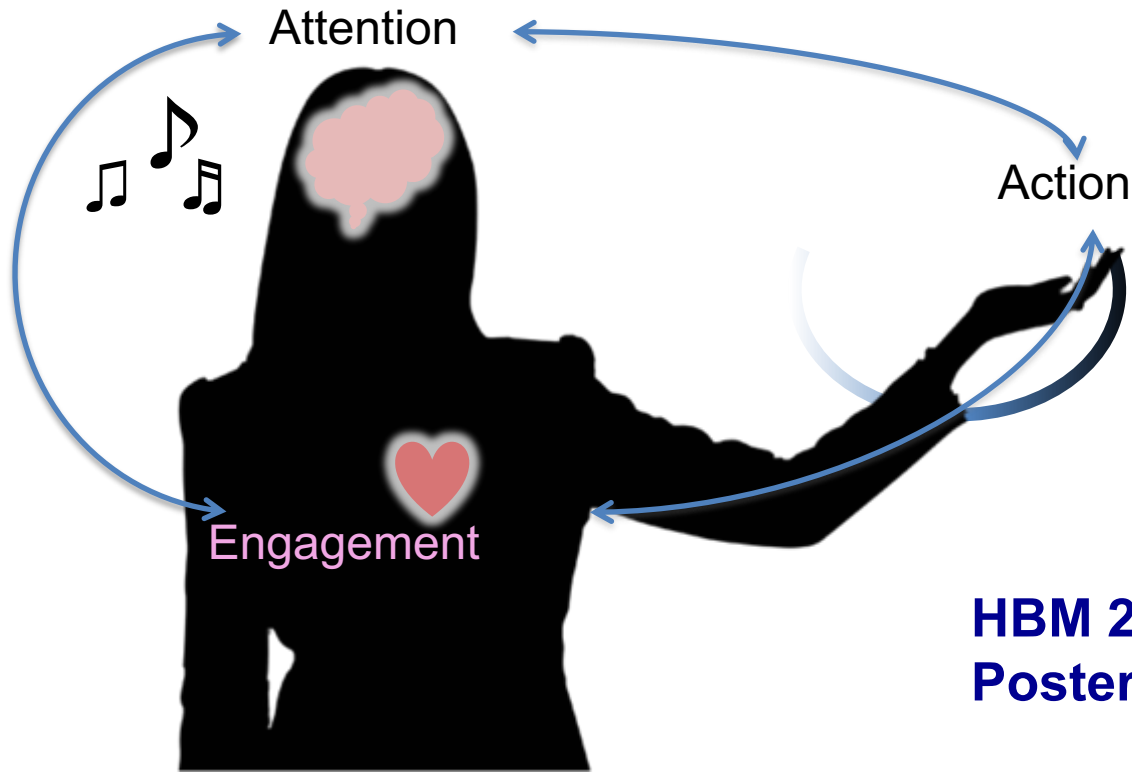
MoBILAB – a Matlab-based multimodal data browser and pre-processing app.





Measuring Musical Engagement Through Expressive Rhythm

How can we measure listeners' engagement?

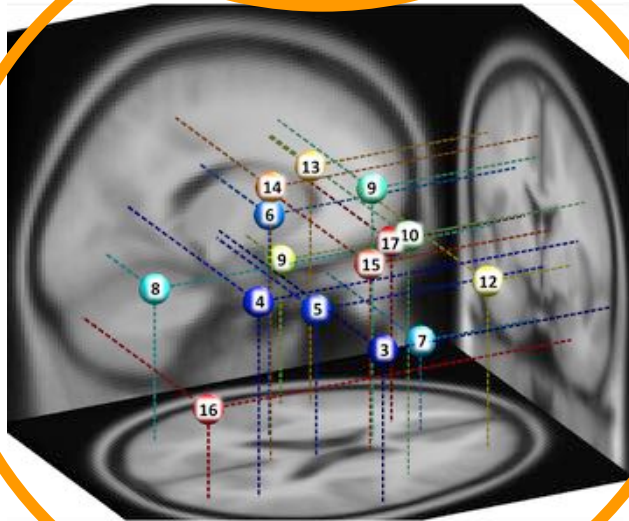
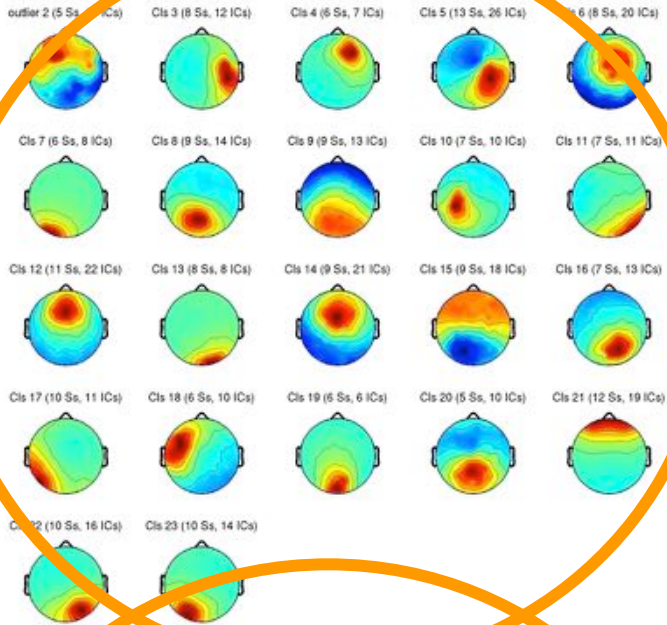


HBM 2014
Poster #1538 online

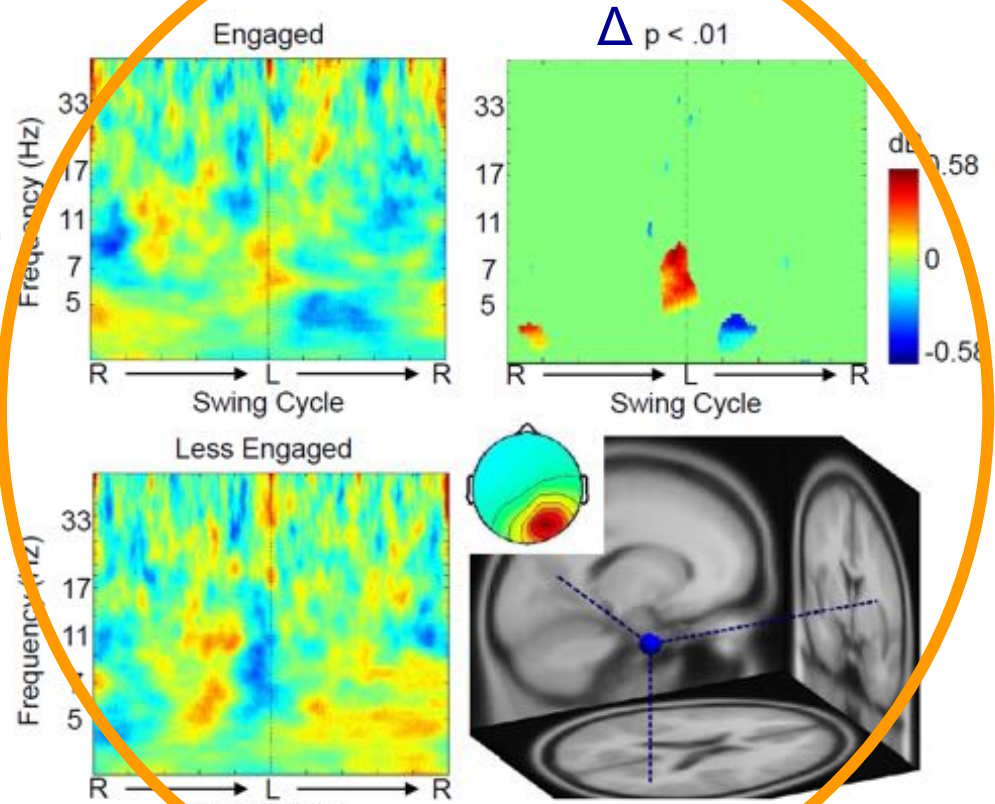
EEG Result

Right TPJ

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



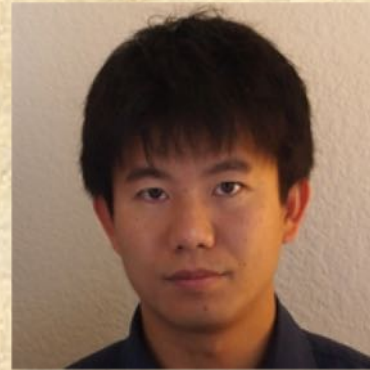
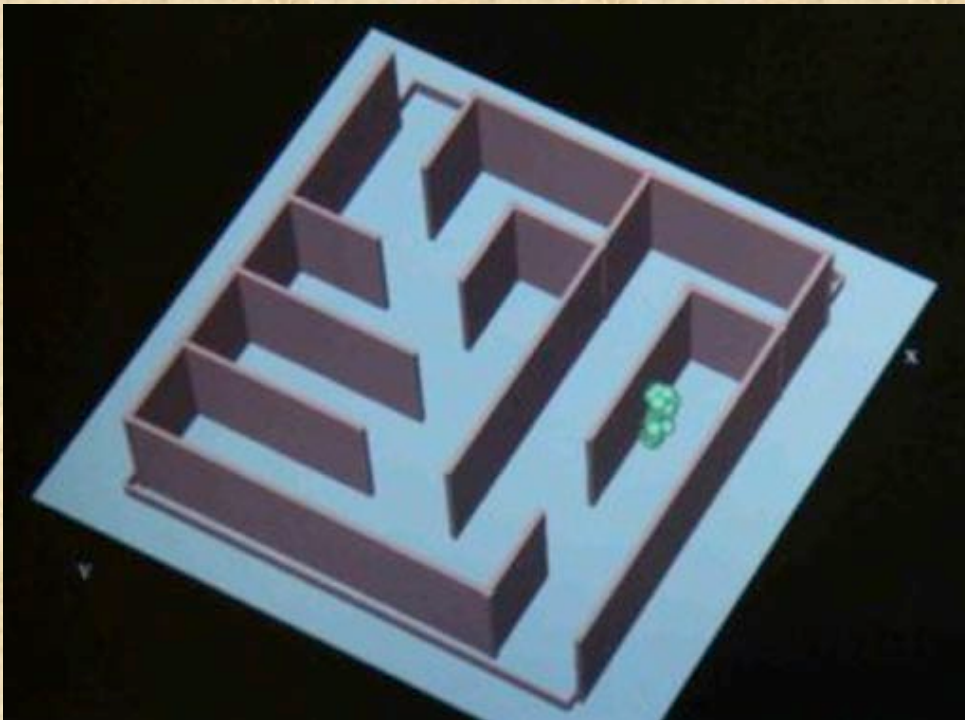
Frequency (Hz)



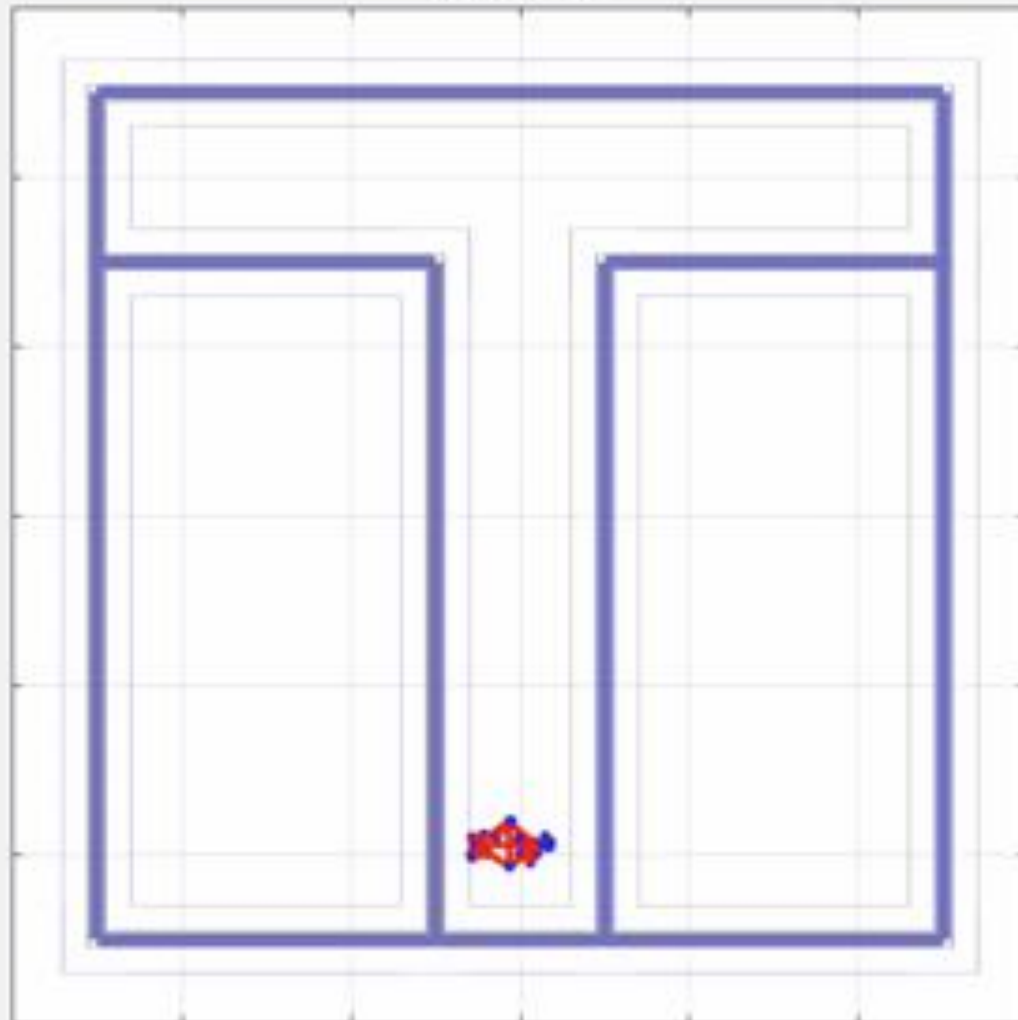
Swing Cycle

Spatial Navigation Experiment – the *Audiomaze*

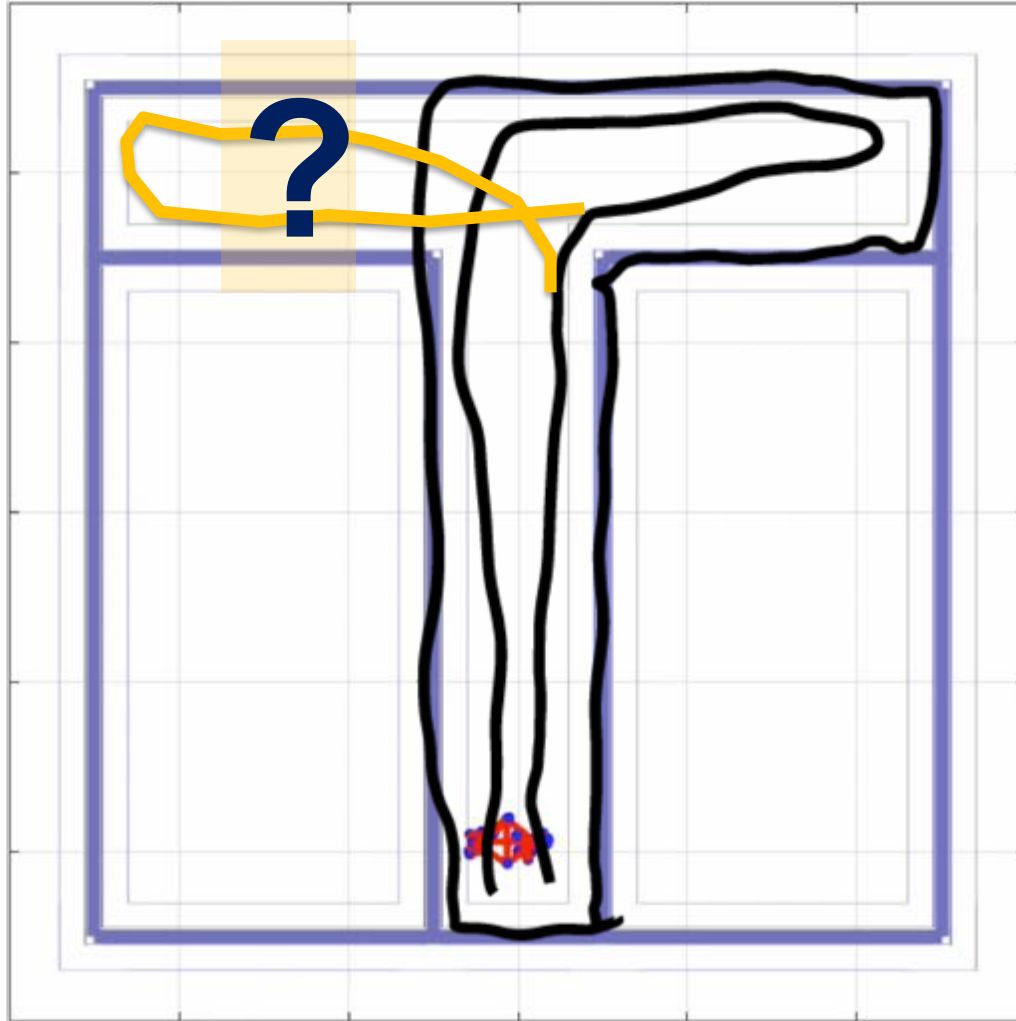
- Navigate an ‘invisible’ maze in the dark.
- Receive directional audio feedback, not tactile feedback.
- Task: Explore the maze and learn its configuration.
- Test: Draw the maze.



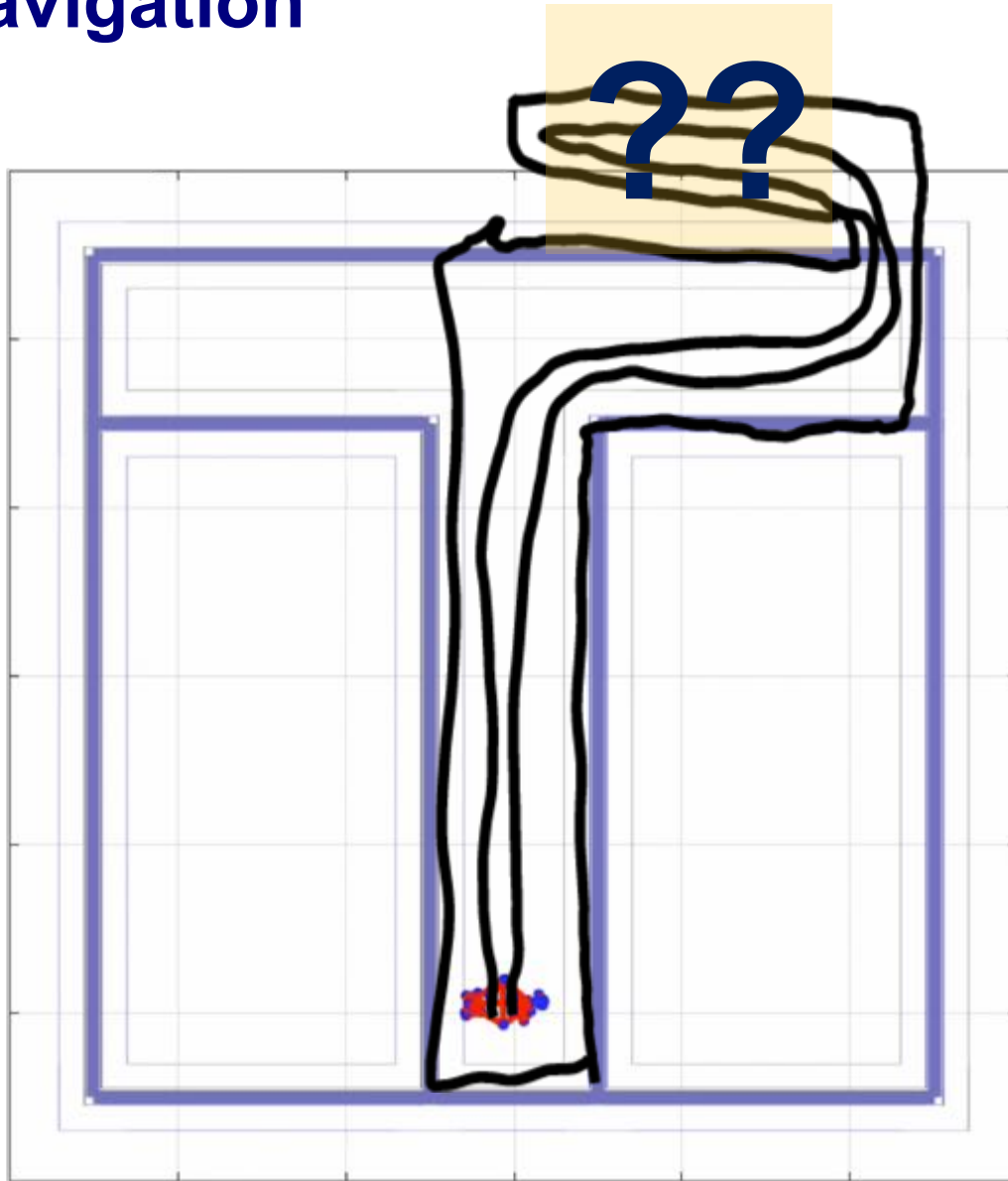
Run 1 0.1



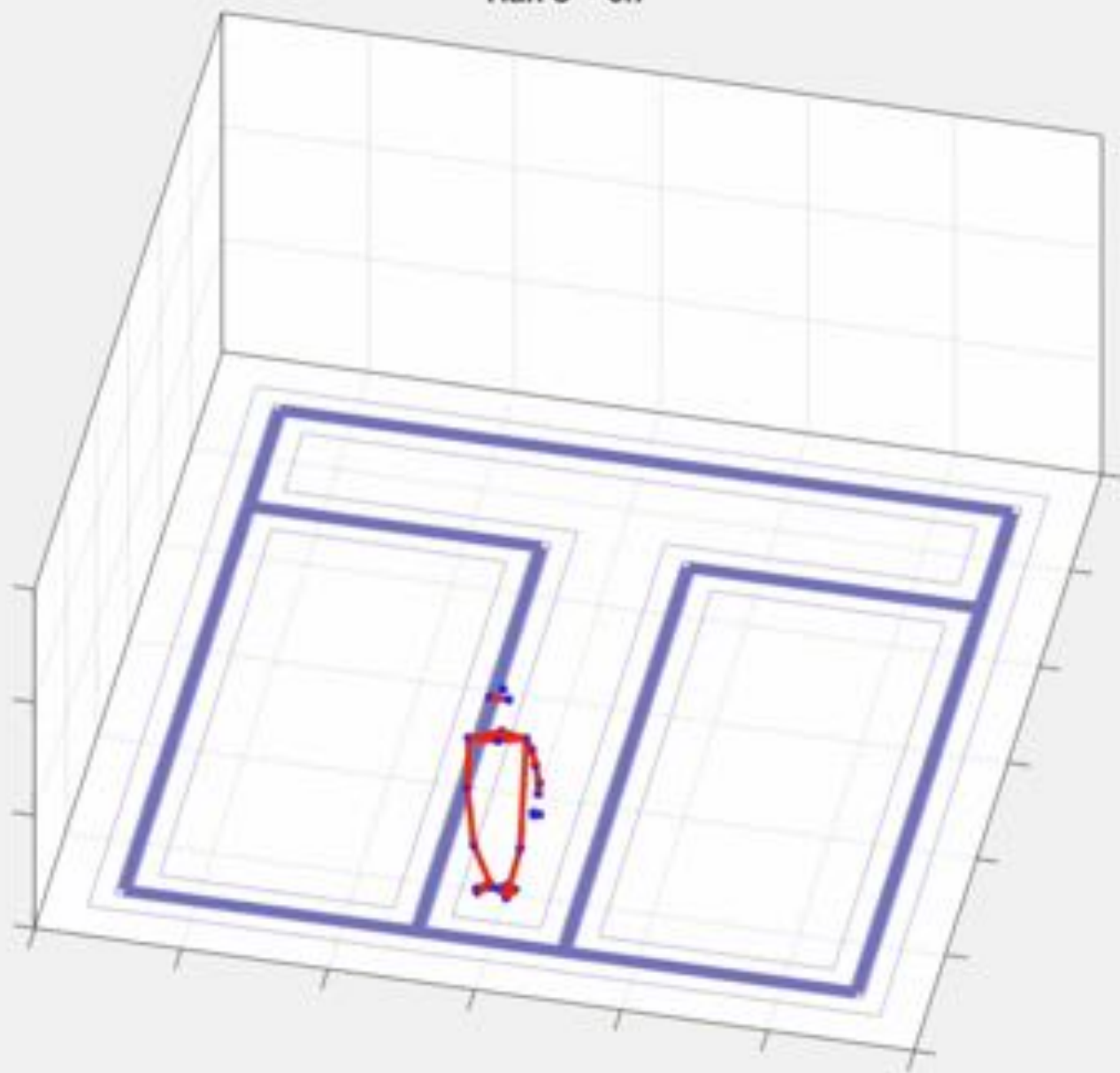
1st Pass Navigation



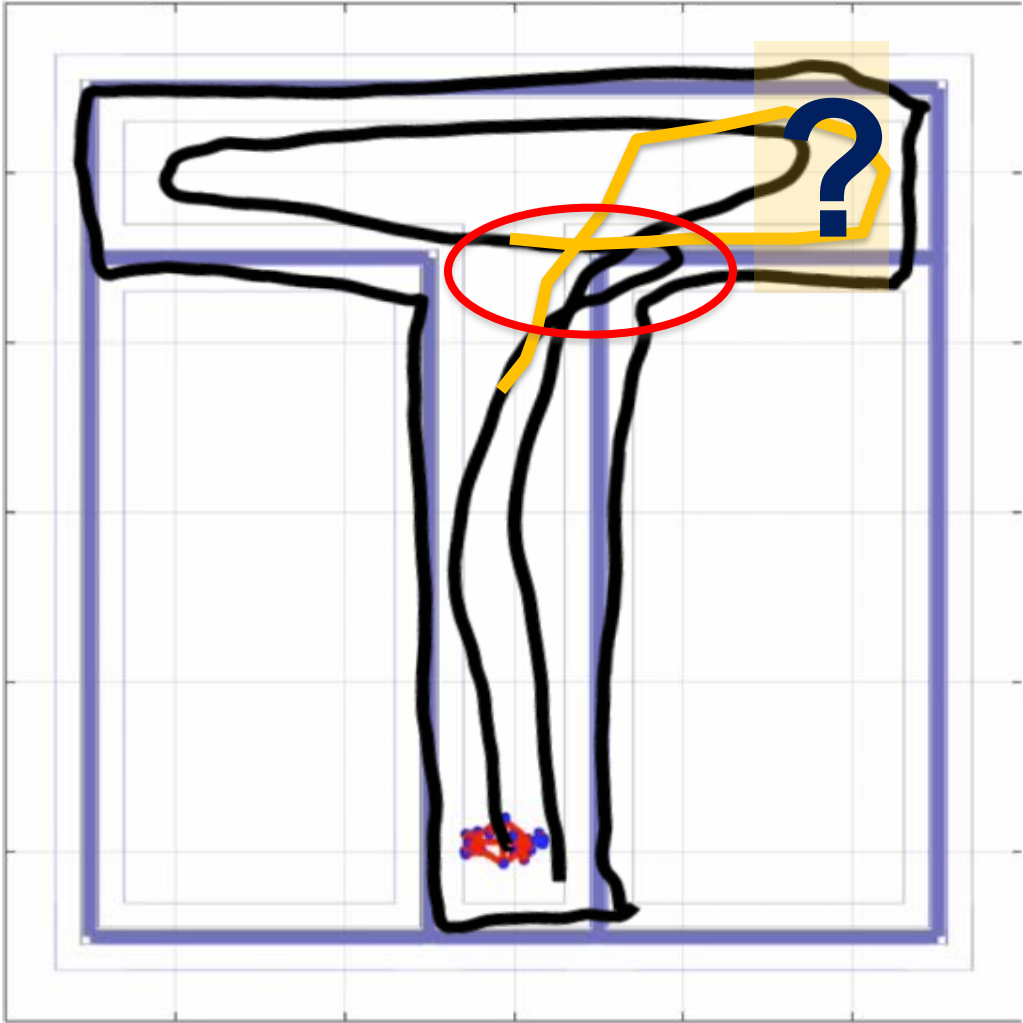
2nd Pass Navigation



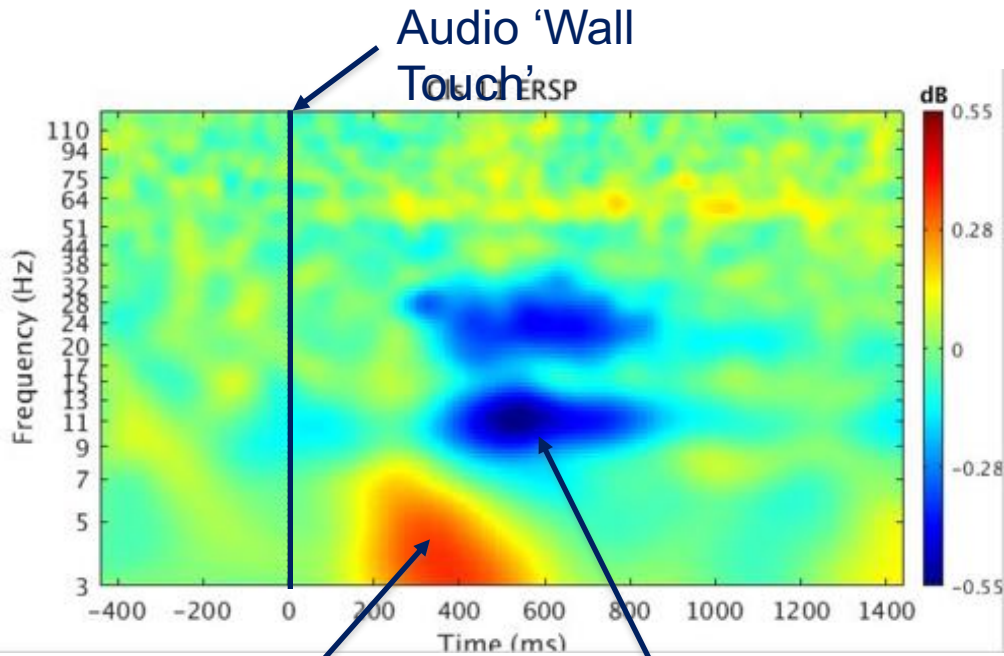
Run 3 -0.7



3rd Pass Navigation

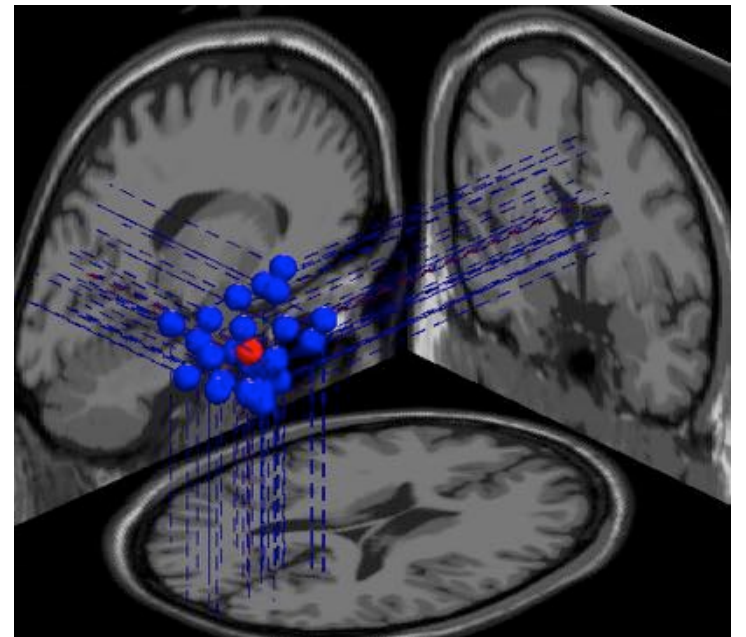
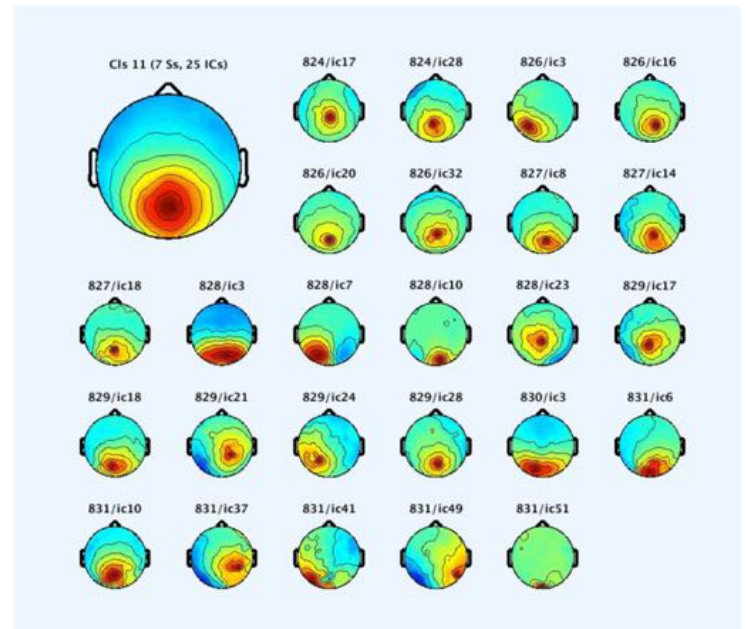


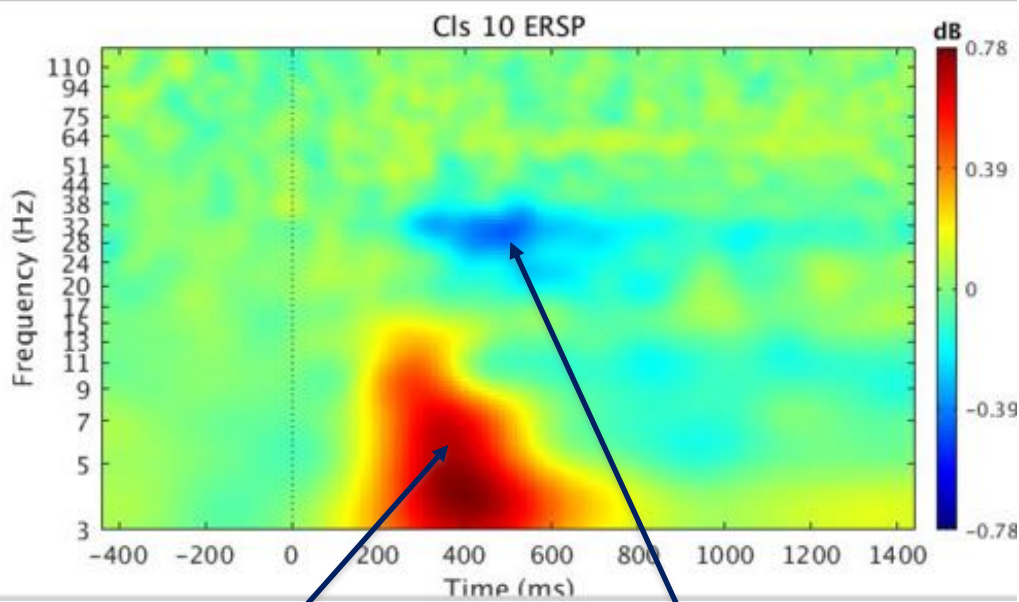
Central Posterior Independent Component Effective Source Cluster



Low-frequency
increase

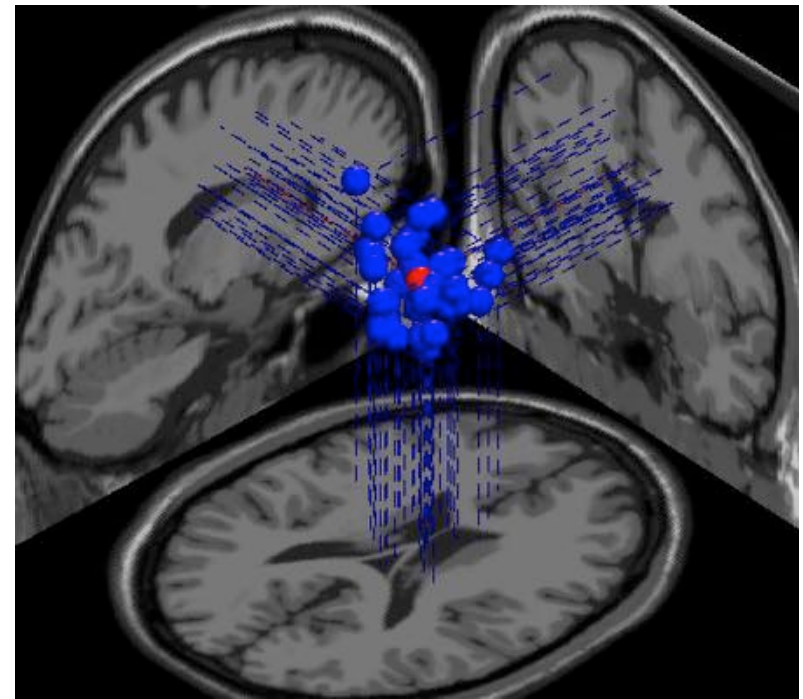
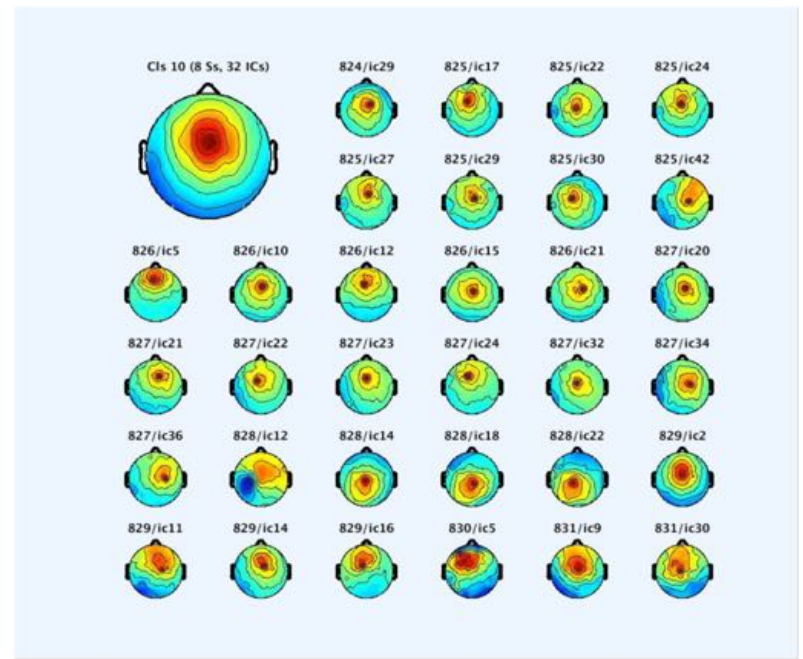
Alpha suppression





Alpha/theta increase

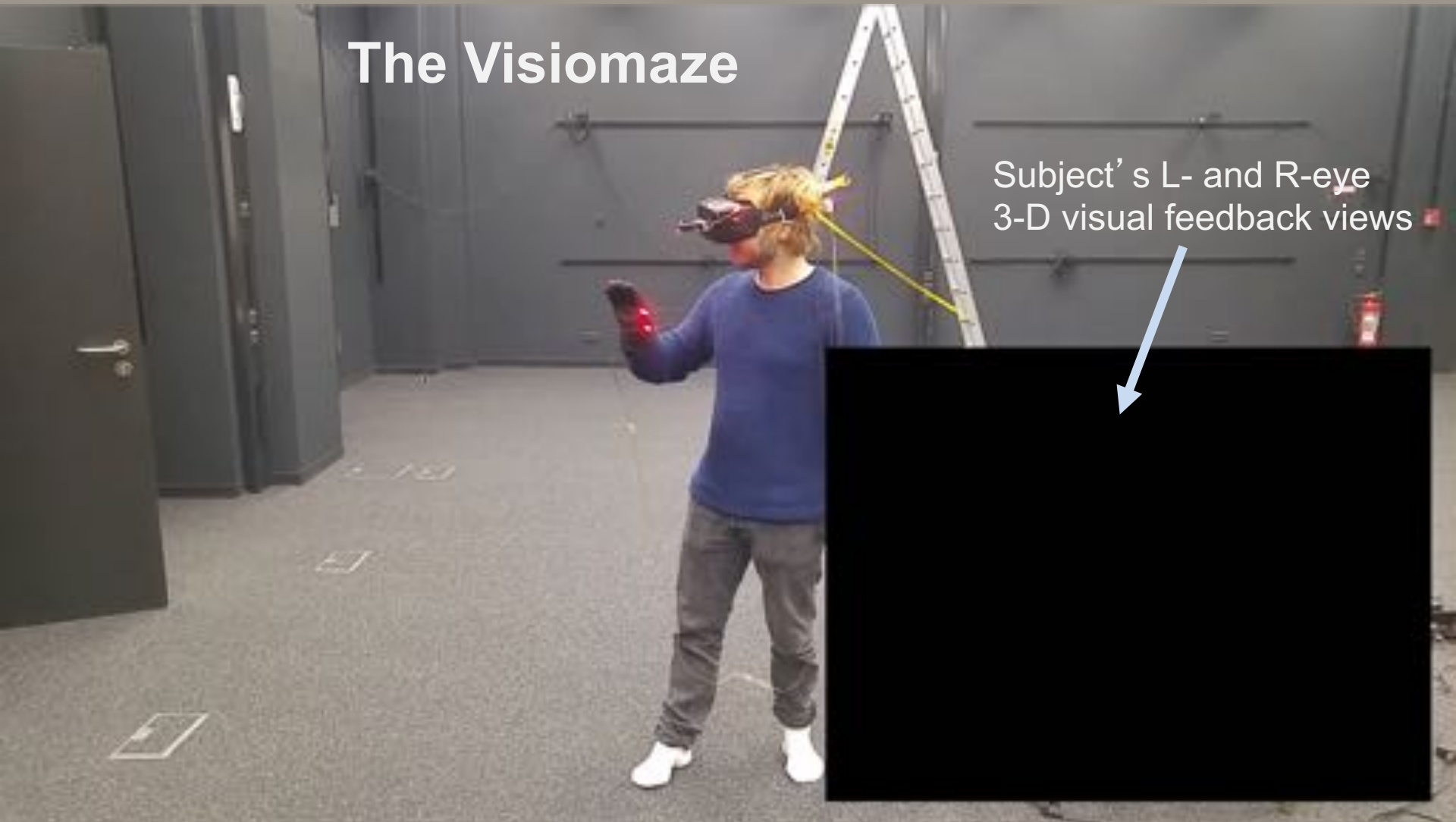
High beta suppression



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

The Visiomaze

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





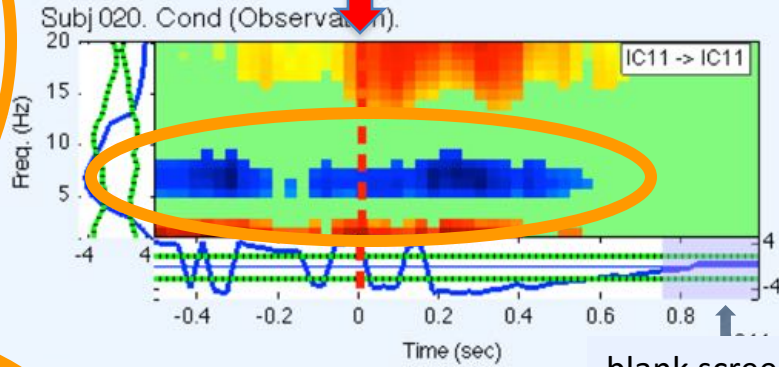
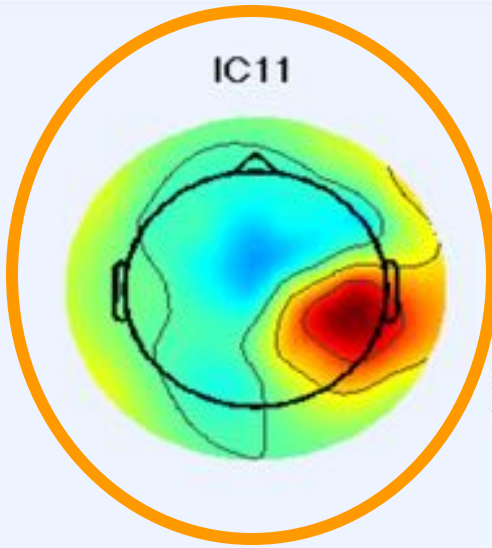
**Imaging Human Agency
and Social Interactions**

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

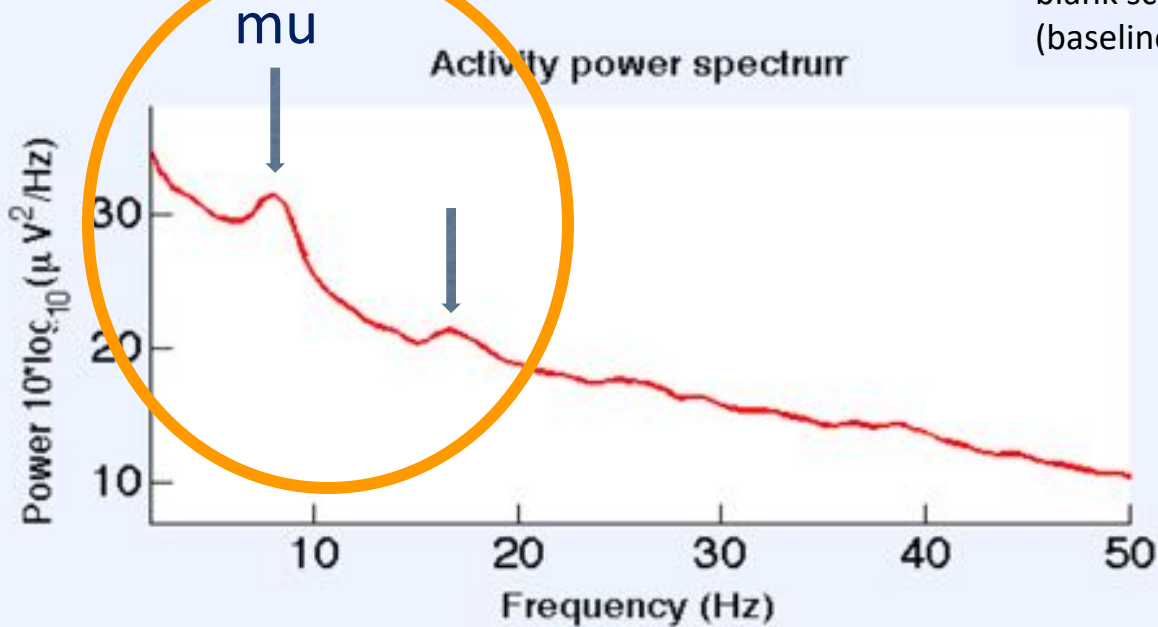


3-yr old child – Reward Observation

Mother Pops the Bubble!



blank screen
(baseline)



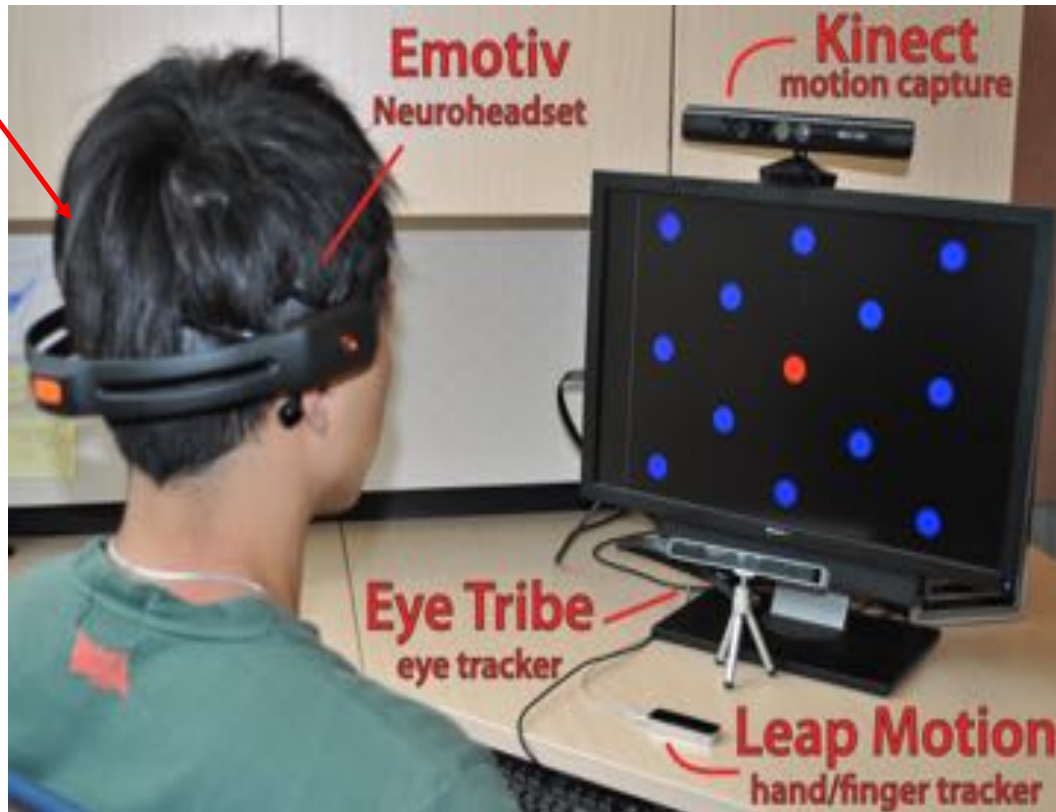
Now feasible – Low-cost MoBI Systems

Low-Cost MoBI

Any EEG System

< \$500

< \$500



< \$500
Touchscreen

< \$1000

Full Body
Wireless Inertial
Motion Capture

< \$100

< \$100

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

Brain dynamics are inherently multi-scale

EEG (scalp surface fields)

ECOG (larger cortical surface fields)

Imaging Brain Support for

At each spatial recording scale, the signal is produced by active partial coherence of distributed activities at the next smaller scale.

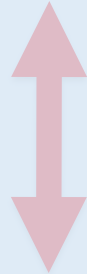
for

Three Aspects of

Consciousness

Cross-scale coupling is bi-directional!

Large



Smaller

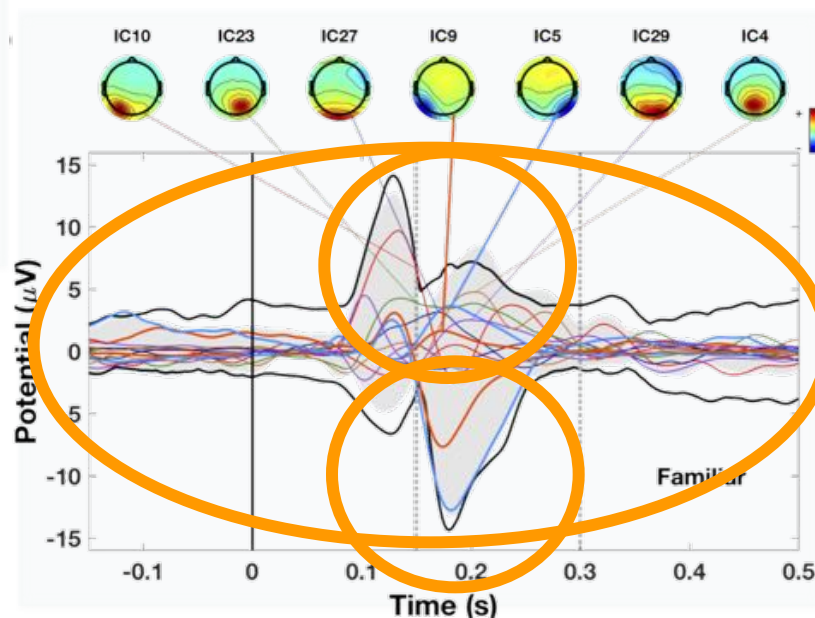
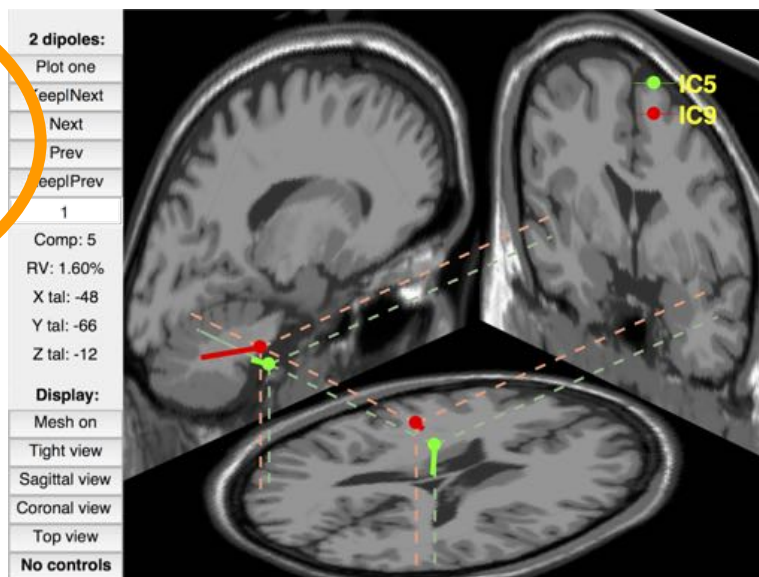
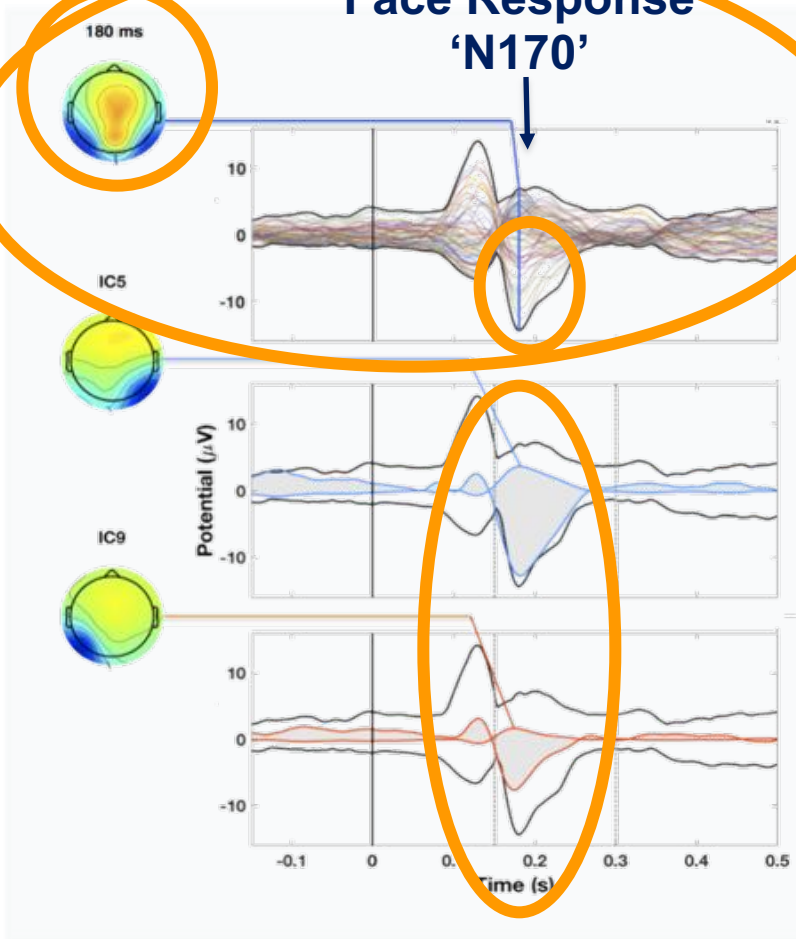
Intracellular and extracellular fields

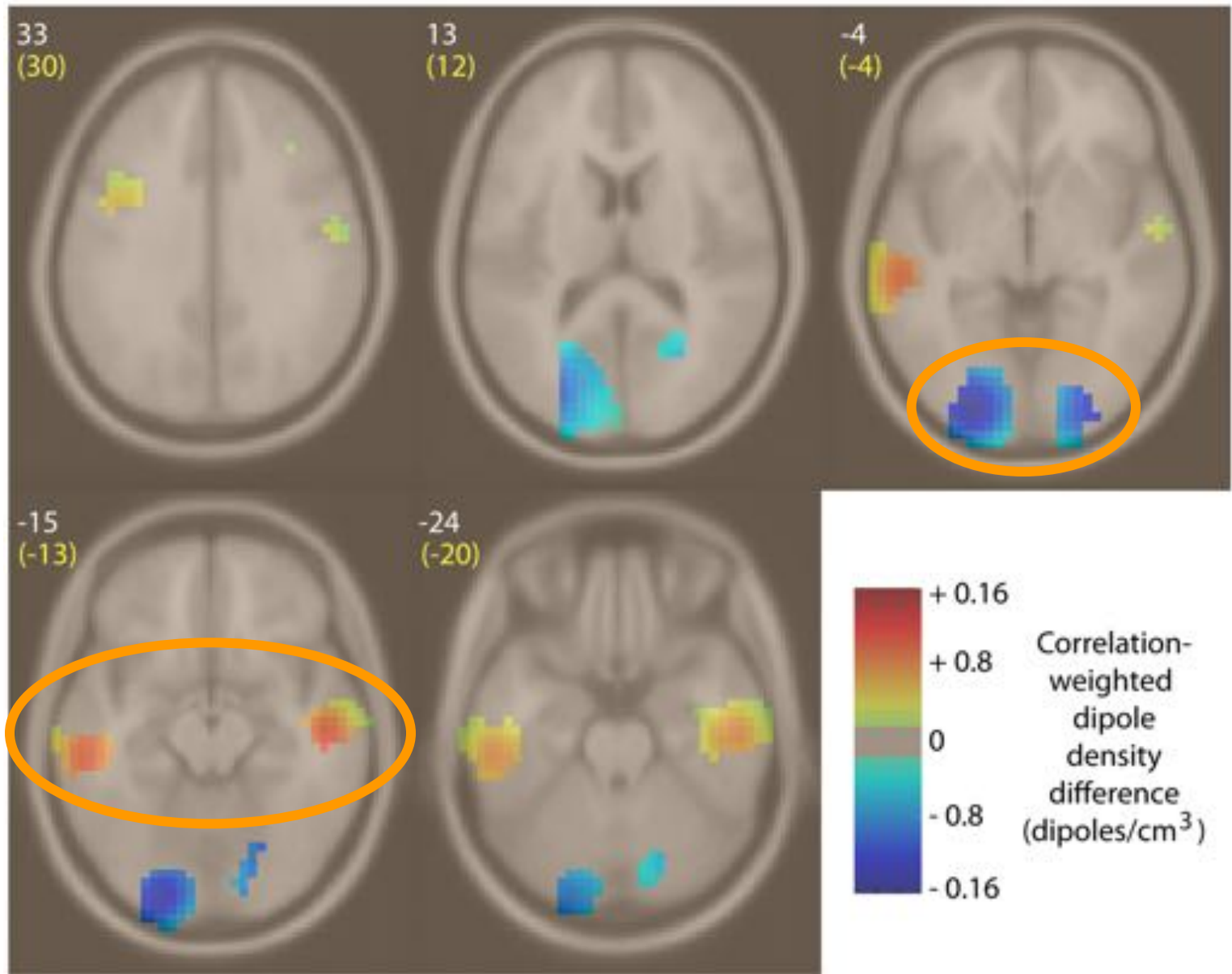
Synaptic and other transmembrane potentials



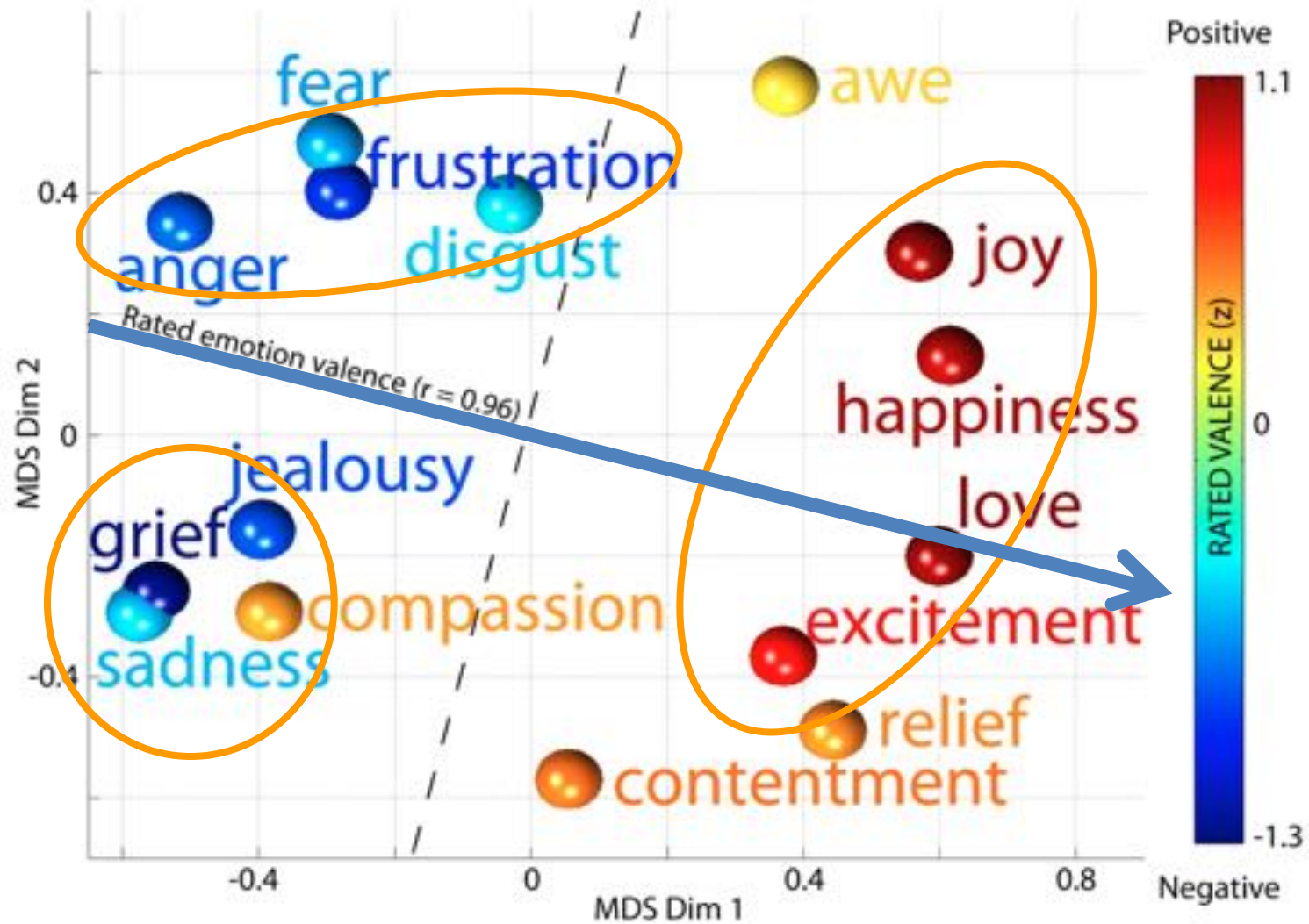
Knowing

Face Response
'N170'





Feeling



Willing



Imaging Human Agency

Mobile Brain/Body Imaging (MoBI)

Embodied Cognition & Agency

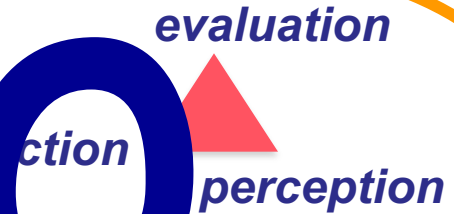
Brain processes
have evolved a function
to optimize the outcome
of behavior.

the brain organizes
in response to
perceived challenges
and opportunities.

am

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

who



The Beginning

fEEG, BCI, MoBI,

NFB, BrainStim ...