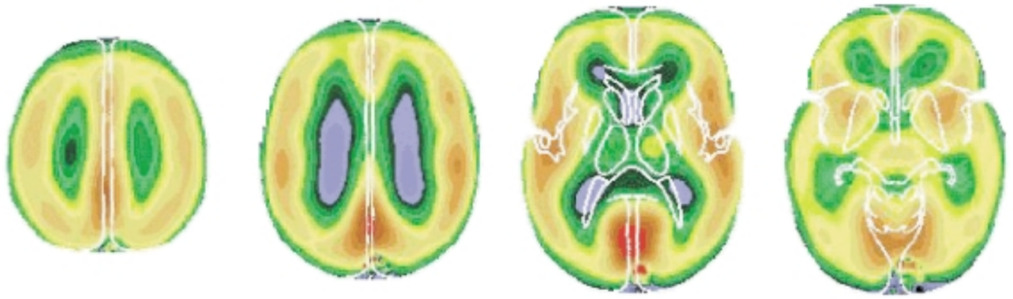
Resting state fMRI and ICA

- Introduction to resting state
- Independent Component Analysis
- Single subject
- Multi-subject ICA
- Dual regression

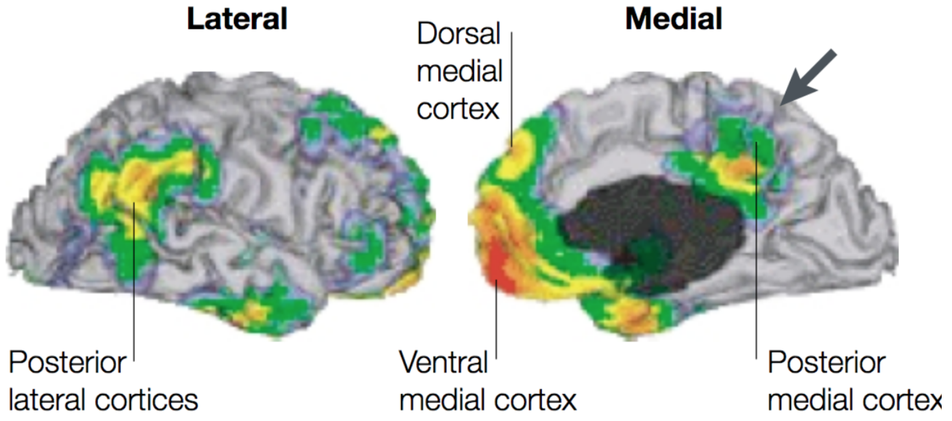
Energy consumption in the brain

- Brain < 2% body weight but consumes ~20% of total energy
- estimated 60-80% of this energy used to support communication between cells
- task-evoked activity accounts for ~1%

Oxygen consumption



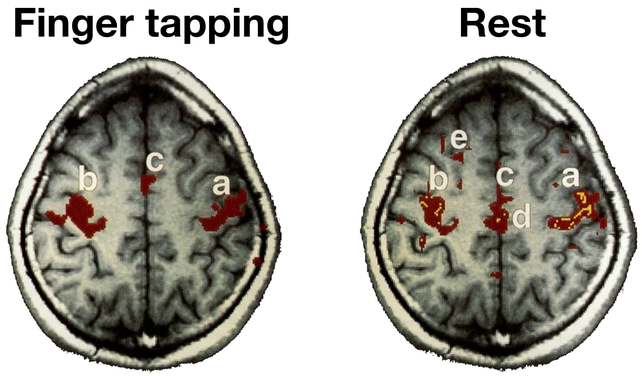
Decreased activity during tasks (PET)

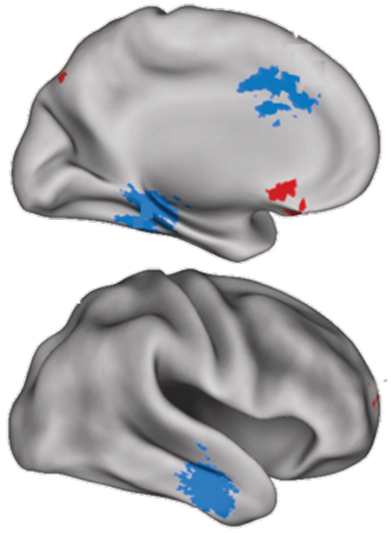


Raichle et al (2001), Gusnard et al (2001)

Why study the brain at rest?

- Localisation versus connectivity
- Understand the inherent functional organisation of the brain
- Clinical/ cognitive biomarker
- Pragmatic benefits: can be done in any population, with relatively little setup and expertise required





Biswal et al (1995), *Sheline et al (2010)*

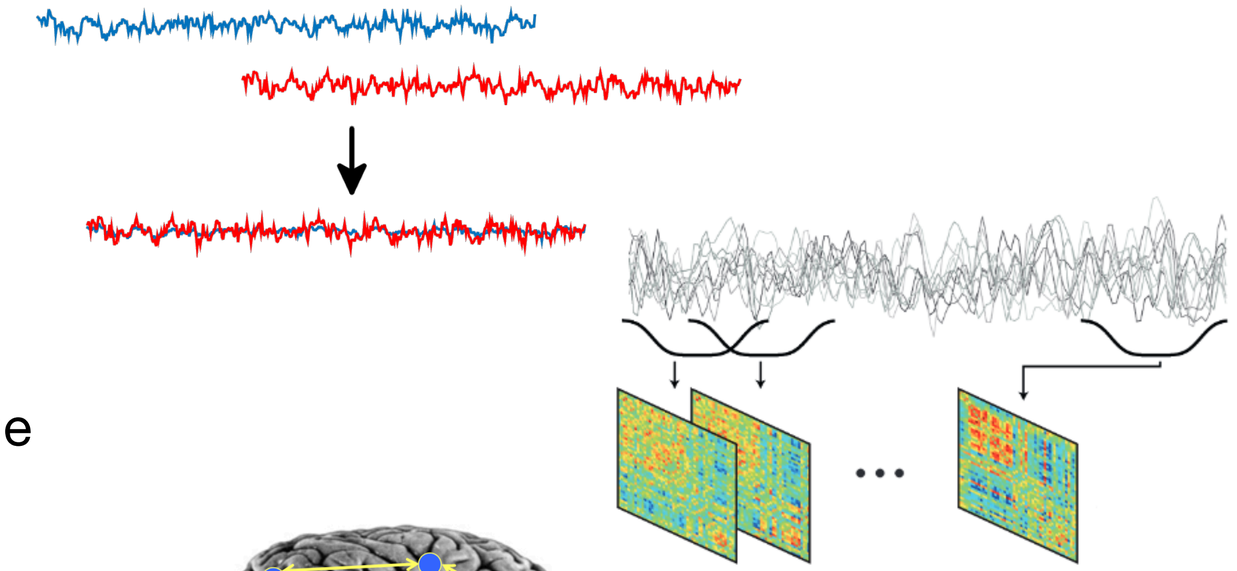
Principles of resting state analysis

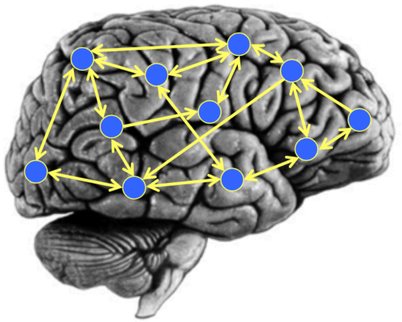
- Many different methods available for analysis
- All have one assumption in common:
- i.e. definition of functional connectivity is based on a statistical dependency between timeseries
- Differences between methods lie in the way these similarities are estimated and/or represented

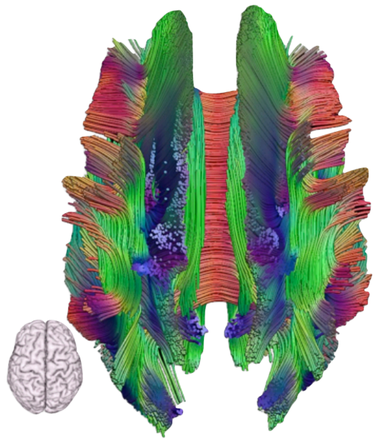
If two brain regions show similarities in their BOLD timeseries, they are functionally connected

Types of connectivity

- Functional connectivity
  - Statistical dependency
- Dynamic connectivity
  - Changes in functional connectivity over time
- Effective connectivity
  - Directional influence
- Anatomical (structural) connectivity
  - Presence of a white matter tract



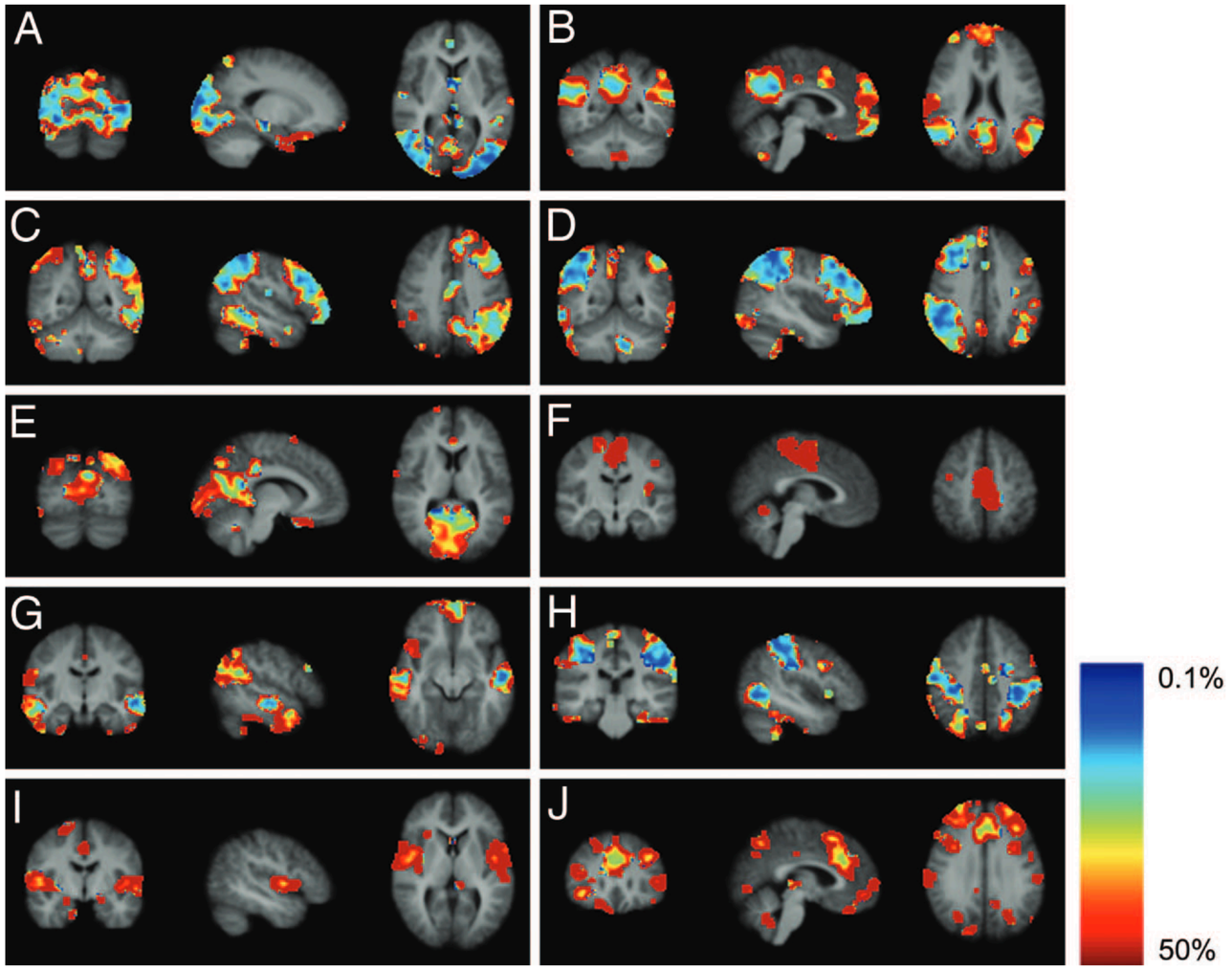




Features of resting state data

Replicable networks

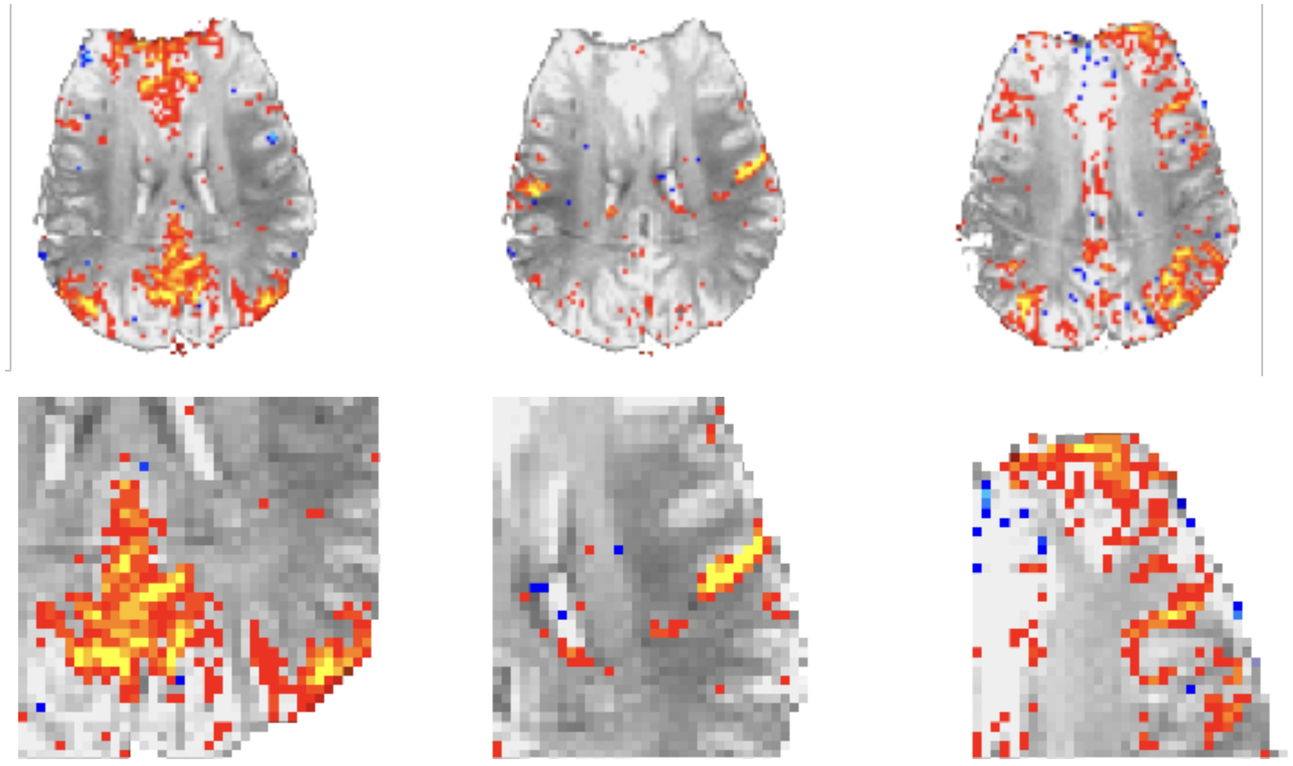
Large-scale inherent organisation is reproducibly found across studies and approaches



Damoiseaux et al (2006)

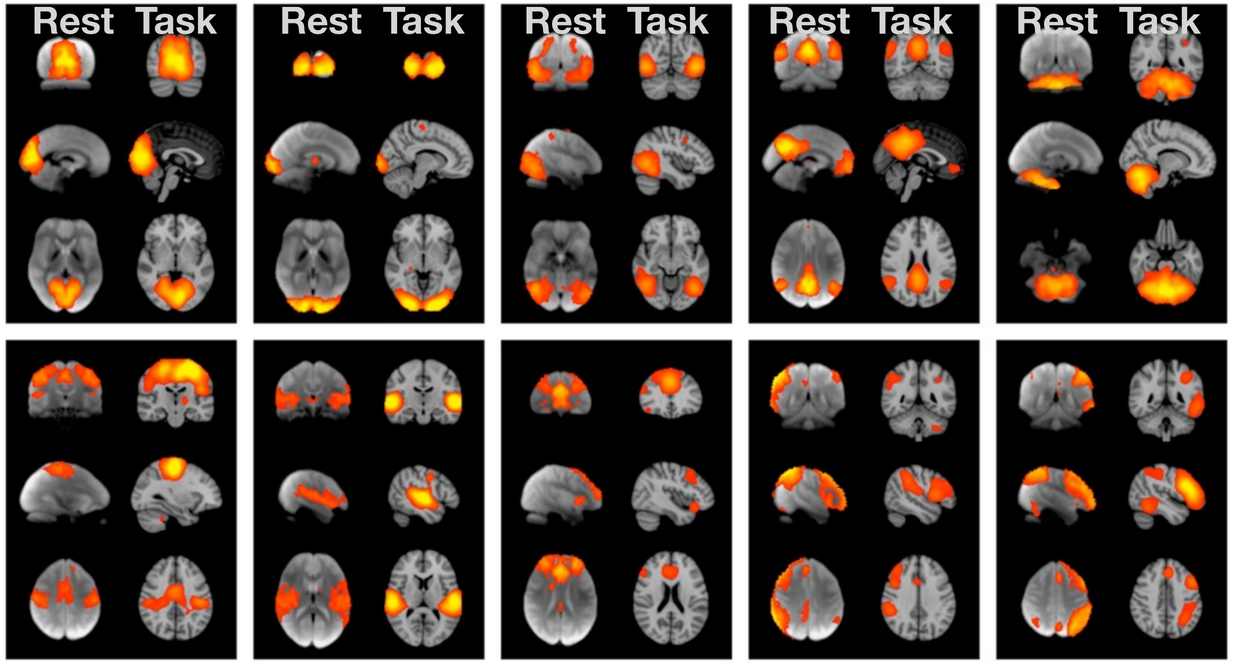
Grey matter networks

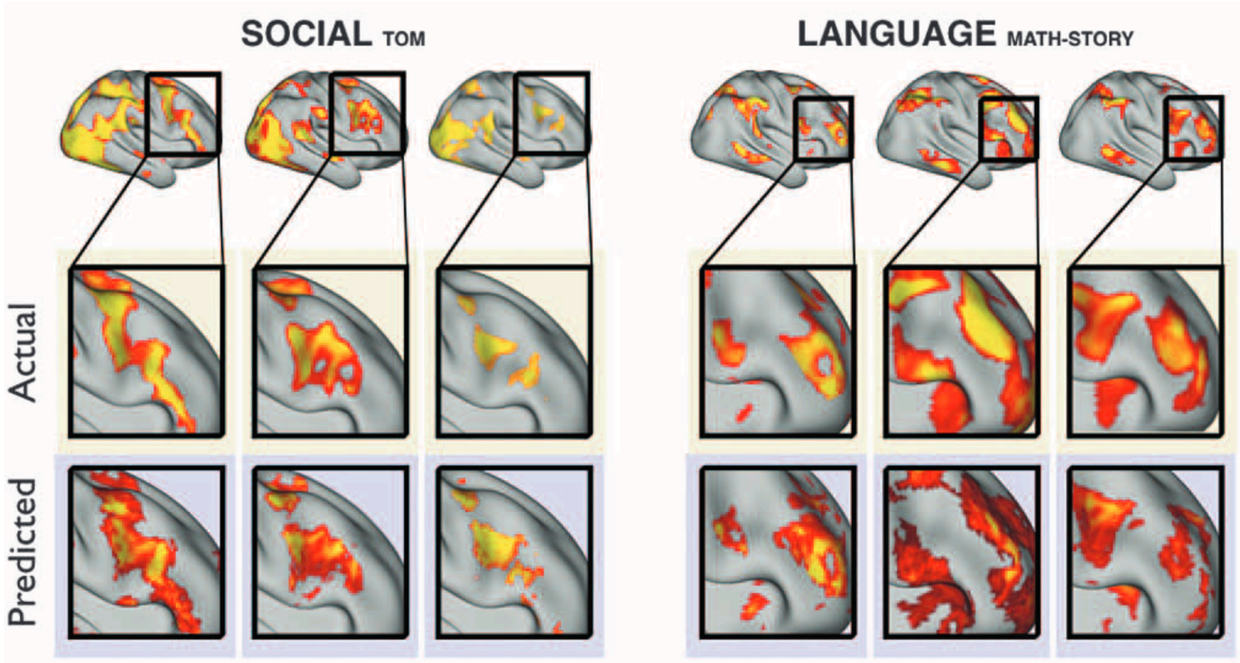
Resting state network structure is localised in grey matter



Relationship to task

Resting state networks are similar to task activation patterns at group and single subject level

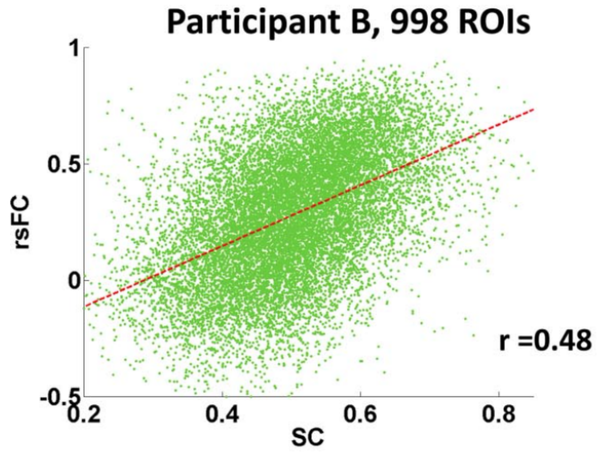


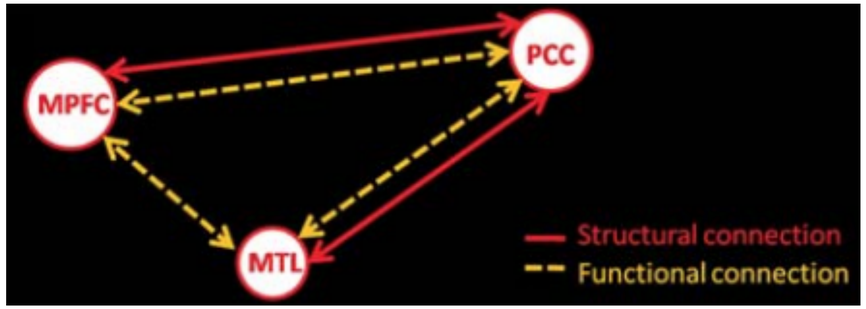


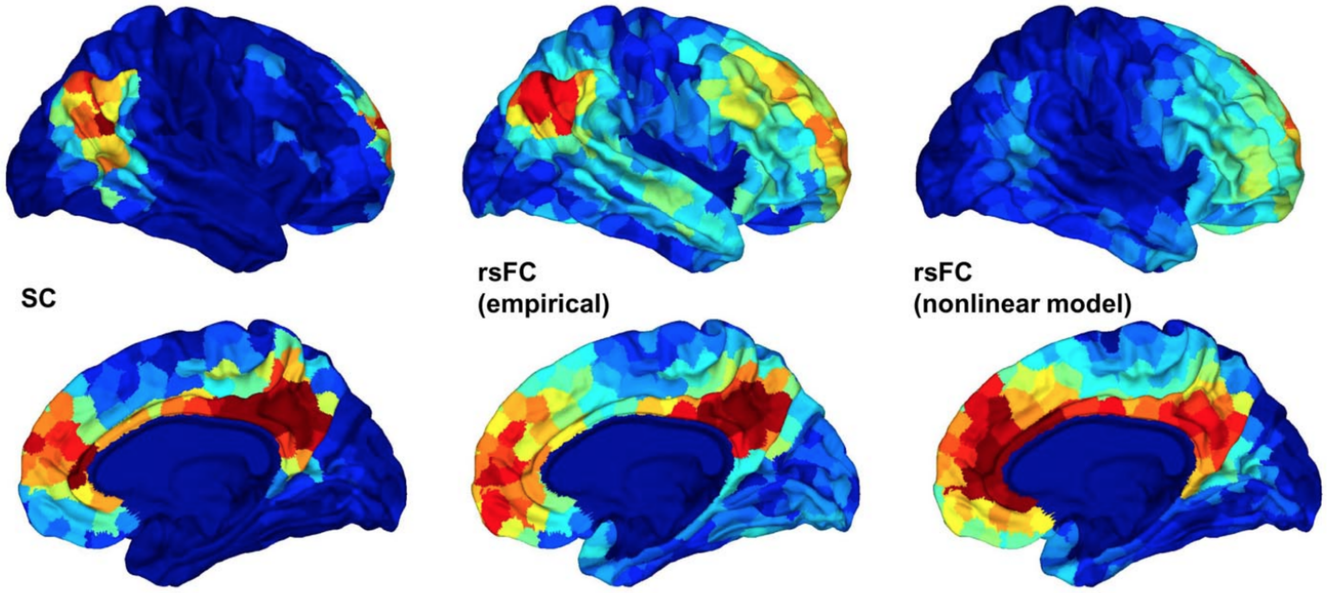
Smith et al (2009), Tavor et al (2016)

Functional vs structural connectivity

Functional connectivity is related to structural connectivity

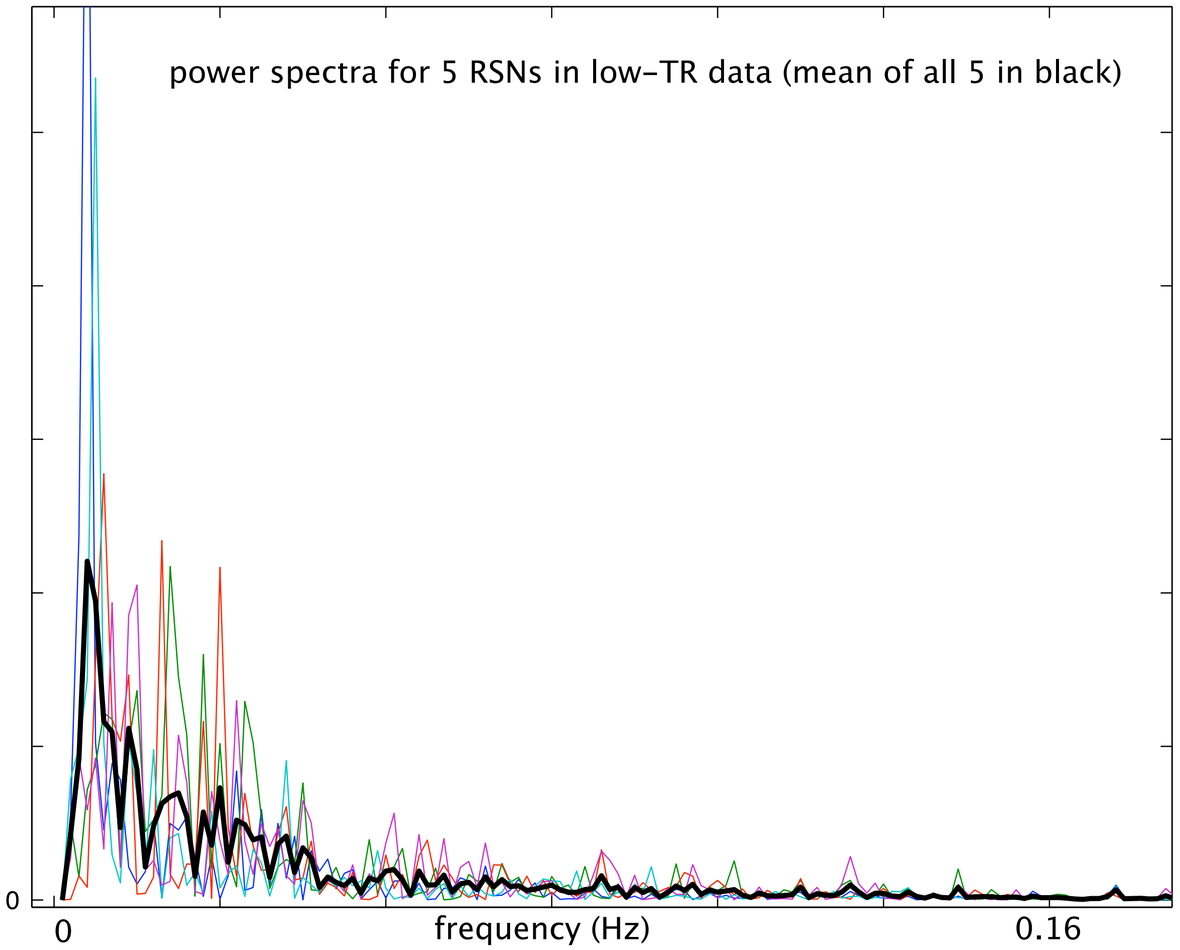


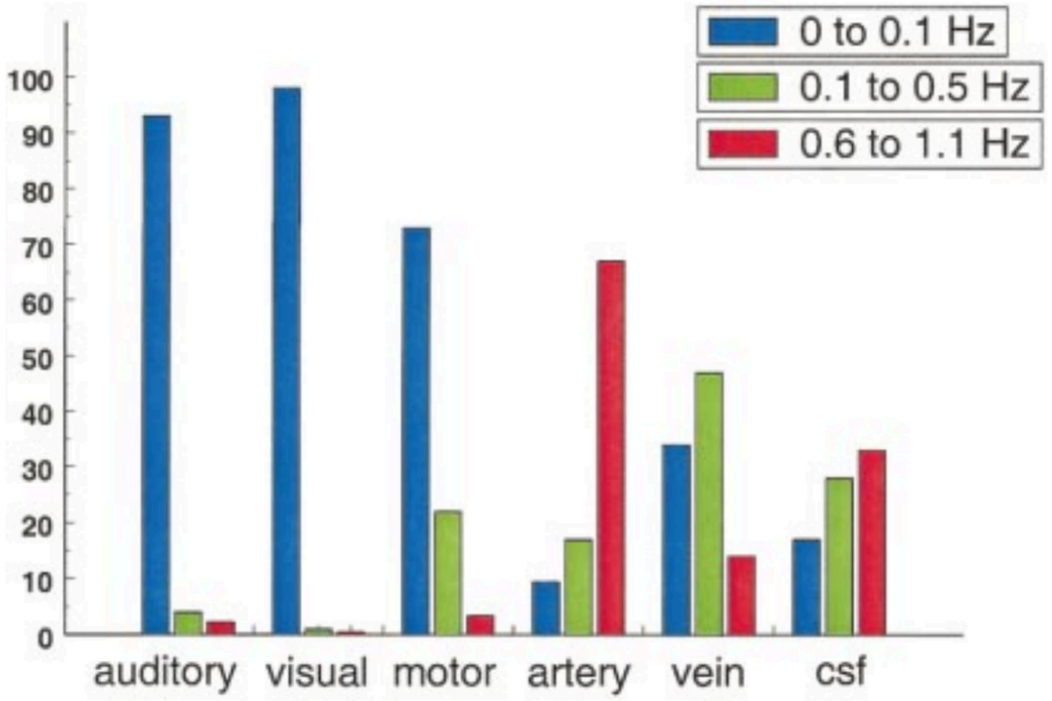




Honey et al (2009), *Damoiseaux & Greicius (2009)*

Low frequency fluctuations?

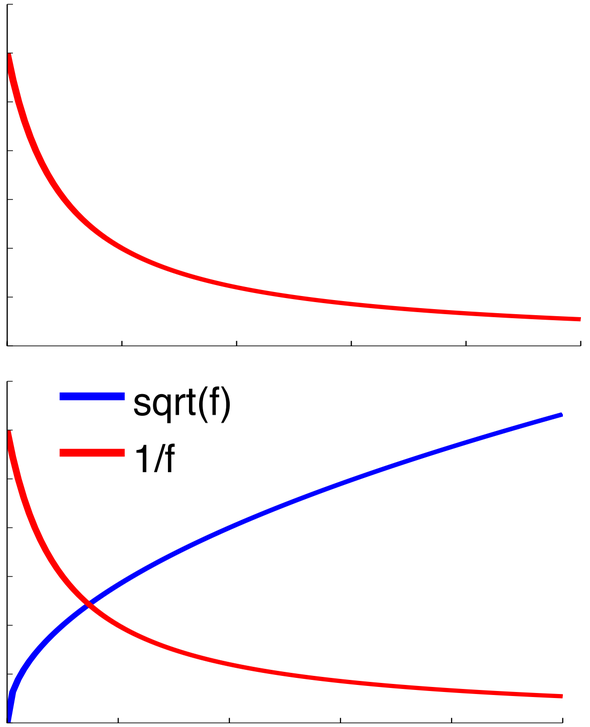




Cordes et al (2001)

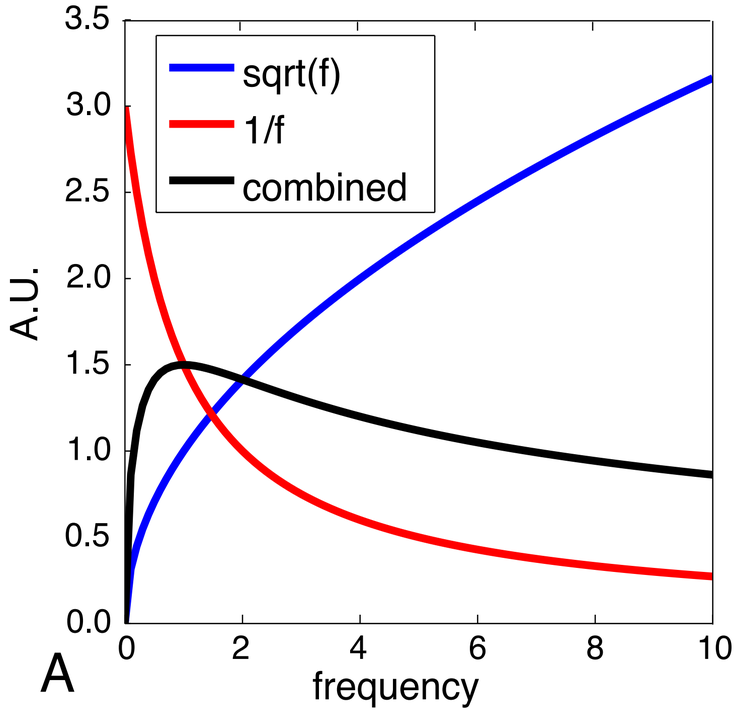
Low frequency fluctuations?

- BOLD decreases as 1/*f*
- Degrees of freedom increase as sqrt(*f*)



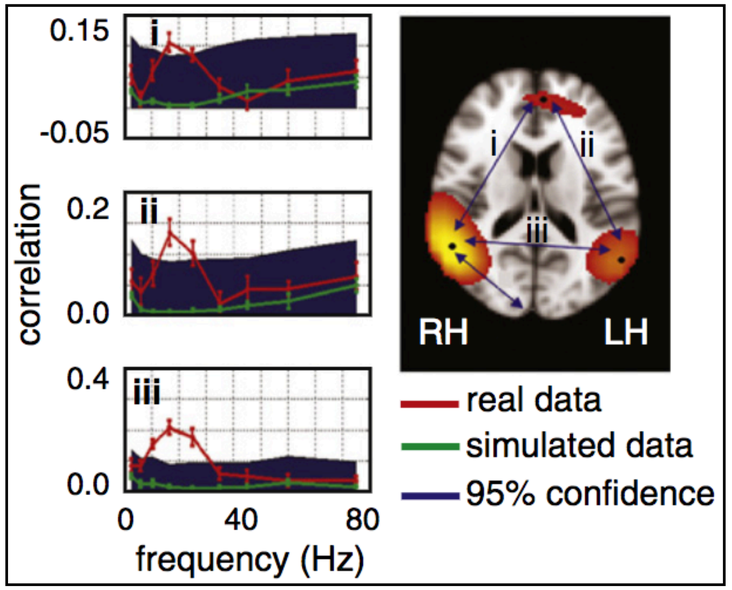
Low frequency fluctuations?

- BOLD decreases as 1/*f*
- Degrees of freedom increase as sqrt(*f*)
- Combined effect contributes to RSN estimation across frequency range!

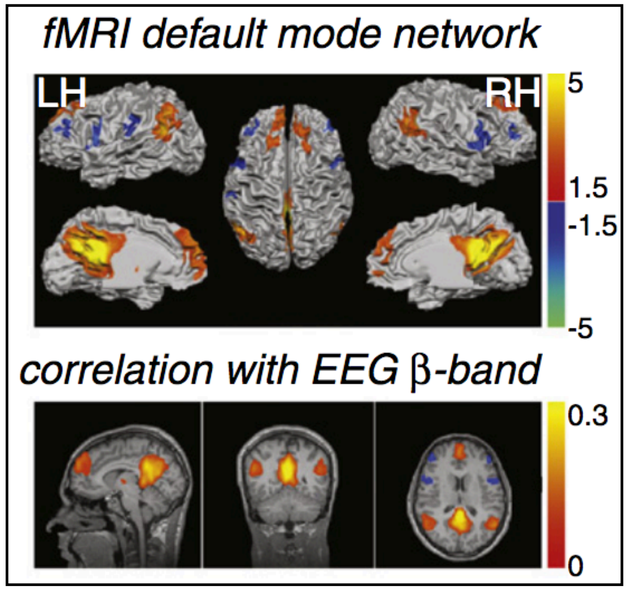


Electrophysiology of BOLD connectivity

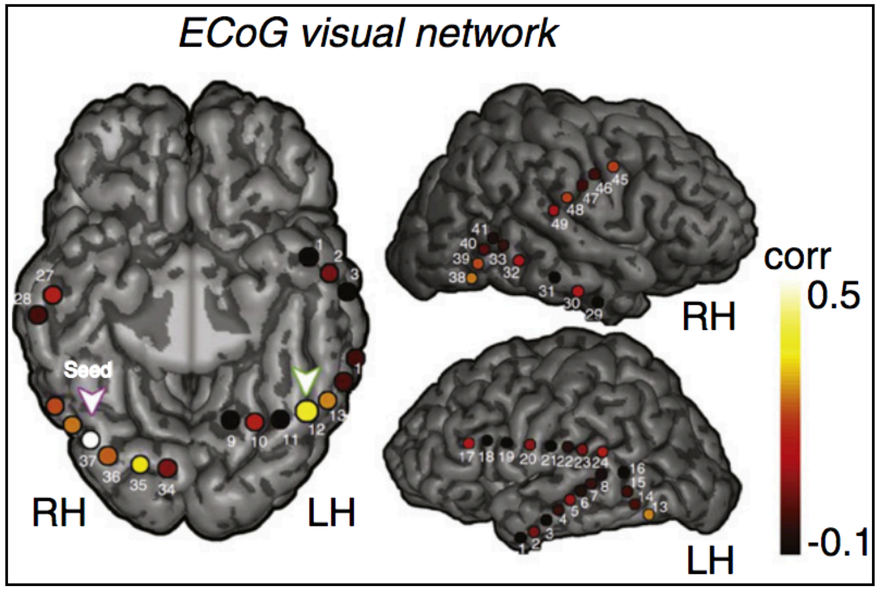
MEG



EEG



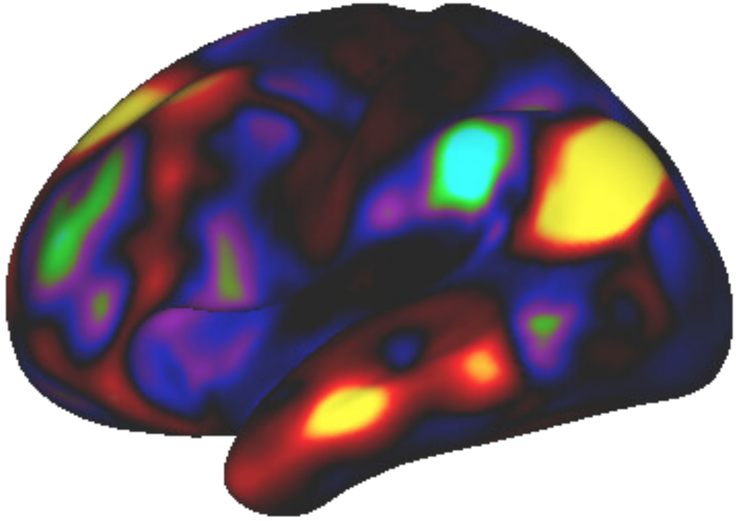
ECoG



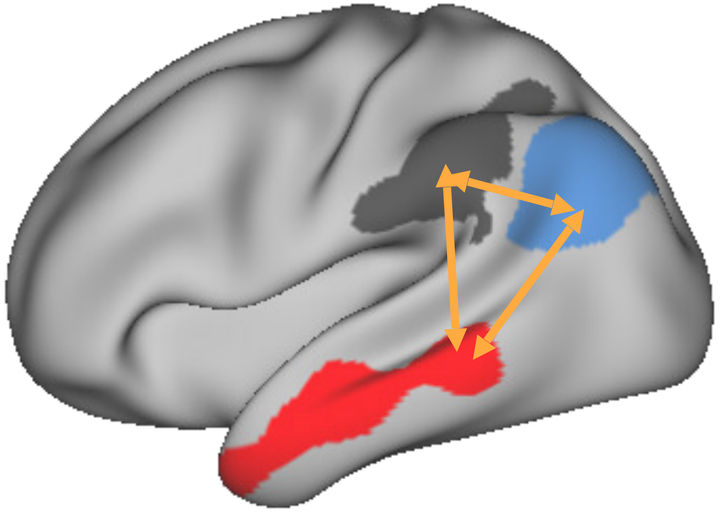
Schölvinck et al (2013), Brookes et al (2011), Mantini et al (2007), Nir et al (2008)

Analysis overview

Overview of resting state methods



Voxel-based methods



Node-based methods

Overview of resting state methods

Voxel-based methods

- Seed-based correlation analysis
  - SCA
- Independent component analysis
  - ICA
- Amplitude of low frequency fluctuations
  - ALLF/fALLF
- Regional homogeneity
  - ReHo

Node-based methods

- Network modelling analysis
  - FSLnets
- Graph theory analysis
  - Such as degree, hub, path length
- Dynamic causal modelling
  - DCM
- Non-stationary methods
  - Such as windowed analyses

Overview of resting state methods

Voxel-based methods

- Seed-based correlation analysis
  - SCA
- Independent component analysis
  - ICA
- Amplitude of low frequency fluctuations
  - ALLF/fALLF
- Regional homogeneity
  - ReHo

Node-based methods

- Network modelling analysis
  - FSLnets
- Graph theory analysis
  - Such as degree, hub, path length
- Dynamic causal modelling
  - DCM
- Non-stationary methods
  - Such as windowed analyses

Resources

- FSL mailing list
- Book (Amazon/ OUP)
- All references on the bottom of slides contain ‘clickable’ links