Mining Event-related Brain Dynamics II

Scott Makeig

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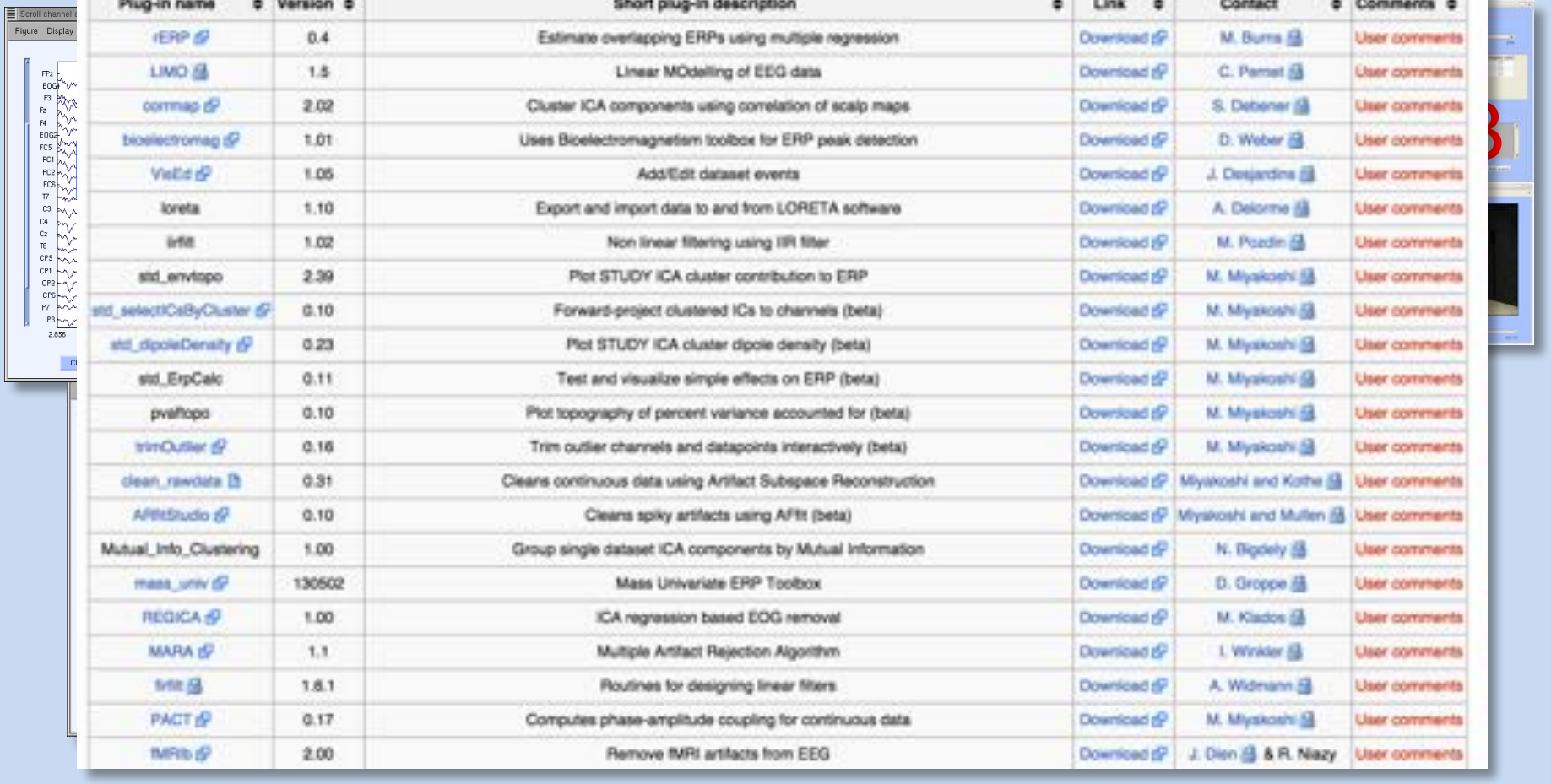
University of California San Diego

26th EEGLAB Workshop

Be'er Sheva, Israel

October, 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
commap	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_selectICsByCluster	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
AFfitStudio	0.10	Cleans spiky artifacts using AFfit (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.

S Makeig, 2012

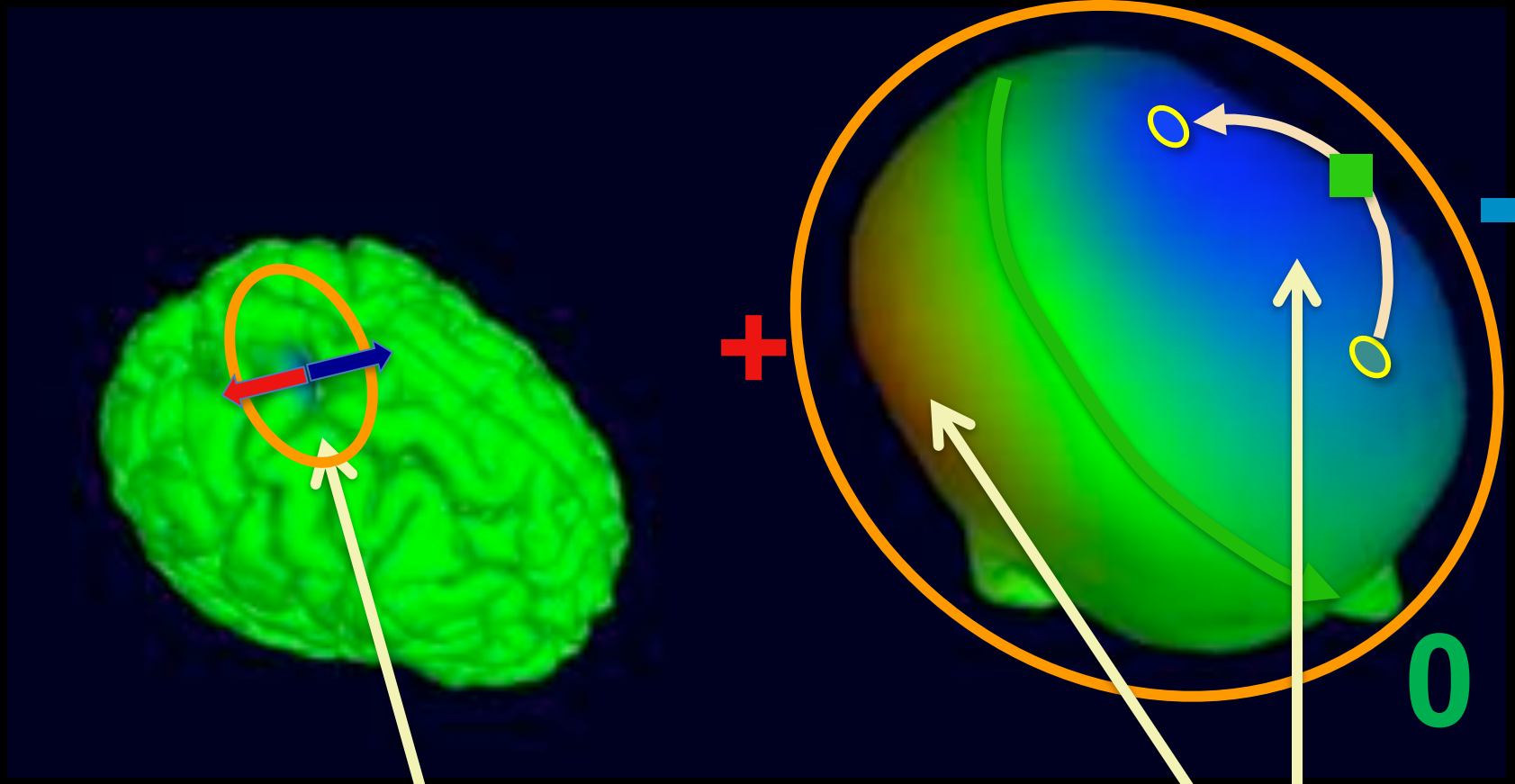
What is EEG?

- 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.**

Cloud art: Berndnaut

The very broad EEG point-spread function

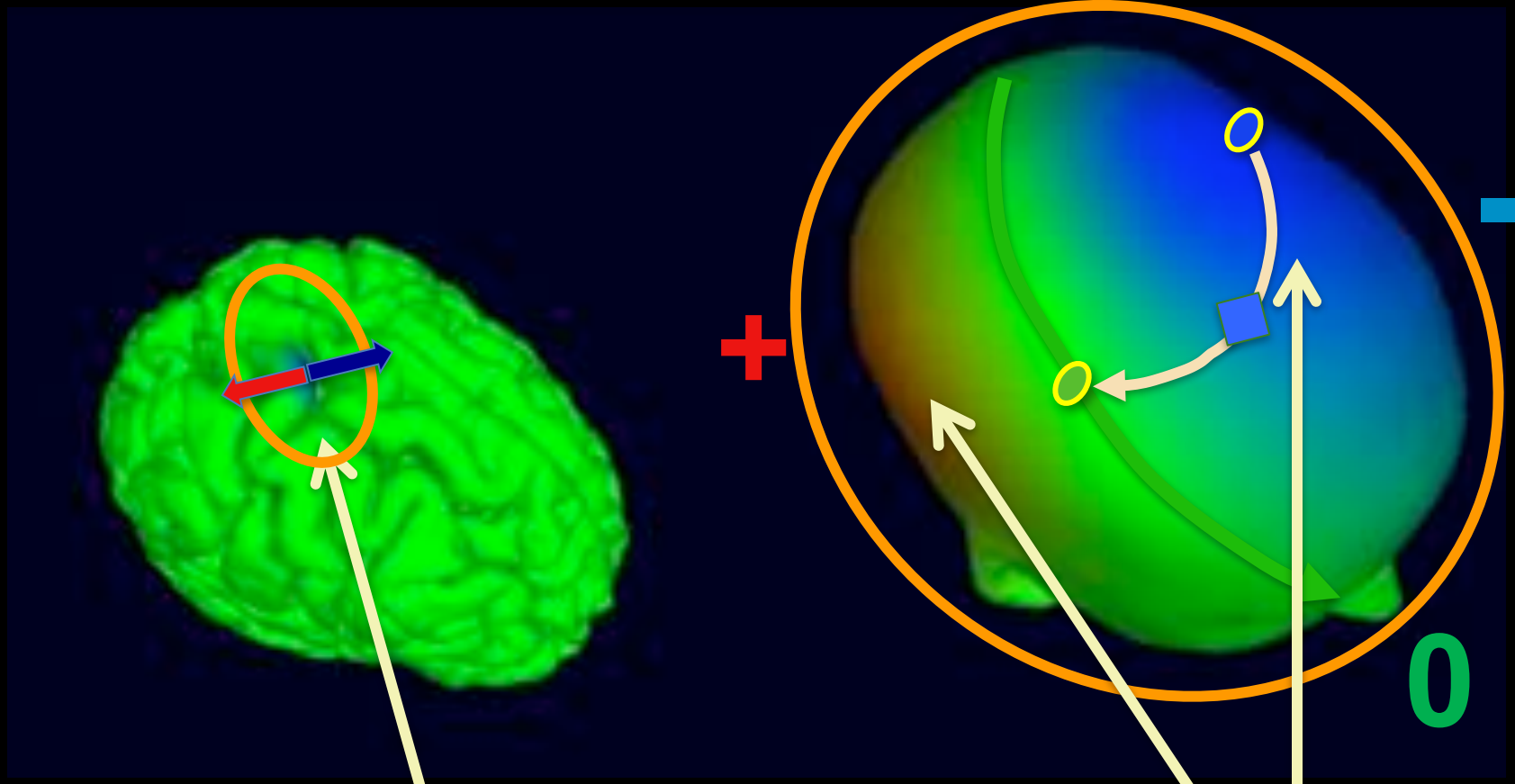


Single simulated parietal source →

Very broad projected scalp potentials

Akalin Acar & Makeig 2010

The very broad EEG point-spread function



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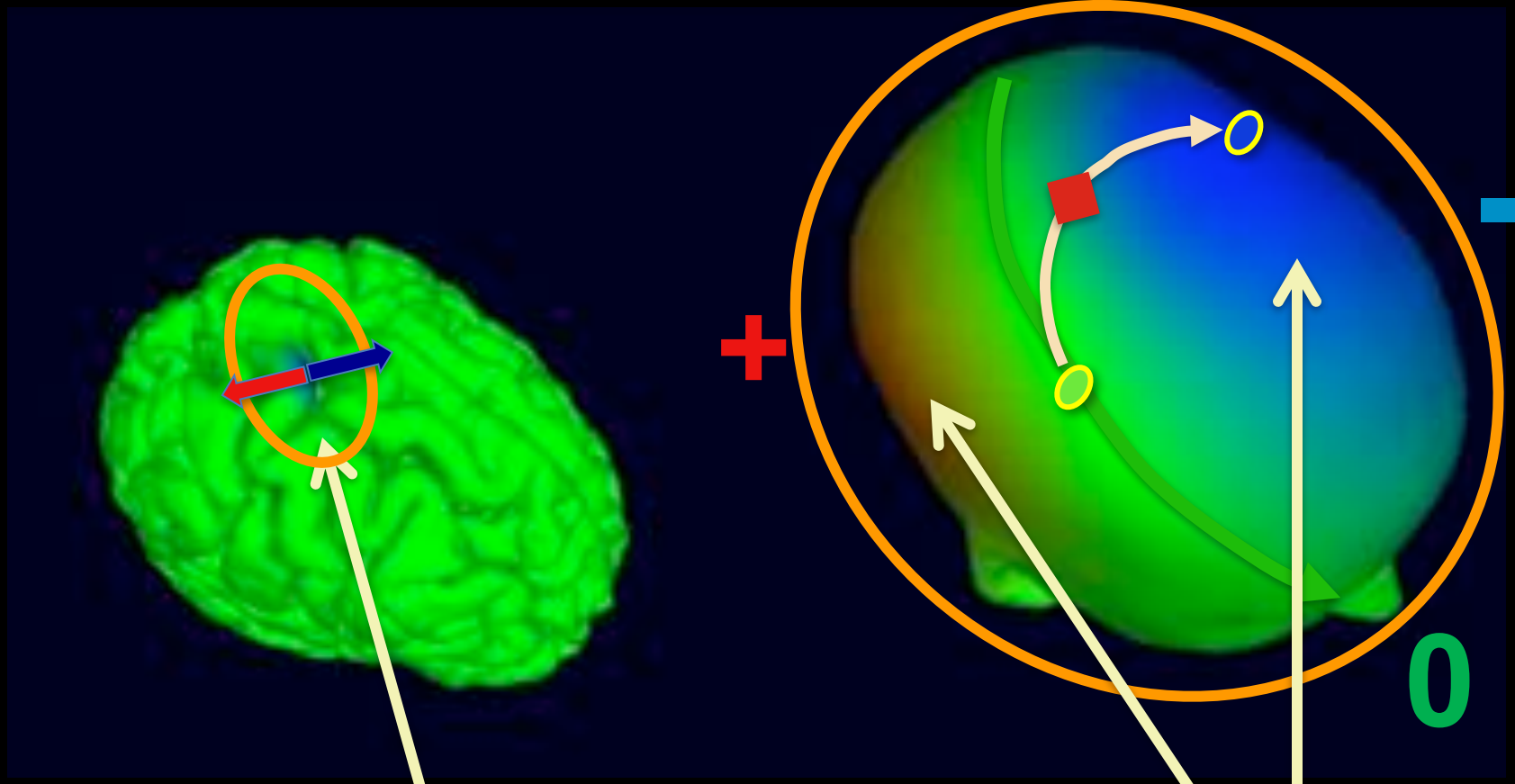

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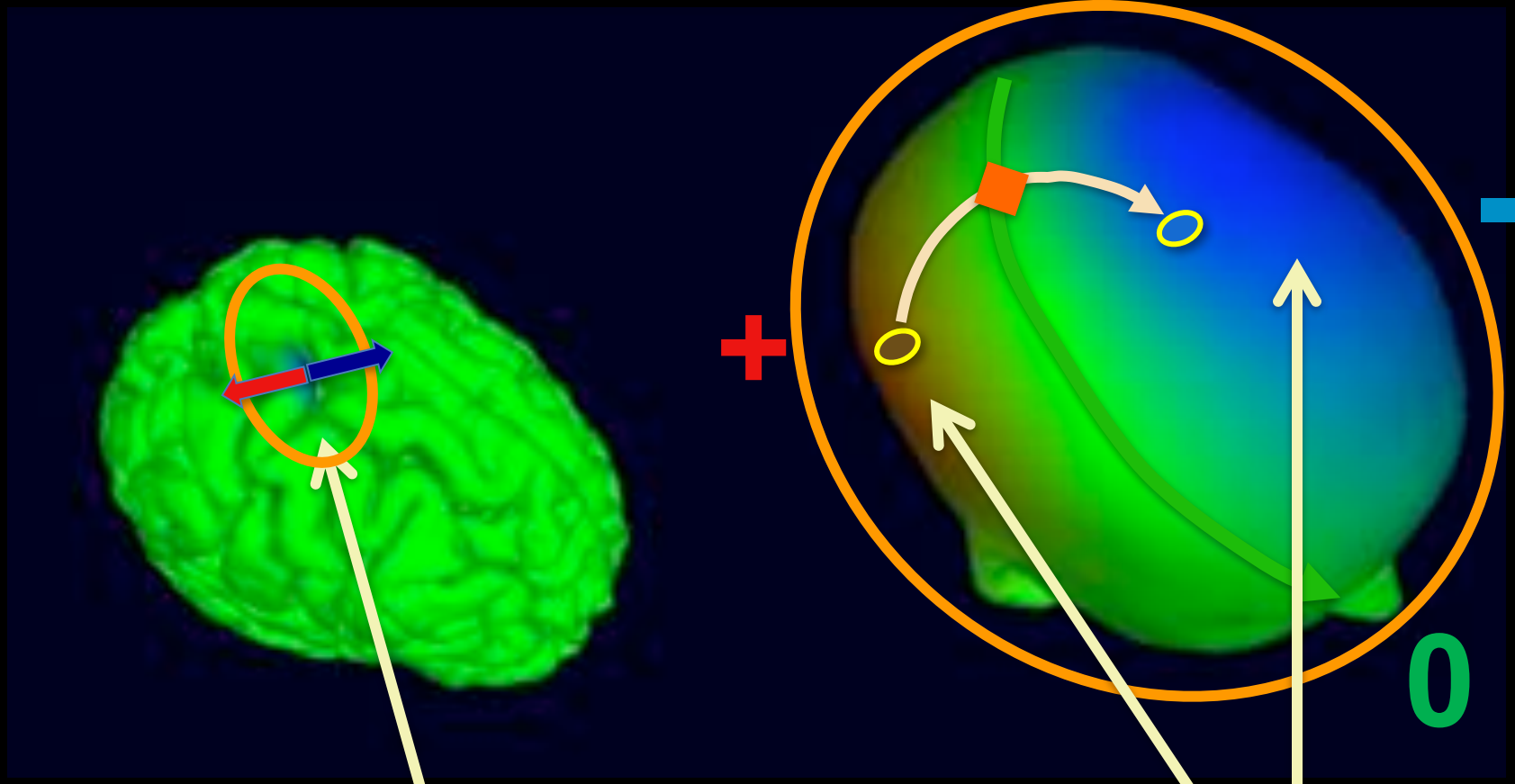
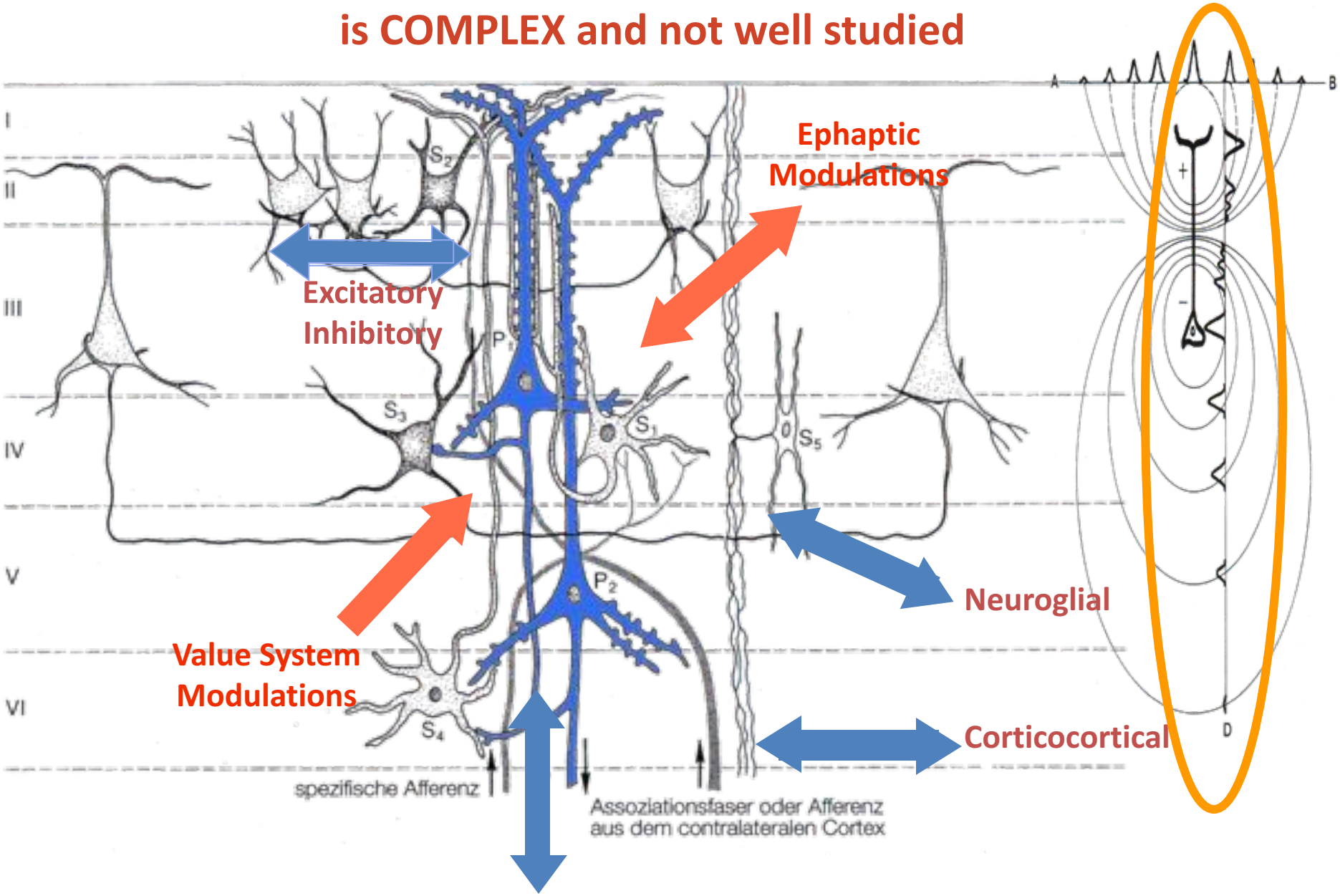


Single simulated parietal source →

Very broad projected scalp potentials

Akalin Acar & Makeig 2010

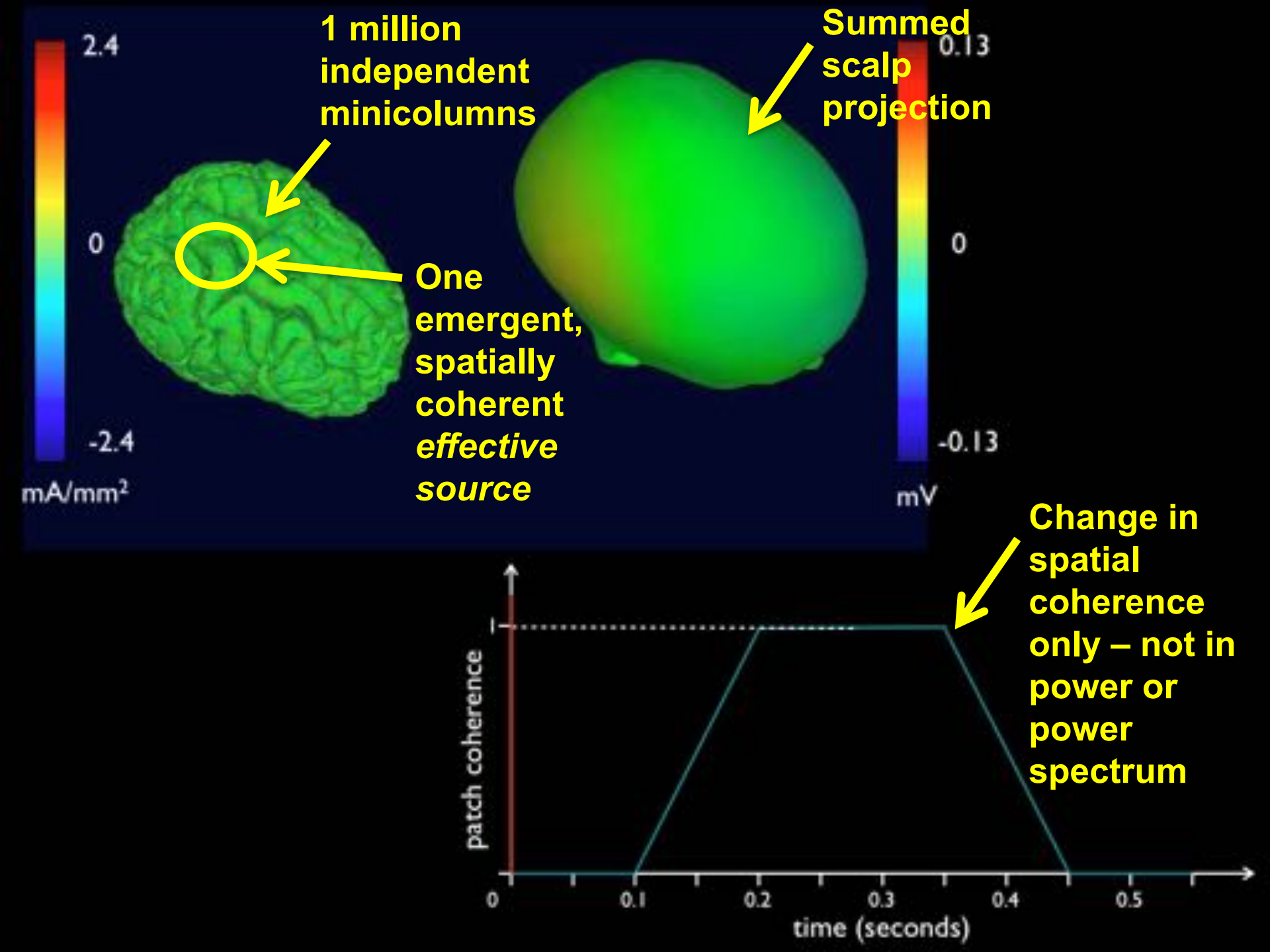
The generation and modulation of EEG is COMPLEX and not well studied

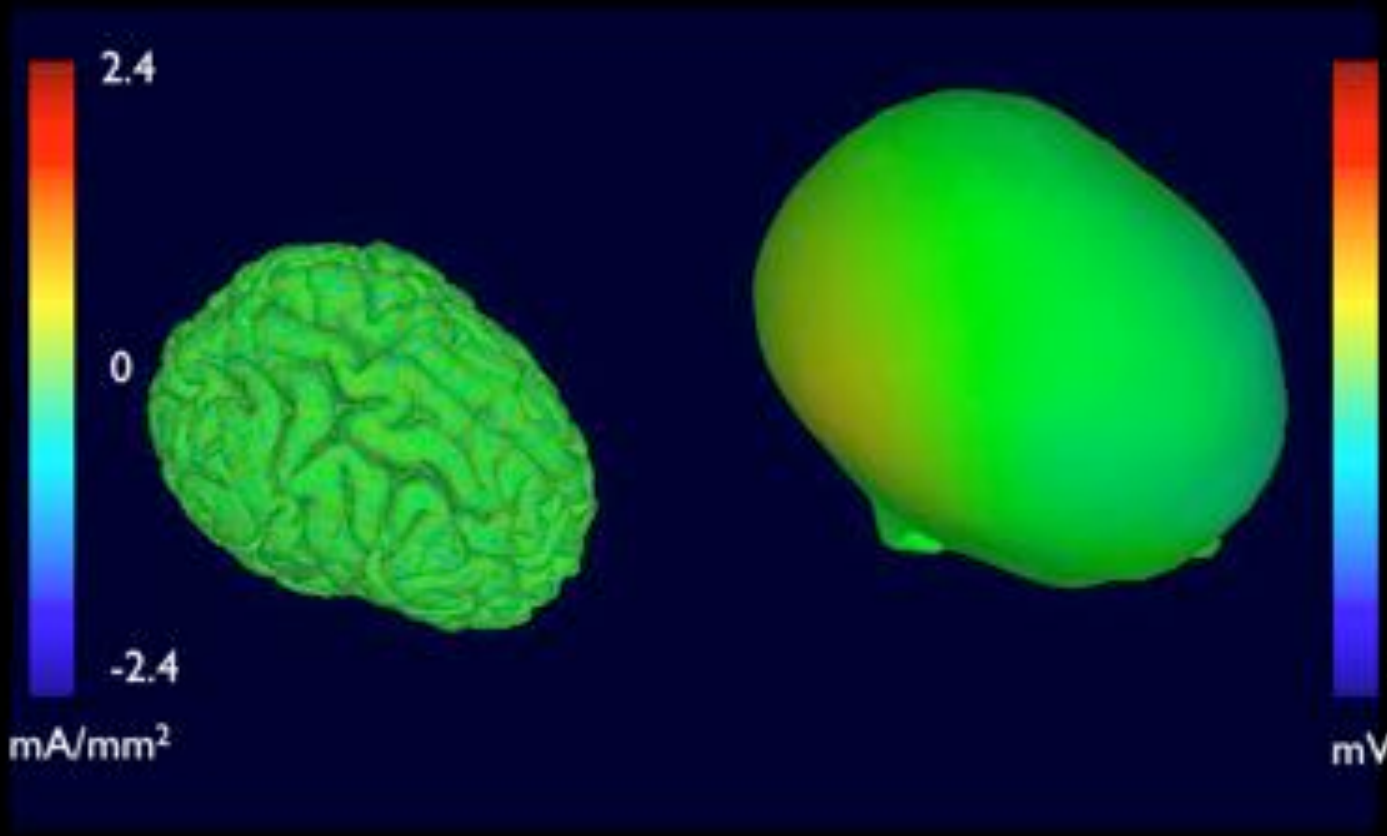


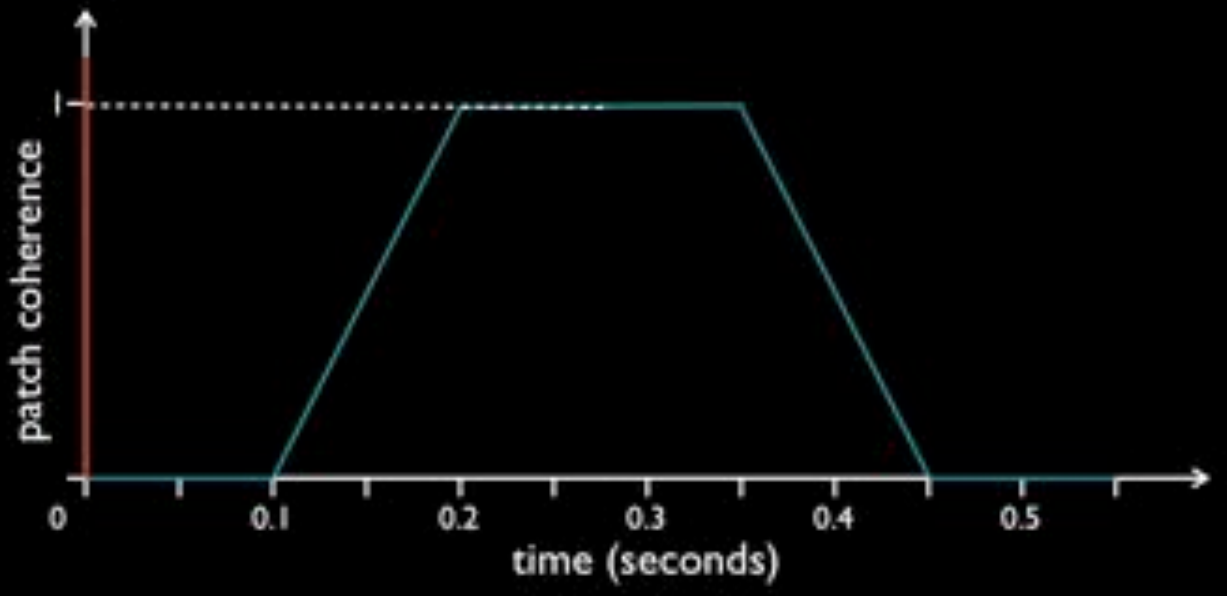
S. Makeig 2007

Phase cones (Freeman)

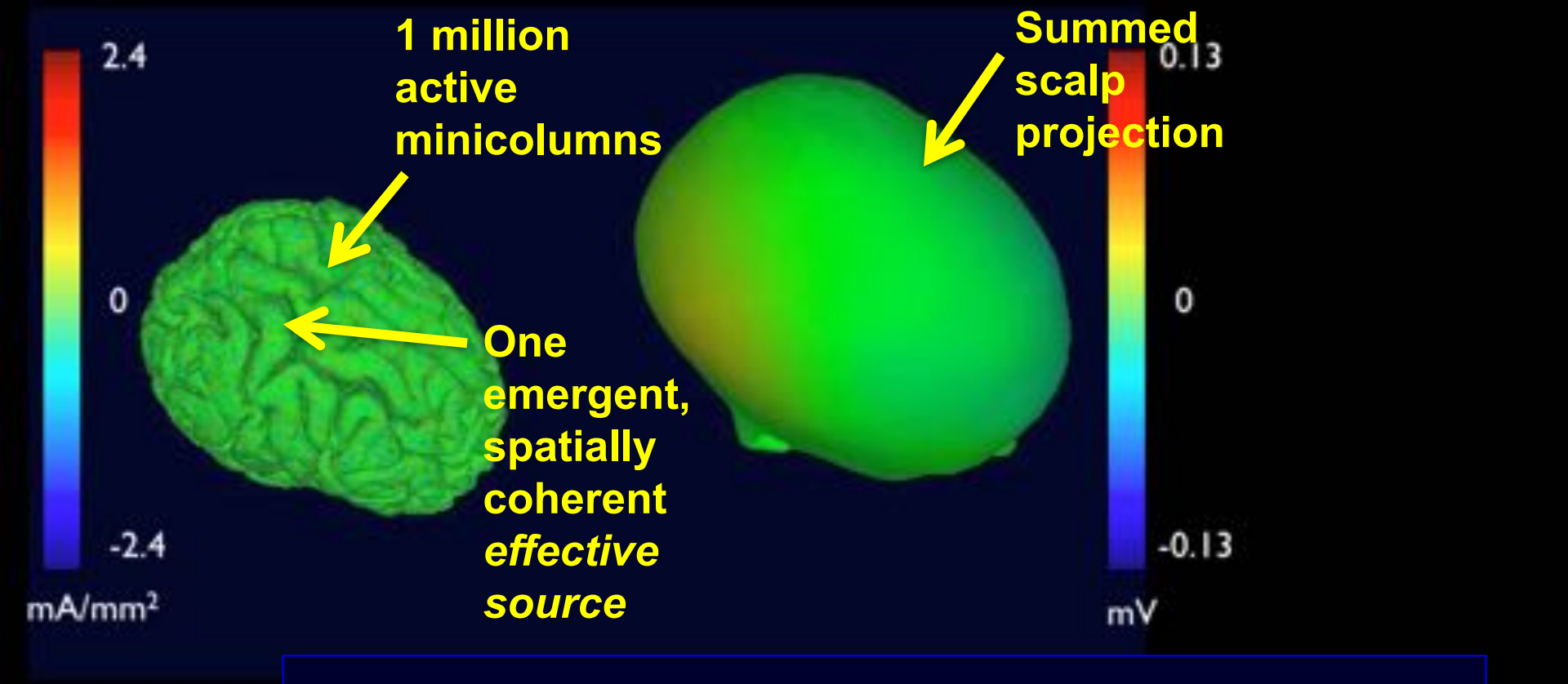
Avalanches (Plenz)


1 million independent minicolumns
Summed scalp projection
One emergent, spatially coherent *effective source*
2.4
0
-2.4
mA/mm²
0.13
0
-0.13
mV
Change in spatial coherence only – not in power or power spectrum
patch coherence
1
0
0.1
0.2
0.3
0.4
0.5
time (seconds)

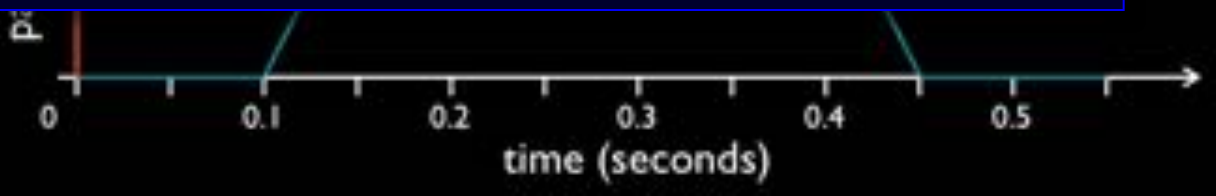


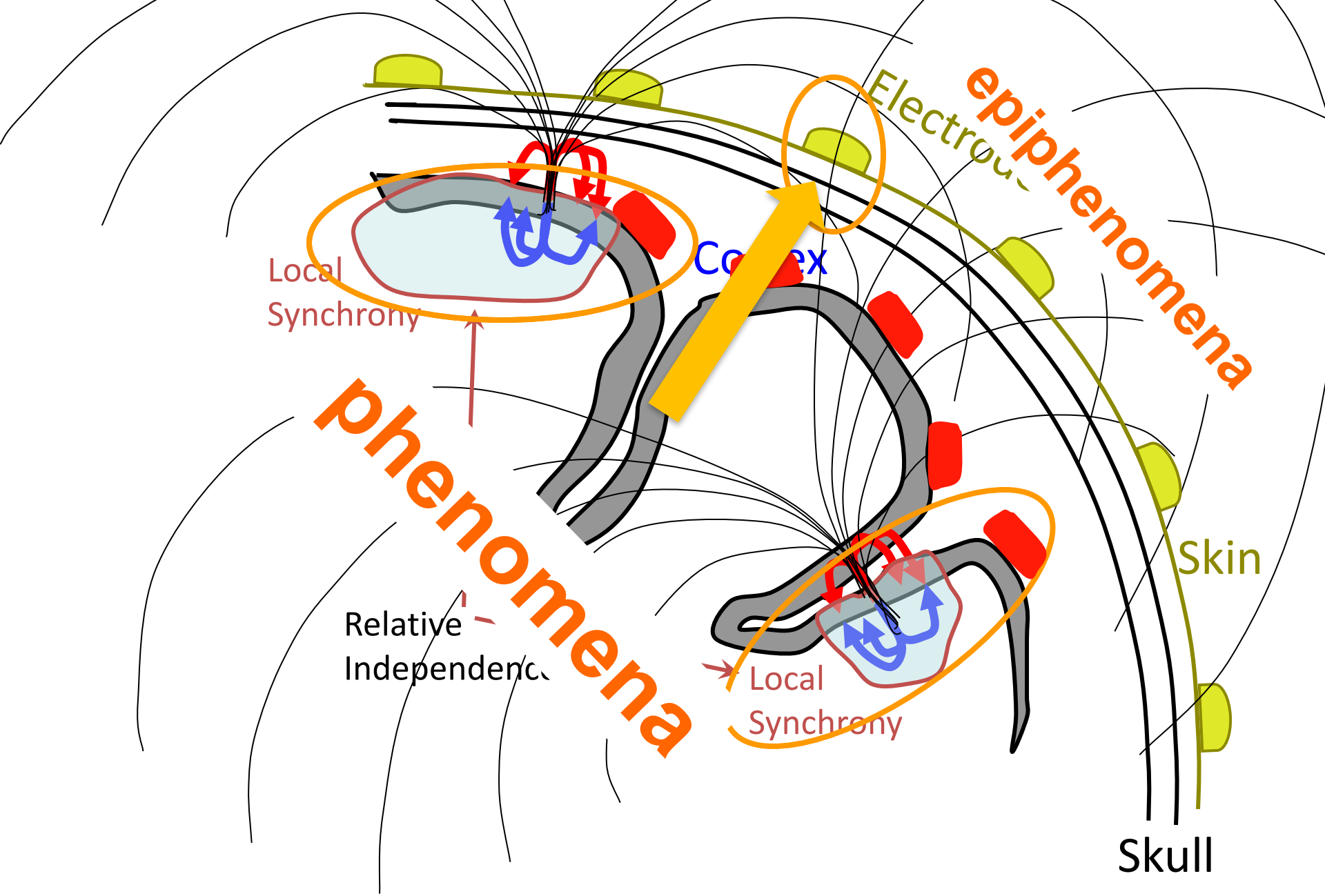


Z. Akalin Acar & S. Makeig (2015)



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

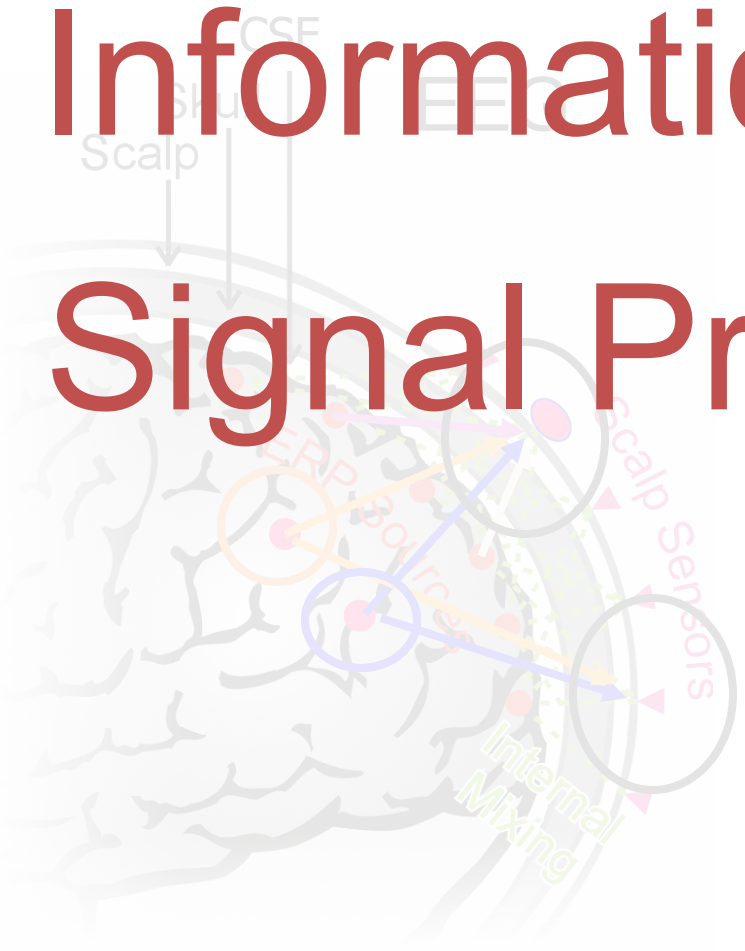




S. Makeig 2007

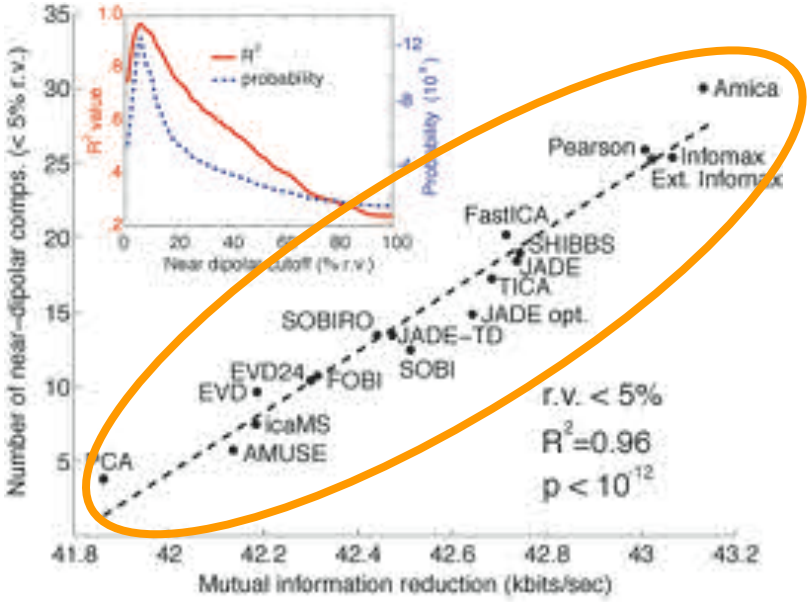
Blind EEG Source Separation by ICA

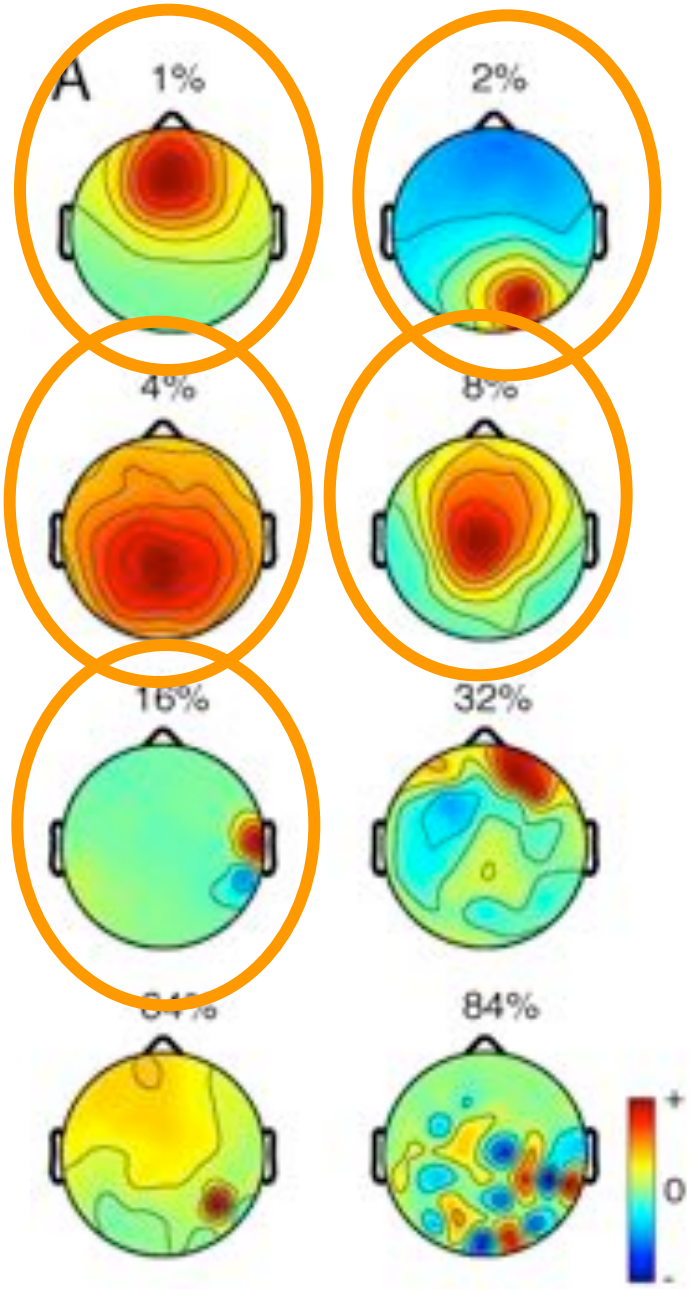
Information-based Signal Processing



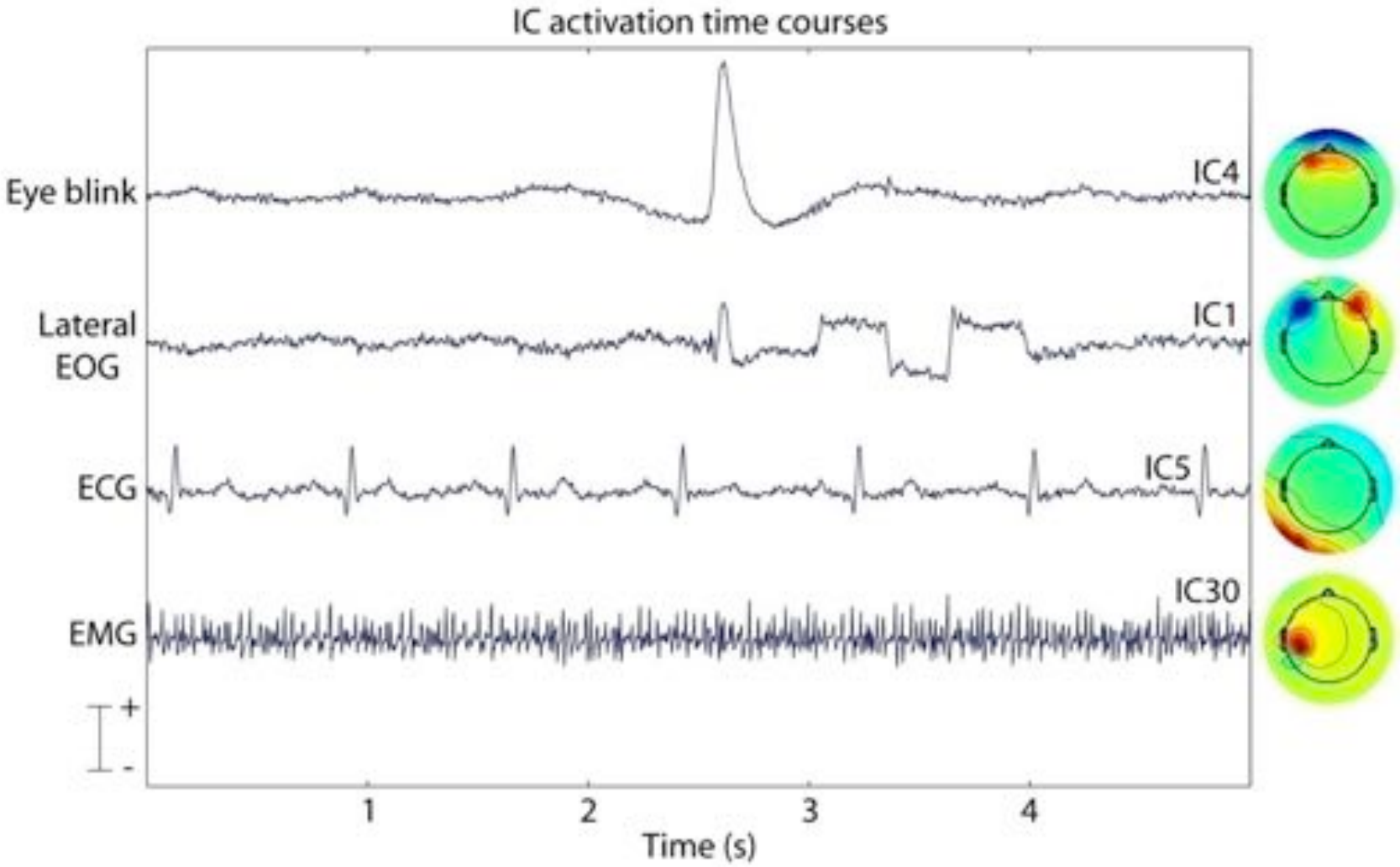
Independent Component Dipolarity

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



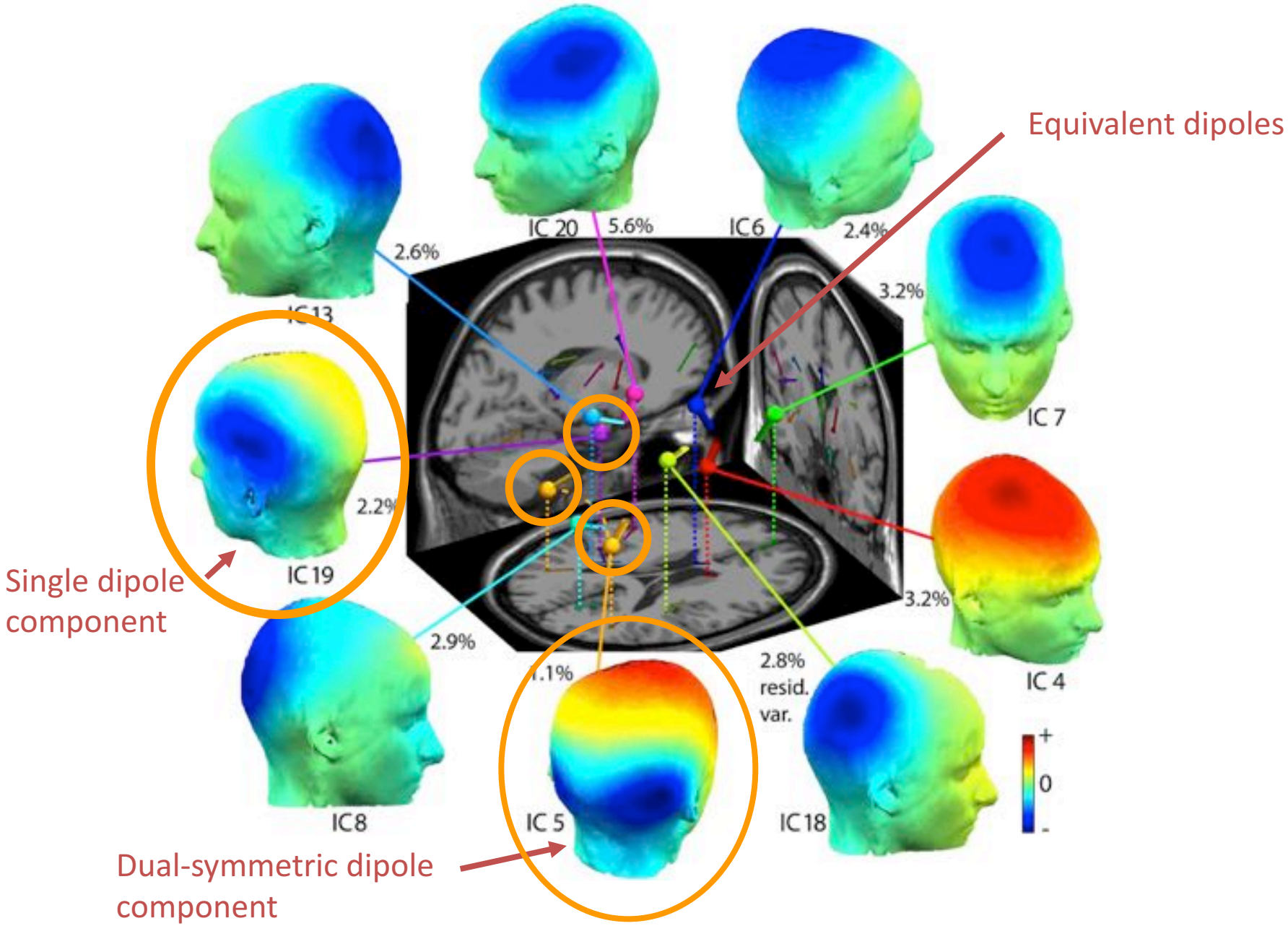


ICA separates *non-brain* effective source processes



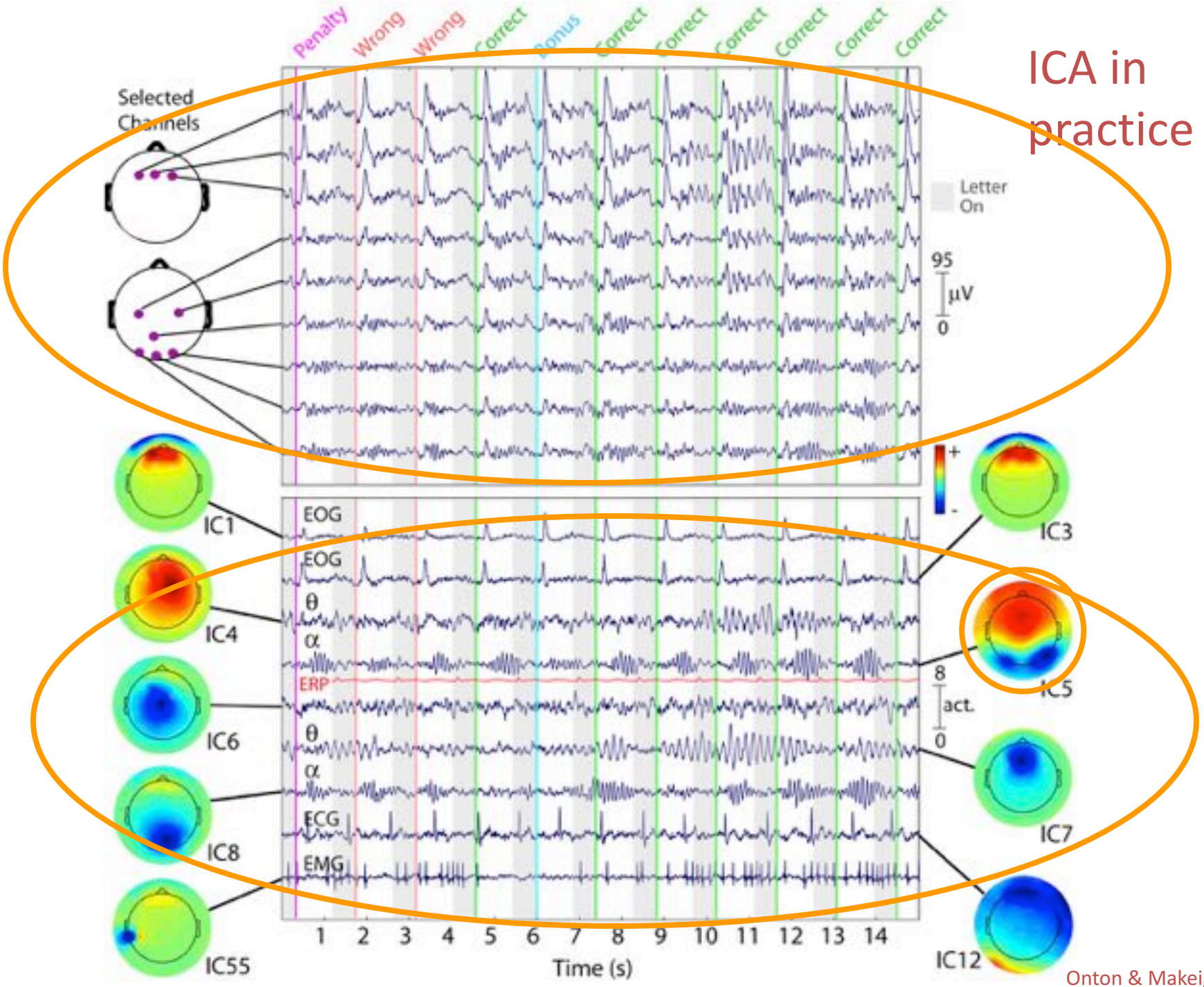
J. Onton & S. Makeig 2006

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

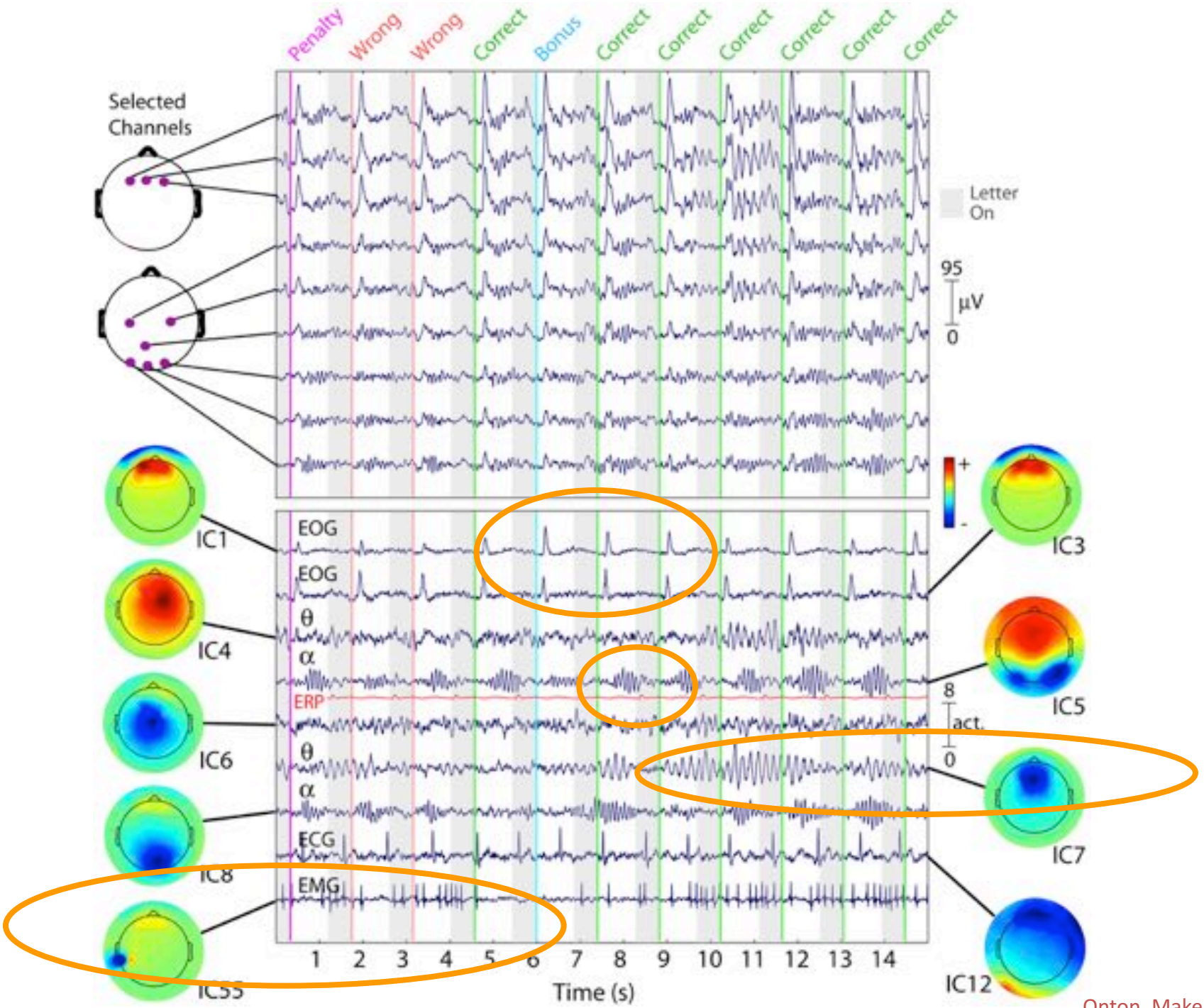


Julie Onton & S. Makeig (2006)

ICA in practice



Onton & Makeig, 2006



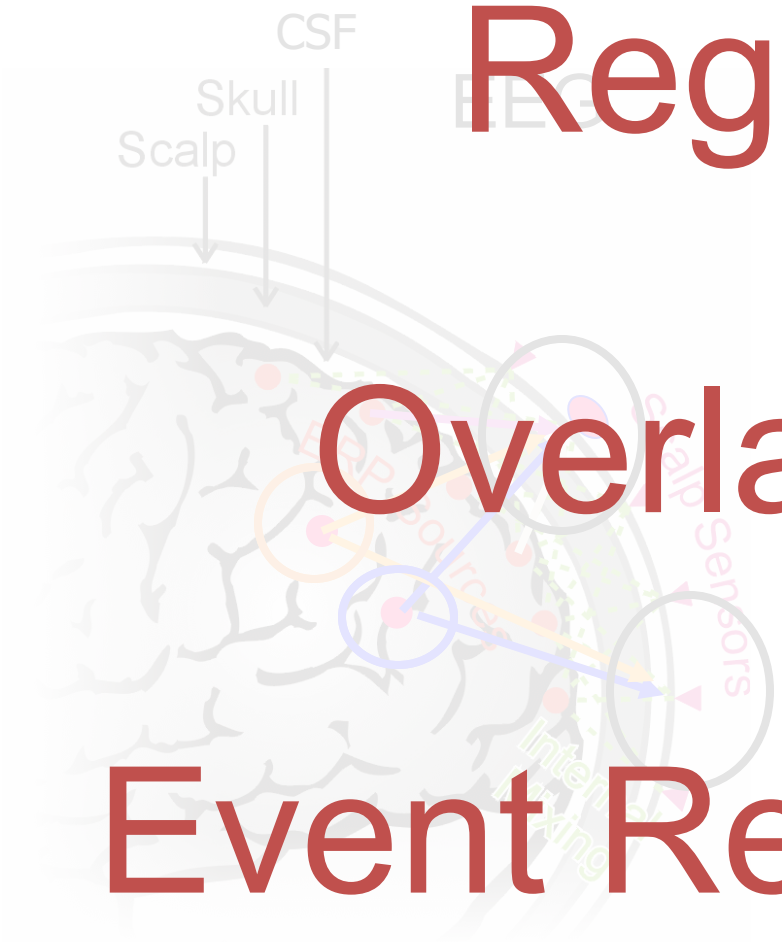
Onton, Makeig (2006)

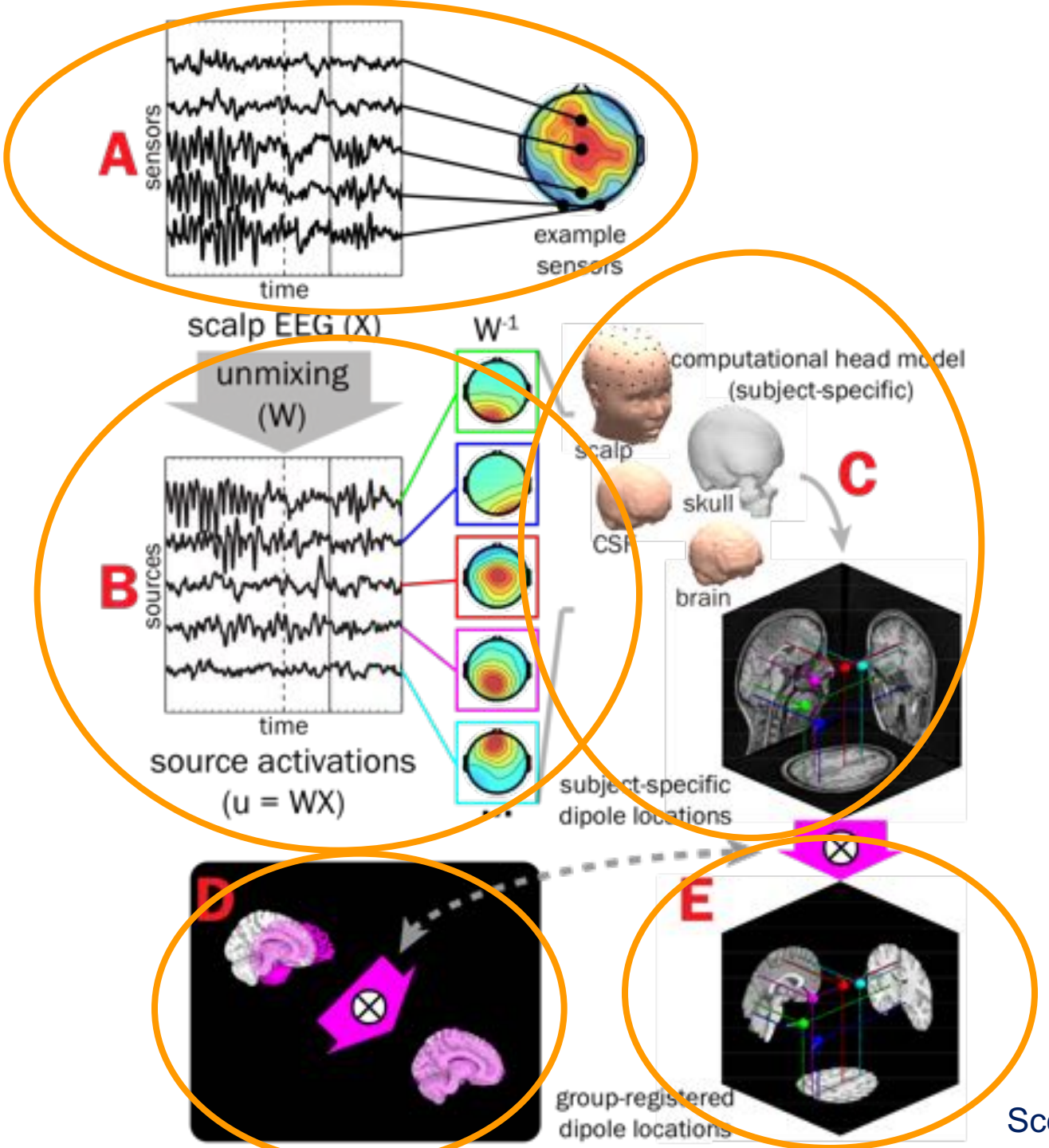
Blind EEG Source Separation by ICA

Regress

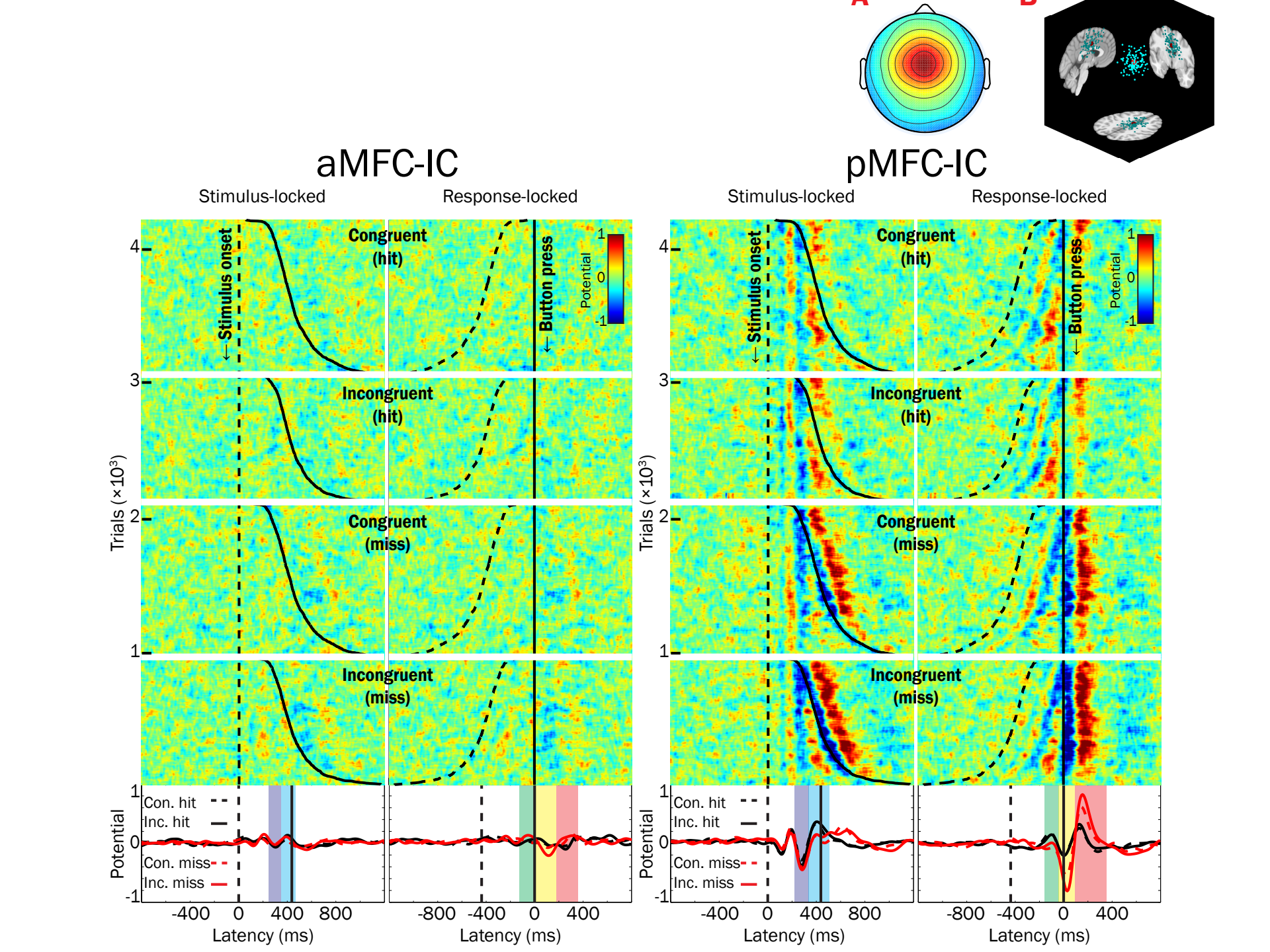
Overlapping

Event Responses



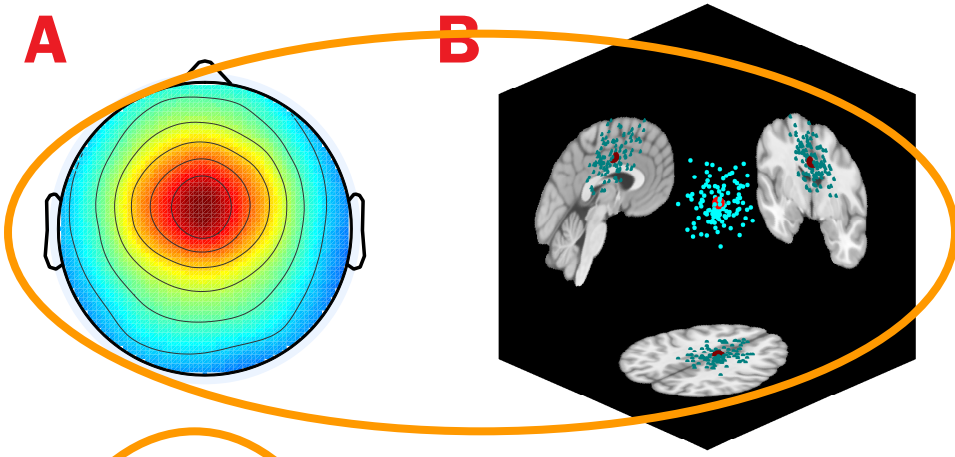


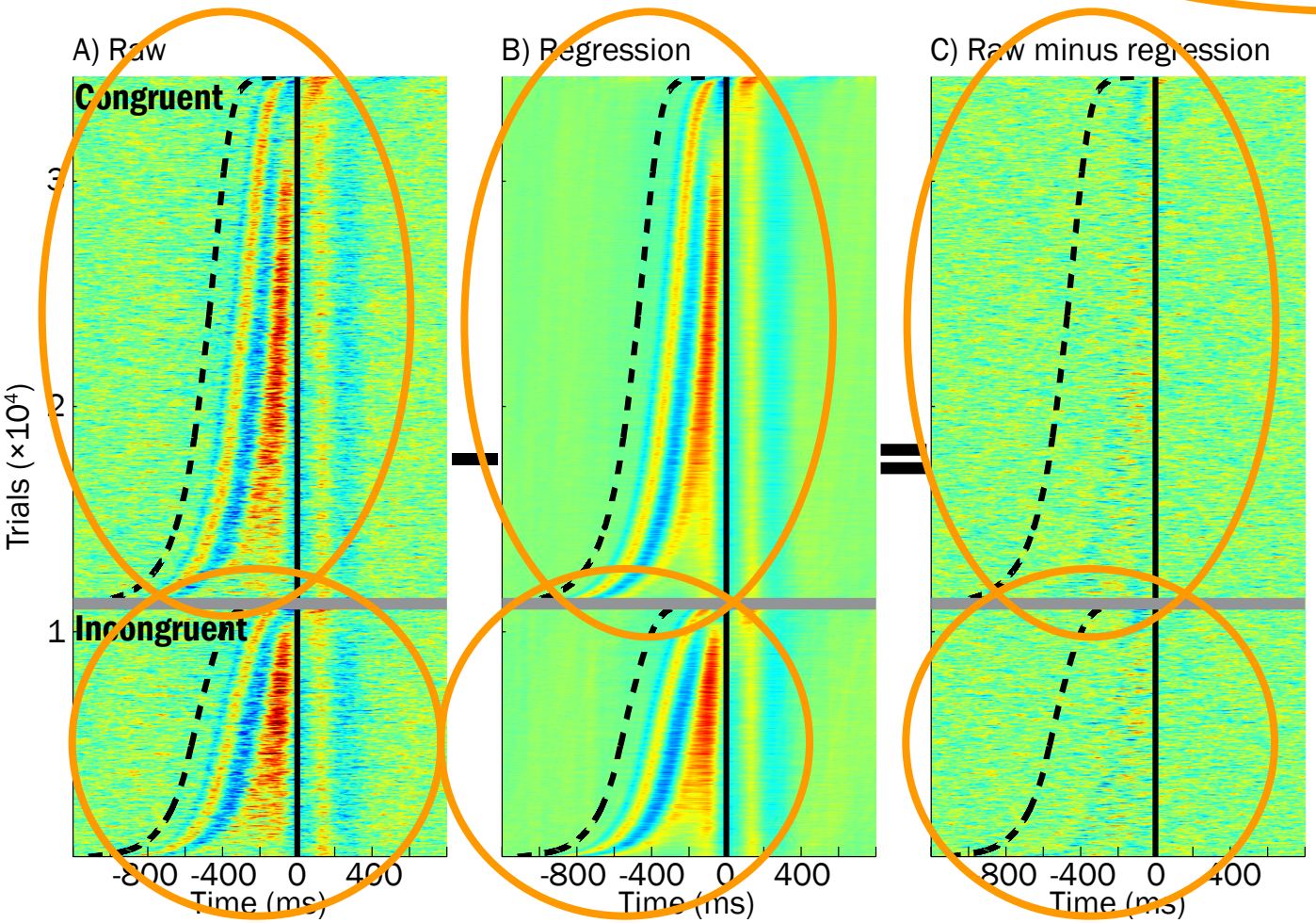
Scott Burwell, 2017

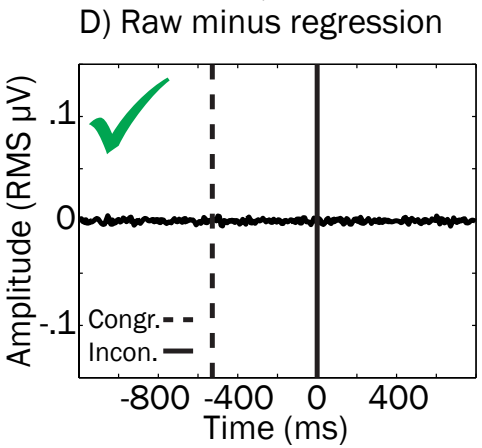

A
B
aMFC-IC
pMFC-IC
Stimulus-locked
Response-locked
Stimulus onset
Button press
Congruent (hit)
Incongruent (hit)
Congruent (miss)
Incongruent (miss)
Potential
Trials (×10³)
Con. hit
Inc. hit
Con. miss
Inc. miss
Latency (ms)

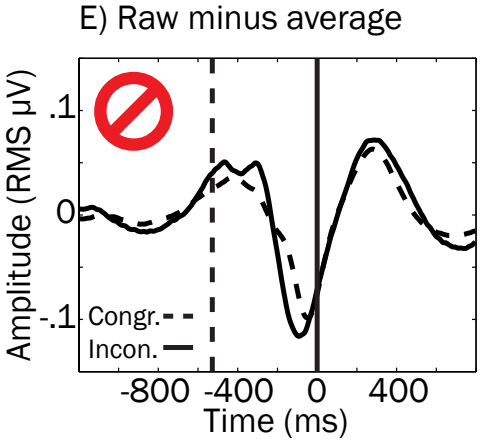
Trial-by-Trial Analysis

erpimage()
regression





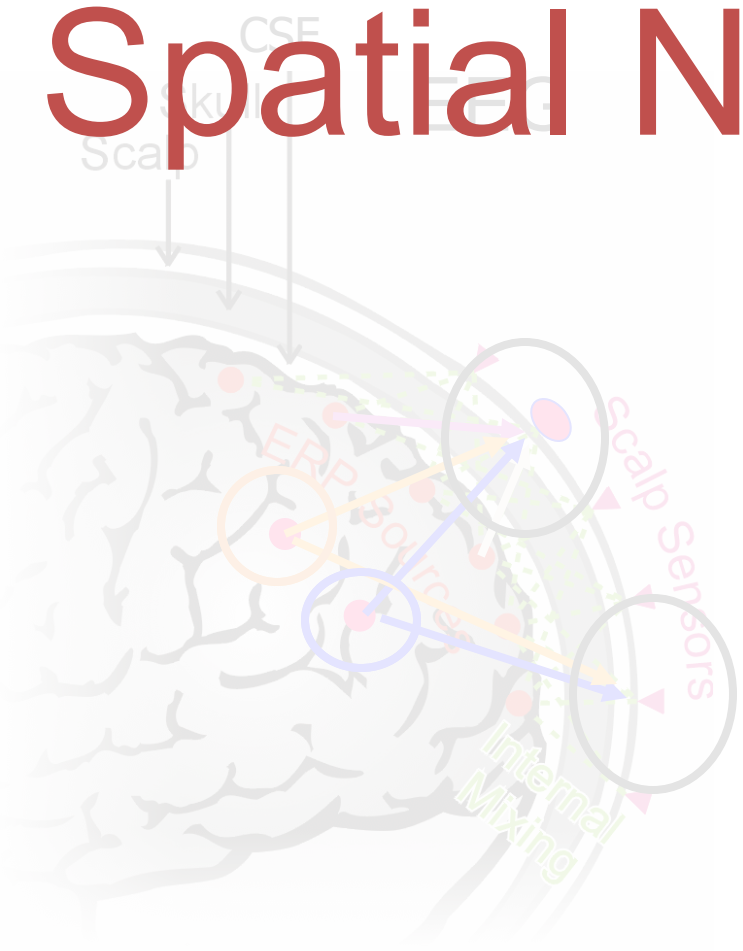


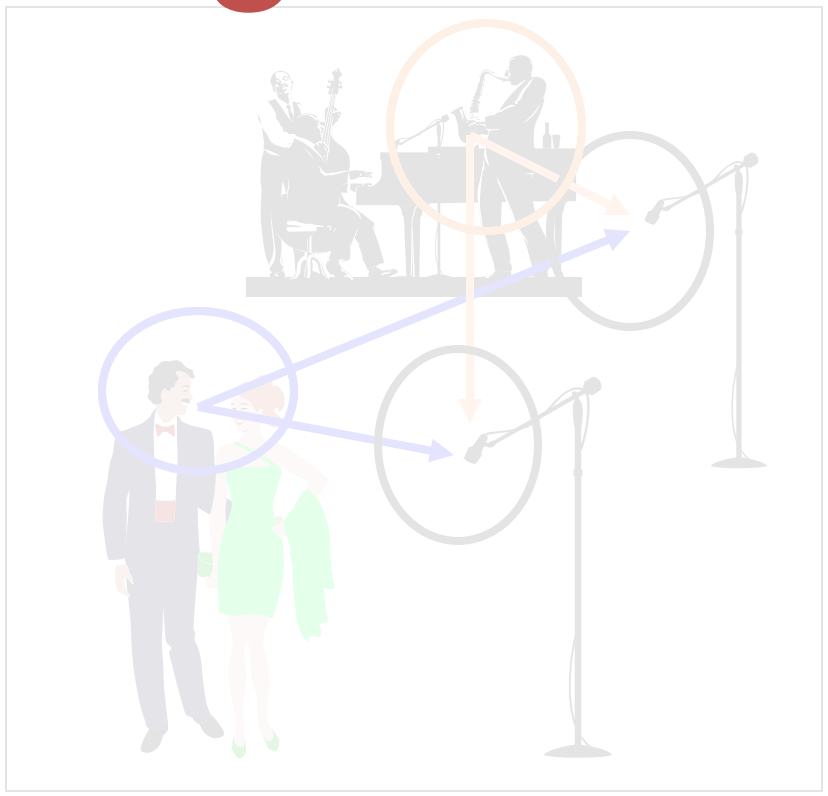


Scott Burwell, 2017

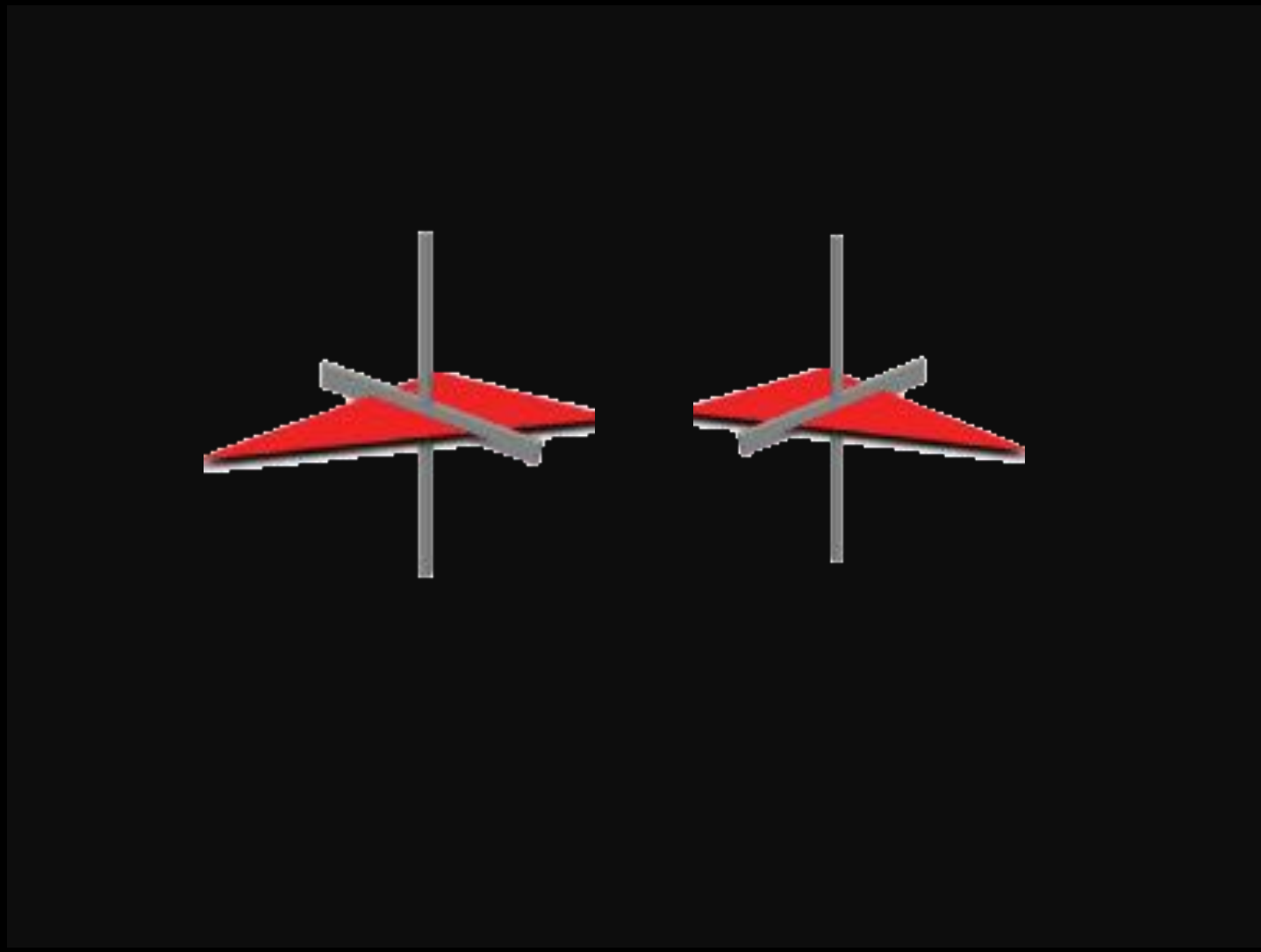
Blind EEG Source Separation by ICA

Spatial Navigation



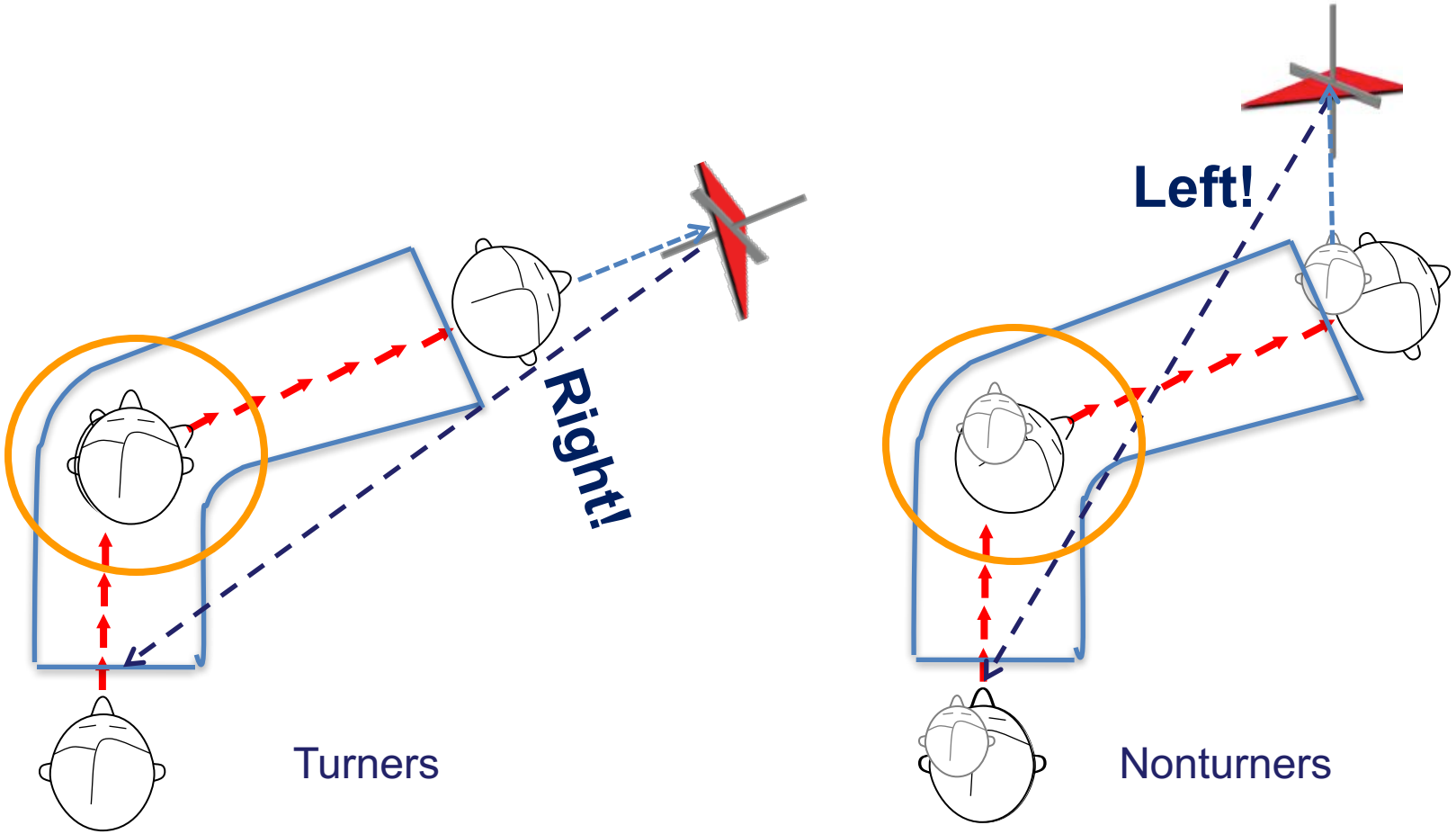


Tunnel Task – A Passive Spatial Navigation Paradigm



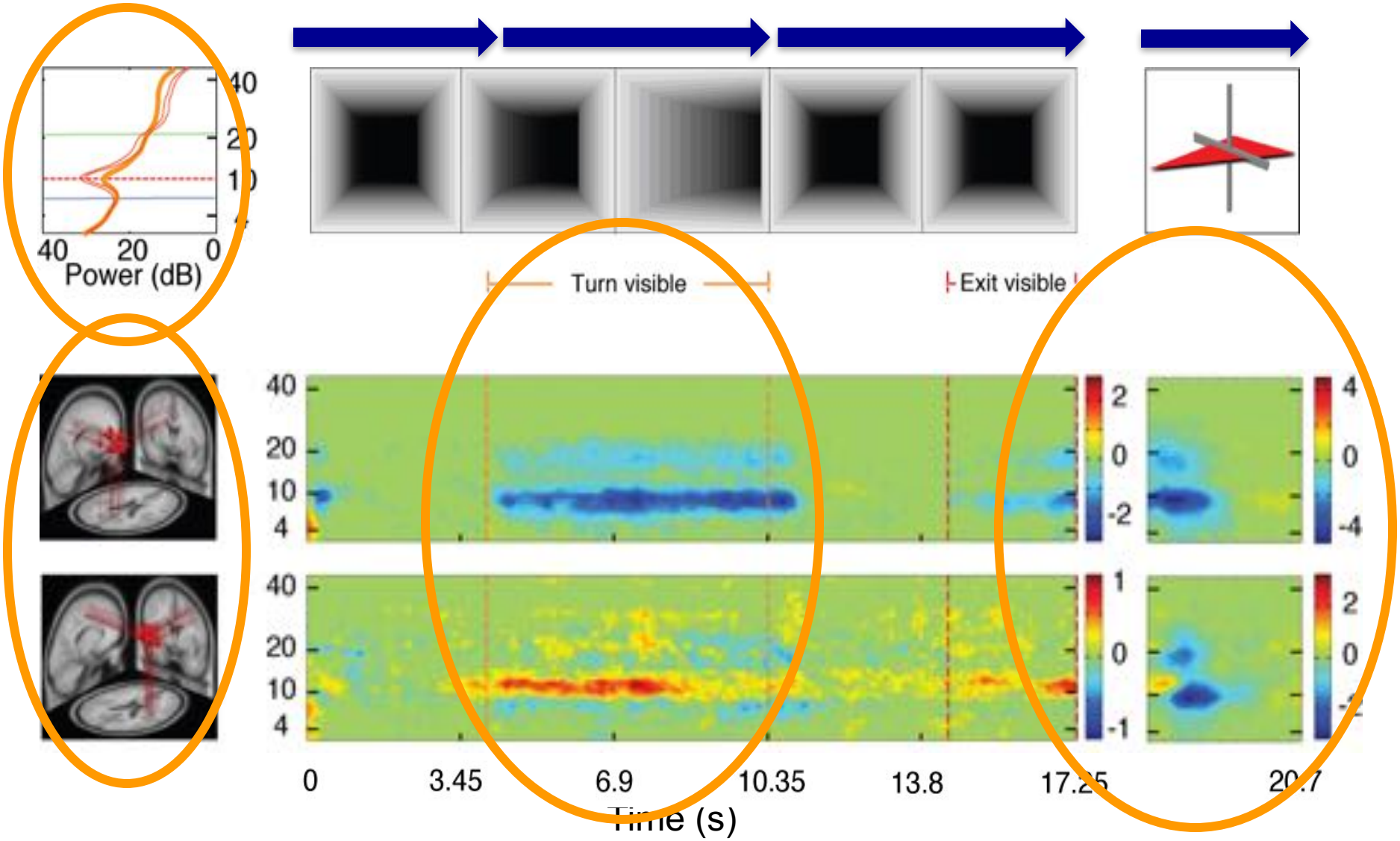
Klaus Gramann et al., 2010

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



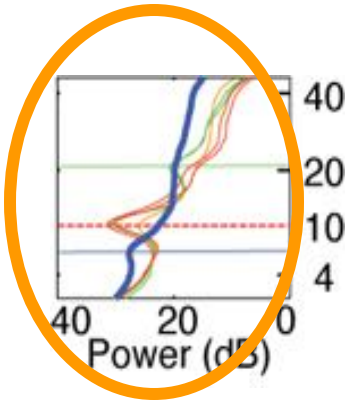
Klaus Gramann & S. Makeig, 2010

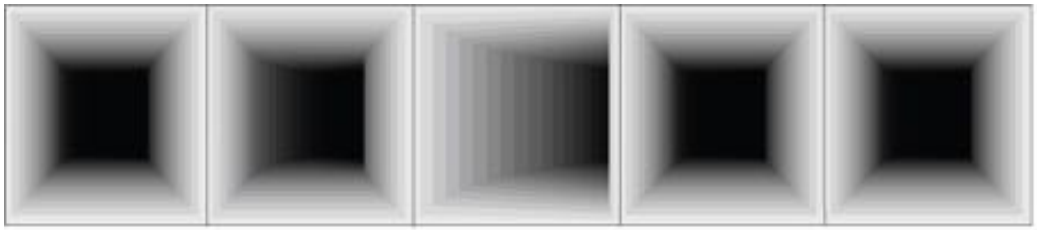
Two parietal component clusters



Klaus Gramann et al., 2010

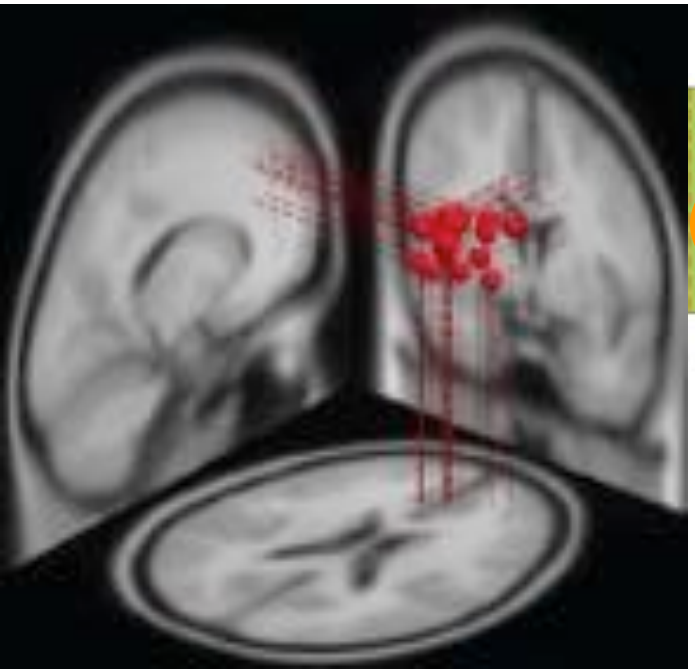
Medial prefrontal component cluster

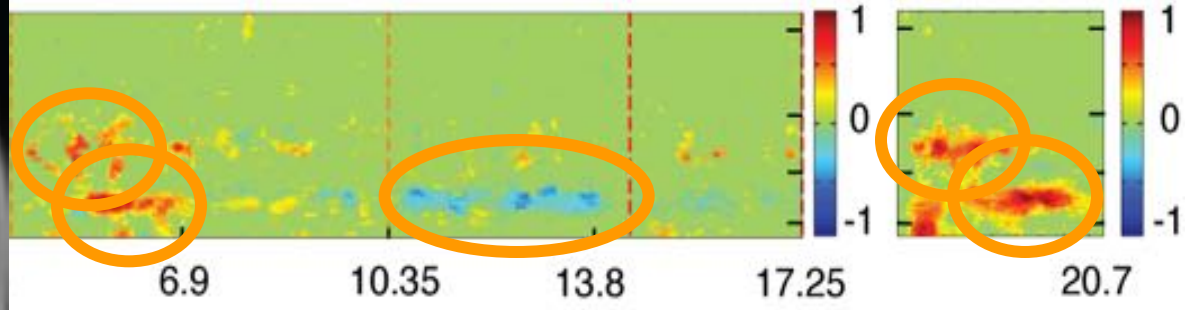




Turn visible

Exit visible

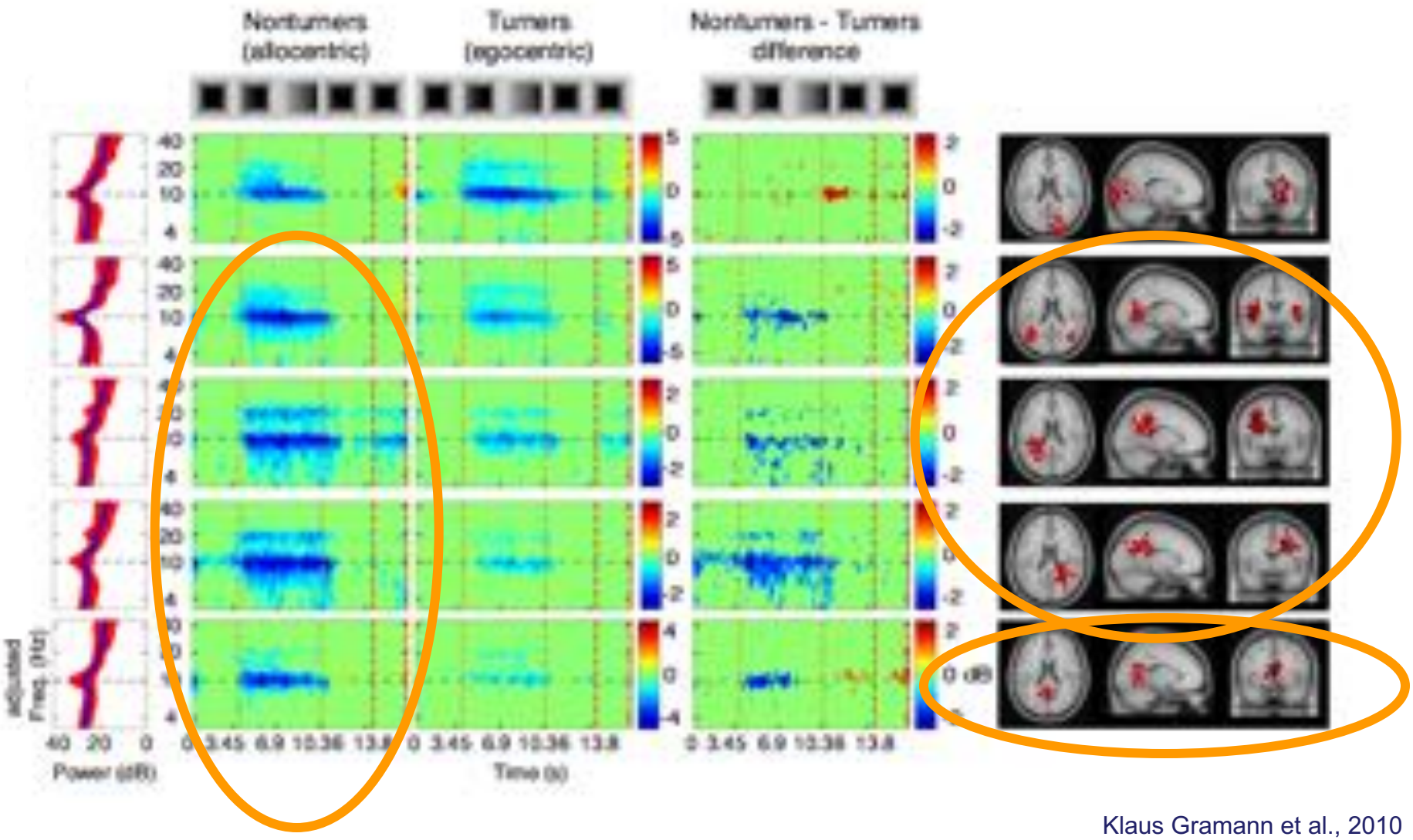




Time (s)

Klaus Gramann et al., 2010

Clusters distinguishing Turners & Nonturners



Klaus Gramann et al., 2010

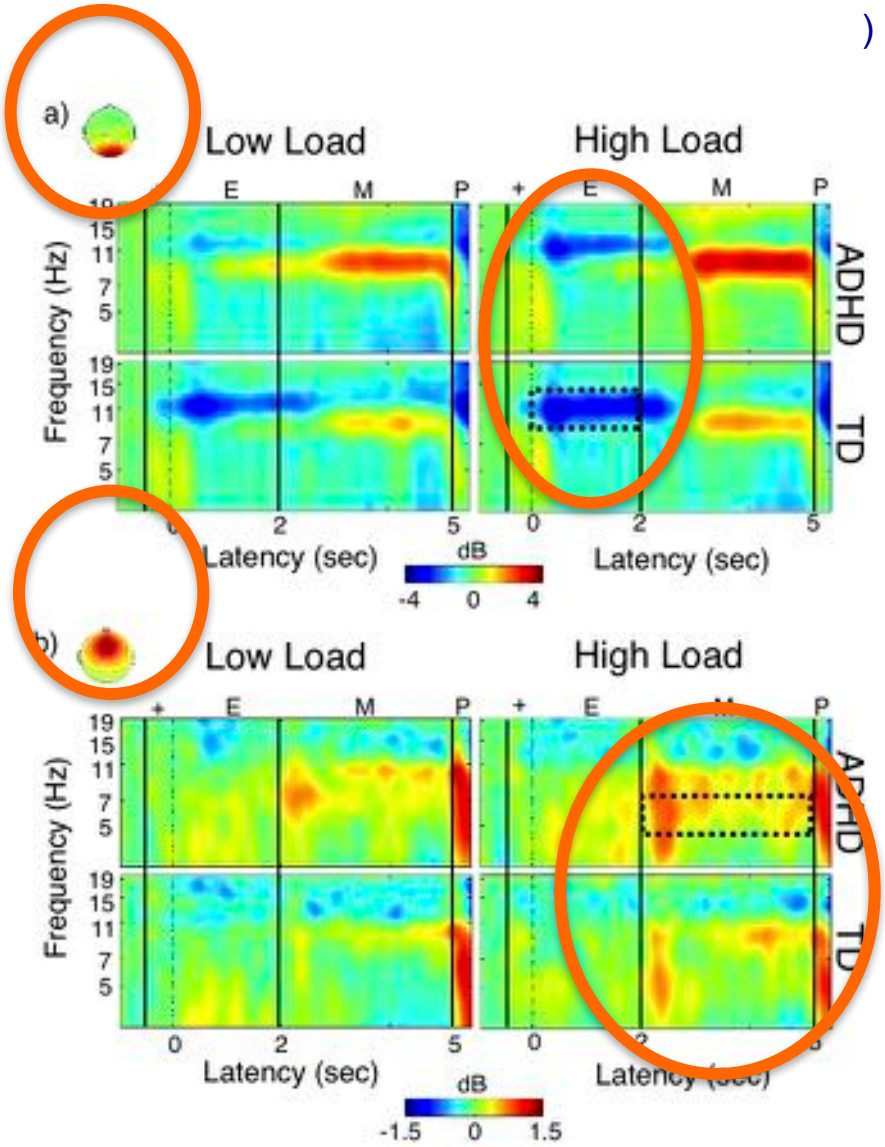
Blind EEG Source Separation by ICA

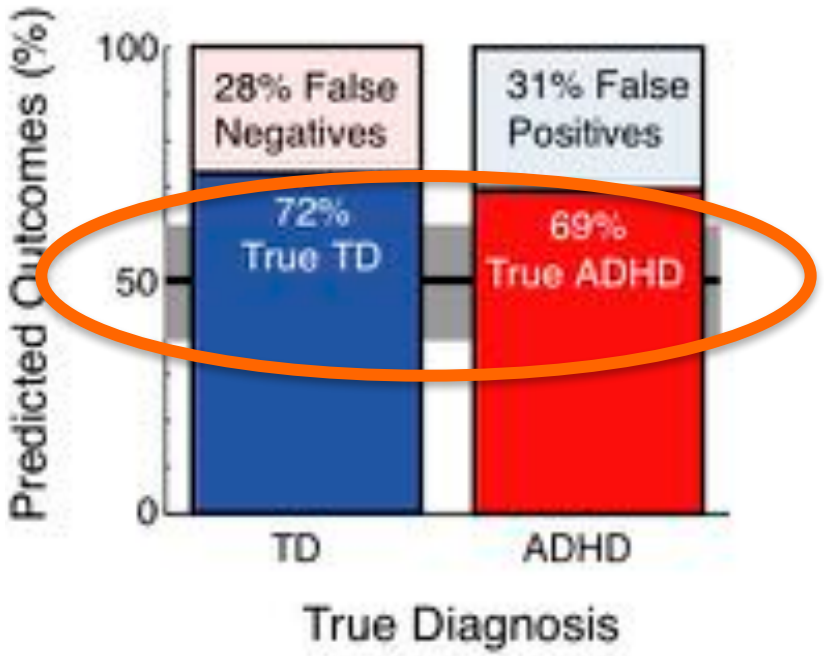
Clinical Research

Data Analysis

ADHD Working Memory

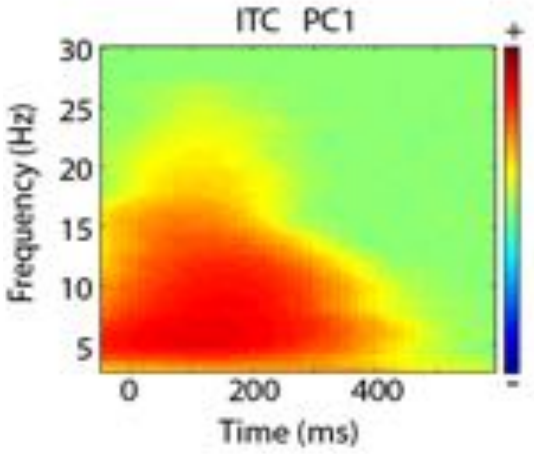
)

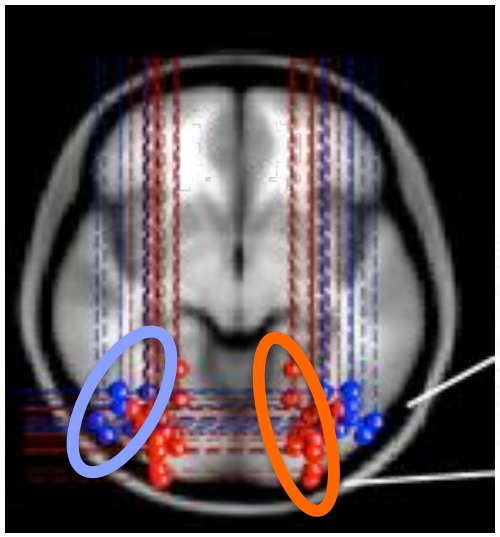


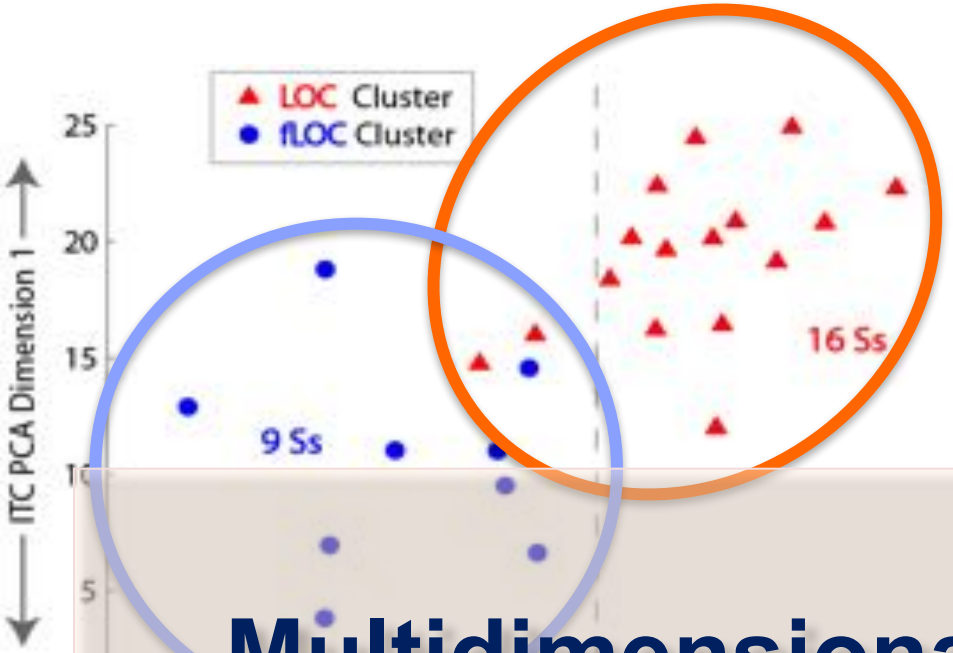


Lenartowizc et al., *J. Neurosci.,* 2014

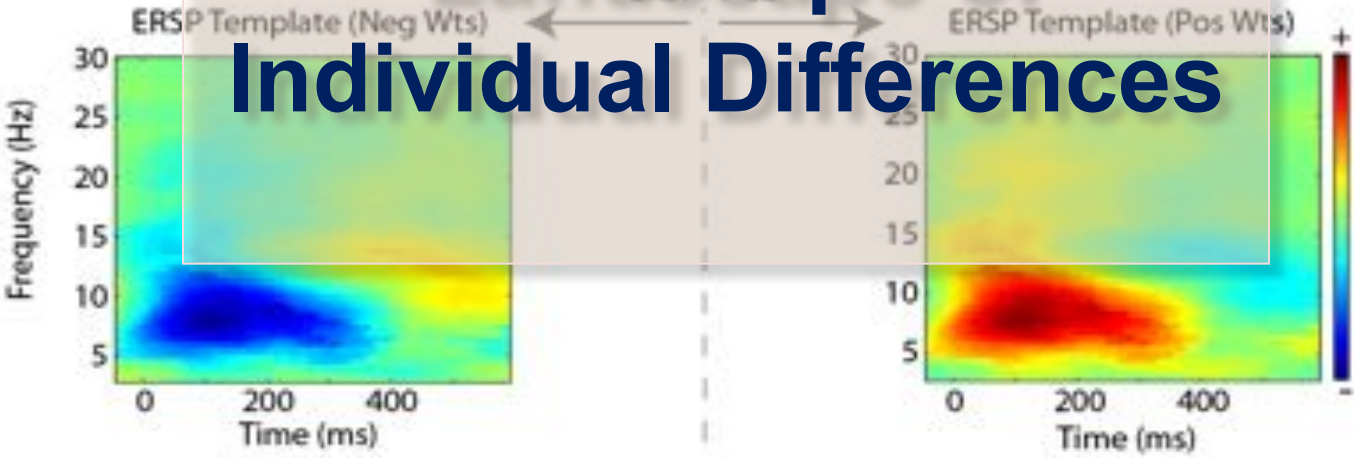
Can ICA reveal subject differences?







Multidimensional Landscape of Individual Differences



Blind EEG Source Separation by ICA

High-Resolution EEG Source Imaging

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):

△8%

△5%

△12%

△8%

	BD	FR	AV	RB	LH	GV	AS	JH	SE
STRUM	28 (10)	**43** (14)	30 (13)	68 (15)		31 (11)	63 (12)	**48** (15)	**31.5** (15)
Darts		**45** (14)			20 (16)				
Arrow Flanker								**54** (13)	**34** (13)

3:1

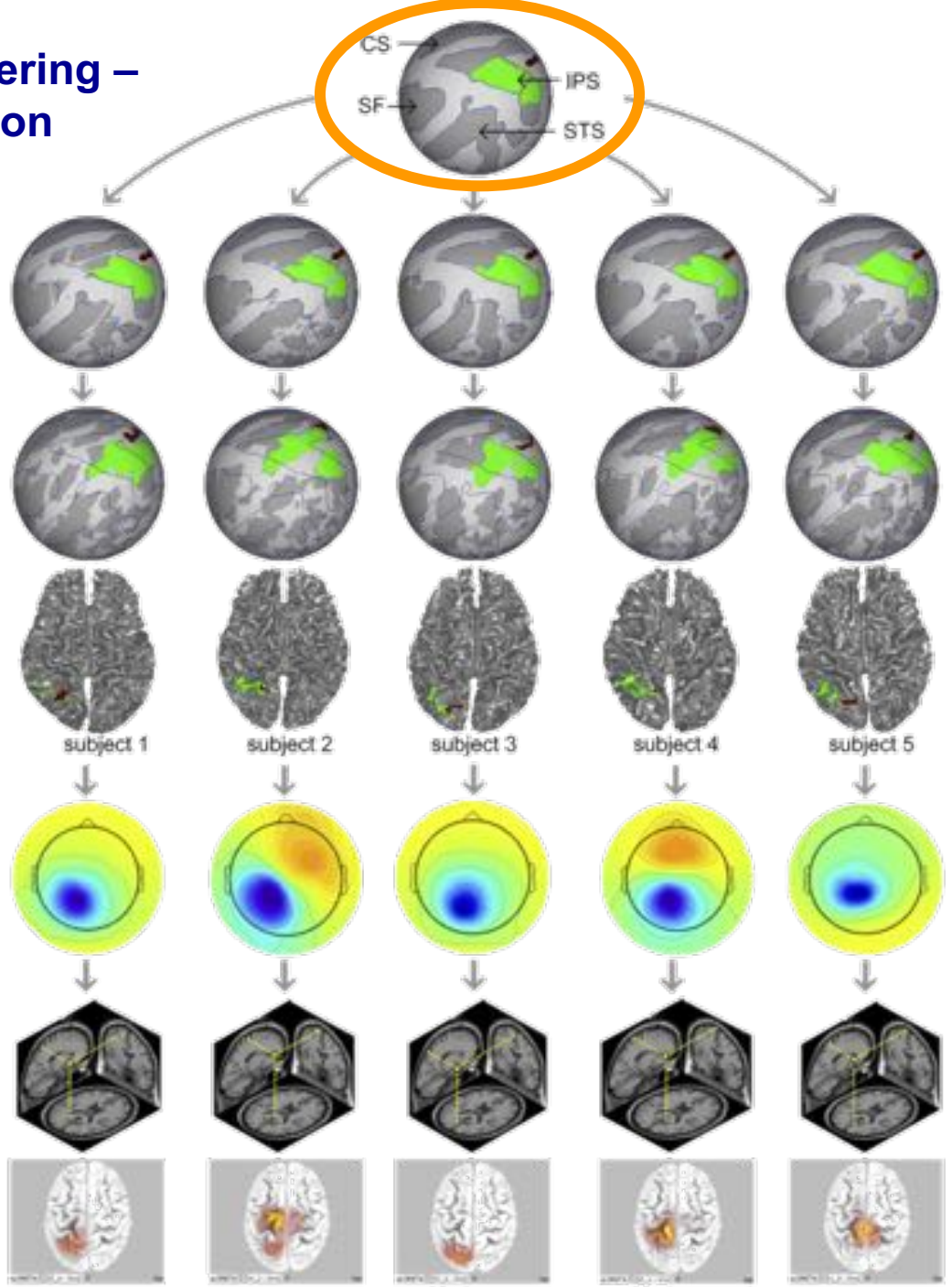
△16%

△33%

△56%

△34%

Topological source clustering – 2-D measure projection



Arthur Tsai et al., *NeuroImage*, 2014

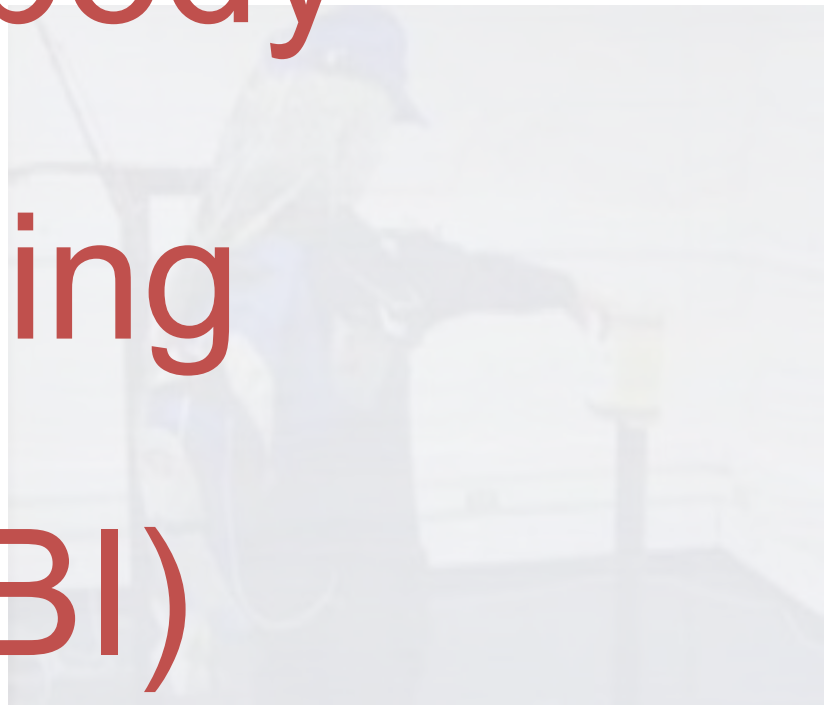
Brain imaging during movement – How?

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

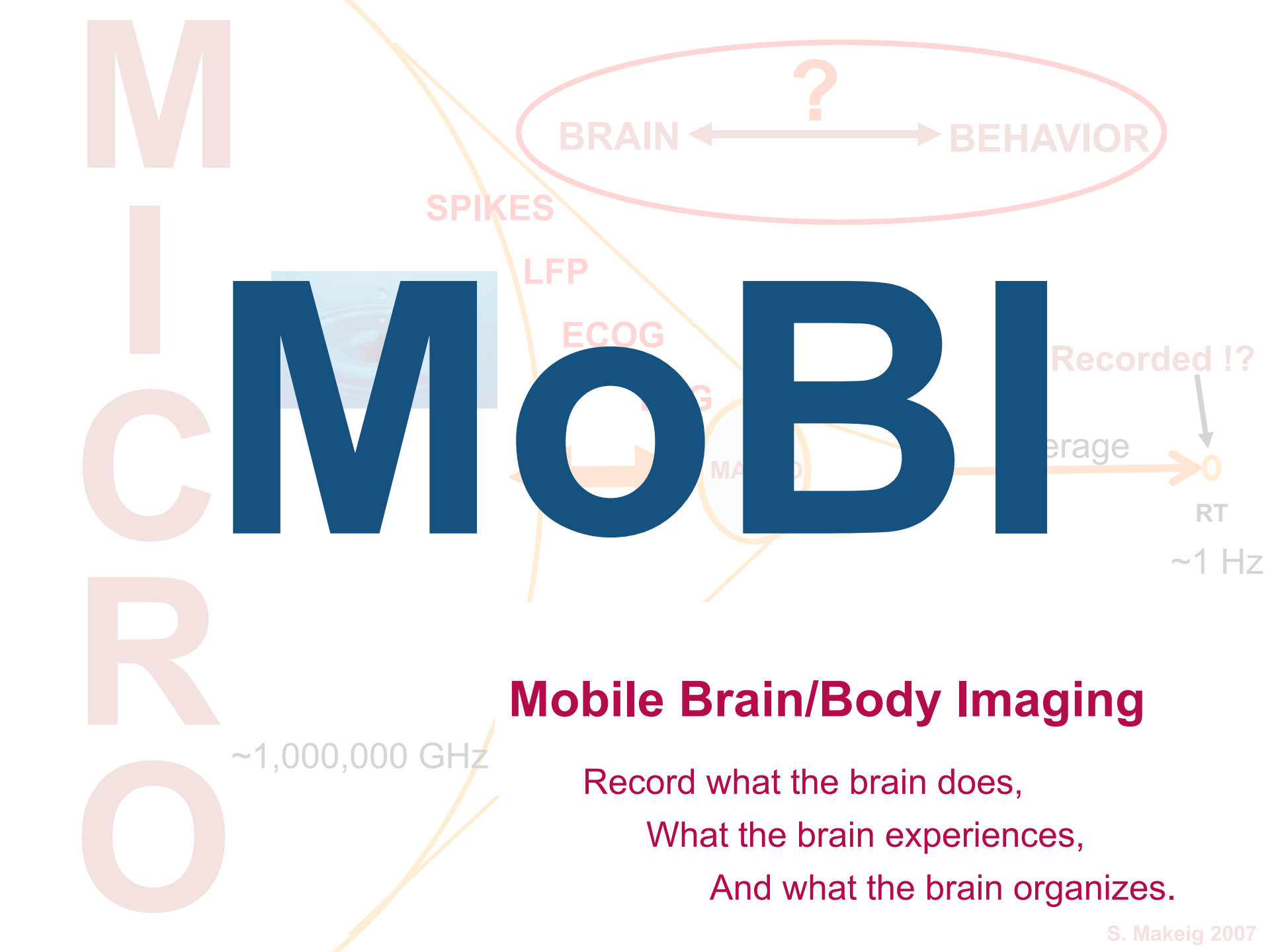
→ **Mobile Brain/Body Imaging** (MoBI)

Concept:

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



Mobile Brain/body Imaging (MoBI)



MoBI

Mobile Brain/Body Imaging

Record what the brain does,

What the brain experiences,

And what the brain organizes.

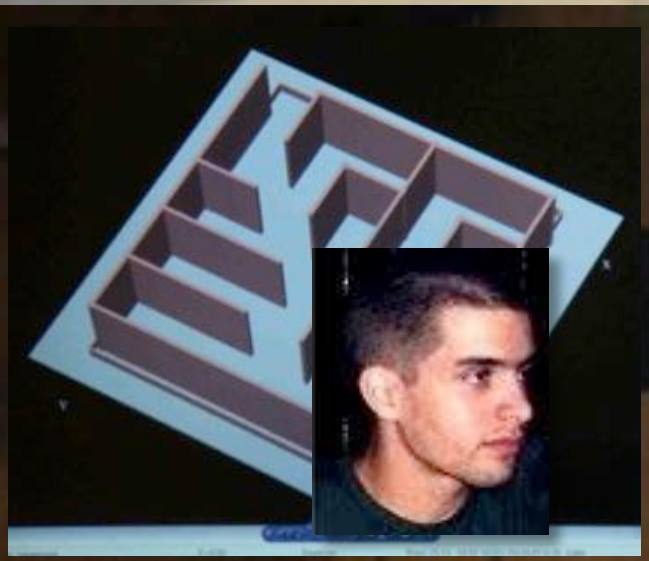
S. Makeig 2007

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.



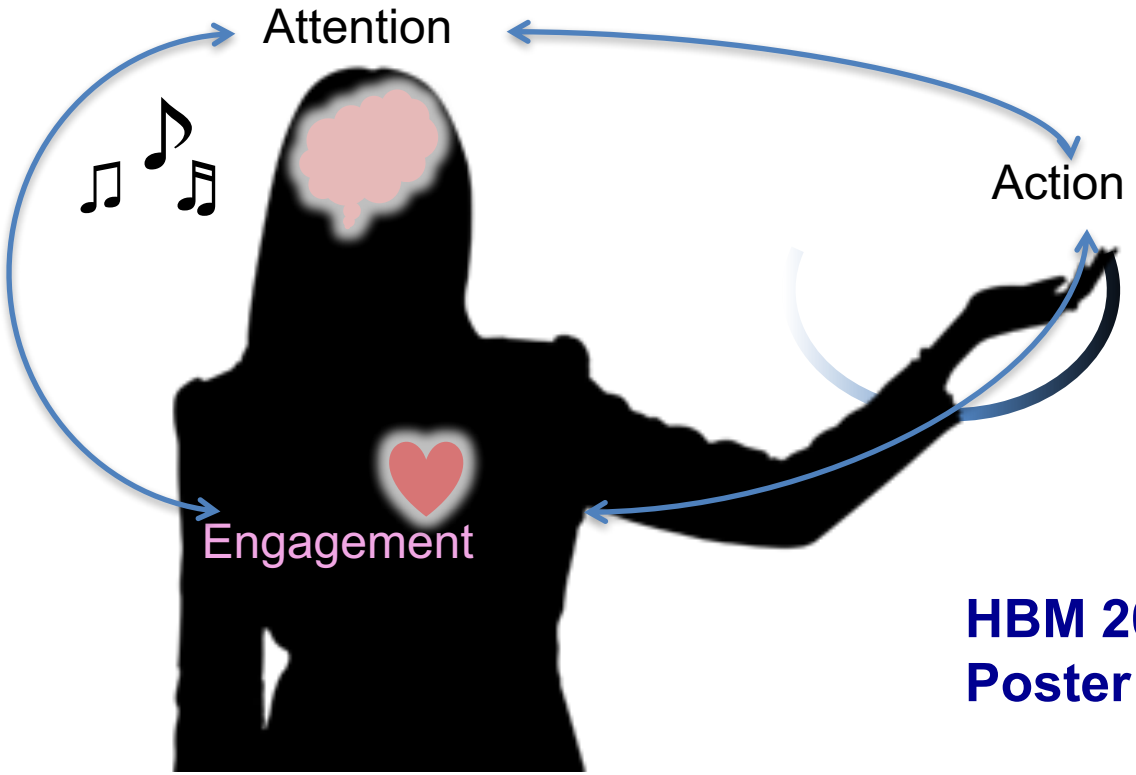
SNAP – a python-based framework running on Unity for control of simple or complex MoBI experiments.

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

S Makeig & M Miyakoshi, 20112

Measuring Musical Engagement Through Expressive Rhythm

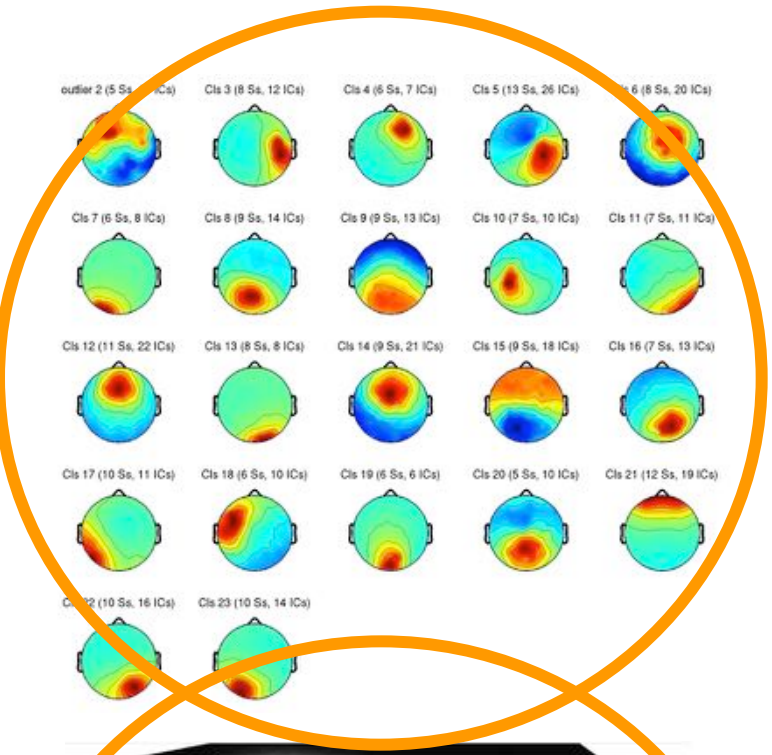
How can we measure listeners' engagement?

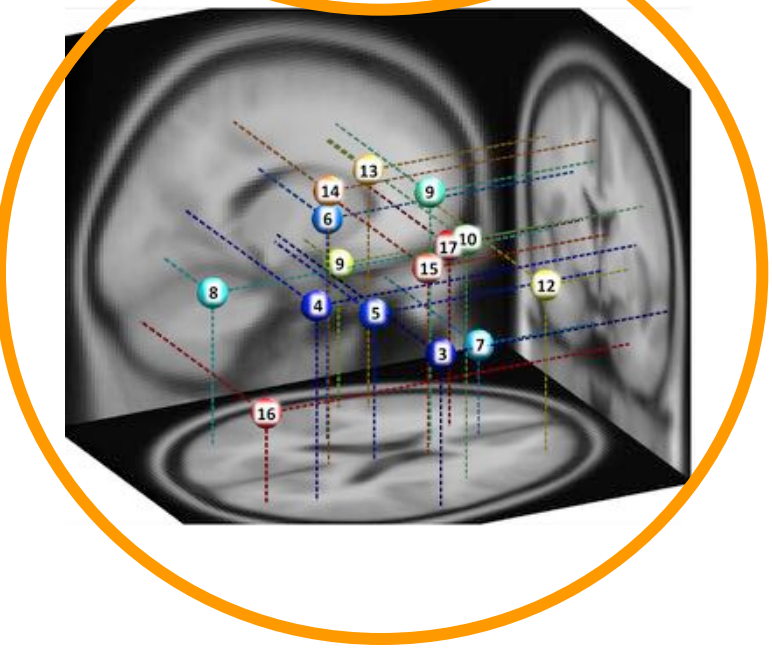


HBM 2014
Poster #1538 online

G Leslie & S Makeig,

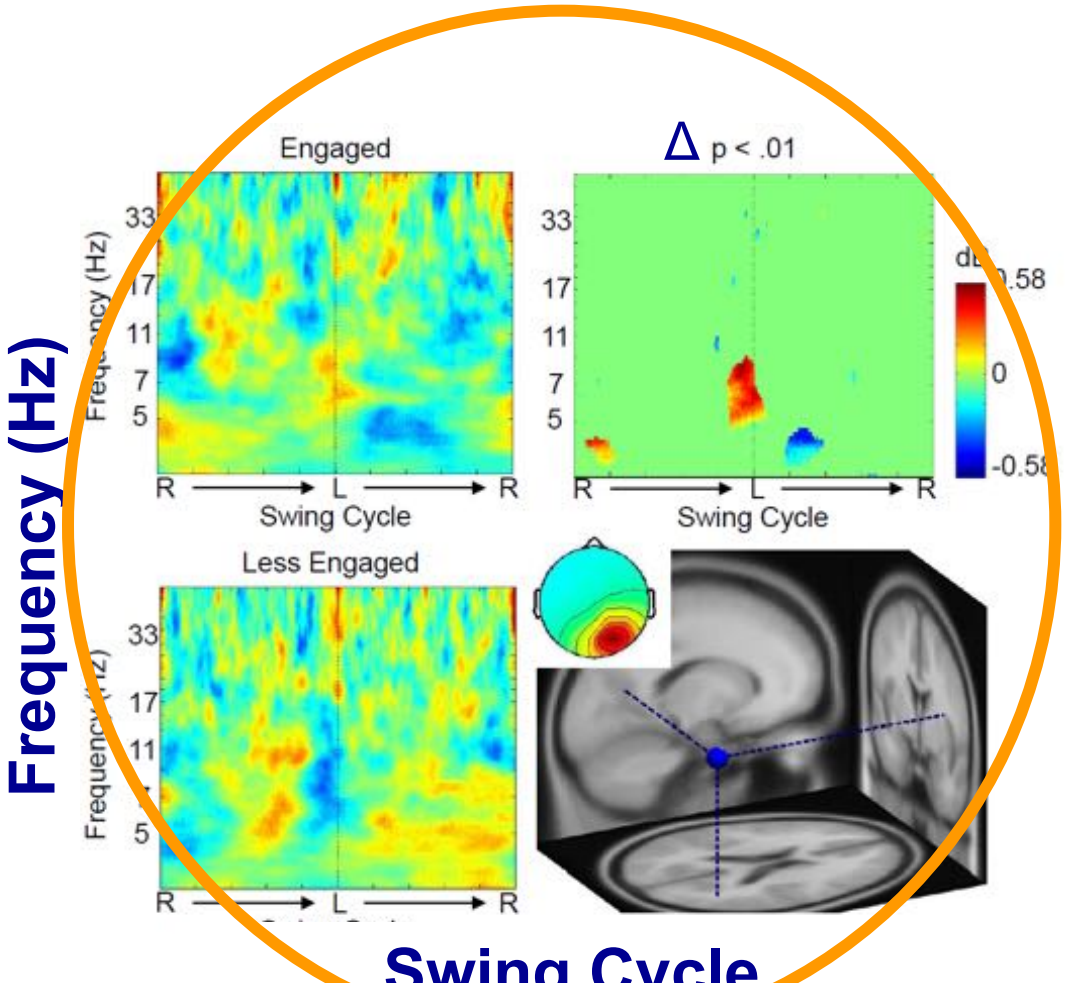
EEG Result





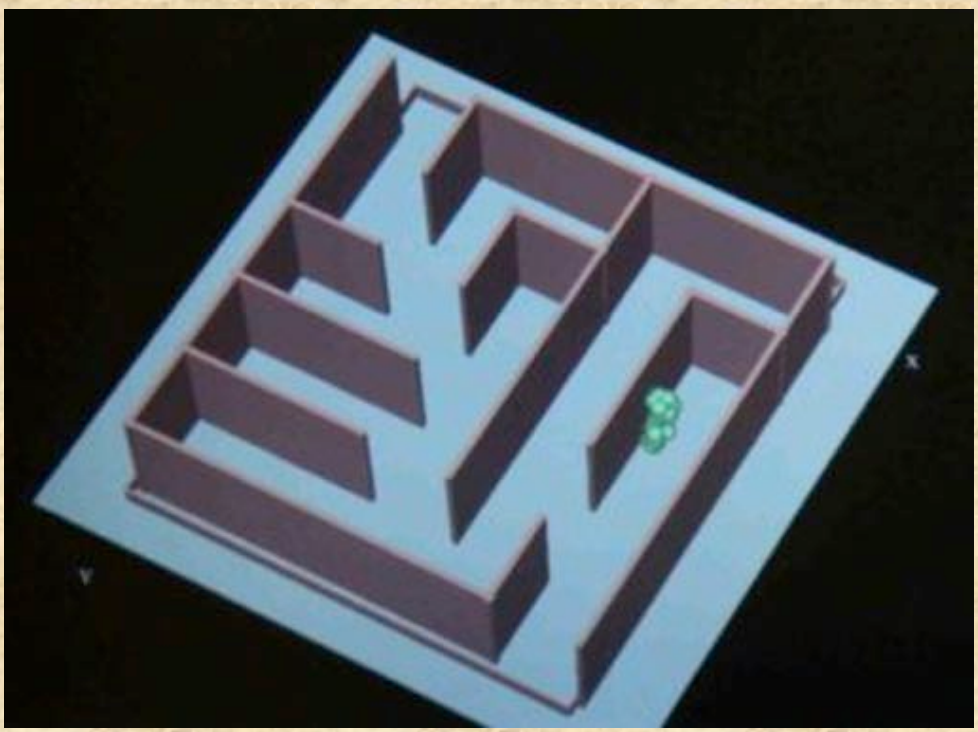
Right TPJ

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

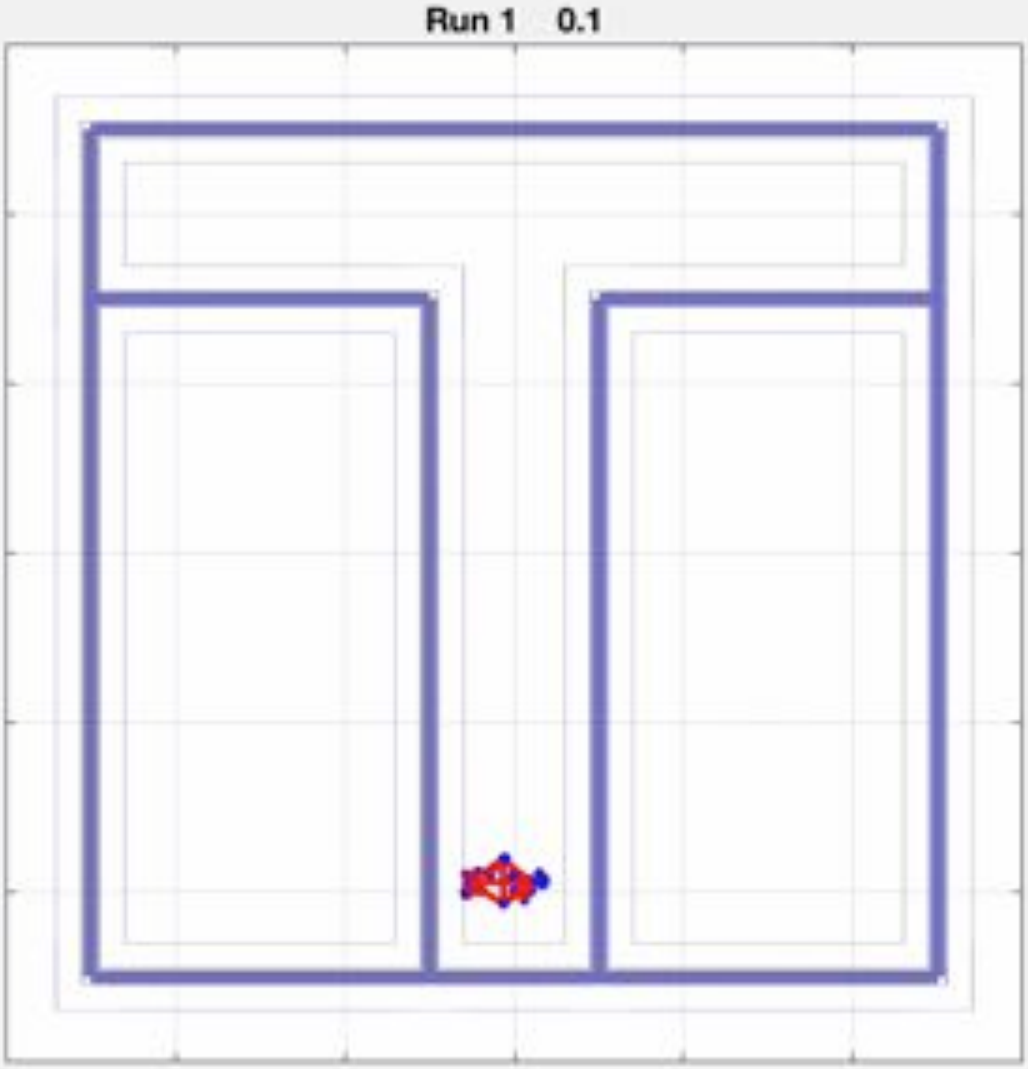


Spatial Navigation Experiment – the *Audiomaze*

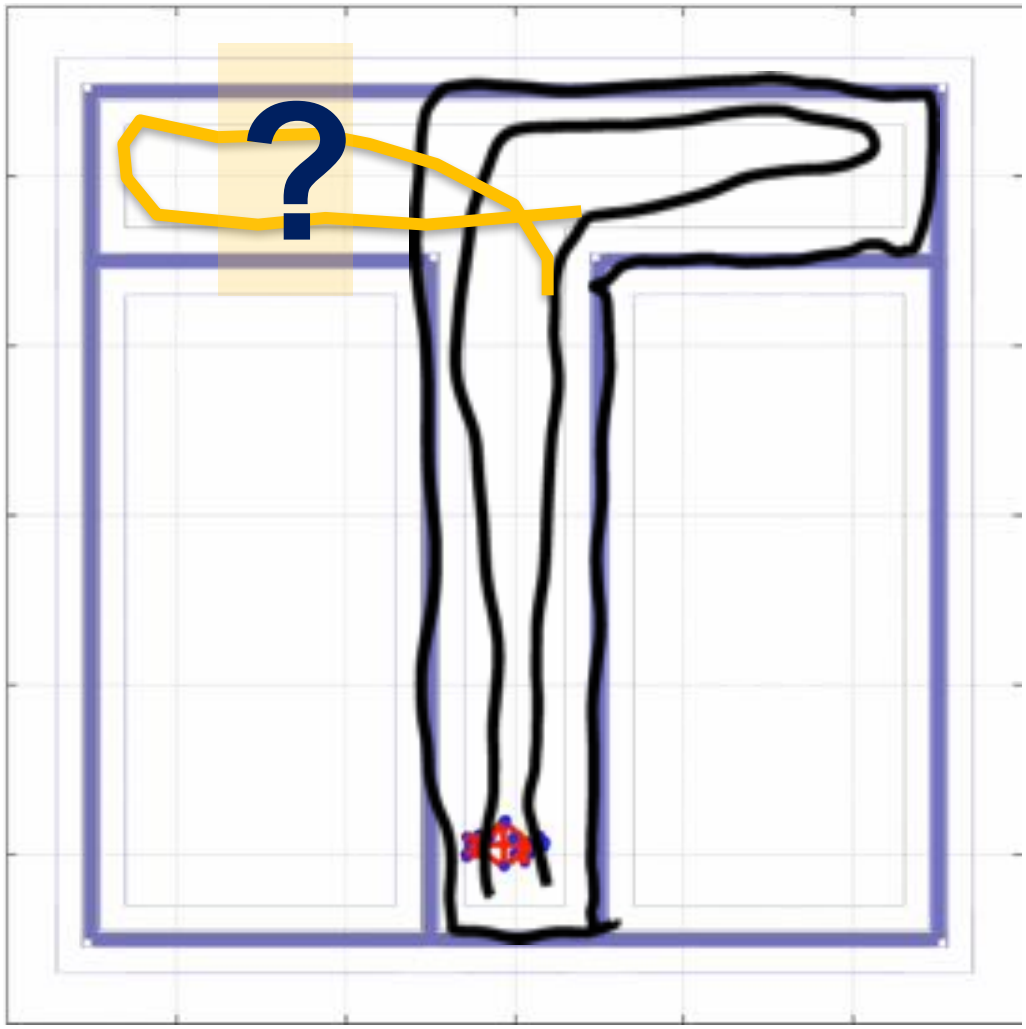
- Navigate an ‘invisible’ maze in the dark.
- Receive directional audio feedback, not tactile feedback.
- Task: Explore the maze and learn its configuration.
- Test: Draw the maze.



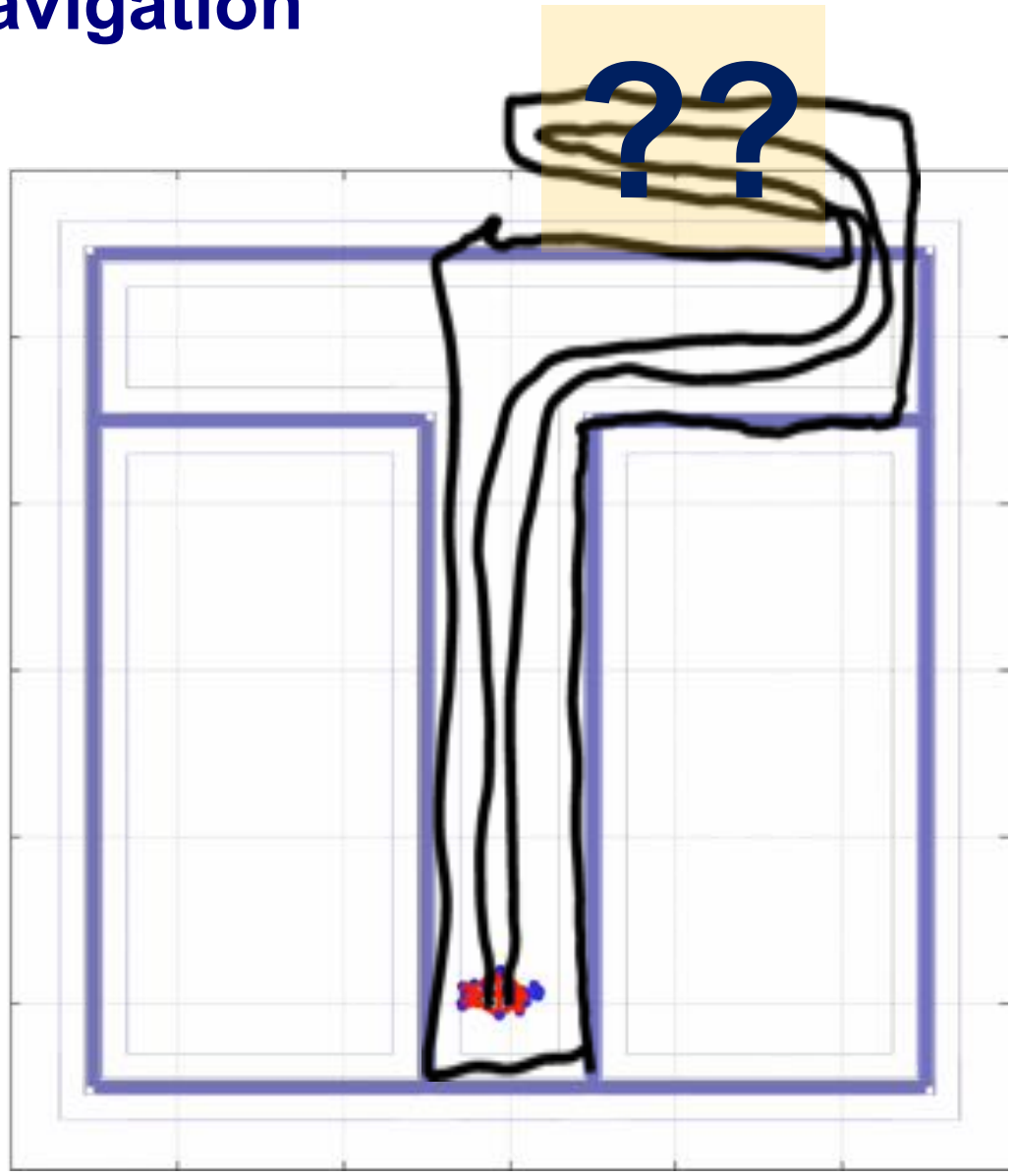
S. Makeig, 2016

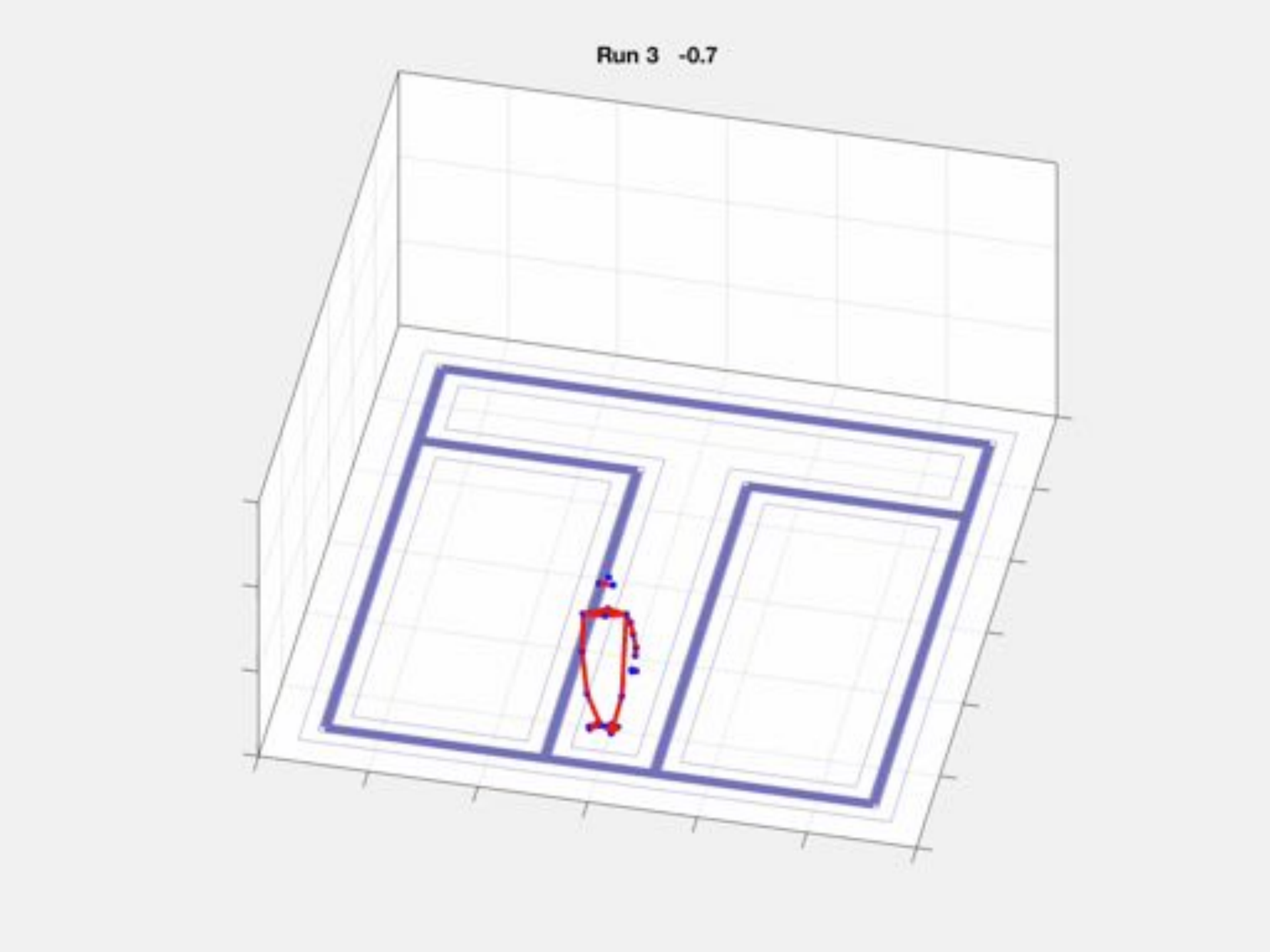

Run 1 0.1

1st Pass Navigation

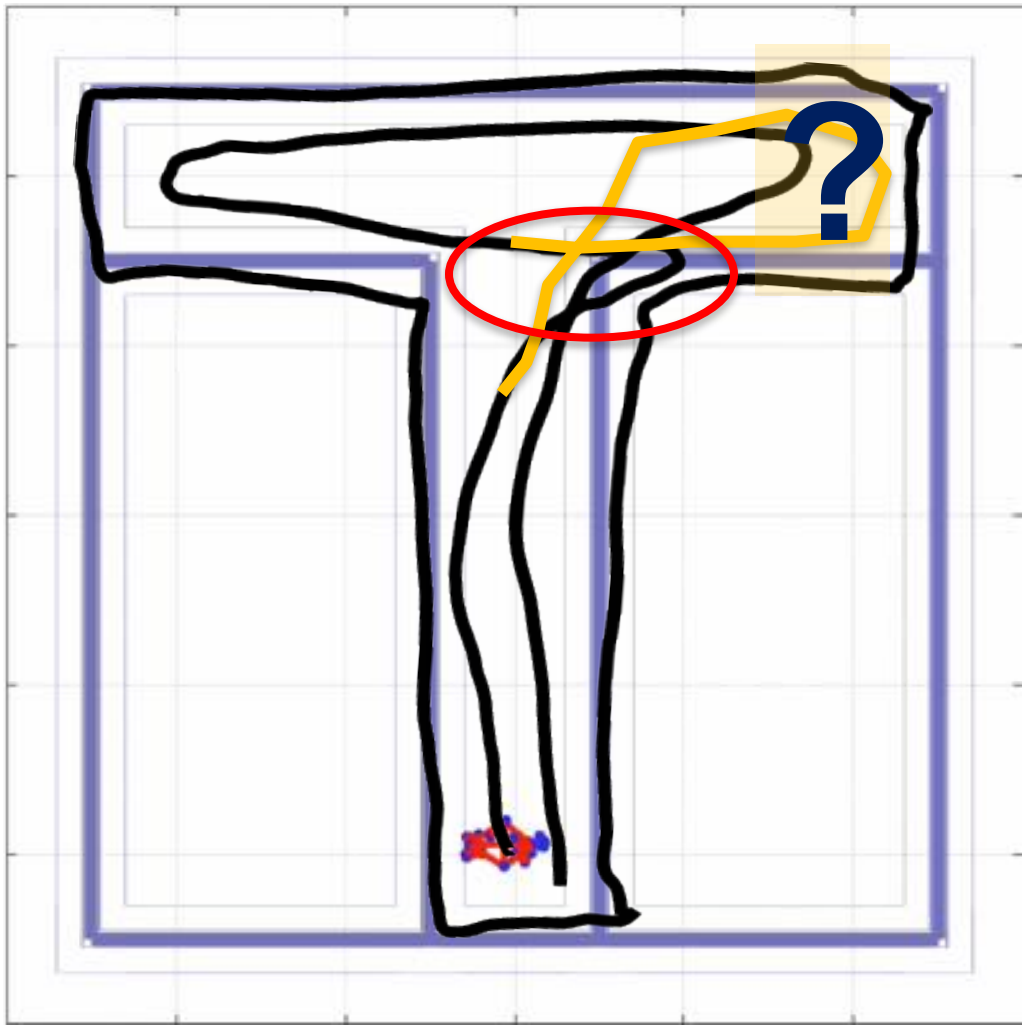


2nd Pass Navigation

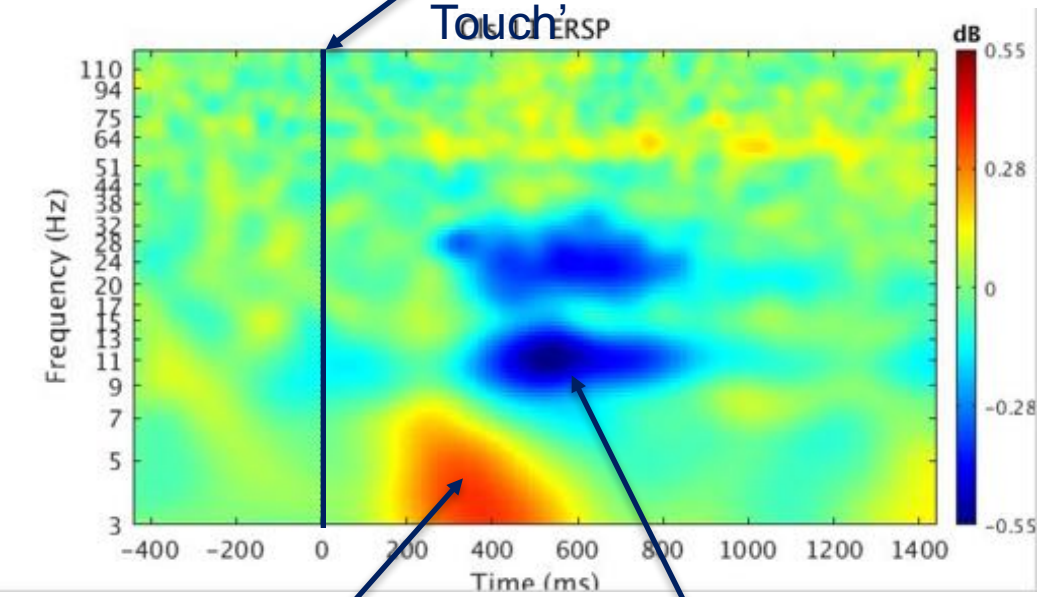



Run 3 -0.7

3rd Pass Navigation

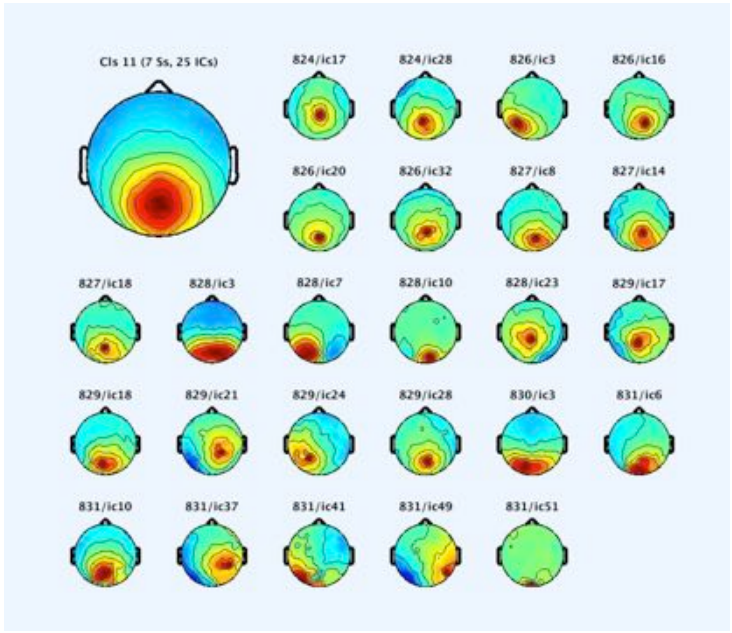


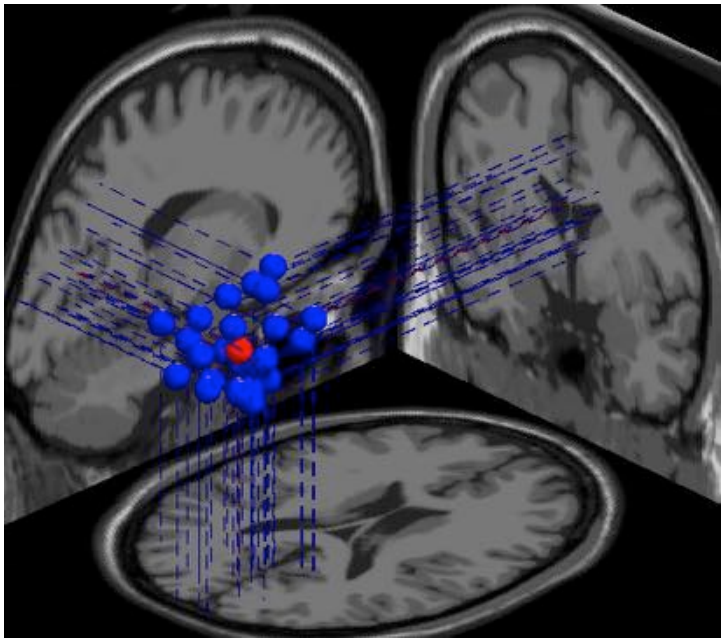
Central Posterior Independent Component Effective Source Cluster

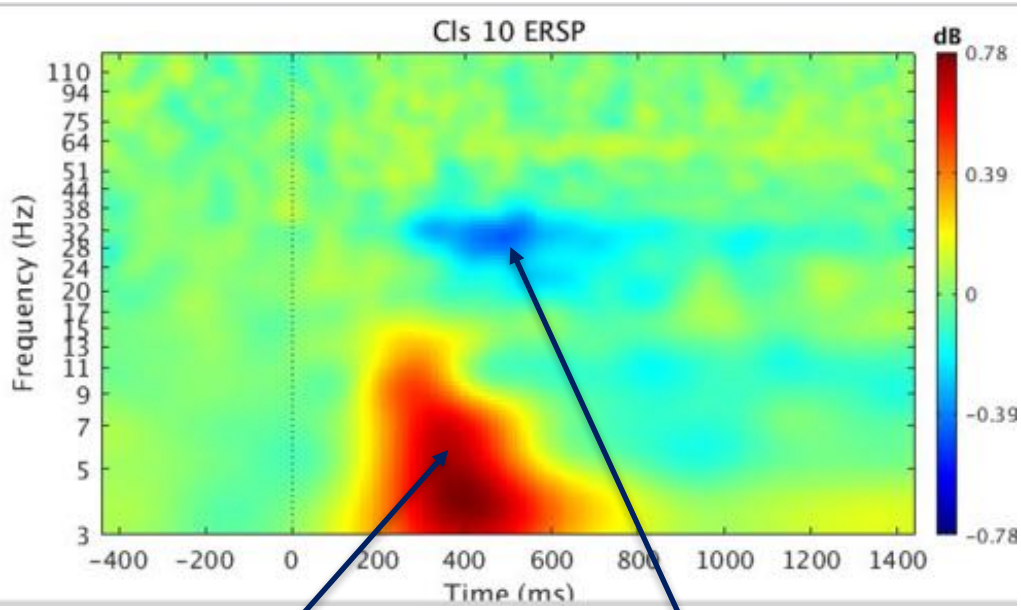


Low-frequency increase

Alpha suppression

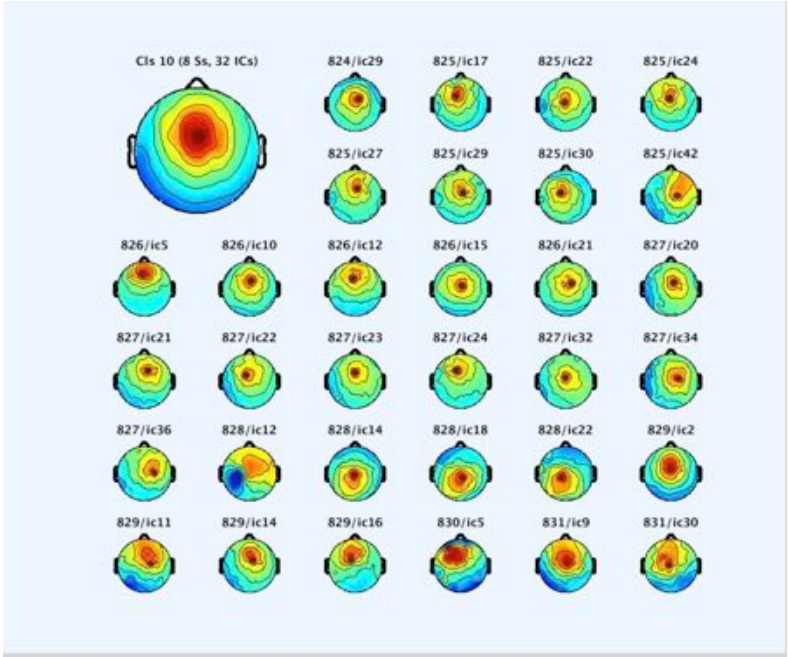


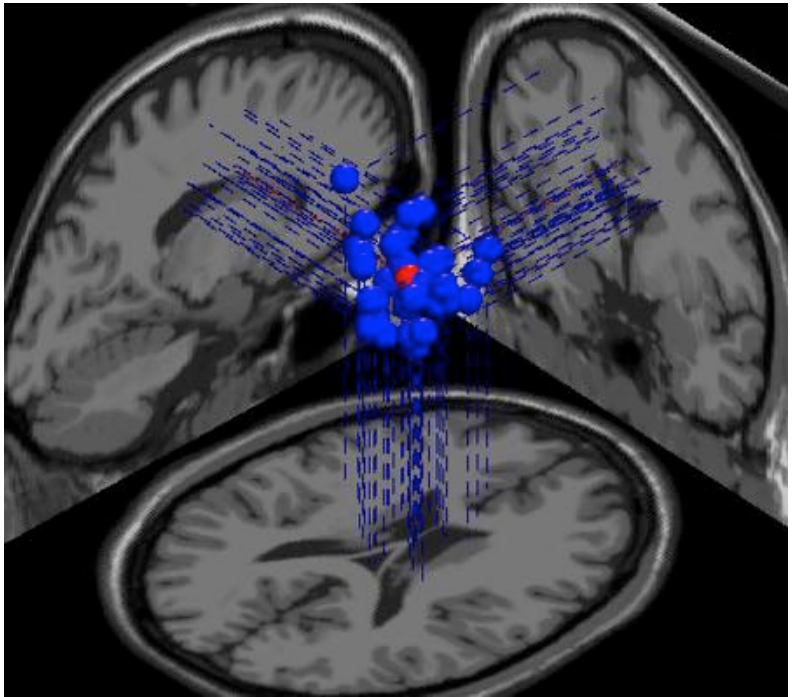




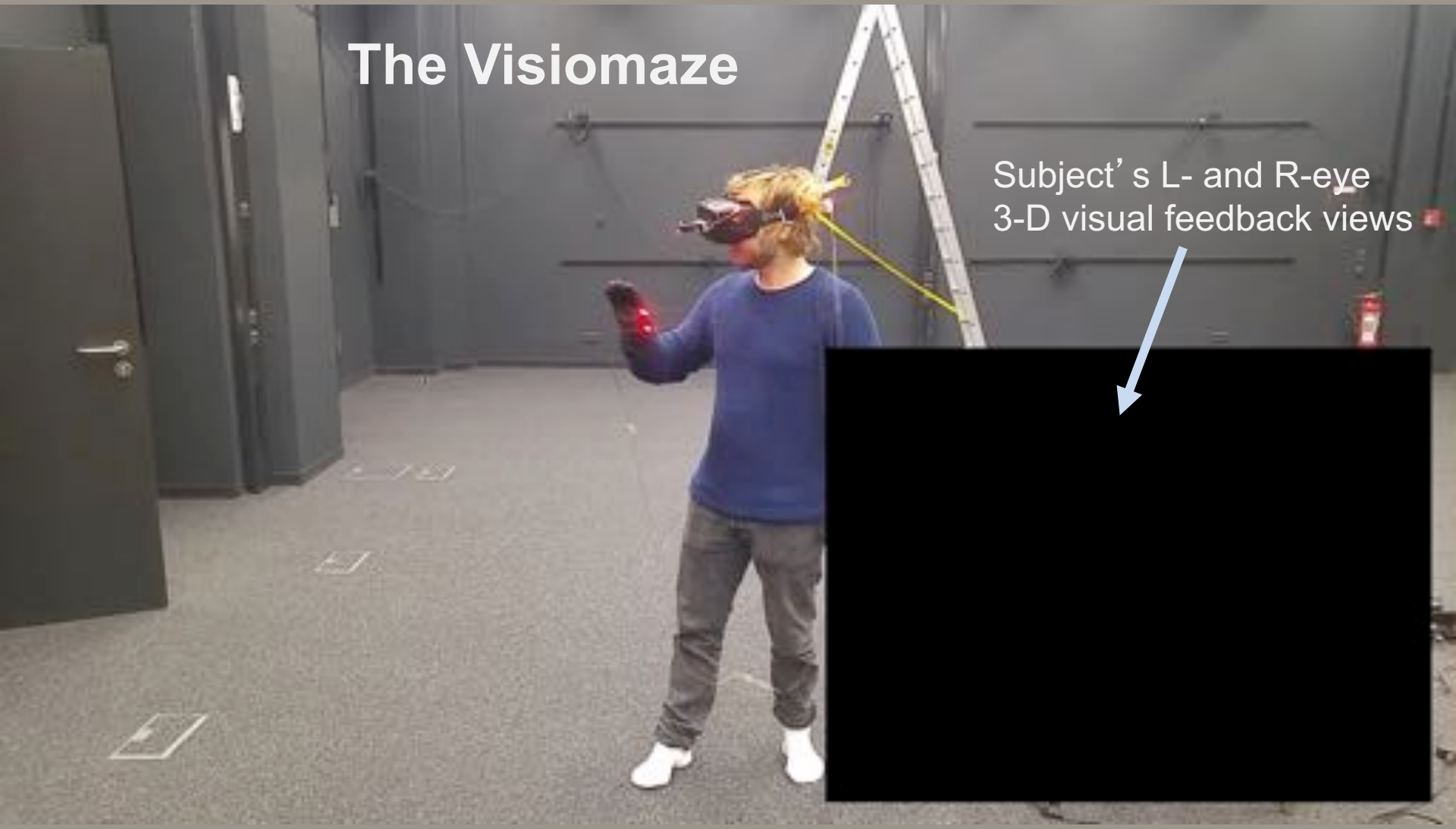
Alpha/theta increase

High beta suppression





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



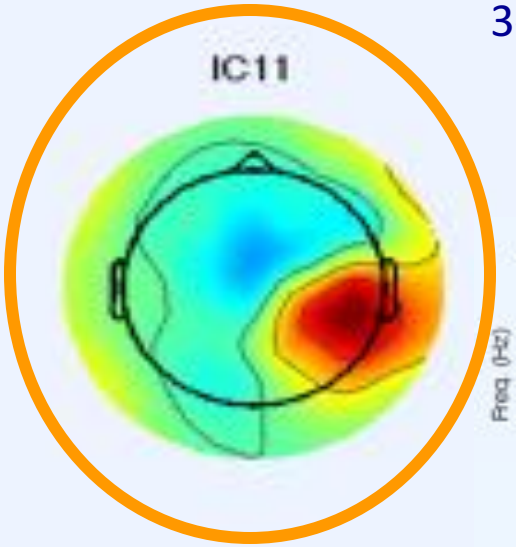
*Brain imaging **natural cognition** -- actions & **interactions***

Imaging Human Agency and Social Interactions

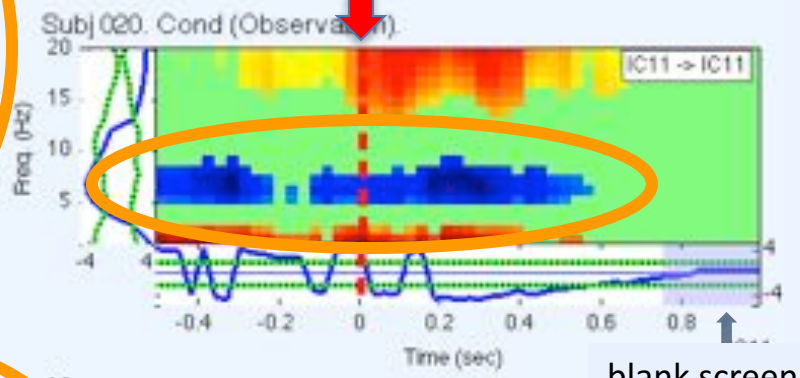
S . Makeig, 2007

Gedeon Deak et al., 2011

3-yr old child – Reward Observation

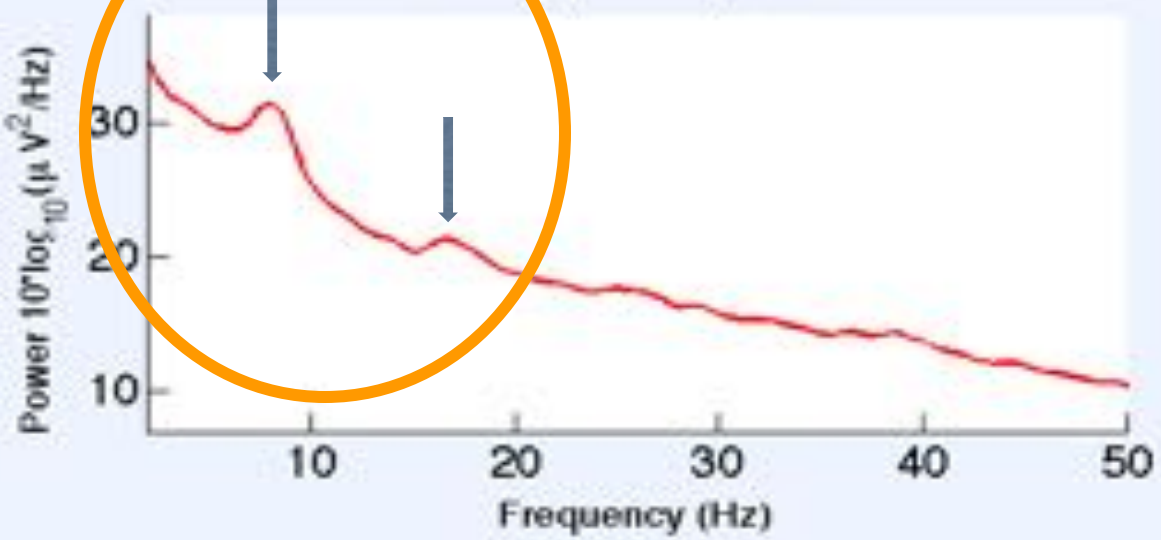


Mother Pops the Bubble!



blank screen (baseline)

mu



Yu Liao, T Mullen ,S Makeig, G. Deak 2011

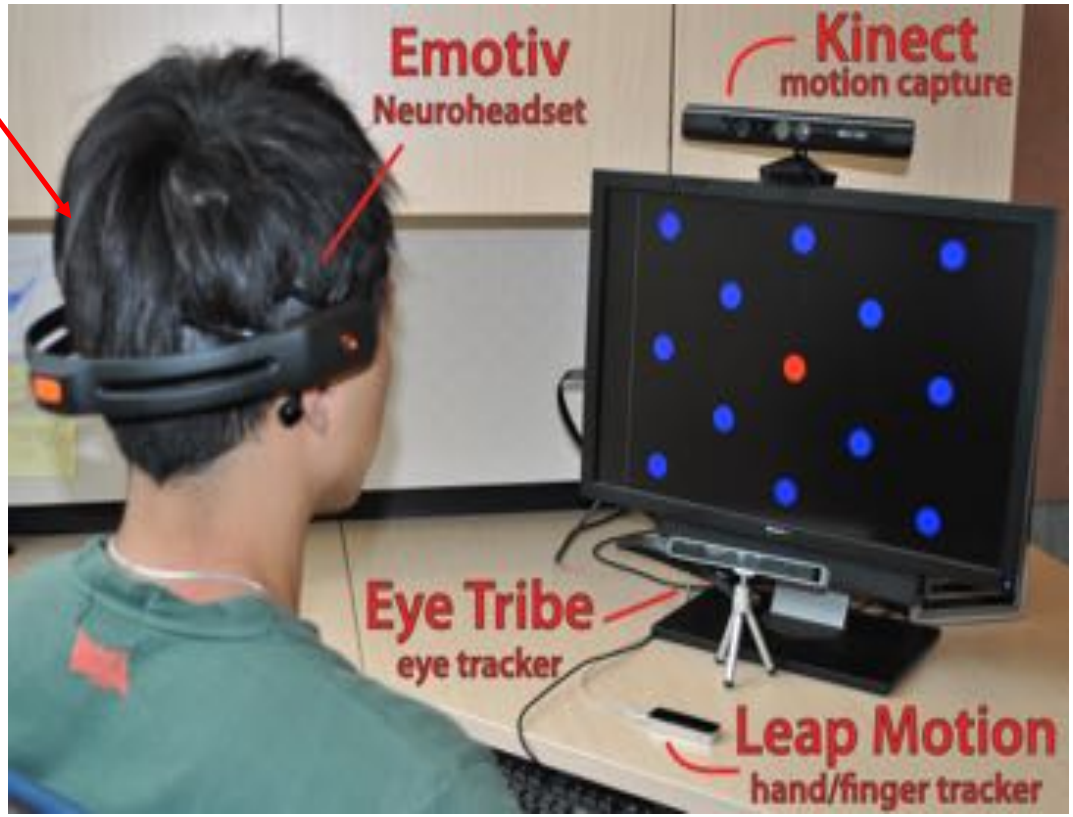
Now feasible – Low-cost MoBI Systems

Low-Cost MoBI

Any EEG System

< $500

< $500



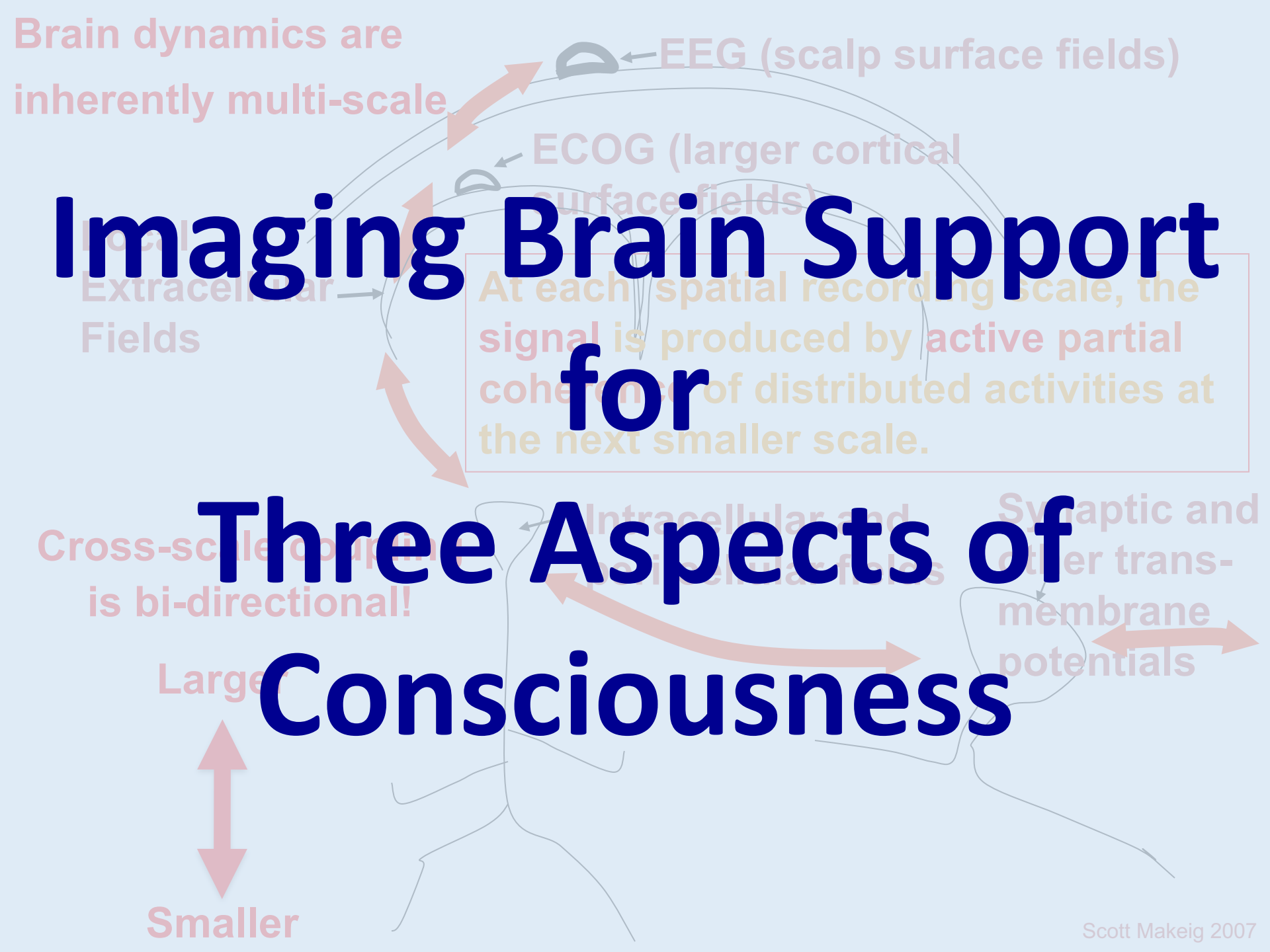
< $500 Touchscreen

< $1000 Full Body Wireless Inertial Motion Capture

< $100

< $100

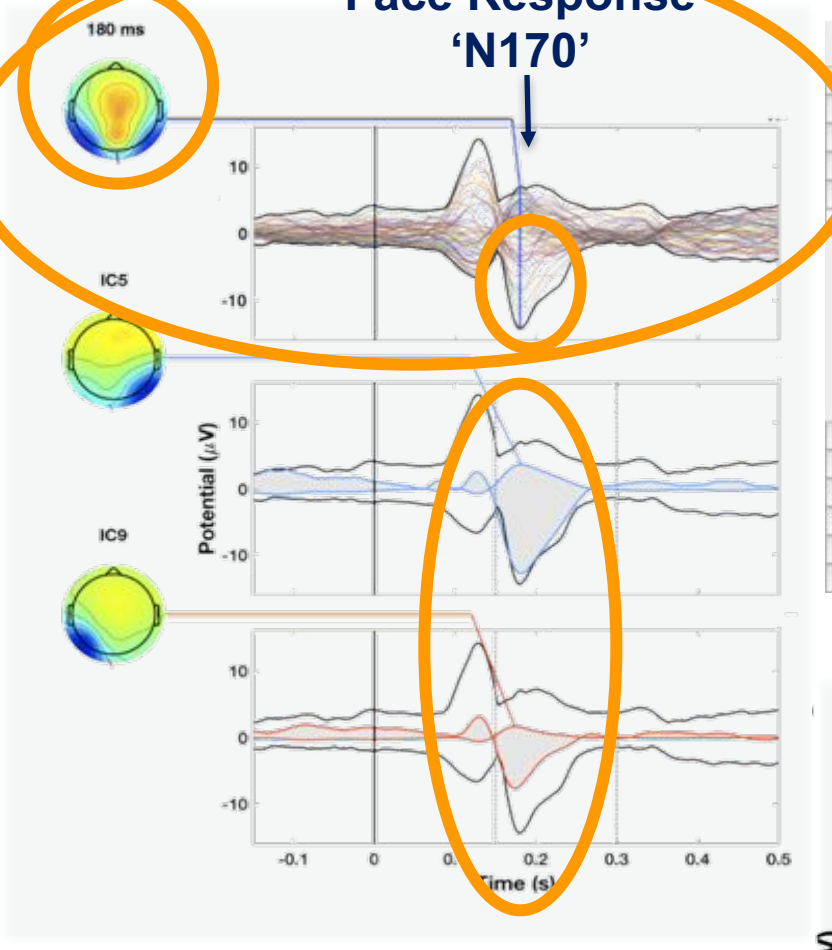
LSL software drivers exist for all these (and more) devices

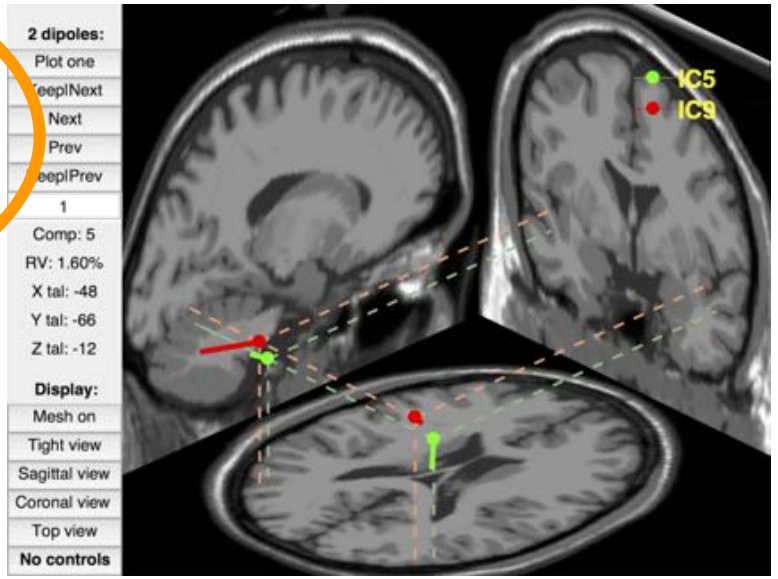


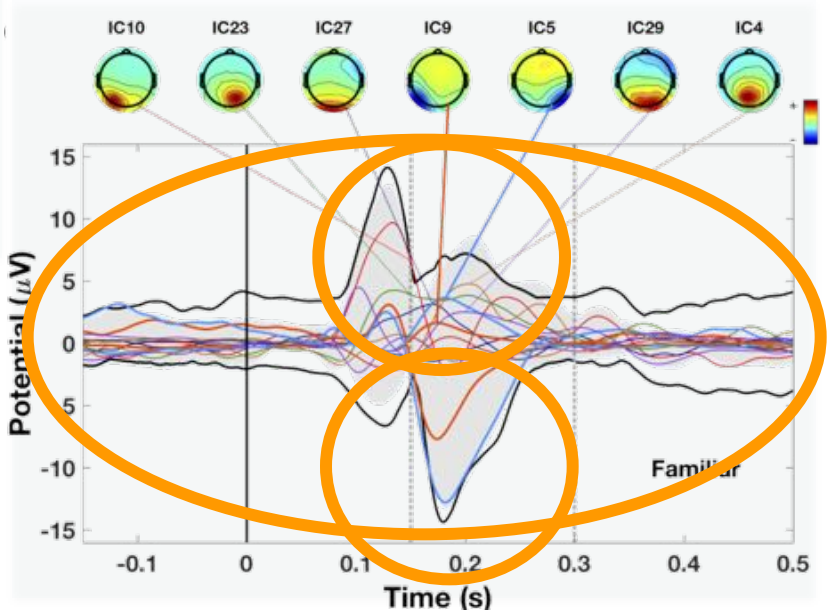
Imaging Brain Support for Three Aspects of Consciousness

Scott Makeig 2007

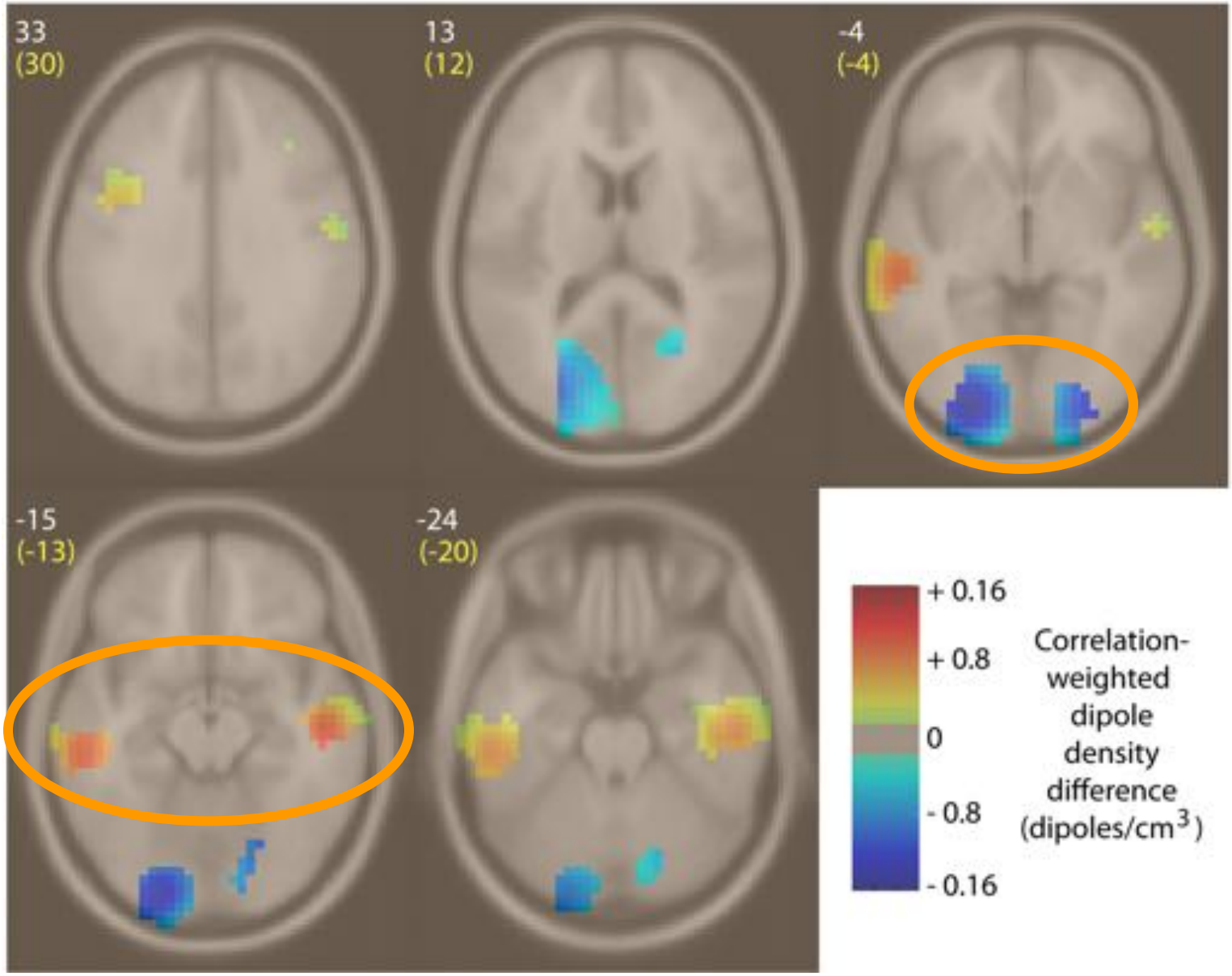
Knowing







S. Makeig (2017)

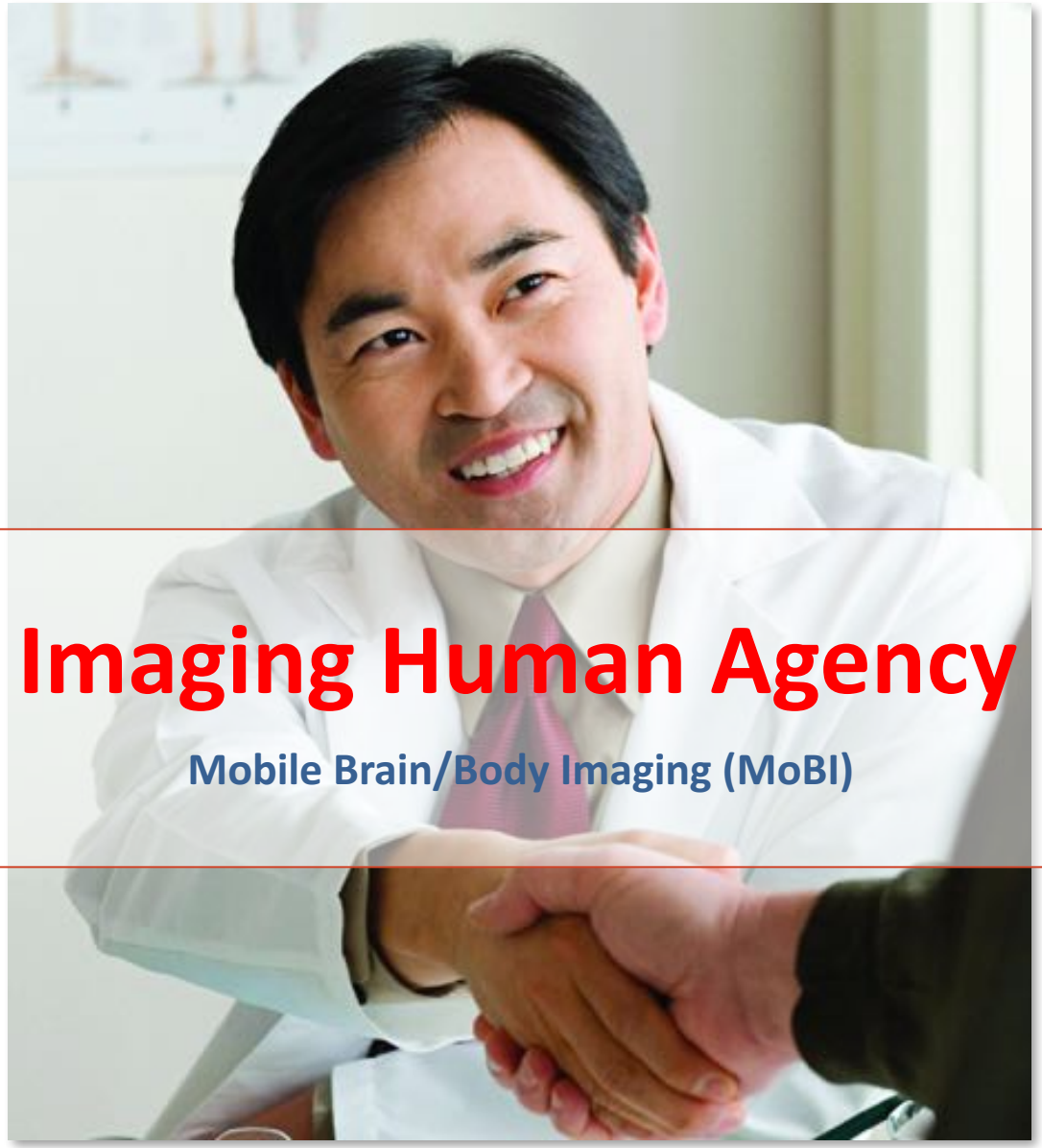


Onton & Makeig, *Frontiers in Human Neuroscience* '09

Feeling

Julie Onton & Scott Makeig, *Frontiers in Human Neuroscience*, 2009

Willing



Imaging Human Agency

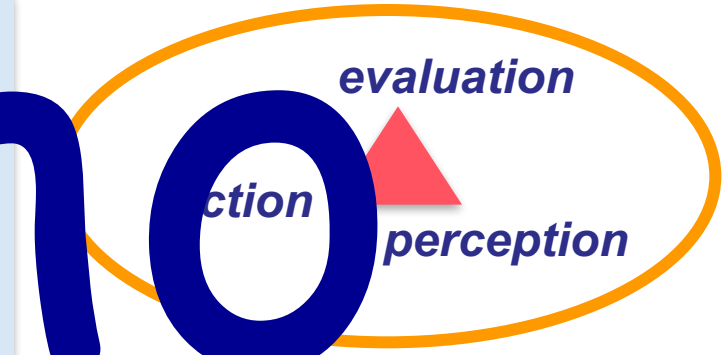
Mobile Brain/Body Imaging (MoBI)

S . Makeig, 2007

Embodied Cognition & Agency

Who

rain pr sses
have olve a l func on
to opt iz the utc me
of ***beha***
the brain organizes
in response to
perceived challenges
and opportunities.



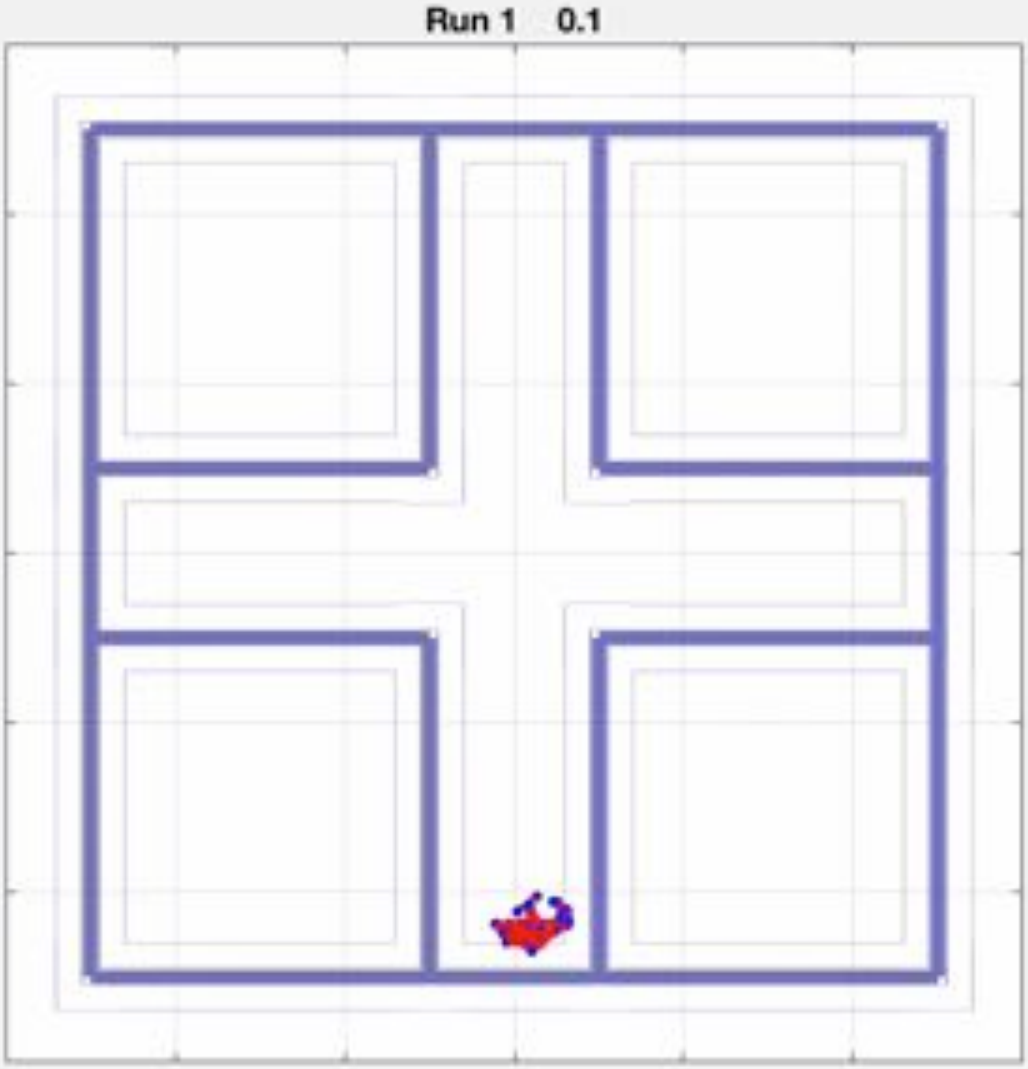
am I?

Brains seize the opportunity of the moment!

The Beginning

fEEG, BCI, MoBI,

NFB, BrainStim …


Run 1 0.1