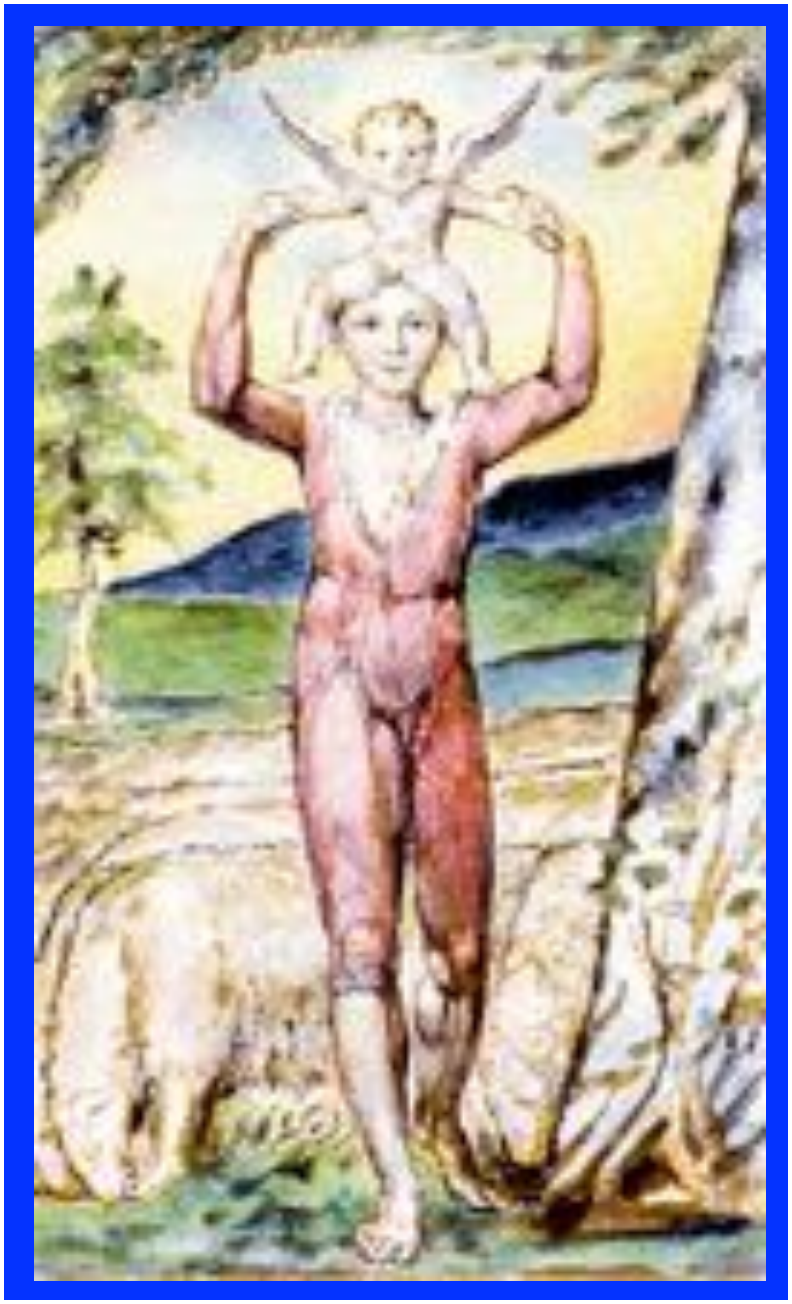


Mining Event-related Brain Dynamics II

Scott Makeig

Institute for Neural Computation

University of California San Diego

Santa Margherita Ligure, Italy

April, 2016

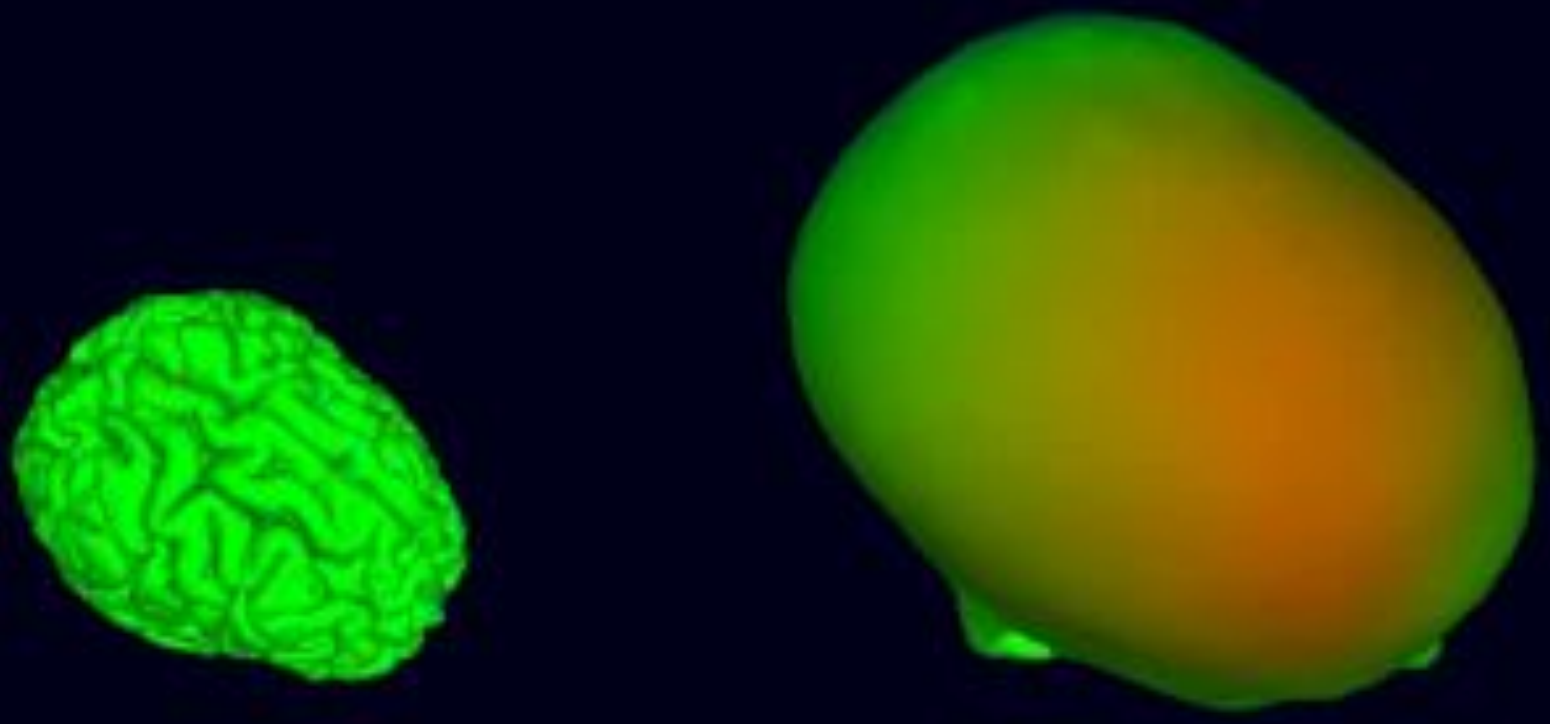
What is EEG?

- 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?**

Cloud art: Berndnaut

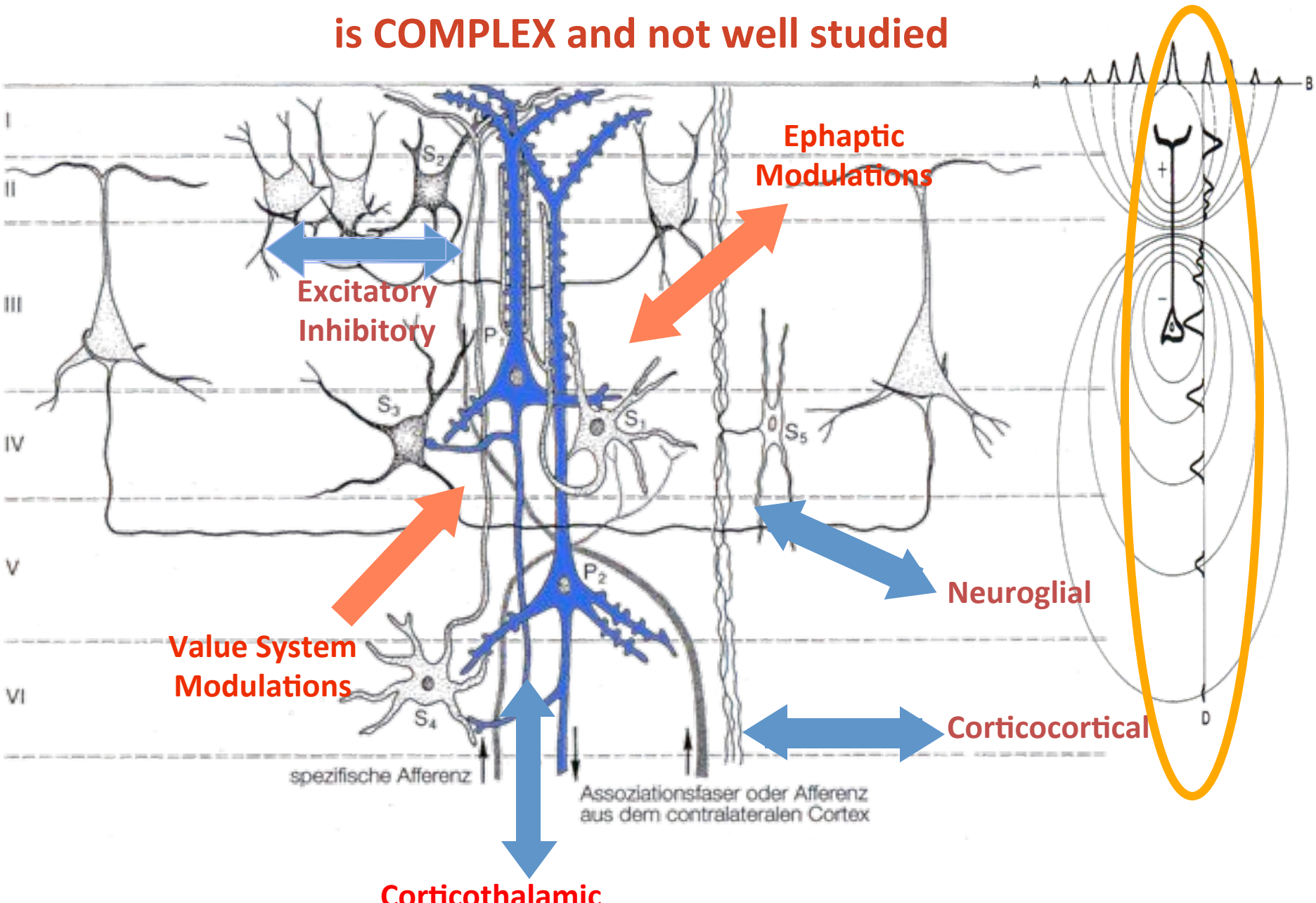
The very broad EEG point-spread function



Simulated EEG summing 30 cortical sources
(animation at 1/5th real time)

Akalin Acar & Makeig 2010

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



S. Makeig 2007

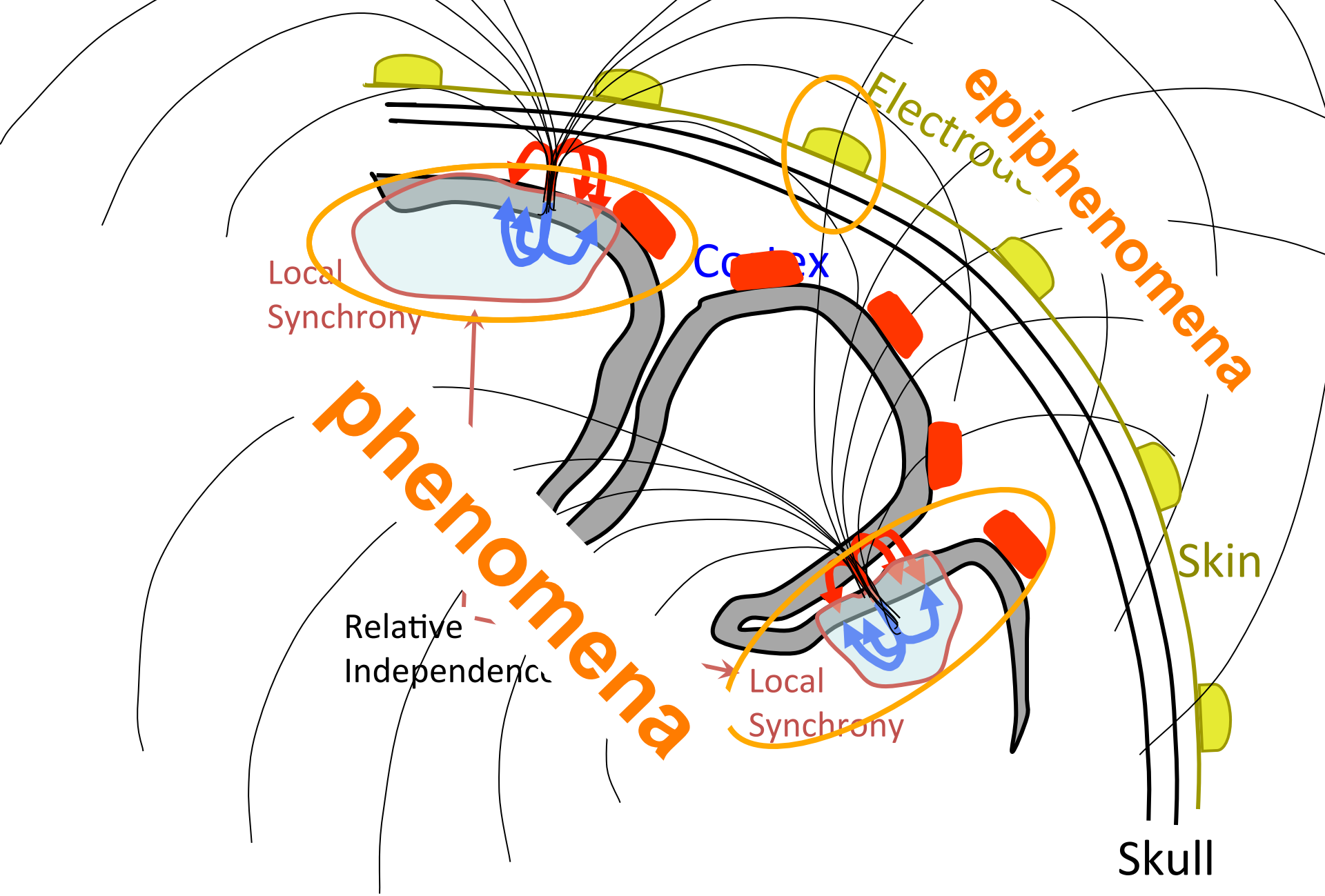
Phase cones (Freeman)

Avalanches (Plenz)

[1M Sources Movie]

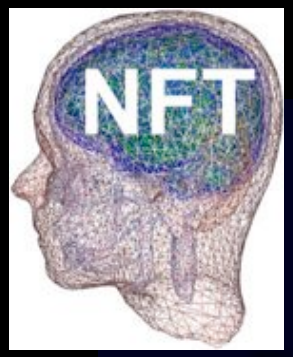
The spatiotemporal field dynamics of cortex and brain have not yet been imaged on multiple spatial scales!

Alan Friedman



S. Makeig 2007

The very broad EEG point-spread function

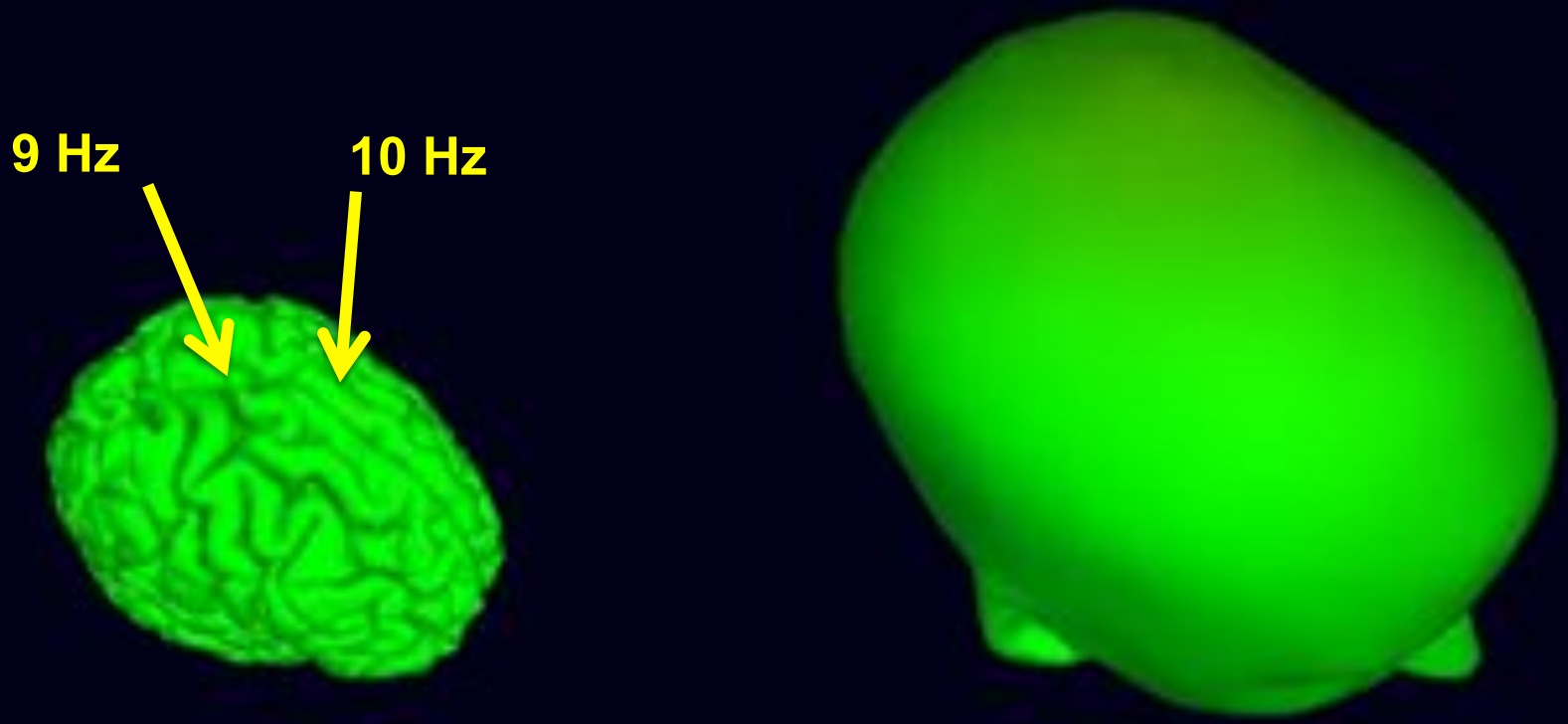


Simulated parietal source

Very broad projected scalp potentials

Akalin Acar & Makeig 2010

Effects of volume conduction on scalp EEG



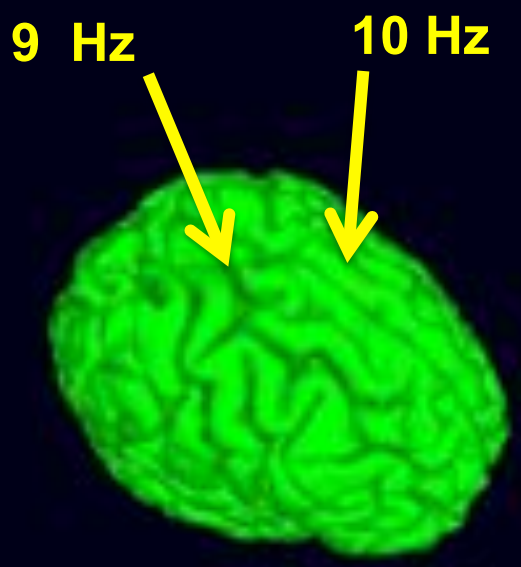
Simulated EEG summing TWO cortical alpha band source activities (animated at 1/5th real time)

Two cortical sources

Their summed scalp projection

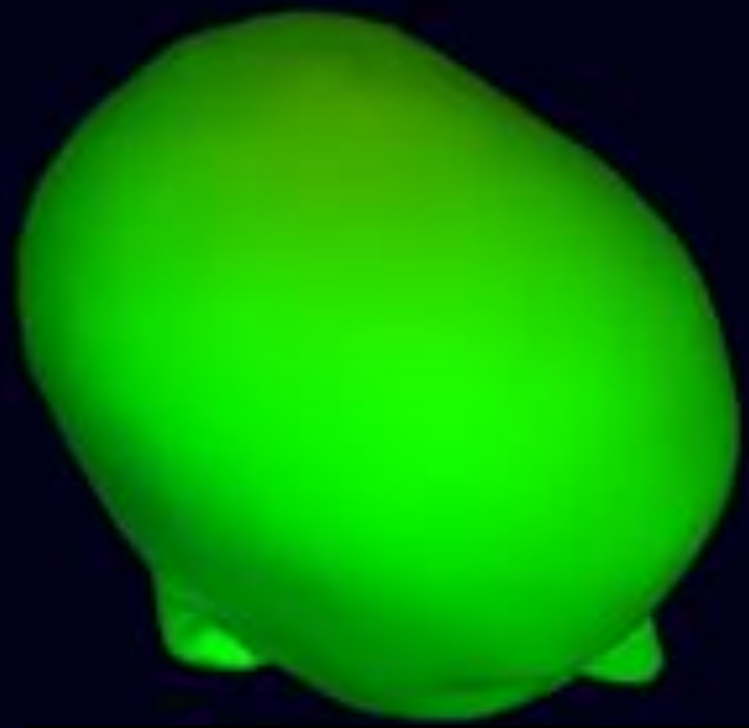
[2 Sources Movie]

Effects of volume conduction on scalp EEG



phenomena of interest

Two cortical sources

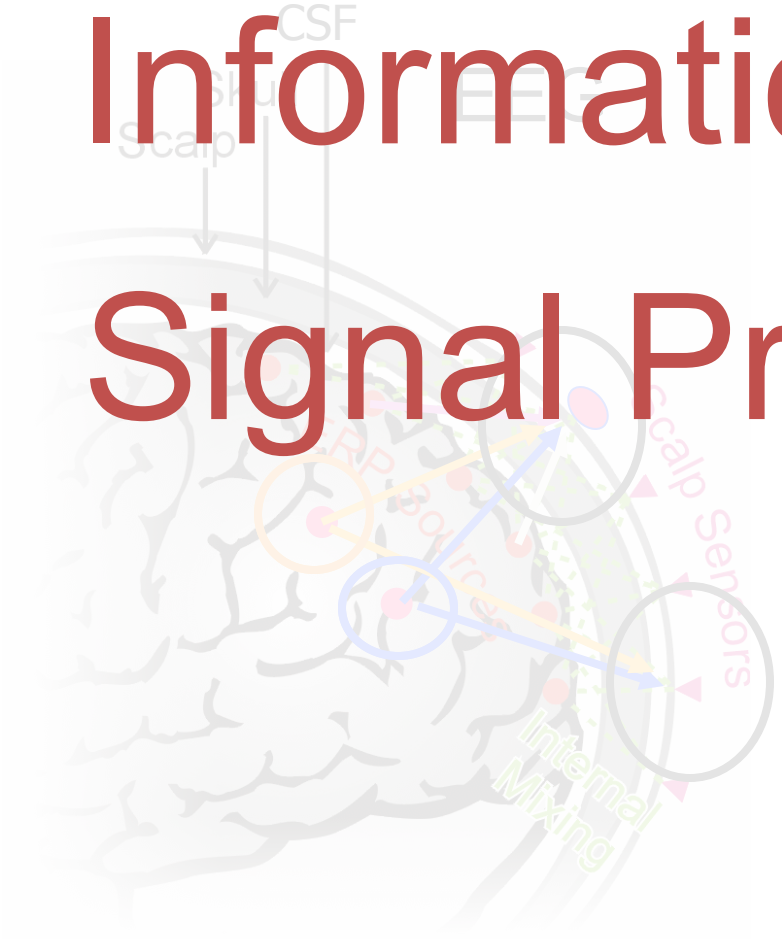


epiphenomena

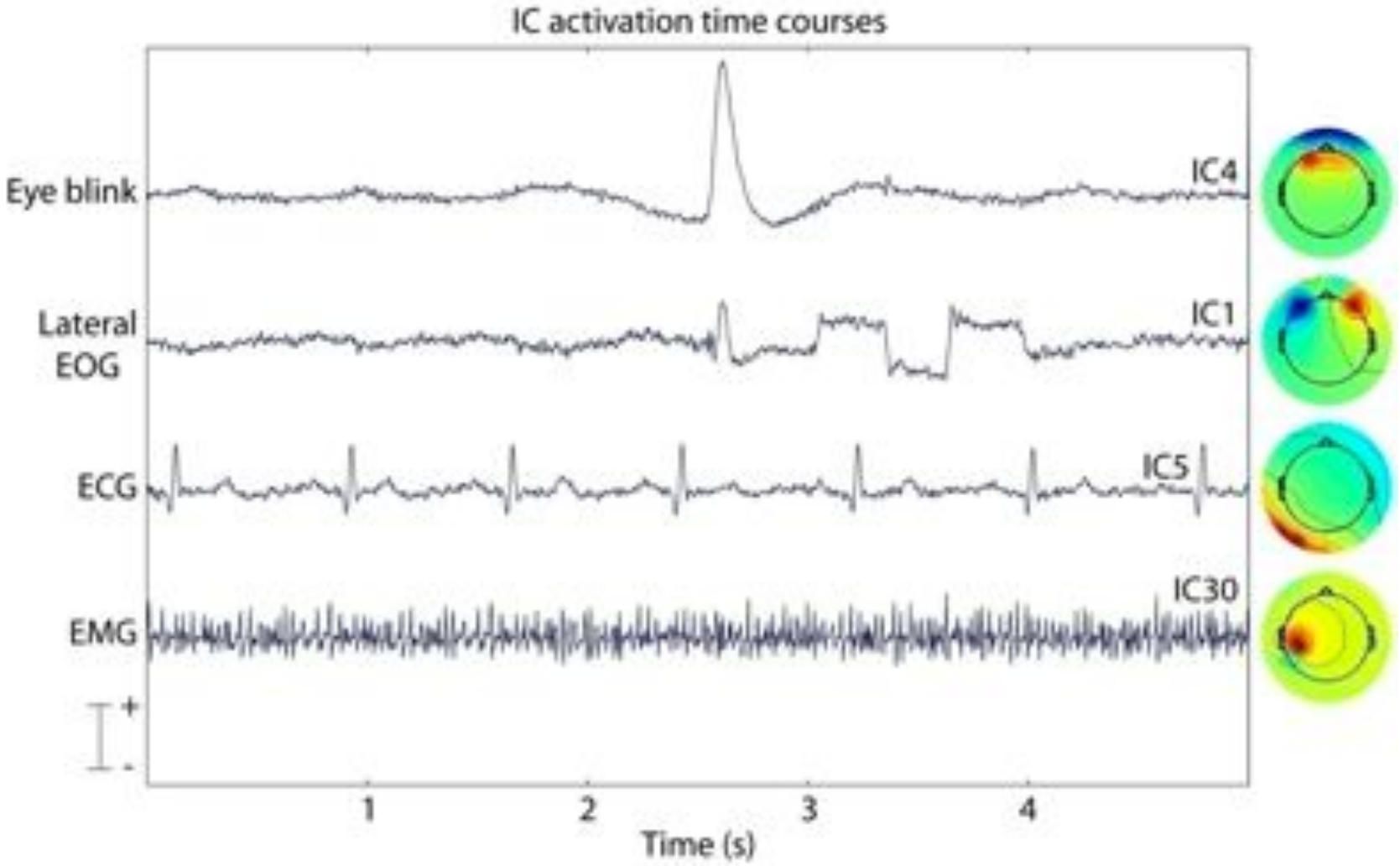
Their summed scalp projection

Blind EEG Source Separation by ICA

Information-based Signal Processing

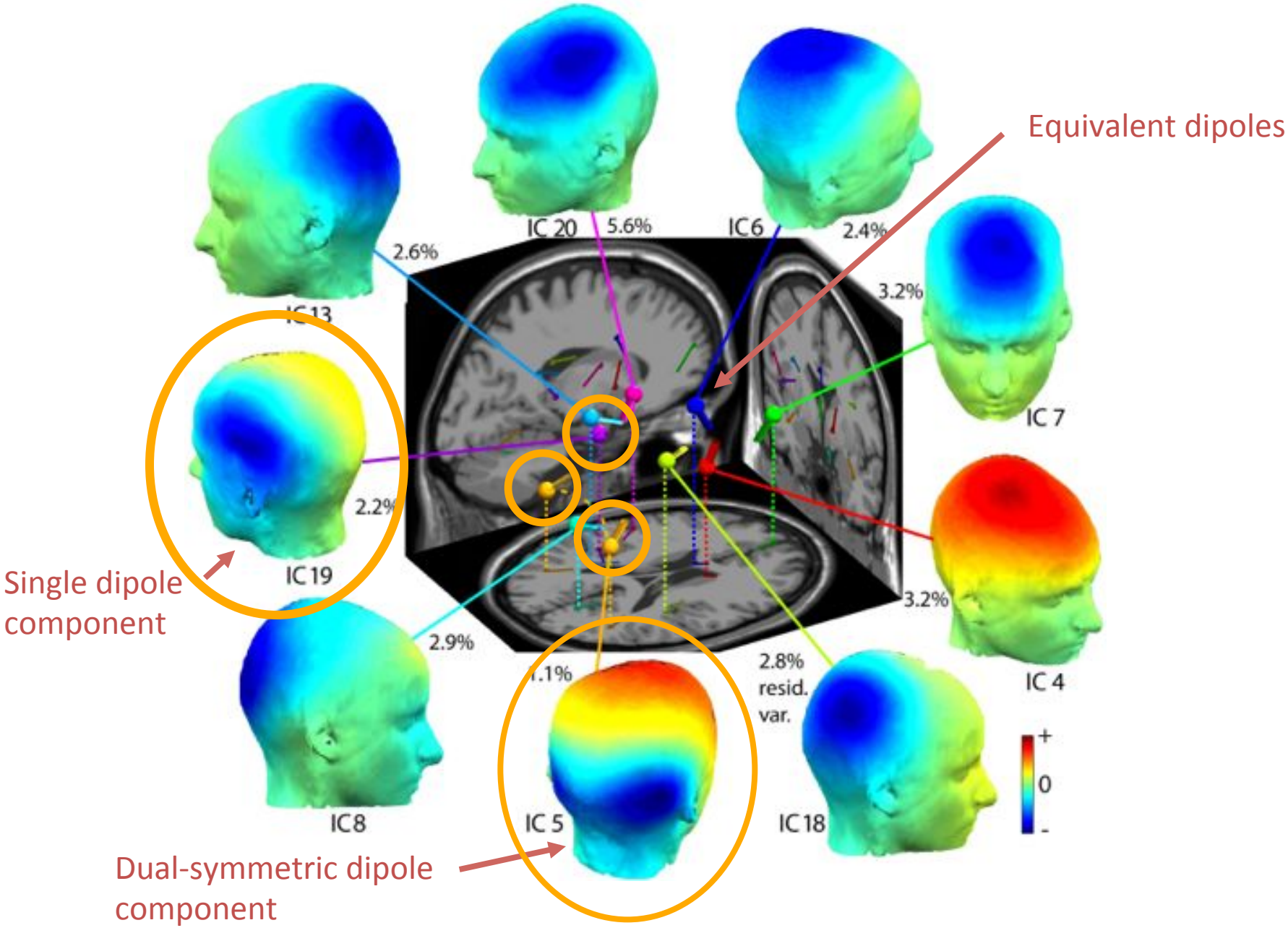


Non-brain effective source processes



J. Onton & S. Makeig 2006

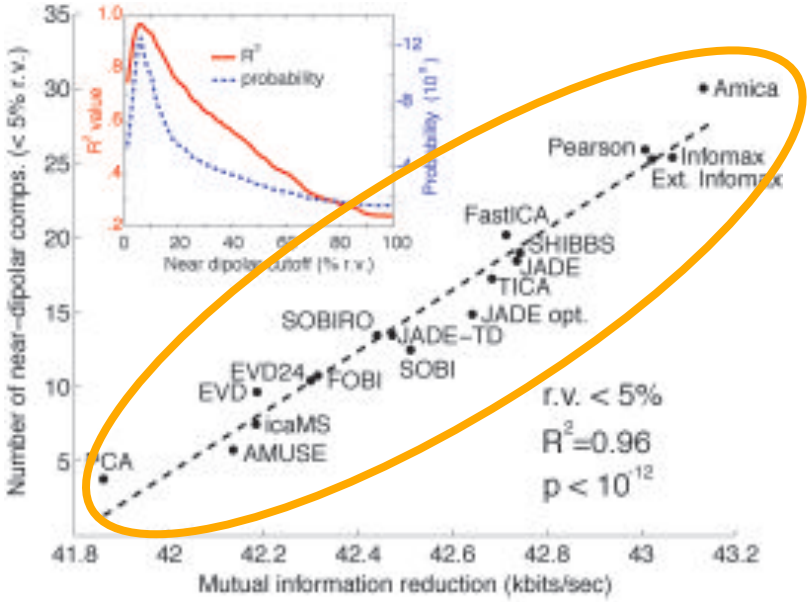
… and also separates cortical brain IC processes

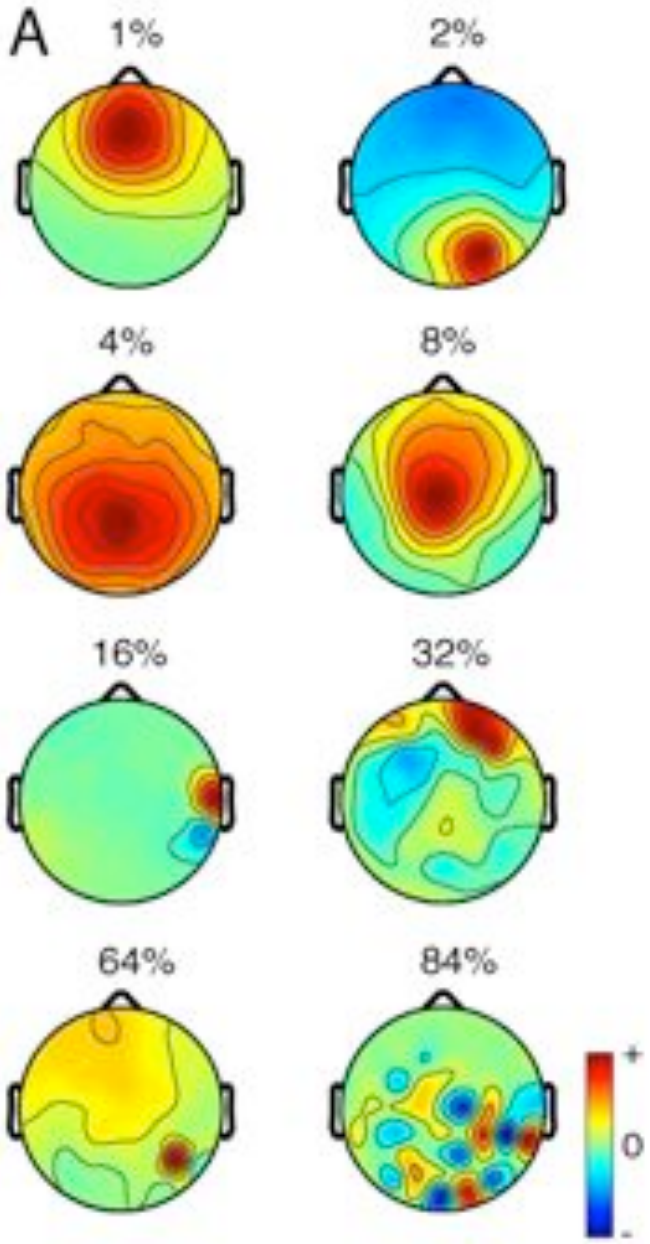


Julie Onton & S. Makeig (2006)

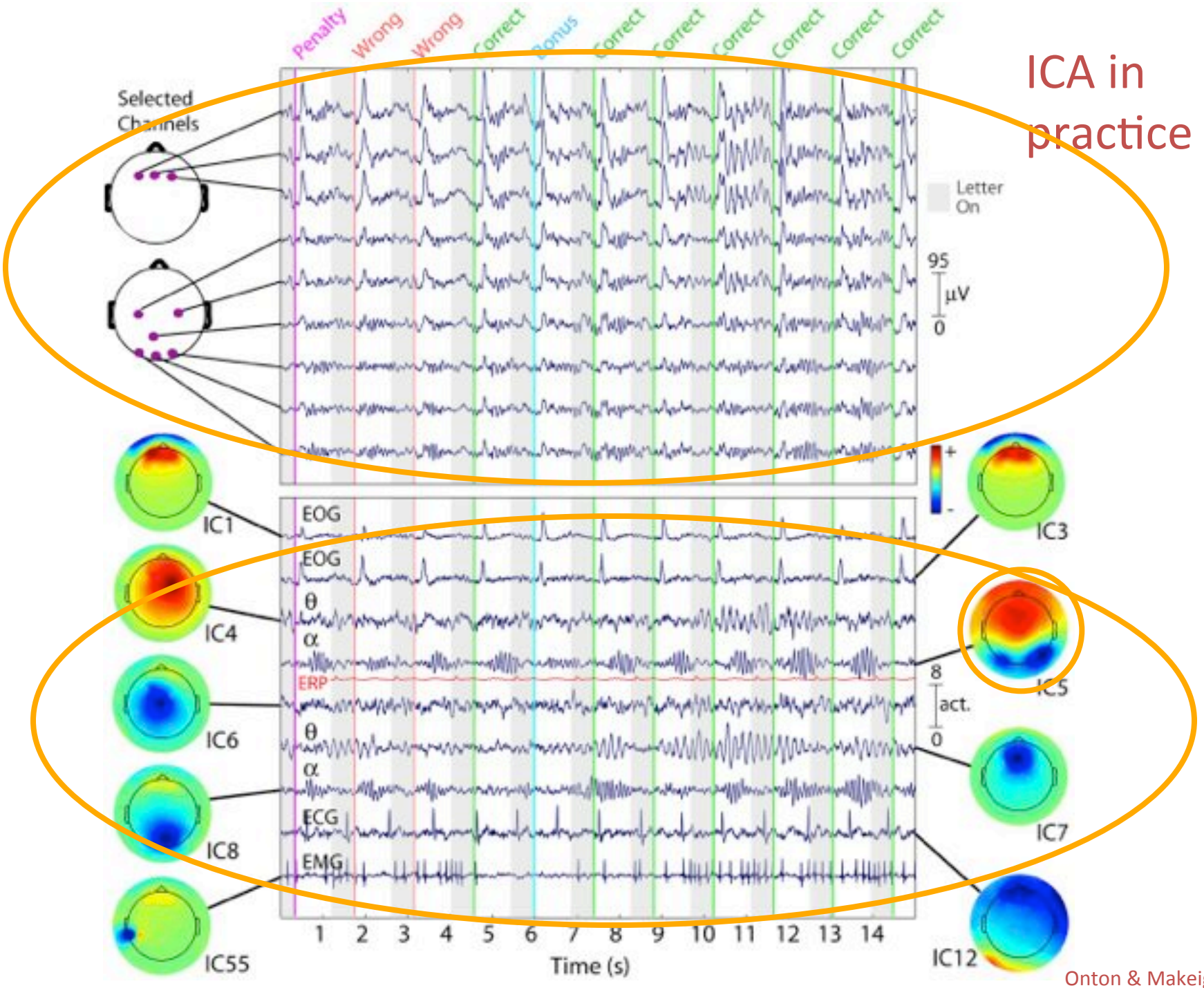
Independent Component Dipolarity

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

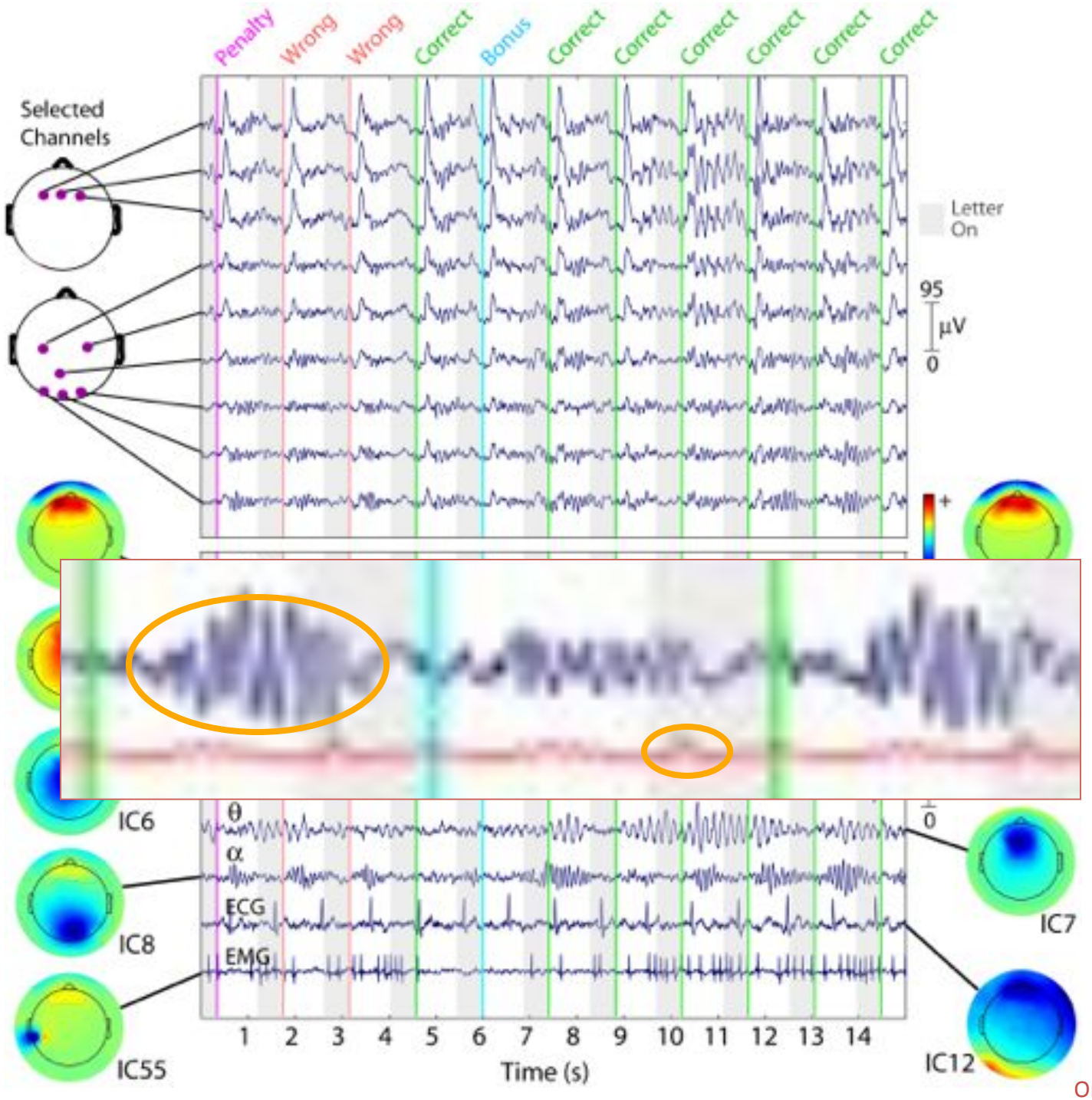




ICA in practice



Onton & Makeig, 2006



Onton, Makeig (2006)

Three Eras of EEG Studies

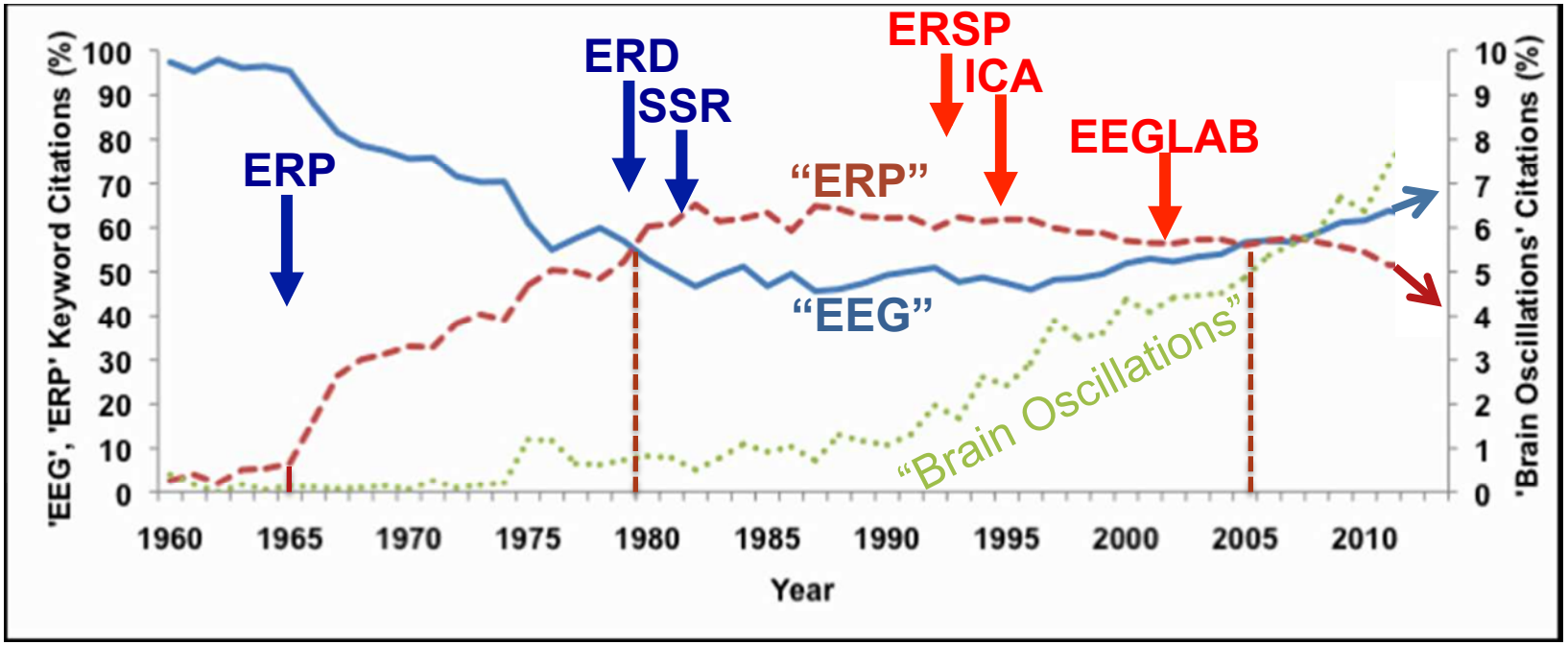
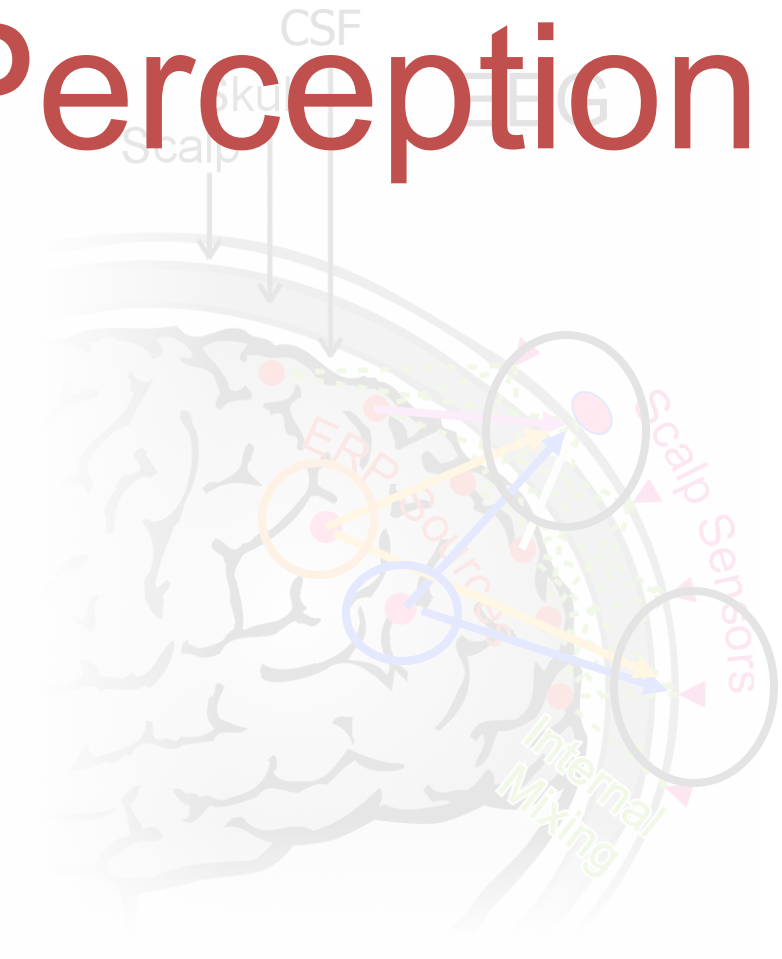


Figure 1. Relative number of PubMed citations retrieved by 'All Fields' search terms: 'EEG,' 'ERP,' and 'Brain Oscillations.' The percent of citations for each search term relative to the total number of citations returned by a search for any of the three terms is plotted relative to the other two search terms. For visual clarity, 'Brain Oscillations' citations are graphed with a green dotted line according to the Y-axis labels on the right; 'EEG' with a blue solid line and 'ERP' with a red dashed line according to the Y-axis labels on the left.

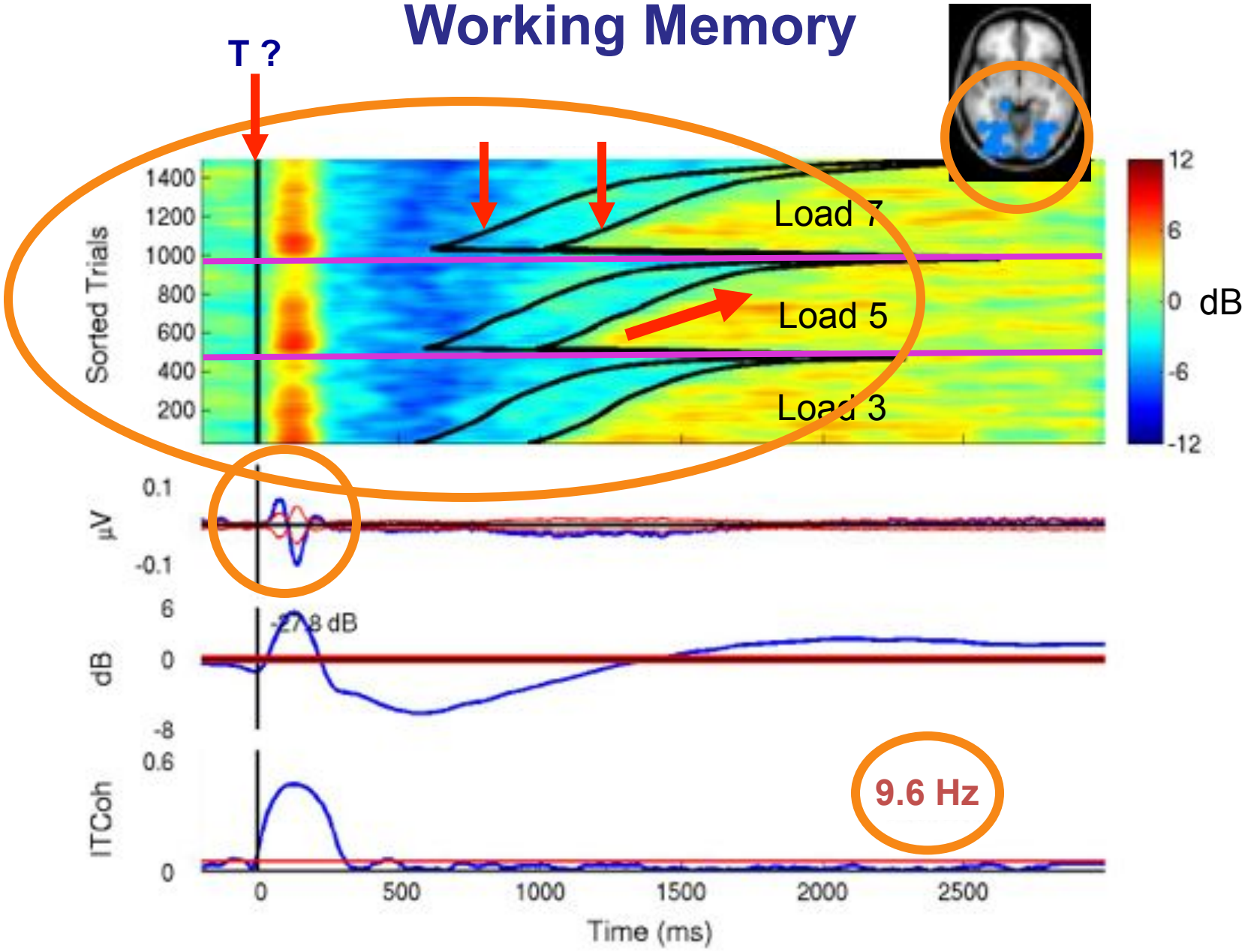
Loo & Makeig, 2015

Blind EEG Source Separation by ICA

Perception & Attention



Working Memory

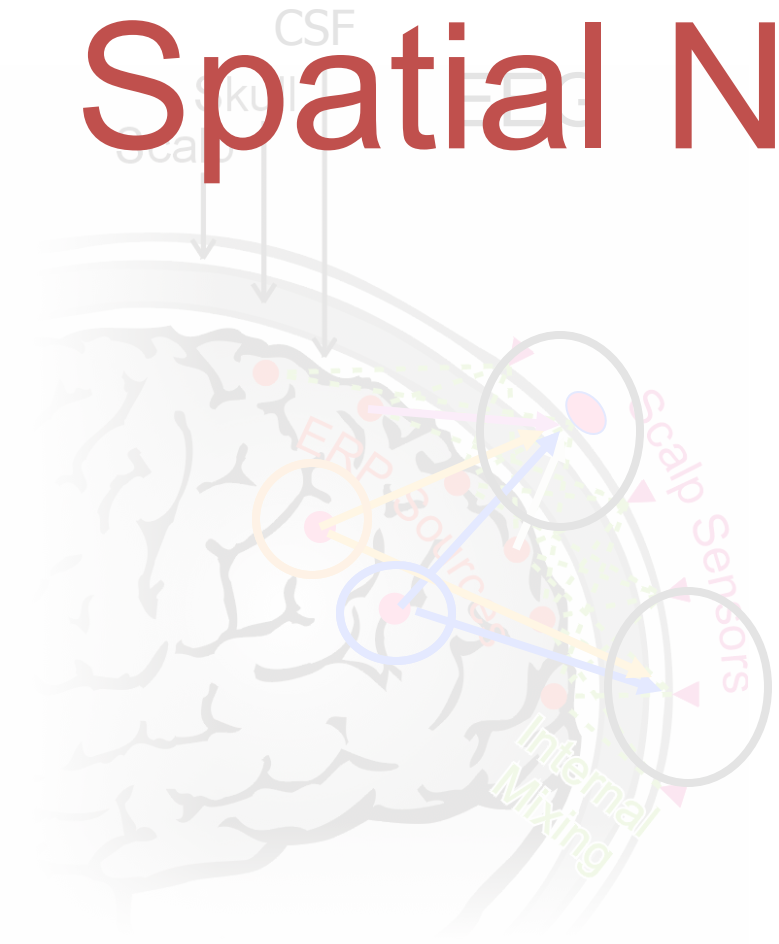


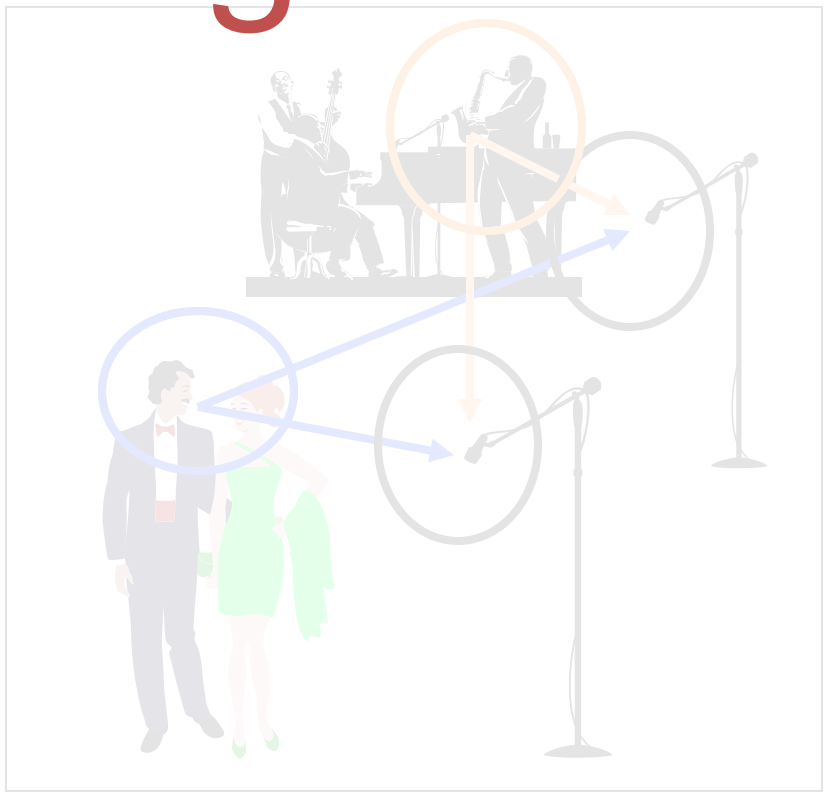
erpimage()

Onton & Makeig, 2005

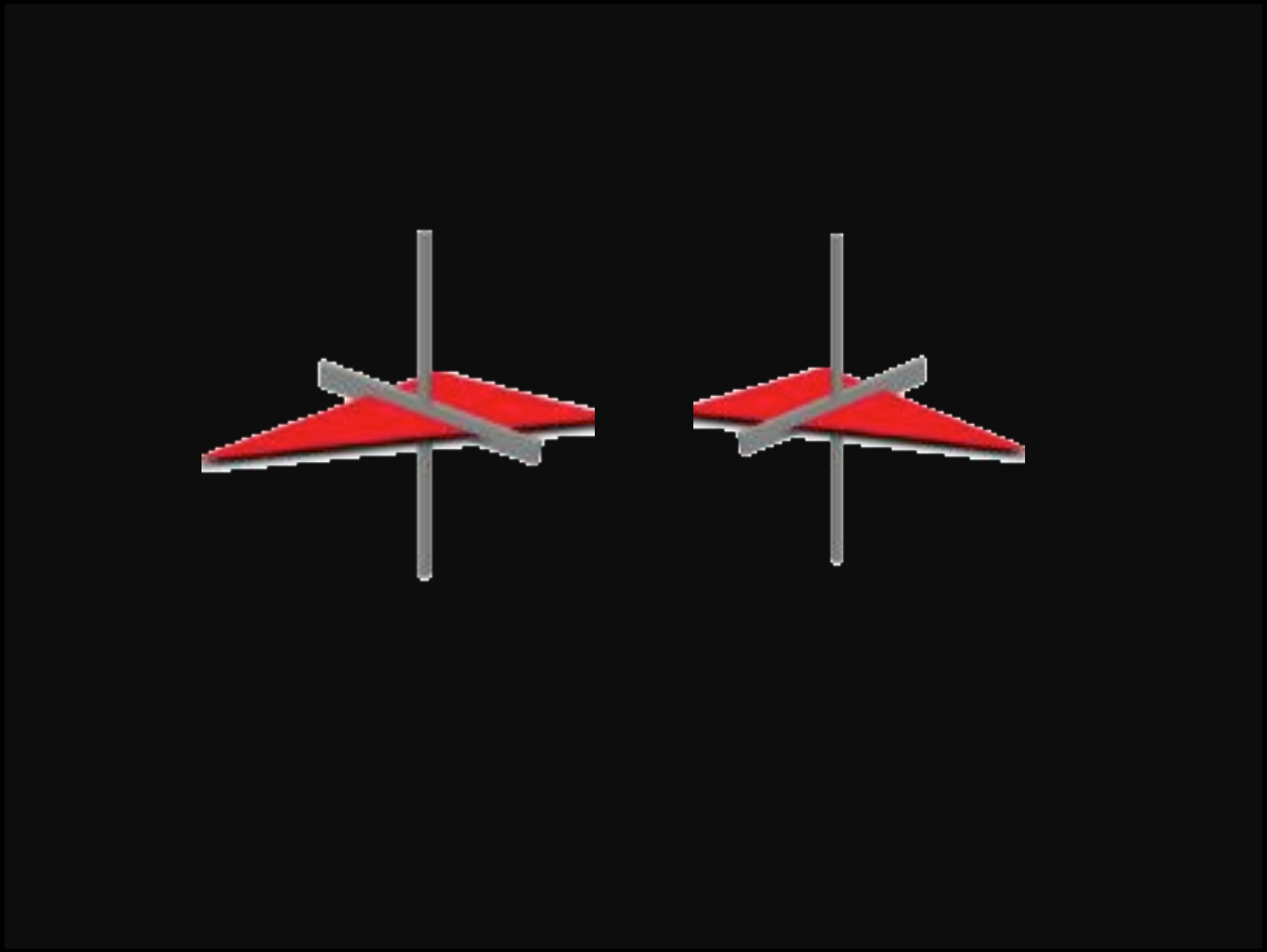
Blind EEG Source Separation by ICA

Spatial Navigation



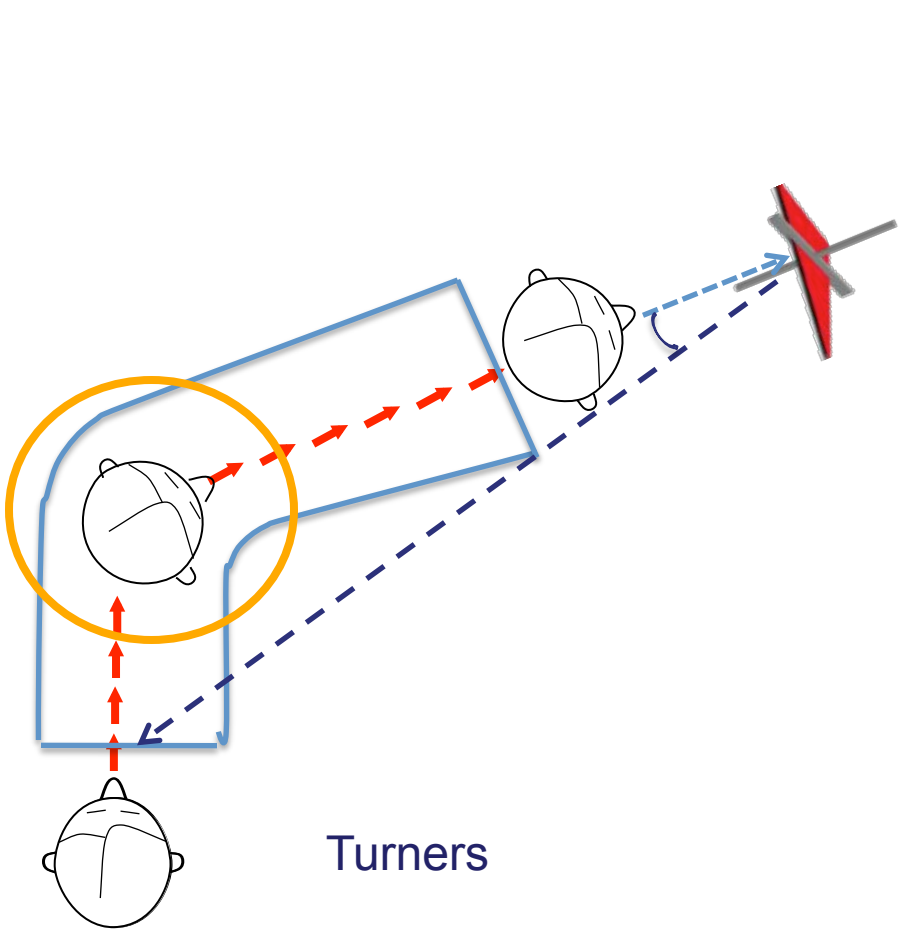


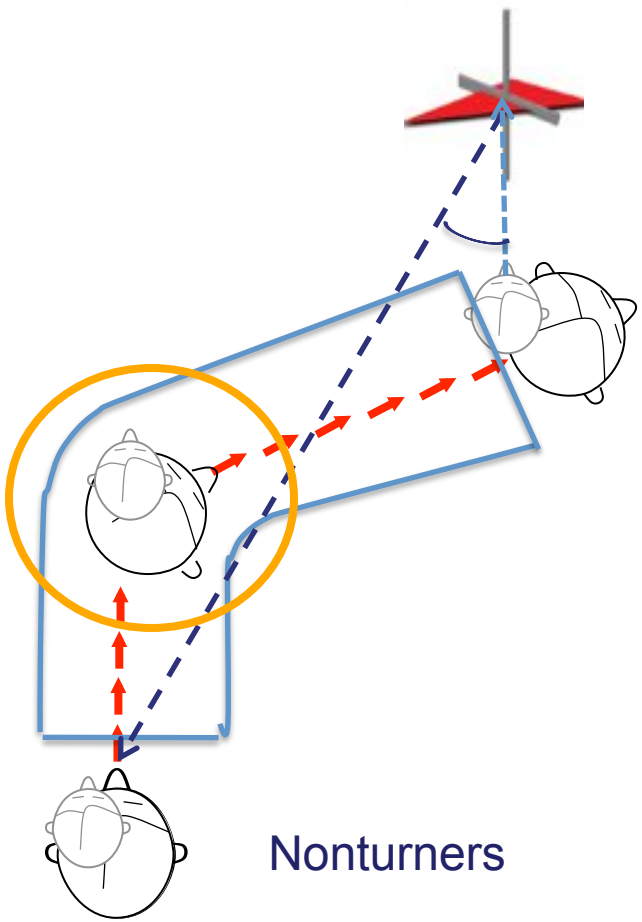
A Passive Spatial Navigation Paradigm



Klaus Gramann et al., 2010

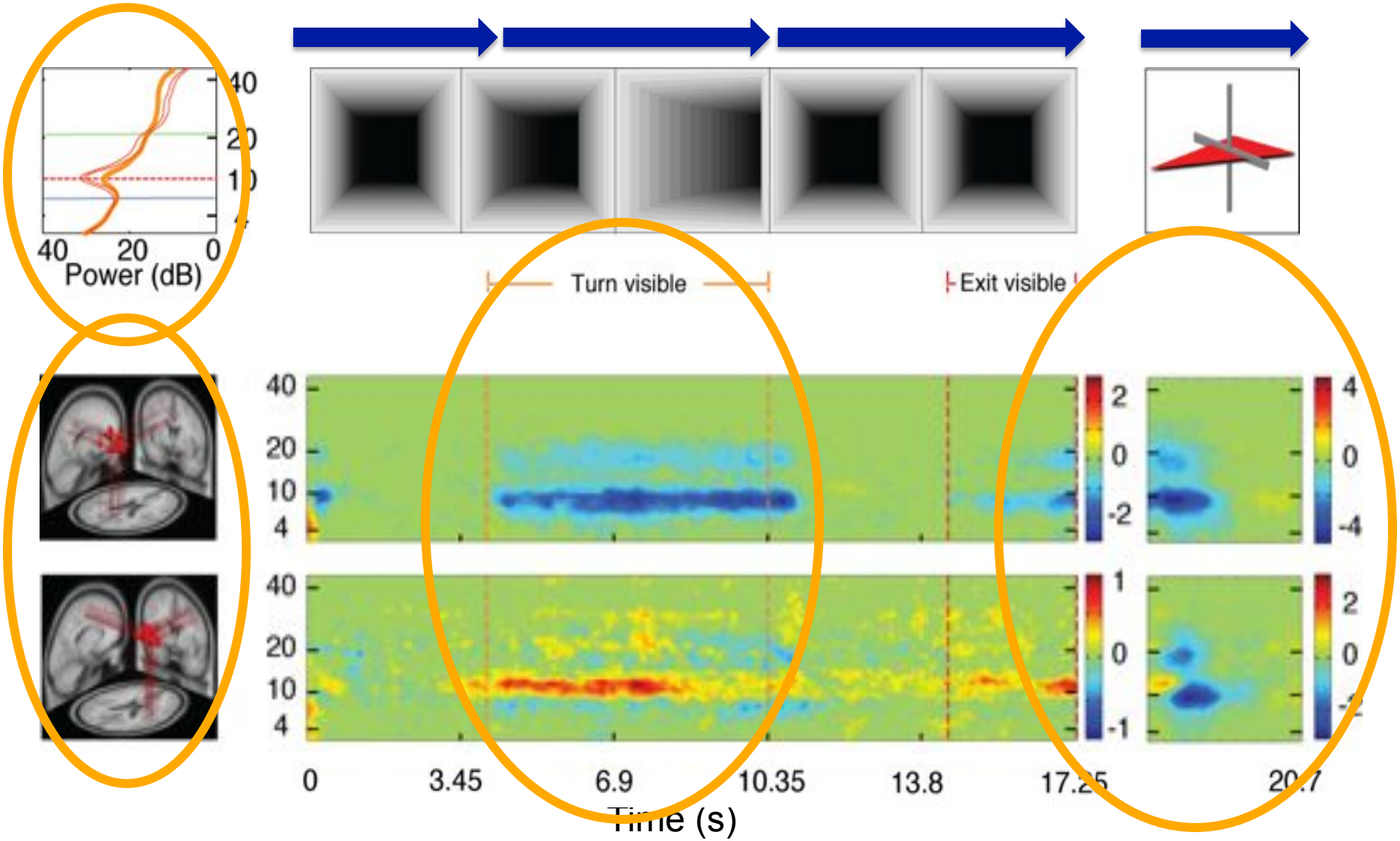
‘Turner’ and ‘Nonturner’ subjects use different spatial orienting styles





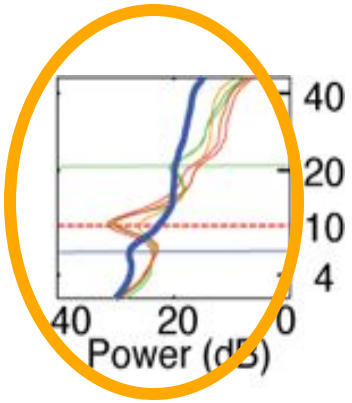
Klaus Gramann & S. Makeig, 2010

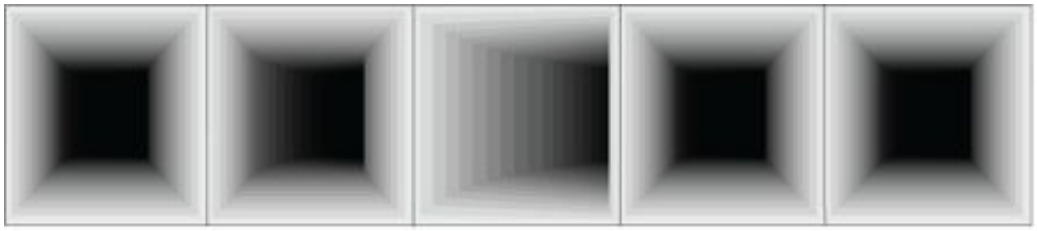
Two parietal component clusters

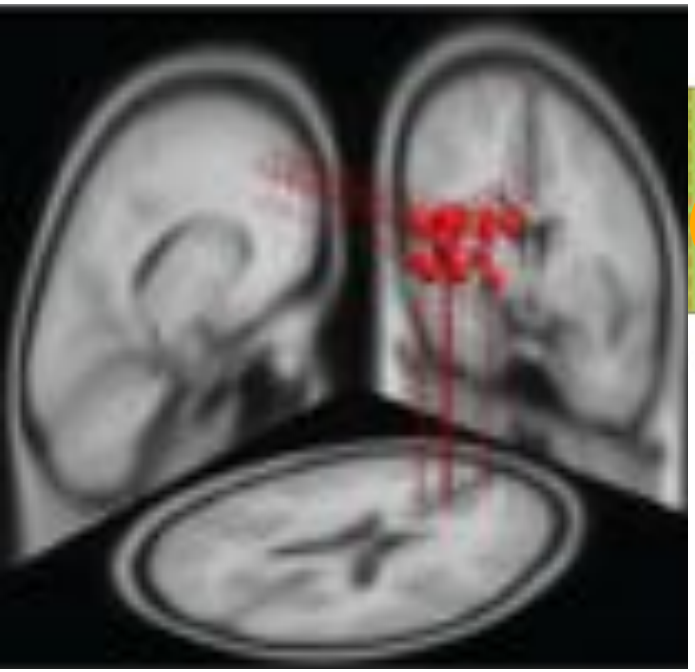


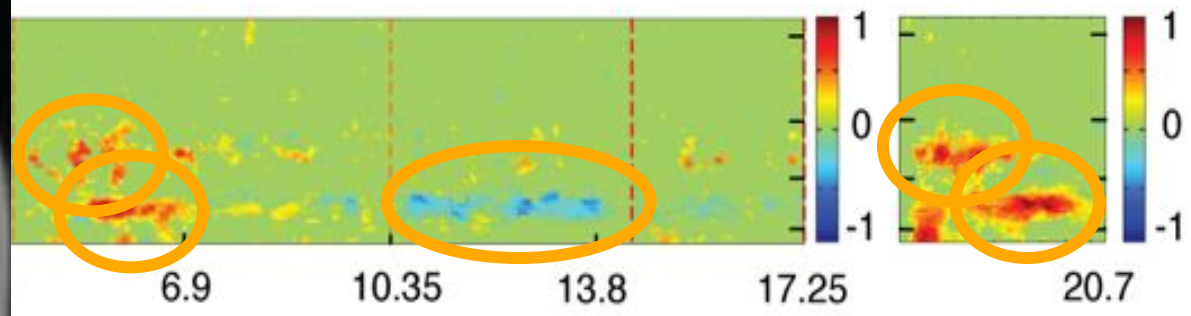
Klaus Gramann et al., 2010

Medial prefrontal component cluster



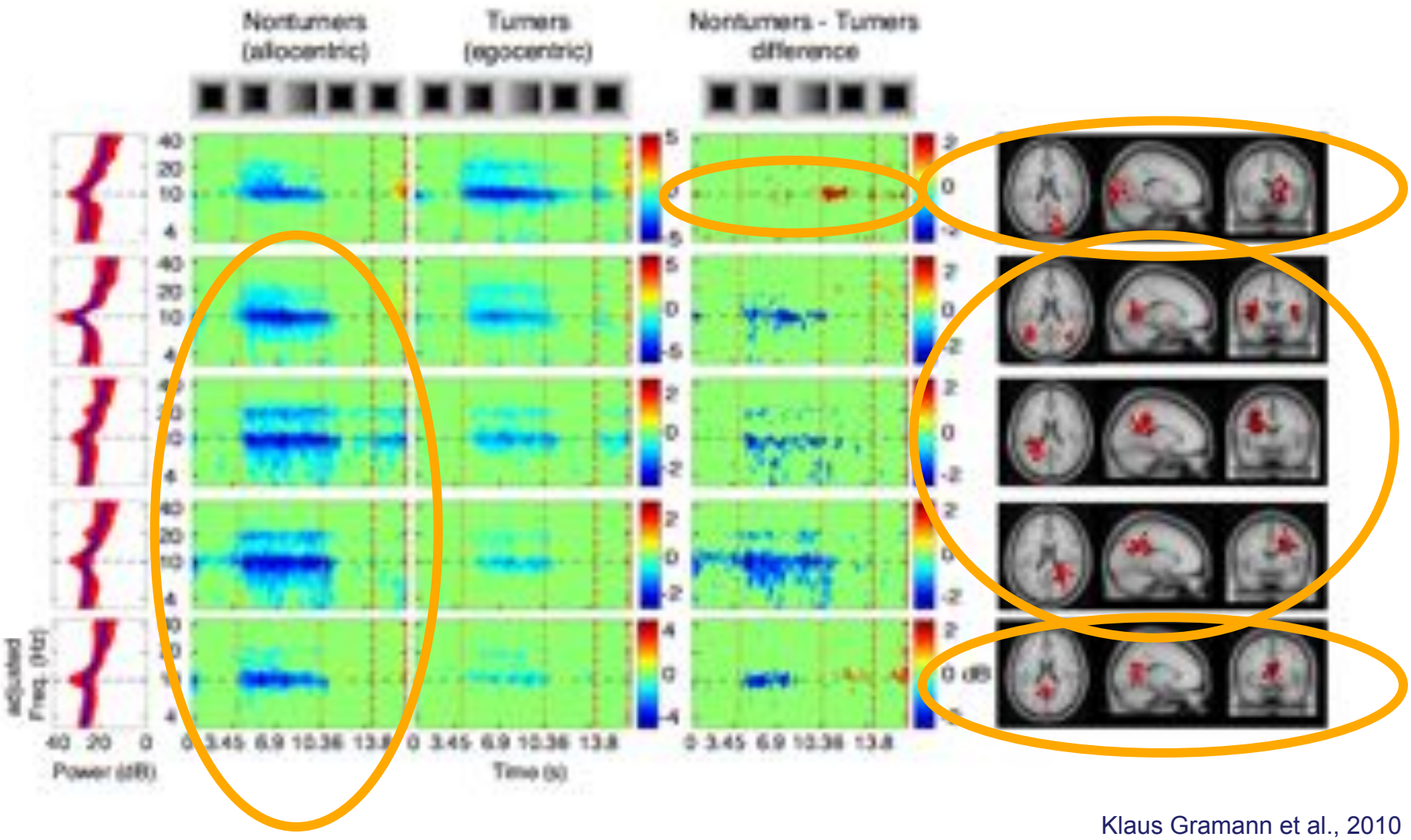






Klaus Gramann et al., 2010

Clusters distinguishing Turners & Nonturners



Klaus Gramann et al., 2010

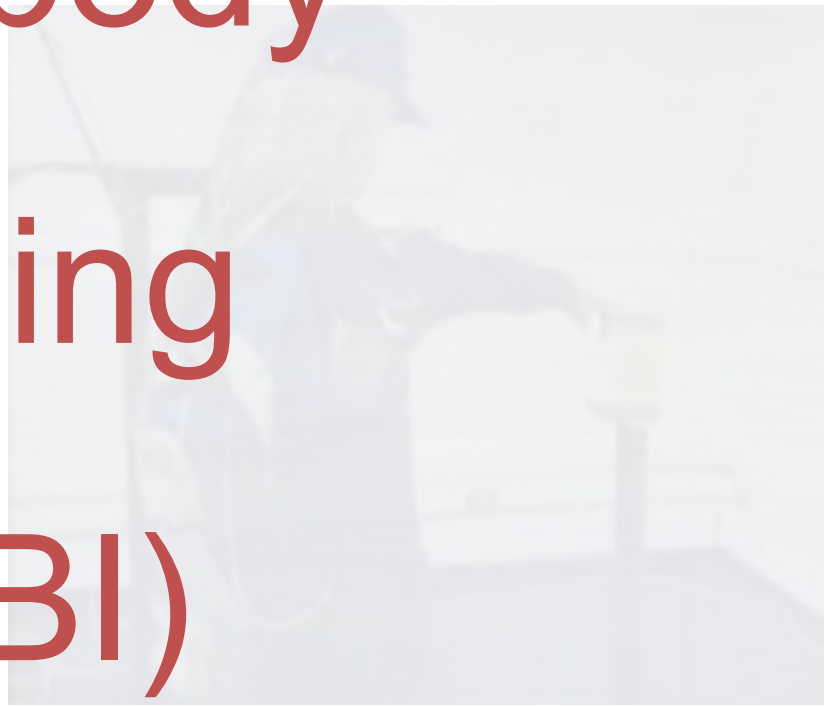
Brain imaging during movement – How?

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

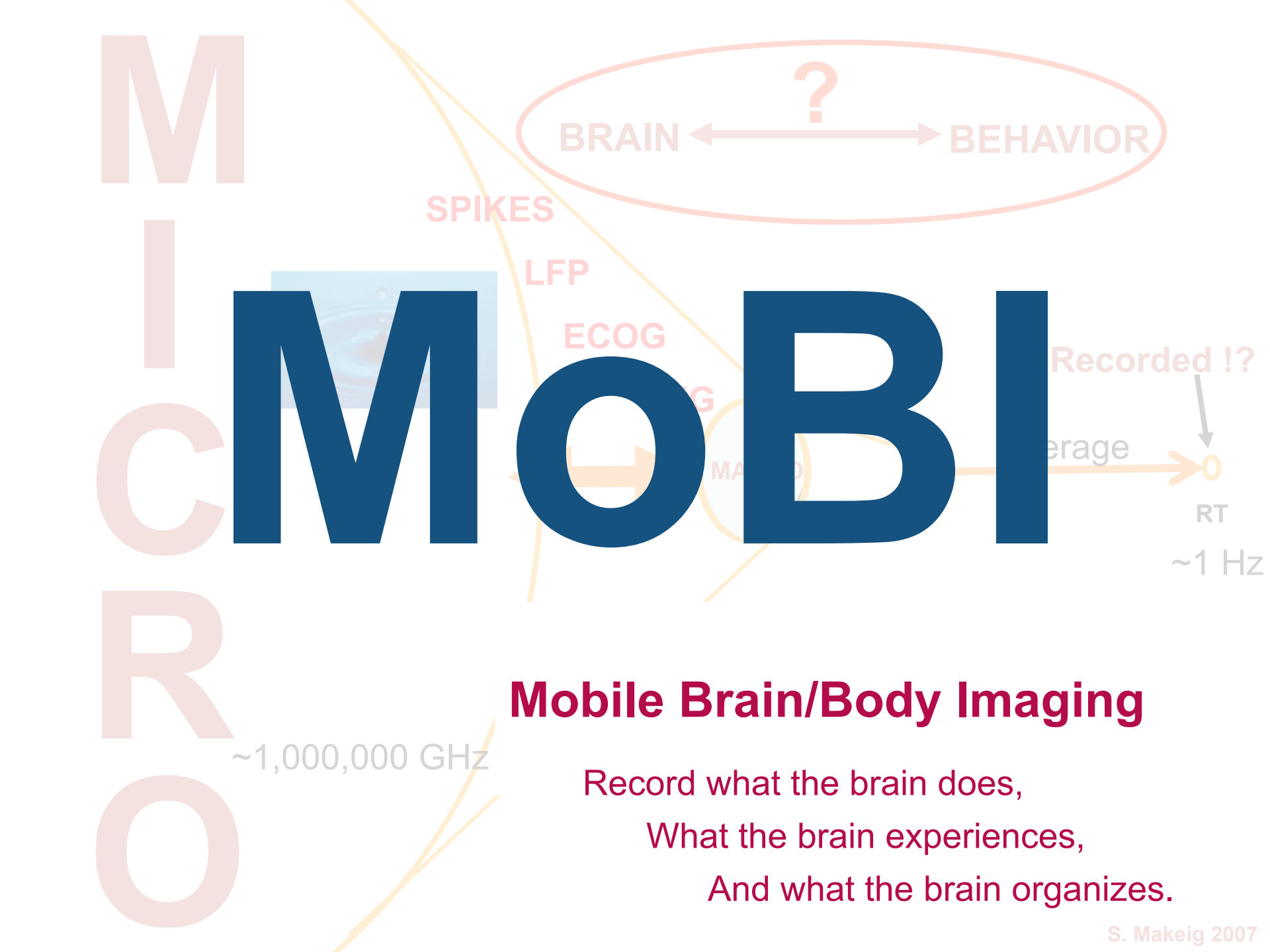
→ **Mobile Brain/Body Imaging** (MoBI)

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,

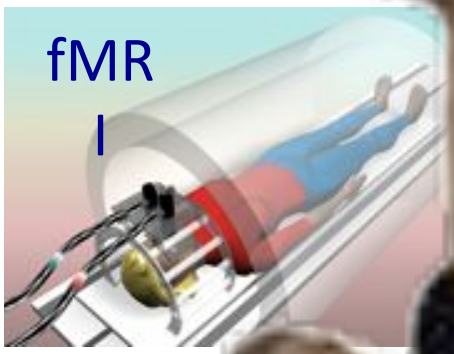
What the brain experiences,

And what the brain organizes.

S. Makeig 2007

Brain imaging during motor behavior?

- Nearly all brain imaging studies (MEG, PET, fMRI, and EEG) are conducted in rigidly static[illegible]ted or prone positions with only the most minimal fi[illegible]moven[illegible] allowed.



Why?

- In all modalities but EEG, [illegible]ors are **heavy**.
- Muscle and movements contri[illegible]('noise') signals.

- **But this limitation is highly artificial.** Nearly all our life [illegible]lves *active movements* and *interactions* within a 3-D environment.
- → **Brain activity during free movement in 3-D space**

has never been observed or modeled!

Scott Makeig 2008

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

S . Makeig, 2007

Mobile Brain/Body Imaging (MoBI)

1. Record simultaneously, during naturally motivated behavior,

What the brain does (high-density EEG)

What the brain experiences (sensory scene recording)

What the brain organizes (body & eye movements, psychophysiology)

2. Then –

Use evolving signal processing methods

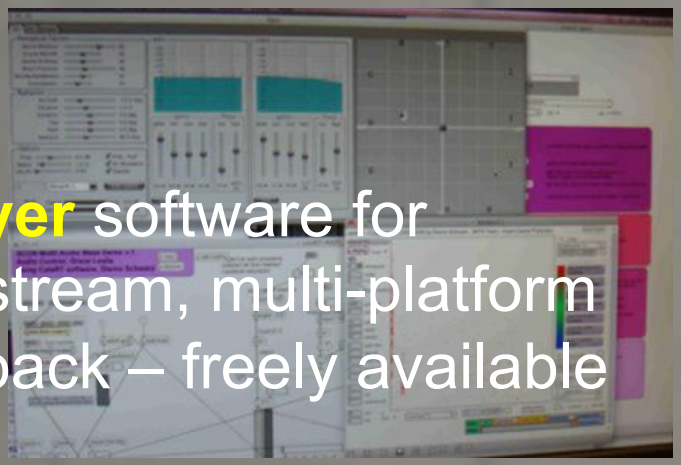
to find, model, and measure

non-stationary (context- and intention-related)

functional relationships among these data modalities.

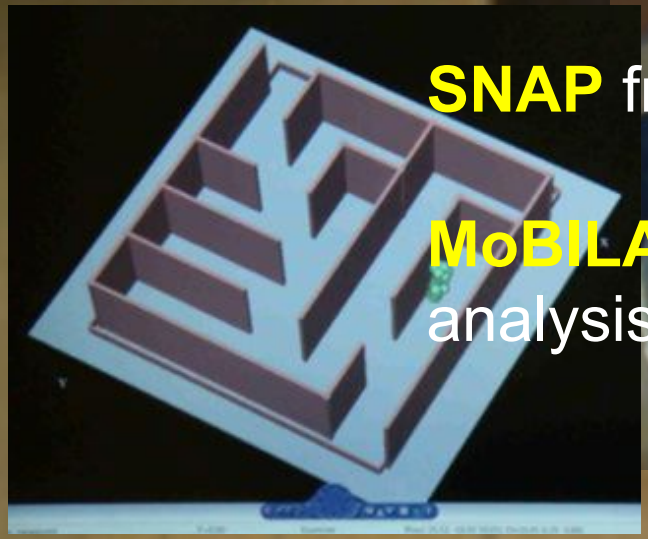
Scott Makeig, 2011

MoBI Lab at SCCN, UCSD



Lab Streaming Layer software for synchronous multi-stream, multi-platform recording and feedback – freely available on Google Code.

XDF file format for multimodal time series data.



SNAP framework for experiment control.

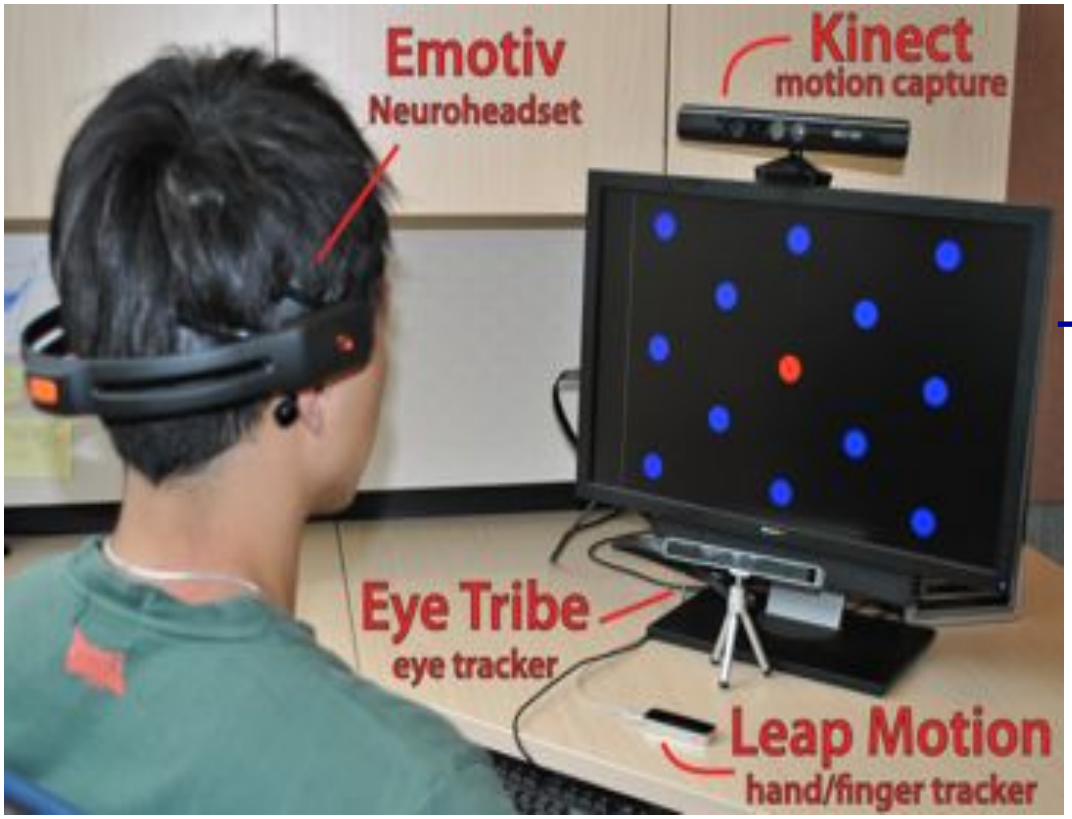
MoBILAB multistream browser and analysis environment.

http://thesciencenetwork.org/programs/inc-sccn-open-house/inc-sccn-open-house-hi-lite-reel

Now possible – Inexpensive 'MoBI-In-A-Box' Systems

< $1000

< $500



< $500

Touchscreen

< $100

< $100

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

S Makeig & M Miyakoshi, 20112

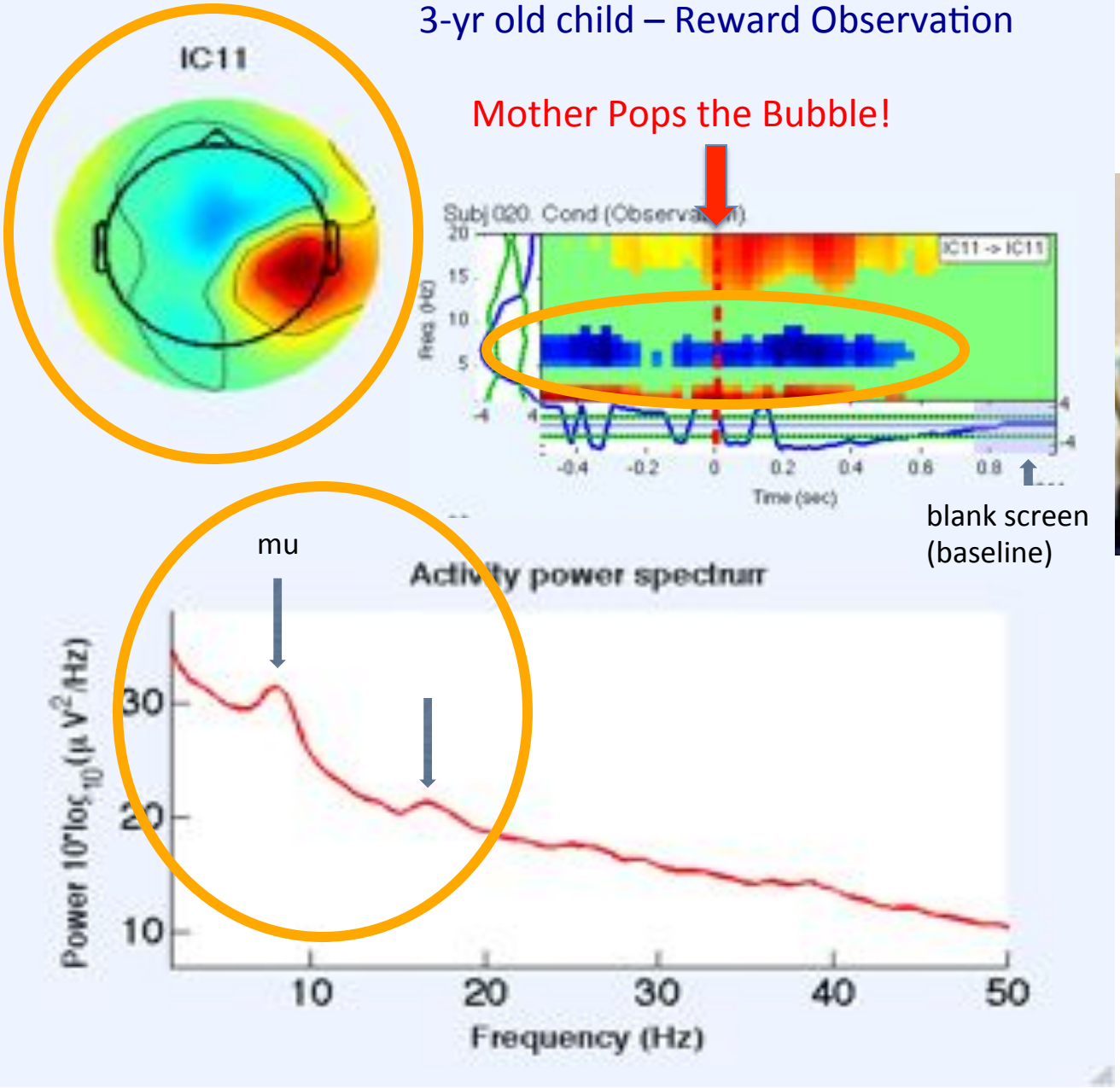
MoBI Lab: Two-Person Mirroring Experiment

Photo: T Bel Bahar & E Tumer, 2011

Development of Shared Attention –
A Mom and Child MoBI Experiment

Gedeon Deak et al., 2011

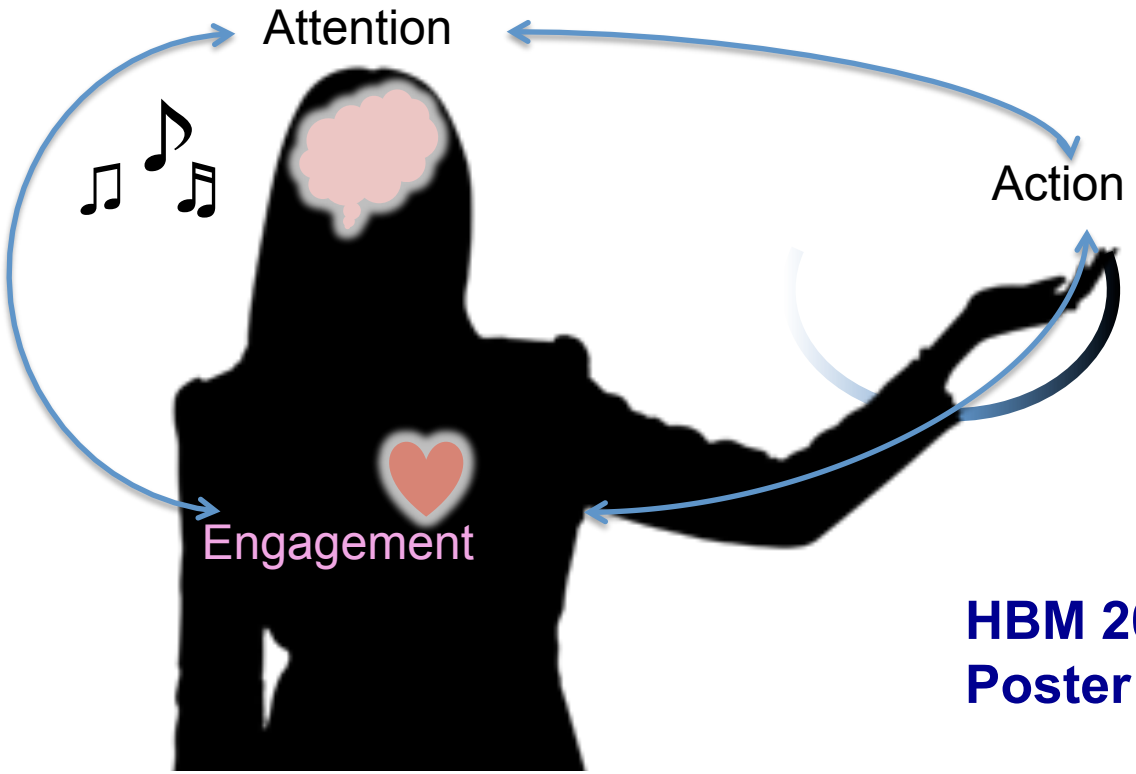
3-yr old child – Reward Observation



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

Measuring Musical Engagement Through Expressive Rhythm

How can we measure listeners' engagement?



HBM 2014
Poster #1538 online

G Leslie & S Makeig,

Expressive ‘conducting’

The Heart is a Lonely Hunter (1968)

Two conditions:

- Fully Engaged

- Less Engaged

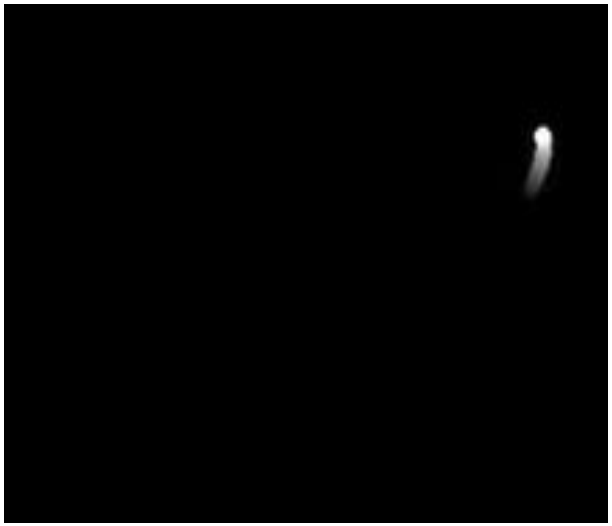
The Conducting Experiment

G Leslie & S Makeig,

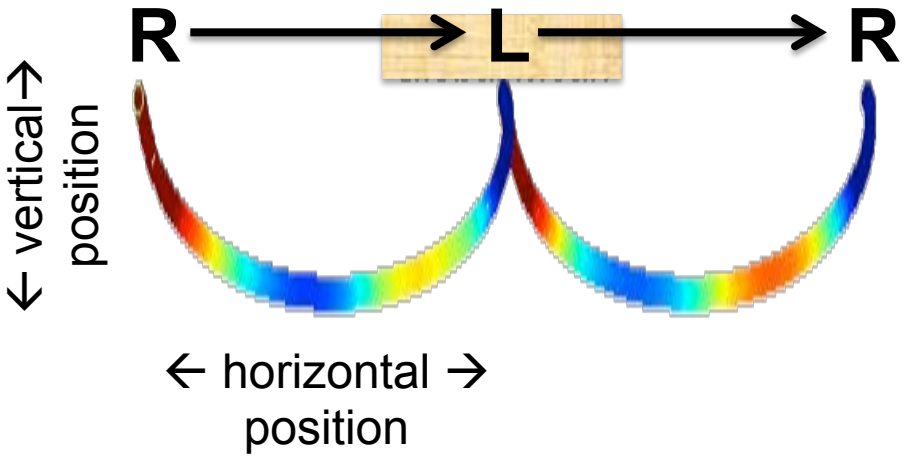
Modeling Musical Engagement

G Leslie & S Makeig, 2011

Live translation of the conducting gesture to moving dot



Average Conducting Cycle



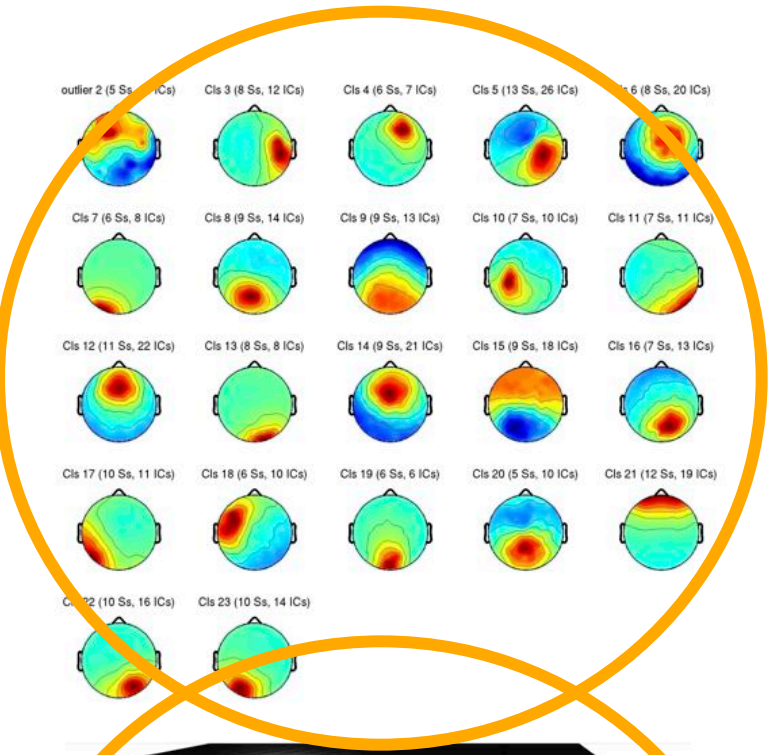
G Leslie & S Makeig,

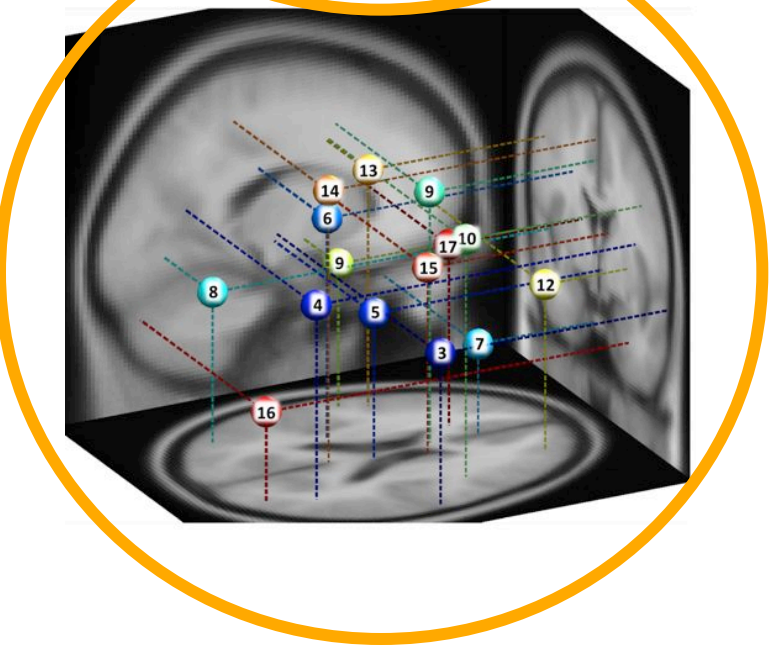
Survey respondents by Internet location

Moving spot animations

G Leslie & S Makeig,

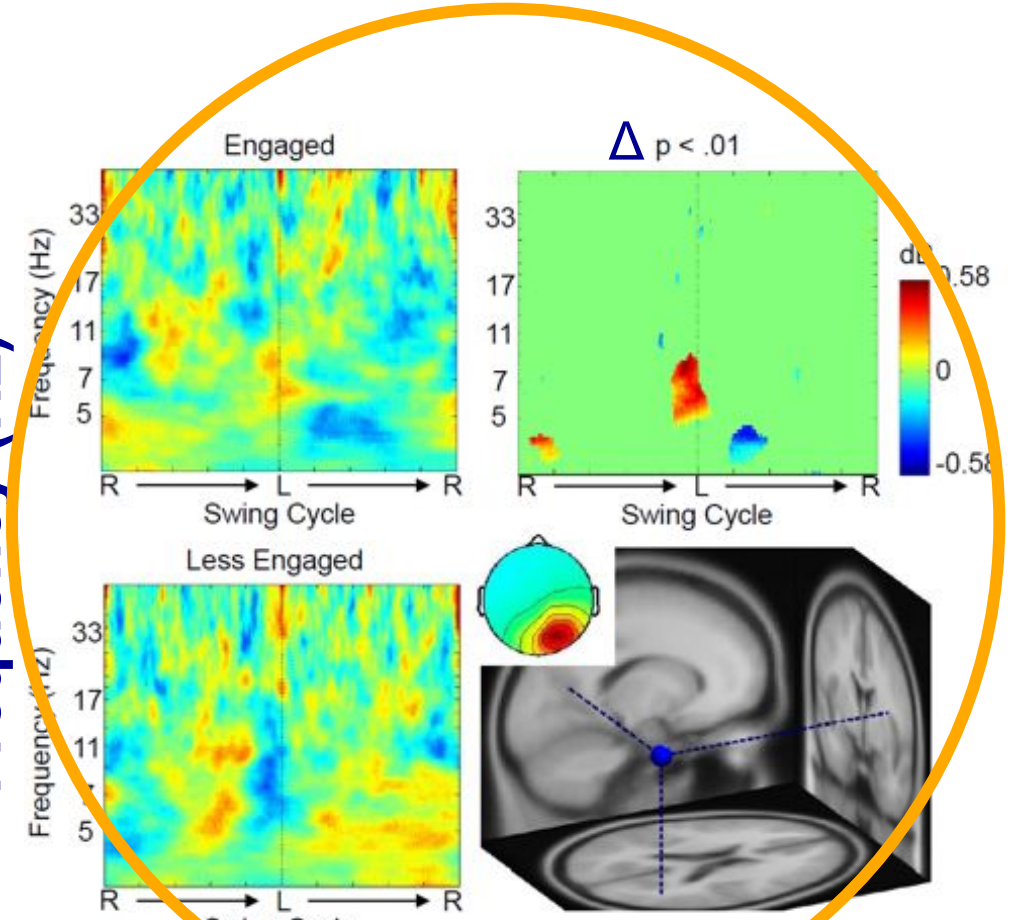
EEG Result





Right TPJ

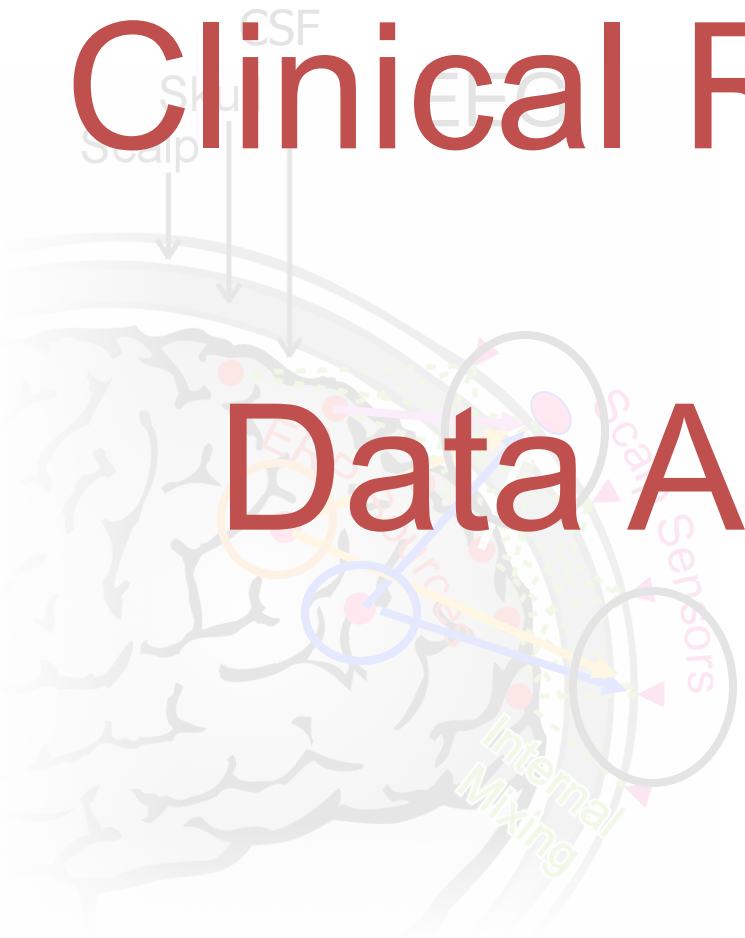
- Theory of Mind
- Sense of Agency
- both Action **&** Emotion Inhibition



Blind EEG Source Separation by ICA

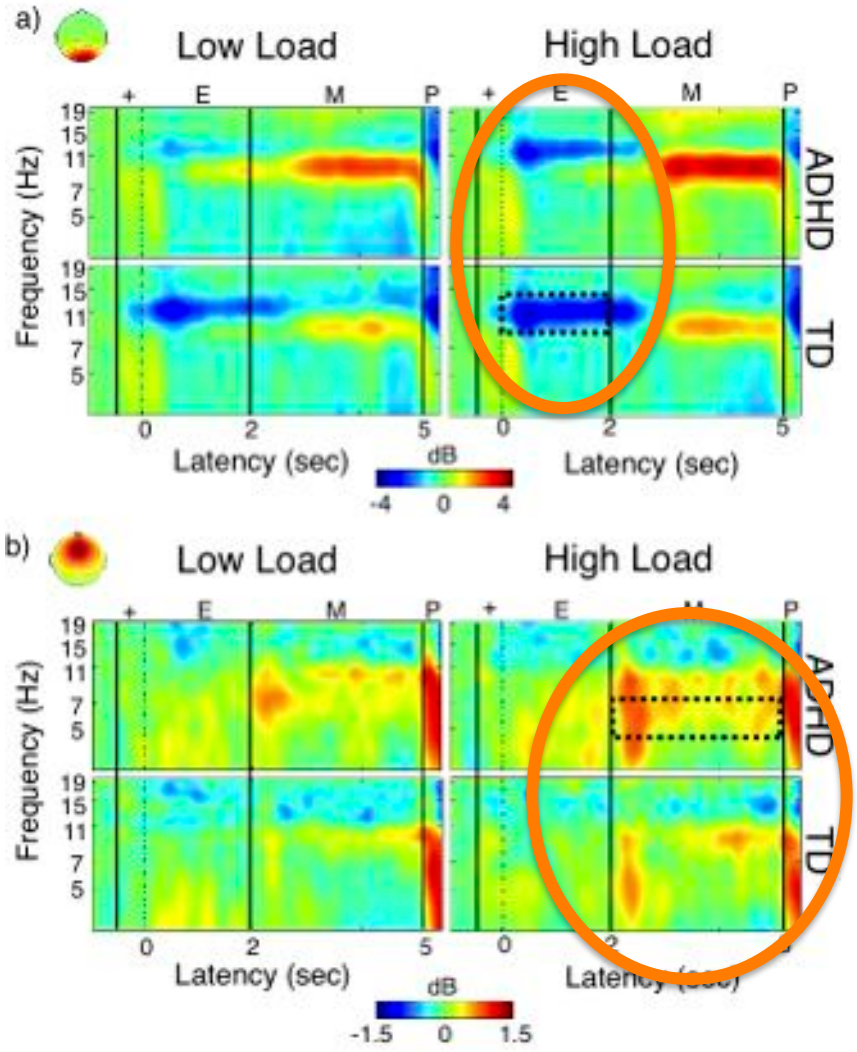
Clinical Research

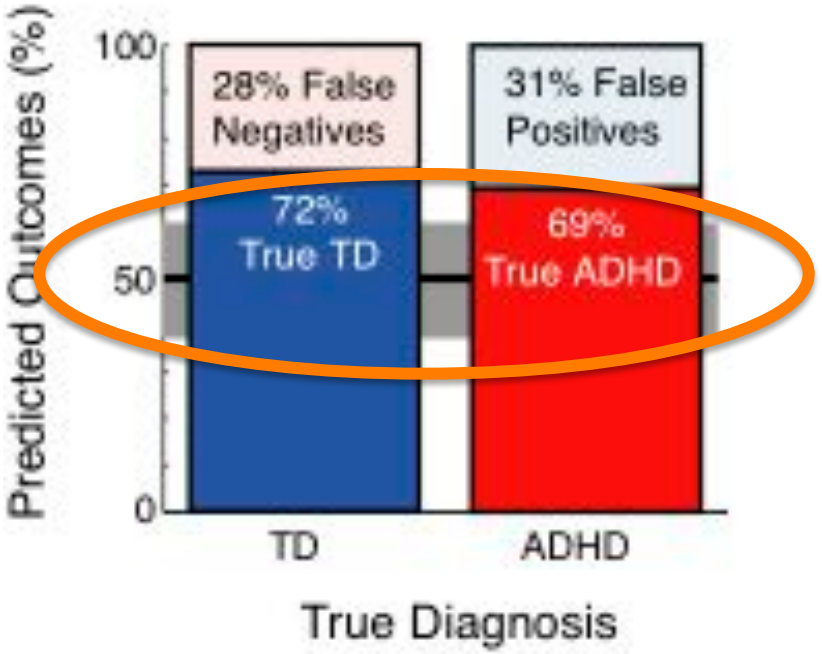
Data Analysis



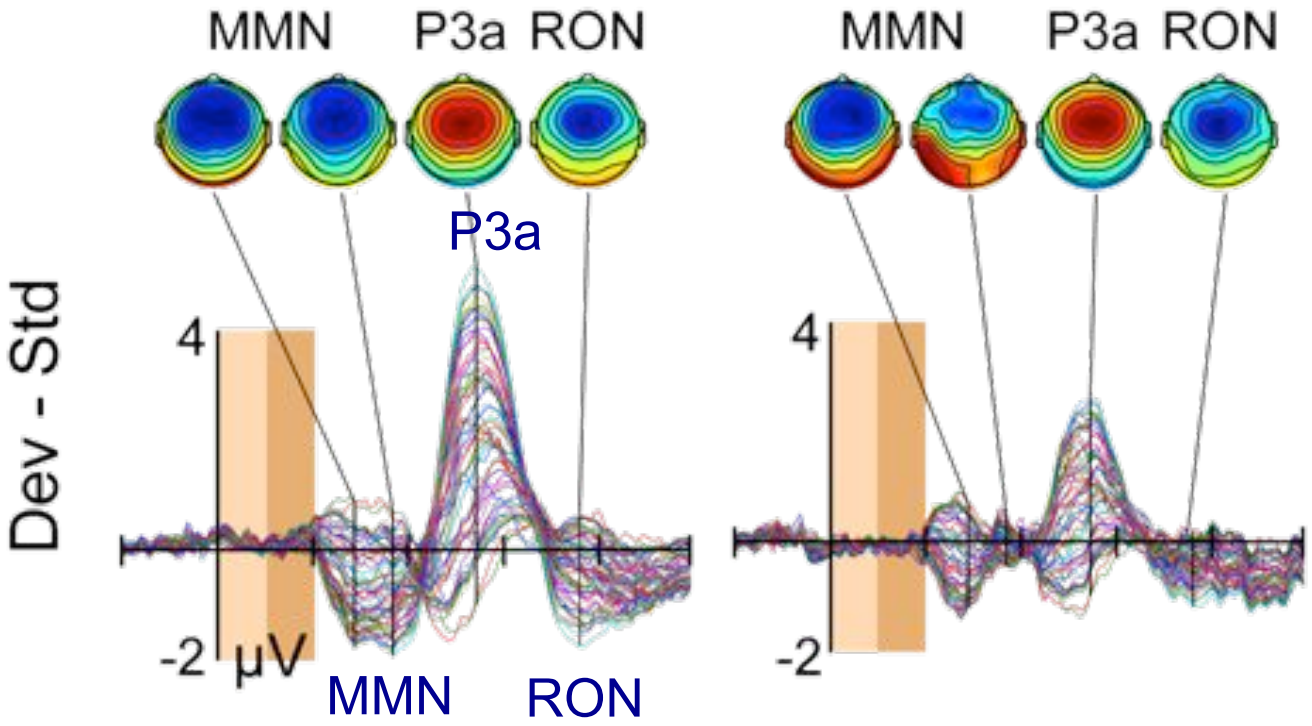
ADHD Working Memory

(Lenartowizc et al., J. Neurosci., 2014)



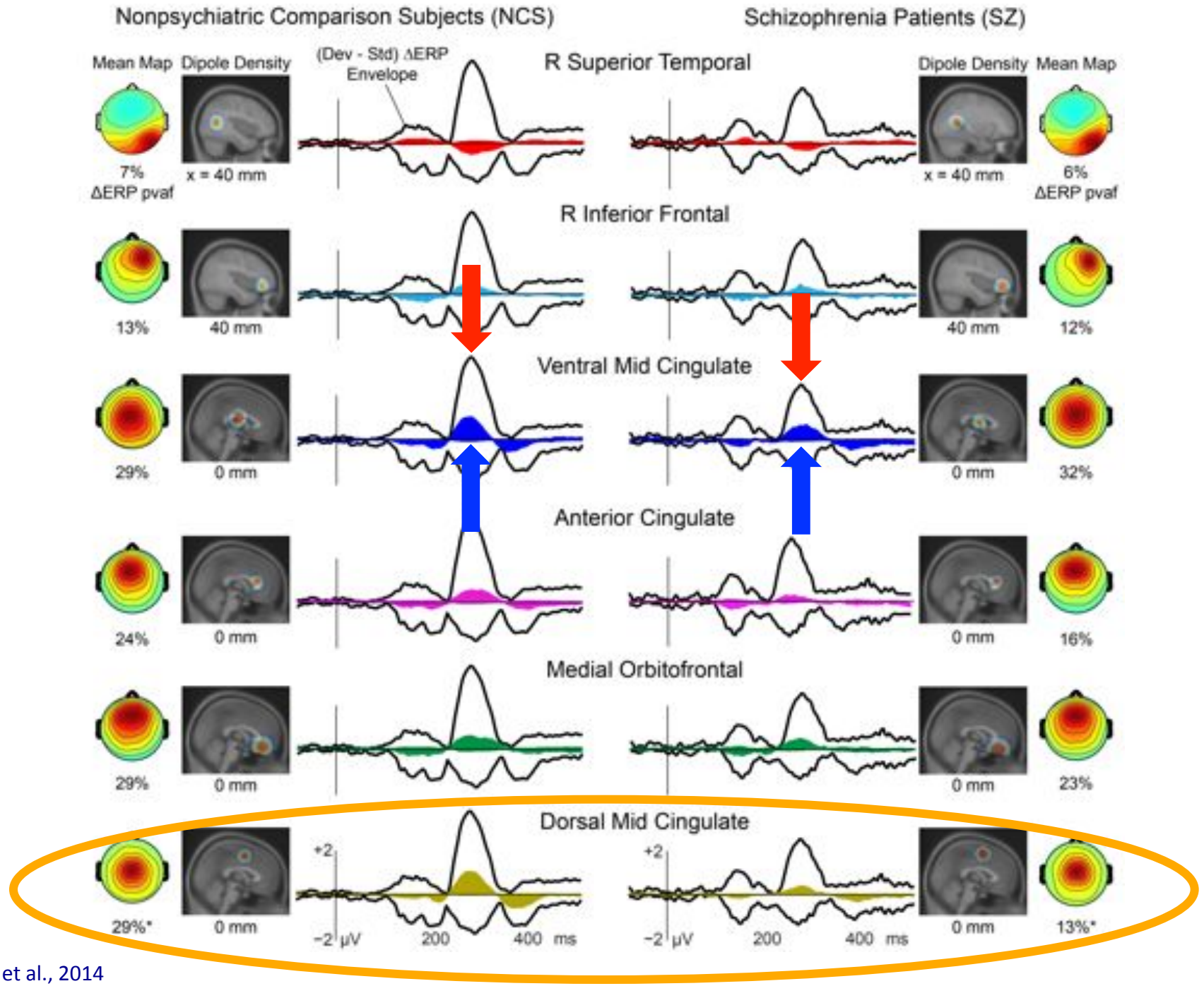


Auditory Deviance Response



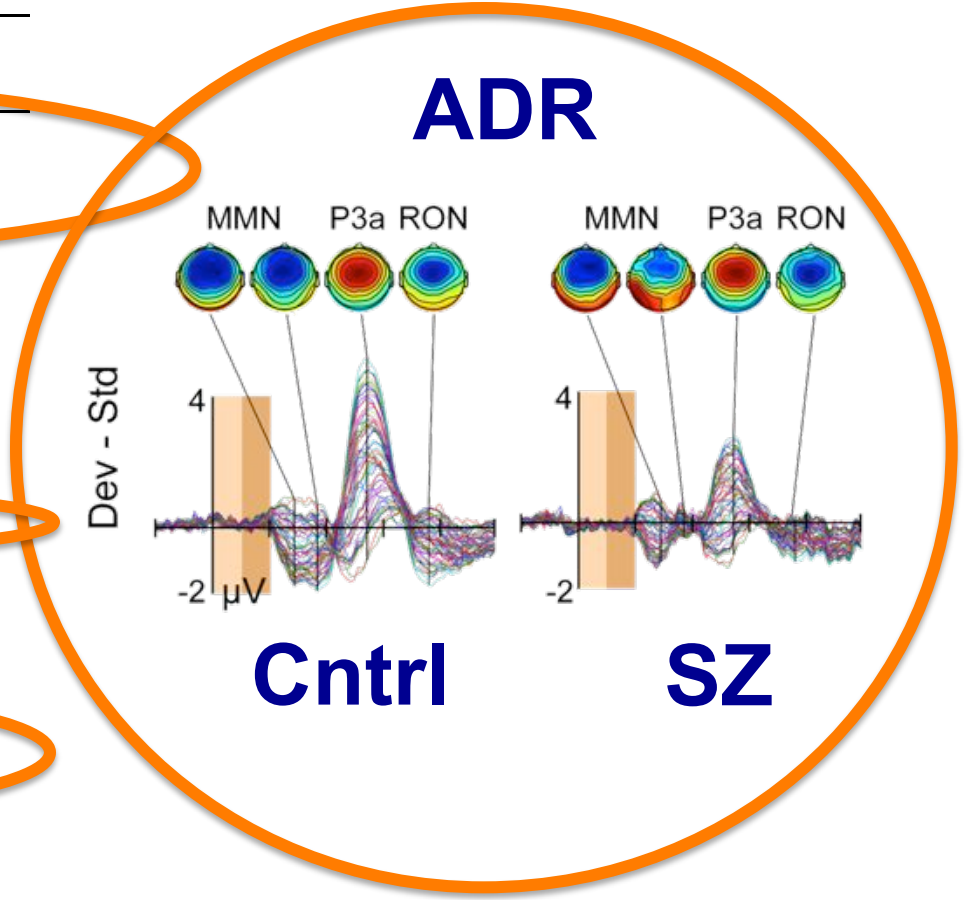
Cntrl **SZ**

The deepest mental trap in electrophysiology is the word/concept "**THE**" !!!



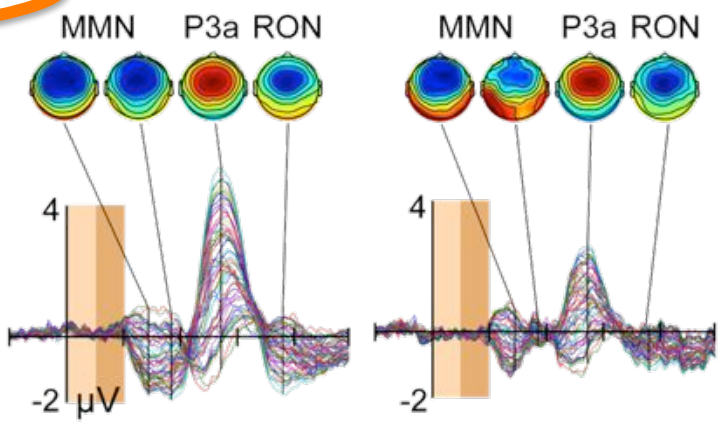
Rissling et al., 2014

PEAK AMPLITUDES	ERP	r^2
Scalp Electrode (Fz)		
Verbal IQ (WRAT)	P3a	0.11
Functional Capacity (UPS	RON	0.12
R Superior Temporal		
Working Memory (LNS Reorder)	RON	0.15
Verbal IQ (WRAT)	RON	0.15
Immediate Verbal Memory (CVLT)	**RON**	**0.28**
Delayed Verbal Memory (CVLT)	RON	0.26
Functional Capacity (UPSA)	**MMN**	**0.48**
Functional Capacity (UPSA)	RON	0.26
R Inferior Frontal		
Negative Symptoms (SANS)	**RON**	**0.36**
Psychosocial Functioning (SOF)	RON	0.24
Auditory Attention (LNS Forward)	**MMN**	**0.38**
Working Memory (LNS Reorder)	**MMN**	**0.30**
Verbal IQ (WRAT)	**MMN**	**0.46**
Ventral Mid Cingulate		
Positive Symptoms (SAPS)	**RON**	**0.29**
Negative Symptoms (SANS)	**P3a**	**0.36**
Immediate Verbal Memory (CVLT)	**RON**	**0.41**
Delayed Verbal Memory (CVLT)	RON	0.24
Verbal IQ (WRAT)	**RON**	**0.29**
Executive Functioning (WCST)	RON	0.24
Anterior Cingulate		
Functional Status (GAF)	MMN	0.18
Functional Status (GAF)	RON	0.17
Immediate Verbal Memory (CVLT)	RON	0.25
Delayed Verbal Memory (CVLT)	RON	0.17
Medial Orbitofrontal		
Positive Symptoms (SAPS)	**P3a**	**0.40**
Negative Symptoms (SANS)	**P3a**	**0.54**
Psychosocial Functioning (SOF)	**P3a**	**0.37**
Functional Capacity (UPSA)	**P3a**	**0.32**
Dorsal Mid Cingulate		
Verbal IQ (WRAT)	P3a	0.15
Executive Functioning (WCST)	MMN	0.18



PEAK LATENCIES	ERP	r^2
Scalp Electrode (Fz)		
---n/a---	---	---
R Superior Temporal		
Functional capacity (UPSA)	MMN	0.25
Delayed Verbal Memory (CVLT)	MMN	0.17
R Inferior Frontal		
Negative Symptoms (SANS)	**RON**	**0.51**
Psychosocial Functioning (SOF)	RON	0.25
Executive Functioning (WCST)	**MMN**	**0.30**
Executive Functioning (WCST)	**P3a**	**0.28**
Ventral Mid Cingulate		
Negative Symptoms (SANS)	**P3a**	**0.33**
Negative Symptoms (SANS)	**RON**	**0.33**
Psychosocial Functioning (SOF)	**P3a**	**0.31**
Verbal IQ (WRAT)	MMN	0.25
Executive Functioning (WCST)	**P3a**	**0.30**
Anterior Cingulate		
Functional Capacity (UPSA)	RON	0.17
Verbal IQ (WRAT)	MMN	0.24
Auditory Attention (LNS-Forward)	MMN	0.17
Medial Orbitofrontal		
Negative Symptoms (SANS)	**RON**	**0.41**
Positive Symptoms (SAPS)	**RON**	**0.40**
Auditory Attention (LNS-Forward)	**MMN**	**0.29**
Executive Functioning (WCST)	**P3a**	**0.32**
Dorsal Mid Cingulate		
Negative Symptoms (SANS)	MMN	0.20
Negative Symptoms (SANS)	P3a	0.17
Global Functioning (GAF)	RON	0.24
Functional Capacity (UPSA)	P3a	0.13

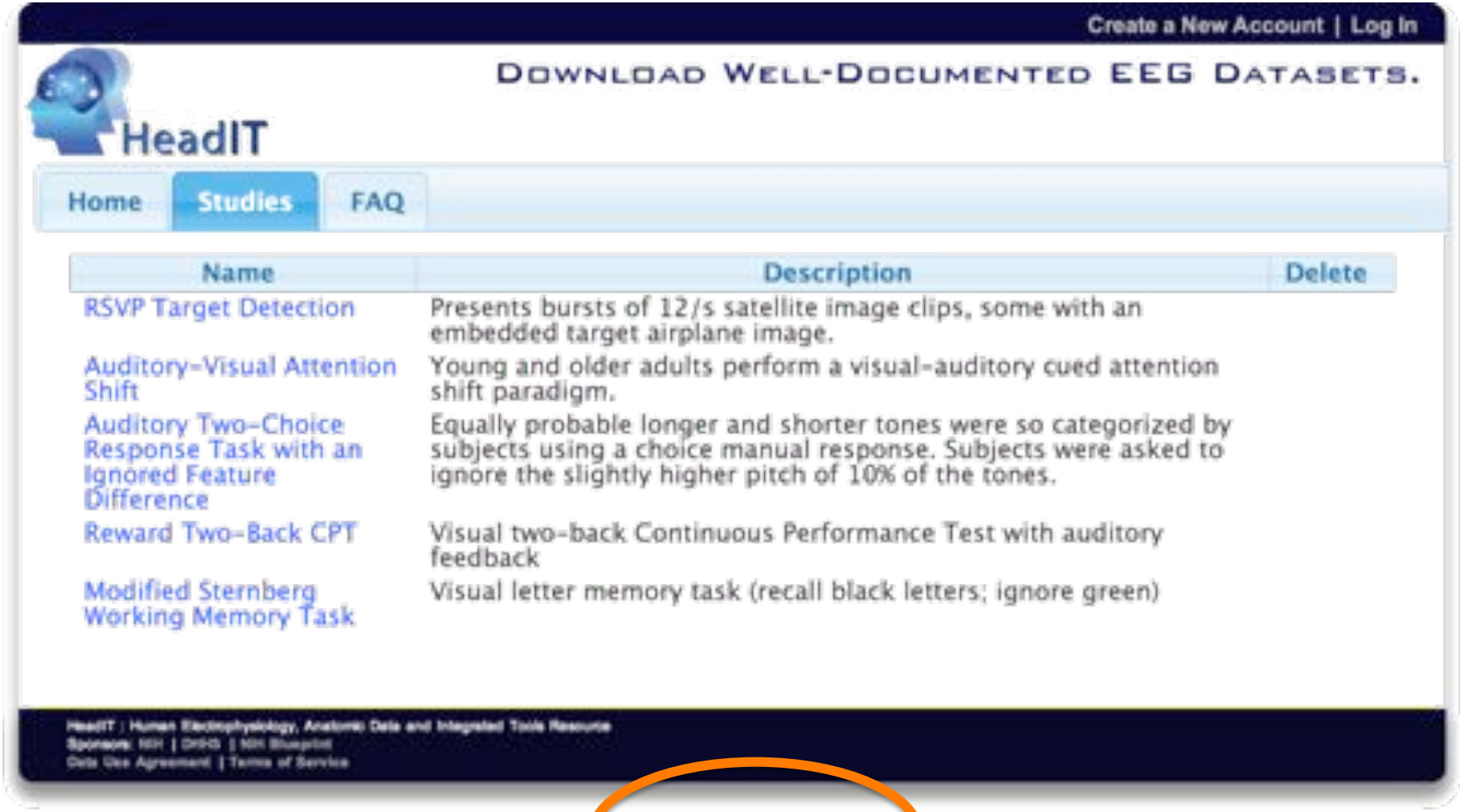
ADR



Cntrl **SZ**

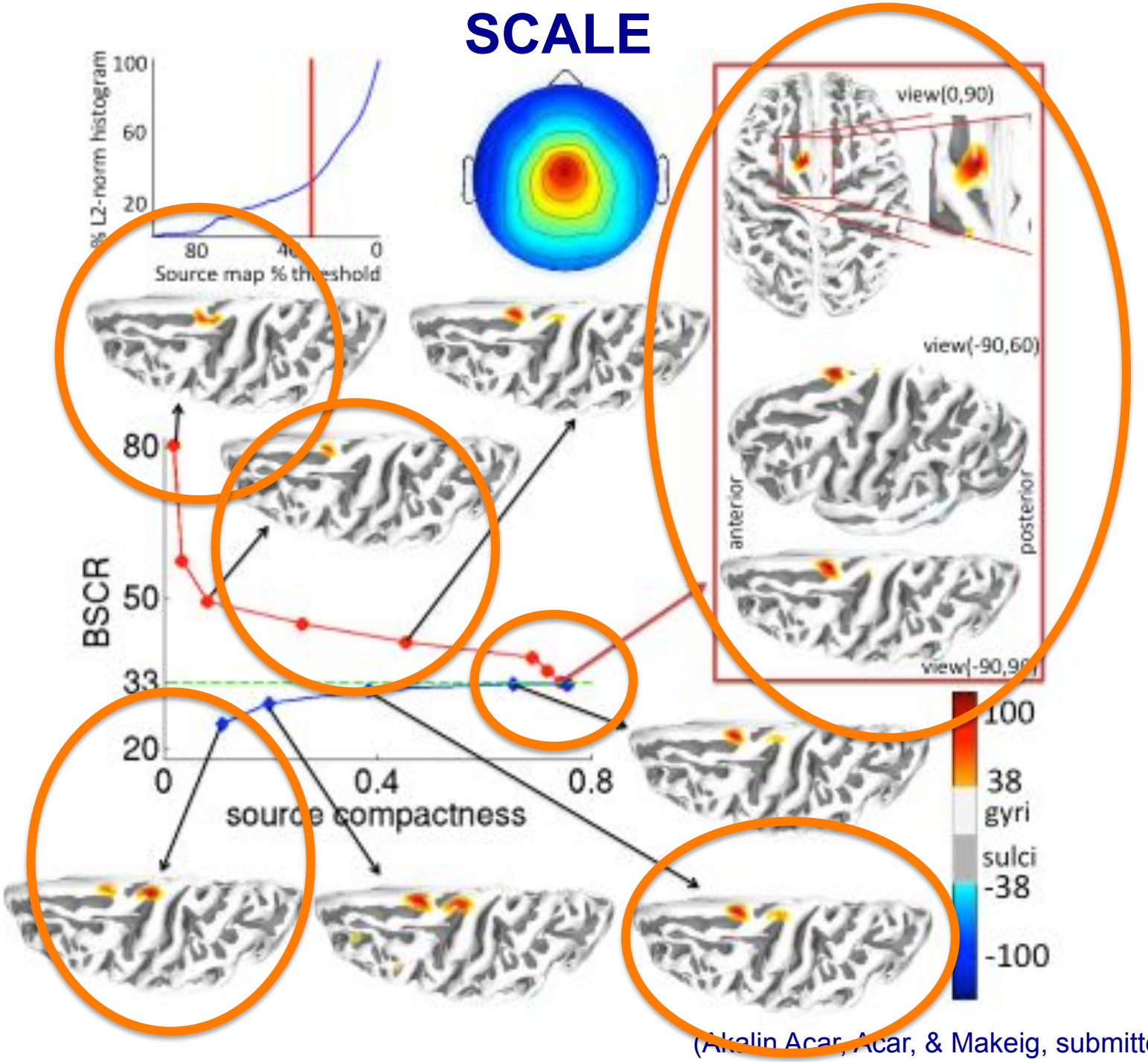
HeadIT

A Human Electrophysiology, Anatomic Data, and Integrated Tools Resource



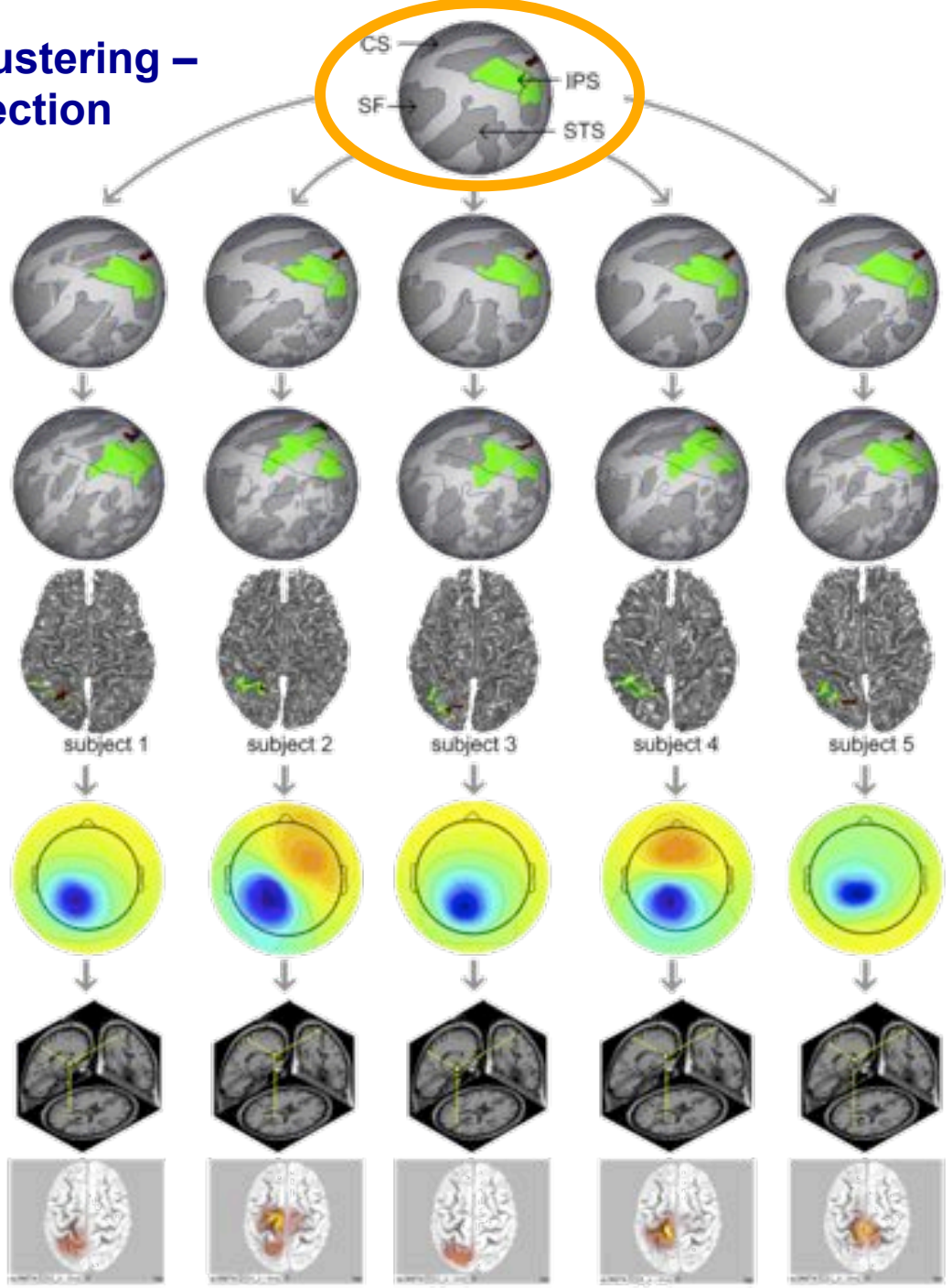
HeadIT.org

SCALE



(Akalin Acar, Acar, & Makeig, submitted 2015)

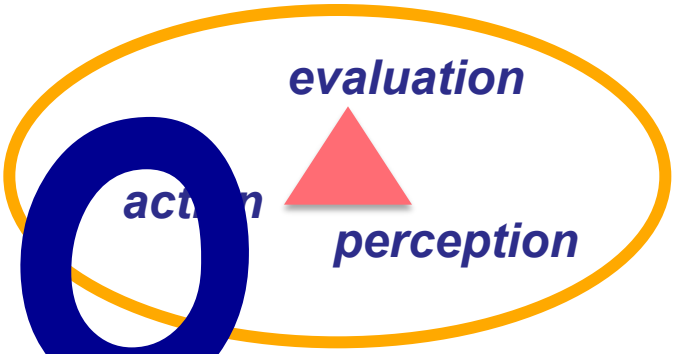
Topological source clustering – 2-D measure projection



Arthur Tsai et al., *NeuroImage*, 2014

Embodied Cognition & Agency

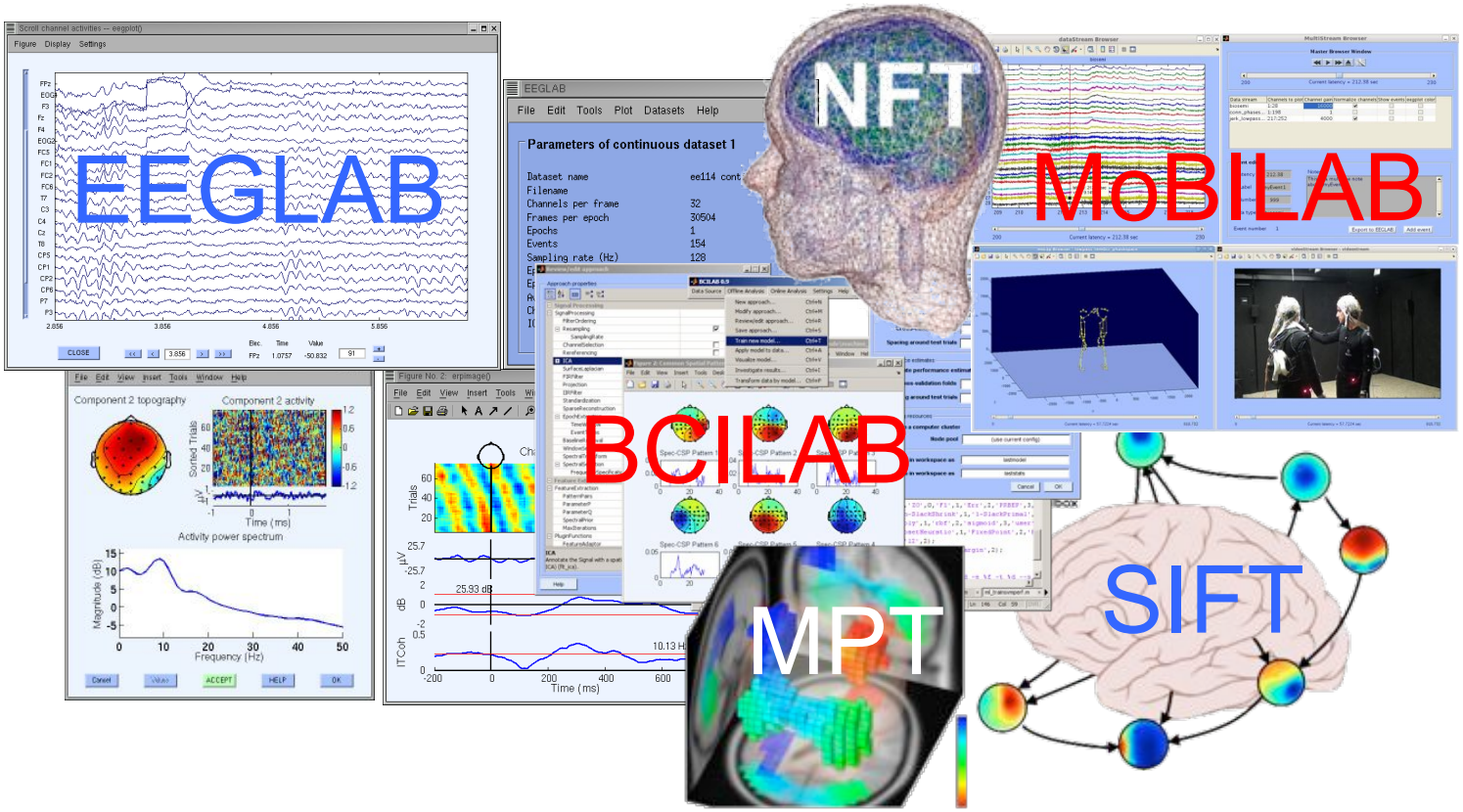
Brain processes have evolved and function to optimize the outcome of the behavior the brain organizes in response to *perceived challenges and opportunities*.



Who am I?

Brains seize the opportunity of the moment!

SCCN Open Source Software Tools for MATLAB etc.



Tools now available -- but a two-cultures problem …

S Makeig, 2012

The Beginning

fEEG, BCI, MoBI,

NFB, BrainStim …