

Factorizing the EEG: Independent component analysis, microstates, and their links to the analysis of connectivity

Prof. Dr. T. Koenig

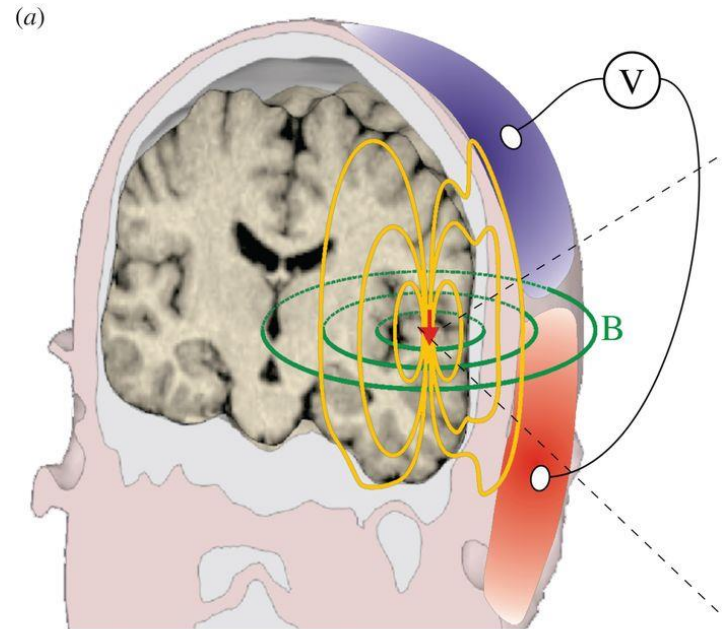
Translational Research Center
University Hospital of Psychiatry and Psychotherapy
University of Bern, Switzerland

thomas.koenig@puk.unibe.ch

Volume conduction in EEG

A single source event produces a **distributed** and **simultaneous** event on the scalp.

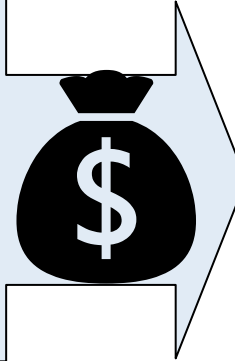
- Temporal correlations of scalp signals may be explained by source correlation, volume conduction, or both
- Time-shifted relations cannot be explained by volume conduction



Riitta Hari, and Lauri Parkkonen *Phil. Trans. R. Soc. B* 2015;370:20140170

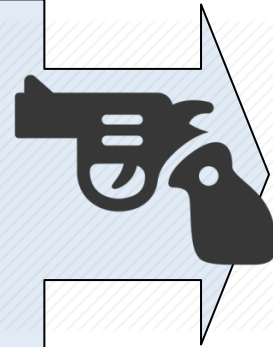
Two very different starting points

Temporal correlations of scalp signals may be explained by source correlation, volume conduction, or both



Add arguments separating connectivity from volume conduction

Time-shifted relations cannot be explained by volume conduction



Remove what may be explained by volume conduction



Kill volume conduction:

➤ Time-shifted relations cannot be explained by volume conduction



Remove everything that may be explained by volume conduction

We need a systematic measure for lagged relationship among uncorrelated components of two signals:
-> Imaginary coherence

$$\text{Lag}R_{xy\omega}^2 = \frac{[\text{Im Cov}(x, y)]^2}{\text{Var}(x) \times \text{Var}(y) - [\text{Re Cov}(x, y)]^2}$$

Possible solutions

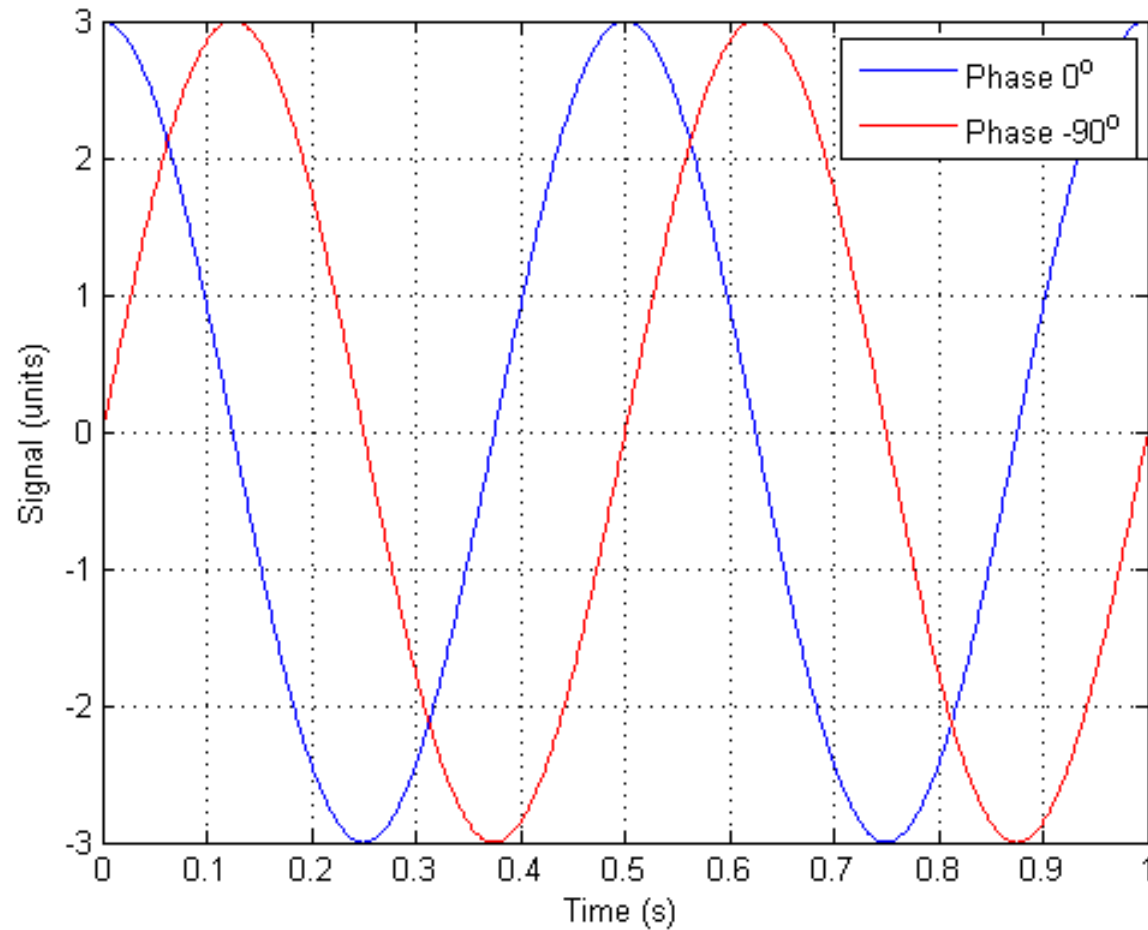
Established solutions:

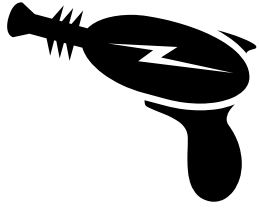
- Lagged coherence (Nolte, Pascual-Marqui)
- Phase locking index (Stam)
- Granger causality
- ...

Global quantifiers of lagged networks:

- Graph measures

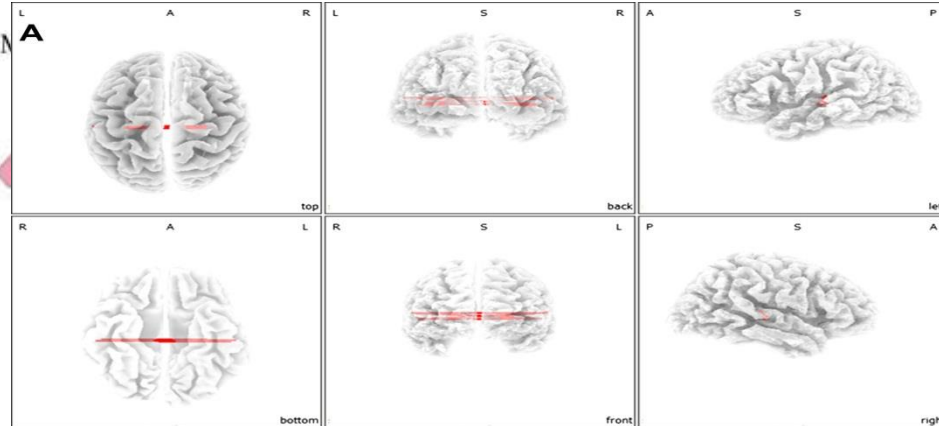
Using the imaginary part of the FFT allows just this



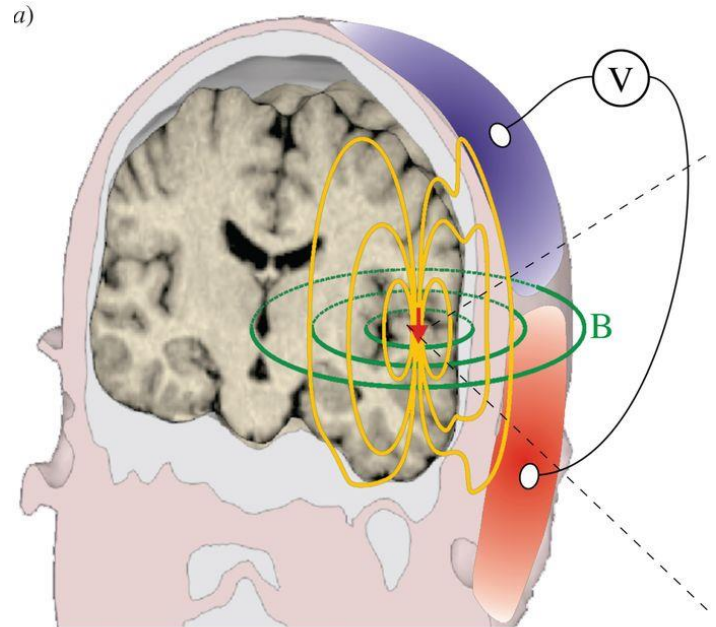


Are we done?

A single source event produces a **distributed** and **simultaneous** event on the scalp.



Song et al., 2013



Riitta Hari, and Lauri Parkkonen Phil. Trans. R. Soc. B 2015;370:20140170



Your deal

You pay by:

- Being bound to a particular lag for a frequency
- Having problems with more than 2 interconnected nodes
- Still risking false conclusions because of volume conduction

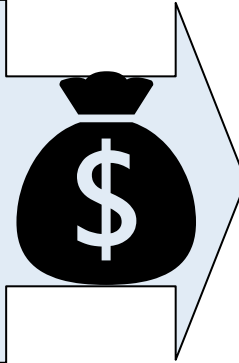
What you earn:

- The potential to go into directed, thus potentially causal interactions

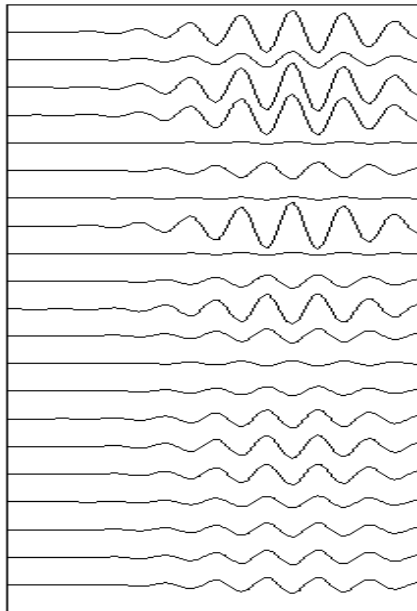


Argue more

Temporal correlations of scalp signals may be explained by source correlation, volume conduction, or both



Add arguments separating connectivity from volume conduction



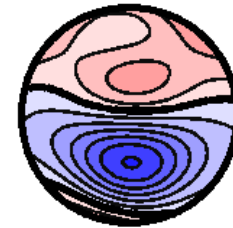
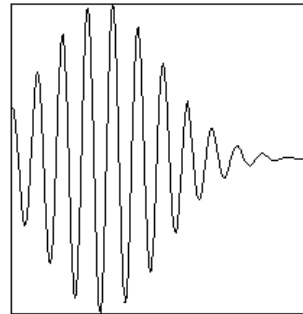
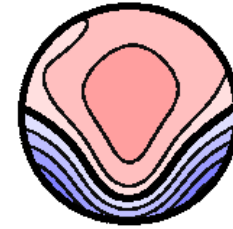
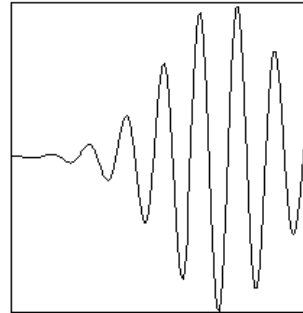
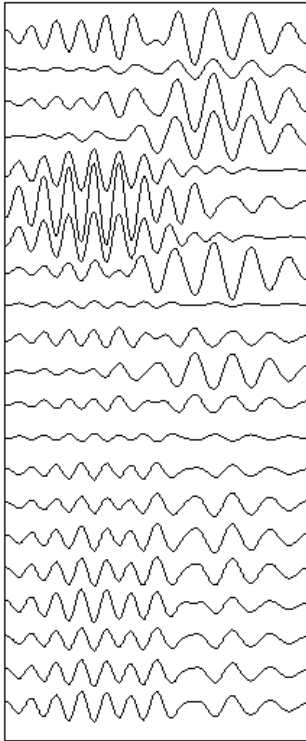
A special case: All channels have 100% common variance

- Either: It's only ~~volume~~ conduction
→ Only one source active
- Or: It's more than one source
→ These sources are in sync
→ It is a network

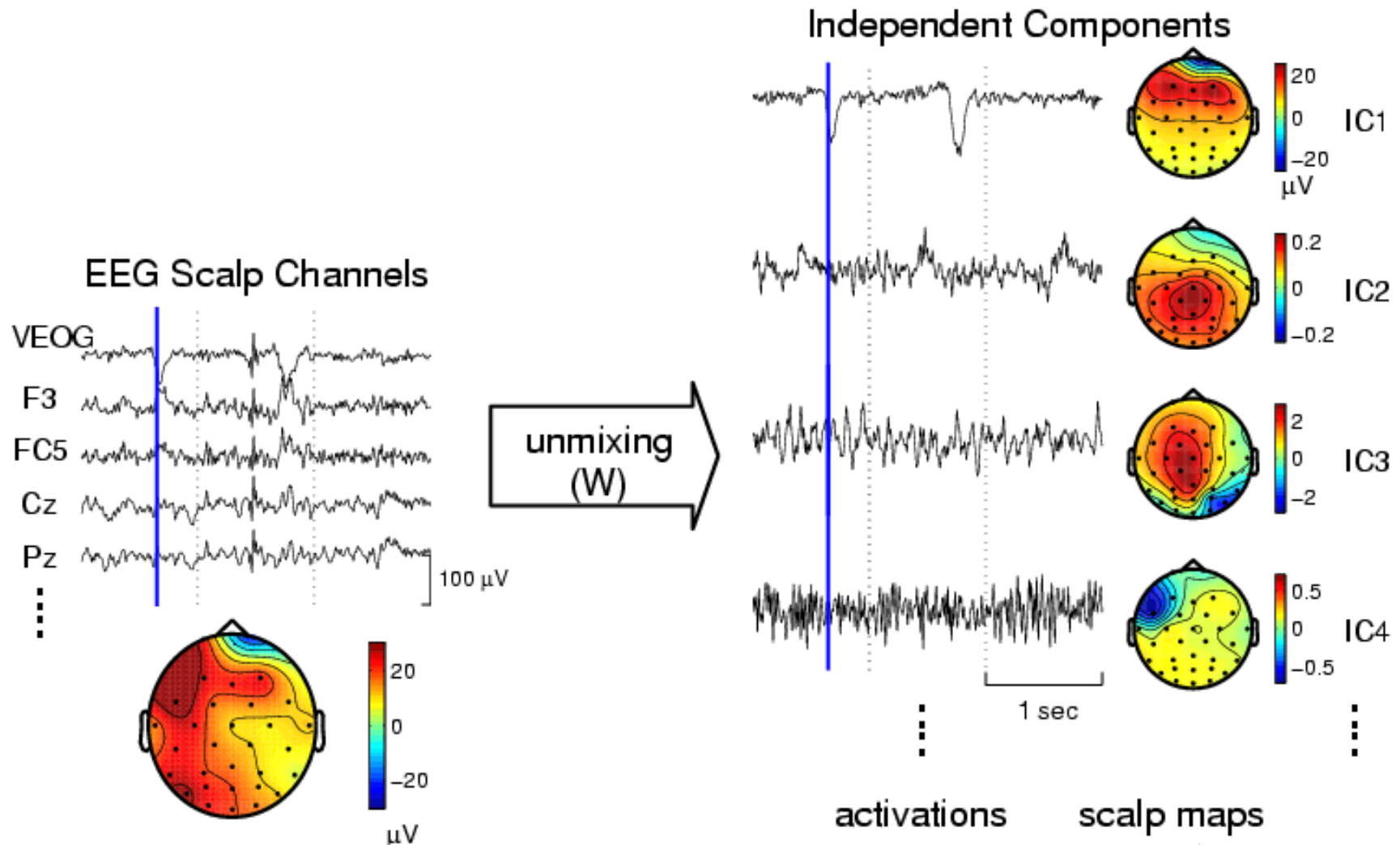


The resulting problem:

Problem to solve



Independent Component Analysis





Possible solutions

Established solutions:

- Principal Component Analysis (Roy John)
- Microstates (Dietrich Lehmann)
- Independent Component Analysis (Scott Makeig)

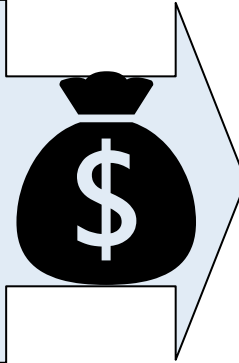
Global quantifiers of non-laggedness:

- Omega complexity (Jiri Wackermann)
- Global Field Synchronization (Thomas Koenig)

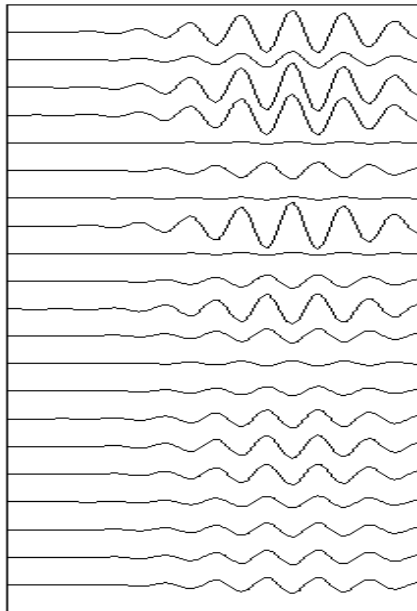


Argue more

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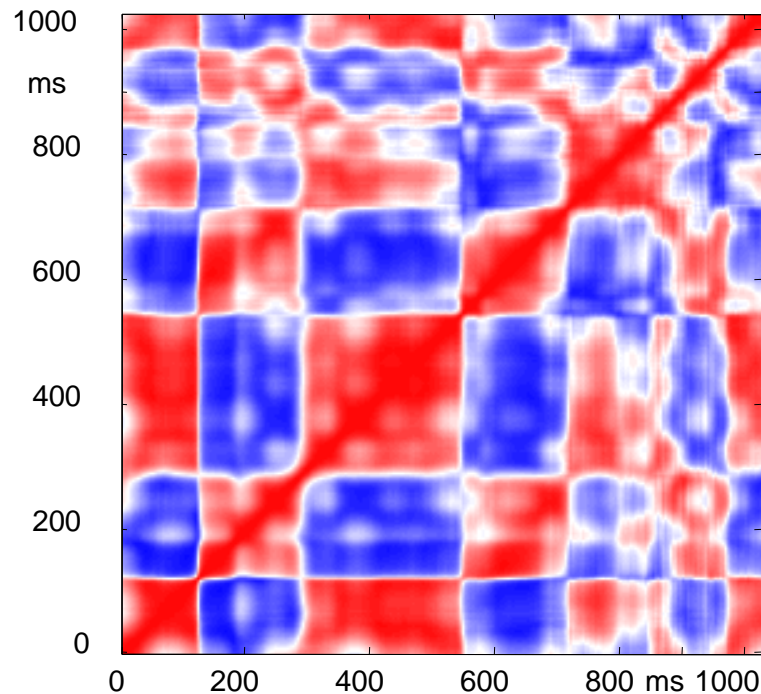


A special case: All channels have 100% common variance

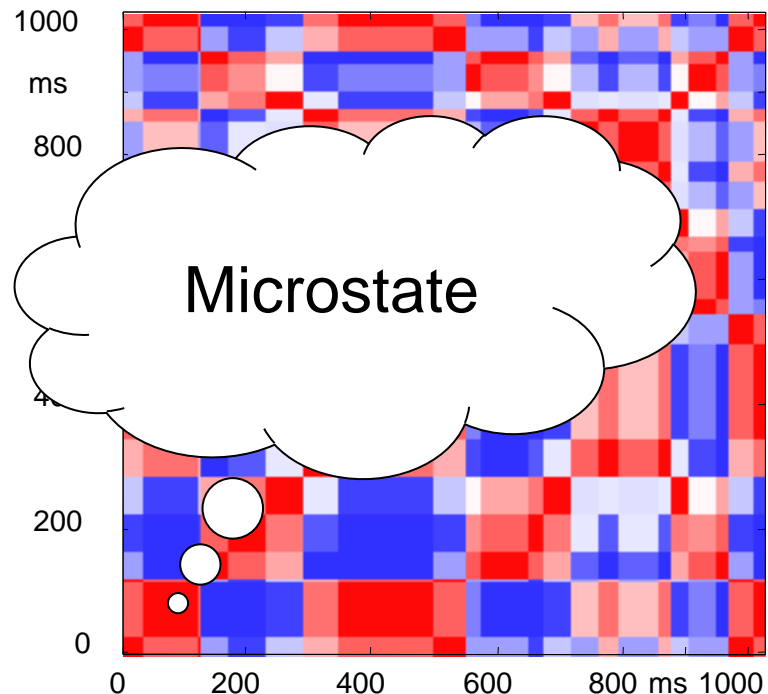
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Correlation structure of scalp field data

Measured



Model



Approximate by a few completely stable states & a little noise

Synchronization implies non-causality

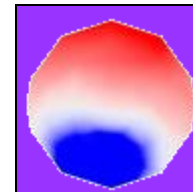
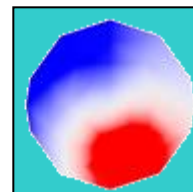
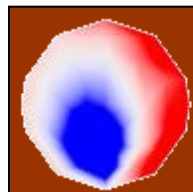
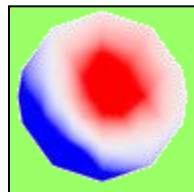
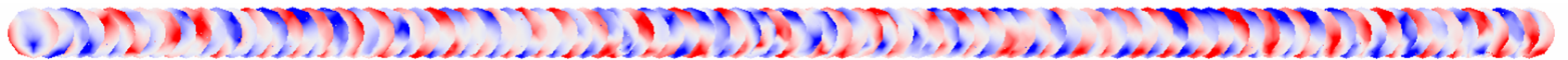
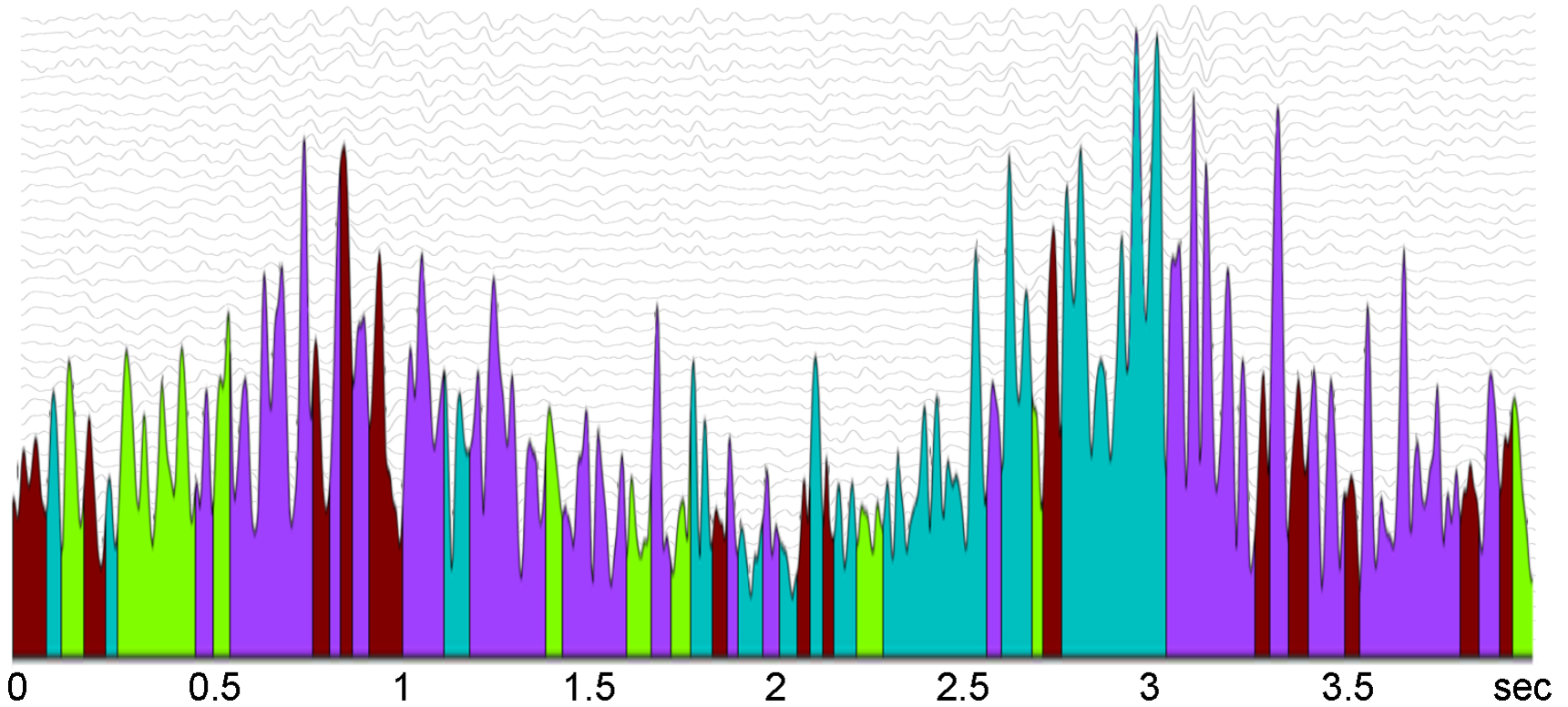
Unitary experience

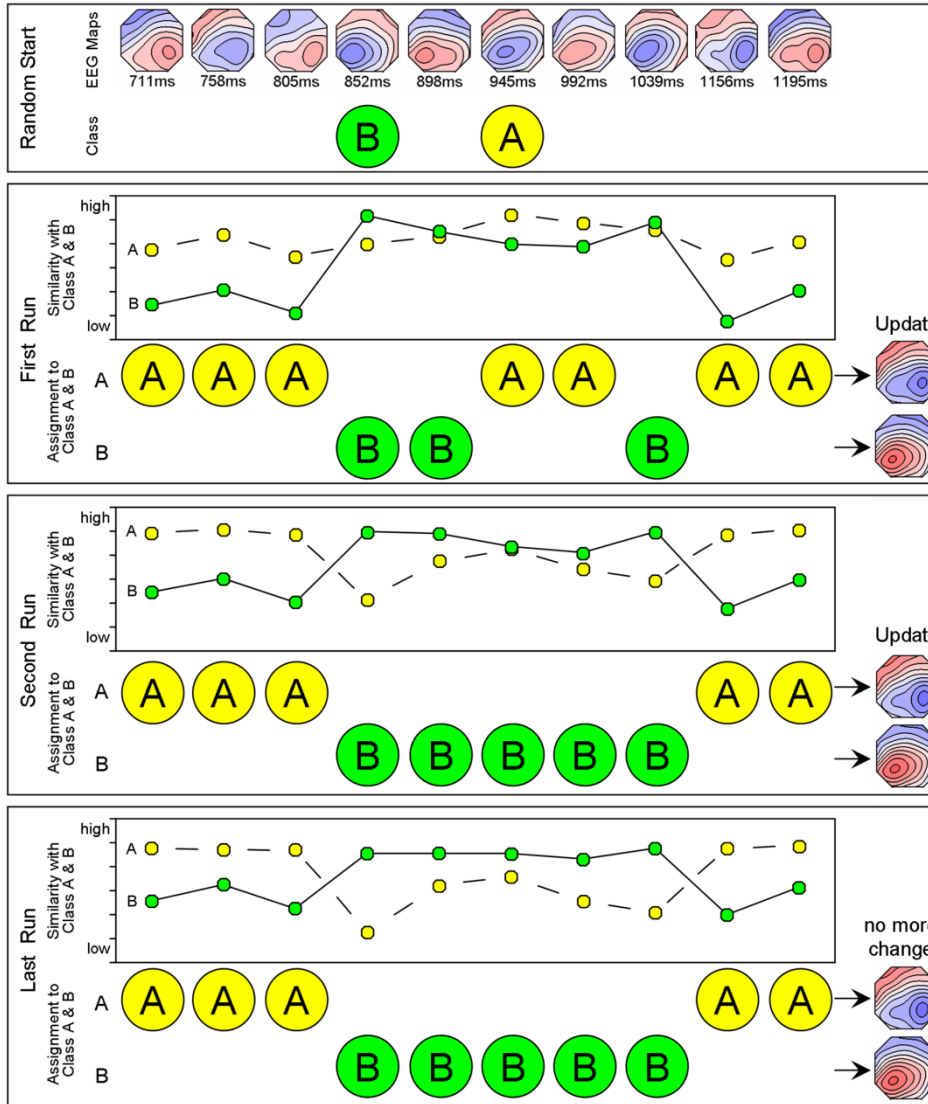


Spontaneous microstates (Sync packs)

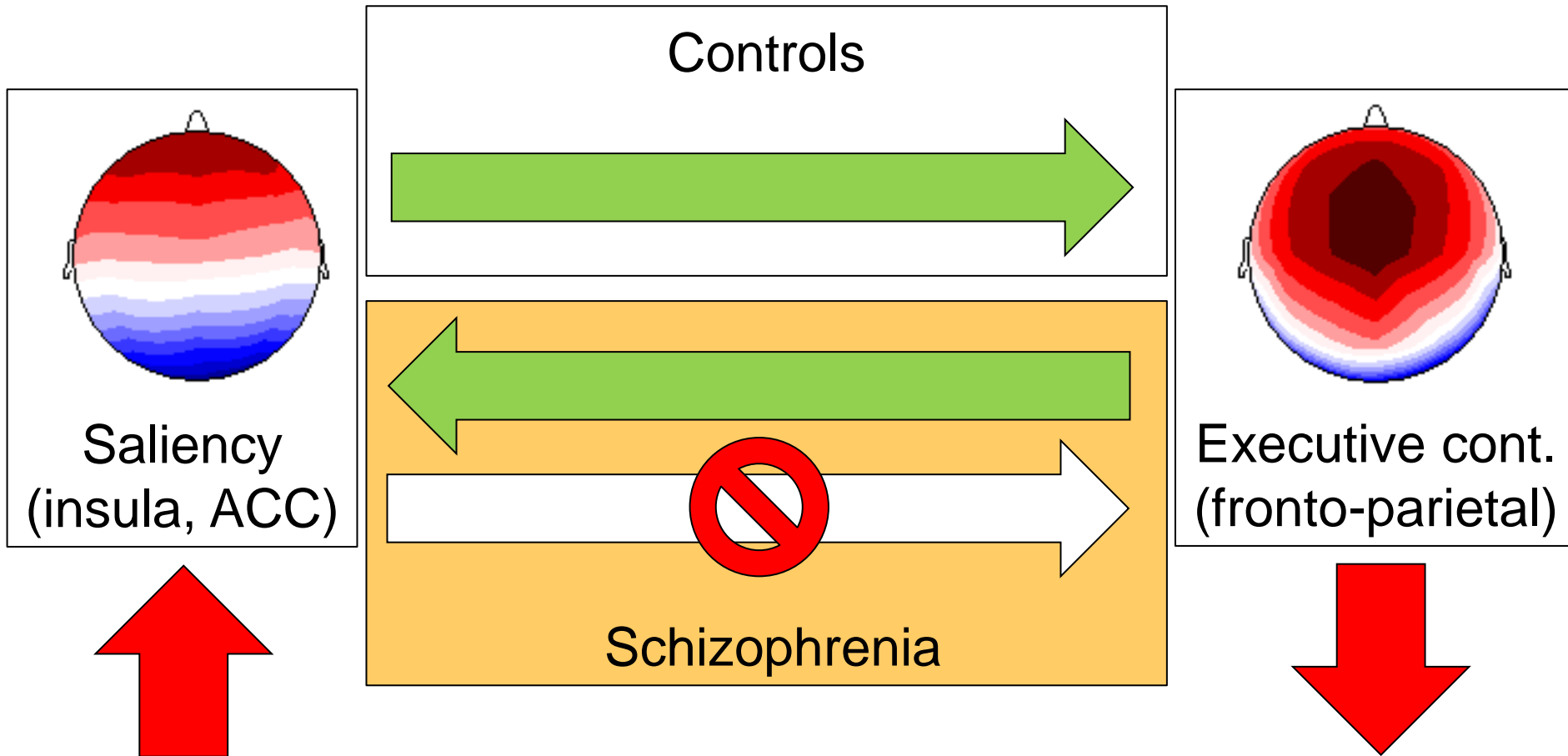
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Microstate interactions in schizophrenia





Your deal

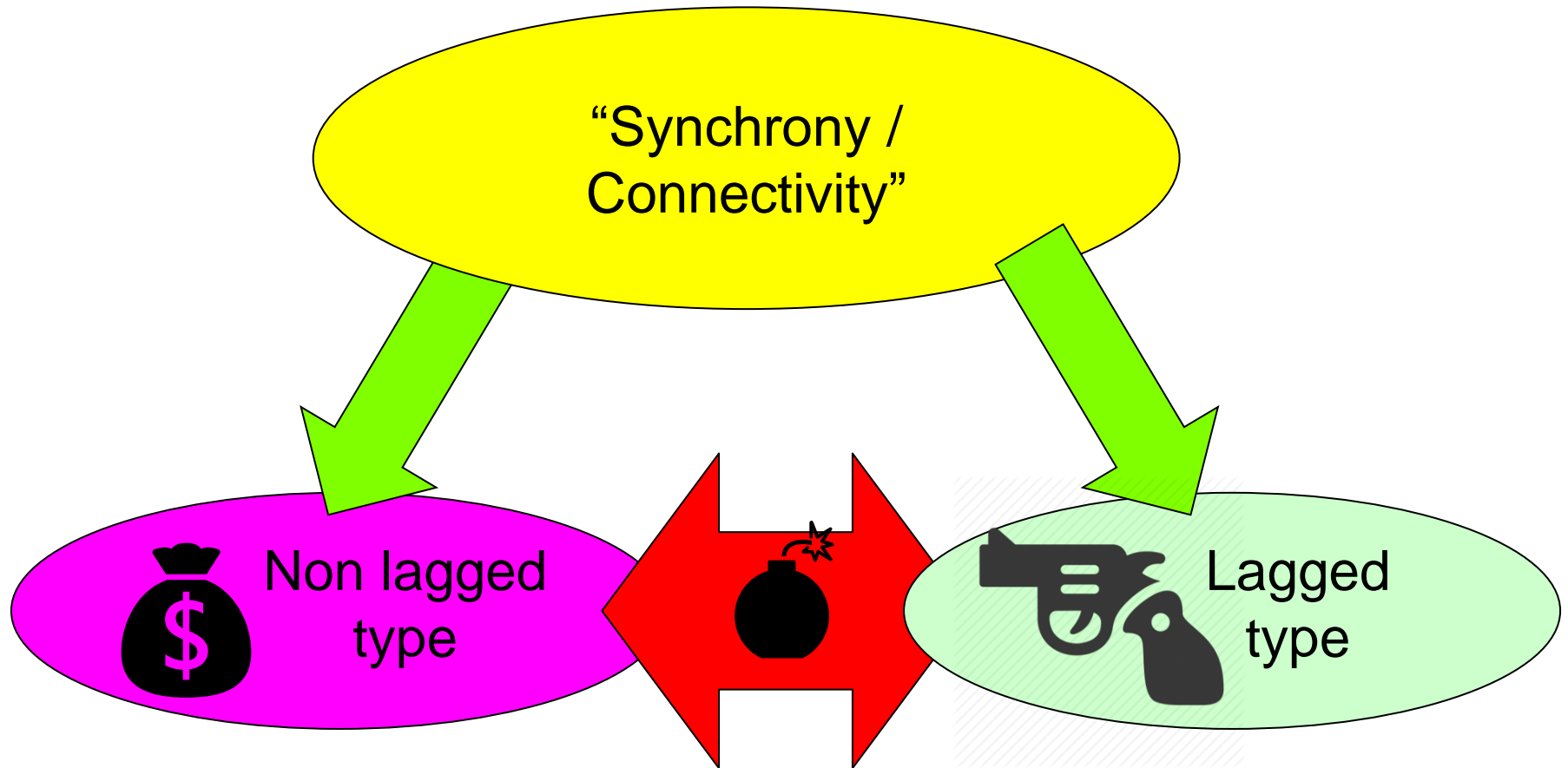
You pay by:

- Adding a plausible a-priori assumption about the distribution of the dynamics
- Have no clue about localization

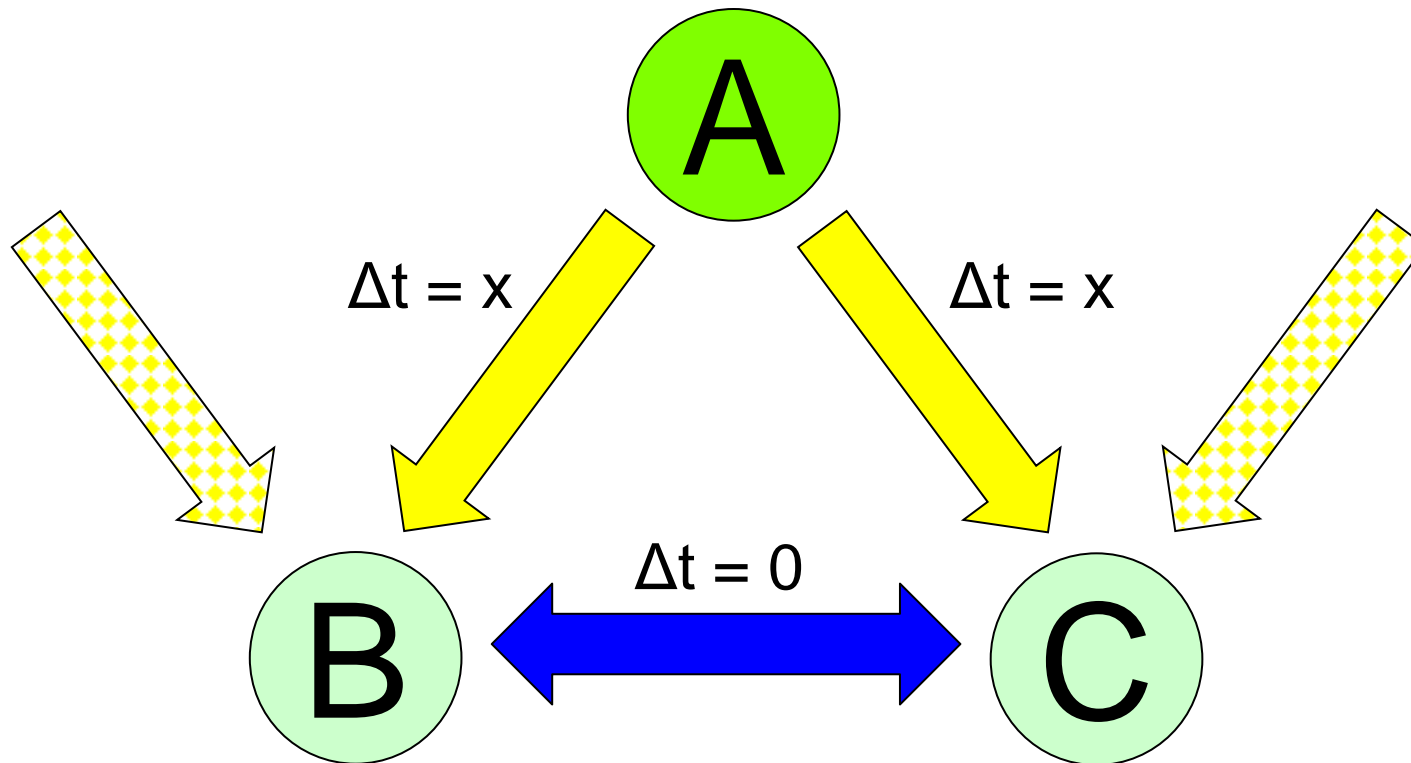
What you earn:

- The non-lagged, non-causal, integrative binding type of networks

“Understanding” of terms like Connectivity and Synchronization in EEG



Having both



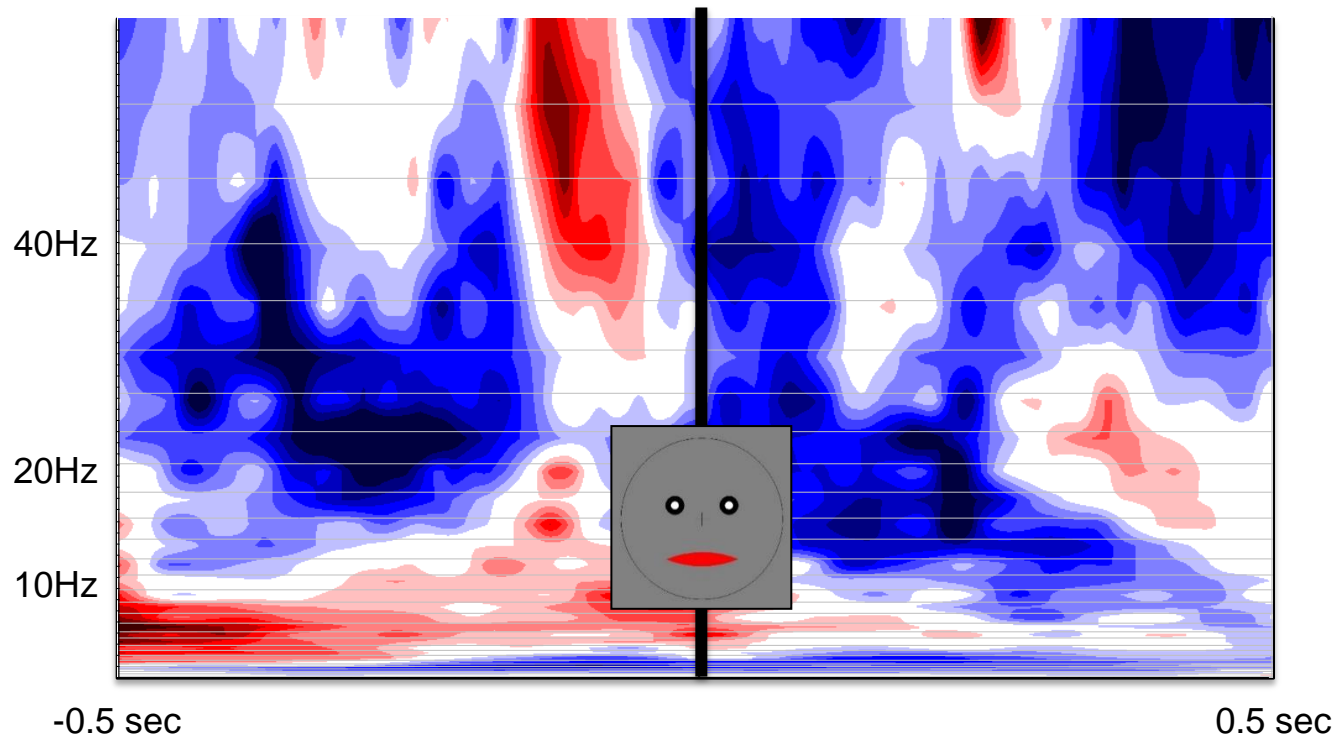
Co-incidence detection
Hebbian processes
Multi-modal integration

Conclusions

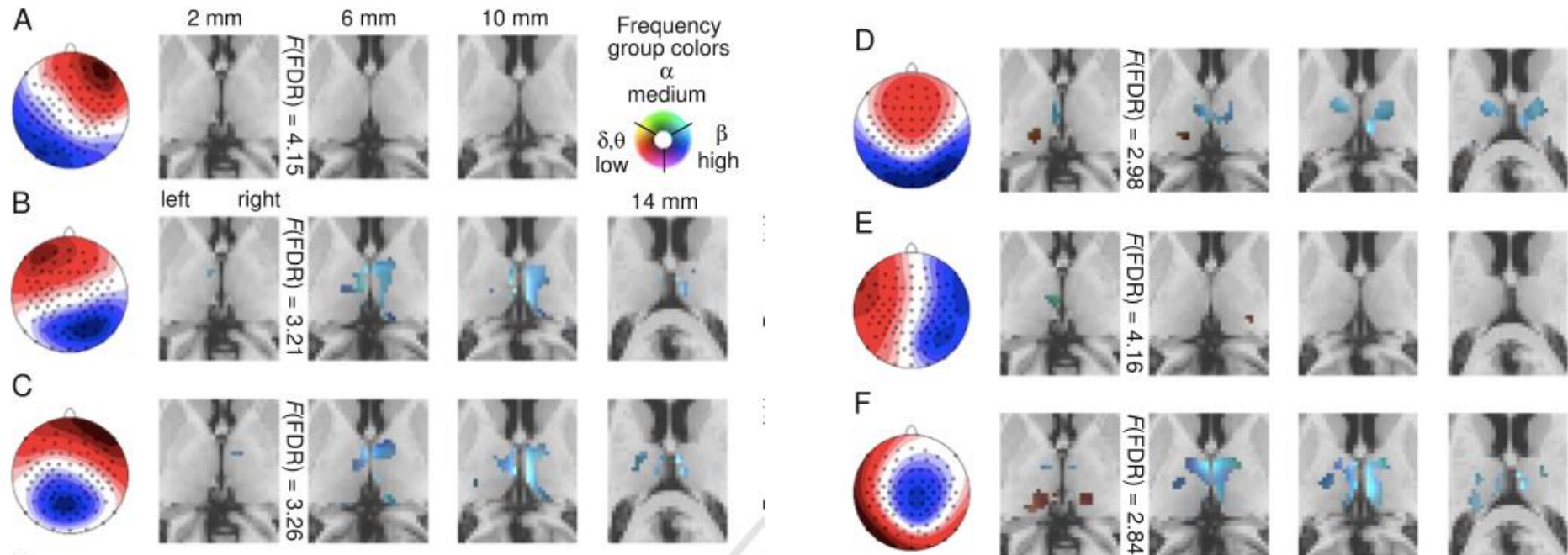
- > Volume conduction is not the enemy
- > EEG connectivity analyses requires strong models
- > Existing models may define connectivity in very different, and sometimes incompatible terms
 - You cannot simply combine
- > Hierarchical and multimodal approaches may be needed to accommodate it all
- > Unique information in health and disease

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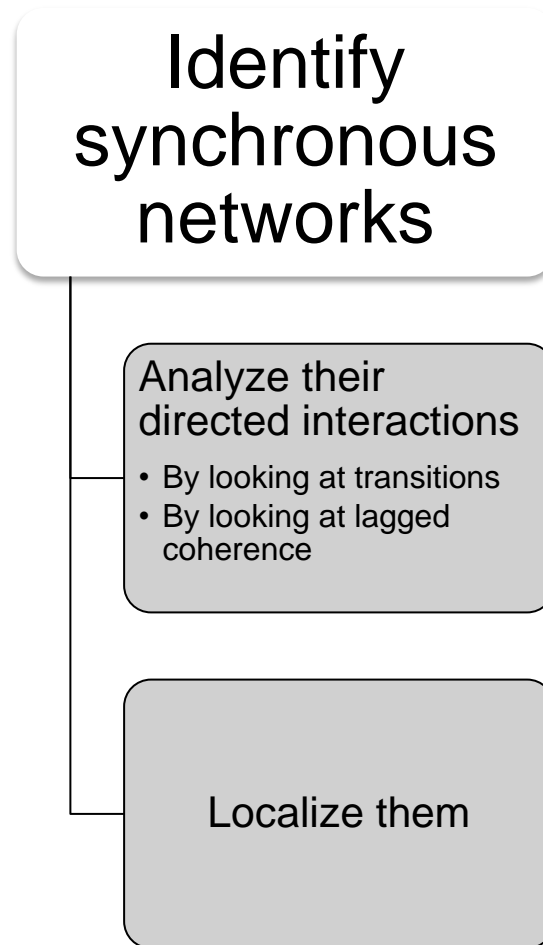
Zero lag Synchrony and face integration



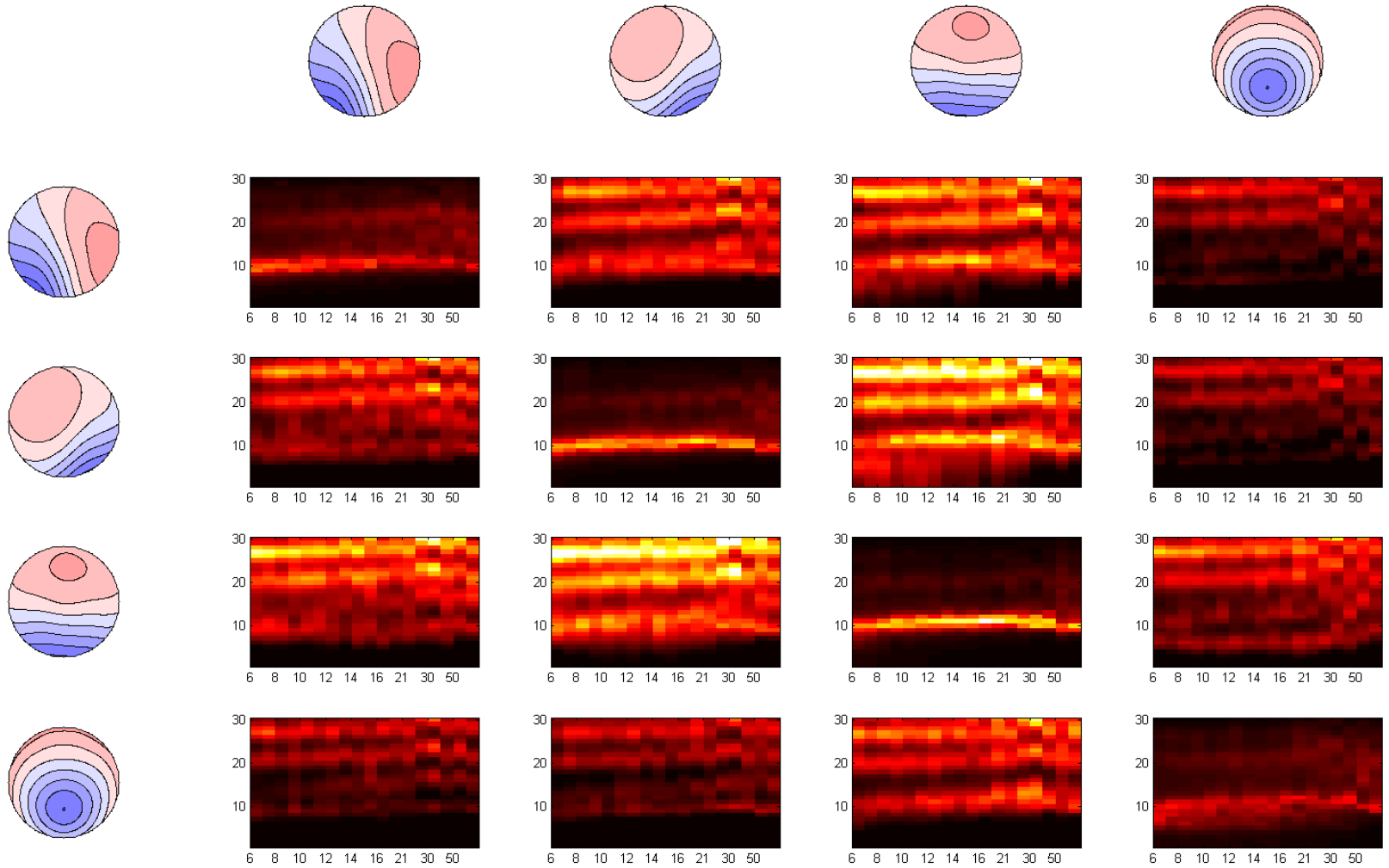
There's pace-maker



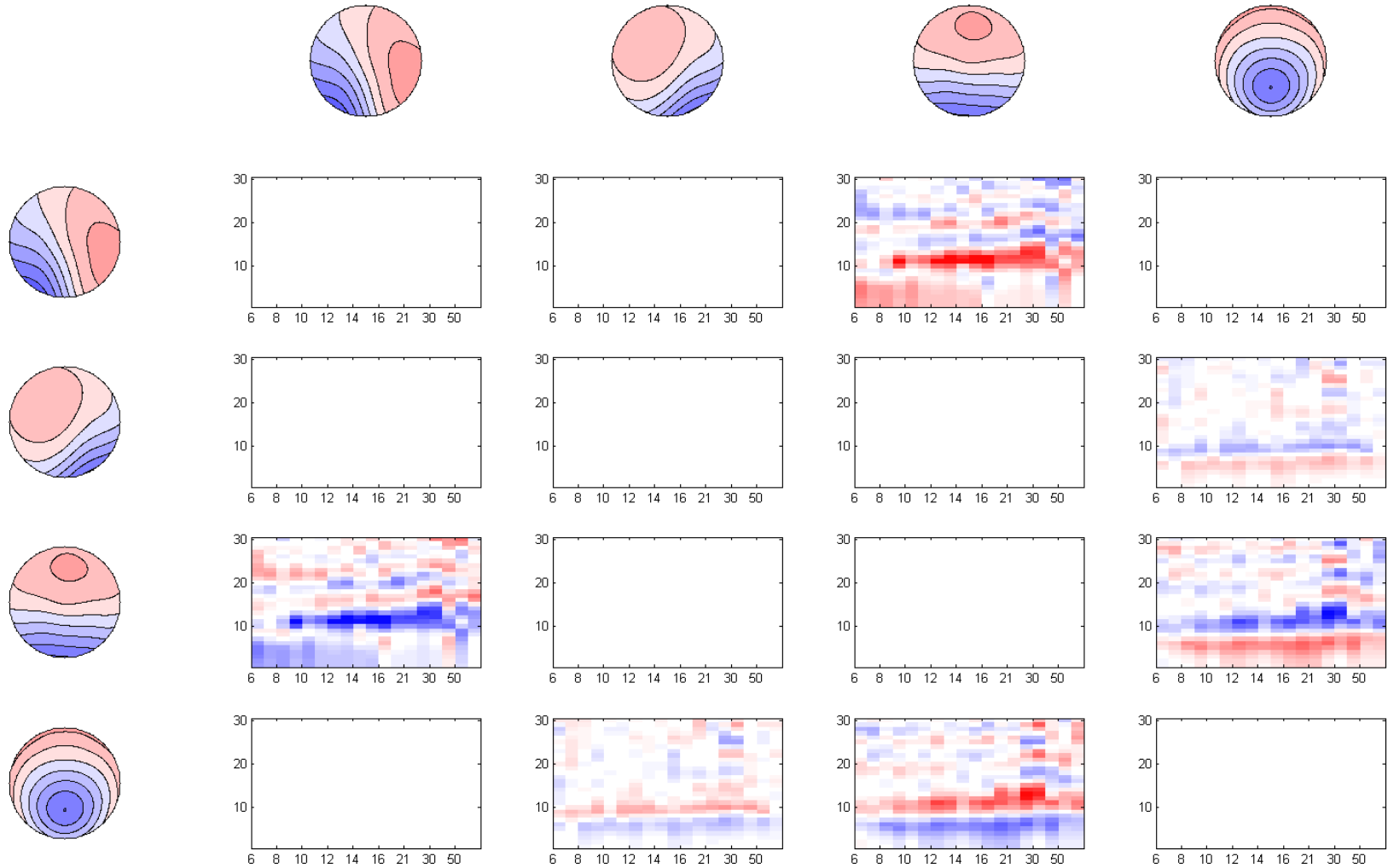
The proposal: a two-level approach

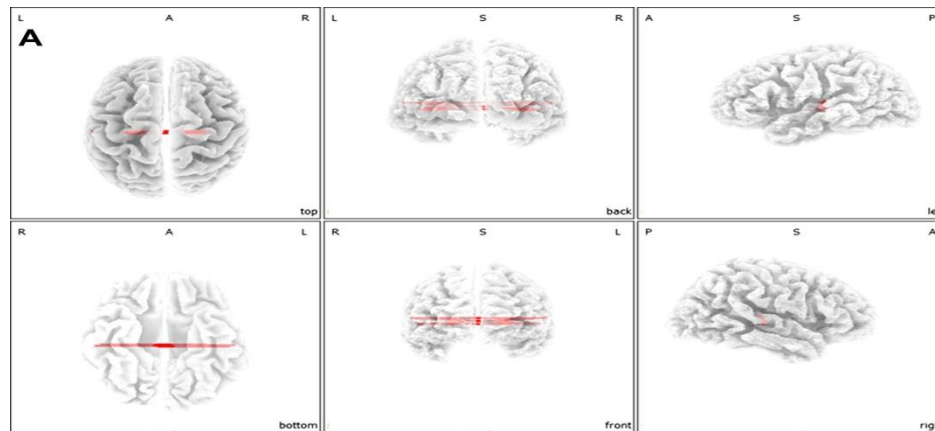


Partial directed coherence



Asymetry





Song et al., 2013

Fig. 5 Connectivity contrast analysis between the late-onset tinnitus group and the early-onset tinnitus group. Increased lagged connectivity between bilateral auditory cortices for theta and between bilateral insulae (A) and, with marginal significance, b...

Jae-Jin Song , Dirk De Ridder , Winfried Schlee , Paul Van de Heyning , Sven Vanneste

“Distressed aging”: the differences in brain activity between early- and late-onset tinnitus

Neurobiology of Aging Volume 34, Issue 7 2013 1853 - 1863

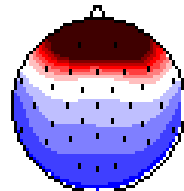
<http://dx.doi.org/10.1016/j.neurobiolaging.2013.01.014>



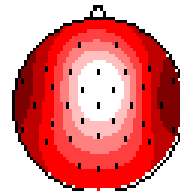
Possible solutions

Established solutions:

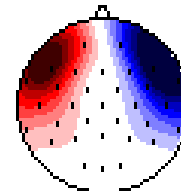
- Principal Component Analysis (John,)
- Microstates (Lehmann,
- Independent Component Analysis (Makeig)



0ms



1ms



2ms

