Imaging Empathy

with

Mobile Brain/Body Imaging

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Sepatember, 2012

Embodied Agency

Brain processes

have evolved and function

to optimize the ***outcome***

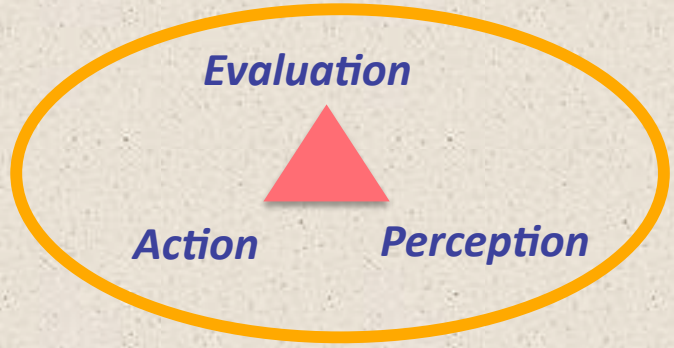
of the ***behavior***

the brain organizes

in response to

perceived challenges

and opportunities.



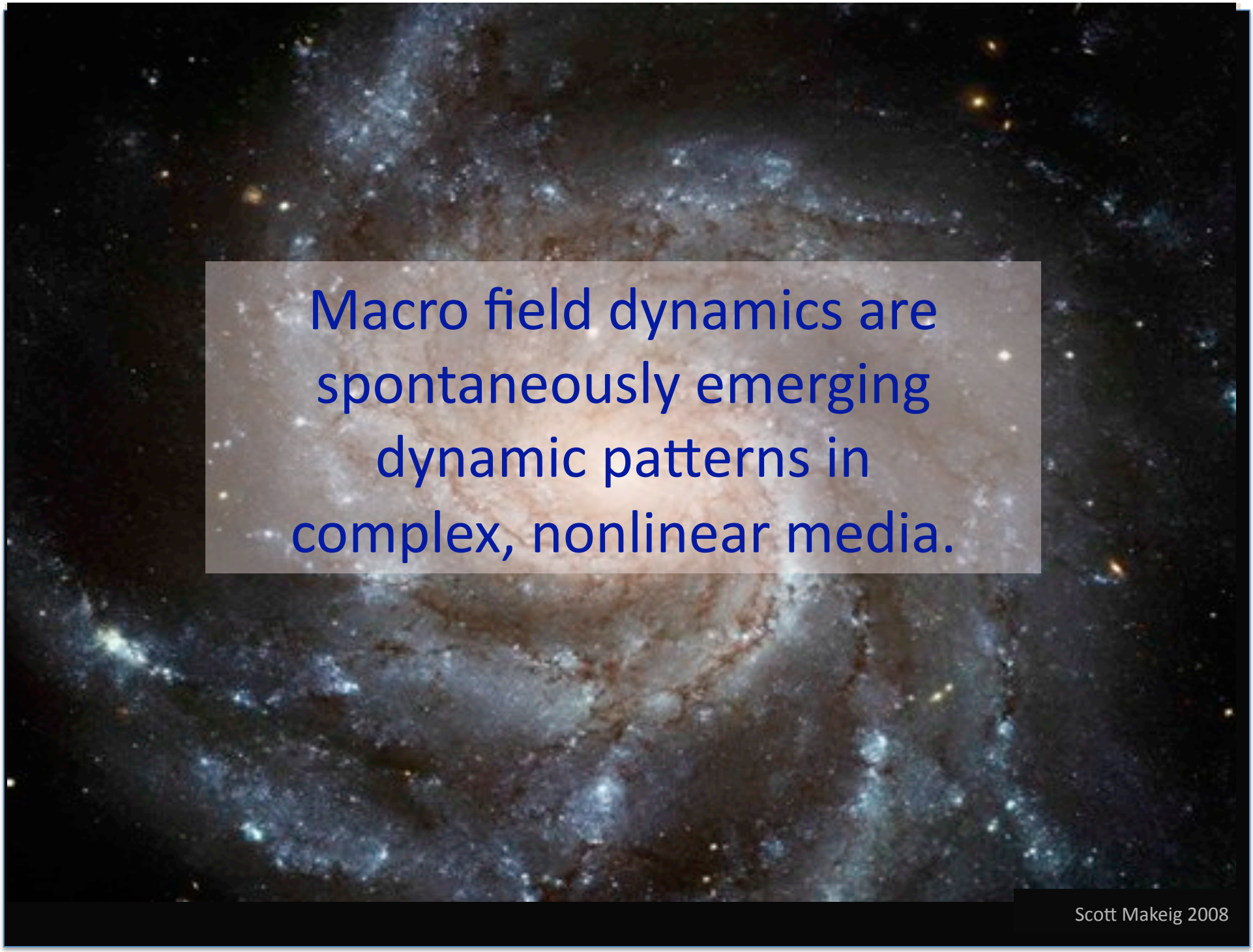
Brains meet the challenge of the moment!

S Makeig 2010

What is EEG?

- Brain electrical activity
- A small portion of cortical brain electrical activity
- An even smaller portion of total brain electrical activity

- ***Which* portion?**
- **With *what* functional significance?**

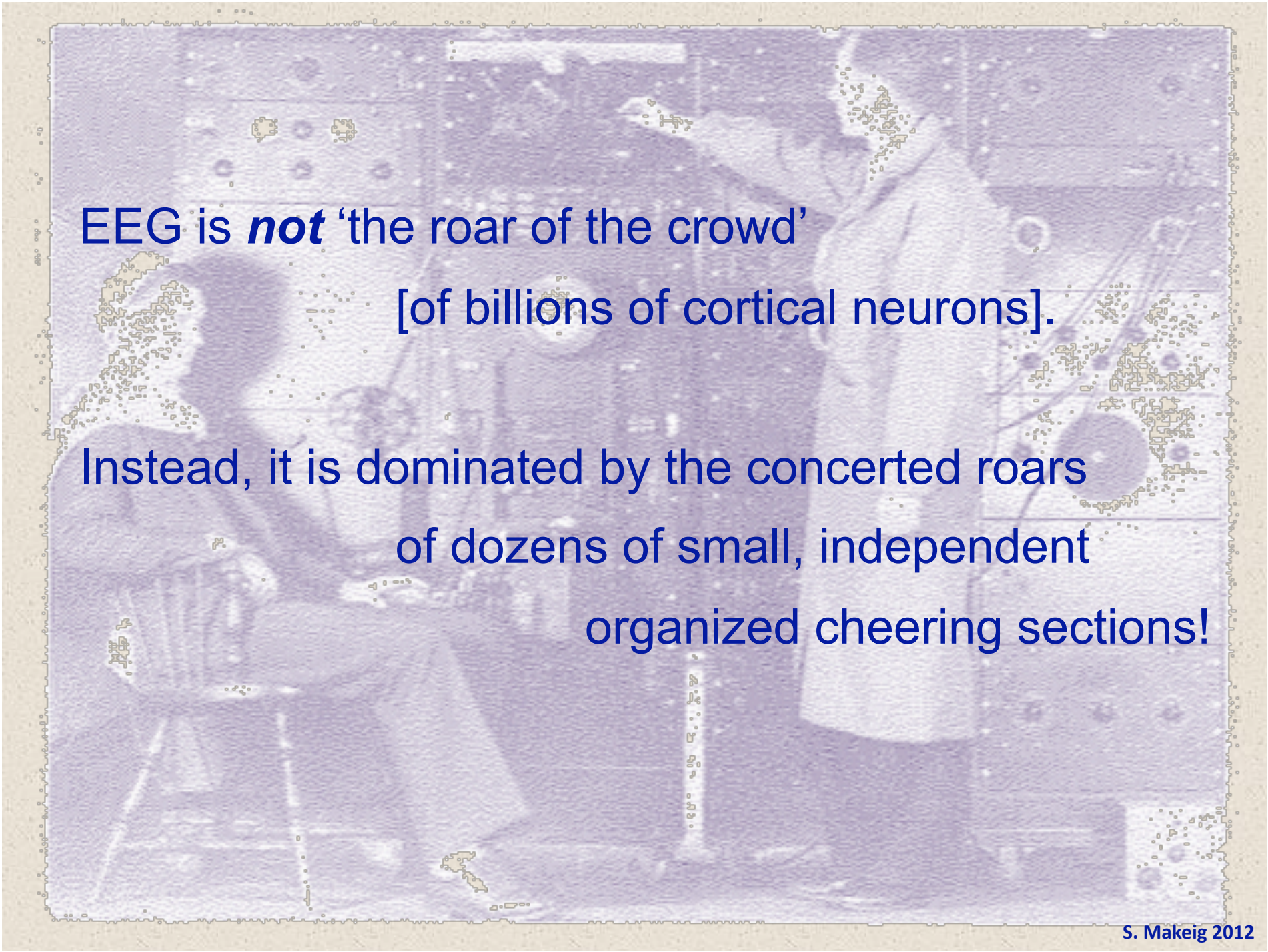

Macro field dynamics are spontaneously emerging dynamic patterns in complex, nonlinear media.
Scott Makeig 2008

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

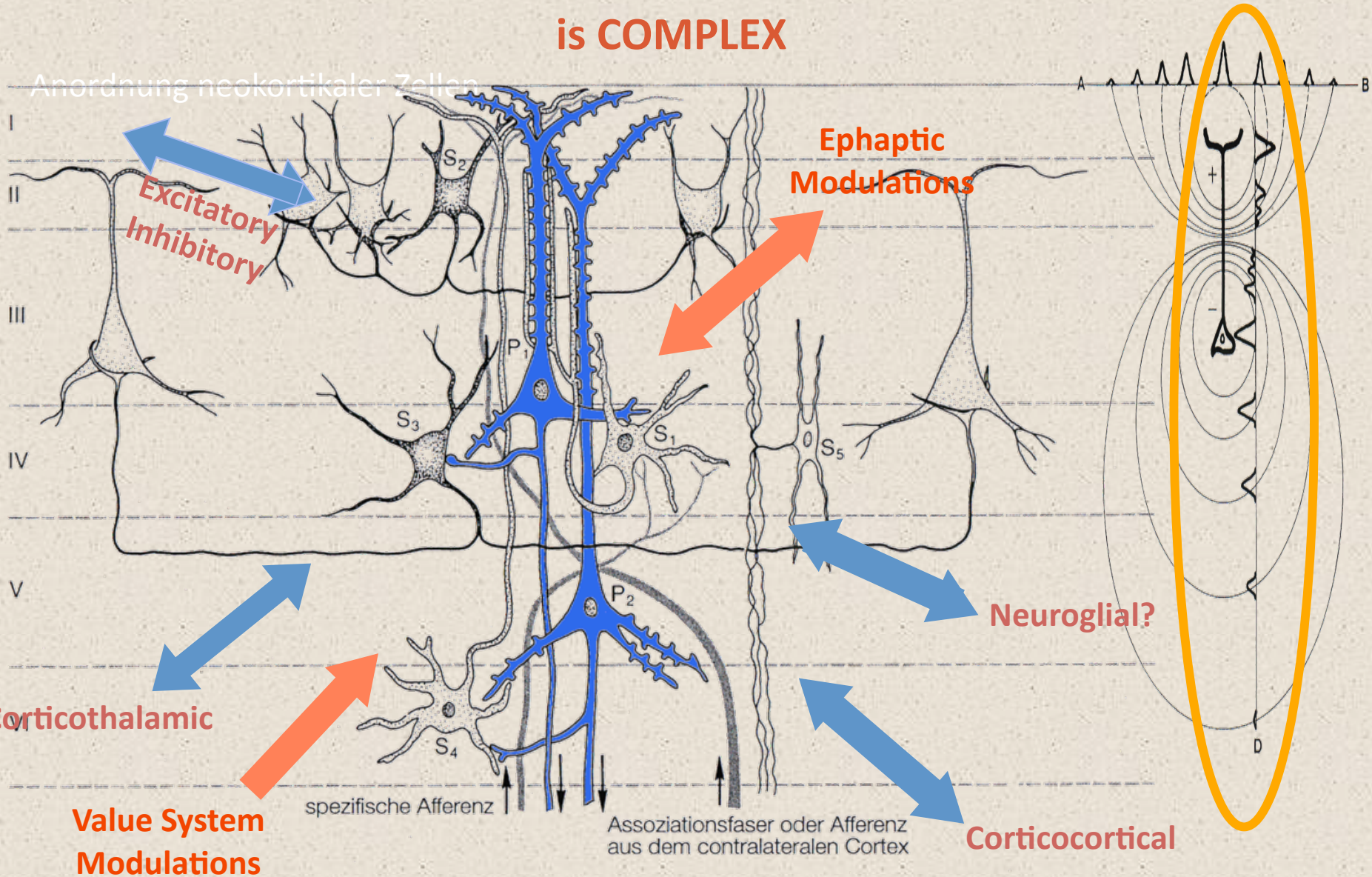
Alan Friedman

Phase cones (Freeman)

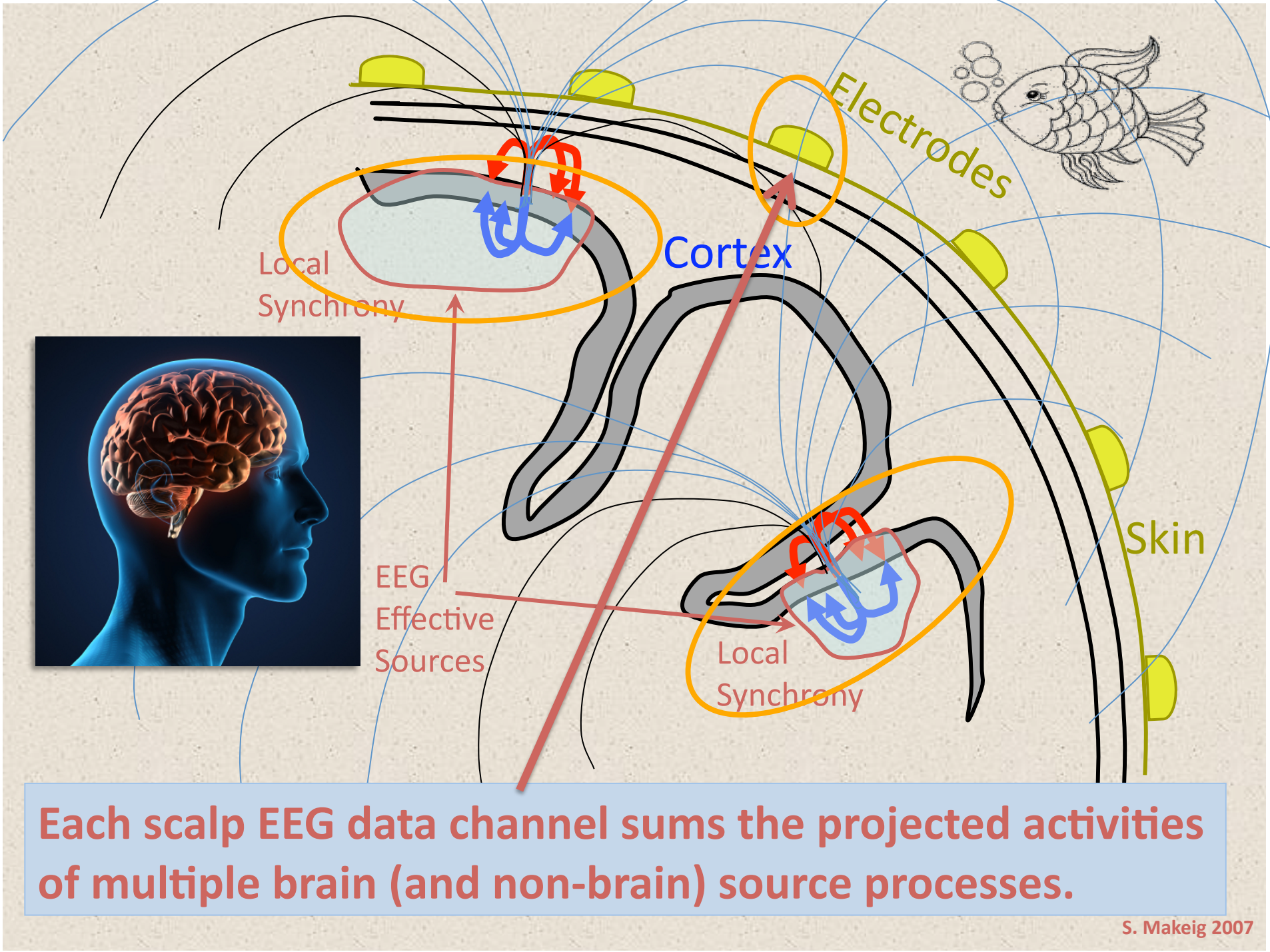
Avalanches (Plenz)


EEG is ***not*** 'the roar of the crowd'
[of billions of cortical neurons].
Instead, it is dominated by the concerted roars
of dozens of small, independent
organized cheering sections!
S. Makeig 2012

The generation and modulation of EEG / LFP is COMPLEX



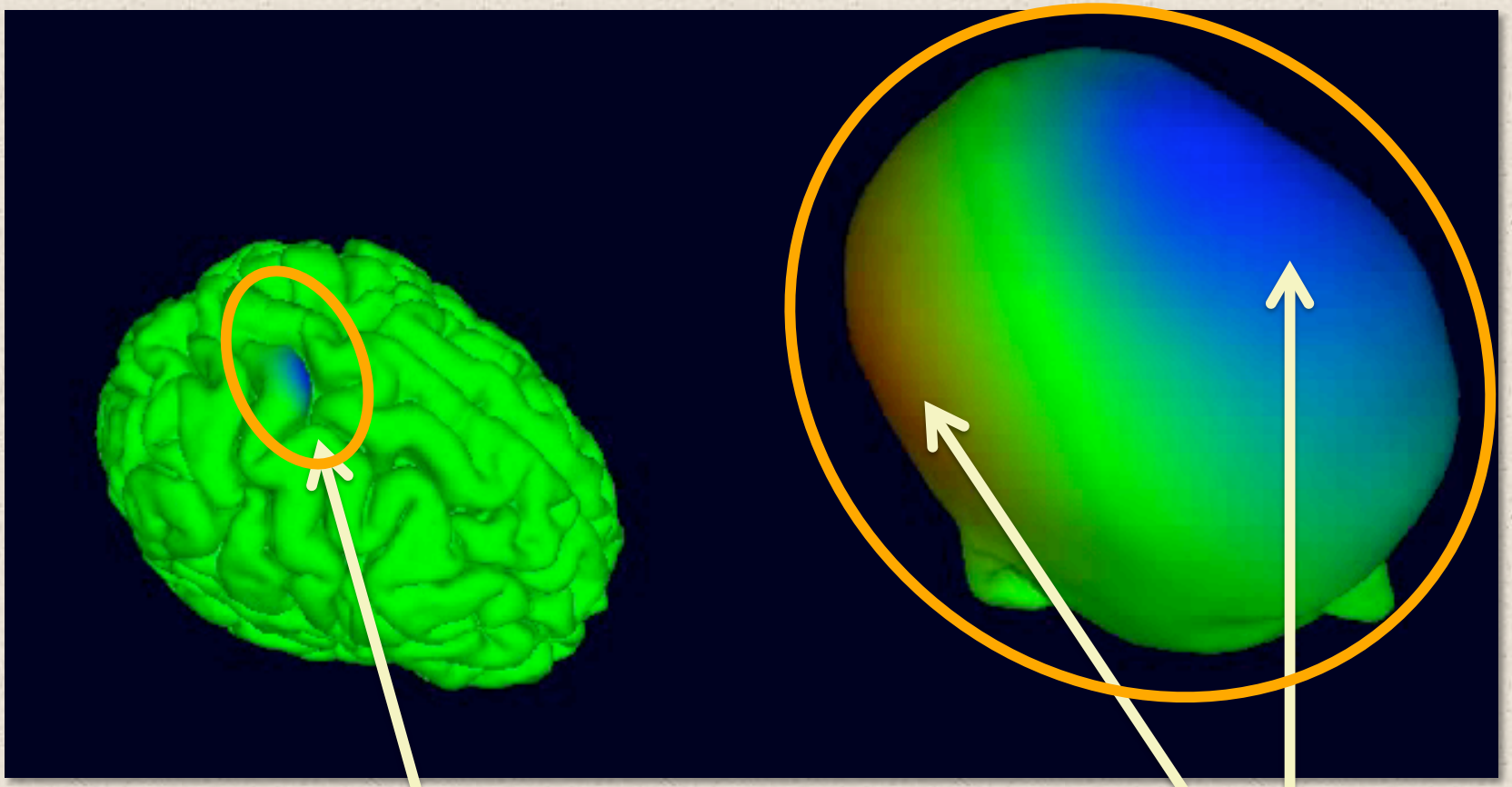
S. Makeig 2007



Each scalp EEG data channel sums the projected activities of multiple brain (and non-brain) source processes.

S. Makeig 2007

The very broad EEG point-spread function

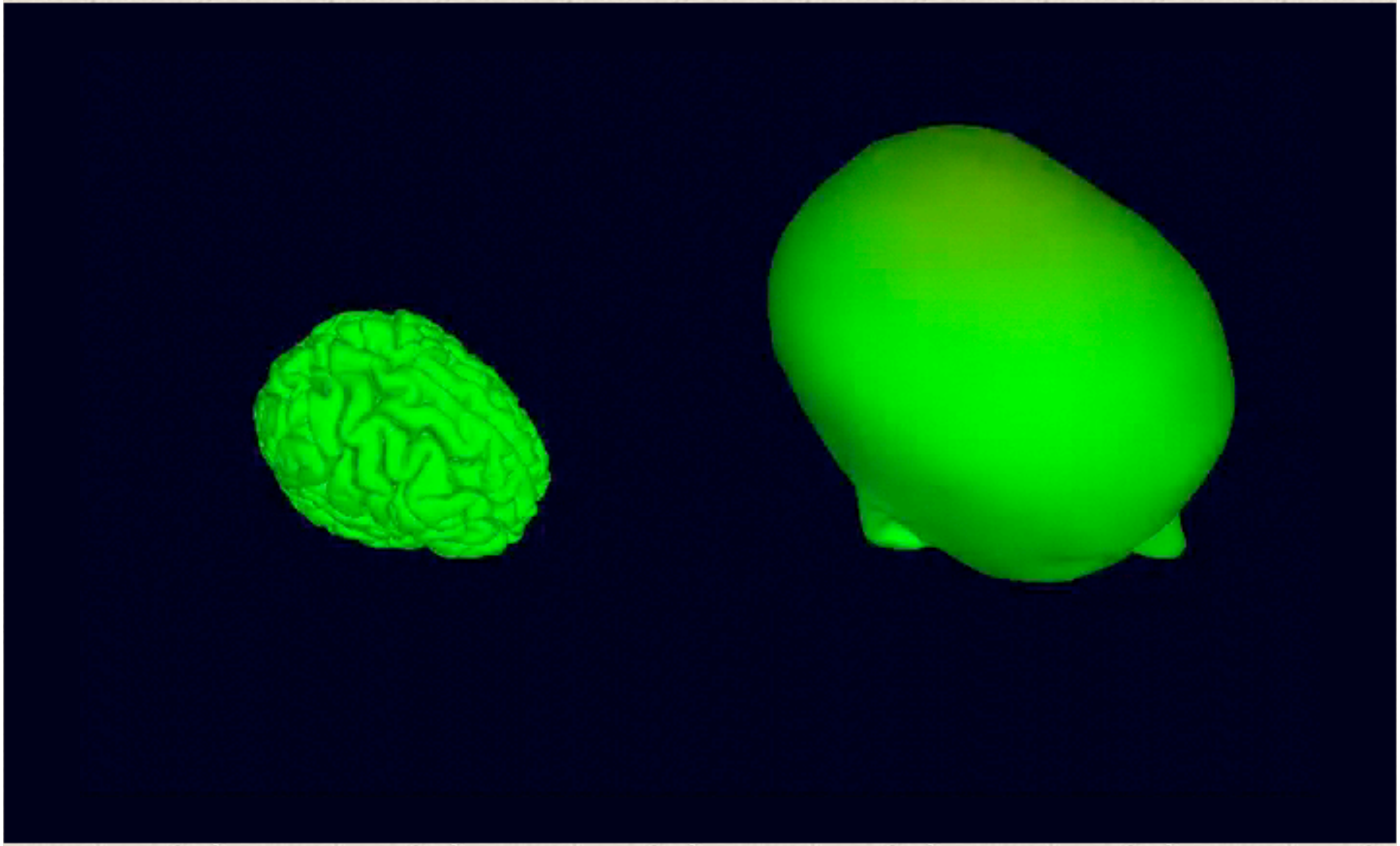


Simulated parietal source

Very broad projected scalp potentials

Akalin Acar & Makeig 2010

The very broad EEG point-spread function



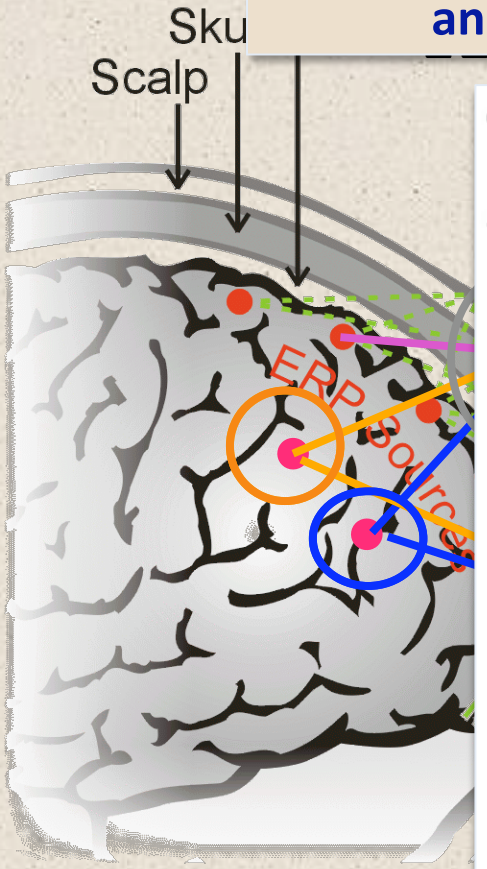
Simulated cm^2-scale multi-source activity, and its EEG projection

Akalin Acar & Makeig 2010

Blind EEG Source Separation by Independent Component Analysis

Tony Bell, developer of Infomax ICA

ICA can find distinct EEG source activities -- and their 'simple' scalp maps!



Independent Component Analysis of Electroencephalographic Data

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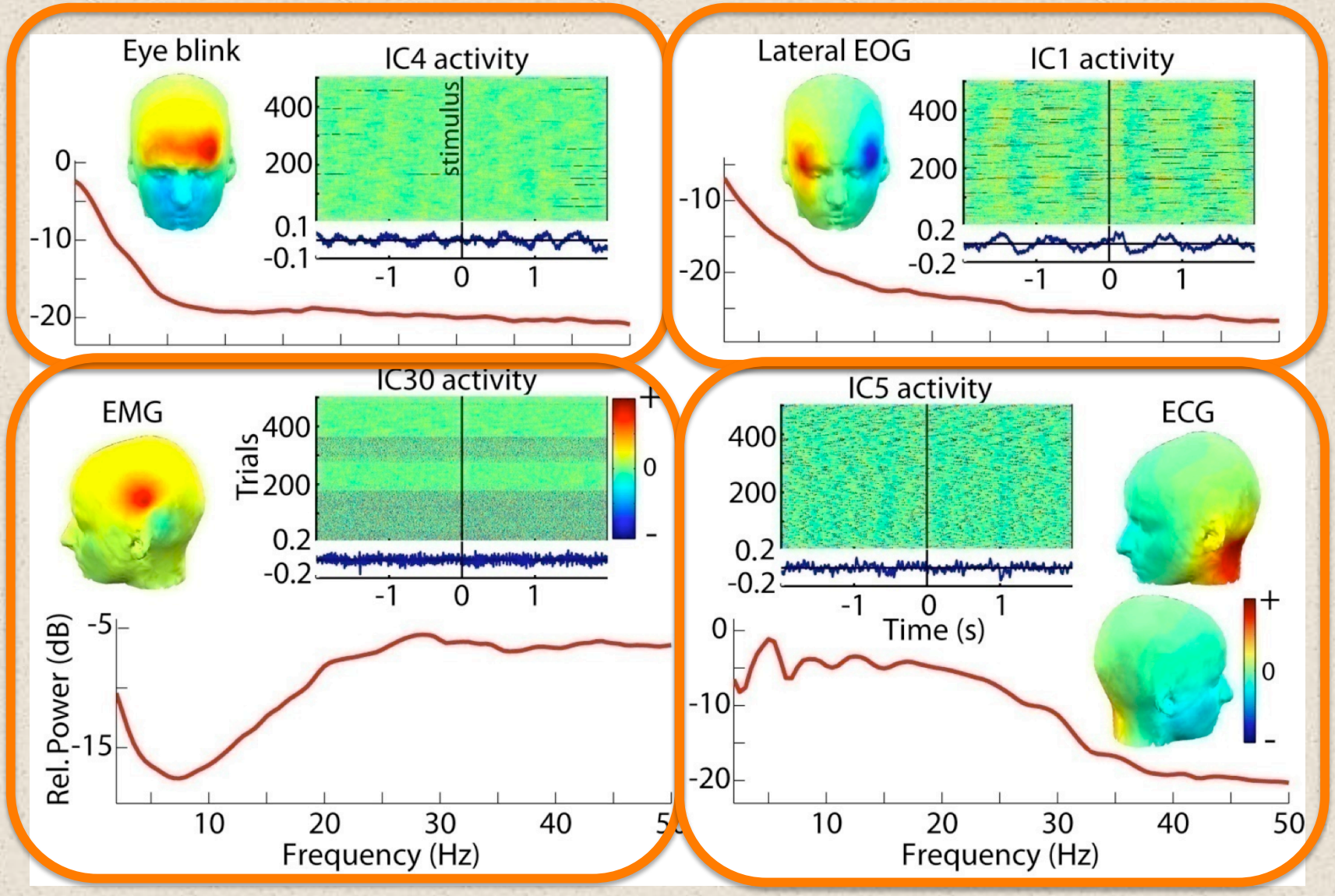
Abstract

Because of the distance between the skull and brain and their different resistivities, electroencephalographic (EEG) data collected from any point on the human scalp includes activity generated within a large brain area. This spatial smearing of EEG data by volume conduction does not involve significant time delays, however, suggesting that the Independent Component Analysis (ICA) algorithm of Bell and Sejnowski (1) is suitable for performing blind source separation on EEG data. The ICA algorithm separates the problem of source identification from that of source localization. First results of applying the ICA algorithm to EEG and event-related potential (ERP) data collected during a sustained auditory detection task show: (1) ICA training is insensitive to different random seeds. (2) ICA may be used to segregate obvious artifactual EEG components (line and muscle noise, eye movements) from other sources. (3) ICA is capable of isolating overlapping EEG phenomena, including alpha and theta bursts and spatially-separable ERP components, to separate ICA channels. (4) Nonstationarities in EEG and behavioral state can be tracked using ICA via changes in the amount of residual correlation between ICA-filtered output channels.

S. Makeig, S. Enghoff (2000)

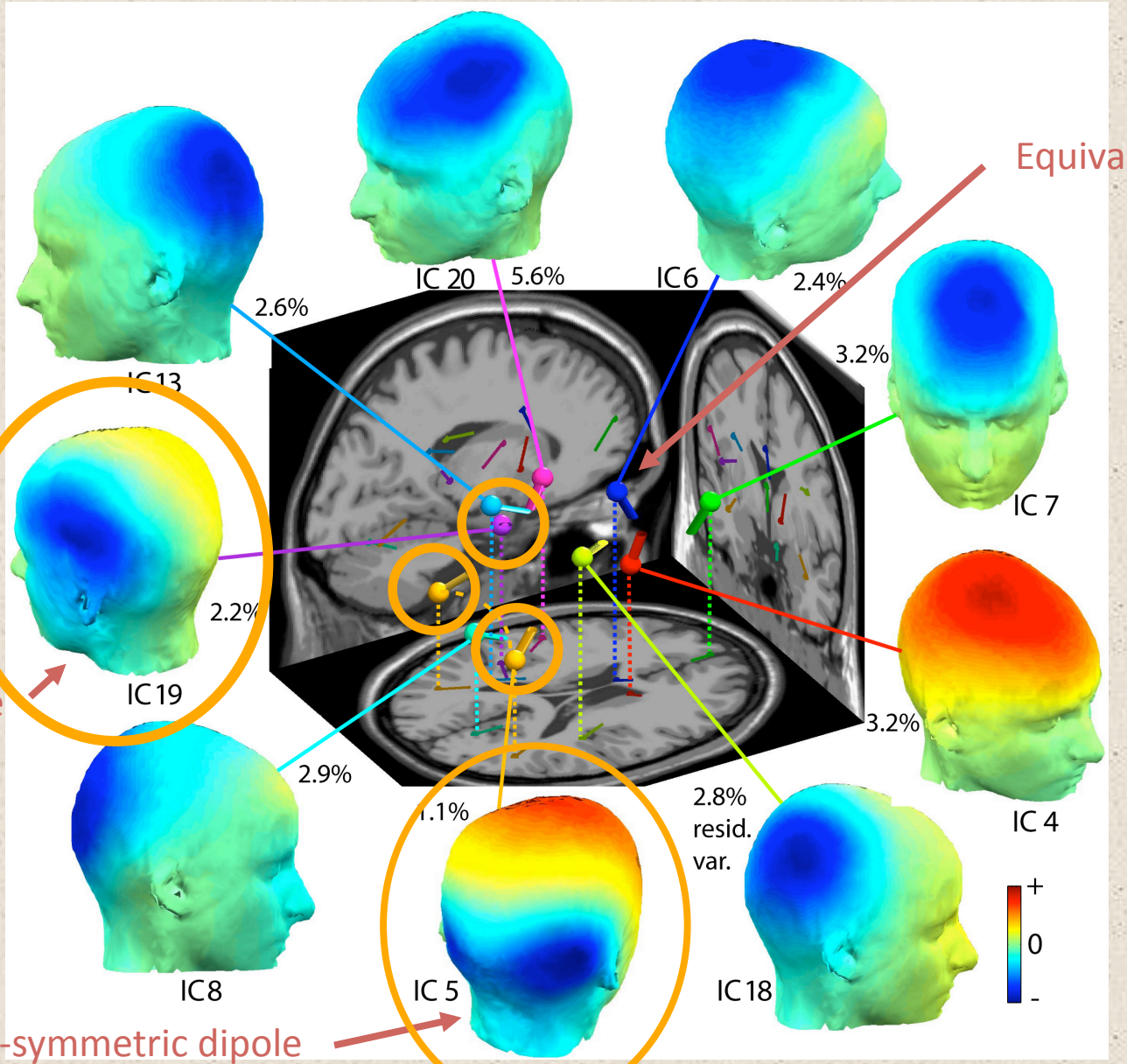
ICA finds Non-Brain Independent Component (IC) Processes …



… separates them from the remainder of the data …

J. Onton & S. Makeig 2006

ICA also separates cortical brain IC processes

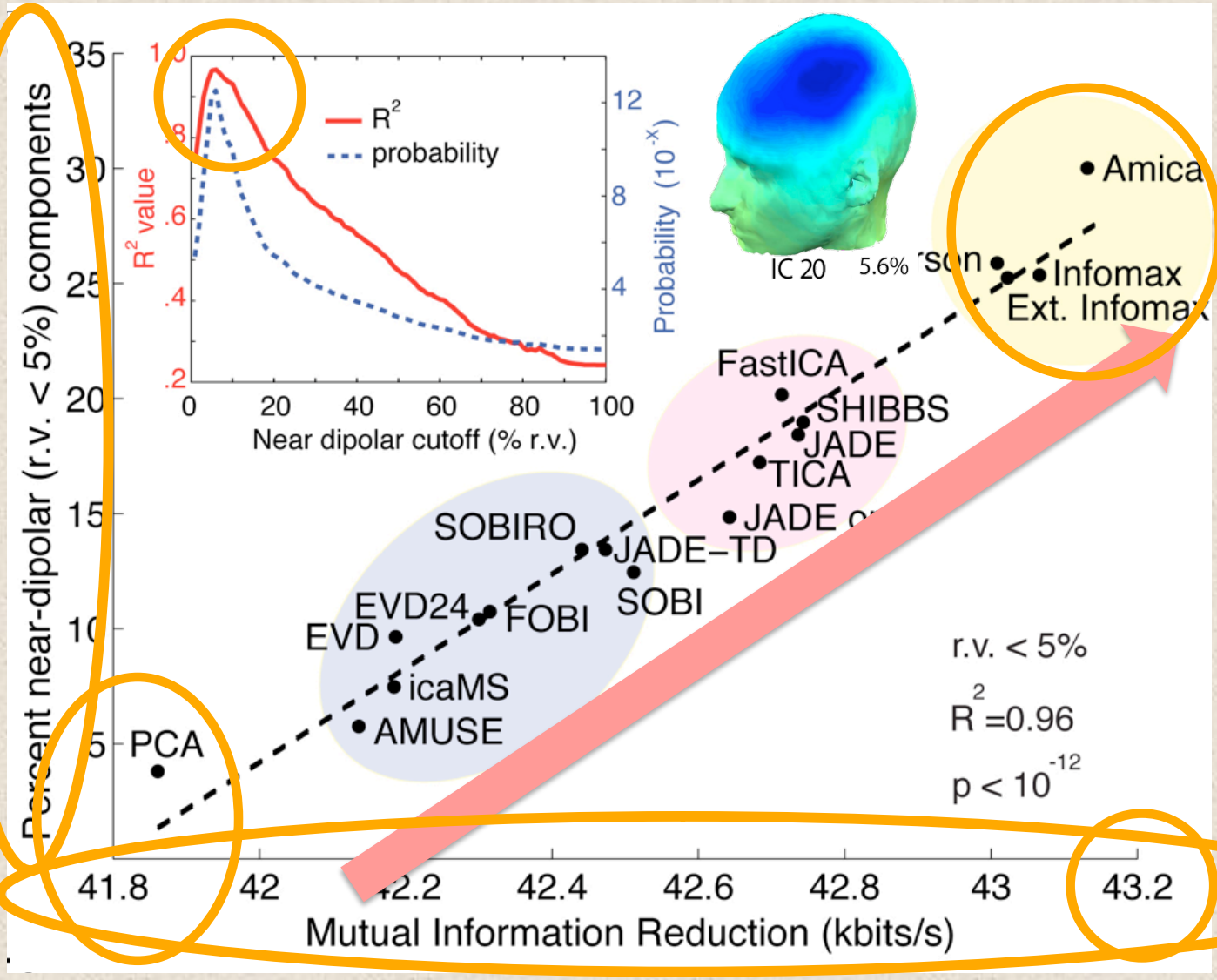


Equivalent dipoles

Single dipole component

Dual-symmetric dipole component

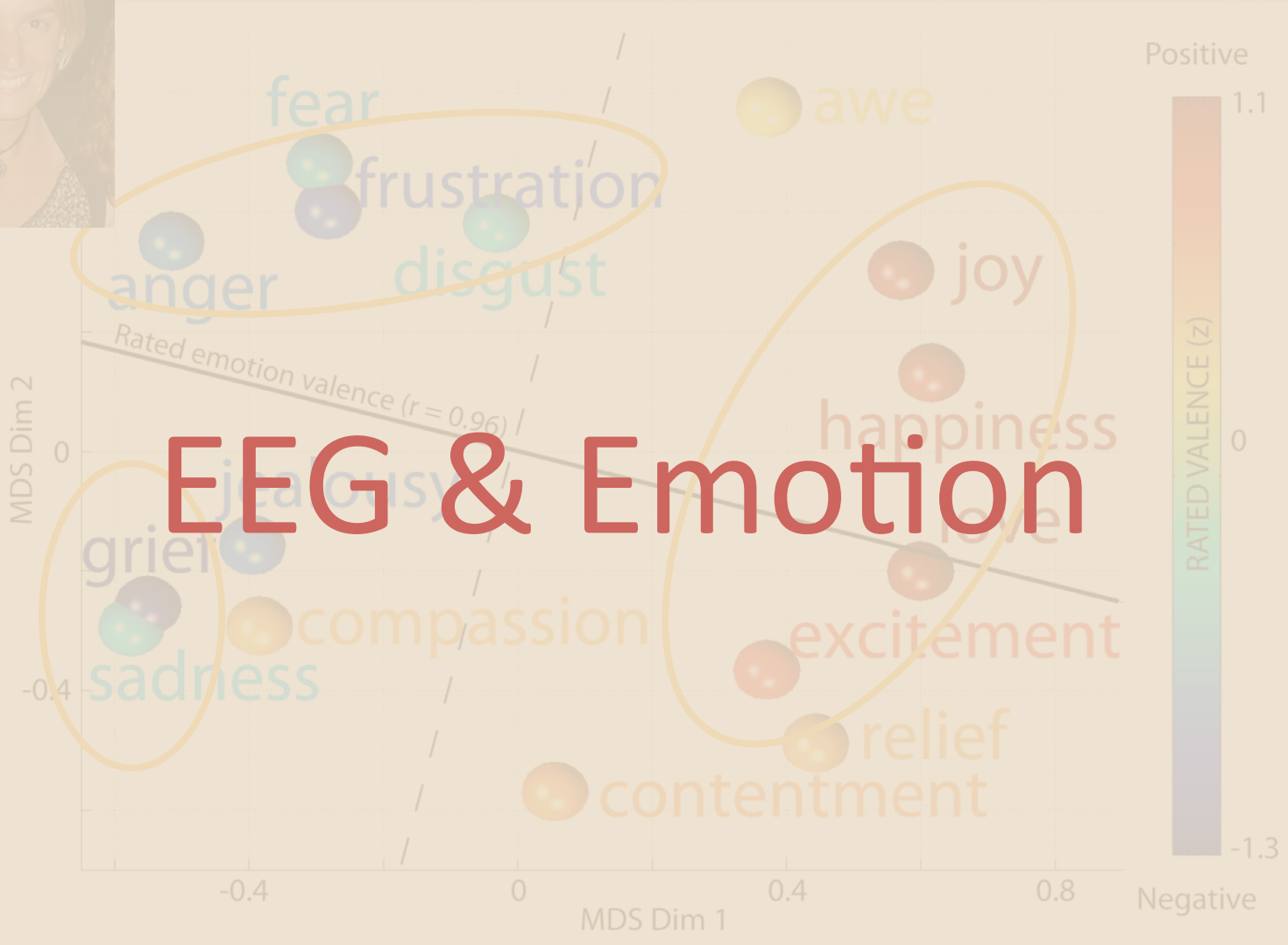
Julie Onton & S. Makeig (2006)



Independent EEG Components are Dipolar

Delorme, Palmer, Onton, & Makeig, 2012

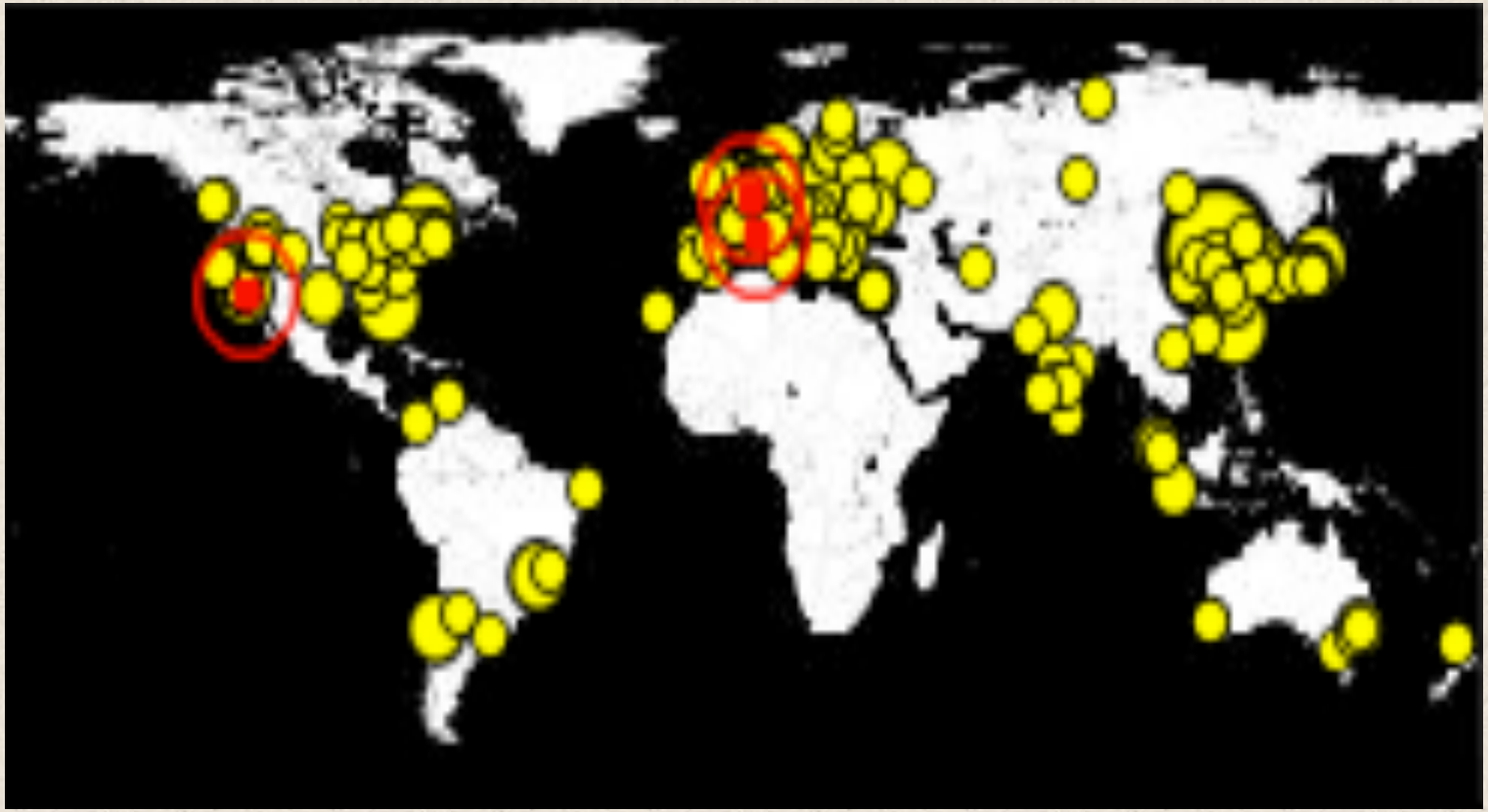
Changes in the distribution of high-frequency broadband EEG power with imagined emotion



EEG & Emotion

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

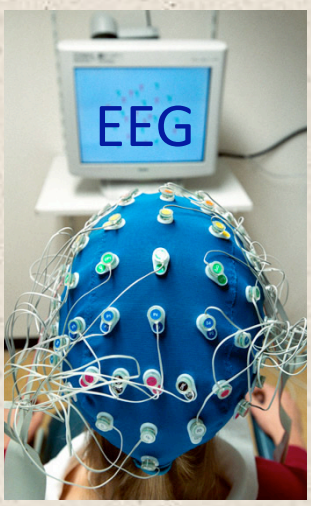
SCCN Open Source Software Tools for MATLAB

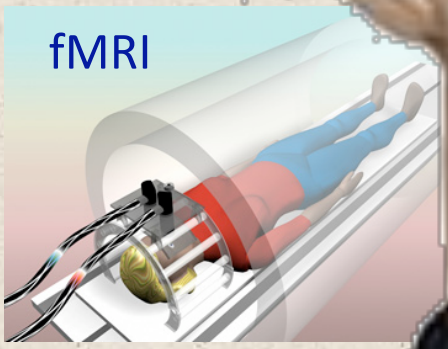


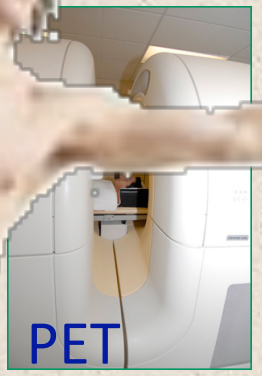
S Makeig, 2012

Brain imaging during motor behavior?

- Nearly all brain imaging studies (MEG, PET, fMRI, and EEG) are conducted in rigidly stationary seated or prone positions with only the most minimal finger movements allowed.







Why?

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

- **But this limitation is highly artificial.** Nearly all our life involves *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

Mobile Brain/Body Imaging (MoBI) Concept

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 machine learning methods

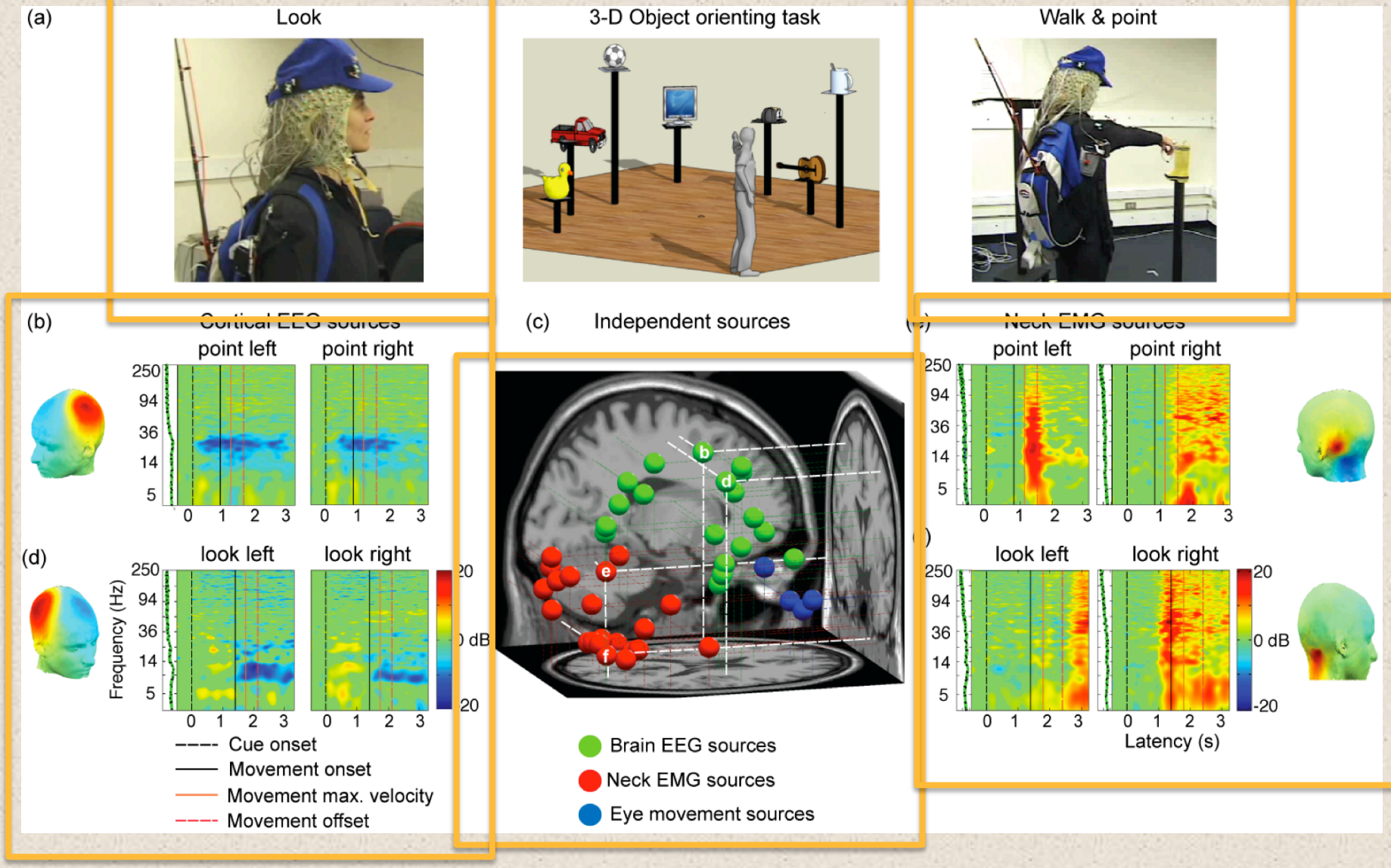
to find, model, and measure

non-stationary (context- and intention-related)

functional relationships among these data modalities.

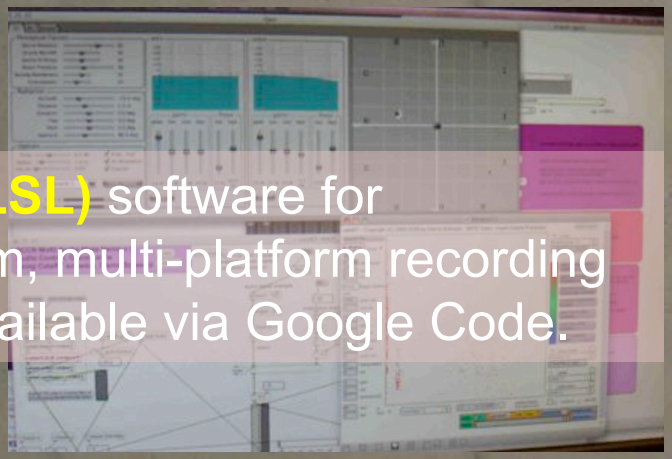
Scott Makeig, 2011

MoBI: Mobile Brain/Body Imaging

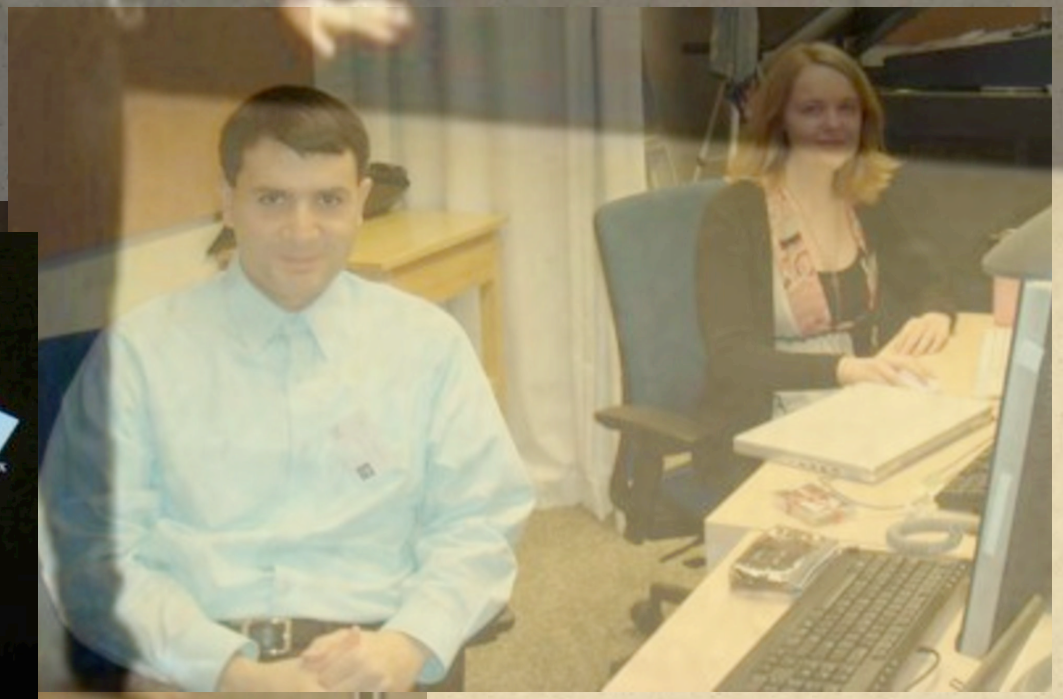


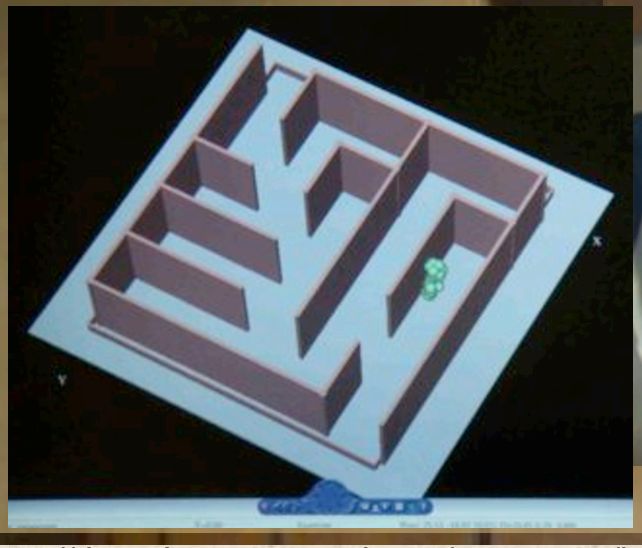
S. Makeig & K. Gramann 2008

MoBI Lab at SCCN, UCSD



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





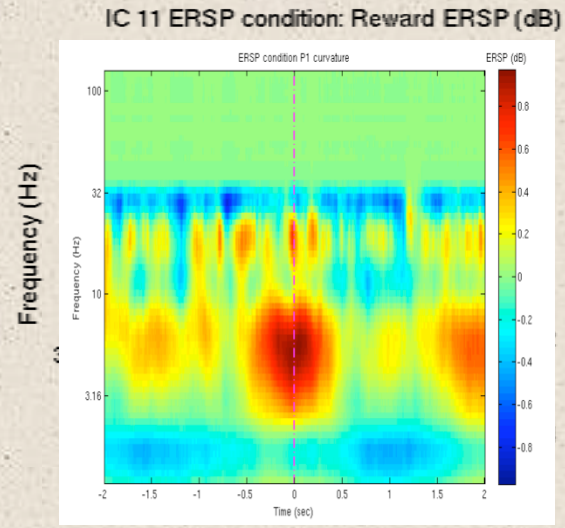
http://thesciencenetwork.org/programs/inc-sccn-open-house/inc-sccn-open-house-hi-lite-reel

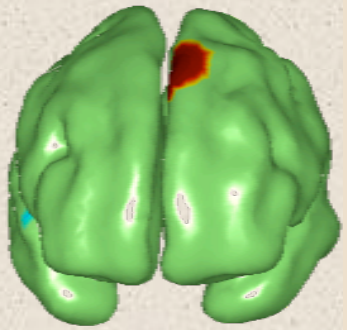
MoBI Lab: Dart Game Experiment

MoBI Lab: Two-Person Mirroring Experiment

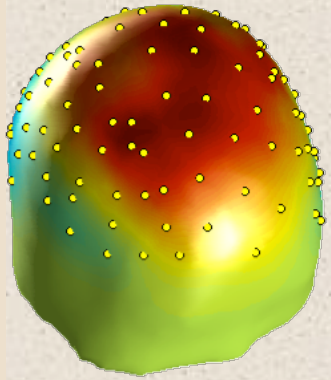
Photo: T Bel Bahar & E Tumer, 2011

MoBI Lab: Two-Person Mirroring Experiment

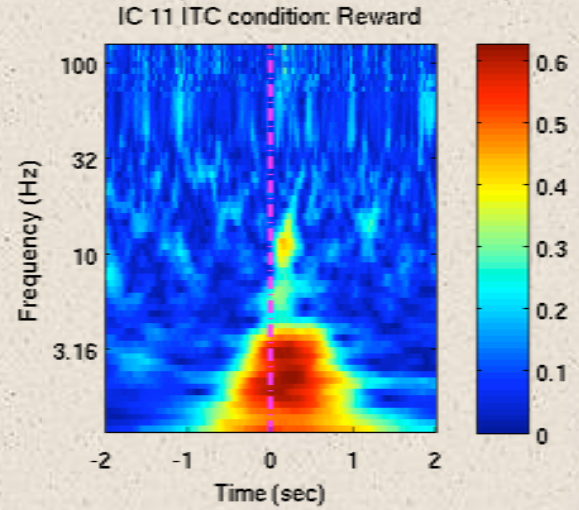


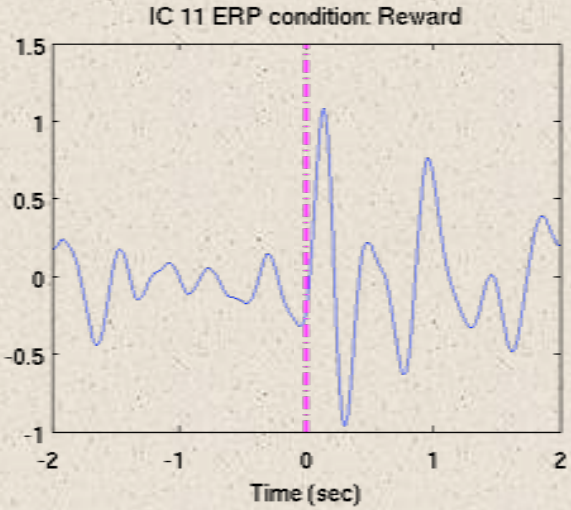


IC Loreta estimate



Laplacian projection





MoBI Lab: Collaborative Gesture Game

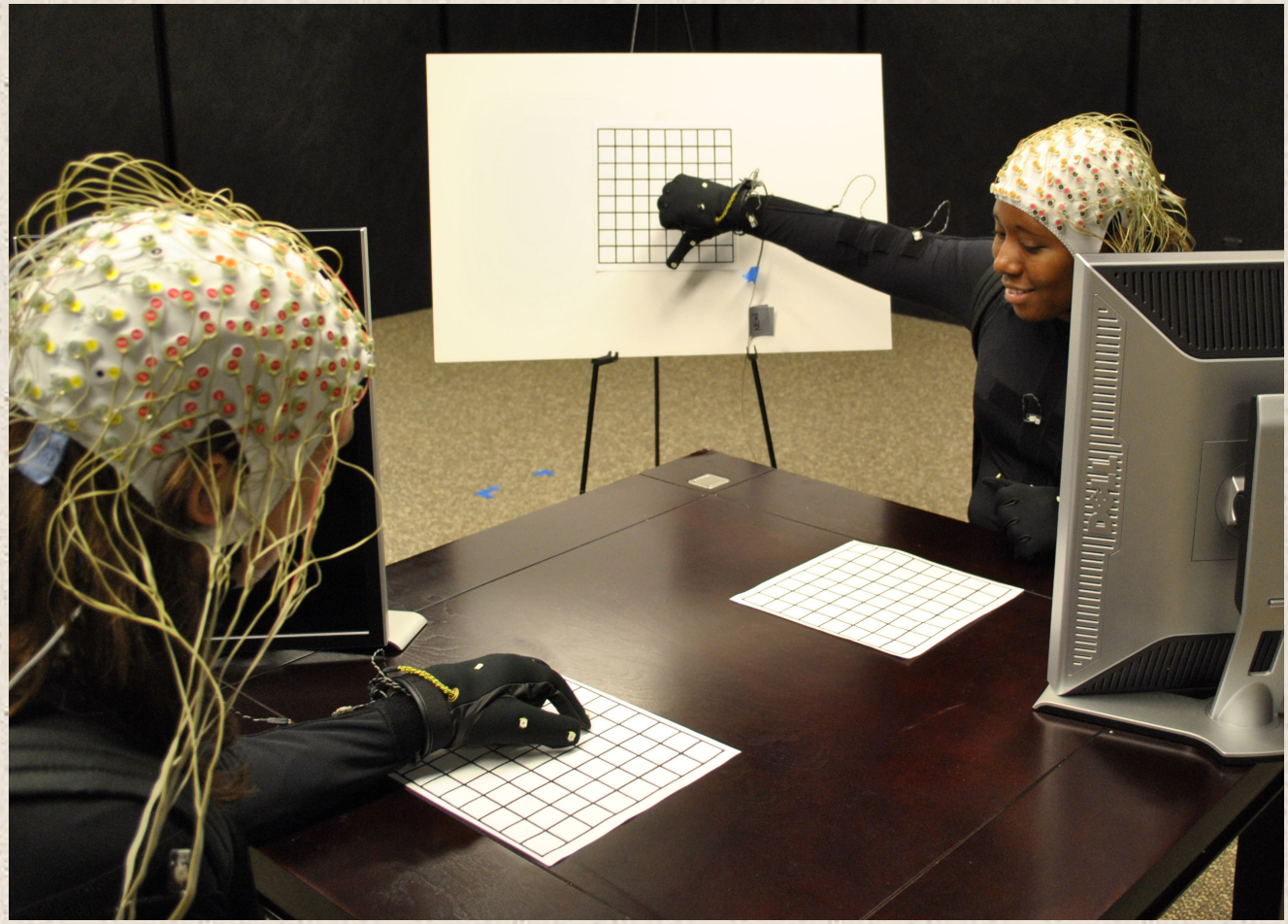


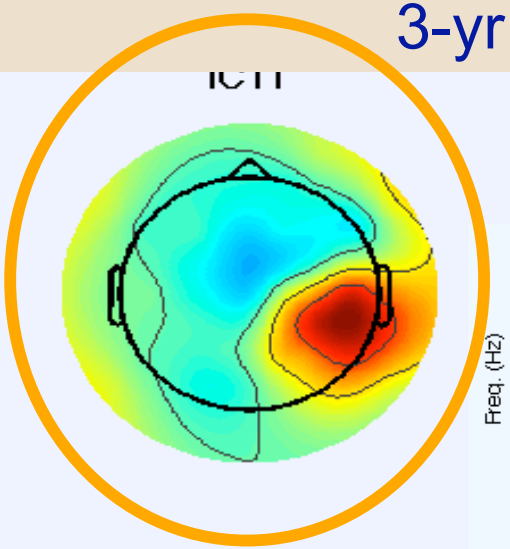
Photo: T Bel Bahar, E Tumer, 2011

Development of Shared Attention – A Mother and Child MoBI Experiment

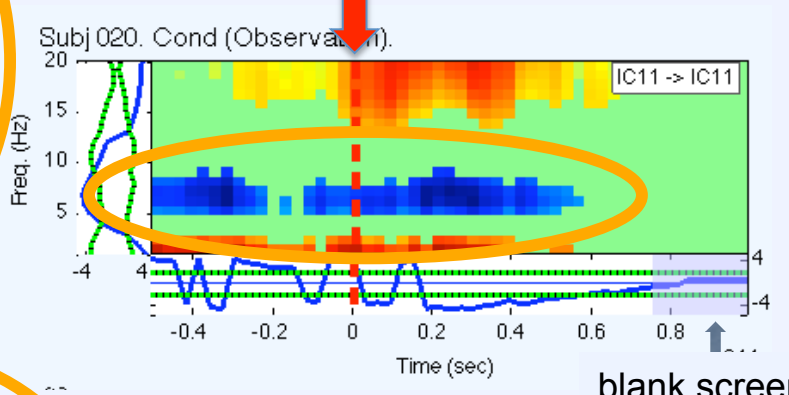
Gedeon Deak et al., 2011

Gedeon Deak et al., 2011

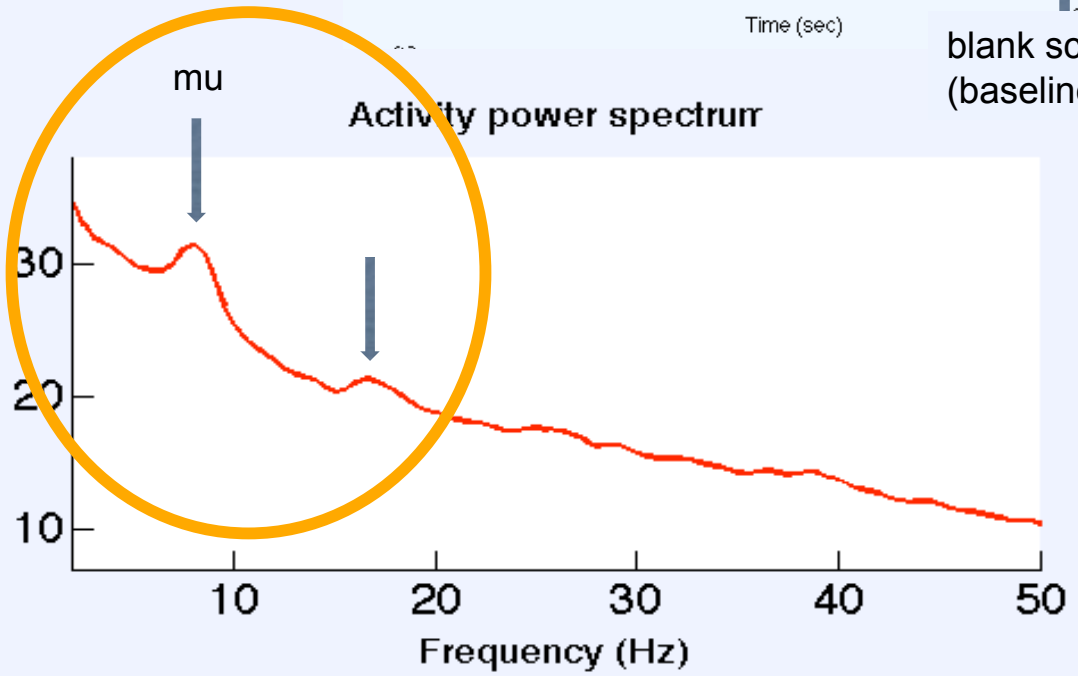
3-yr old child – Reward Observation



Mother Pops the Bubble!



blank screen
(baseline)



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

MoBILAB

A software environment for MoBI data analysis

Alejandro Ojeda et al., 2011

Mobile Brain/Body Imaging (MoBI)

Possible Applications

- Clinical diagnosis & monitoring
- Therapy & rehabilitation
- Learning & performance assistance
- Workplace cognitive monitoring
- Psychotherapy?
- Smart gaming & VE-adventuring
- Multimedia arts …
- Etc. …
- **Empathy ?**

Two Poles of Empathy Research

Empathy (→ compassion)

for all sentient beings …

Empathy (→ sympathy)

for another's pain …

Two Poles of Empathy Research

Compassion involves (or gives rise to)
an active desire
to alleviate others' suffering.

Empathy

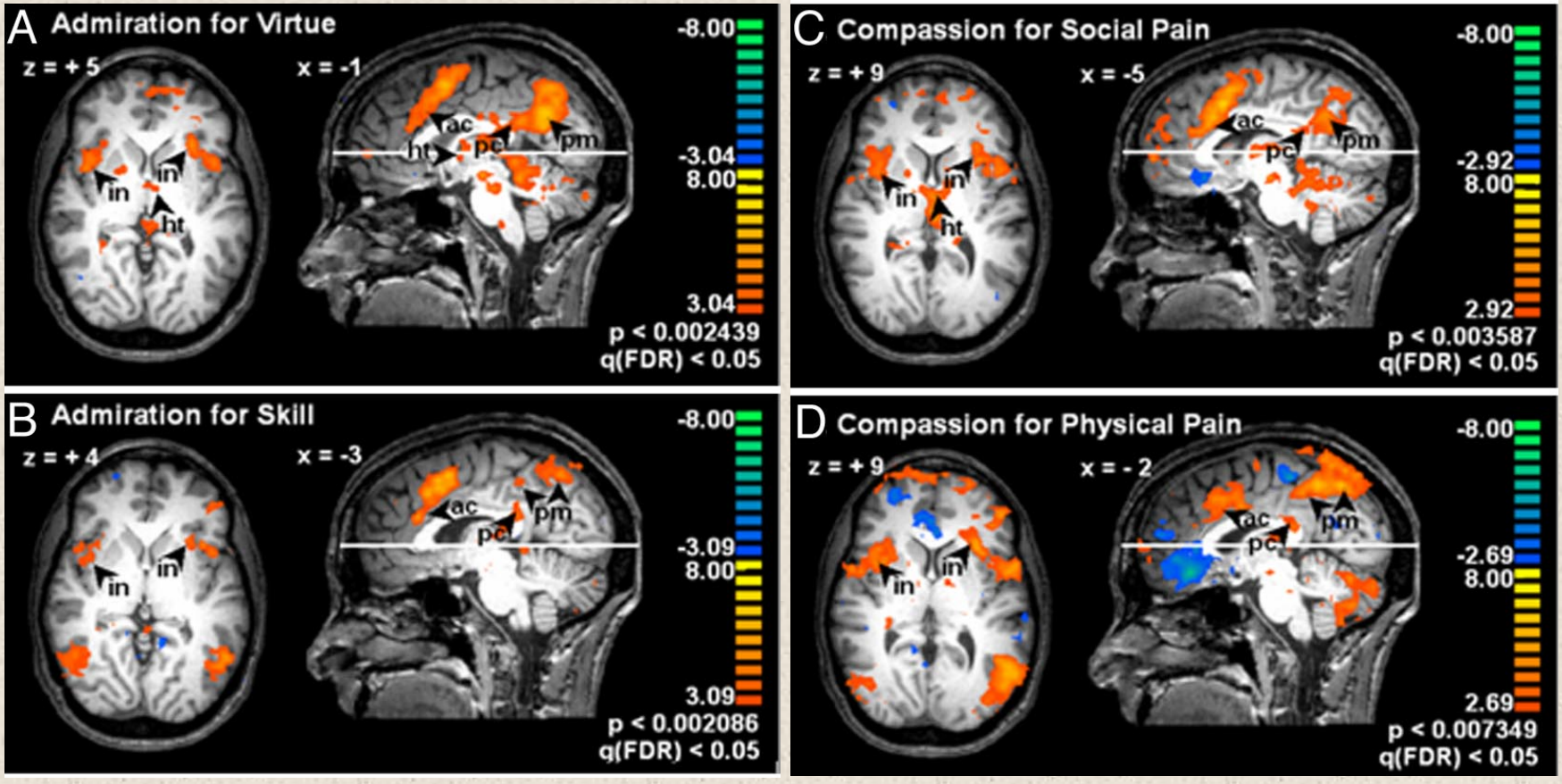
Sympathy is a concern for
the well-being of another.

Brain Imaging of Empathy/Compassion

Admiration | Compassion

Social

Physical



H. Immordino-Yang et al., *PNAS* 2009)

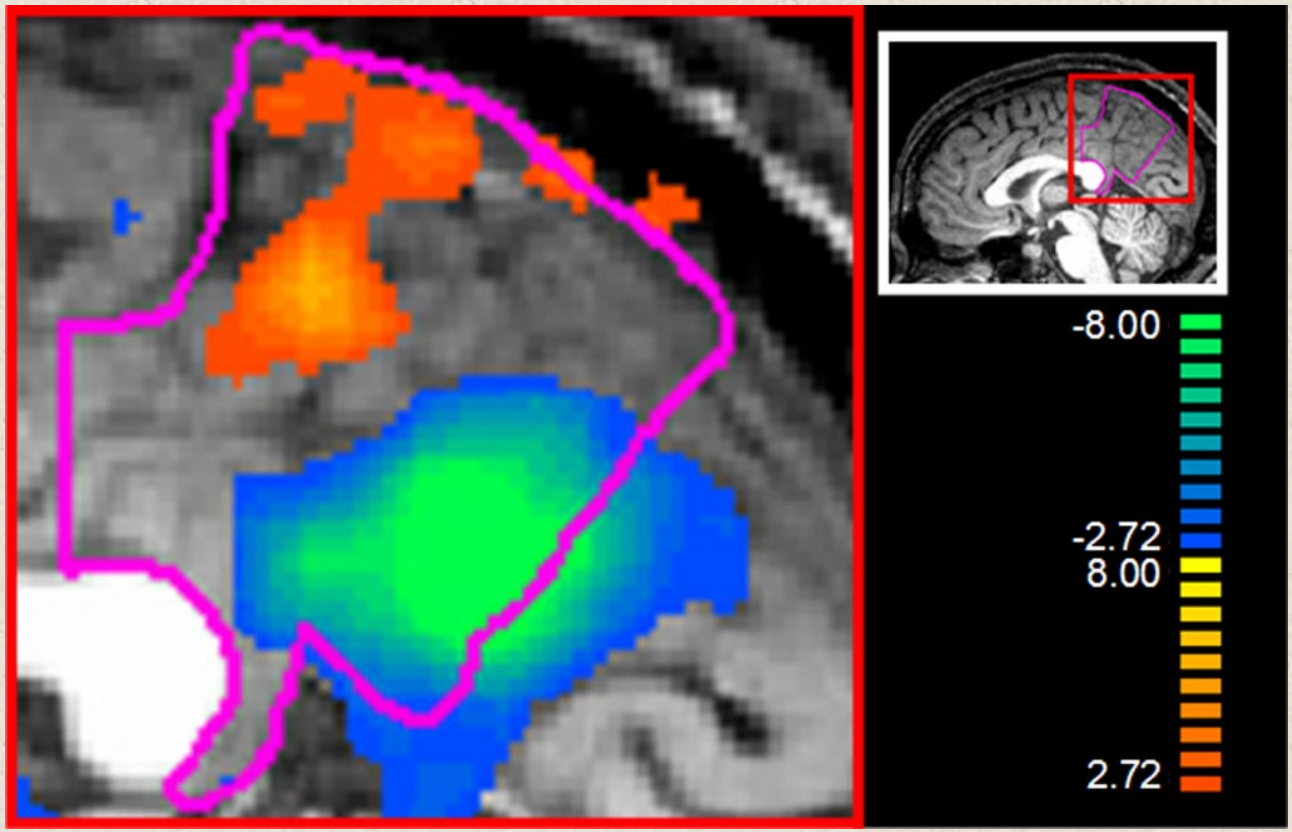
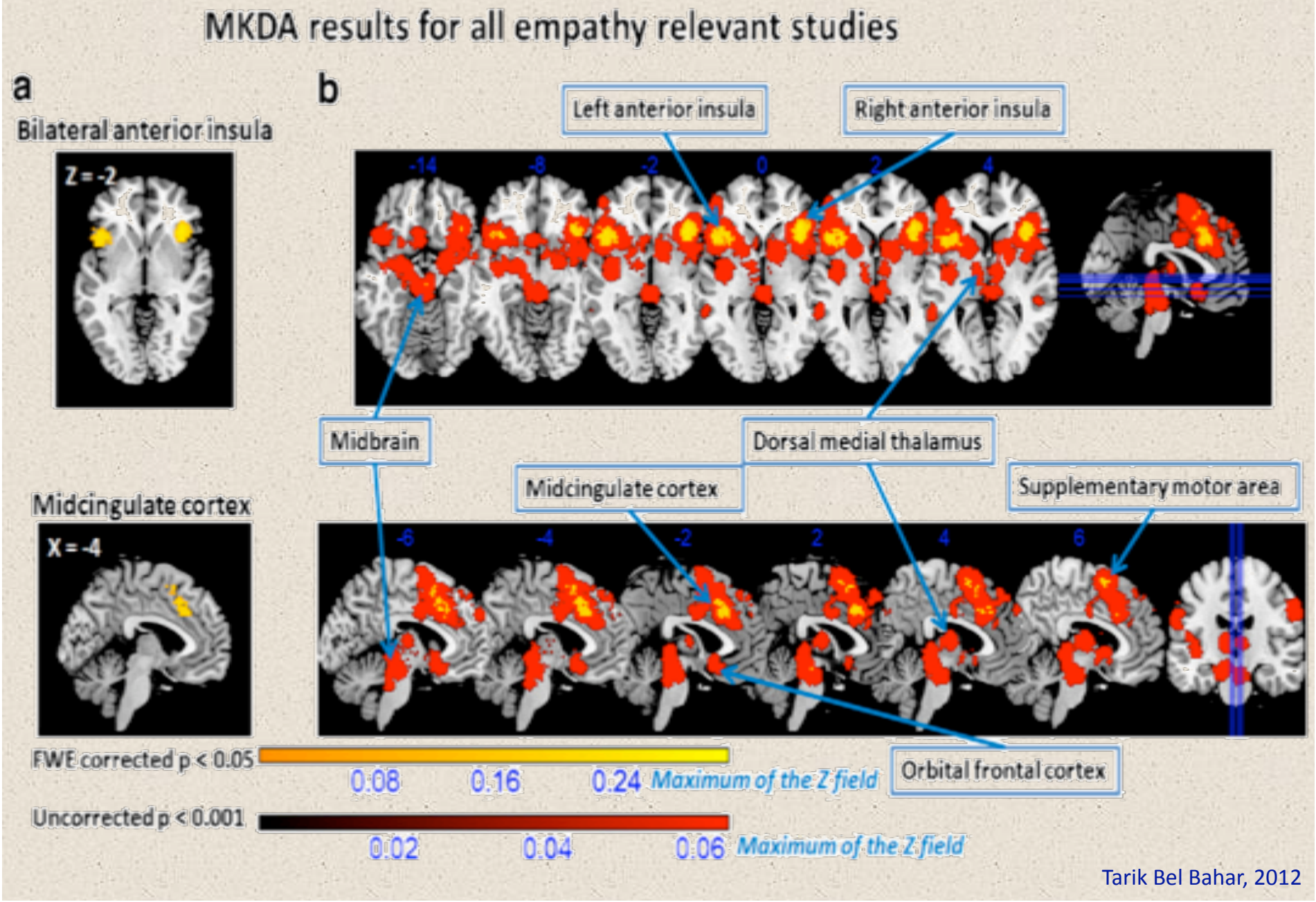


Fig. 2. Relative activation in the posteromedial cortices (PMC, outlined in pink) for admiration for virtue and compassion for social pain (AV/CSP, blue → green) versus admiration for skill and compassion for physical pain (AS/CPP, orange → yellow). The image is thresholded at q(FDR) $<$ 0.05. The bar to the right provides a color code for *t* statistics associated with the contrast. The red box frames the location of the magnified view. Note the clear separation between the anterosuperior sector activated by AS/CPP, and the posteroinferior activated by AV/CSP.

H. Immordino-Yang et al., *PNAS* (2009)

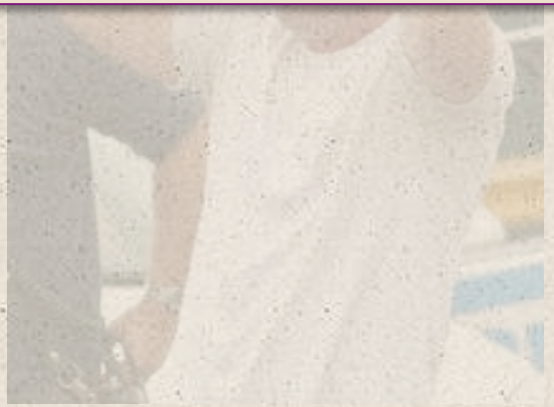
Fan, Y., Duncan, N. W., de Greck, M., Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. Neuroscience & Biobehavioral Reviews 35 (3). 903-911. 40 studies,



Tarik Bel Bahar, 2012

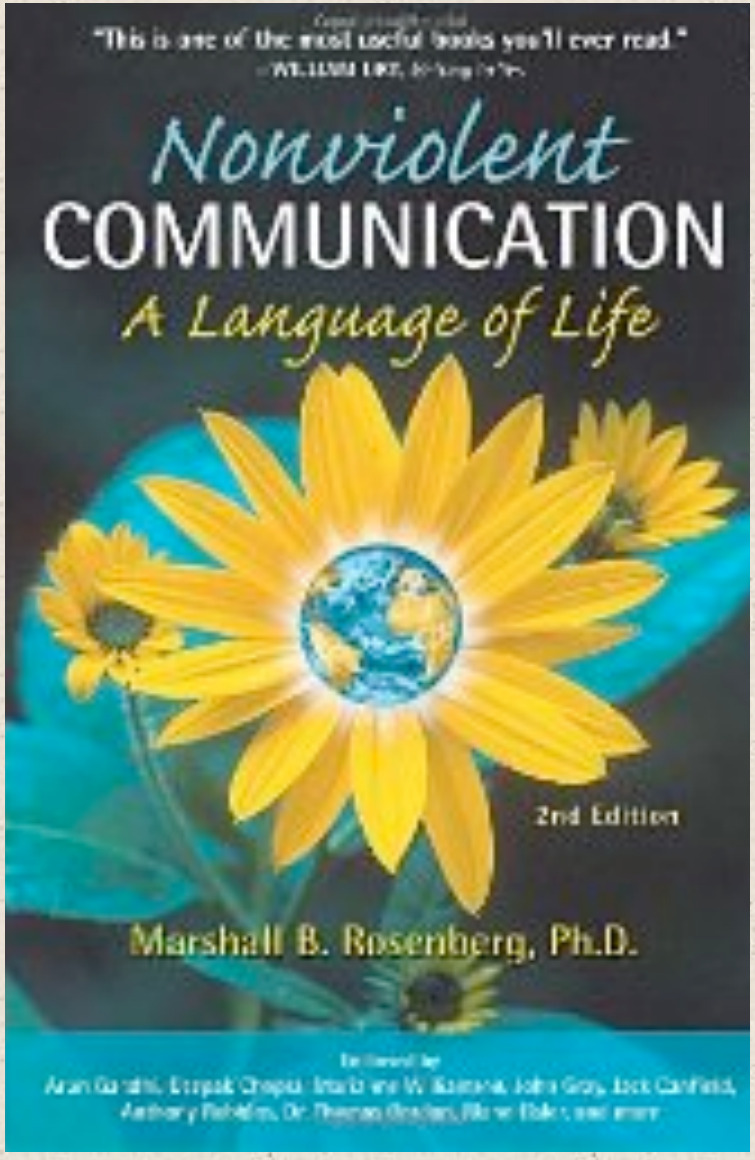
What form of empathy to study ?

Empathic Communication



Empathy (→ sympathy)

Empathic Communication



Empathic communication through listening

Empathy is a respectful understanding of what others are experiencing. Instead of offering empathy we often have a strong urge to give advice or reassurance and to explain our own position or feeling. Empathy, however, calls upon us to empty our mind and **listen** to others with our whole being.

In Nonviolent Communication, no matter what words others may use to express themselves, we simply listen for their observations, feelings, needs, and requests. Then we may wish to reflect back, paraphrasing what we have understood. We stay with empathy, allowing others the opportunity to fully express themselves before we turn our attention to solutions or requests for relief…

Empathic connection is an understanding of the heart in which we see the beauty in the other person, the divine energy in the other person, the life that's alive in them…

With empathy we don't direct, we follow. **Don't just do something, be there!**

- Marshall Rosenberg *(Nonviolent Communication)*

What is empathy?

Empathy, I would say is presence. Pure presence to what is alive in a person at this moment, bringing nothing in from the past. The more you know a person, the harder empathy is. The more you have studied psychology, the harder empathy really is. Because you can bring no thinking in from the past. If you surf, you'd be better at empathy because you will have built into your body what it is about – being present and getting in tune with the energy that is coming through you in the present. It is not a mental understanding.

Is it speaking from the heart?

In empathy, you don't speak at all. You speak with the eyes. You speak with the body. If you say any words at all, it's because you are not sure you are with the person. So you may say some words. But the words are not empathy. Empathy is when the other person feels the connection to what's alive in you. …

The greatest gift one can give another person is empathy.

- Marshall Rosenberg *(Nonviolent Communication)*

Empathic communication

To address a person with whom you are having some difficulty:

- Say what they've done that you don't like.
- Say what you feel.
- Say what needs of yours are not being met.
- Say what your request is.

- Marshall Rosenberg *(Nonviolent Communication)*

Possible experiment design?

Design:

CNV leader / trainer + volunteer participant group

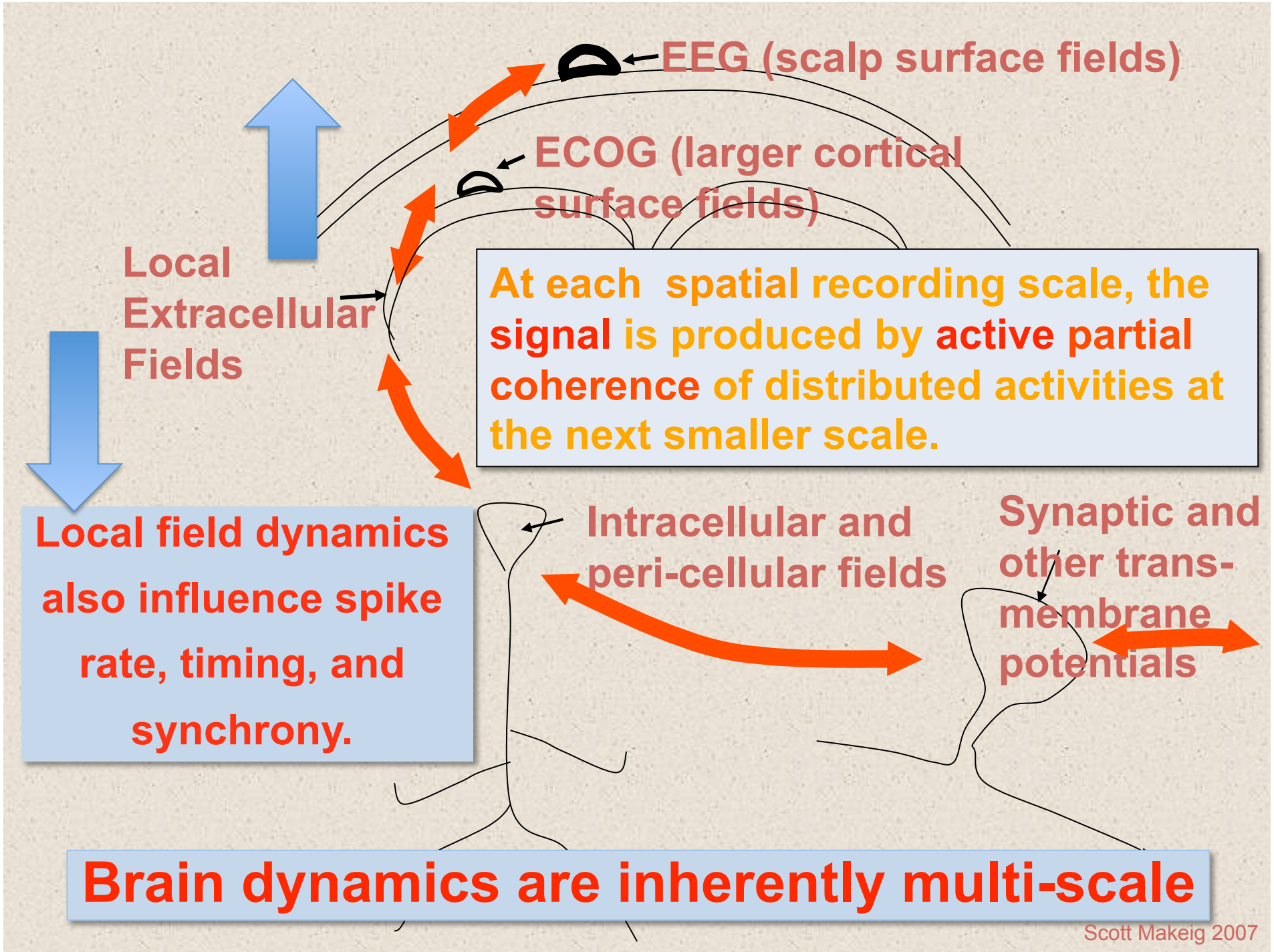
- Group practice sessions
- Participant pair practice sessions ← ←

Measures:

- Video debriefing (each participant, trainer)
  - During utterances,
    contrast listener-experienced
    - Empathic connection increases
    vs. Empathic connection decreases
  - Listener empathy level estimates

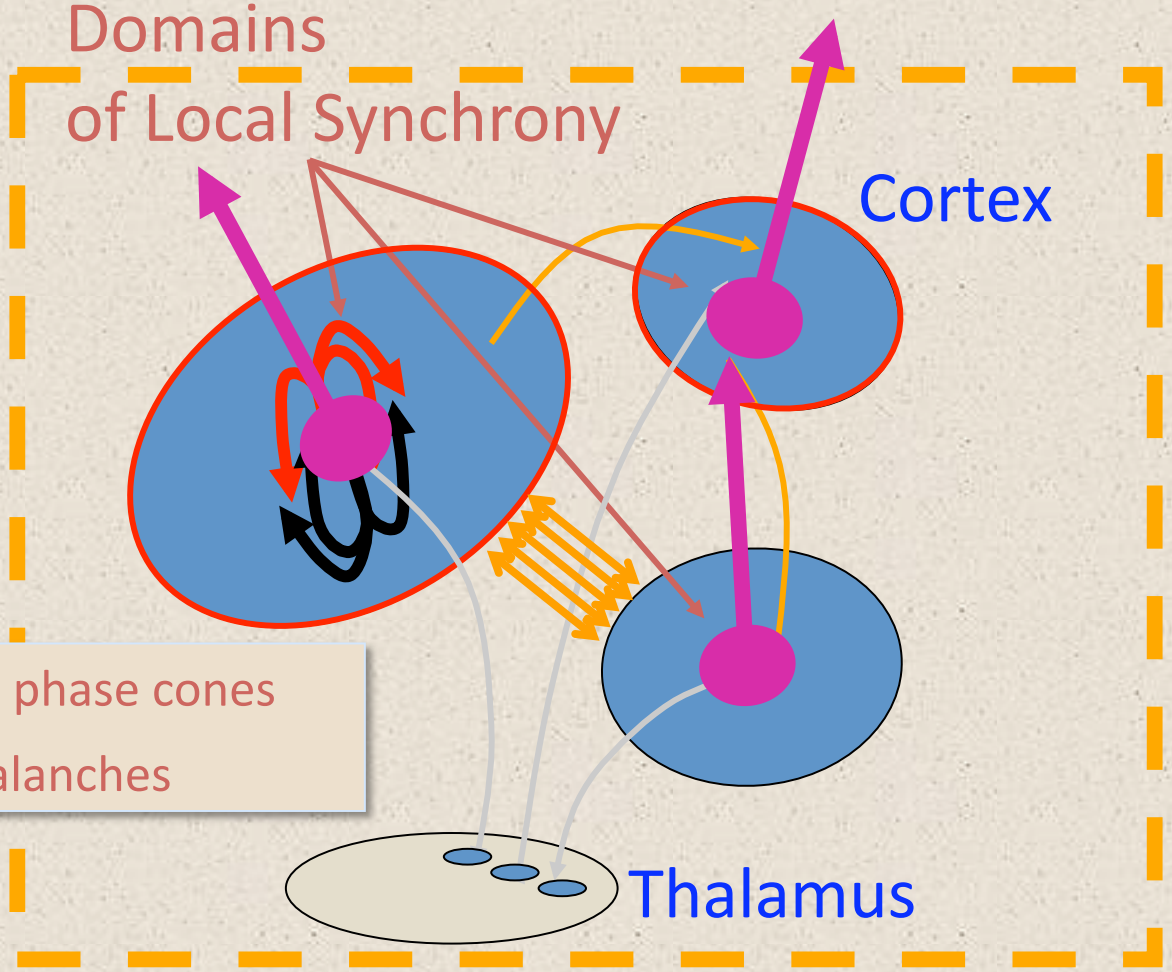
Goals:

- Image EEG source dynamics
- Image EEG source network dynamics
- Develop & test BCI feedback tools


EEG (scalp surface fields)
ECOG (larger cortical surface fields)
Local Extracellular Fields
At each spatial recording scale, the signal is produced by active partial coherence of distributed activities at the next smaller scale.
Local field dynamics also influence spike rate, timing, and synchrony.
Intracellular and peri-cellular fields
Synaptic and other trans-membrane potentials
Brain dynamics are inherently multi-scale
Scott Makeig 2007

Are EEG source outputs (near) independent?

Independent
Domains
of Local Synchrony



Freeman - phase cones

Plenz - avalanches

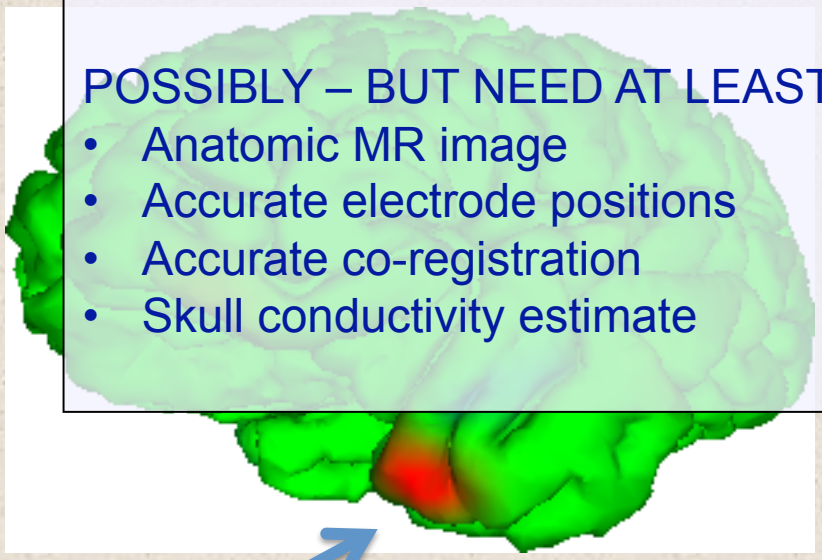
S. Makeig (2007)

Locating independent component processes

FOR SCALP EEG ALSO?

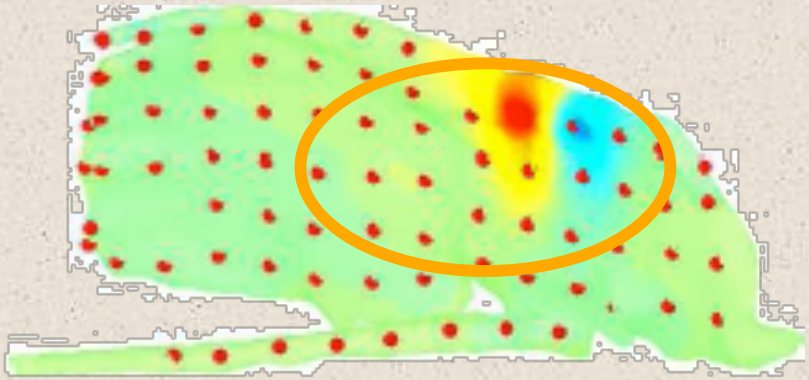
POSSIBLY – BUT NEED AT LEAST:

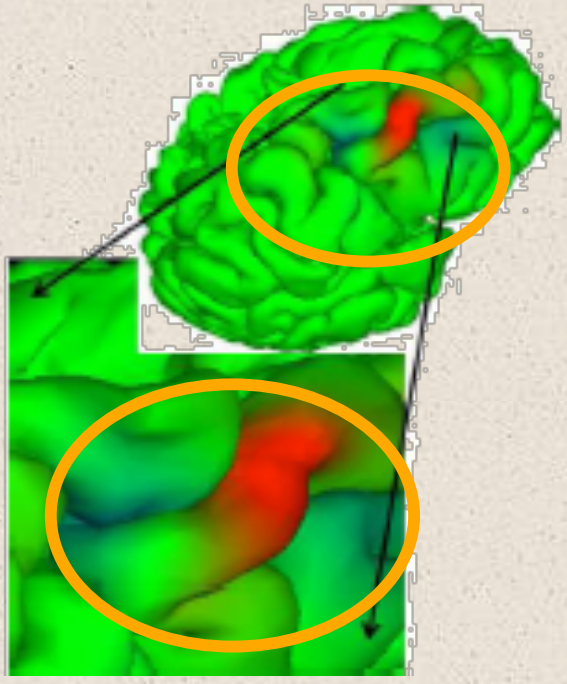
- Anatomic MR image
- Accurate electrode positions
- Accurate co-registration
- Skull conductivity estimate



IC source domain estimate

Scalp EEG source





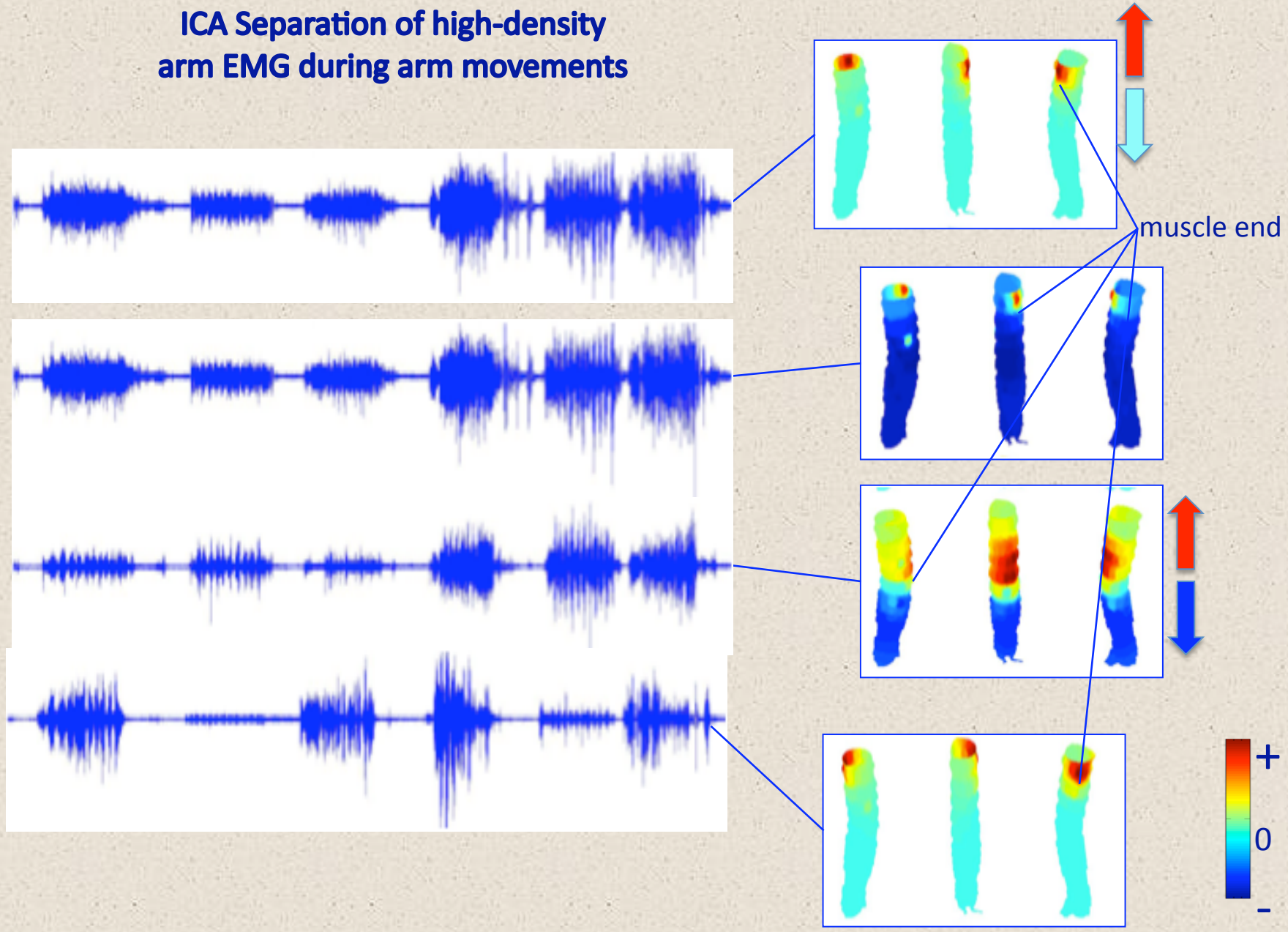
iEEG seizure activity source

Onton et al., '05

High-Dimensional EMG

Cheng Cao, S Makeig 2011

ICA Separation of high-density arm EMG during arm movements



Cheng Cao, S Makeig, J Brown 2011

ICA for BCI Theory and Design ?

IEEE TRANSACTIONS ON REHABILITATION ENGINEERING, VOL. 8, NO. 2, JUNE 2000

A Natural Basis for Efficient Brain-Actuated Control

Scott Makeig, Sigurd Enghoff, Tzyy-Ping Jung, and
Terrence J. Sejnowski

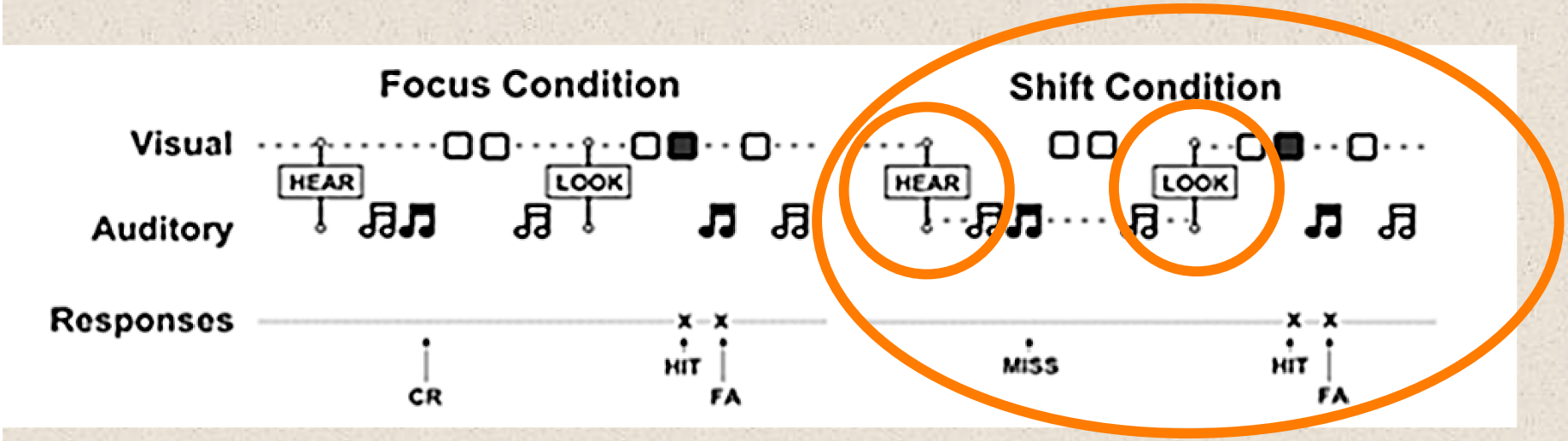
***Abstract*—The prospect of noninvasive brain-actuated control of computerized screen displays or locomotive devices is of interest to many and of crucial importance to a few 'locked-in' subjects who experience near total motor paralysis while retaining sensory and mental faculties. Currently several groups are attempting to achieve brain-actuated control of screen displays using operant conditioning of particular features of the spontaneous scalp electroencephalogram (EEG) including central μ-rhythms (9–12 Hz). A new EEG decomposition technique, independent component analysis (ICA), appears to be a foundation for new research in the design of systems for detection and operant control of endogenous EEG rhythms to achieve flexible EEG-based communication. ICA separates multichannel EEG data into spatially static and temporally independent components including separate components accounting for posterior alpha rhythms and central μ activities. We demonstrate using data from a visual selective attention task that ICA-derived μ-components can show much stronger spectral reactivity to motor events than activity measures for single scalp channels. ICA decompositions of spontaneous EEG would thus appear to form a natural basis for operant conditioning to achieve efficient and multidimensional brain-actuated control in motor-limited and locked-in subjects.**

I. Introduction

Recent work in several laboratories has demonstrated that noninvasively recorded electric brain activity can be used to voluntarily control switches and communication channels, allowing a few so-called locked-in near-totally paralyzed subjects the ability to communicate, however slowly, with their families and aides ([4]; [14]; [2]). Communication rates achieved to date are in the range of several bits a minute, far from rates that would allow locked-in persons access to normal social interaction. This communication briefly describes a technique for blind decomposition of electroencephalogram (EEG) data into temporally and often functionally independent components that

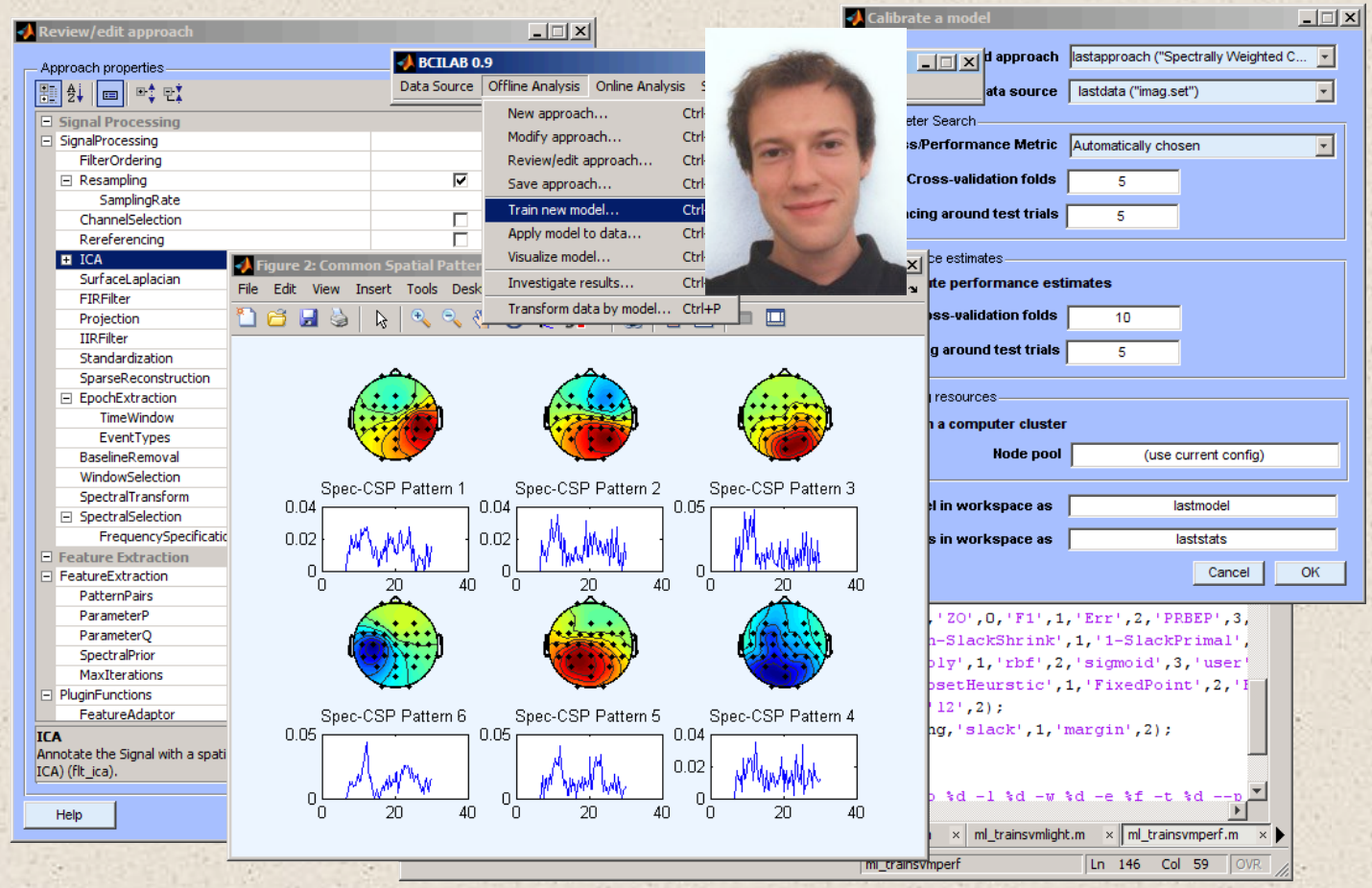
Audiovisual Attention Shift Experiment

Question: What is the brain activity signature of switching between auditory and visual attention? (DAS)



J Townsend et al., 2003

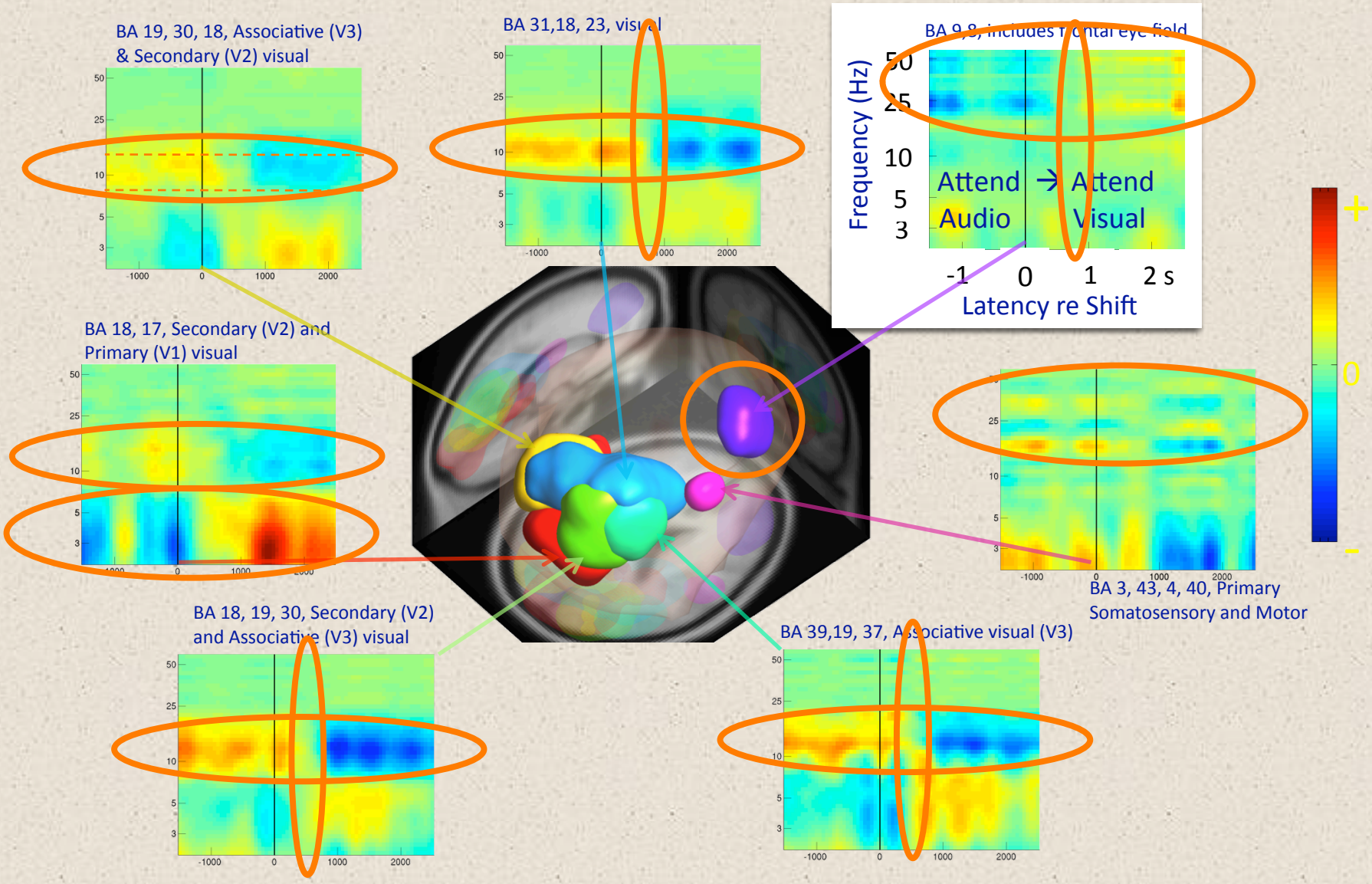
BCILAB



sccn.ucsd.edu/wiki/BCILAB

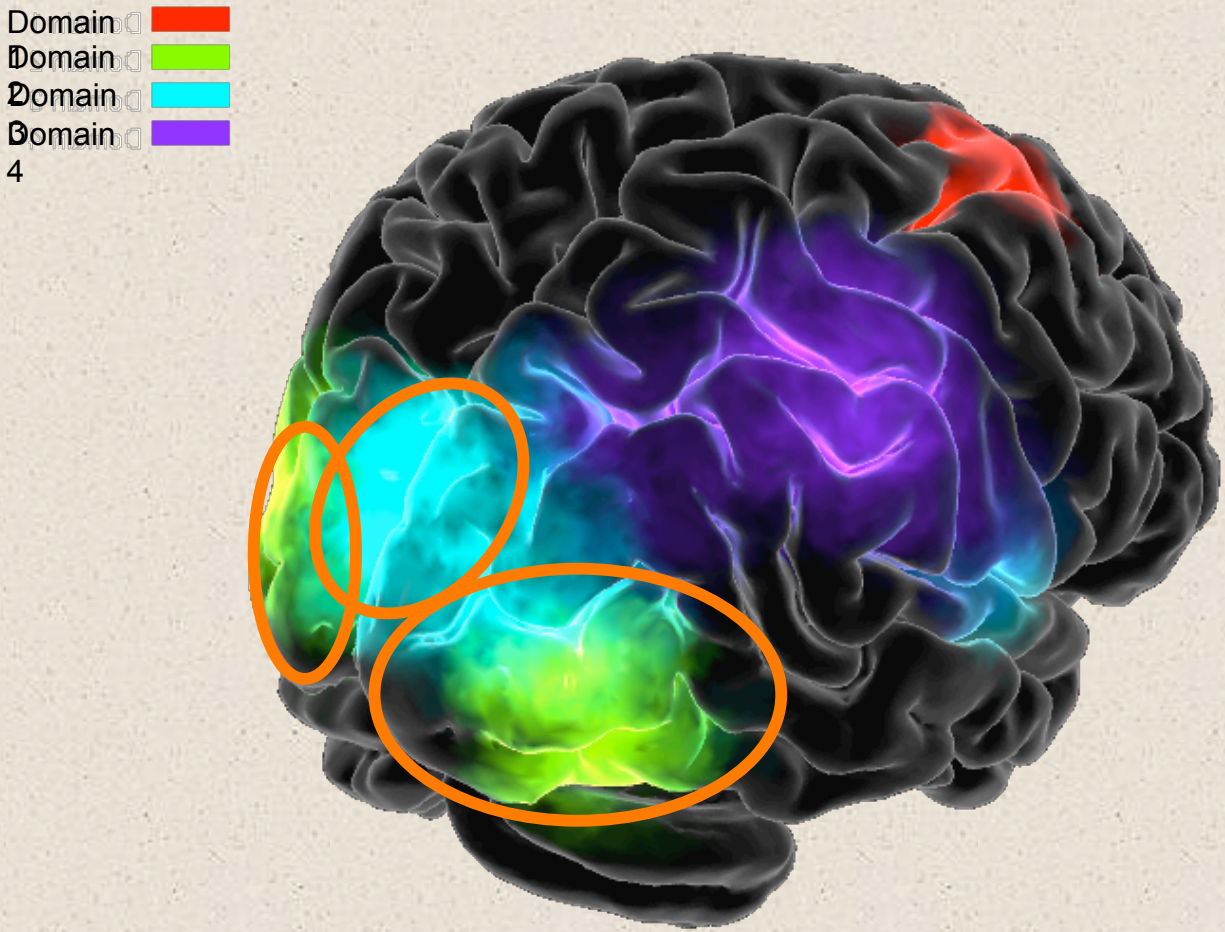
C Kothe 2011

An EEG Attention-Shift Network

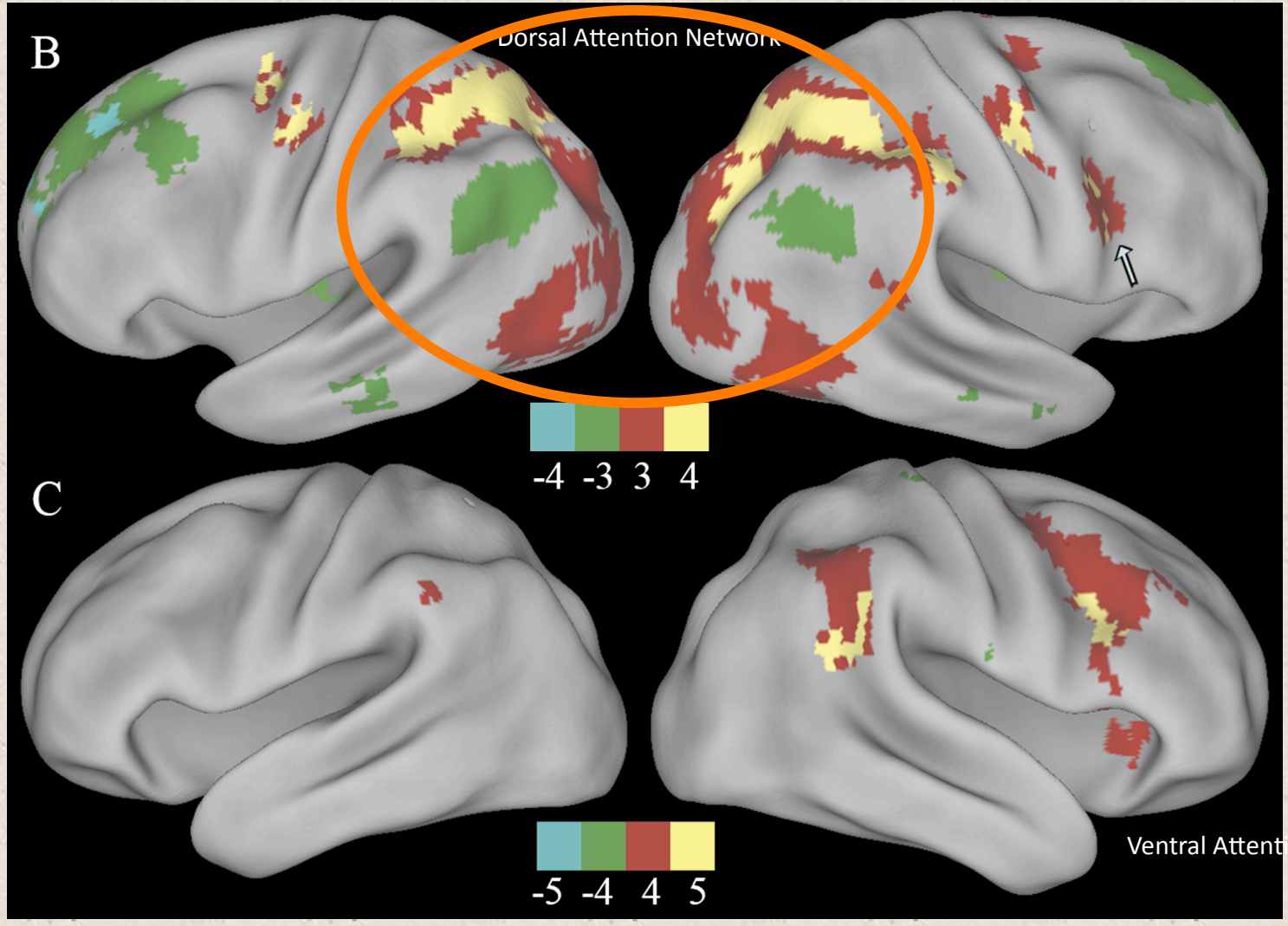


N Bigdely-Shamlo, C Kothe, S Makeig 2011

The EEG Attention-Shift Network



Dorsal and Ventral Attention Networks (2007)



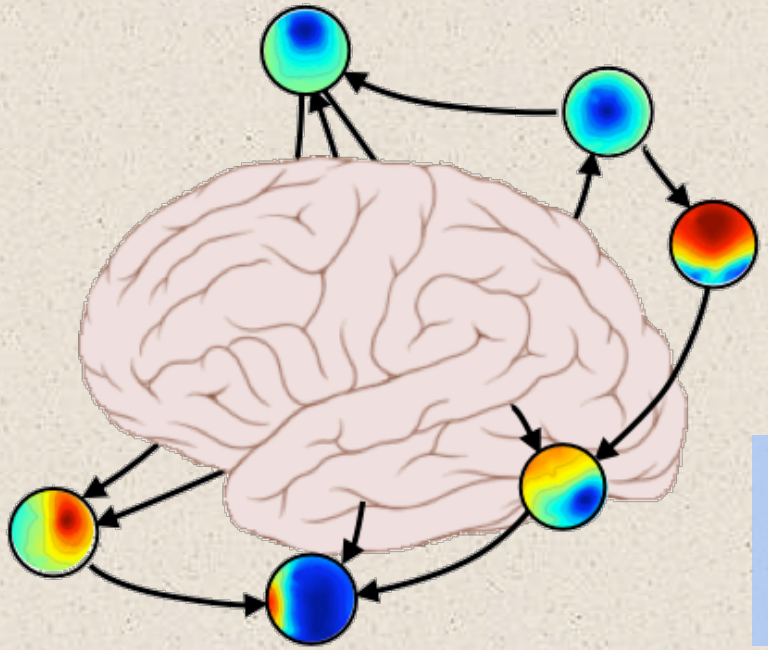
He, Snyder, Vincent, Epstein, Shulman, Corbetta, *Neuron* 2007

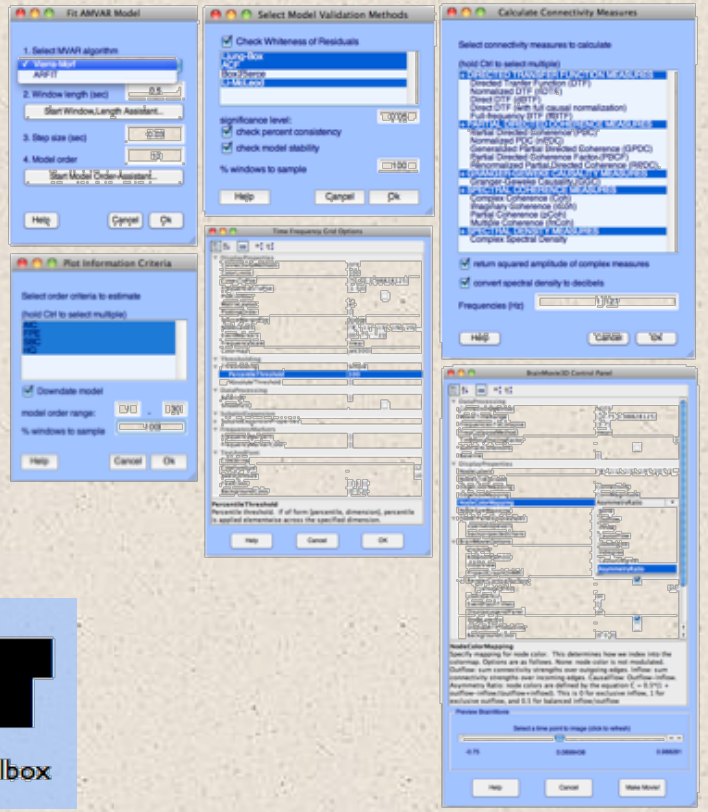
http://sccn.ucsd.edu/wiki/SIFT

Mullen, et al, *Journal of Neuroscience Methods* (in prep, 2011)

Mullen, Delorme, Kothe, Makeig, *Society for Neuroscience*, 2010

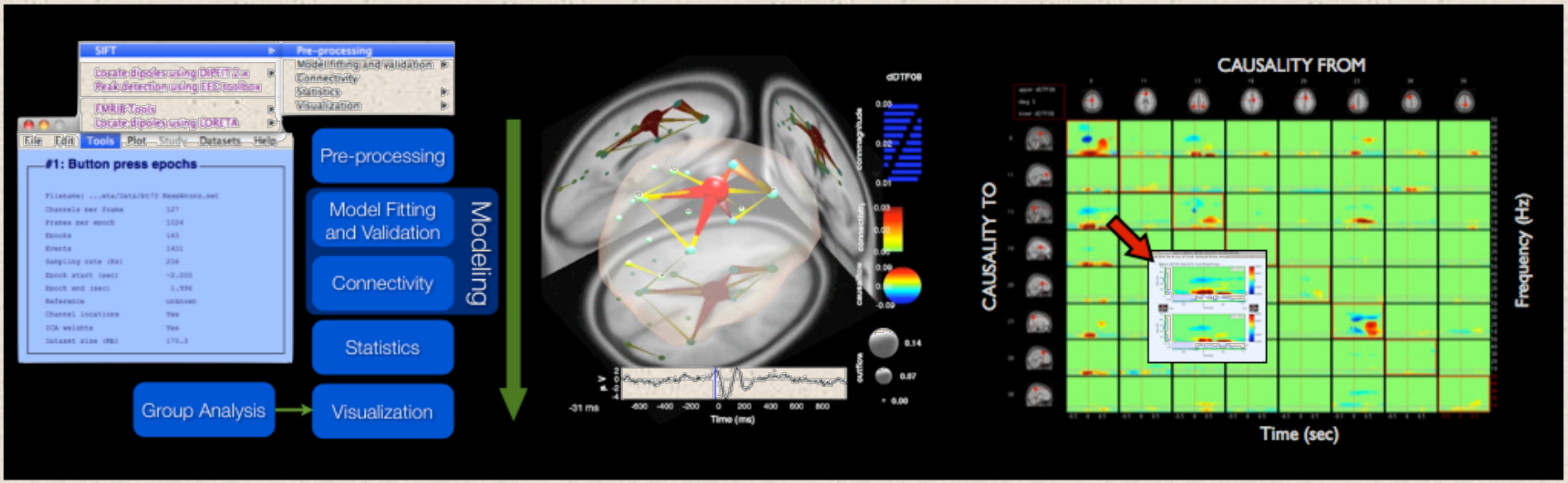
Delorme, Mullen, Kothe et al, *Computational Intelligence and Neuroscience*, vol 12, 2011



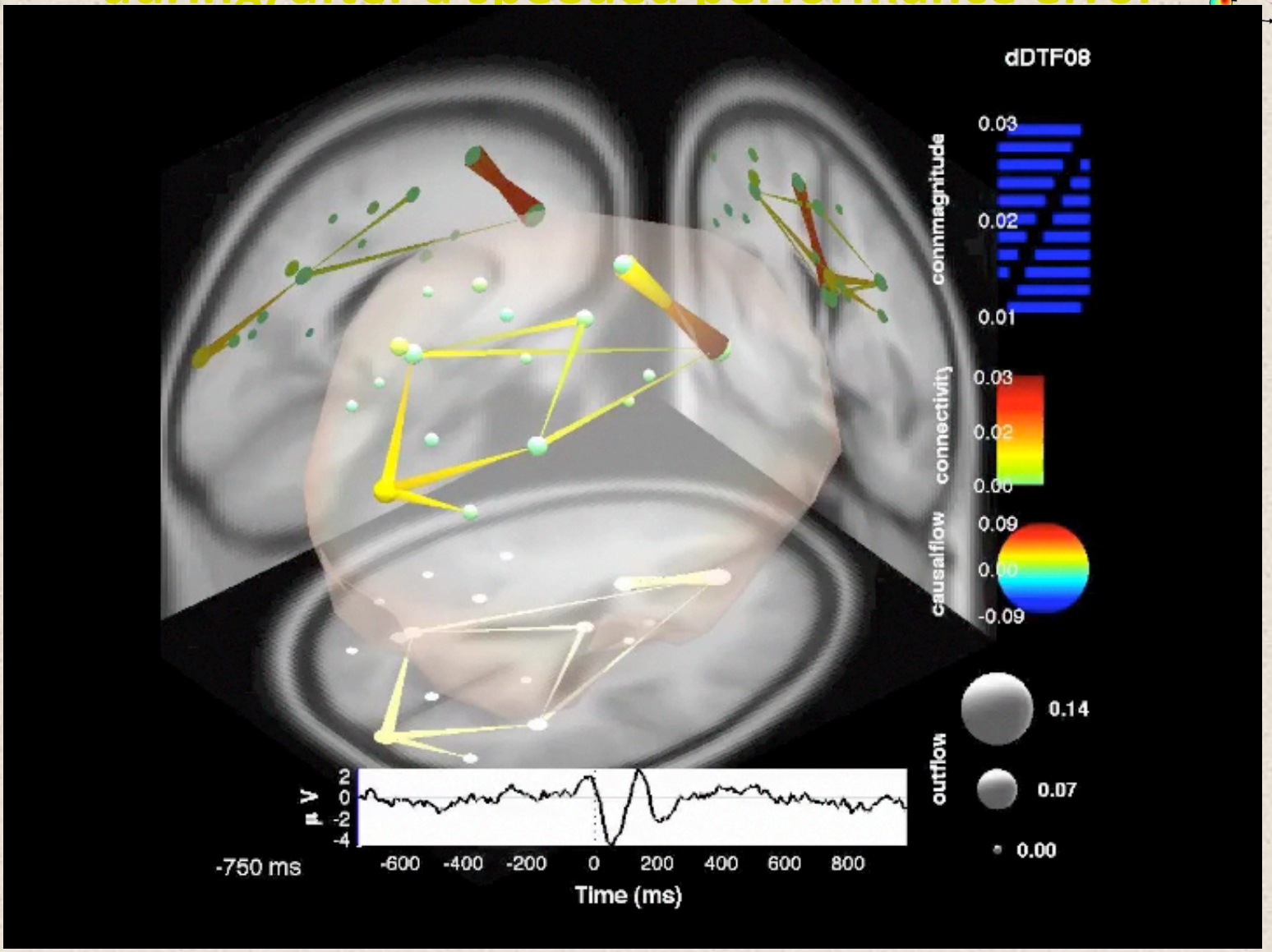


SIFT

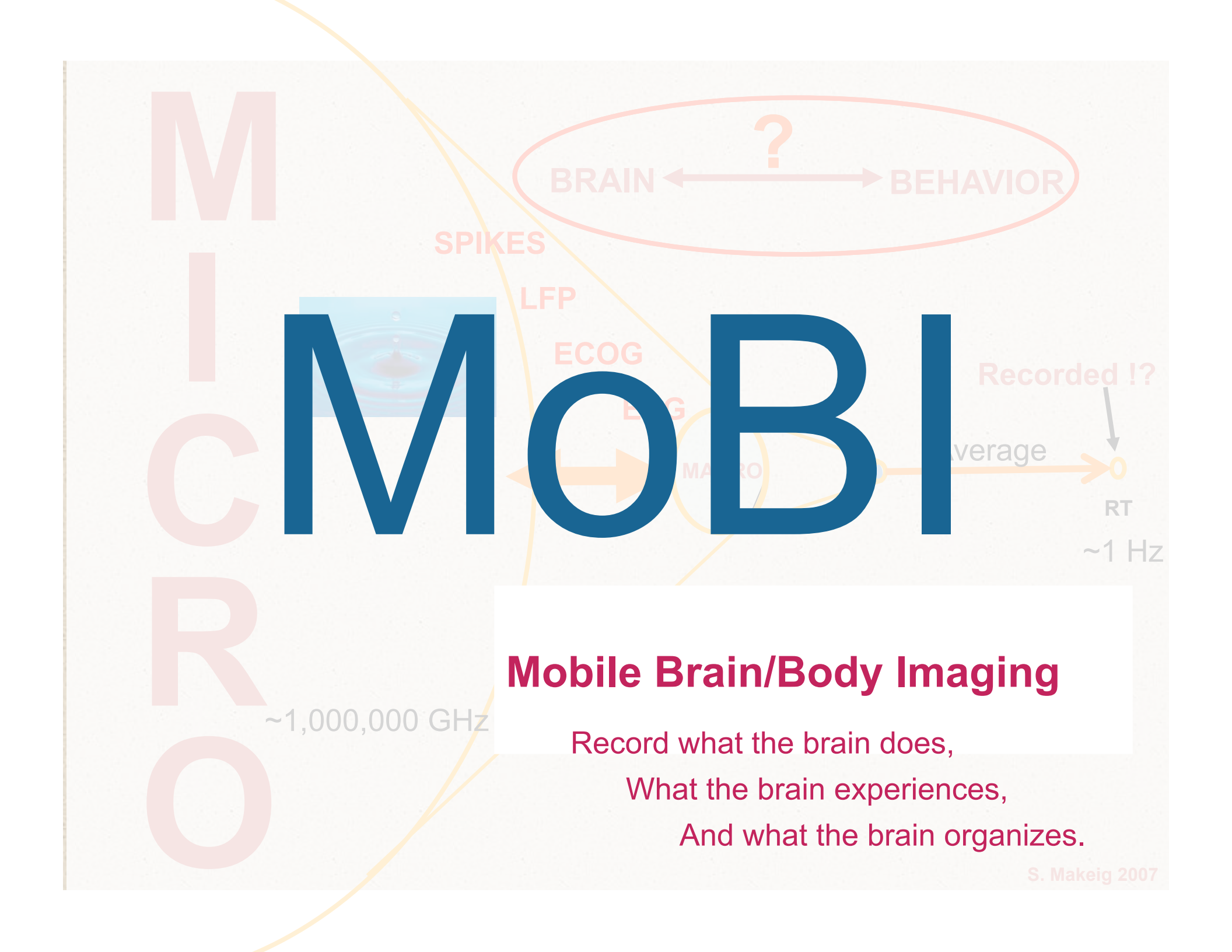
Source Information Flow Toolbox



Transient ERN Theta Network Connectivity during/after a speeded performance error



Tim Mullen, S. Makeig et al. unpublished



MoBI

Mobile Brain/Body Imaging

Record what the brain does,

What the brain experiences,

And what the brain organizes.

S. Makeig 2007

Cheng Cao & S. Makeig, 2011

Fan, Y., Duncan, N. W., de Greck, M., Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. Neuroscience & Biobehavioral Reviews 35 (3). 903-911.

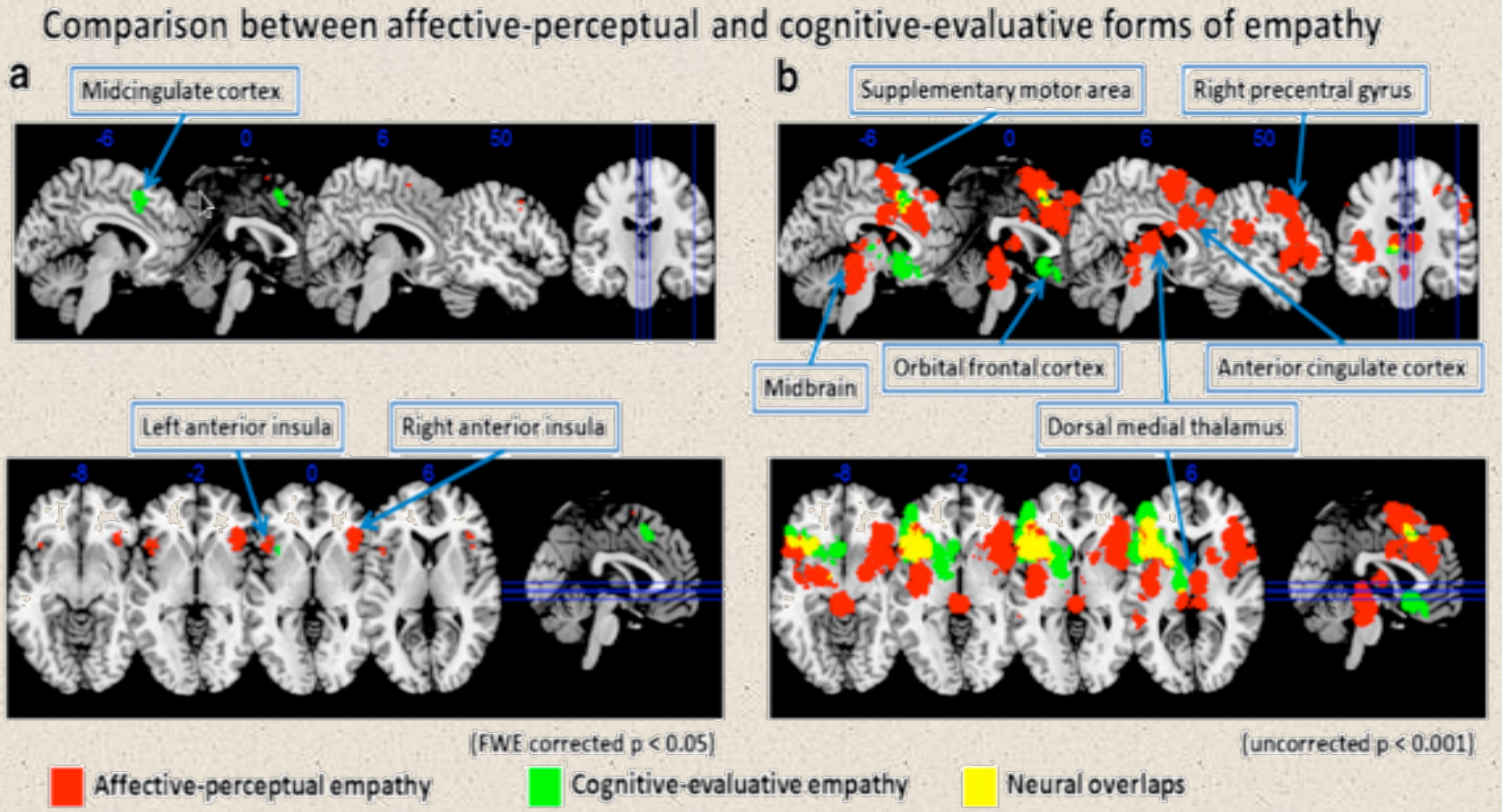


Fig. 2. Comparison between brain regions consistently activated in the affective-perceptual (red colour in a and b) and the cognitive-evaluative forms of empathy (green colour in a and b), with threshold level at (a) FWE corrected $p<0.05$ and (b) $p<0.001$ uncorrected, respectively. Neural overlapping regions were shown in yellow colour. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

Tarik Bel Bahar, 2012