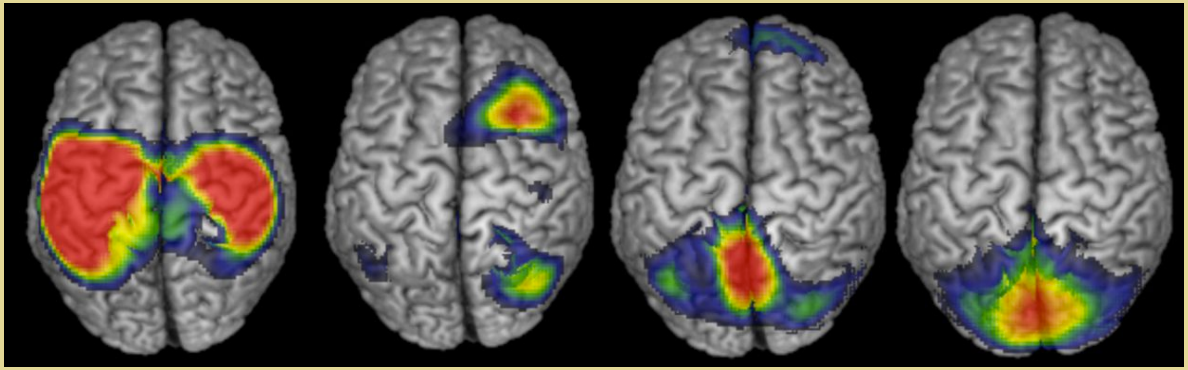
Electrophysiological Brain Networks in Resting State MEG



Vincent Wens

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ULB – Neuroscience Institute

FERB – UET meeting Milan May 2, 2013

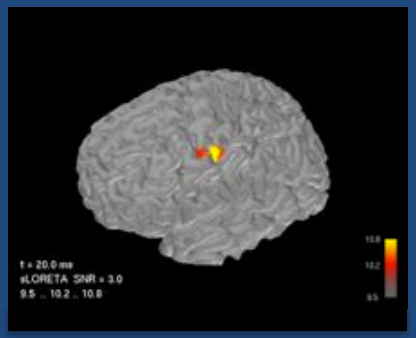
OUTLINE

- 1. Resting State Networks (RSN)
  - The brain as an integrated system
  - Resting state functional connectivity
- 2. MEG Resting State Networks
  - Magnetoencephalography
  - MEG rhythms functional connectivity
  - Seed-based correlation maps
  - Inter- and intra-subject variability of RSNs
  - Independent Component Analysis
- 3. Last Considerations
  - The dynamic brain network
  - Further developments

RESTING STATE NETWORKS

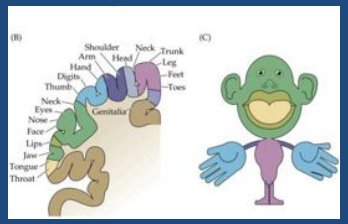
THE BRAIN AS AN INTEGRATED SYSTEM

- Neuroimaging : long focused on focal activity.



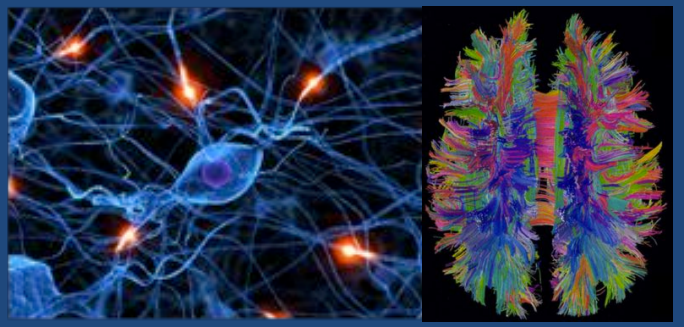
Focal response to basic somato-sensori stimulus

- Principle of functional specialization.



Somatotopy of post-central gyrus

- But even focal macroscopic activity results from neural connectivity.

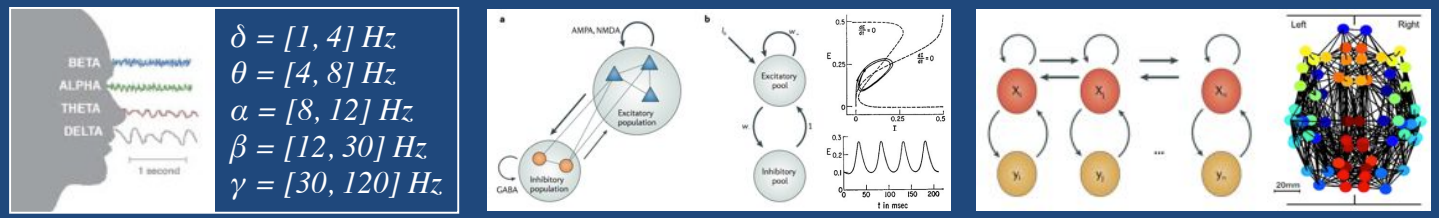


Local and global connectivity

- Functional integration : brain = network.

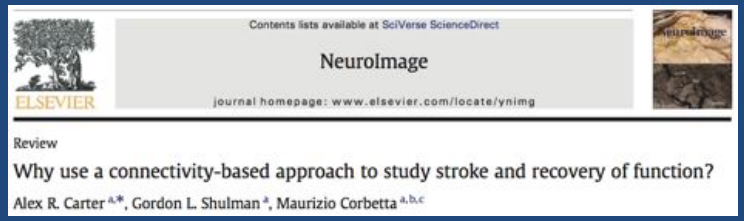
THE BRAIN AS AN INTEGRATED SYSTEM

- Connectivity has consequences on seemingly focal properties.



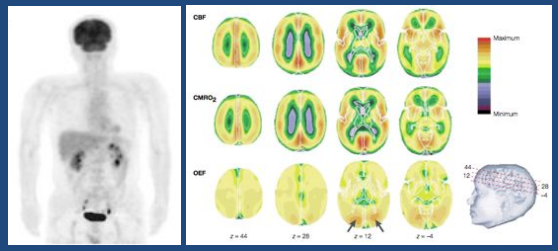
Brain rhythms (left) = consequences of local (middle) and/or large-scale (right) connectivity.

- Modifications in connectivity may lead to both focal and global changes in brain activity!
- E.g. Focal lesion in white matter can lead to large-scale changes in activity.


Contents lists available at SciVerse ScienceDirect
NeuroImage
journal homepage: www.elsevier.com/locate/ynimg
ELSEVIER
Review
Why use a connectivity-based approach to study stroke and recovery of function?
Alex R. Carter [a,*], Gordon L. Shulman [a], Maurizio Corbetta [a,b,c]

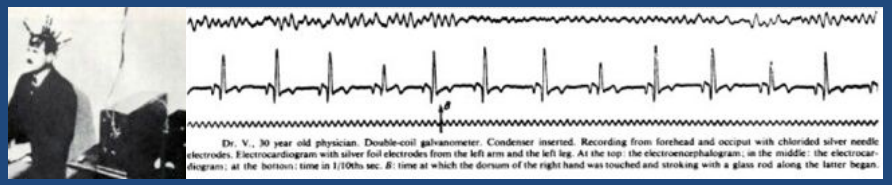
RESTING STATE FUNCTIONAL CONNECTIVITY

- Resting state : simple experimental paradigm.
- Brain at rest : metabolically and functionally active.

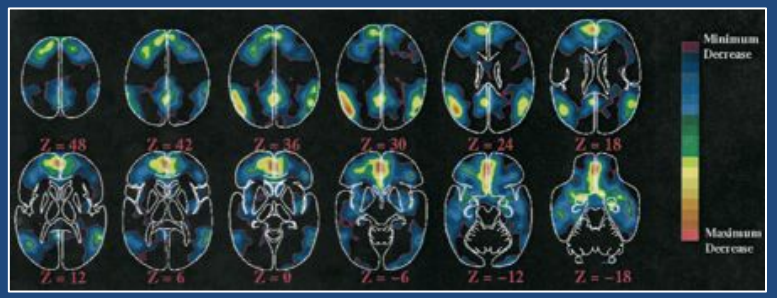


[Gusnard et al. 2001]

- Spontaneous brain activity : not mere noise, but presents structures.



Occipital α-rhythm [Berger 1924–1929]

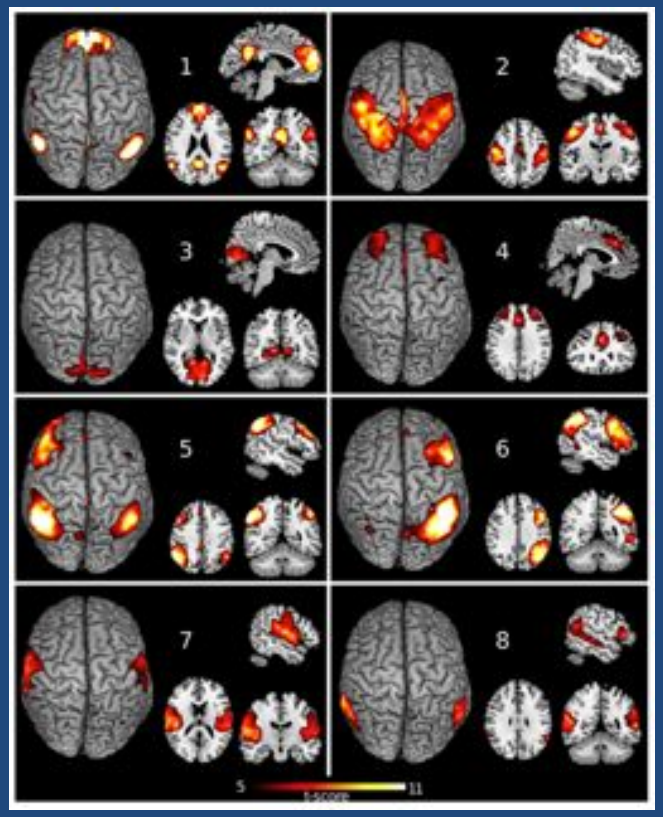


DMN [Raichle et al. 2001]

- Confirmation that DMN is a brain network : resting state functional connectivity.

RESTING STATE FUNCTIONAL CONNECTIVITY

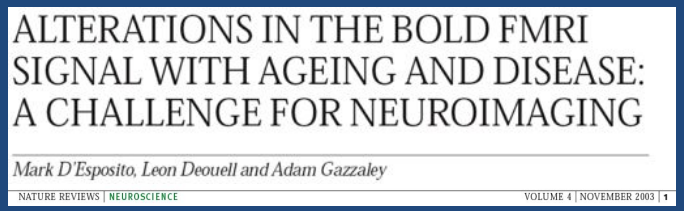
- Functional connectivity = study of co-variation patterns between distant brain regions.
- Resting state fMRI functional connectivity : DMN + other networks!
- Ongoing BOLD activity : structured spatiotemporal patterns = *RESTING STATE NETWORKS*.



[Rosazza et al. 2011]

RESTING STATE FUNCTIONAL CONNECTIVITY

- Main limitation of BOLD connectivity : its hemodynamic origin.
  - Limited in study neural dynamics of RSNs.
  - Dependent on neurovascular coupling.


ALTERATIONS IN THE BOLD FMRI SIGNAL WITH AGEING AND DISEASE: A CHALLENGE FOR NEUROIMAGING

Mark D'Esposito, Leon Deouell and Adam Gazzaley

NATURE REVIEWS | NEUROSCIENCE VOLUME 4 | NOVEMBER 2003 | 1

- Electrophysiological origin of RSNs recently demonstrated using MEG!


Temporal dynamics of spontaneous MEG activity in brain networks

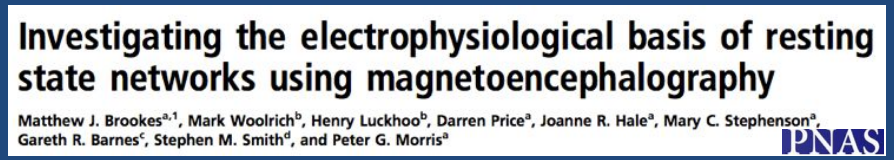
Francesco de Pasquale[a,b,1], Stefania Della Penna[a,b], Abraham Z. Snyder[c,d], Christopher Lewis[a,b], Dante Mantini[a,b,2], Laura Marzetti[a,b], Paolo Belardinelli[a,b], Luca Ciancetta[a,b], Vittorio Pizzella[a,b], Gian Luca Romani[a,b], and Maurizio Corbetta[a,b,c,d]

PNAS


Large-scale cortical correlation structure of spontaneous oscillatory activity

Joerg F Hipp[1,2], David J Hawellek[1], Maurizio Corbetta[3], Markus Siegel[2] & Andreas K Engel[1]

VOLUME 15 | NUMBER 6 | JUNE 2012 NATURE NEUROSCIENCE


Investigating the electrophysiological basis of resting state networks using magnetoencephalography

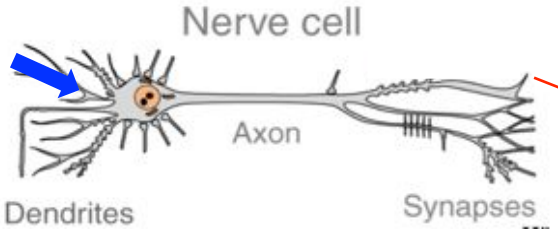
Matthew J. Brookes[a,1], Mark Woolrich[b], Henry Luckhoo[b], Darren Price[a], Joanne R. Hale[a], Mary C. Stephenson[a], Gareth R. Barnes[c], Stephen M. Smith[d], and Peter G. Morris[a]

PNAS

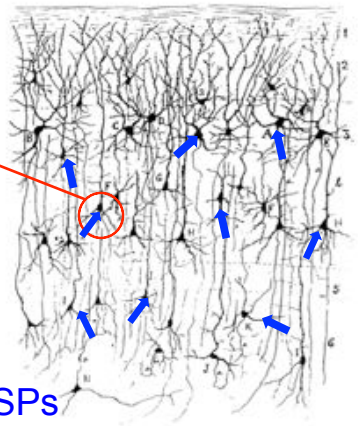
MEG RESTING STATE NETWORKS

MAGNETOENCEPHALOGRAPHY

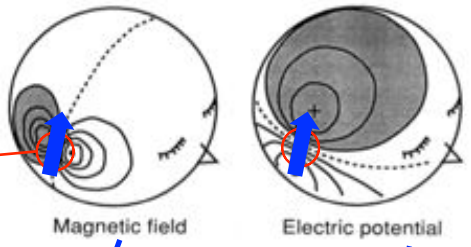
- MEG : direct measure of electrophysiological activity of neural populations.



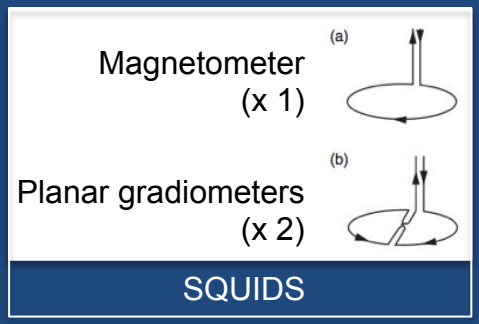
Post-synaptic potential (PSP)



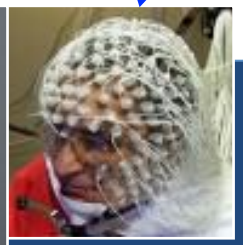
Sum of synchronous PSPs



Macroscopic current dipole



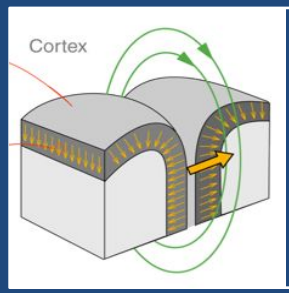
MEG



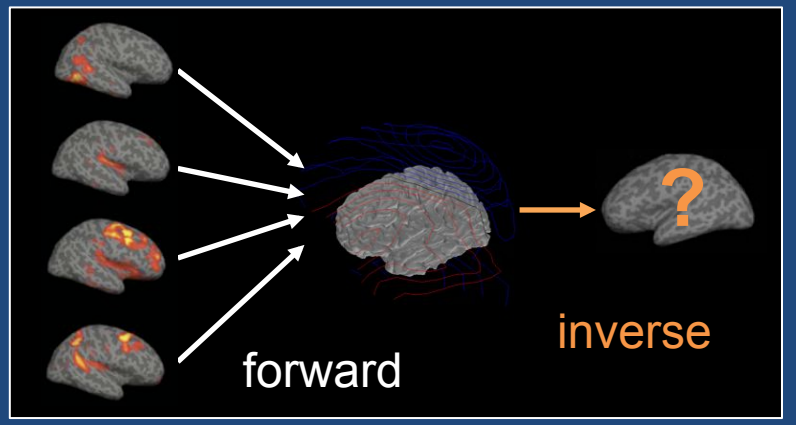
EEG

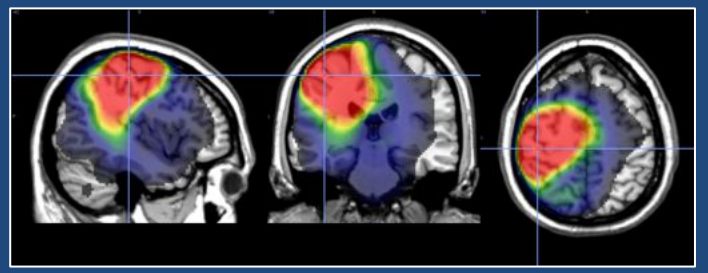
MAGNETOENCEPHALOGRAPHY

- Source reconstruction : Inverse problem from magnetic data to current dipoles.
- No unique inversion scheme.
- Here : L_2 Minimum Norm Estimate.
- Spatial smoothing from sensors to sources space : *SIGNAL LEAKAGE*.



Forward model. A current dipole generates a magnetic field.

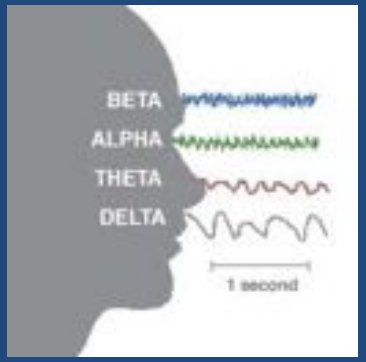


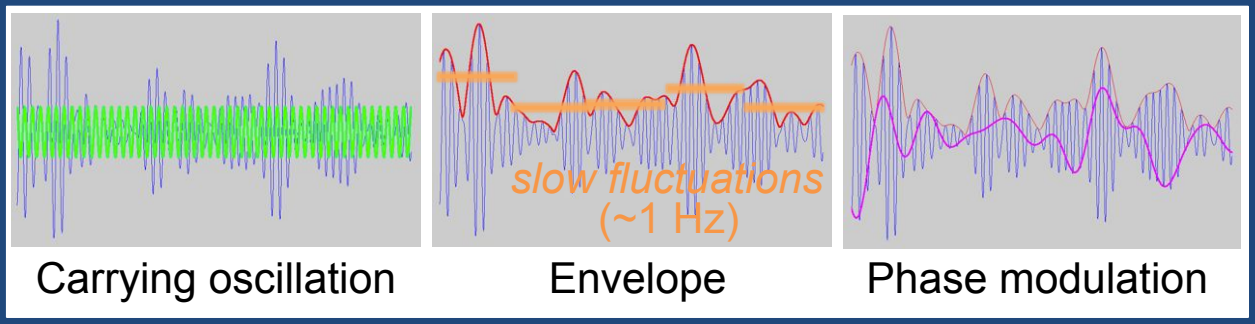


Source correlation with left SM1 (β-band, MNE)

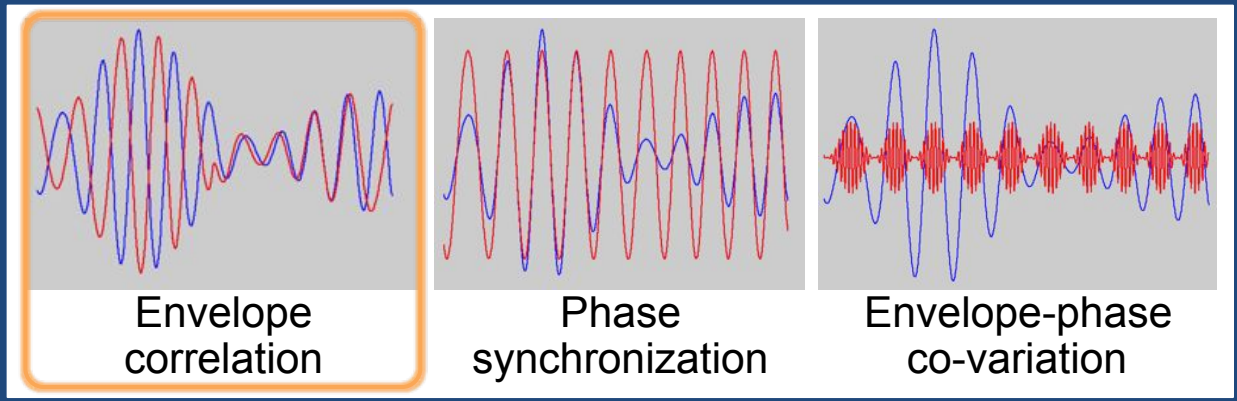
MEG RHYTHMS FUNCTIONAL CONNECTIVITY

- Source-space MEG rhythms.
- Characteristics of a rhythm :





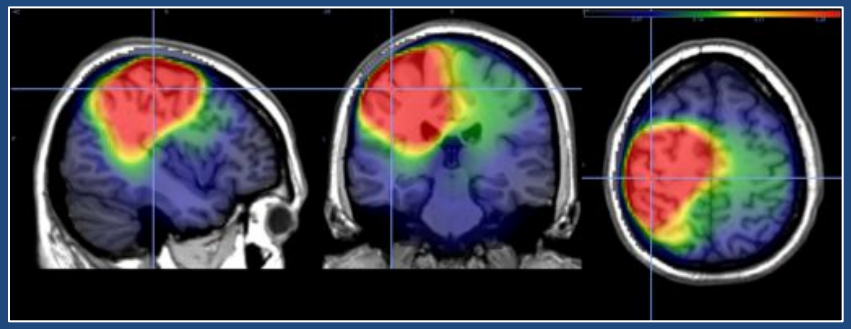
- Functional coupling between 2 rhythms :



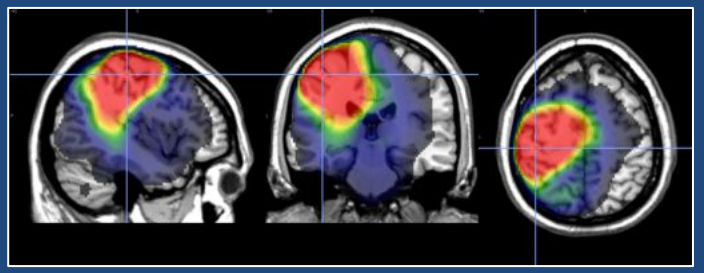
- 2 implementations :
  - Seed-based correlation maps
  - Temporal ICA

SEED-BASED CORRELATION MAPS

- Example : β-band , seed in SM1.

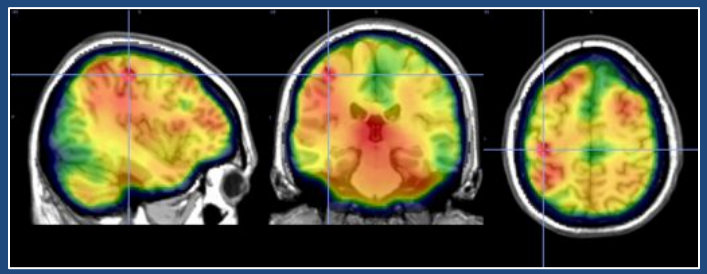


Envelope correlation map (max=1)

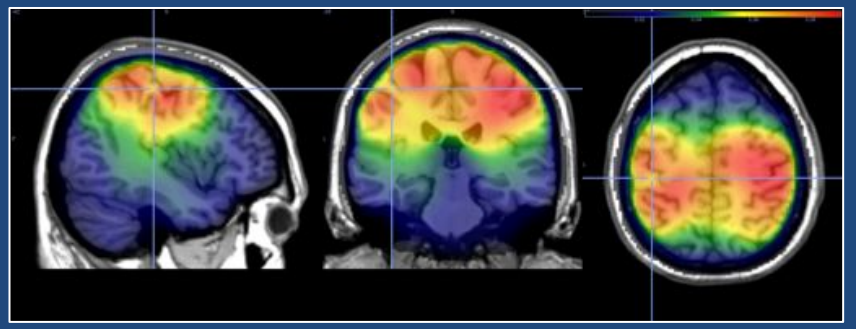


Signal correlation map (max=1)

- Difficulty due to source spreading.
- Solution: linear regression with seed.



Signal correlation map
(max=0.003)

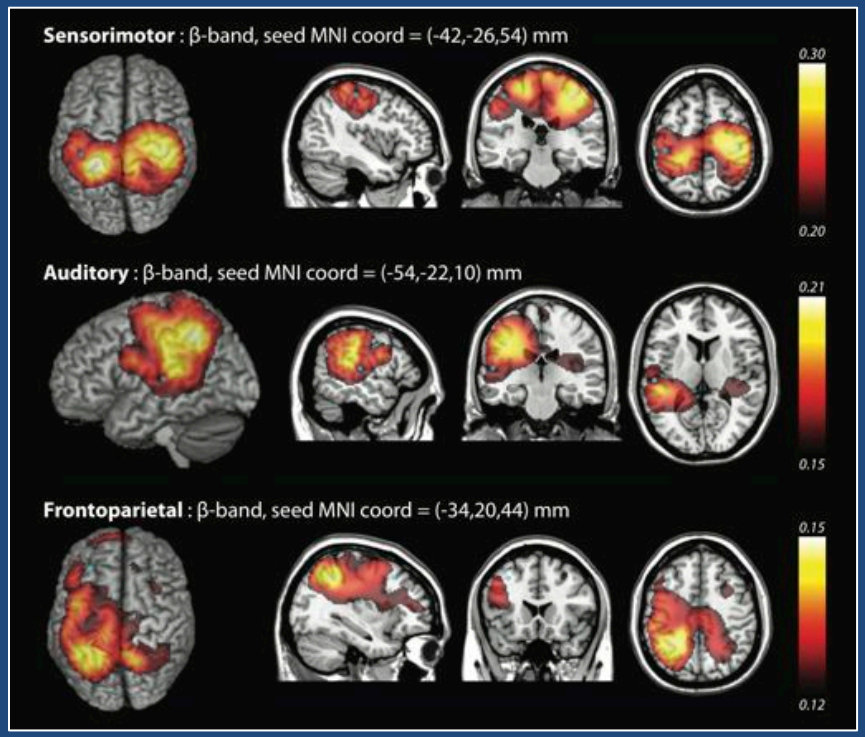


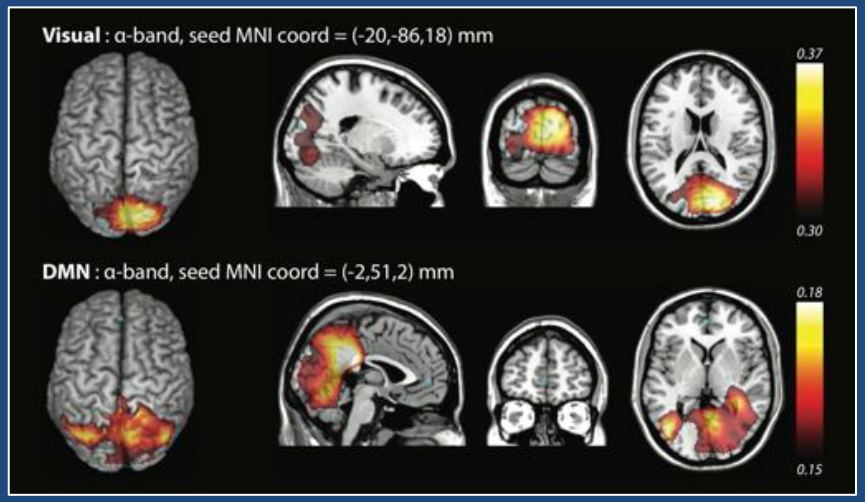
Envelope correlation map (max=0.1)

SEED-BASED CORRELATION MAPS

- Results for well-known networks.

  15 subjects
  Rest data, eyes open, 5 min

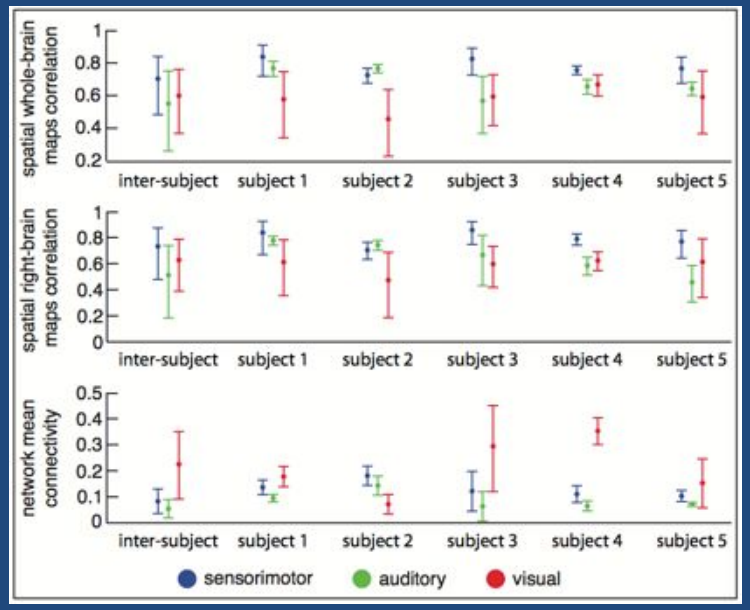




INTER- AND INTRA-SUBJECT VARIABILITY OF RSNS

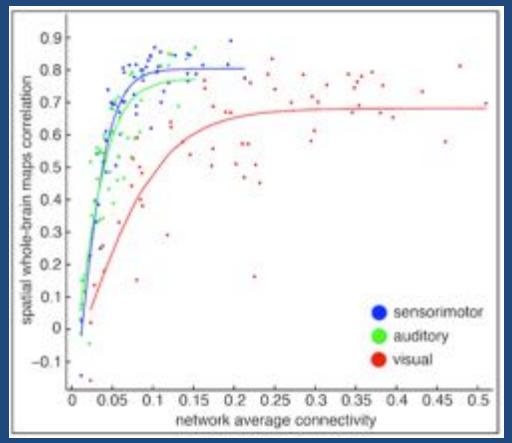
- Reproducibility of single-subject RSNs and associated factors?
- RSN reliability :

  - $P(SM1_\beta)=67\%$, $P(A1_\beta)=53\%$, $P(V1_\alpha)=60\%$.
  - Interaction between $SM1_\beta$ and $A1_\beta$ ($p<10^{-4}$):
    $P(SM1_\beta \mid \text{No } A1_\beta)=6\%$.



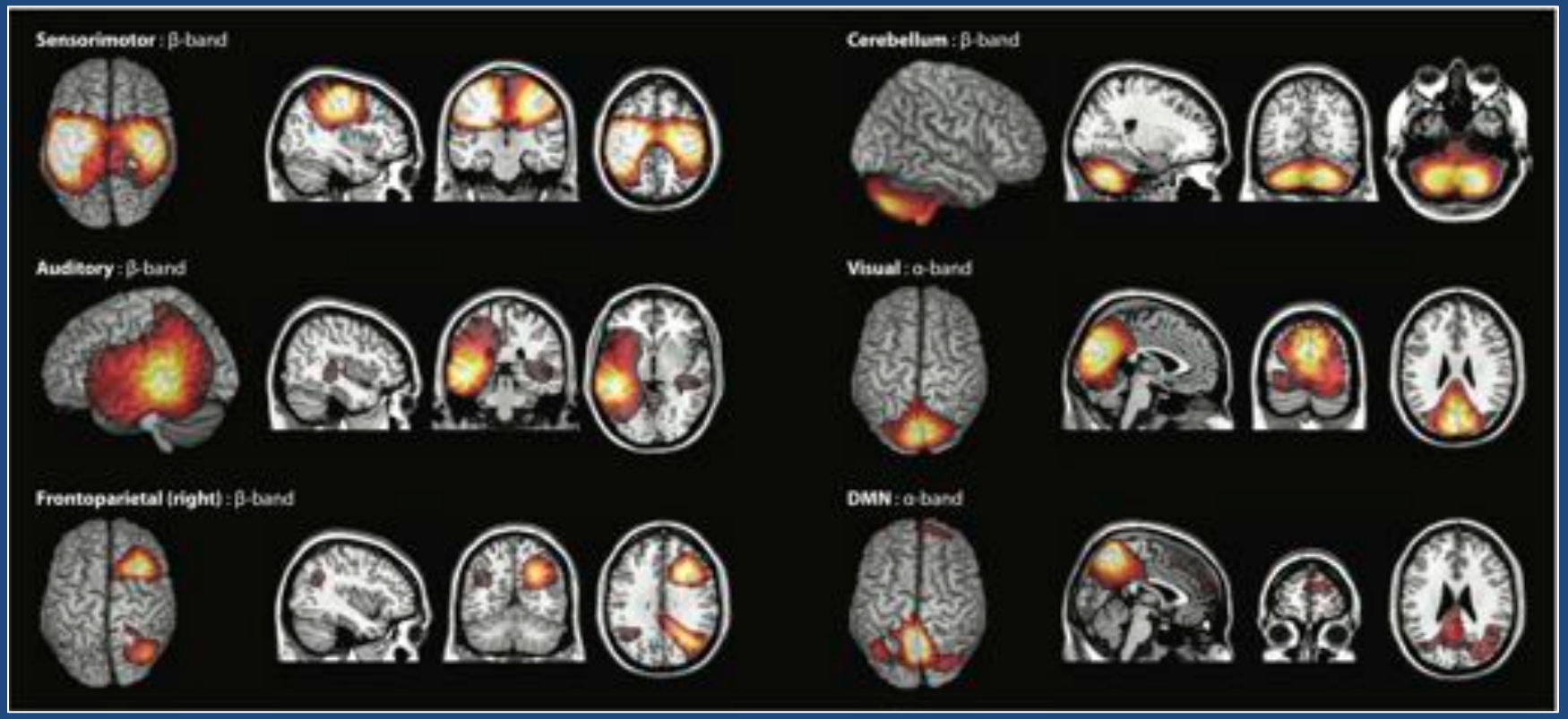
- Individual connectivity spatial pattern correlates with :

  - Network connectivity level ($p<10^{-4}$).
  - $SM1_\beta$: β/θ ($p<10^{-3}$) and β/α ($p<10^{-2}$) power.
  - $A1_\beta$: β/θ power ($p<10^{-2}$).
  - $V1_\alpha$: α ($p<10^{-2}$), α/θ ($p<10^{-4}$), and α/β ($p<10^{-4}$) power.



INDEPENDENT COMPONENT ANALYSIS

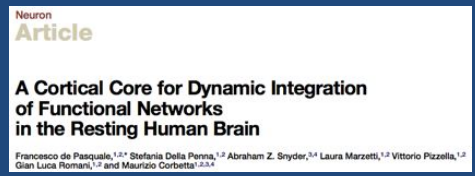
- Another approach to extract co-variation patterns : temporal ICA.



LAST CONSIDERATIONS

THE DYNAMIC BRAIN NETWORK

- Existence of multiple RSNs : integrative picture of brain organization and activity.
- Brain as combination of uncoupled networks : obviously wrong!
- Cross-network interactions:
  - cross-frequency coupling,
  - transient synchronization.


Neuron
Article

A Cortical Core for Dynamic Integration of Functional Networks in the Resting Human Brain

Francesco de Pasquale,[1,2,*] Stefania Della Penna,[1,2] Abraham Z. Snyder,[3,4] Laura Marzetti,[1,2] Vittorio Pizzella,[1,2] Gian Luca Romani,[1,2] and Maurizio Corbetta[1,2,3,4]

- Study of spectral and dynamic properties of functional connectivity : MEG rules !