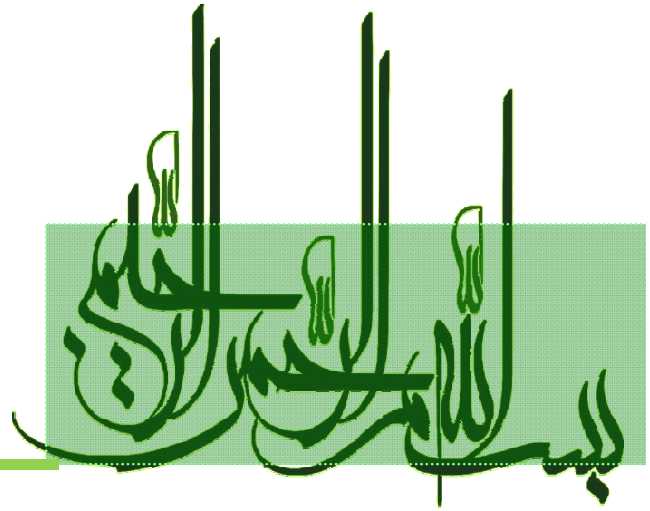
بسم الله الرحمن الرحيم

Functional connectivity

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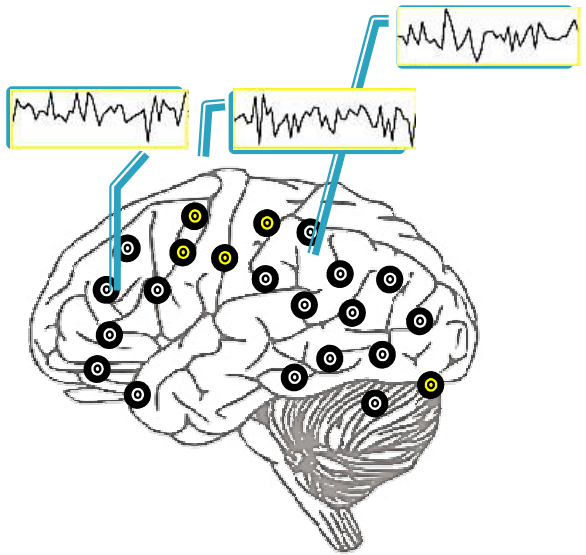
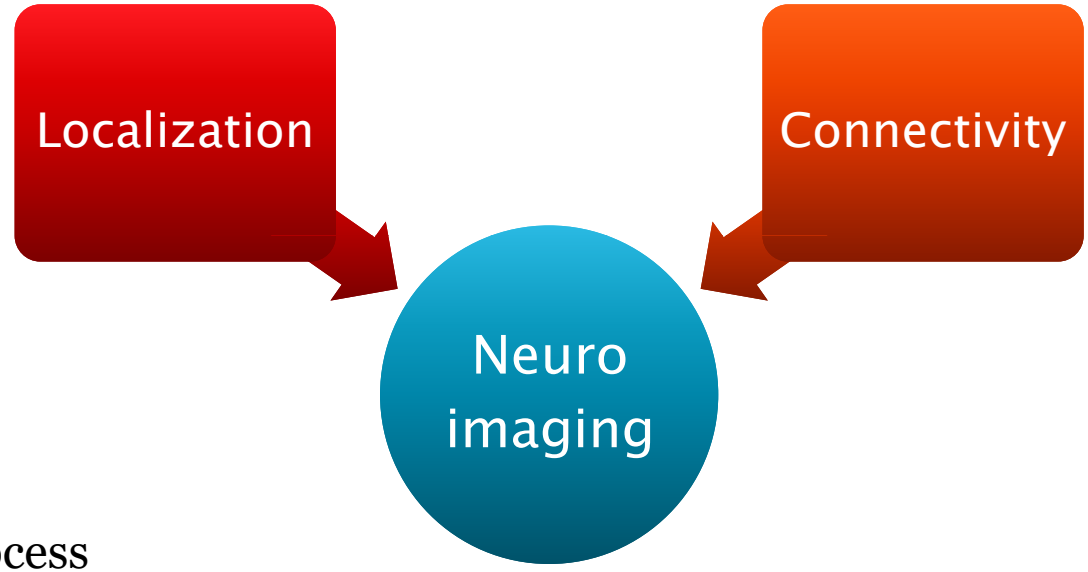
Content

- Introduction
- History of Functional connectivity
- Types of brain connectivity
- What can be gained from Functional connectivity?
- Functional Connectivity analysis methods
- Challenges functional Connectivity
- Dynamic Functional Connectivity

Introduction

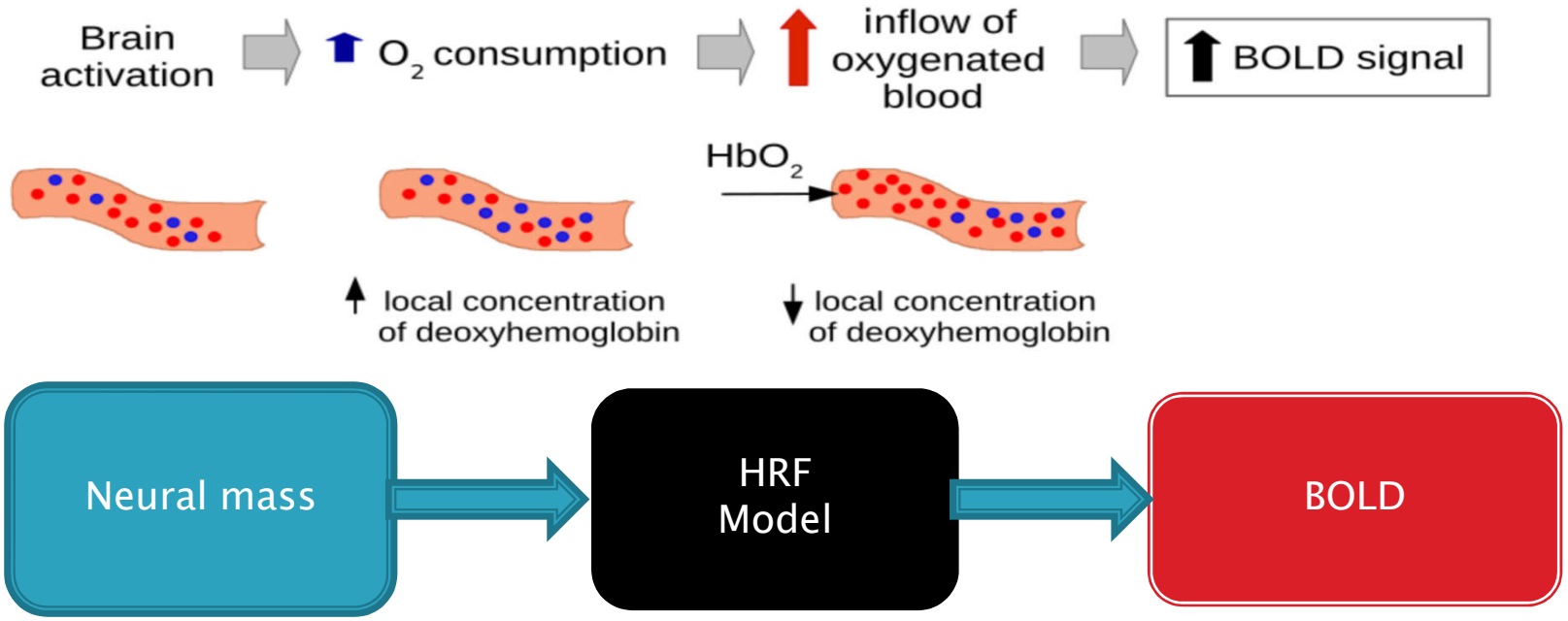
how the brain works?





Understanding Where/How neurons and neural networks process information.

Introduction to fMRI



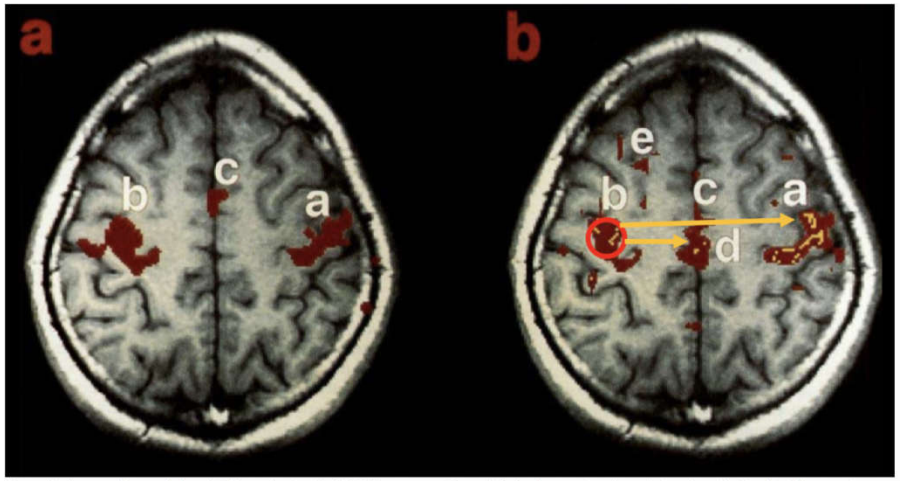
During a stimulus, the resulting local increase in neural activity typically only changes the BOLD signal by 1-3% of the baseline BOLD signal.

S. Ogawa, T. M. Lee, A. R. Kay, and D. W. Tank. Brain magnetic resonance imaging with contrast dependent on blood oxygenation. Proceedings of the National Academy of Sciences, 87(24):9868-9872, dec 1990.

History of Functional Connectivity

- in the early 1990s
- experiments focused on BOLD response to sensory and motor stimuli
- the BOLD response was relatively small compared to the noise
- in 1995 Bharat Biswal scanned subjects when they were doing a task

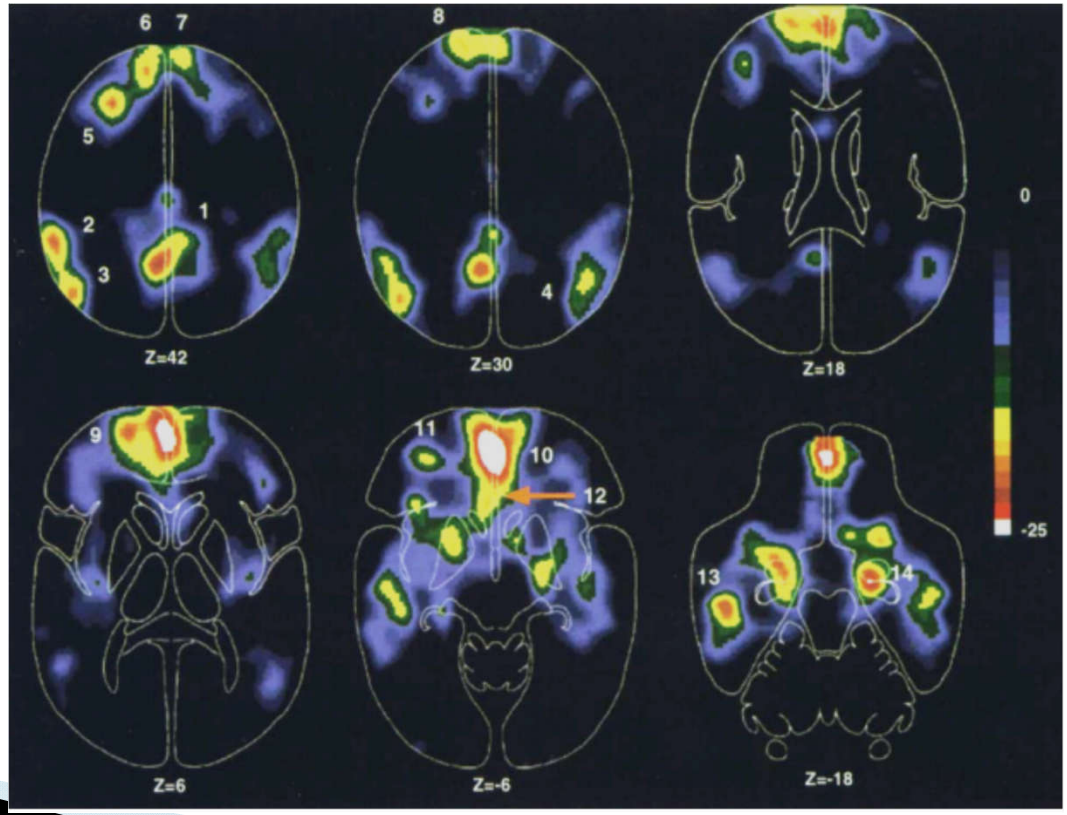
regions that are co-activated during a task are correlated in their activity in the absence of a task!



Result from the original Biswal et al. 1995 paper. Panel (a) shows task-related activity in the motor cortices, while panel (b) shows functional connectivity during a resting-state scan, using the left motor cortex as a seed region. Note the high degree of overlap between the task and the resting-state images.

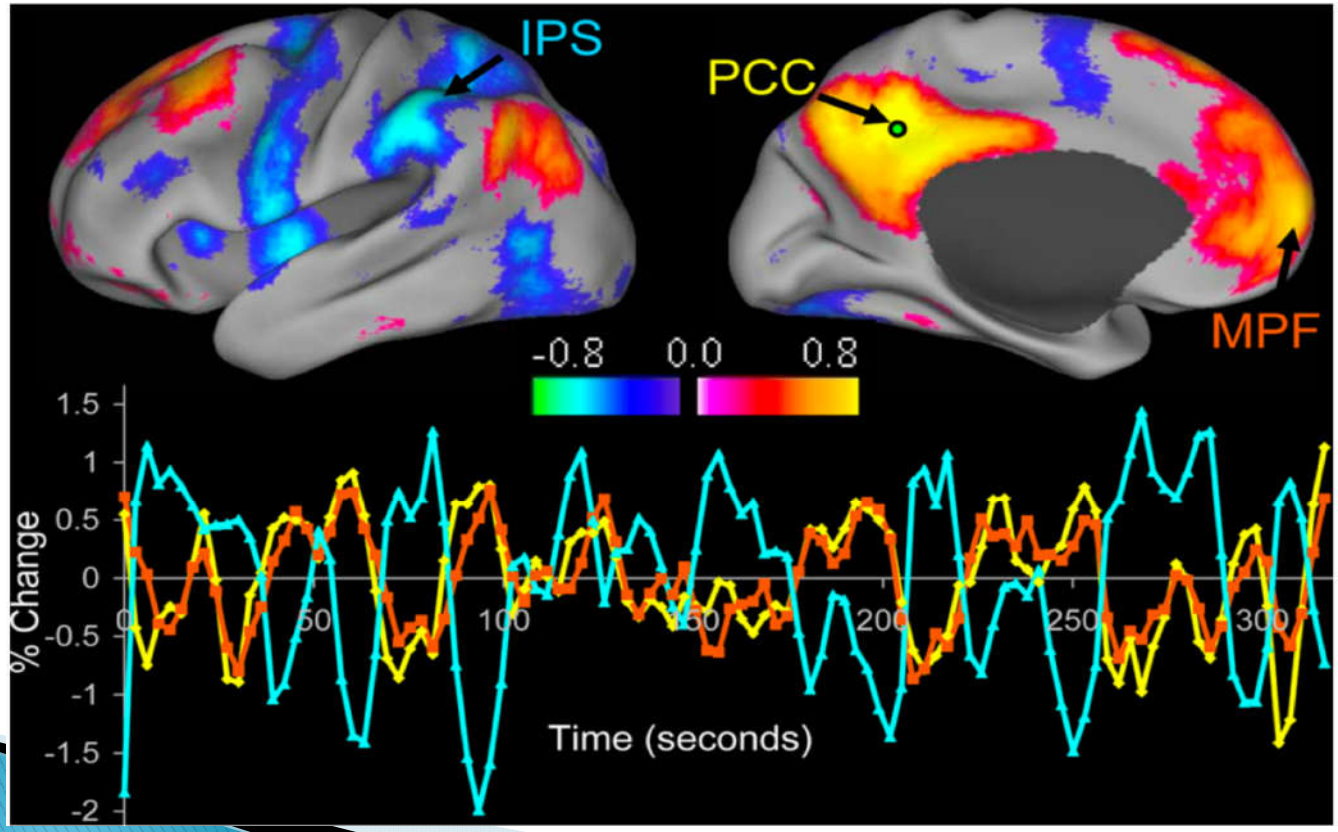
History of Functional Connectivity…

- A couple of years after the Biswal et al: Gordon Shulman
- some regions became more active during cognitive tasks(DMN)



History of Functional Connectivity…

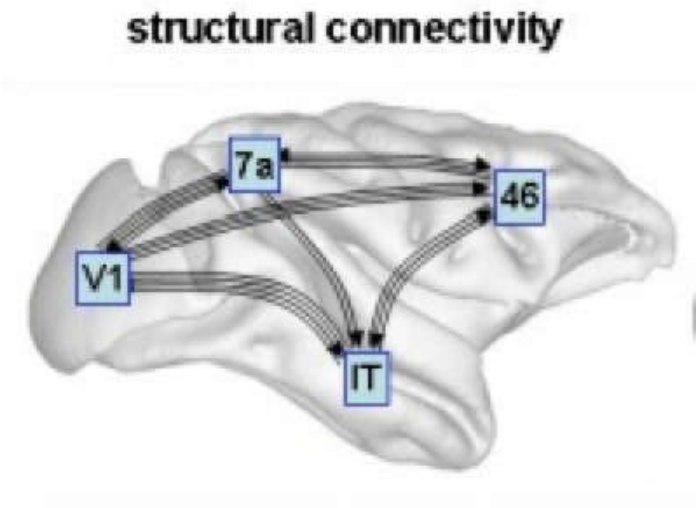
- in 2005, Michael Fox
  - **task-positive** and **task-negative** networks



What is brain connectivity?

Types of brain connectivity

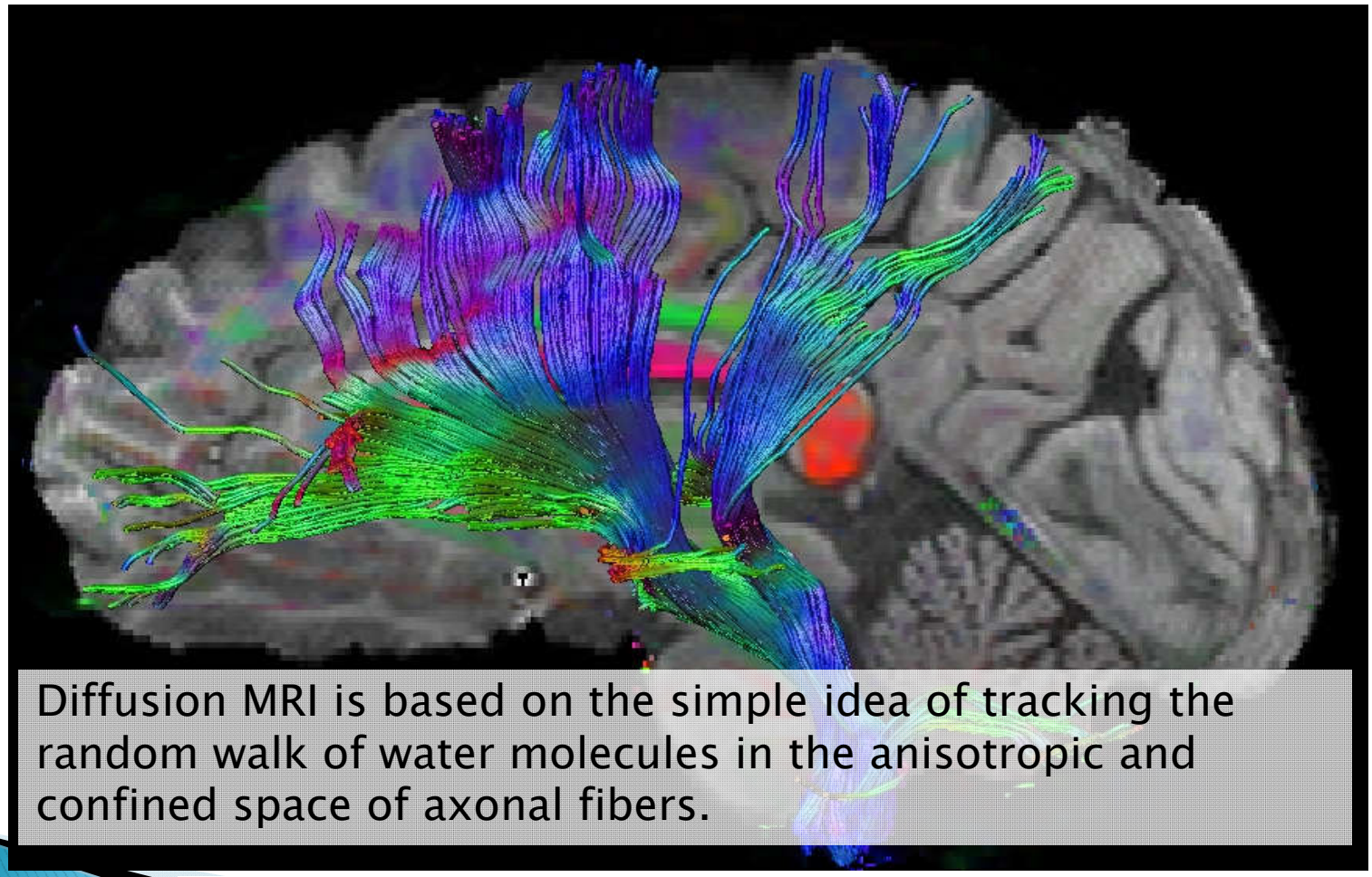
Anatomical/structural connectivity



- **A network of structural connections**
- **The stability of the connections (seconds or minutes, days)**
- **The levels of the connections (microscale/mesoscale/macroscale) resolutions of up to 300 microns.**

Types of brain connectivity

Anatomical/structural connectivity

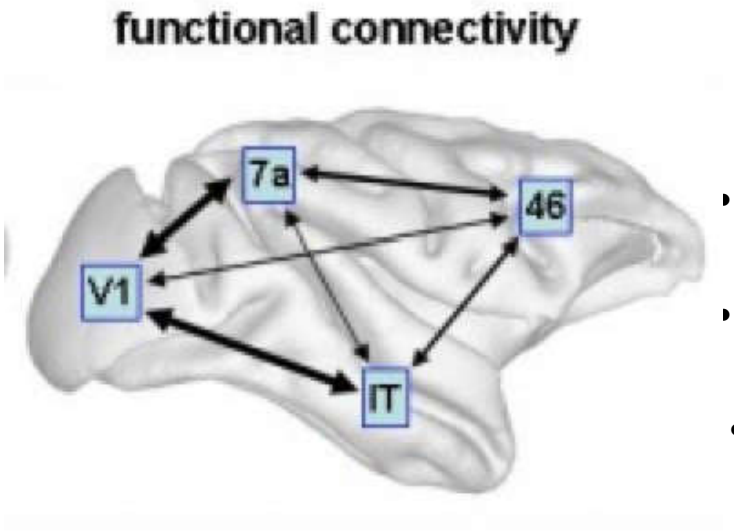


Diffusion MRI is based on the simple idea of tracking the random walk of water molecules in the anisotropic and confined space of axonal fibers.

No information about neural information flow!

Types of brain connectivity

Functional connectivity

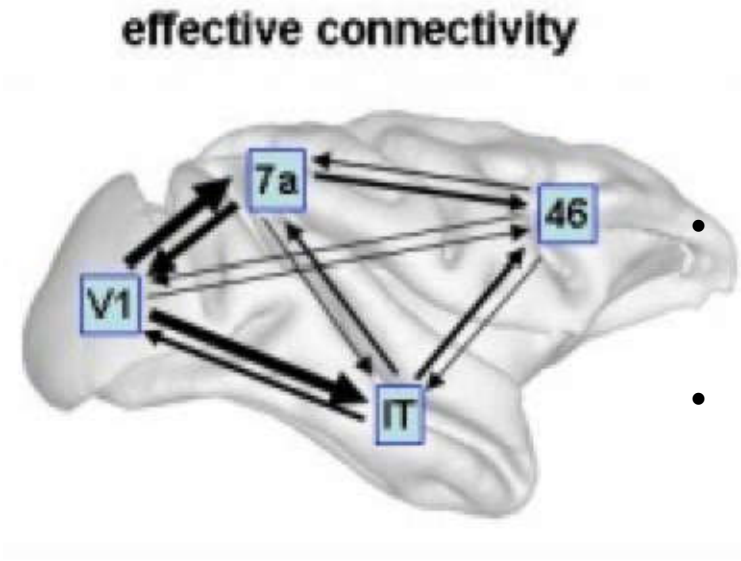


- **A statistical concept**
- **The estimation of statistical dependence**
- **Time-dependent (second-minute)**

if two regions show similarities in their BOLD signals over time, they are functionally connected

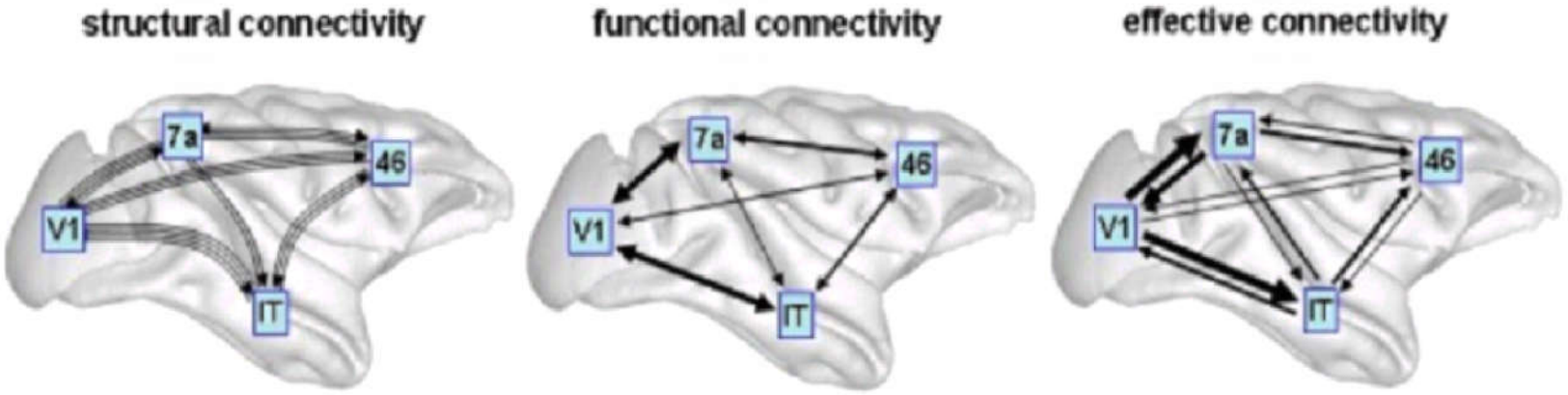
Types of brain connectivity

Effective connectivity

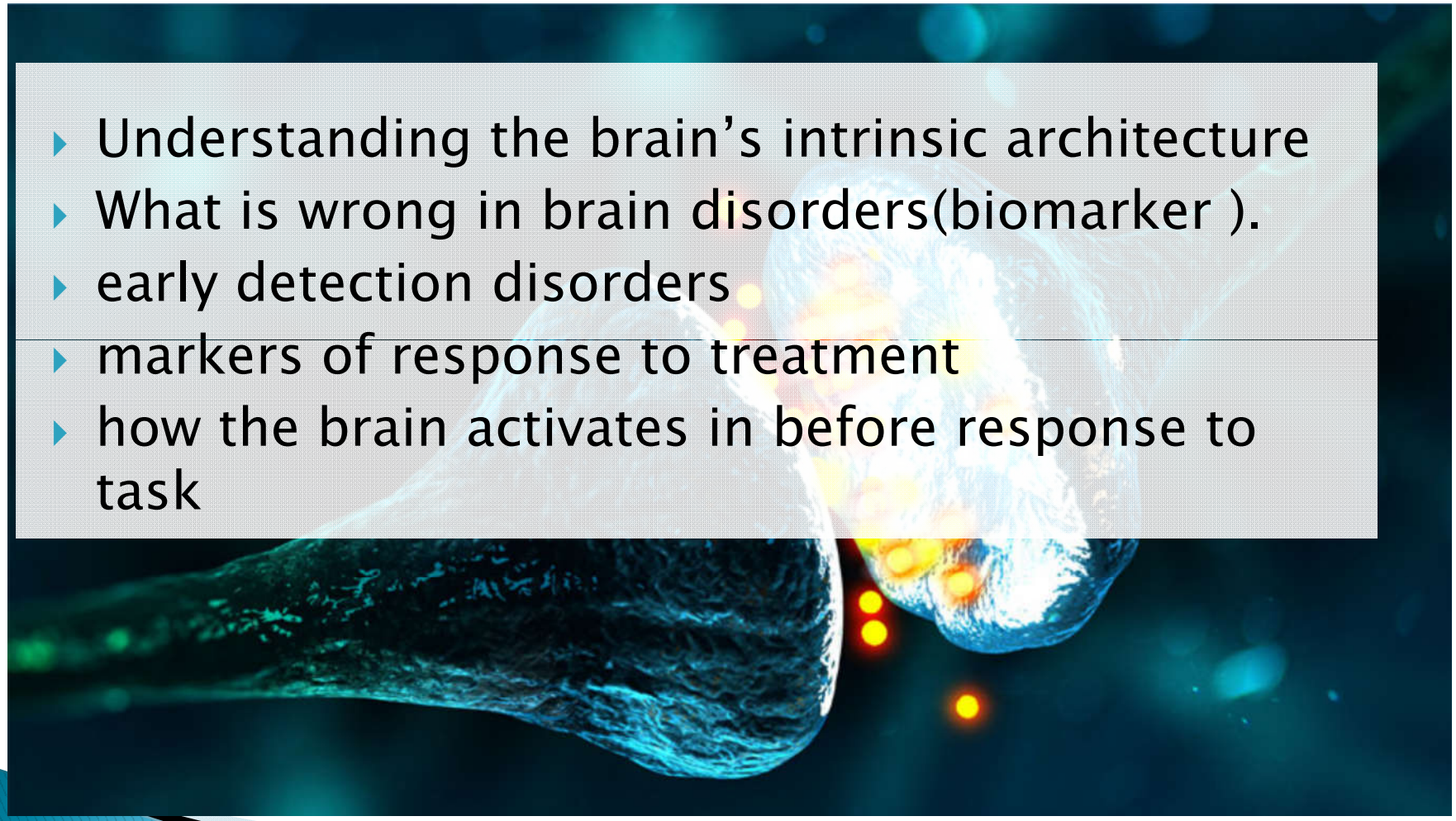


- **It describes networks of directional effects of one neural element over another (causal effects).**
-

Brain Connectivity



What can be gained from Functional connectivity?



- Understanding the brain's intrinsic architecture
- What is wrong in brain disorders(biomarker).
- early detection disorders
- markers of response to treatment
- how the brain activates in before response to task

Functional Connectivity analysis methods

- Voxel-based Connectivity Analysis
- Node-based Connectivity Analysis

Voxel-based Connectivity Analysis

- Seed-based correlation analysis

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

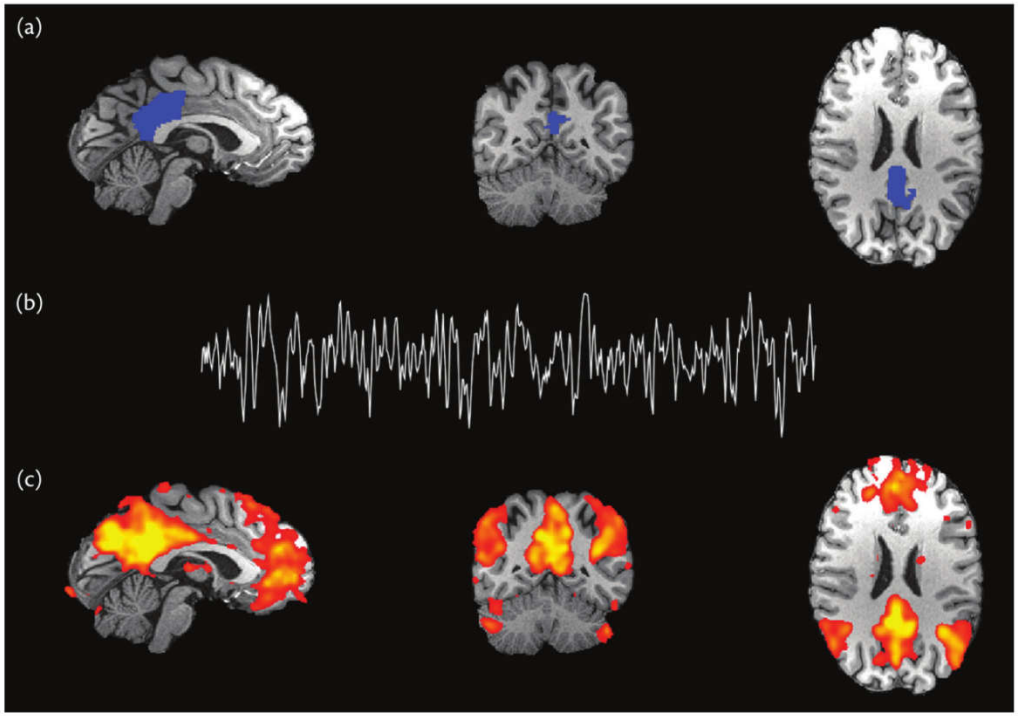
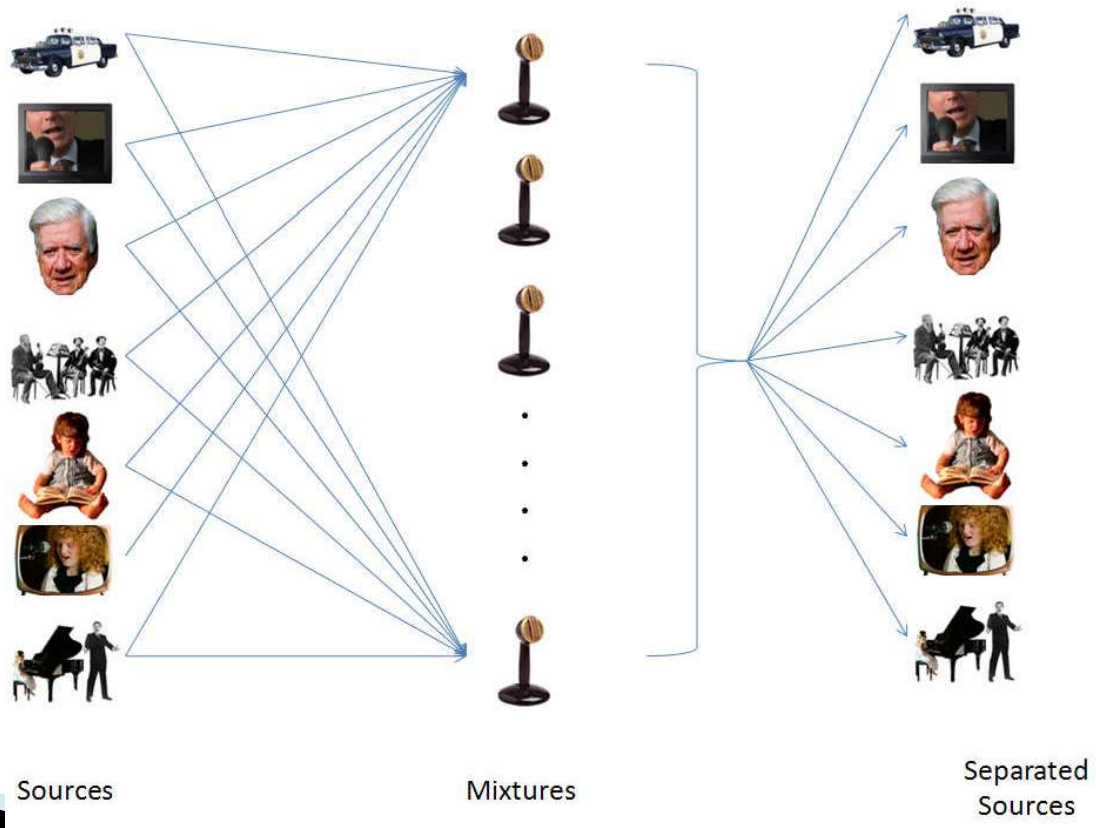


Figure 4.1: Results from a seed-based correlation analysis on a single subject. (a) The seed region of interest in the posterior cingulate cortex is shown in blue. (b) The average BOLD timeseries extracted from this region. (c) A thresholded correlation map of all other voxels with this seed timeseries is shown. SCA can be used to find resting state networks such as the DMN, as shown here, depending on the location of the seed.

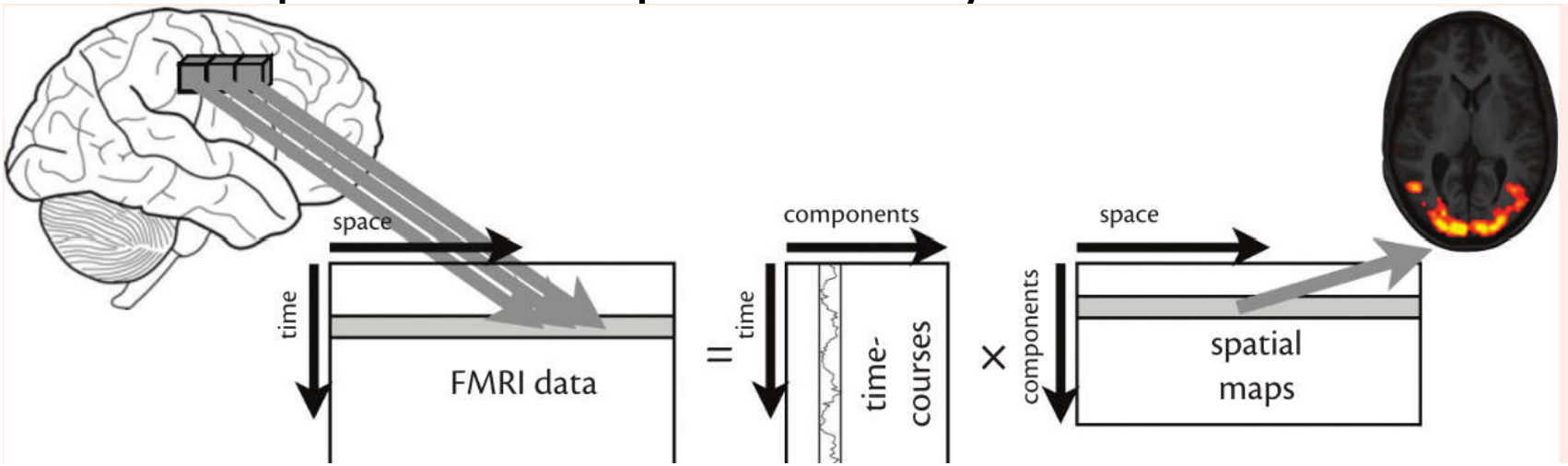
Voxel-based Connectivity Analysis

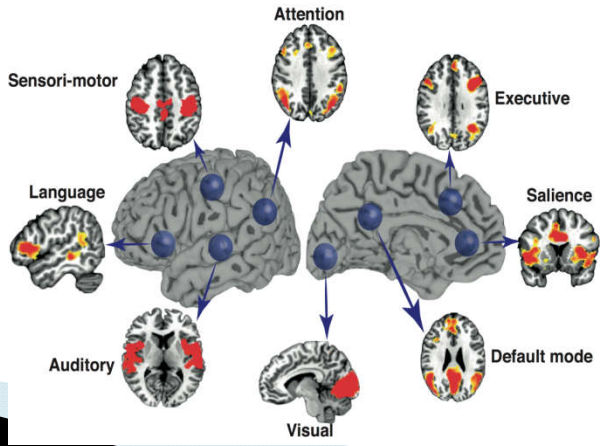
- Seed-based correlation analysis
- Independent component analysis



Voxel-based Connectivity Analysis

- Seed-based correlation analysis
- Independent component analysis

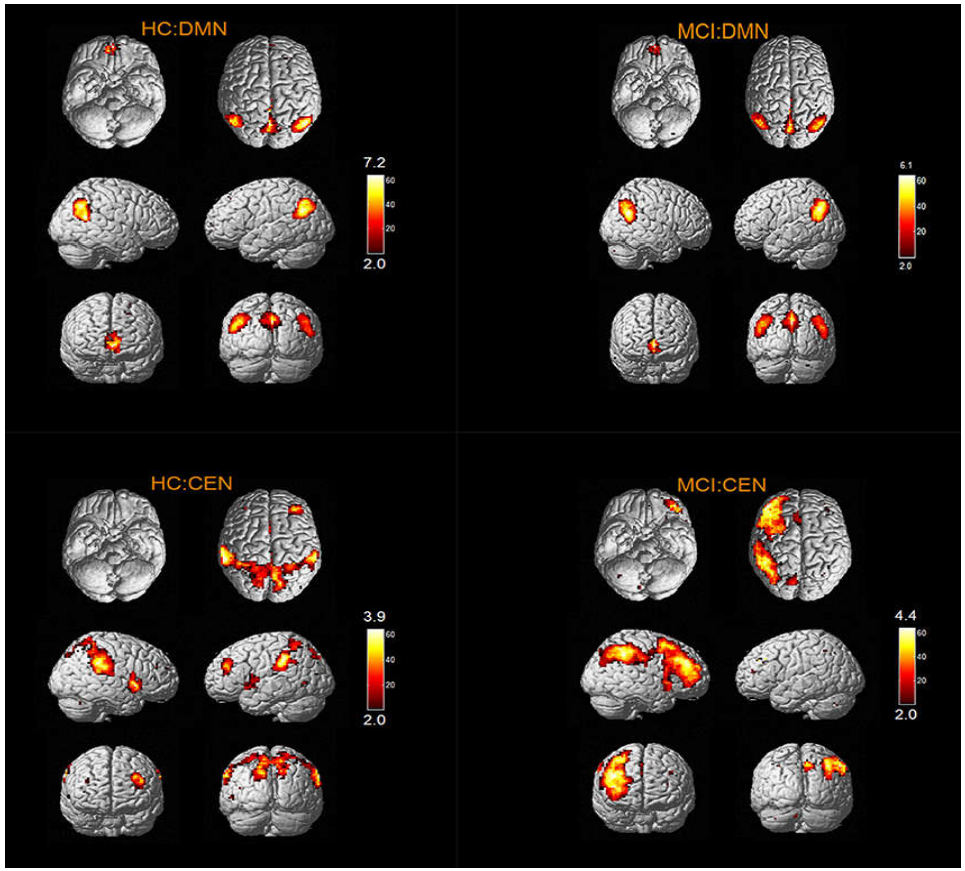




Voxel-based Connectivity Analysis

- Seed-based correlation analysis
- Independent component analysis

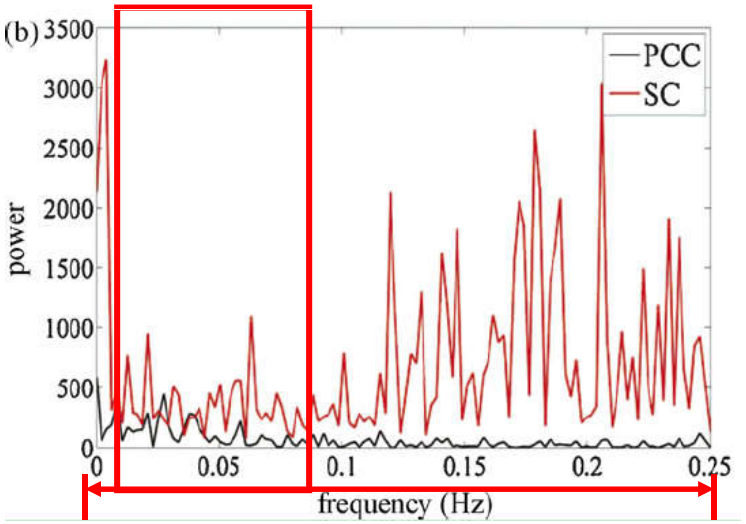
Front. Neurosci.,2018
Non-linear ICA Analysis of Resting-State fMRI in Mild Cognitive Impairment



Voxel-based Connectivity Analysis

- Seed-based correlation analysis
- Independent component analysis
- Amplitude of low-frequency fluctuations

- Averaging the power amplitudes between 0.01-0.08 Hz



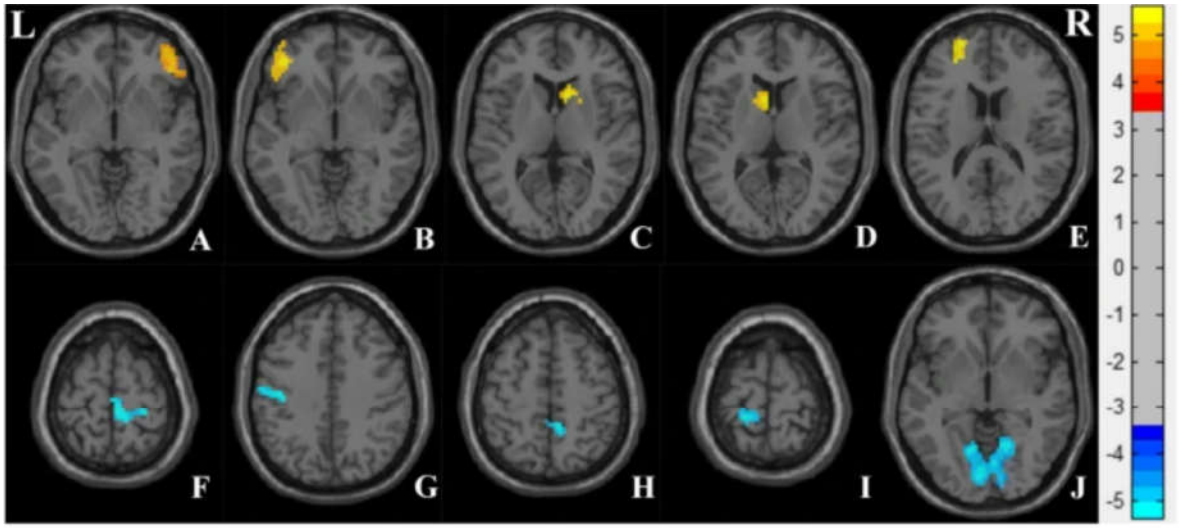
PCC: posterior cingulate cortex

SC: suprasellar cistern

Voxel-based Connectivity Analysis

- Seed-based correlation analysis
- Independent component analysis
- Amplitude of low-frequency fluctuations

BMC Psychiatry, 2019
Amplitude of low-frequency fluctuation (ALFF) may be associated with cognitive impairment in schizophrenia: a correlation study



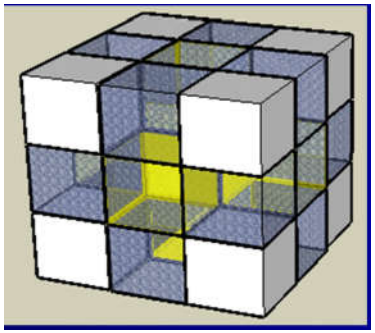
Regions showing altered amplitude of low frequency fluctuation (ALFF) in the SZ group, compared to the HC group. The color bar represents the range of t values. L, left; R, right

Voxel-based Connectivity Analysis

- Seed-based correlation analysis
- Independent component analysis
- Amplitude of low-frequency fluctuations
- Regional homogeneity

Regional Homogeneity (ReHo) is a voxel-based measure of brain activity which evaluates the similarity or synchronization between the time series of a given voxel and its nearest neighbors

Kendall coefficient of concordance

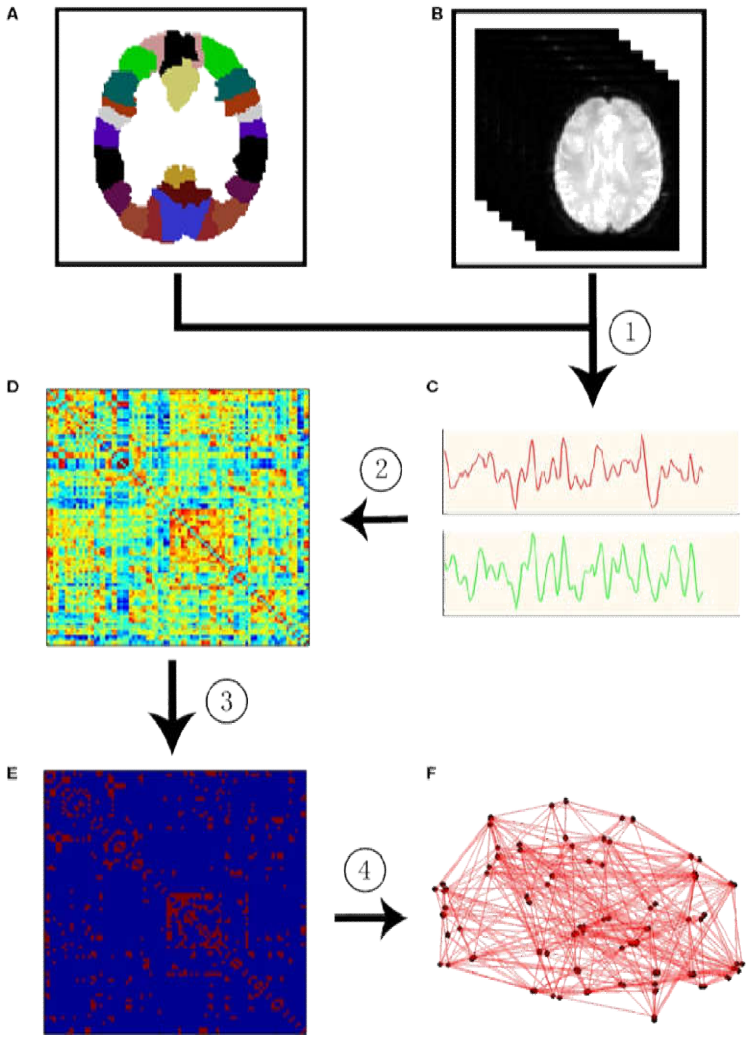


Node-based Connectivity Analysis

1-Defining the Nodes

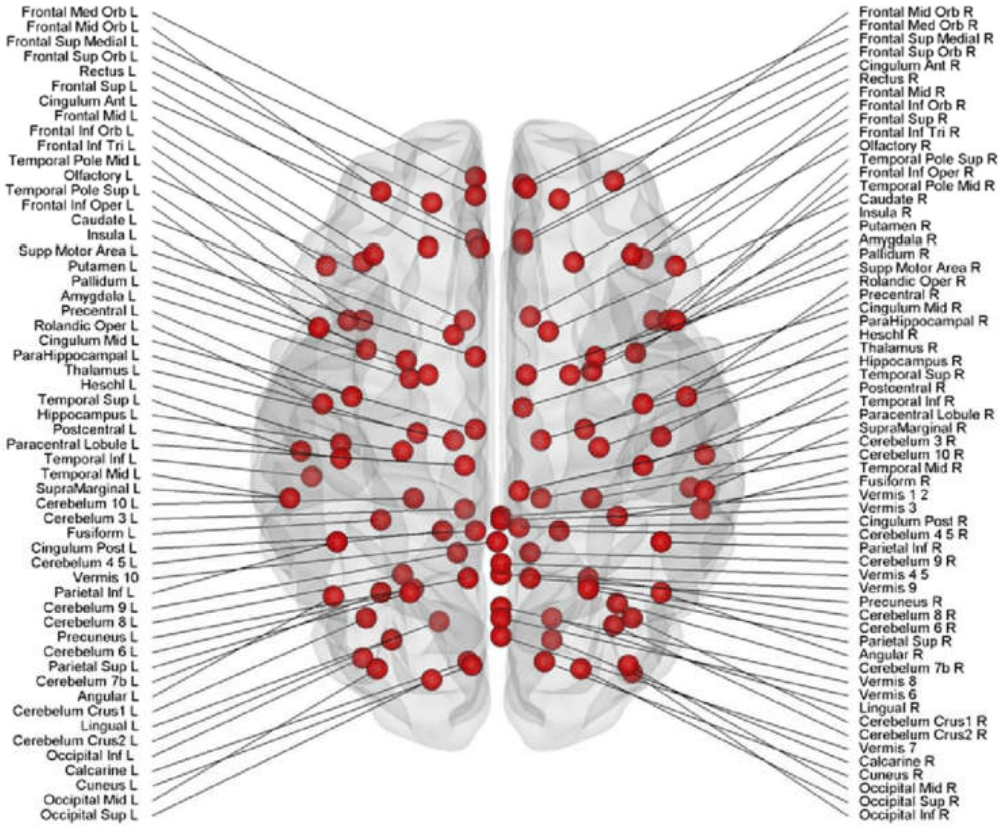
2-Defining the Edges

3-Connectivity Analysis



Node-based Connectivity Analysis

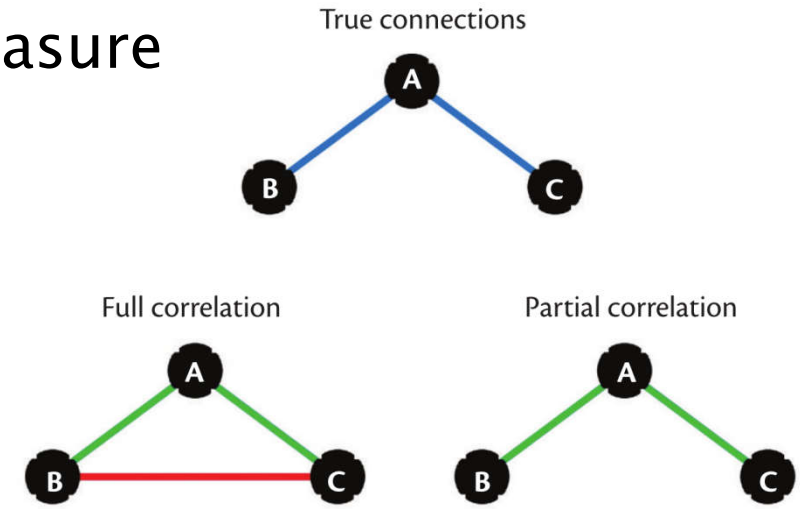
- 1-Defining the Nodes
  - atlas-based
  - data-driven



Karen, 2012, Altered structural networks and executive deficits in traumatic brain injury patients, Brain Structure and Function

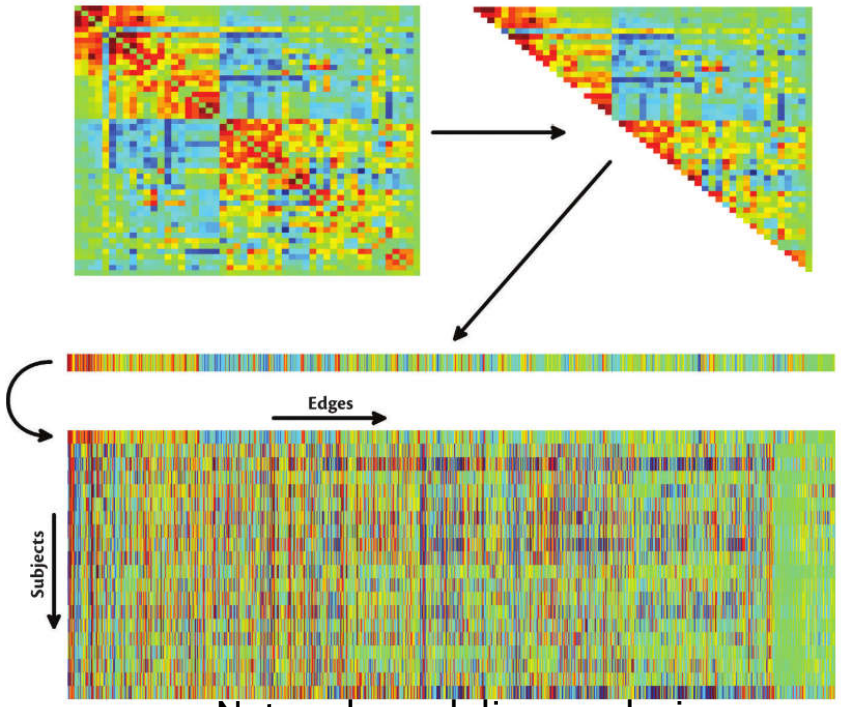
Node-based Connectivity Analysis

- 2-Defining the Edges
  - Pearson Correlation(the simplest way)
    - sensitive to any noise confounds
    - linear
  - Partial Correlation
  - Or other similarity Measure



Node-based Connectivity Analysis

- 3-Connectivity Analysis
  - Network modeling analysis
    - Sensitive to shape or size nodes
    - appropriate for discriminative analysis

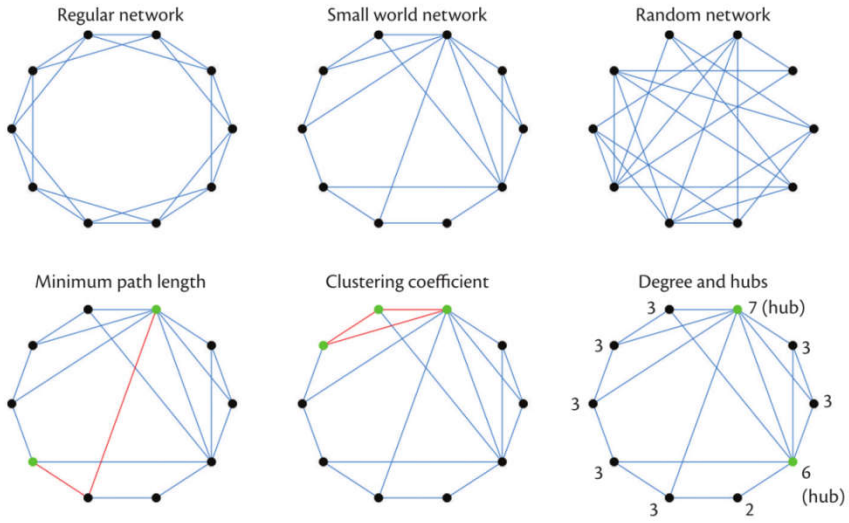


Network modeling analysis

Node-based Connectivity Analysis

- 3-Connectivity Analysis
  - Network modeling analysis
  - Graph theory analysis
    - binary graphs
    - removes a lot of potentially important information

calculated for each subject and compared between groups



Node-based Connectivity Analysis

- 3-Connectivity Analysis
  - Network modeling analysis
  - Graph theory analysis
    - Aging

frontiers in
SYSTEMS NEUROSCIENCE

REVIEW ARTICLE
published: 07 June 2010
doi: 10.3389/fnsys.2010.00016

Graph-based network analysis of resting-state functional MRI

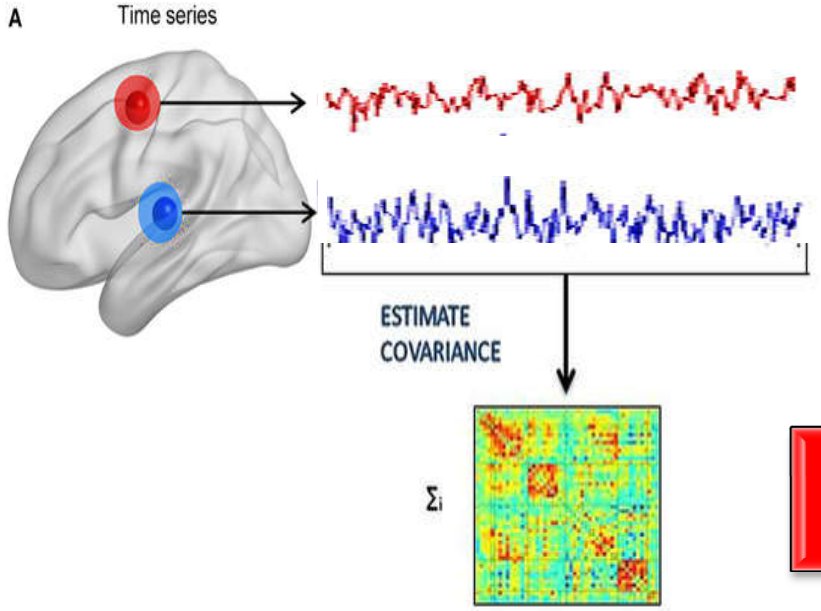
*Jinhui Wang[1], Xinian Zuo[2] and Yong He[1]**

[1] *State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China*
[2] *Phyllis Green and Randolph Cōwen Institute for Pediatric Neuroscience, New York University Langone Medical Center, New York, NY, USA*

Functional Connectivity Challenges

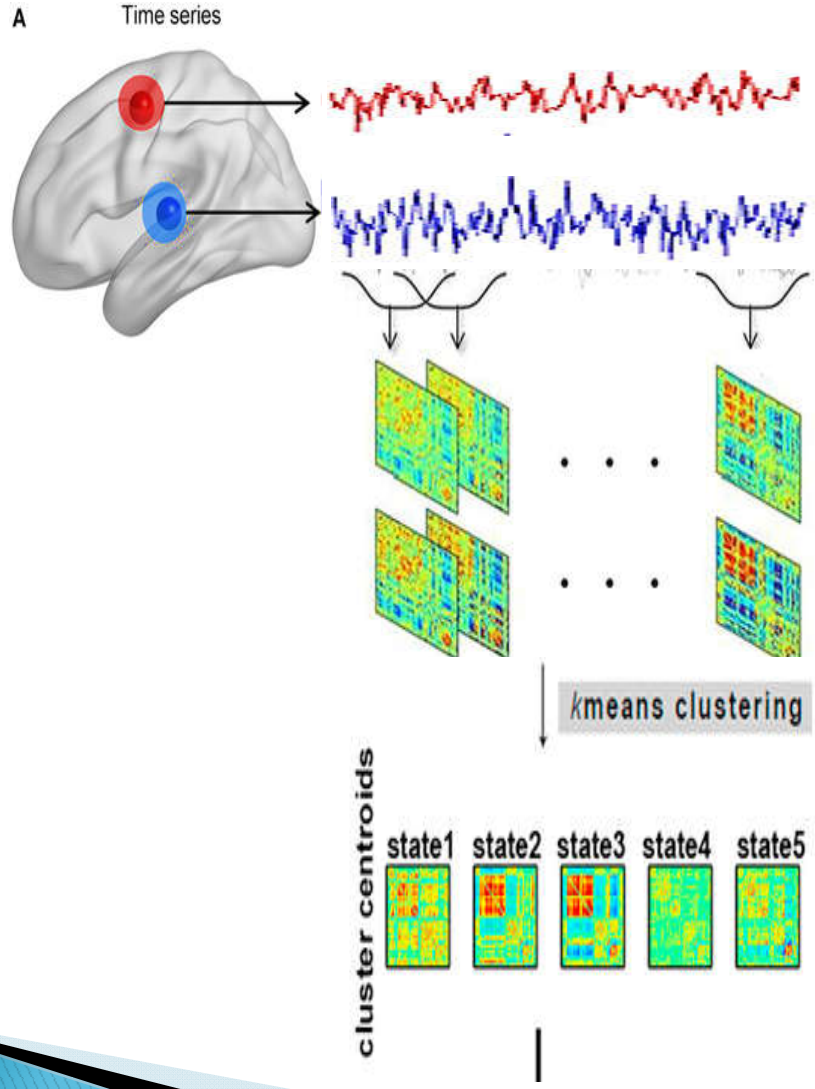
- Aim: find similarities
  - many types of noise may induce such similarities
    - breath
    - Movement
- Inference neural mass connectivity

Dynamic Functional Connectivity

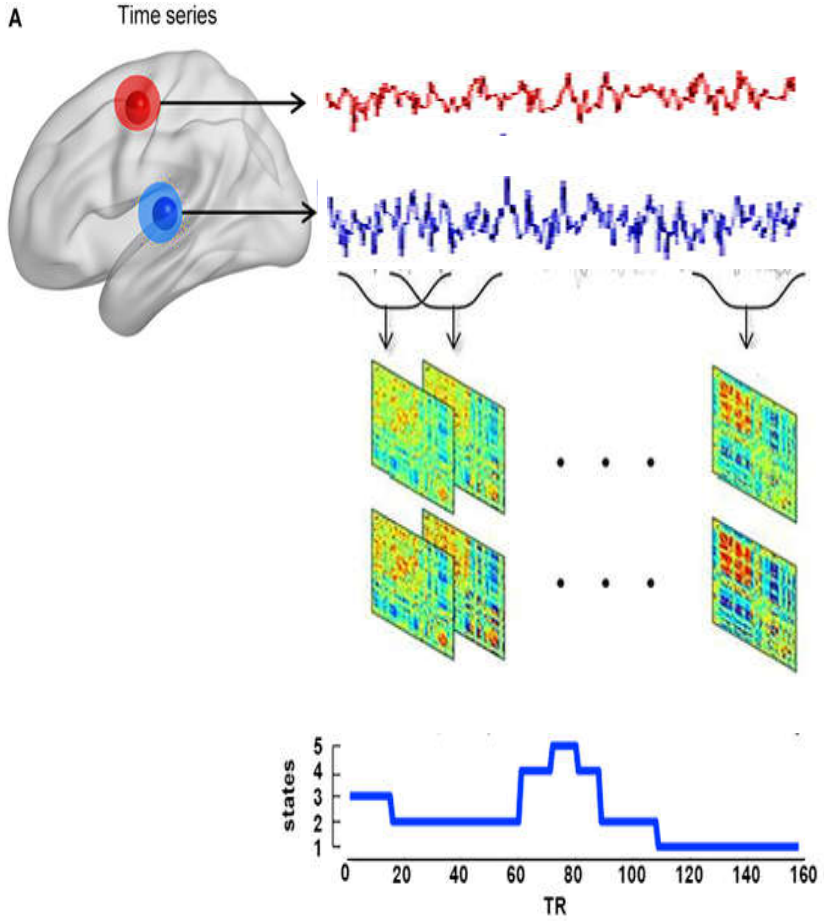


revealed changes in connectivity
Hutchison et al., 2013

Dynamic Functional Connectivity



Dynamic Functional Connectivity



با تشکر از توجه شما