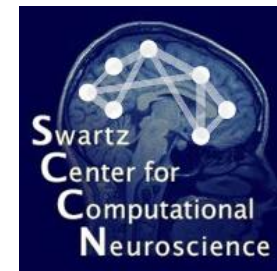




**3<sup>rd</sup> EEGLAB Workshop**  
**Singapore**  
**Mining Event-Related**  
**Brain Dynamics**

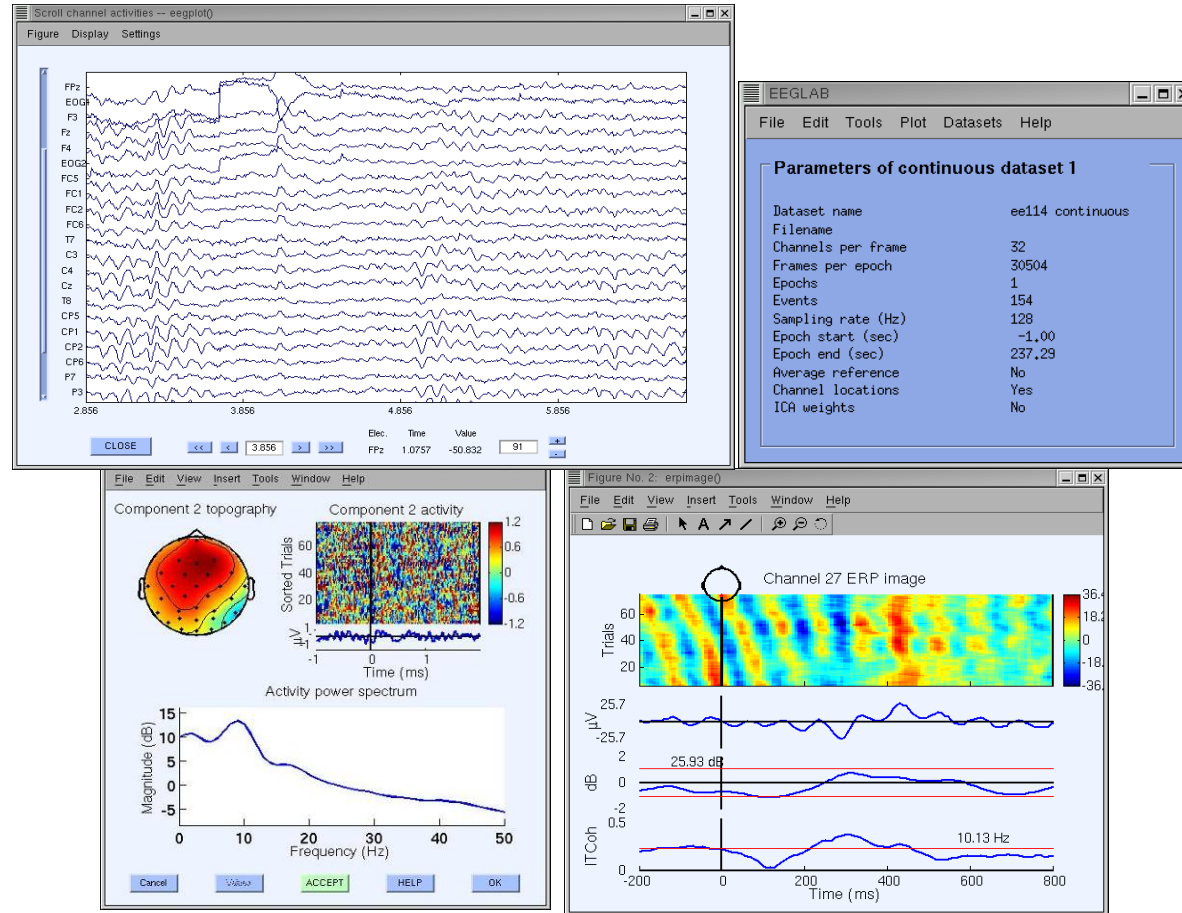


**Scott Makeig**

Swartz Center for Computational  
Neuroscience, Institute for Neural  
Computation, UCSD  
La Jolla CA

# EEGLAB

An open-source EEG/MEG signal processing environment for Matlab



<http://sccn.ucsd.edu/eeglab>

## EEGLAB downloads for 13/11/2006

Total count is 27

Date	Username	Email	Comments
13/11/2006		@yahoo.com.cn	Auditory
13/11/2006		@163.com	Biomedical instrument institution of Fuzhou Univerisity
13/11/2006		@ec.auckland.ac.nz	independent component analysis
13/11/2006		@hotmail.com	3rd year Electrical Engineering group project: ambulatory EEG design.
13/11/2006		@yahoo.com	mouvement humain, commande neuromotrice, eeg
13/11/2006		@honeywell.com	
13/11/2006		@hotmail.com	the use of biofeedback/entrainment in an audio/visual art installation.
13/11/2006		@gmx.de	cognitive neuroscience, emotion, memory
13/11/2006		@uwo.ca	locating foci of epileptic seizures
13/11/2006			
13/11/2006		@smi.suc.dk	
13/11/2006		@smi.auc.dk	EEG and fMRI
13/11/2006		aga@asg	asdgf
13/11/2006		@psy.uni-muenchen.de	
13/11/2006		@psychiat.med.uni-giessen.de	
13/11/2006		k	
13/11/2006		@tiscali.co.uk	yyyyy
13/11/2006		@isc.cnrs.fr	Neural bases of Human Reasoning
13/11/2006		@freemail.hu	higher auditory functions in newborns, crossmodal integration
13/11/2006		@tut.fi	
13/11/2006		@nctu.edu.tw	
13/11/2006		@cms.hu-berlin.de	EKP
13/11/2006		@yahoo.fr	time-frÃ©quency, wavelet signal detection and analysis,faults diagnosis
13/11/2006		@sohu.com	Bioinformatics

# EEGLAB Workshop 06

- USA
- Netherlands
- Singapore
- Malaysia
- Taiwan
- Japan
- Australia
- South Korea
- United Arab Emirates
- Germany
- Italy
- England
- Israel

- Who Am I?
- Cortical macrodynamics
- Limitations of response averaging
- A richer model
- Independent component analysis
- Time/frequency analysis

I gaped ...

I tossed ...

Who

I held ...

I jumped ...

I ducked

I swerved ...

I reached ...

I? I threw ...

I ran ...

I shot ...

am

I pointed ...

I smiled ...

I realized that ...

It struck me that ...

I wondered if ...

All of a sudden ...



The feeling hit me like ...

I looked to see if ...

I noticed that ...

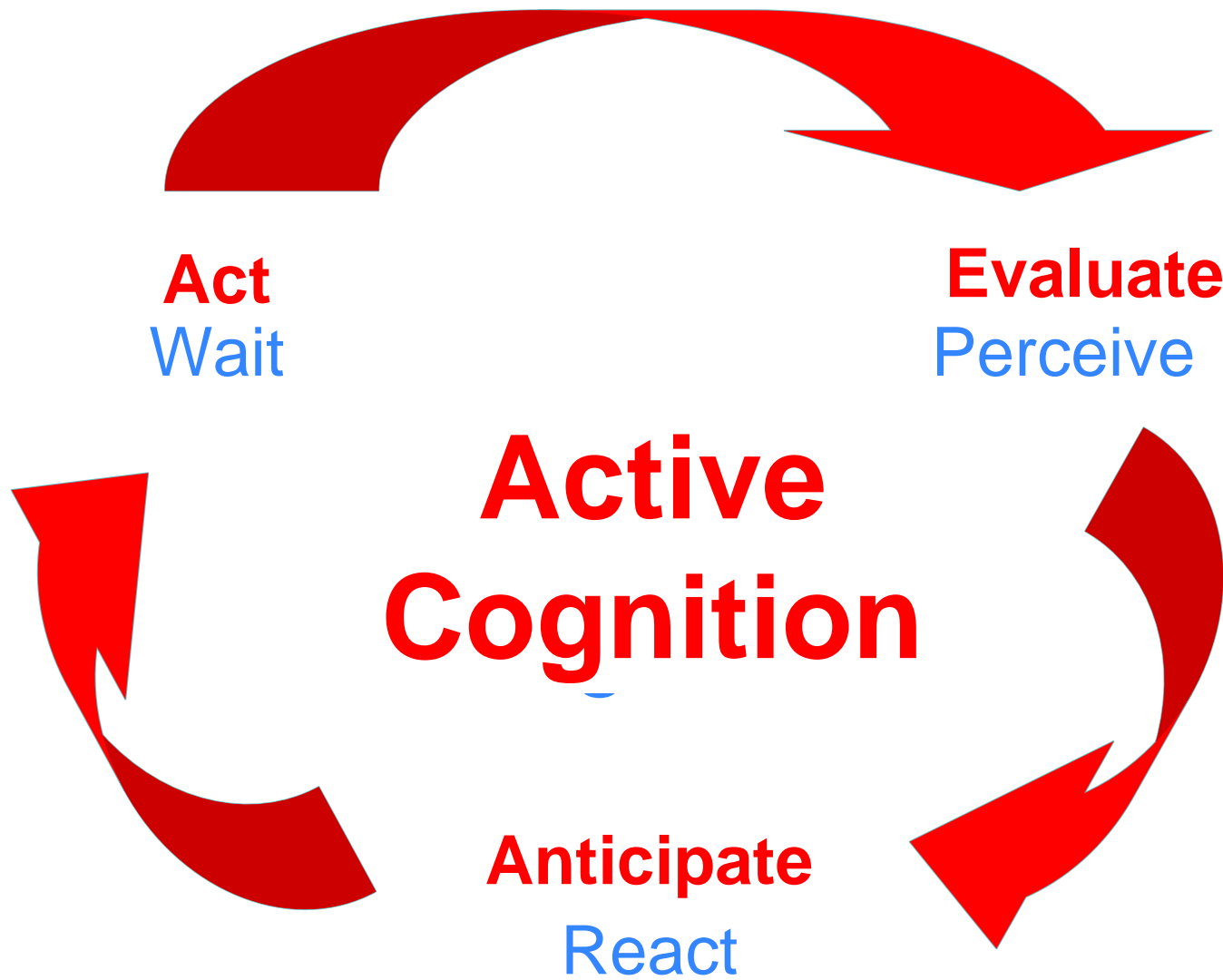
I looked again at ....

I decided that ...

It occurred to me that ...

I imagined ...

I searched the scene for ...

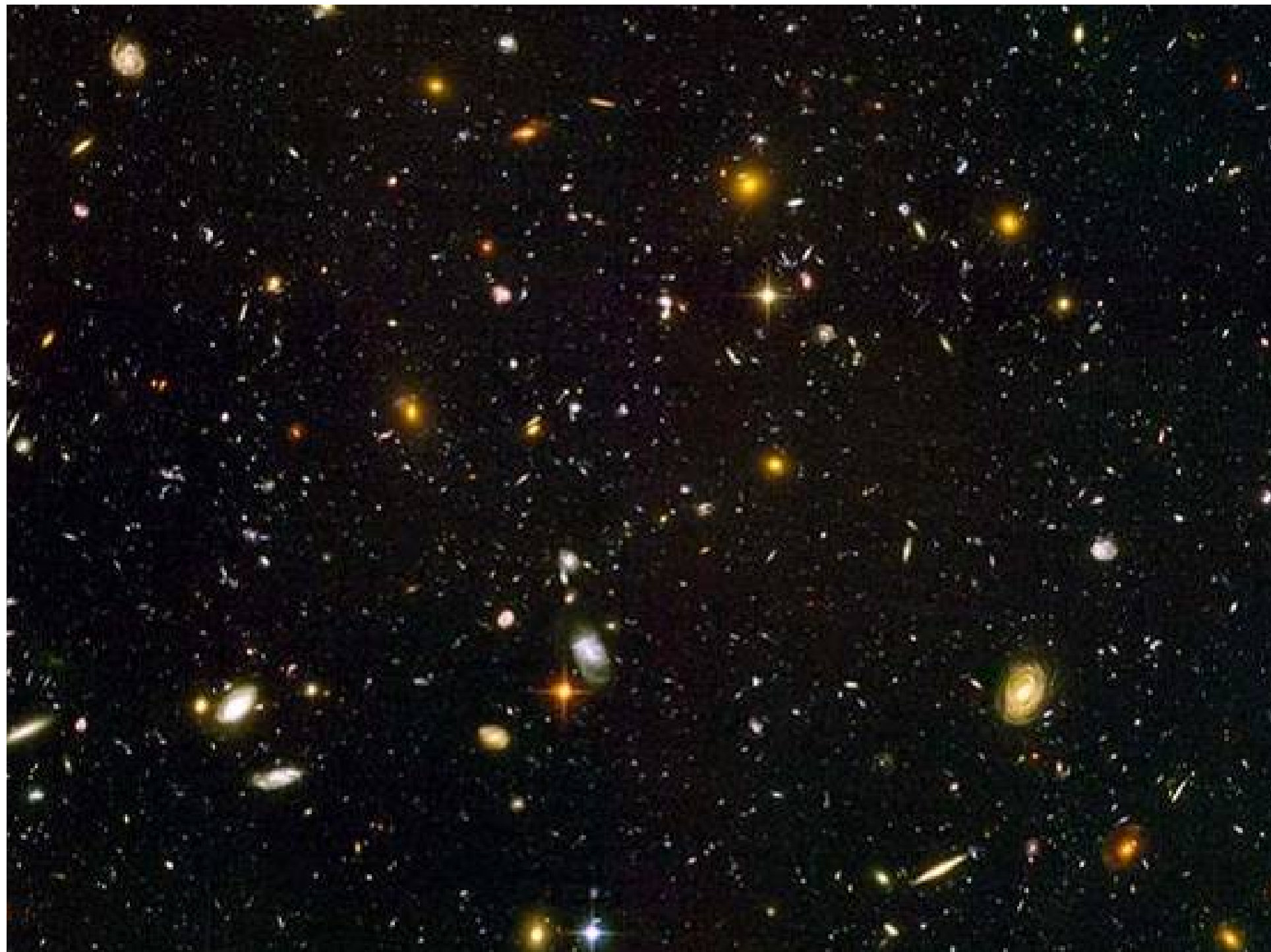




# Cortical Macrodynamics

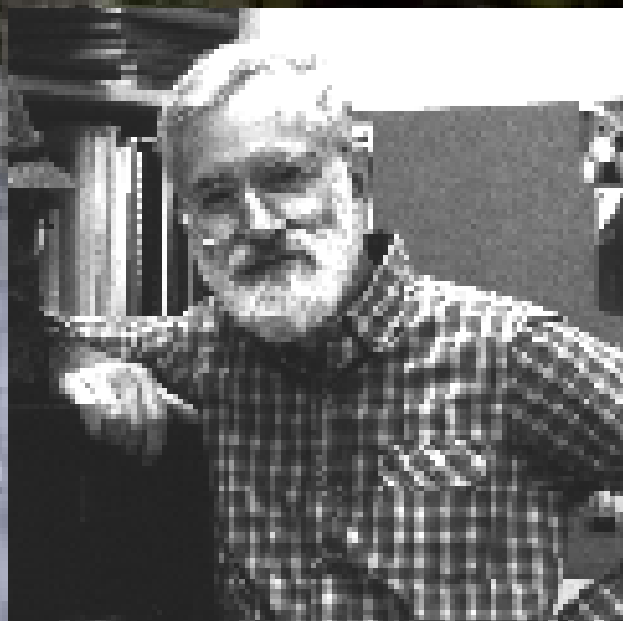
Organized field activities are also coherent, spatially organized phenomena in the electrical 'space' of the cortex.









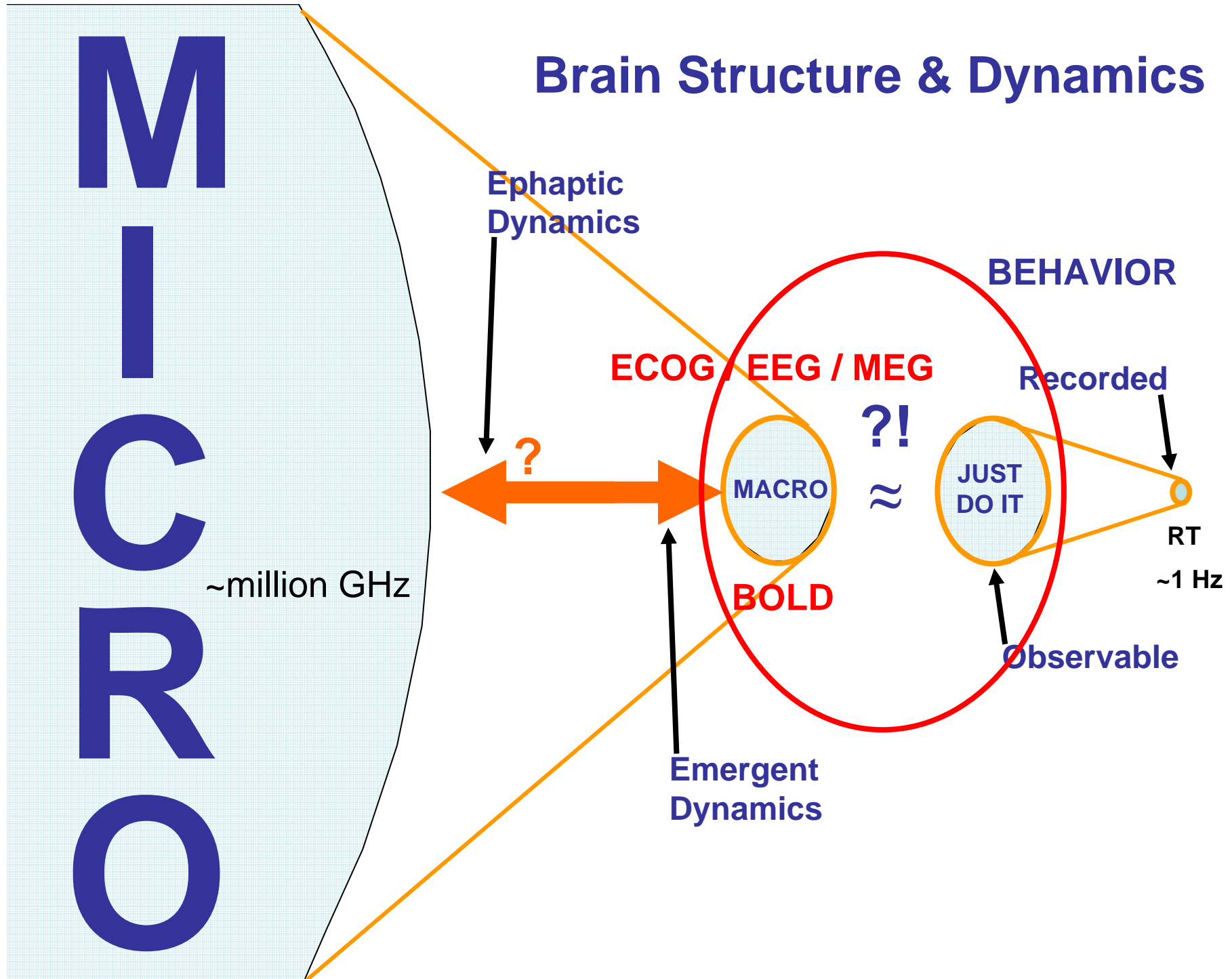


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**Spatiotemporal dynamics  
are complex ...**

# Brain Structure & Dynamics





# Brain Dynamics are Multiscale

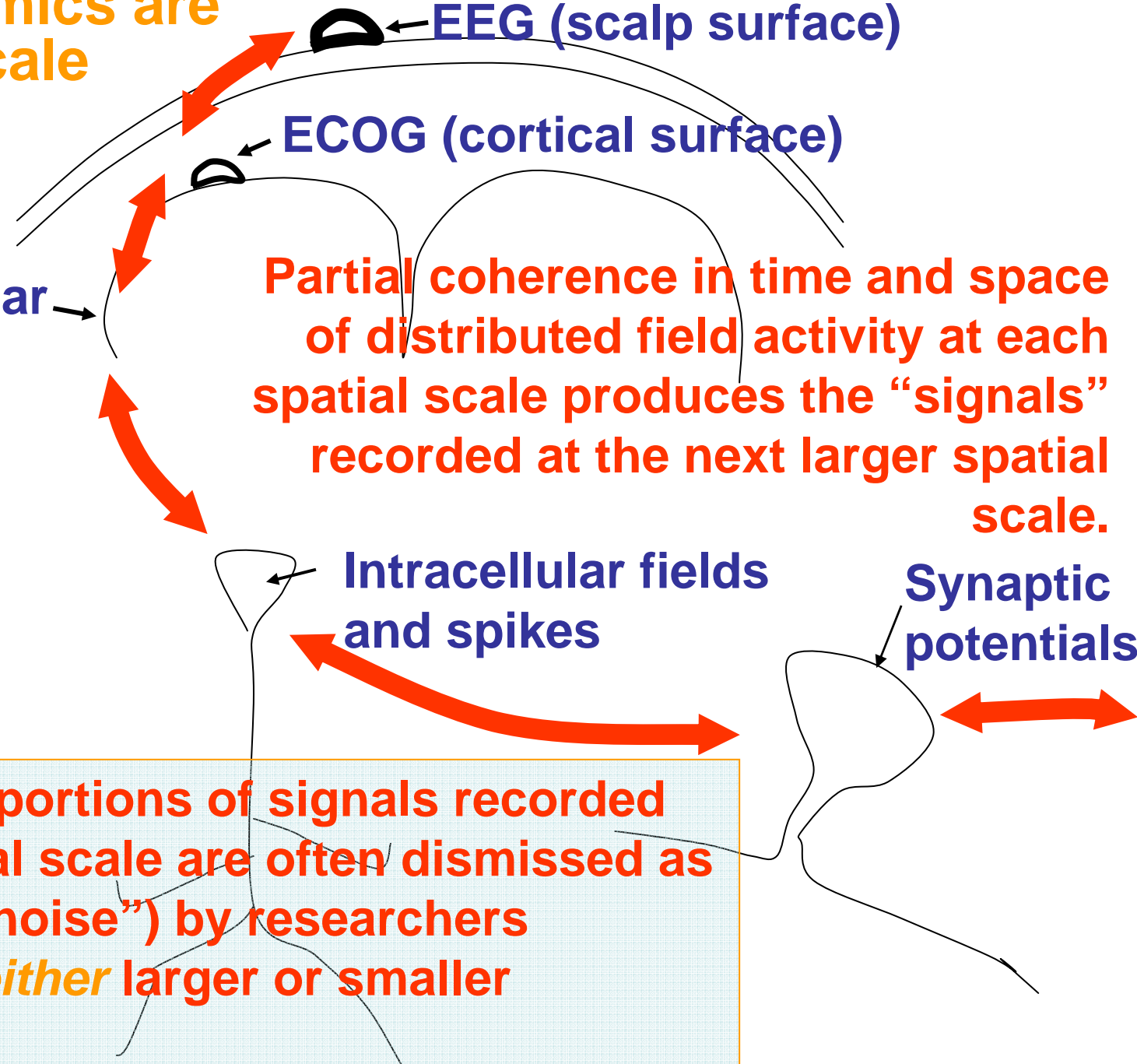
Local Extracellular Fields

EEG (scalp surface)  
ECOG (cortical surface)  
Partial coherence in time and space of distributed field activity at each spatial scale produces the “signals” recorded at the next larger spatial scale.

Intracellular fields and spikes

Synaptic potentials

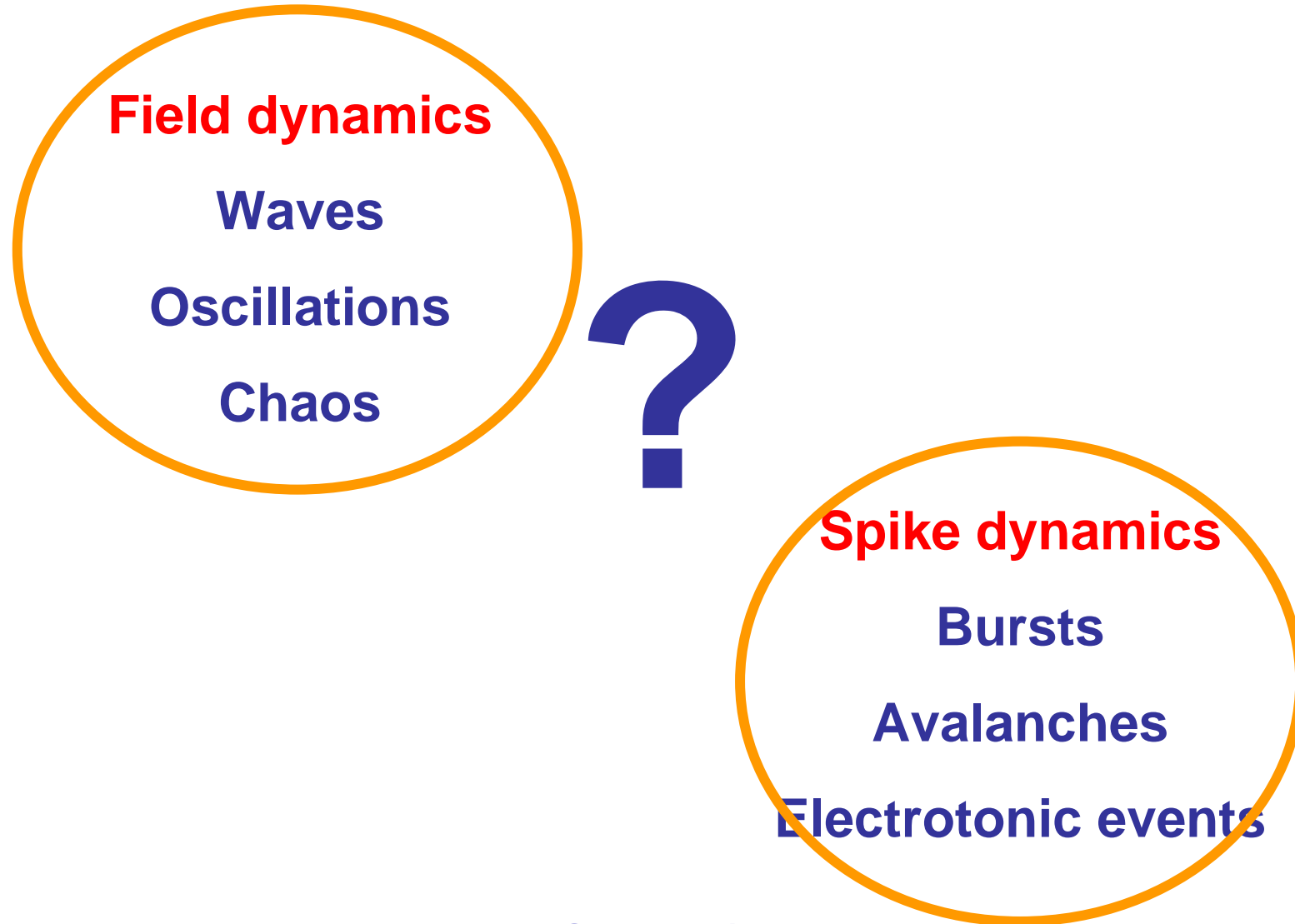
Unmodeled portions of signals recorded at any spatial scale are often dismissed as irrelevant (“noise”) by researchers working at *either* larger or smaller scales...



# 'Spike-Wave Duality' in Neuroscience



# 'Spike-Wave Duality' in Neuroscience



# Standard spike rate coding model: Quasi-thermal information conductance?

## Rate coding

= neural info. transmission via intense stochastically emitted bursts of spike activity (cf. “heat”).

Bursts of spikes from one area →

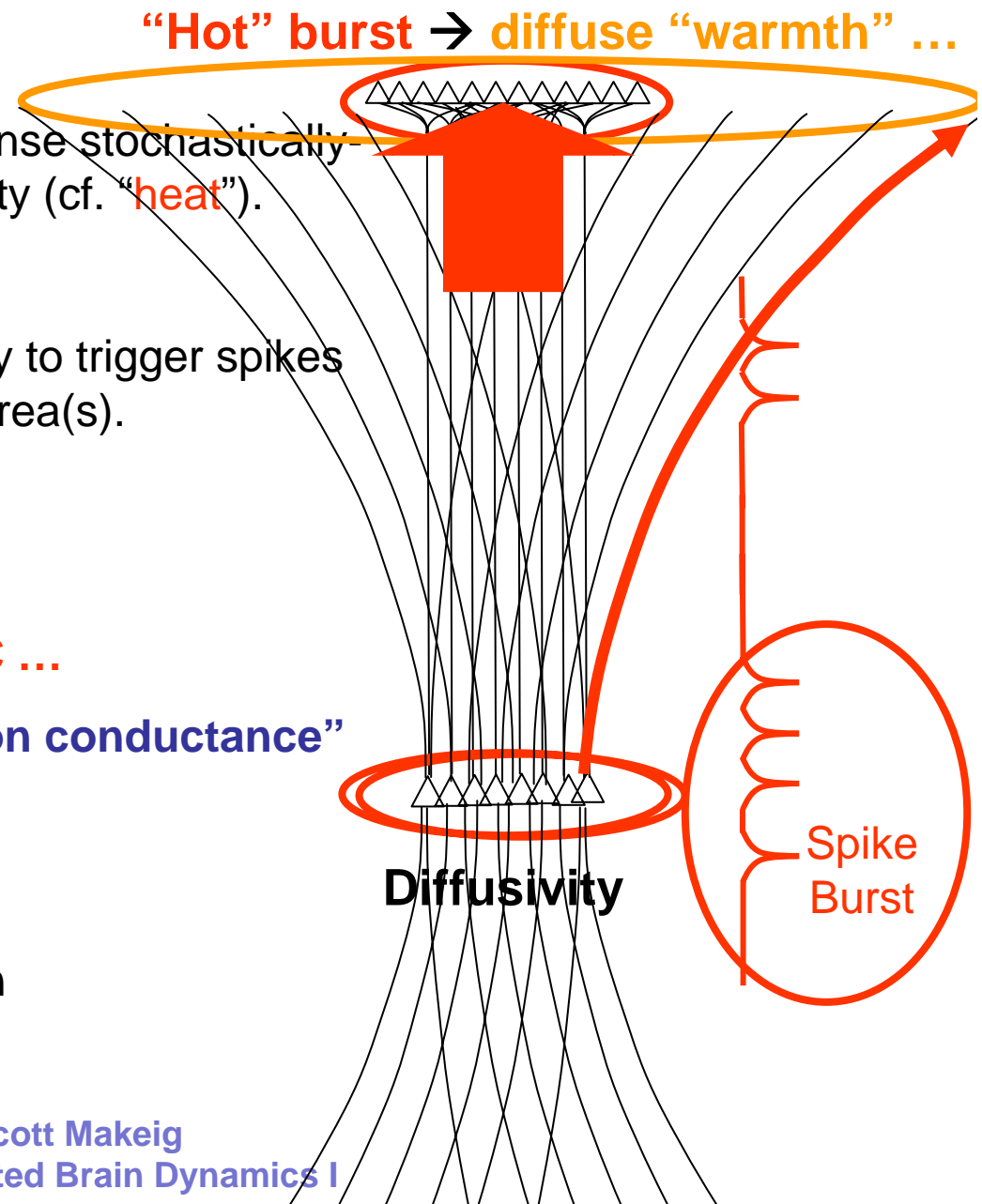
Sufficient synchrony to trigger spikes in target area(s).

- “Hot” burst in area A  
→ “hot” burst in B  
→ “hot” burst in C ...

= “quasi-thermal information conductance”

But this is highly inefficient:

- More Energy
- Less Spatial resolution
- Less Temporal resolution



# Opposite Extreme: Spike Multiplexing

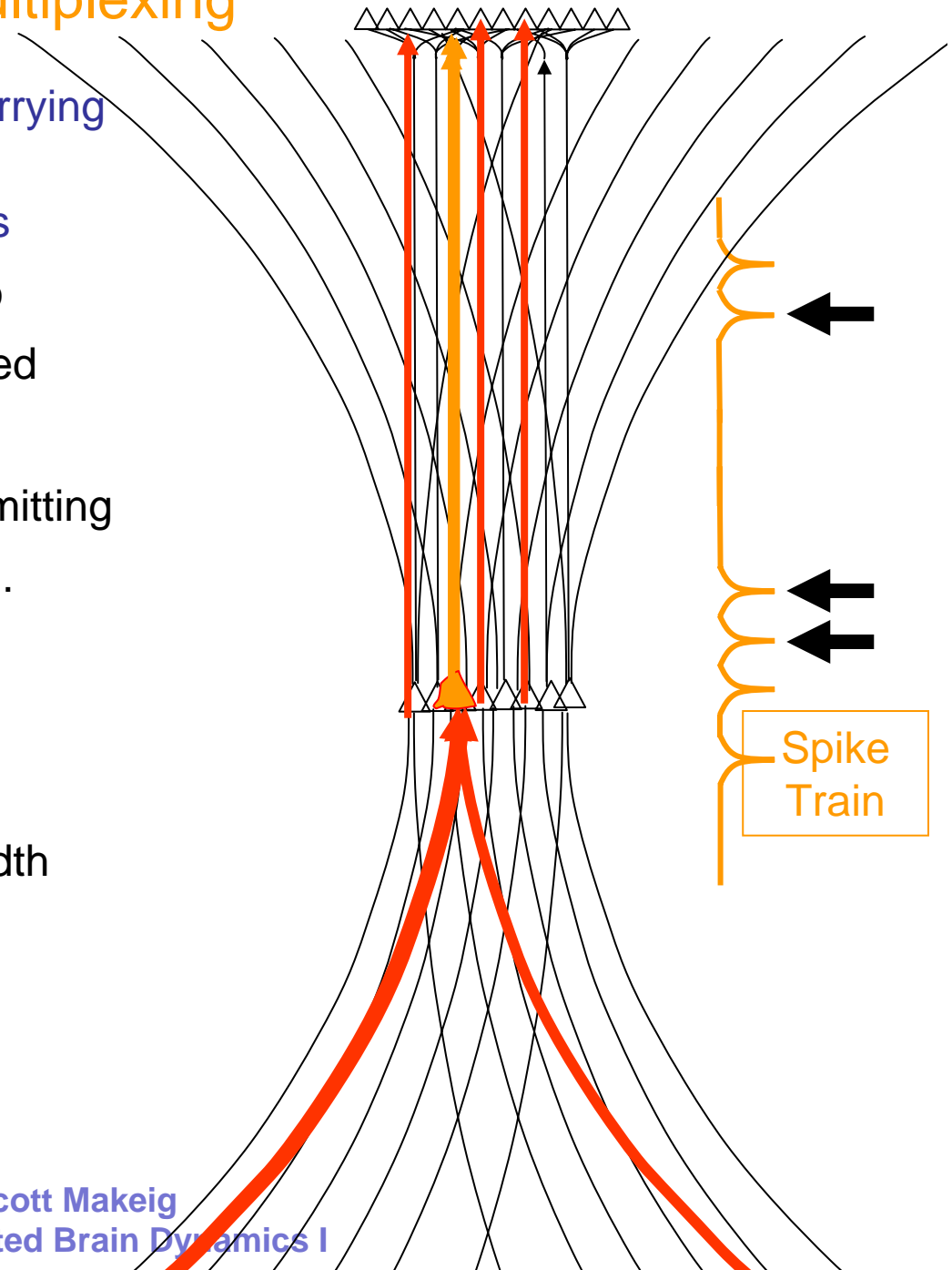
Each spike train may participate in carrying more than one neural signal...

i.e. Spike trains as **multiplexed** signals

**Each spike** in the train may belong to a different, spatially distributed “volley” event and thus participate in transmitting a different neural “word”...

## Advantages:

- Efficient
- Flexible
- High spatial & temporal bandwidth



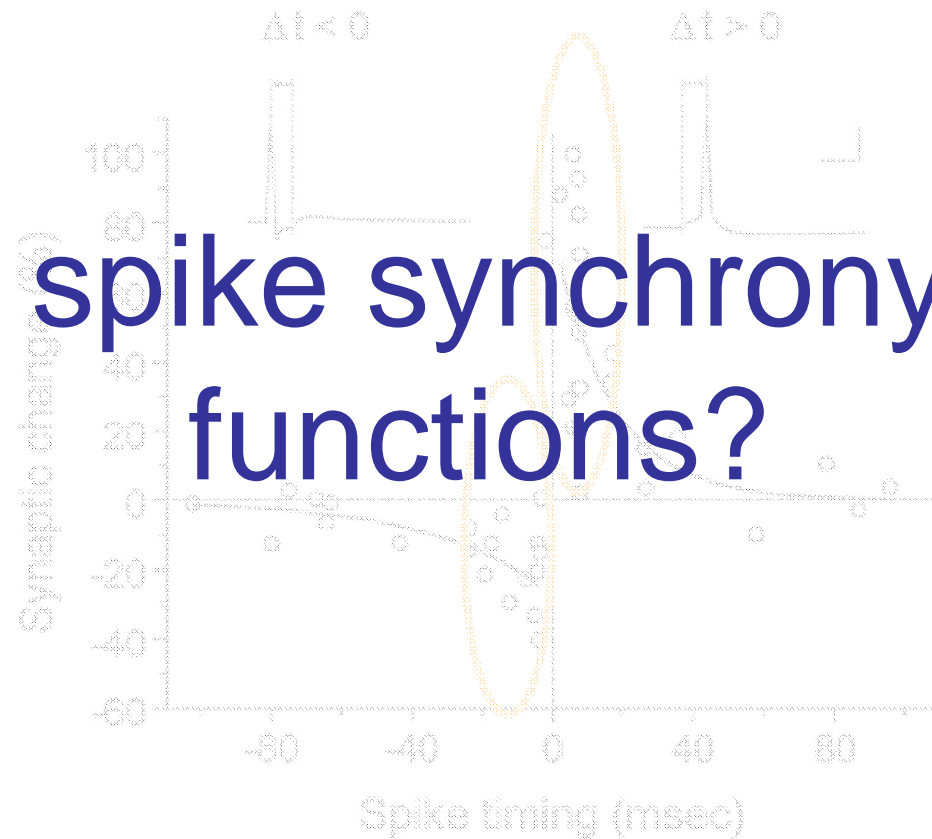
## What creates Synchronous Input Volleys ?

- Electrotonic coupling (threshold sculpting)
- Spike time dependent learning
- Neural-glia interactions
- Extracellular field biasing (ephaptic effects)
- Myelin growth control (conductance speed regulation)
- etc.etc. ...

# Spike-Timing Dependent Learning

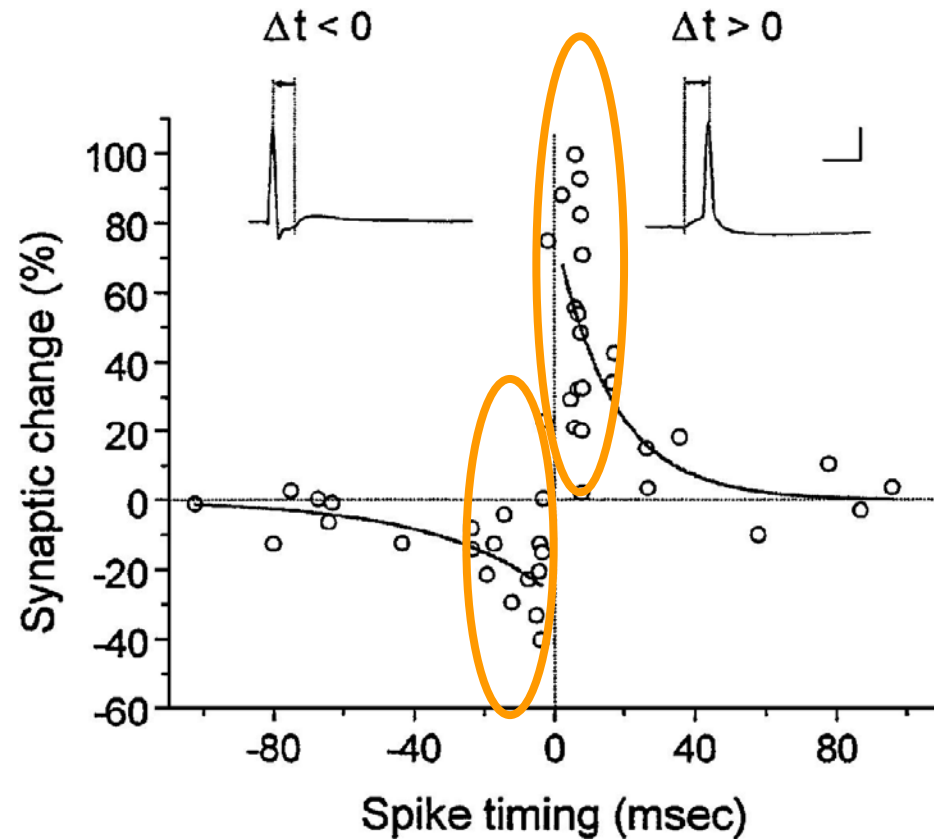
## Synchrony Rewarding / Promoting

Does spike synchrony have functions?



# Spike-Timing Dependent Learning

## Synchrony Rewarding / Promoting





No: Users "roar at the crowd"

Yes, as indicator: Useful index of local synchrony

# Do fields have functions?

Yes: they regulate synchrony (epileptic effects)

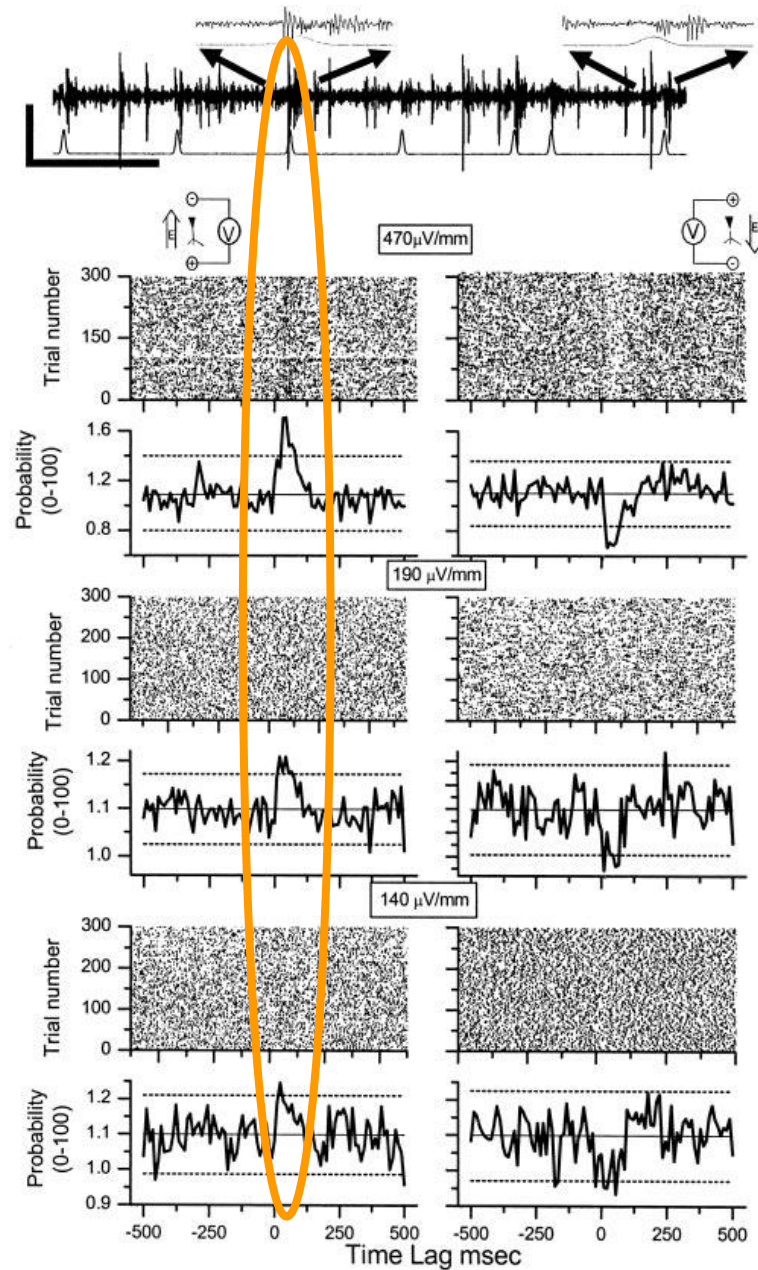
# Ephaptic field effects

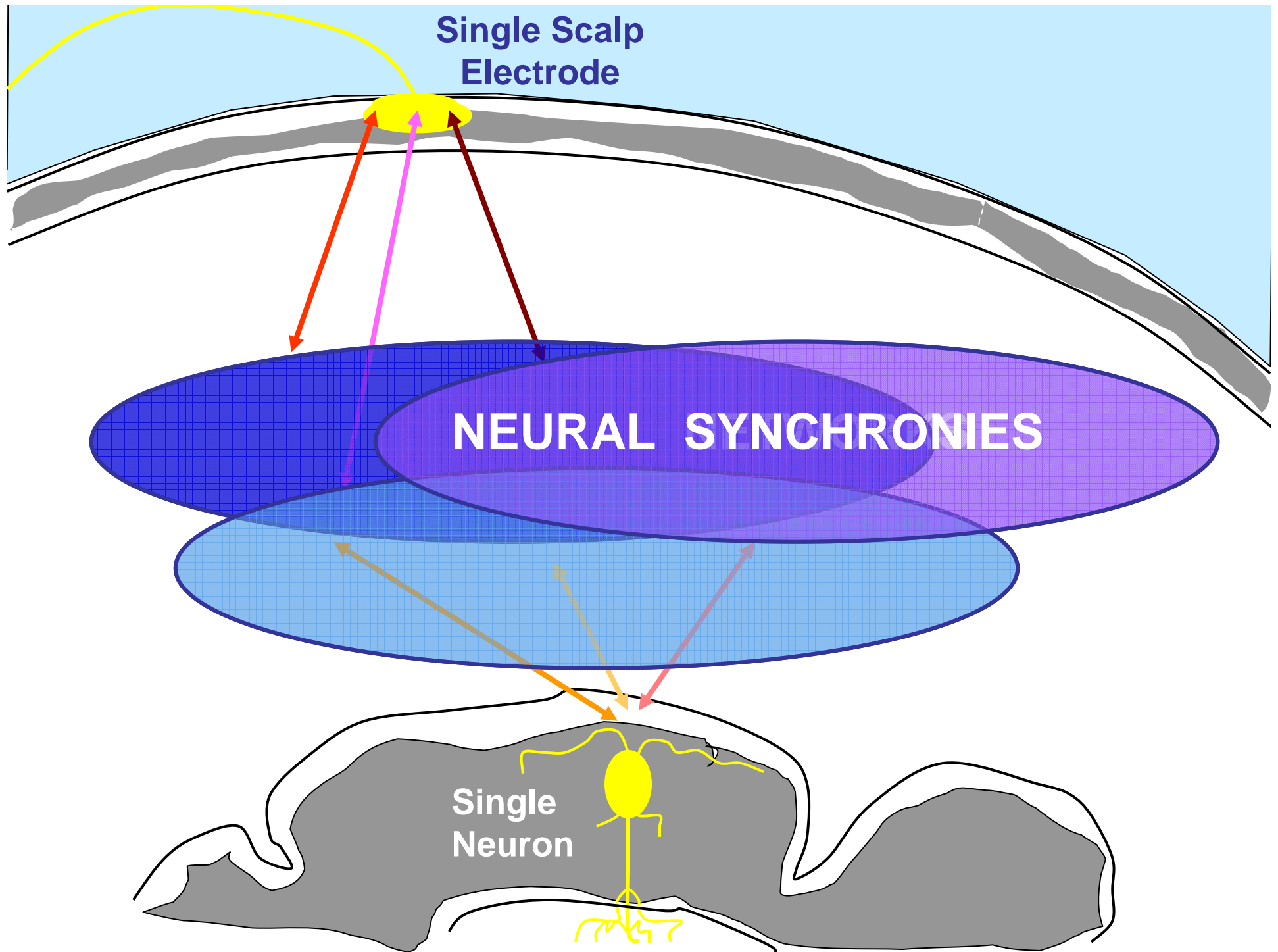
Francis, Gluckman & Schiff (*J Neurosci*, 2003) applied external fields to a hippocampal slice and demonstrated local field effects on neural spiking down to well below the density of hippocampal LFP

→ nearly down to a predicted physical bound.

→ lowest field intensities produced

**stronger spike synchrony !**





“It takes a village to raise a child.” –Hillary Clinton

It takes a neuropile to raise a spike volley

To produce a spike requires

a **near-synchronous spike input volley**

& a near-threshold external environment

& a near-threshold internal environment

& ...

& it takes a neuropile to use a spike volley.

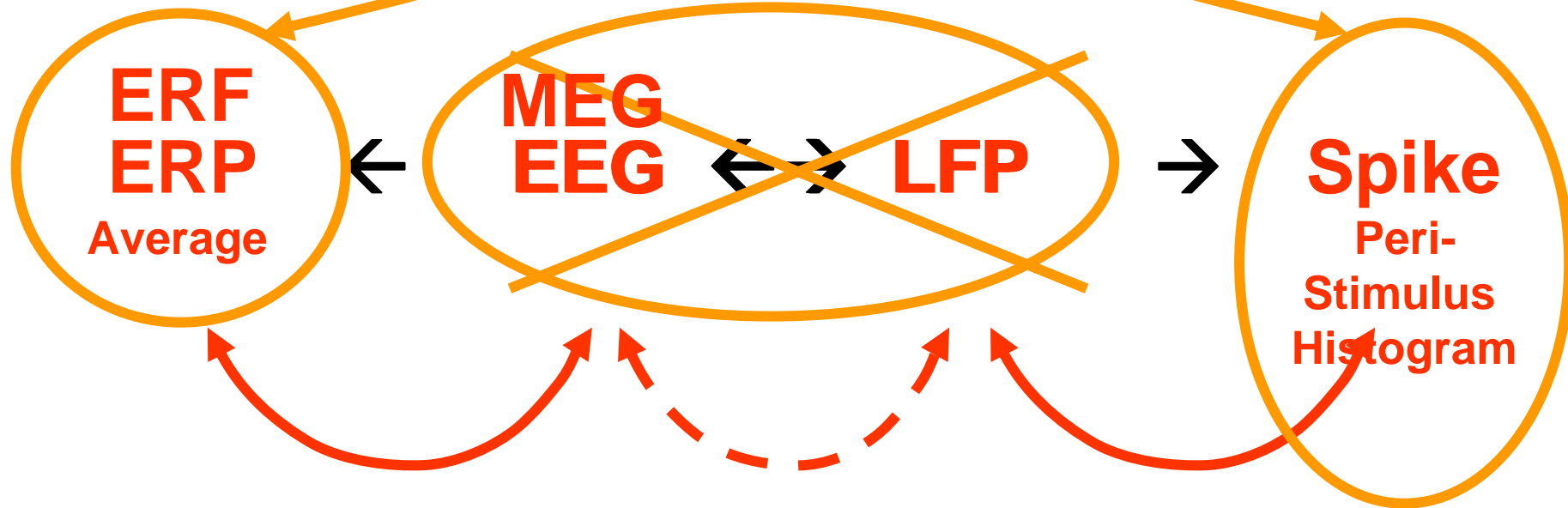
# Multiscale brain communication

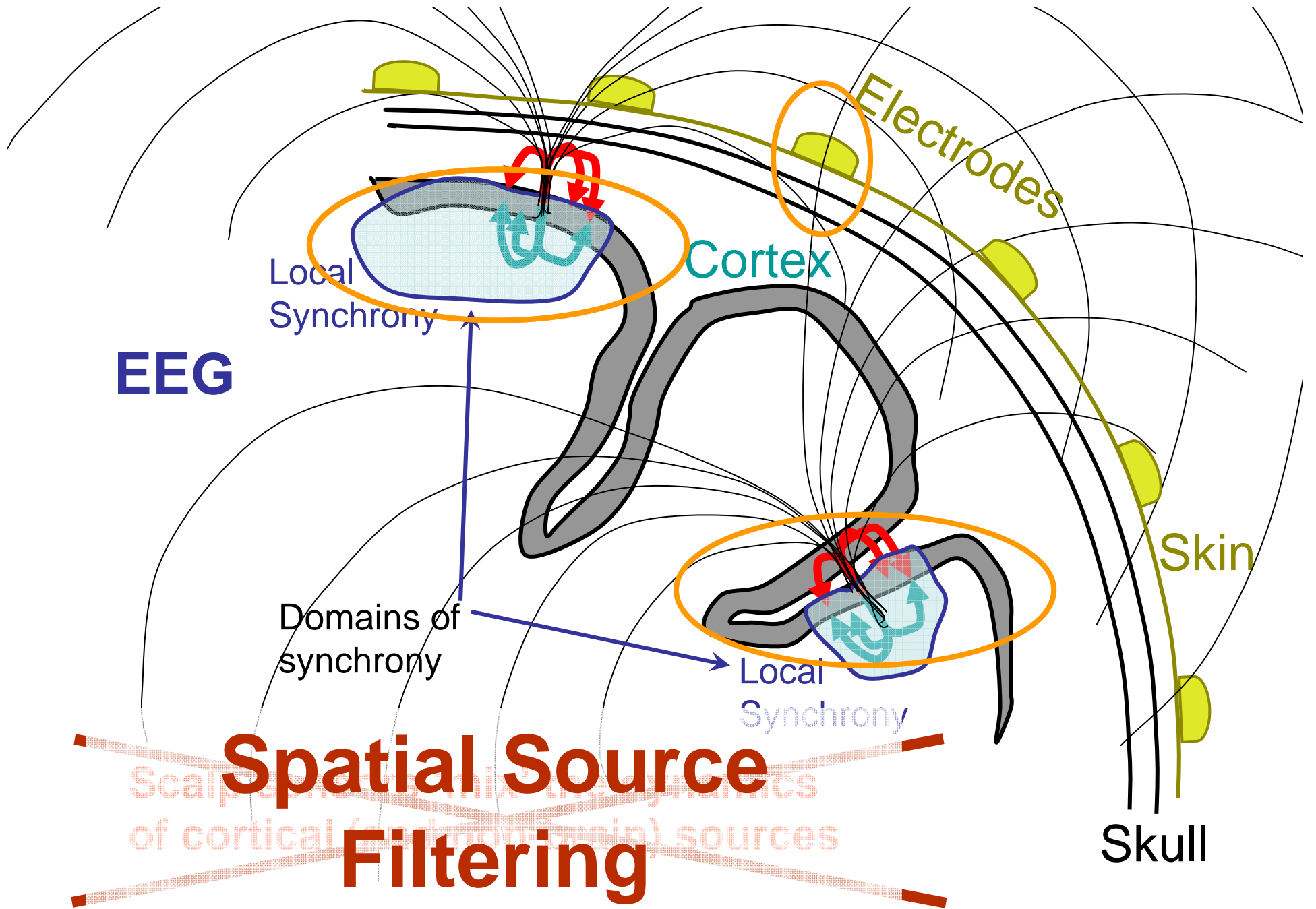
1. Spike synchrony, producing extra-cellular fields, and biasing of spike synchrony *by* extracellular fields, must occur *across different spatial scales*, with different effects.
2. The spatial scales of partial synchrony giving rise to scalp-recorded fields *are currently unknown*, but might be extracted from (future) multiscale recordings.

# Brain Electrophysiology

Response Averaging

1960 →









The response averaging model:

# Limitations of response averaging

But, this linear decomposition is veridical if & only if:

1. The Average appears in each trial  
**Not True / Not Defined**
2. The "Background" is not perturbed  
in other ways by the time locking events.  
**Not True**

## The response averaging model:

$$\begin{array}{ccc} \text{EEG} & \text{ERP} & \text{EEG "noise"} \\ \text{Data} \equiv \text{Average} + \text{"Background"} & & \\ \text{BOLD} & \text{ERB} & \text{BOLD "noise"} \end{array}$$

**But,** this linear decomposition is veridical **if & only if:**

1. The **Average** appears in each trial.
2. The **"Background"** is not perturbed in other ways by the time locking events.

# The adequacy of blind response averaging

## IF ....

- If 'equivalent' stimuli (passively) evoke the same macro field responses (with fixed latencies and polarities or phase) in **all** trials...
- If **all** the REST of the EEG can be considered to be Gaussian noise sources that are **not** affected by the stimuli..

## THEN ...

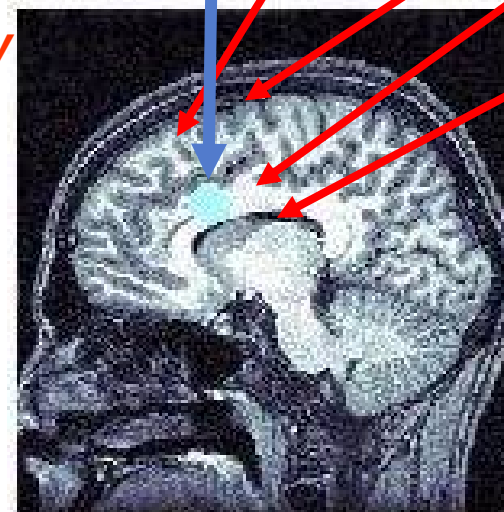
- The stimulus-locked average contains **all** the meaningful event-related EEG/MEG brain dynamics.

# The inadequacy of blind response averaging



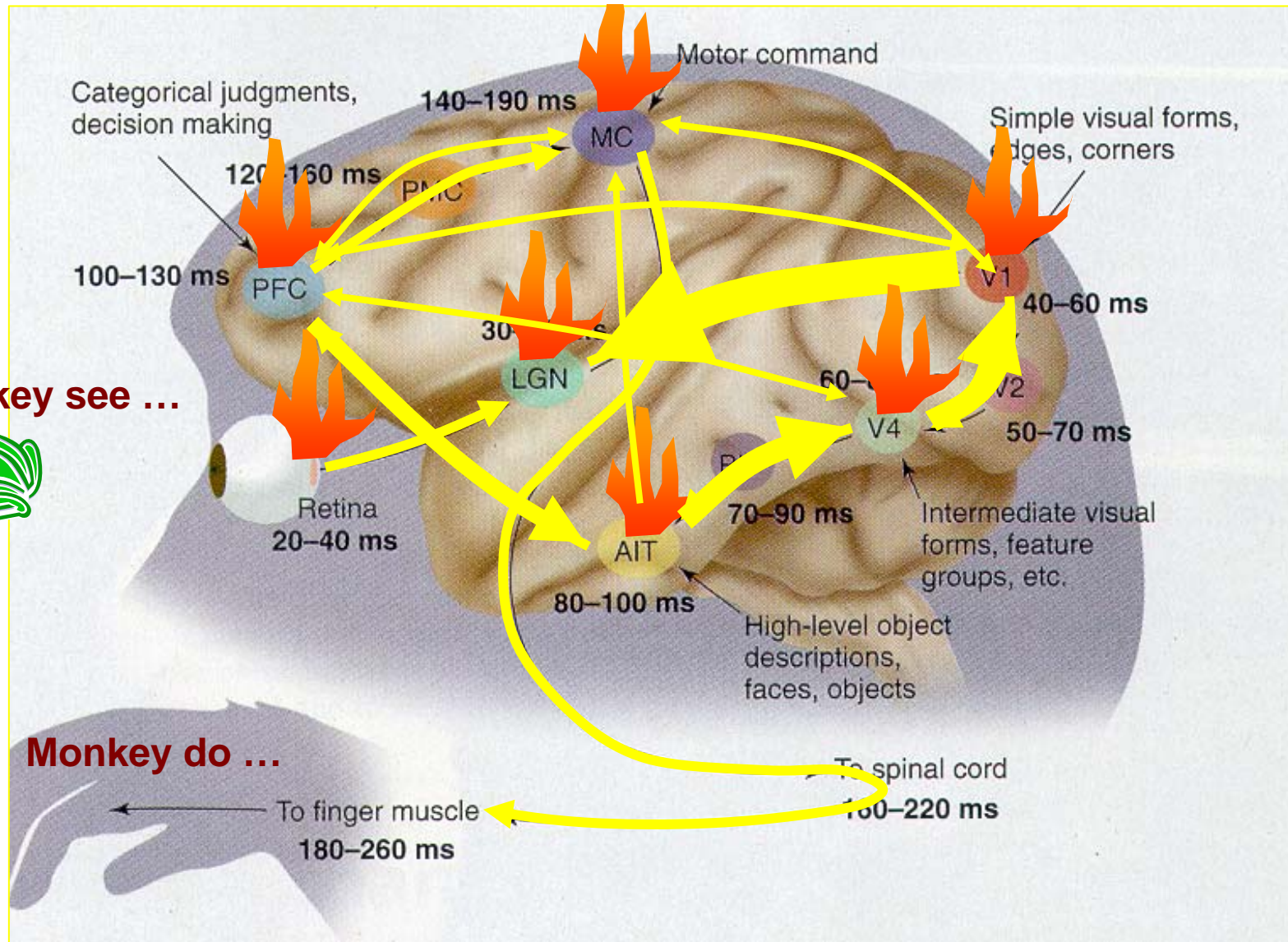
**BUT** this simple model involves some highly questionable assumptions:

- ? The living brain produces *passive* responses ??
- ? Ongoing EEG processes are *not perturbed* by events??
- ? Evoked response processes are *spatially segregated* from ongoing EEG processes ??
- ? 'Equivalent' stimulus events evoke *equivalent* brain responses → event-related brain dynamics are *stationary* from trial to trial ??
- ? The 'true' response baseline is *flat* ??

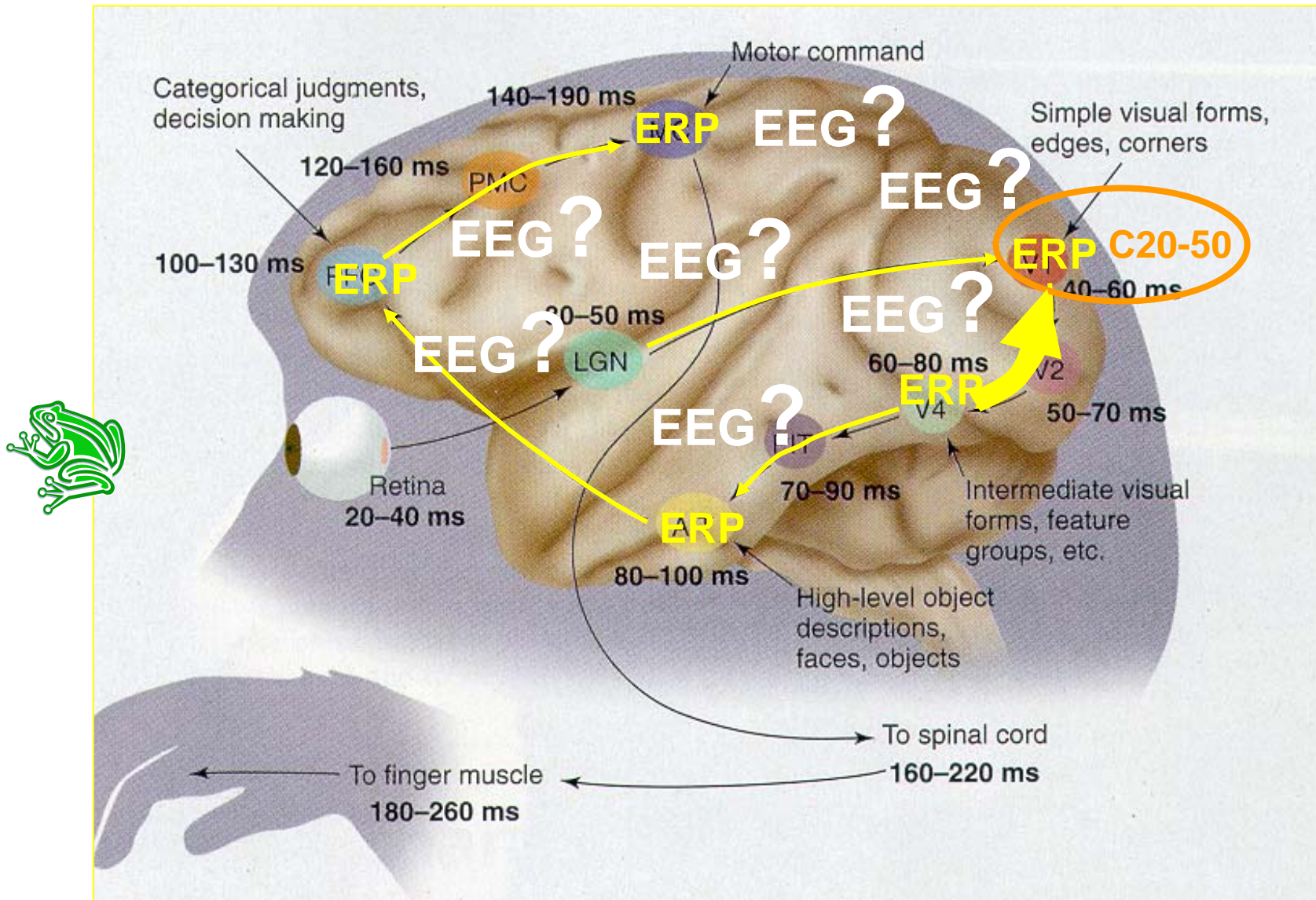


# Monkey LOOK ... Monkey Do

Monkey see ...



Monkey do ...



Thorpe and Farbe-Thorpe, *Science* (2001) 291: 261

# Modeling Event-Related Brain Dynamics

1. Un-mix cortical (and artifact) source contributions to the scalp electrodes using **independent component analysis (ICA)**.
2. Visualize the activities of independent component (IC) sources across single trials using **ERP-image plotting**.
3. Model the event-related dynamics of the IC sources using **time/frequency analysis**.
4. Localize the separated IC sources using **inverse source mapping methods**.
5. Compare similarities in IC dynamics and locations across subjects using **IC cluster analysis**.
6. Assess reliability of differences between IC activities time-locked to conditions, groups, and/or sessions of a **study**.

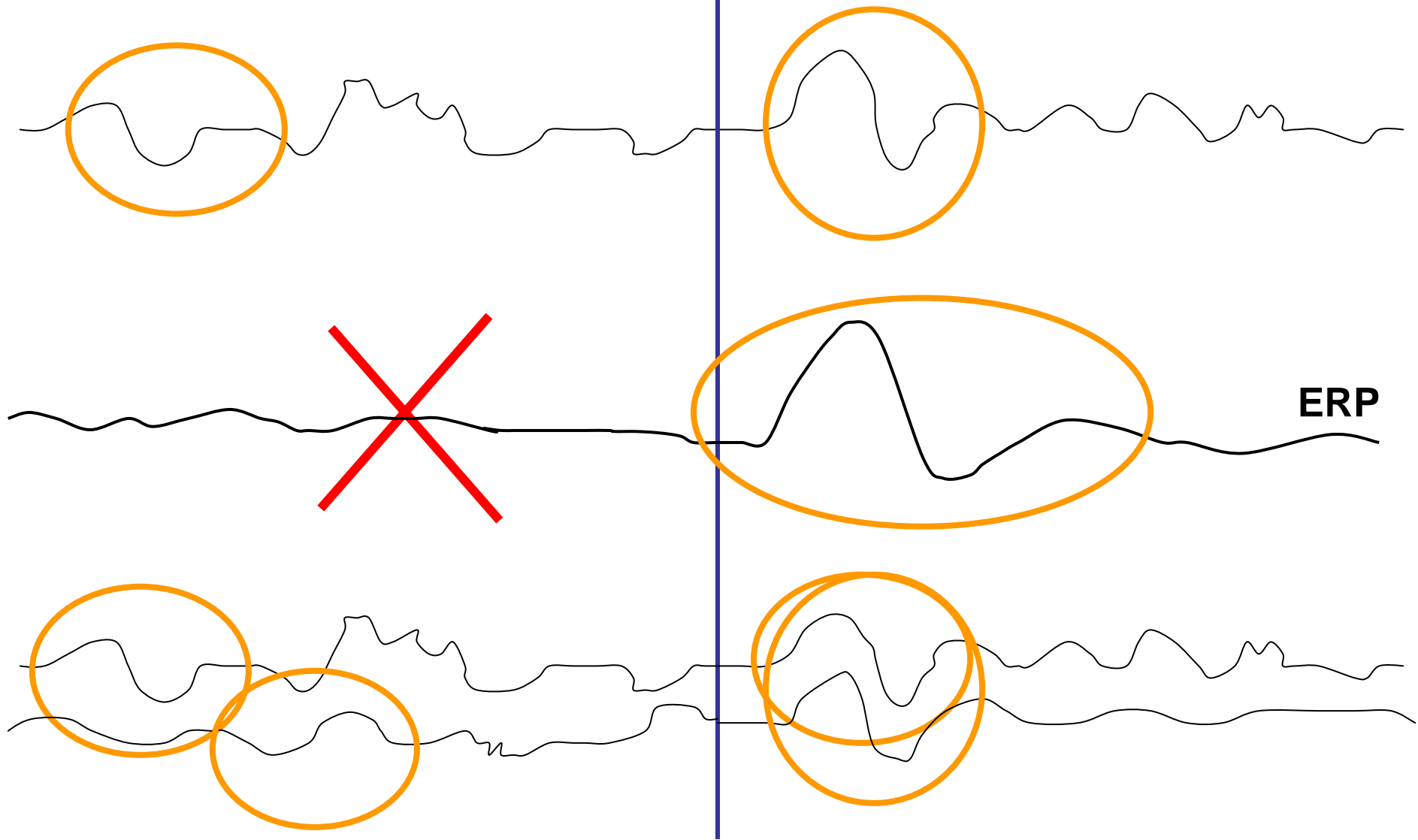
## A richer model

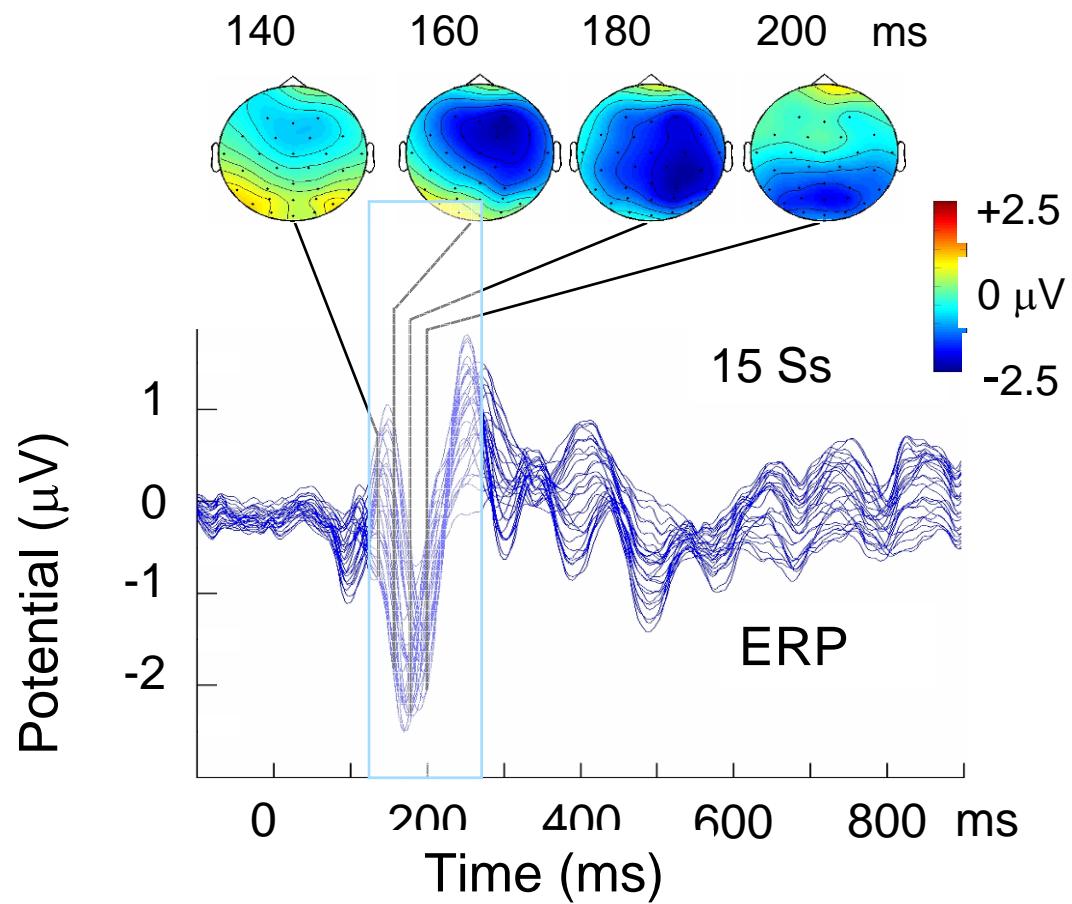
# Modeling Event-Related Brain Dynamics

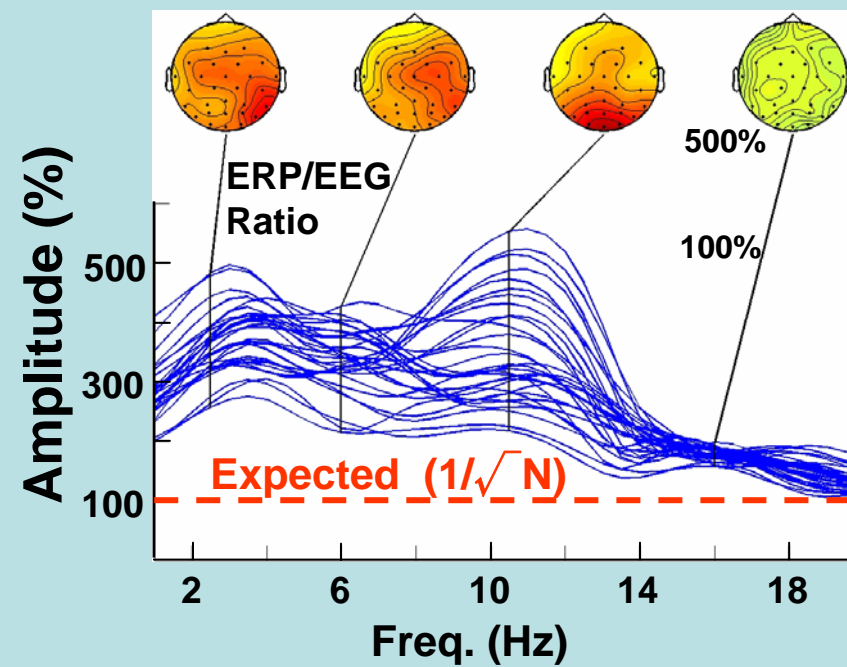
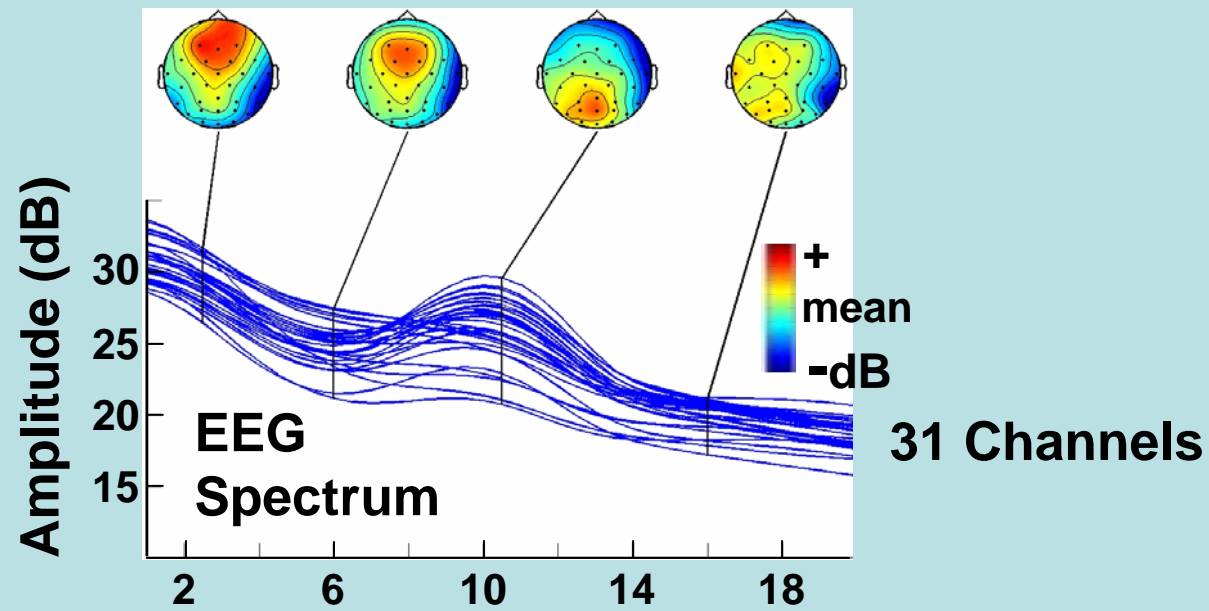
1. Un-mix cortical (and artifact) source contributions to the scalp electrodes using **independent component analysis** (ICA).
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# Event-related perturbations









**Fusiform**

10-Hz Coh

Alpha and Gamma Frequency Range

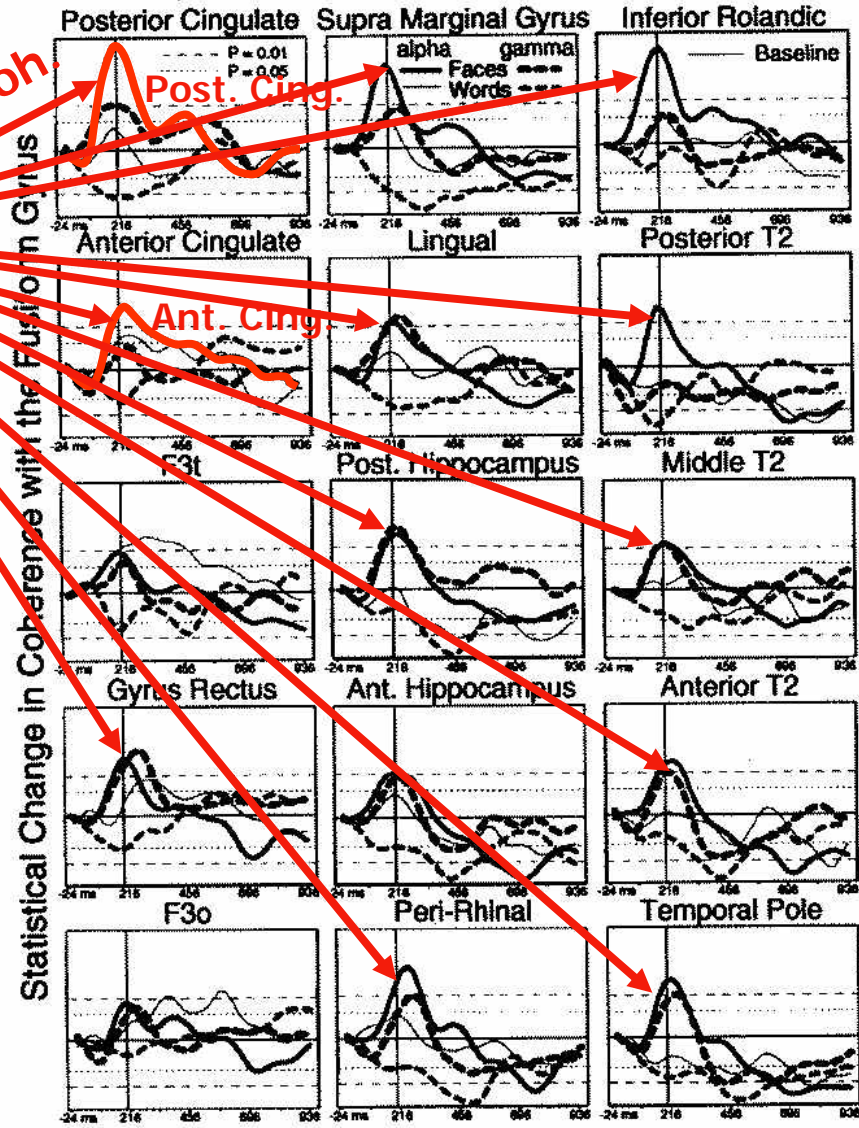


Figure 3.

Across-subject averages of alpha and gamma-band coherence between the fusiform gyrus and 15 other areas. A sharp transient face-selective increase in coherence centered at 200 ms is seen in all sites for alpha activity and a majority of sites in the gamma band. Abbreviations as in Figure 1.

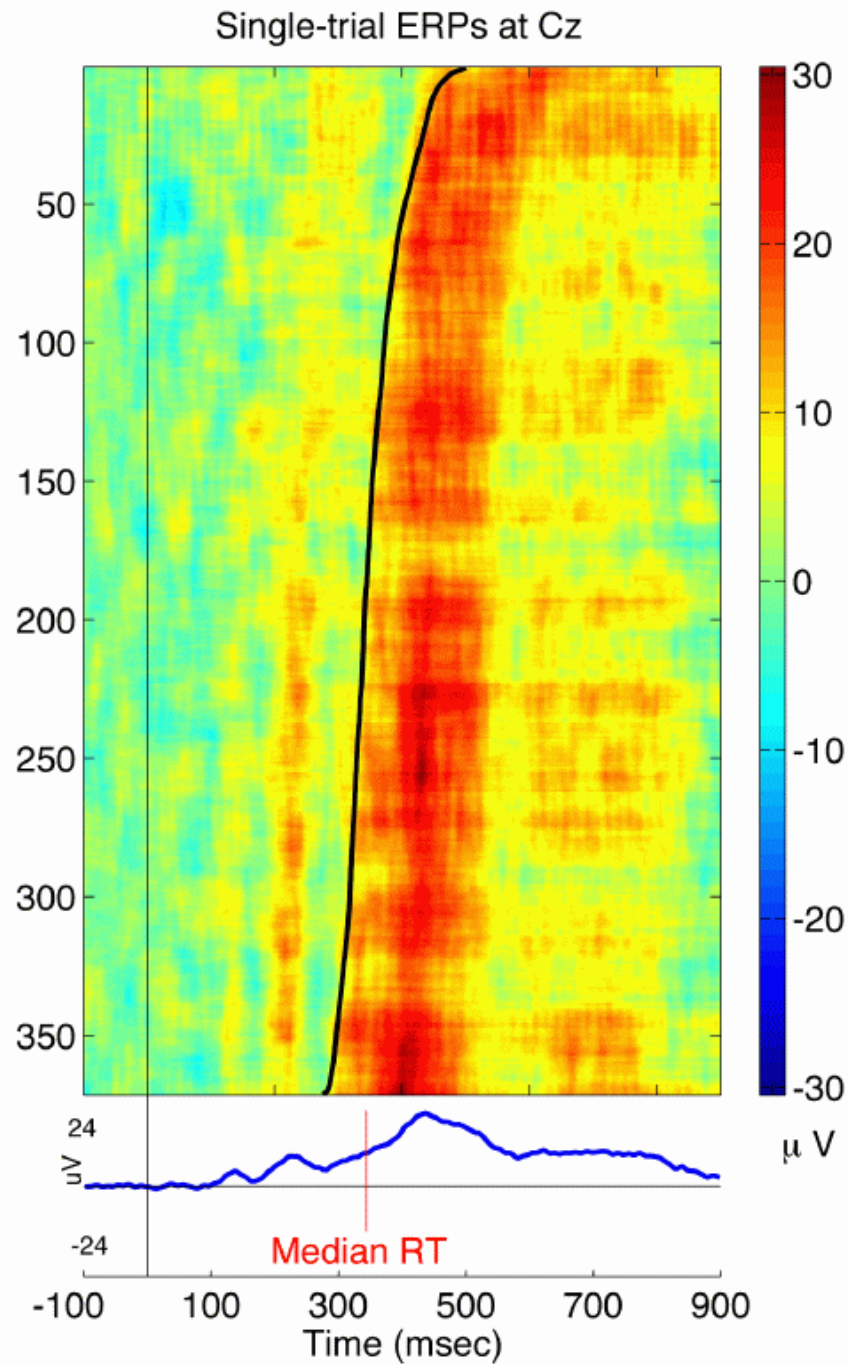
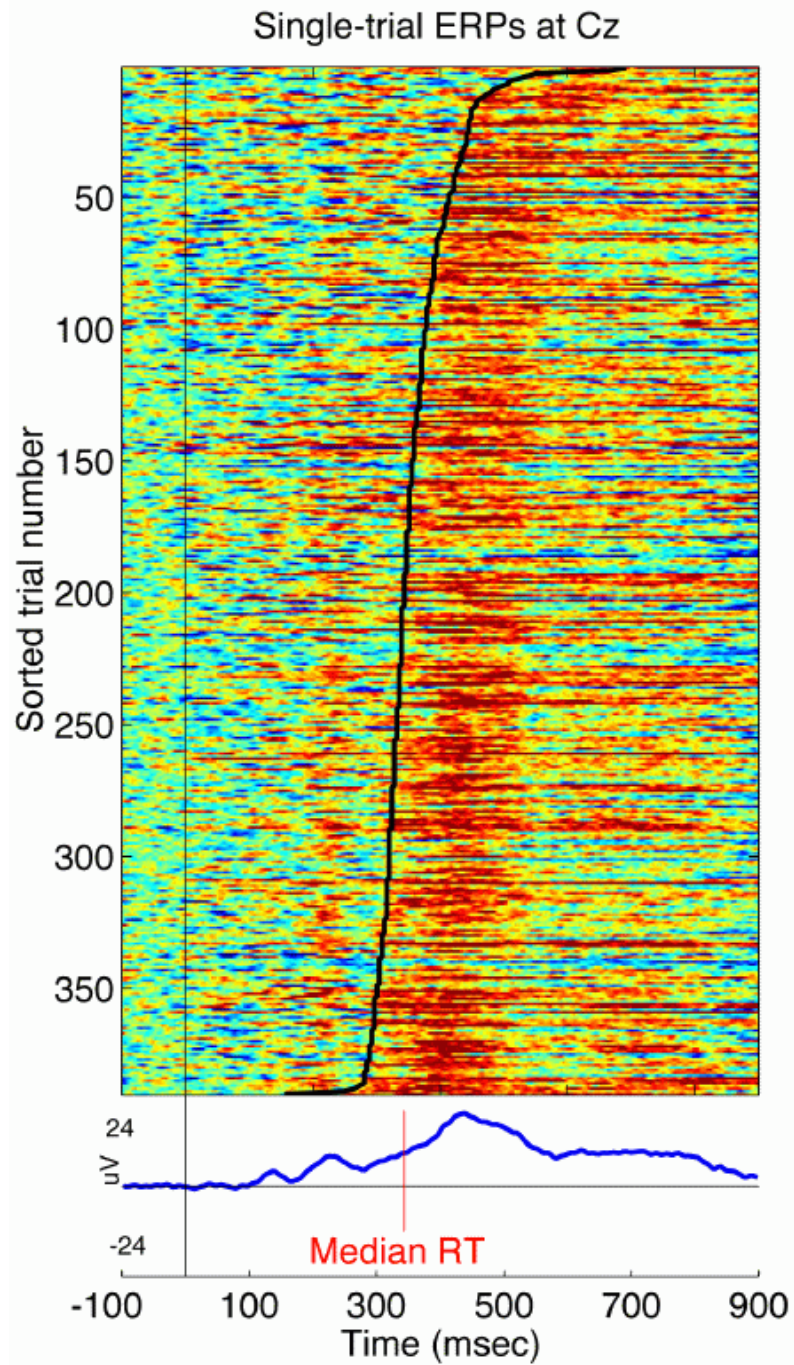
J Klopp, K Marinkovic, P Chauvel, V Nenov, E Halgren  
*Hum Br Map* 11:286-293 (2000)

## New Concepts → New Measures

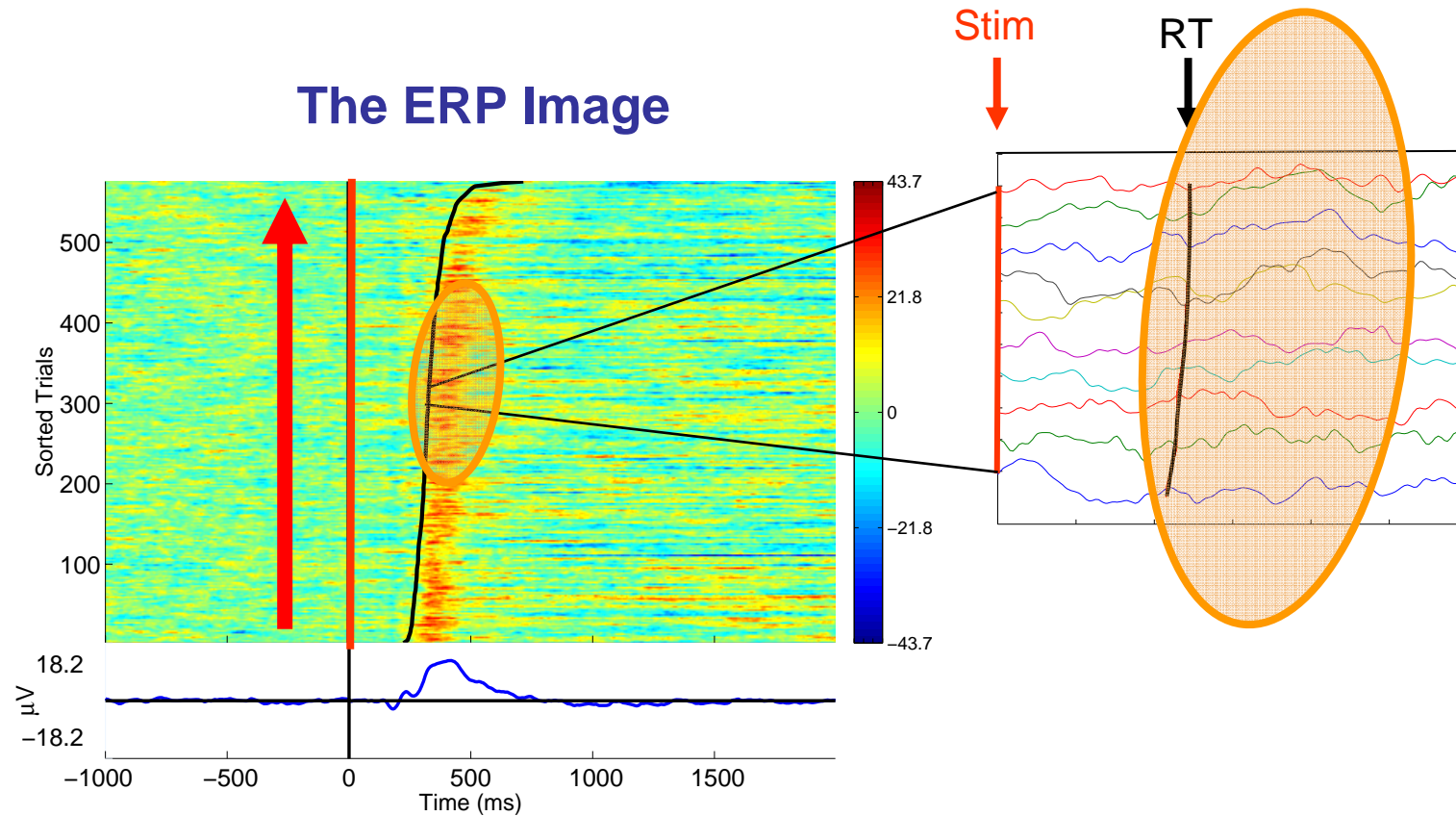
- ERSP – event-related spectral power
- ITC – inter-trial coherence (phase locking)
- ERC – event-related coherence

## New Measures → New Visualizations

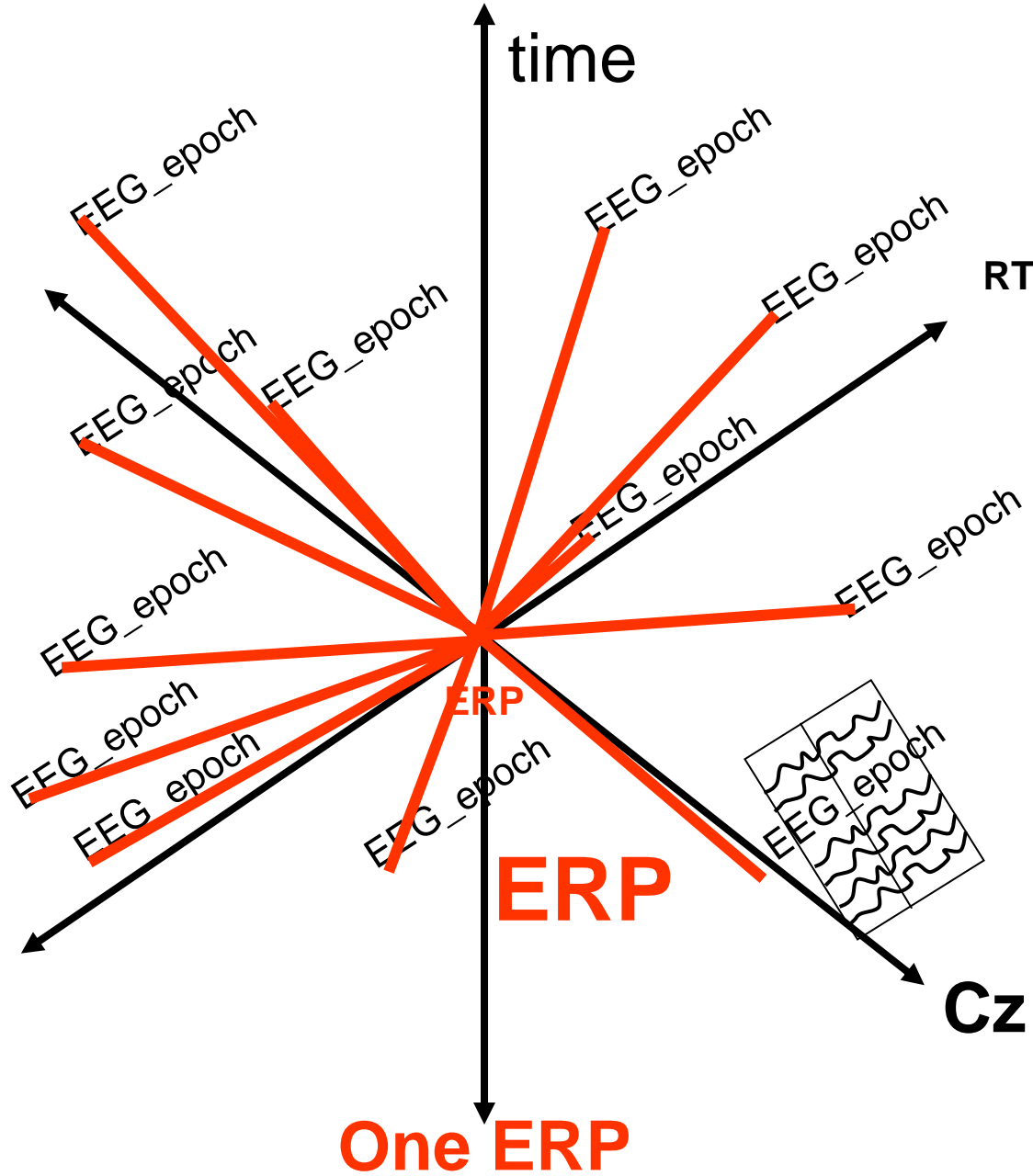
- `erpimage()` – sorted trial-by-trial dynamics
- `envtopo()` – ERPs and components
- `tftopo()` – event-related spectral power changes



Collections of single trials are regular, but in **multiple** ways – so they *appear* noisy!

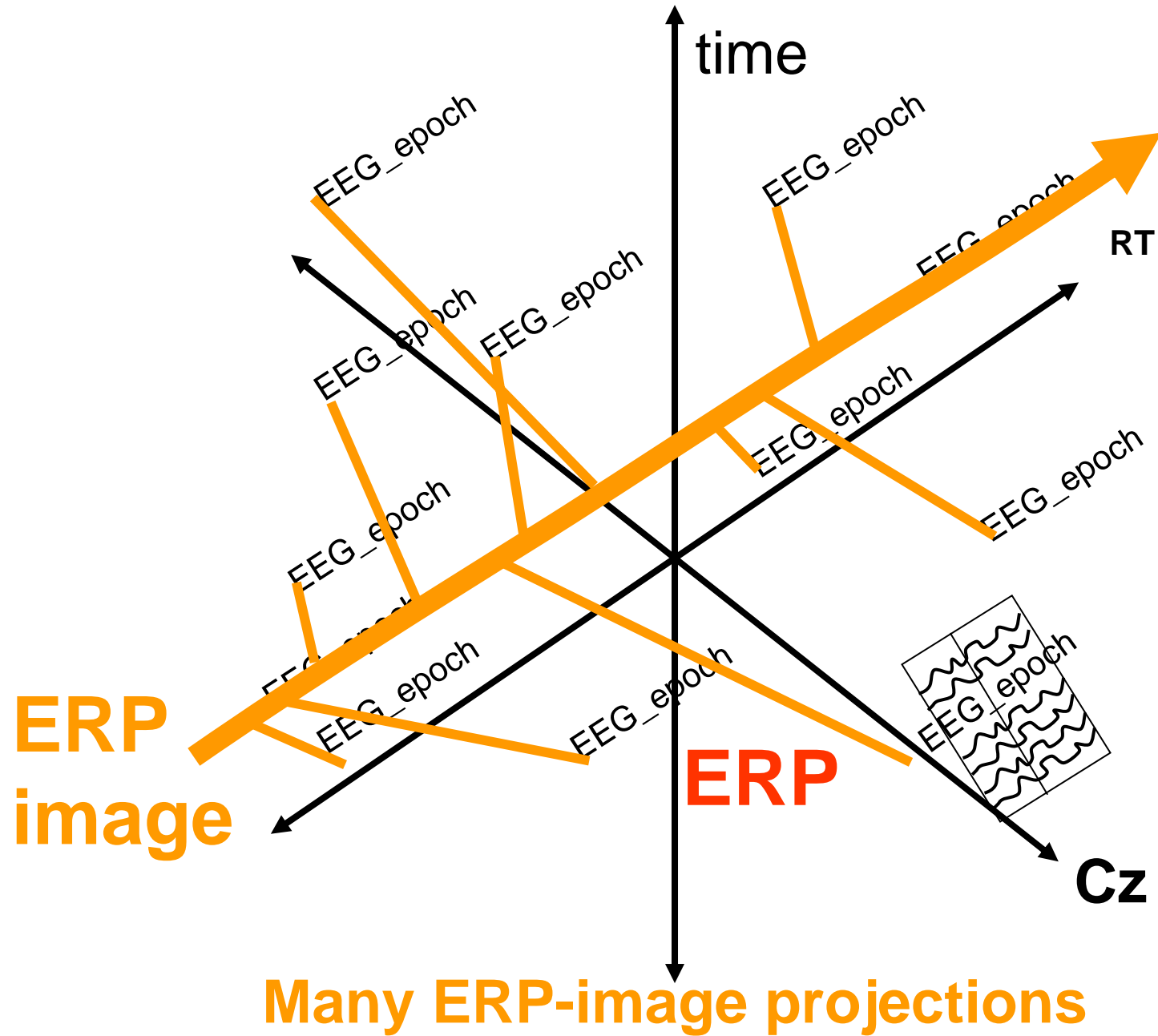


**ERP  
image**



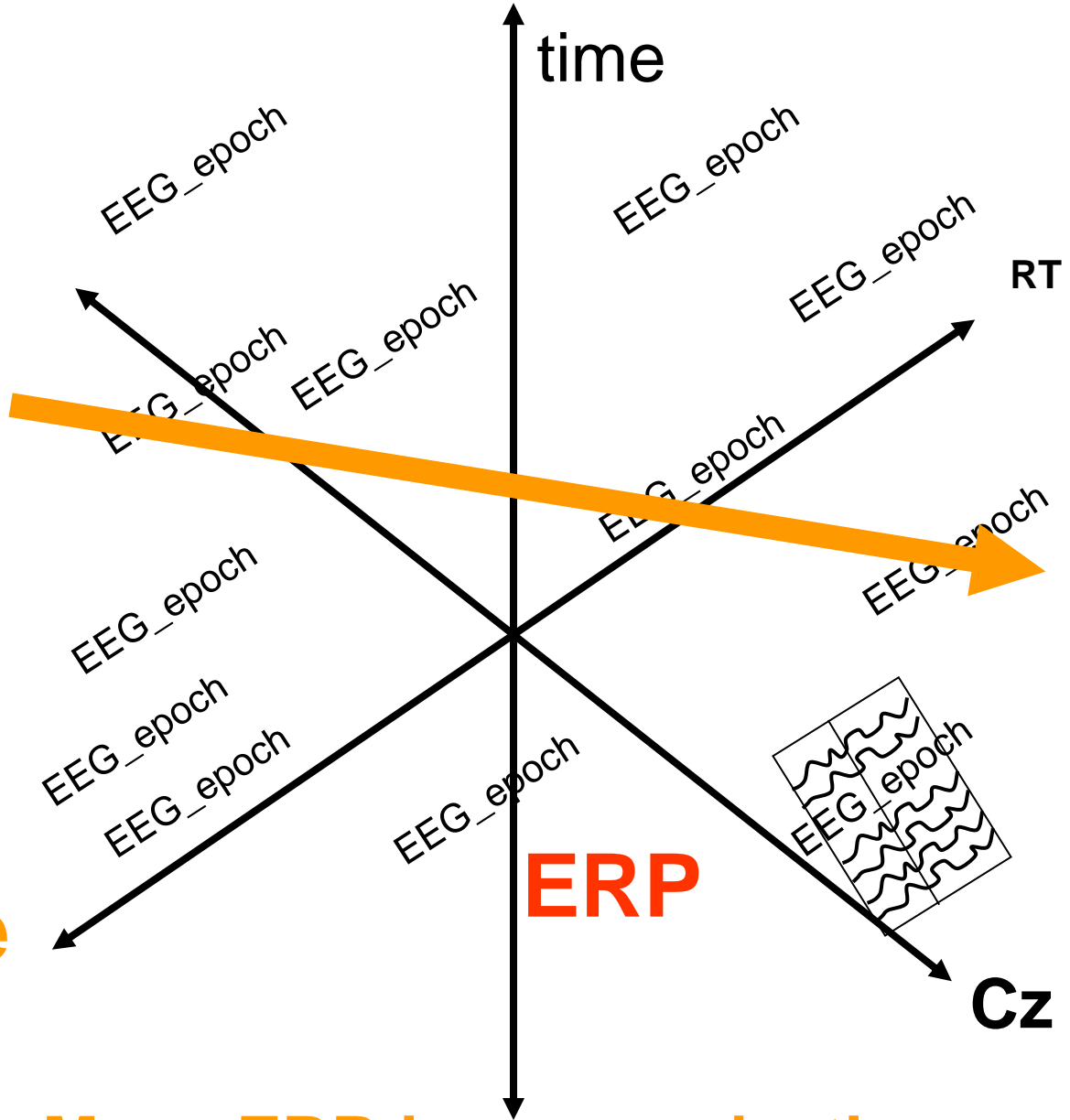
**One ERP**





Many ERP-image projections

**ERP  
image**

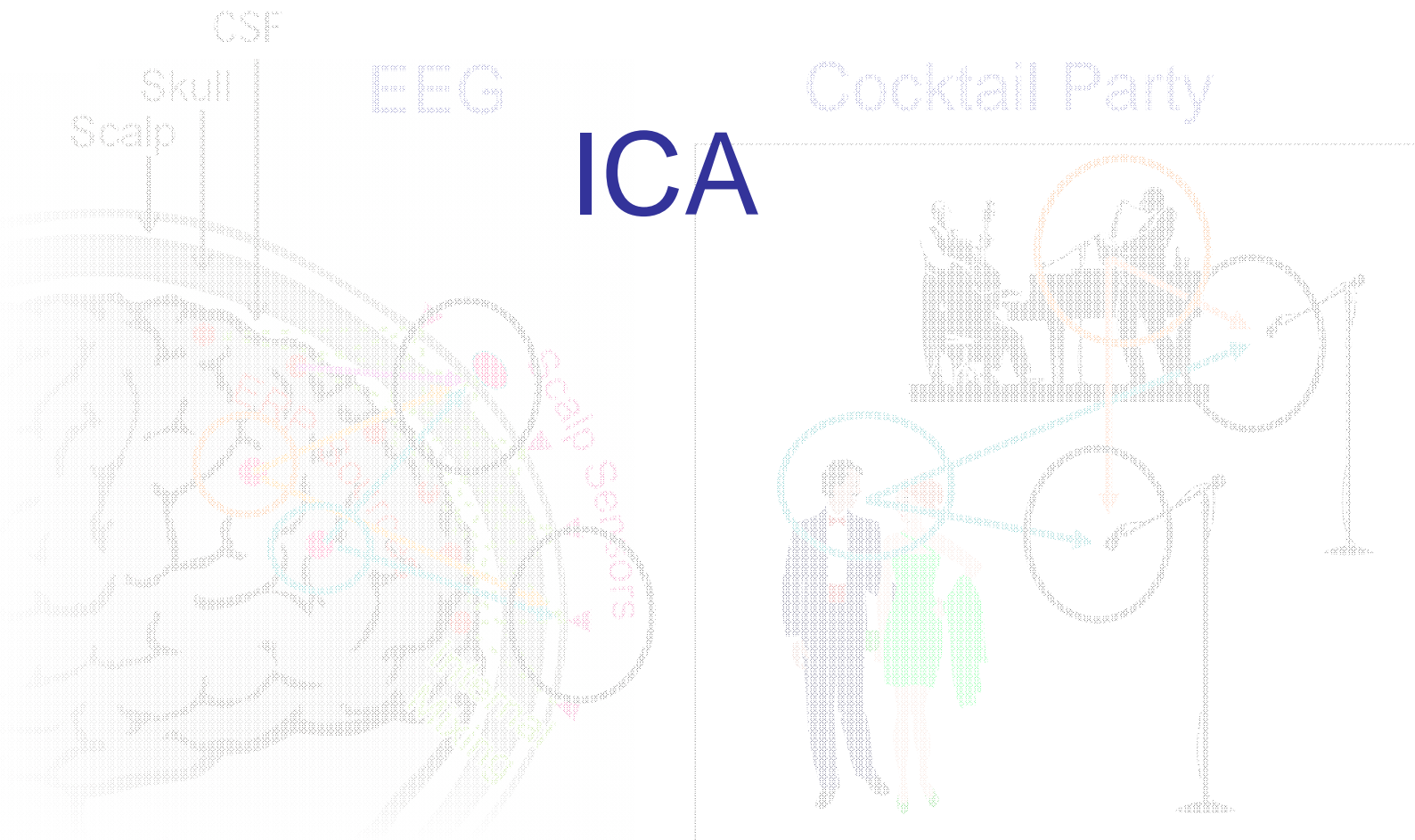


**ERP**

**Many ERP-image projections**

# Blind EEG Source Separation → ICA

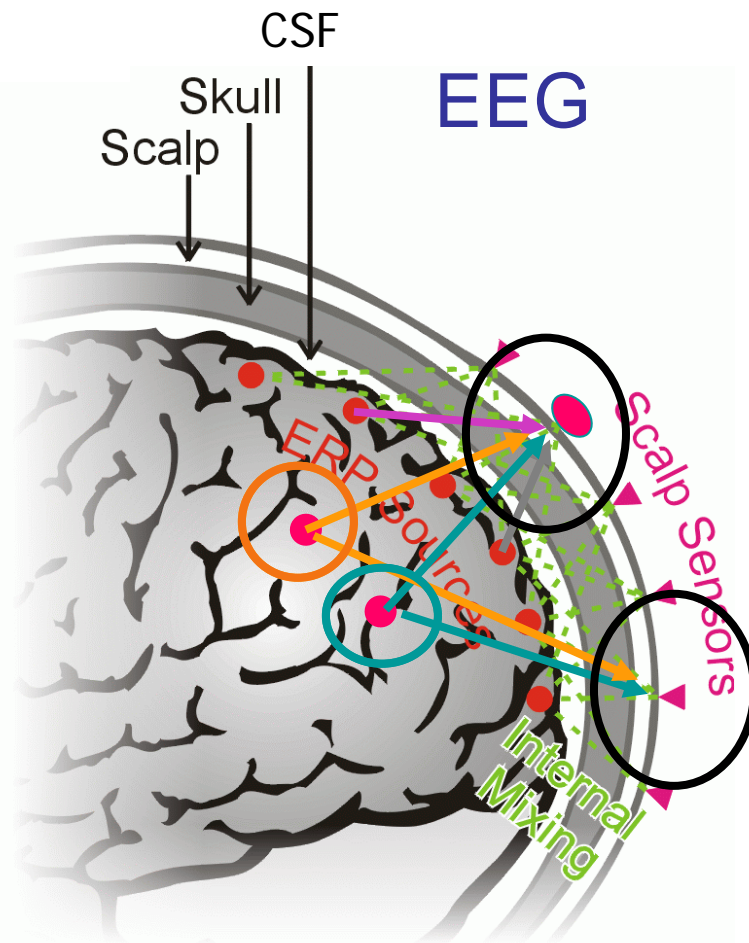
Unmixes scalp channel mixing by volume conduction!



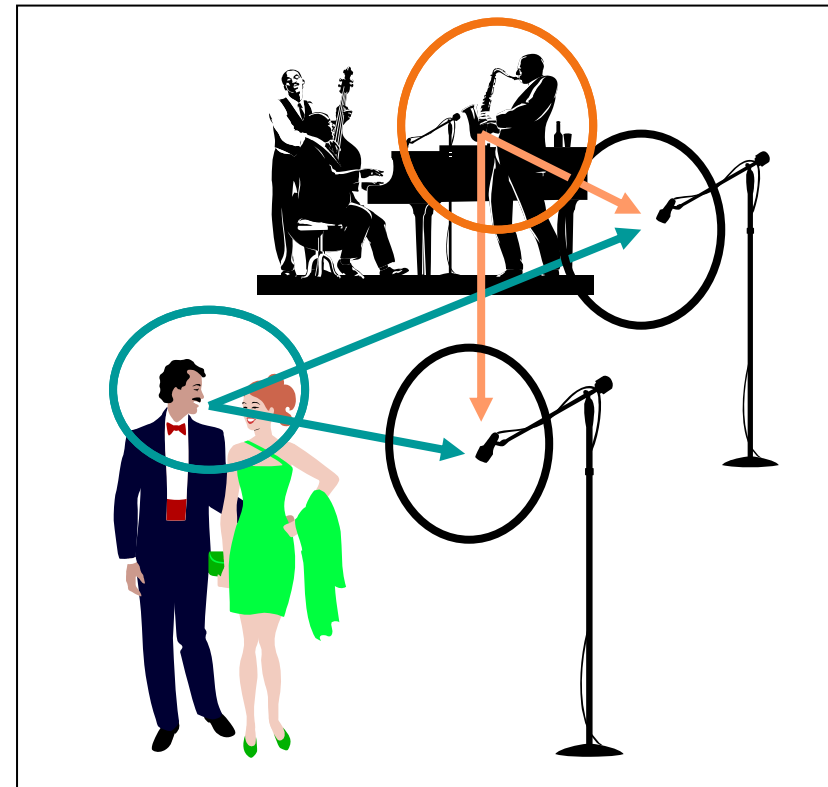
## ICA

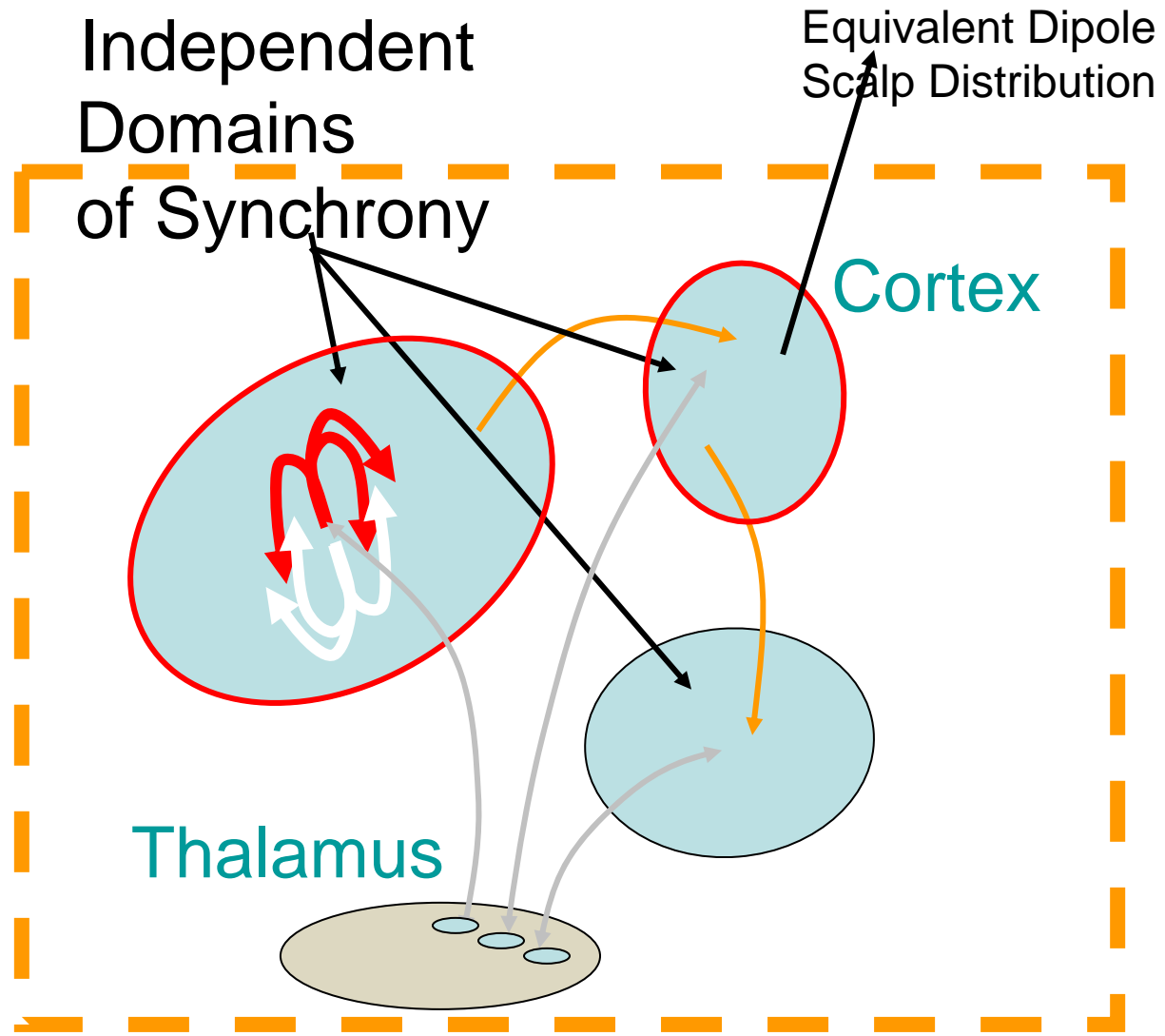
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Unmixes scalp channel mixing by volume conduction!

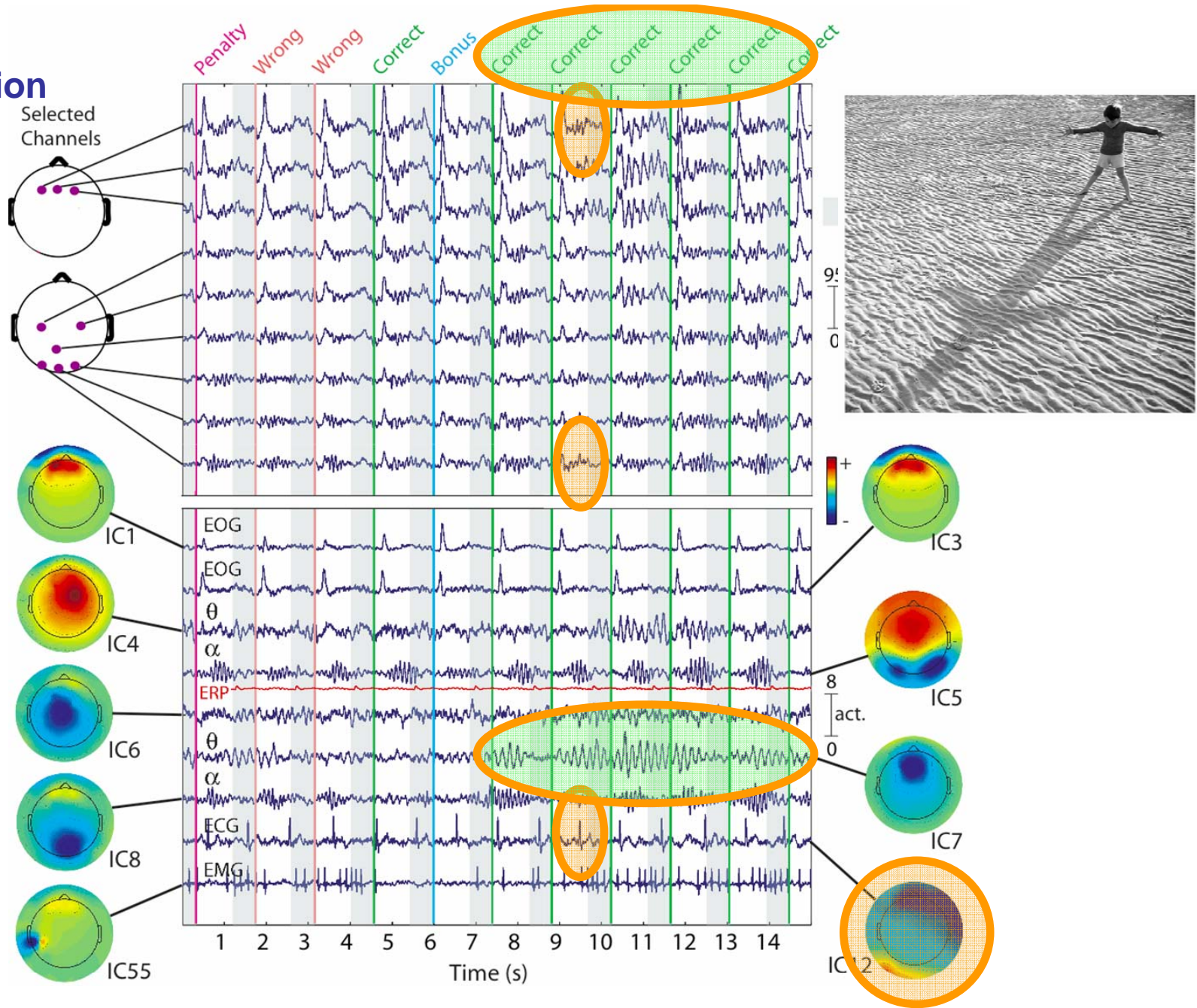


## Cocktail Party





# Sample EEG Decomposition



# *A New Beginning...*