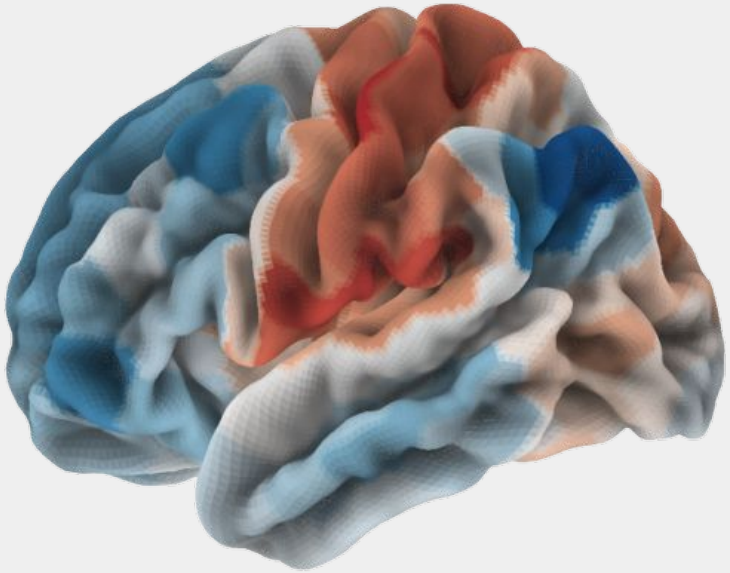
# Advanced fMRI data analysis



**Karolina Finc**

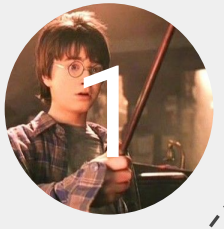
Centre for Modern Interdisciplinary Technologies

Nicolaus Copernicus University in Toruń

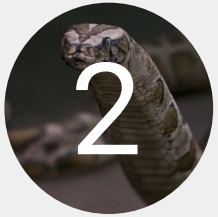
**COURSE #6:** **Functional connectivity** | 5th June 2020

# Study plan

**BEFORE**




Open science &
neuroimaging




fMRI data manipulation
in python


fMRI data
preprocessing


General
Linear Model

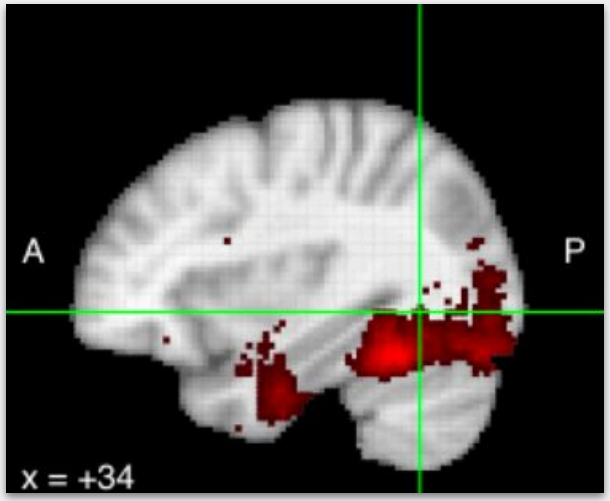

Functional
connectivity

**AFTER**


Machine Learning
on fMRI data

# Goals of task-based fMRI

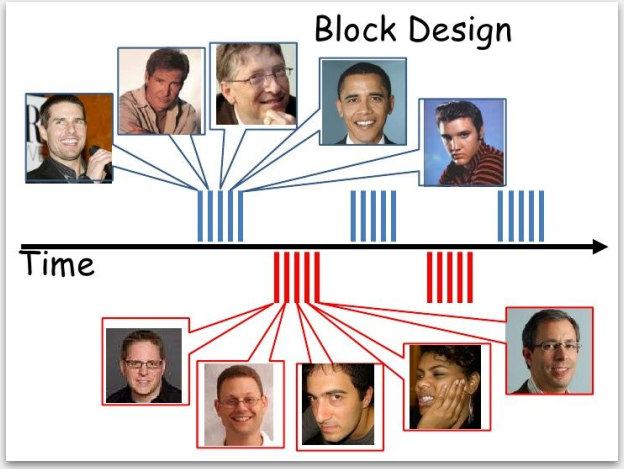
1. Induce in a study participant to do actions or experience cognitive states you're interested in.
2. You want to detect brain signals that are related to this cognitive states or actions.



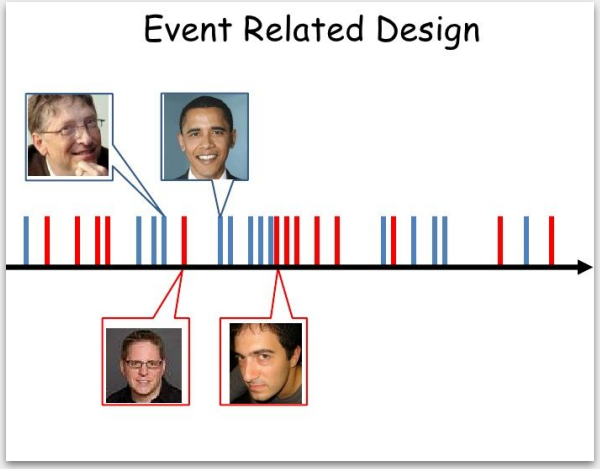
# Task designs

Famous people

Non-famous people



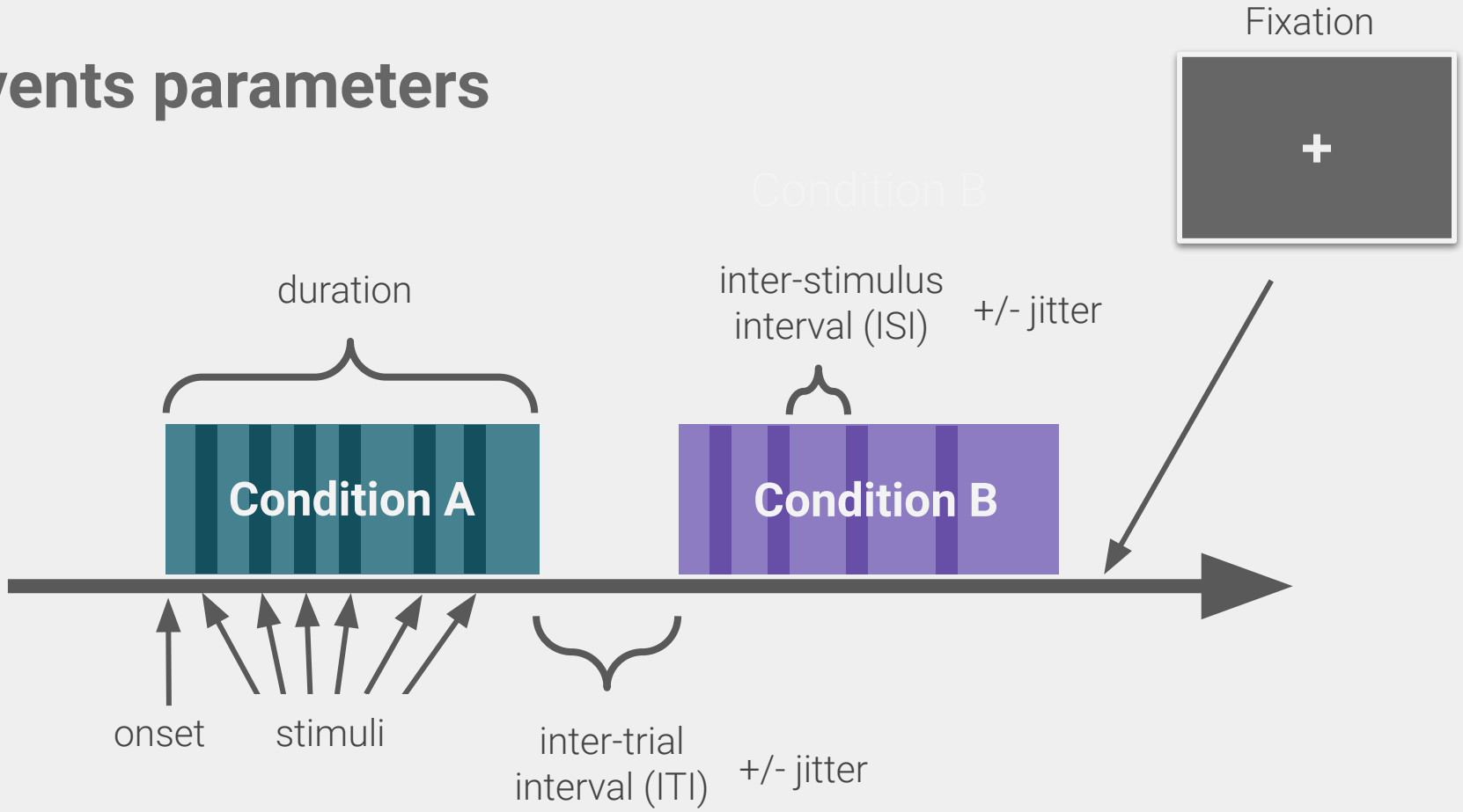

**Block design**
similar events are grouped




**Event-related design**
events are mixed

https://www.slideshare.net/rnja8c/fmri-study-design-9138161

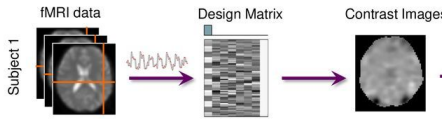
# Events parameters



# Analysis steps

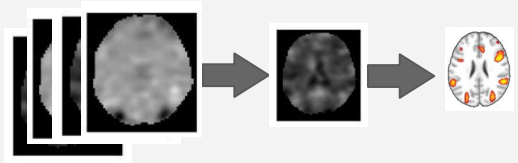
**1-level analysis**
(within-subject; individual)

How was the brain active in a one particular brain?

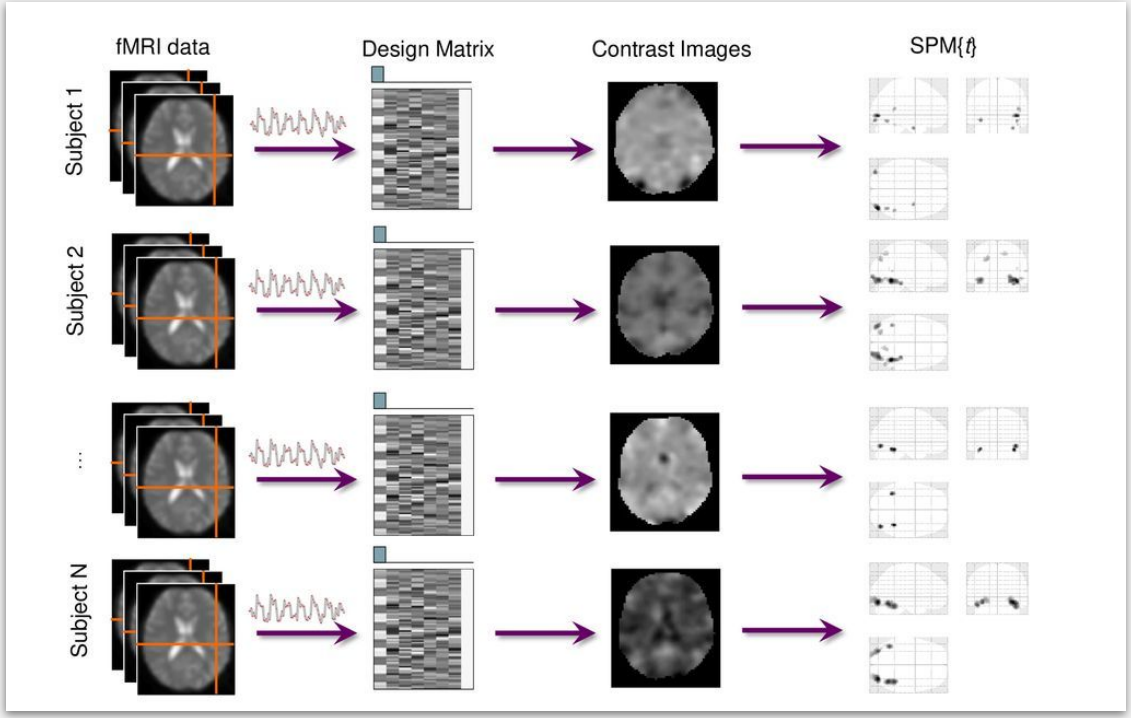



**2-level analysis**
(across-subject; group)

How brain activations look in general (for the whole group? Group differences?



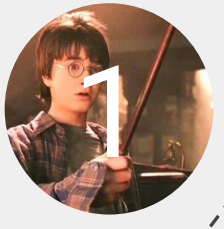
# 1-level analysis




https://slideplayer.com/slide/16403606/

# Study plan

**BEFORE**




Open science & neuroimaging


fMRI data manipulation in python


fMRI data preprocessing


General Linear Model

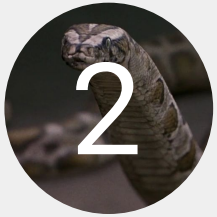

Functional connectivity

**AFTER**

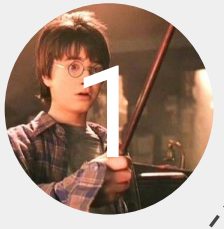

Machine Learning on fMRI data

# Study plan

**BEFORE**




fMRI data manipulation
in python




Open science &
neuroimaging


fMRI data
preprocessing

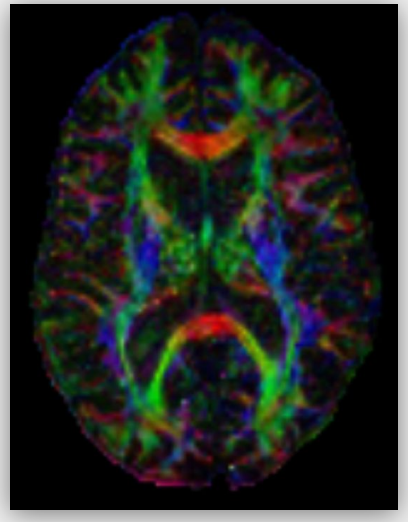

General
Linear Model


Functional
connectivity

**AFTER**

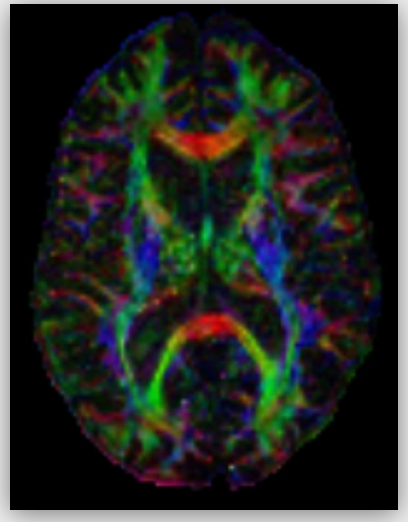

Machine Learning
on fMRI data

# Structural connectivity

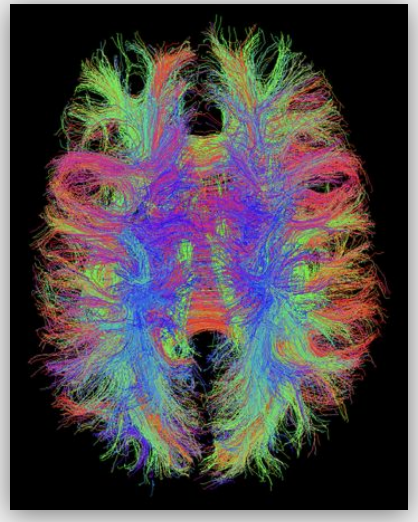


**Diffusion MRI**
image contrast is determined by the random microscopic motion of water protons

# Structural connectivity

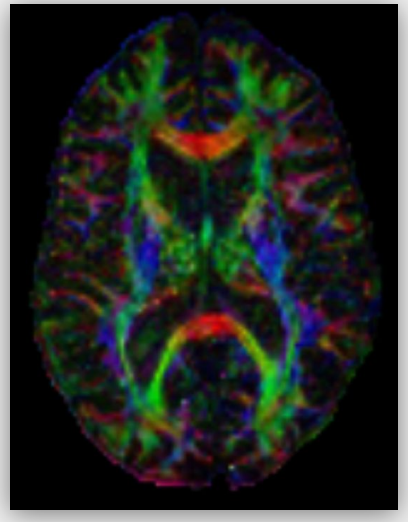


**Diffusion MRI**
image contrast is determined by the random microscopic motion of water protons



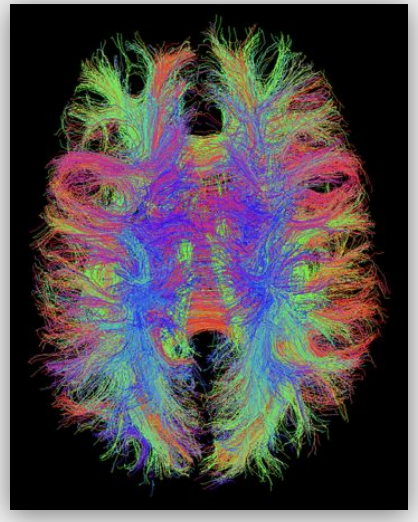
**Tractography**
is a modeling technique used to visually represent nerve tracts using data collected by diffusion MRI.

# Structural connectivity



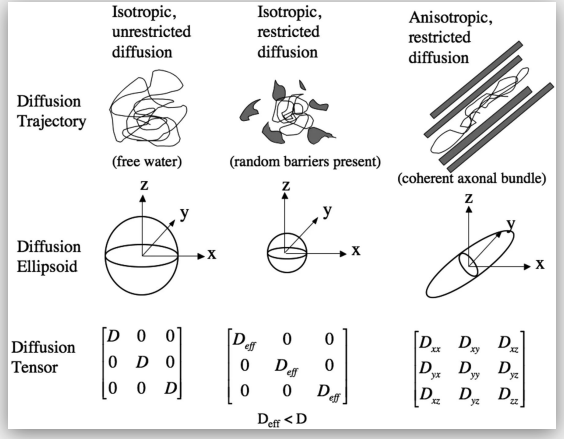
**Diffusion MRI**

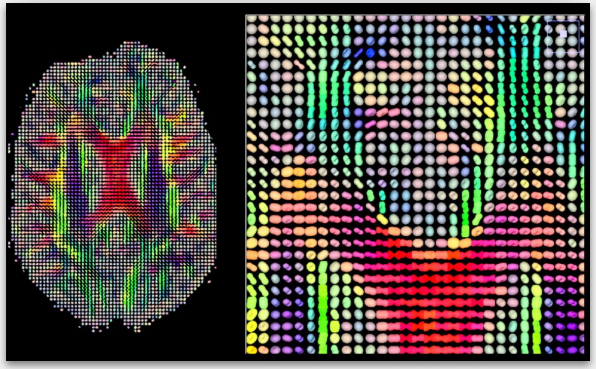
image contrast is determined by the random microscopic motion of water protons



**Tractography**

is a modeling technique used to visually represent nerve tracts using data collected by diffusion MRI.

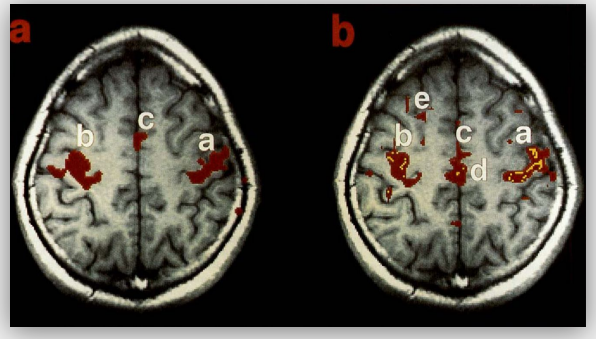


Explore DTI animations

# Functional connectivity

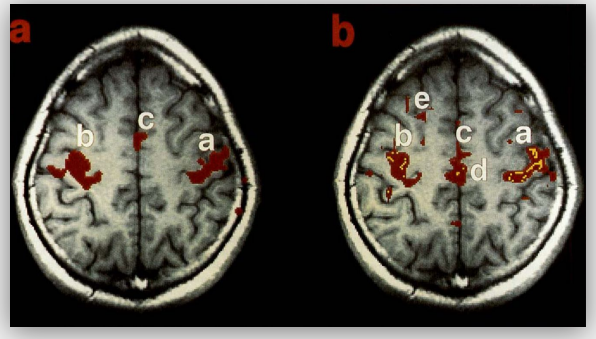
Motor task Resting state




Biswal et al. (1995)

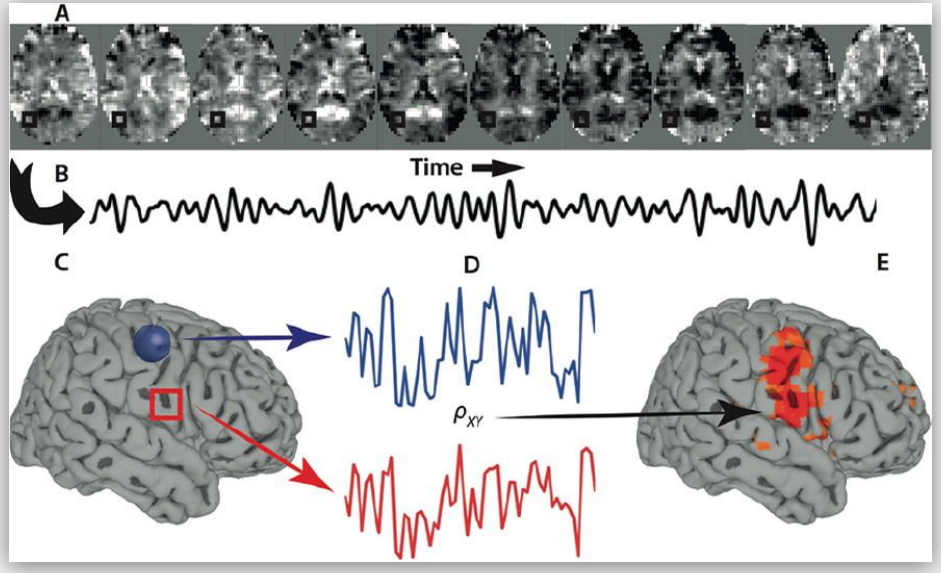
# Functional connectivity

Motor task Resting state




Biswal et al. (1995)

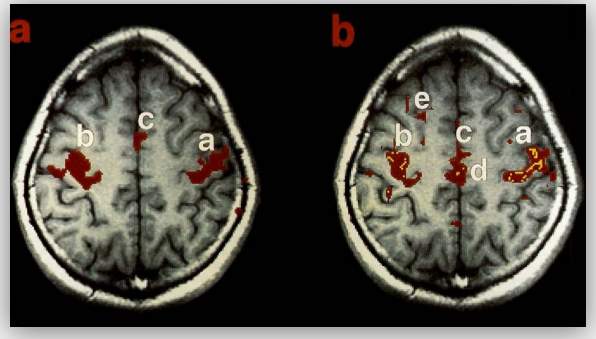
Seed-based approach




Hart et al. (2016)

# Functional connectivity

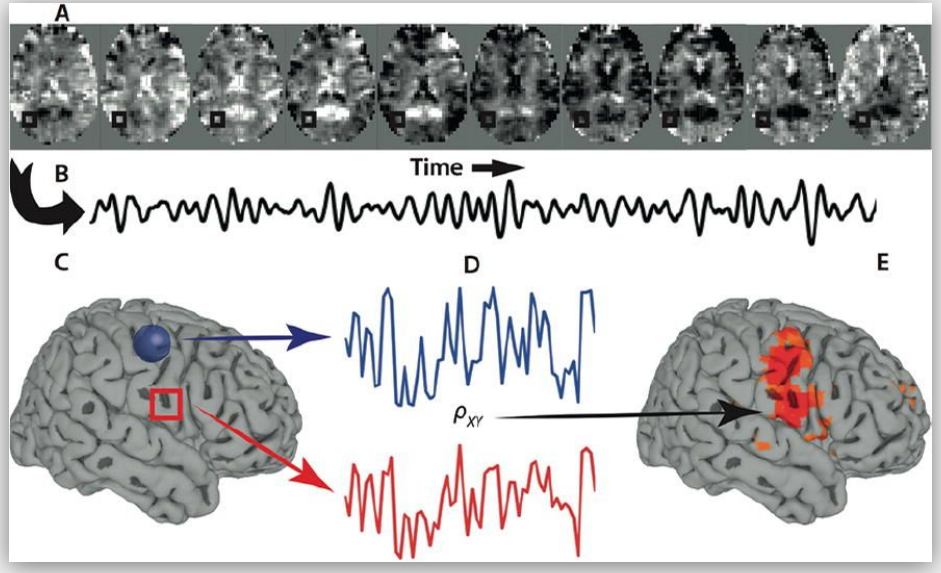
Motor task Resting state




Biswal et al. (1995)

**Resting-state functional connectivity** measures temporal correlation of spontaneous BOLD signal among spatially distributed brain regions, with the assumption that regions with correlated activity form functional networks

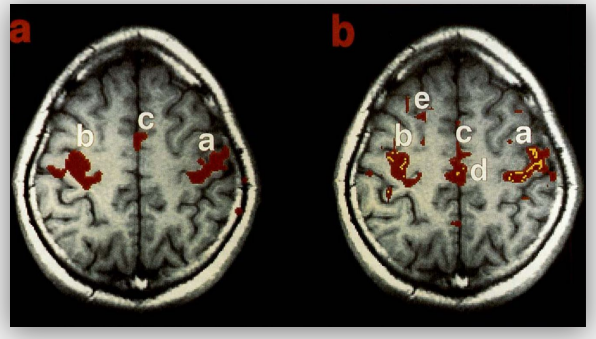
Seed-based approach




Hart et al. (2016)

# Functional connectivity

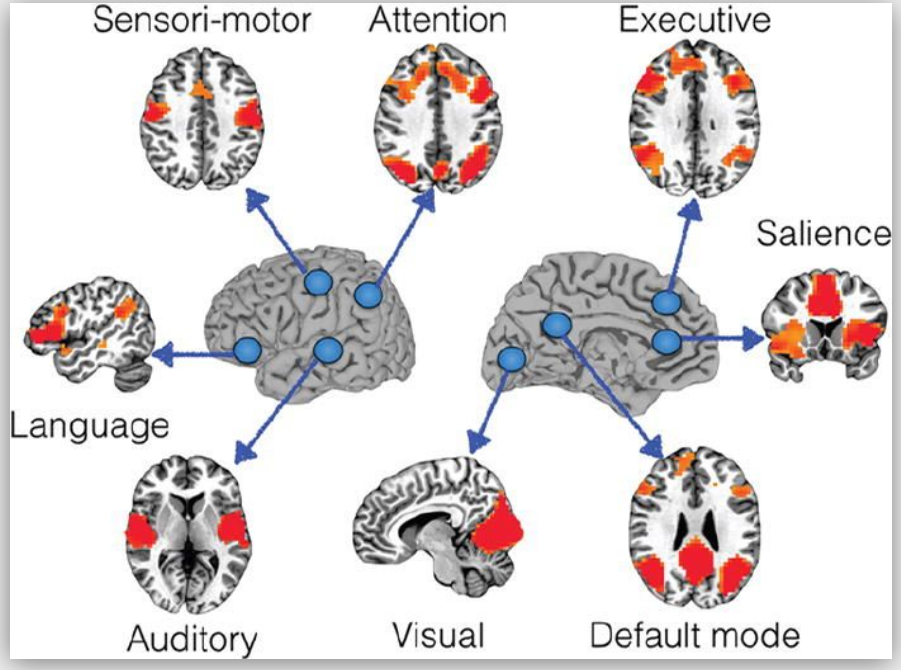
Motor task Resting state




Biswal et al. (1995)

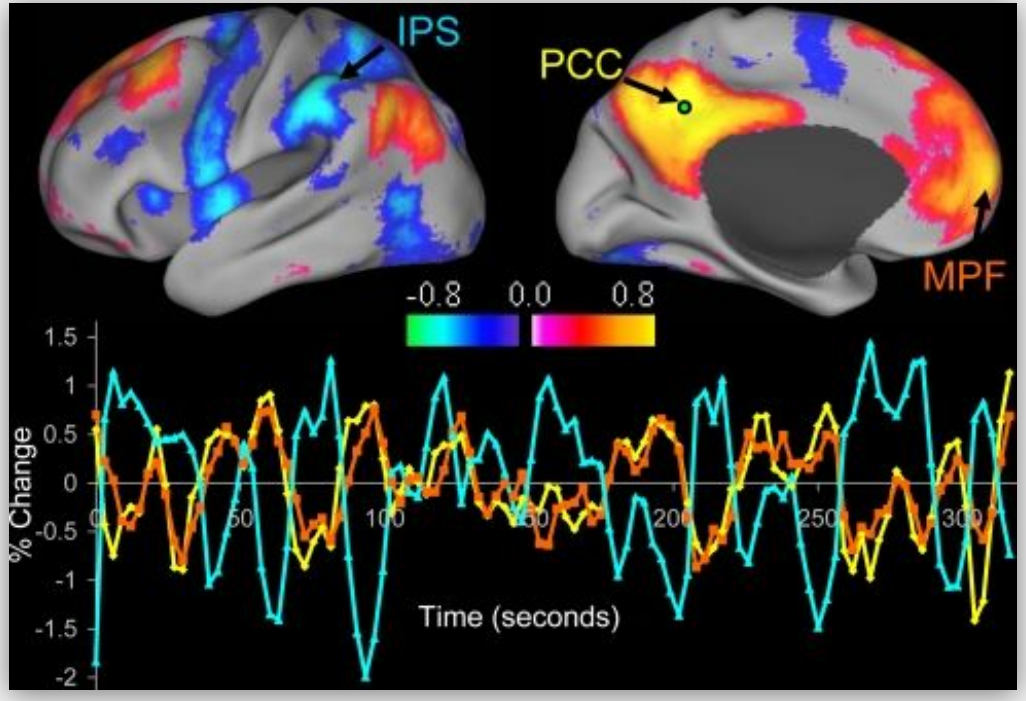
**Resting-state functional connectivity** measures temporal correlation of spontaneous BOLD signal among spatially distributed brain regions, with the assumption that regions with correlated activity form functional networks

Resting-state networks




Hart et al. (2016)

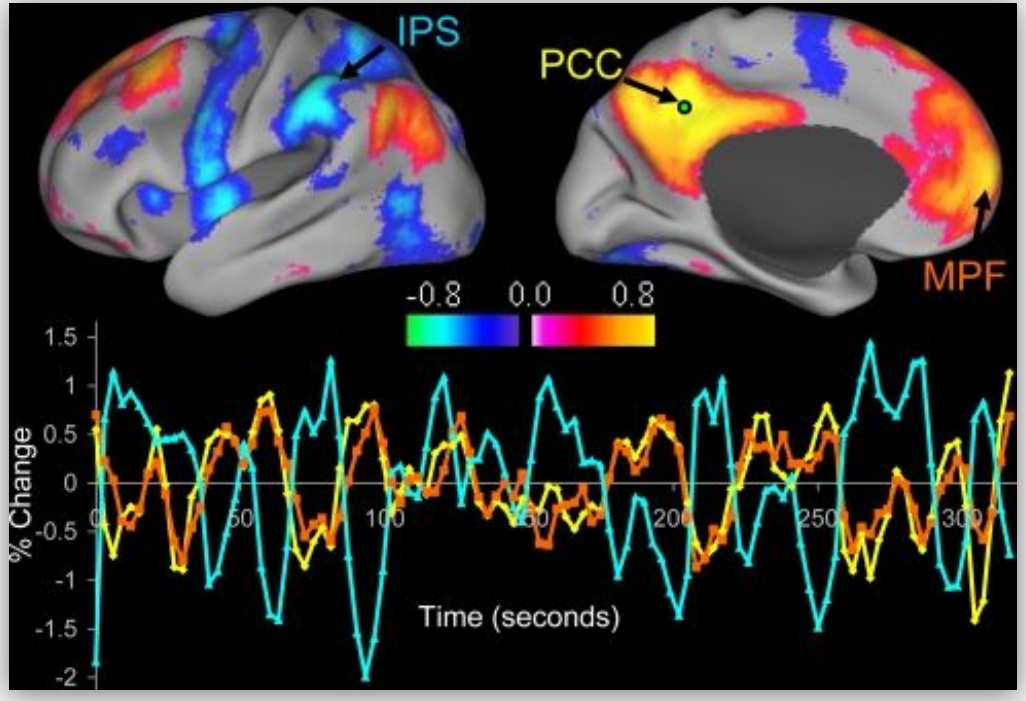
# Anticorrelated networks




Fox et al. (2005)

**Task-positive** networks - networks that are active during cognitively demanding tasks (e.g. frontoparietal network, dorsal attention network).

# Anticorrelated networks

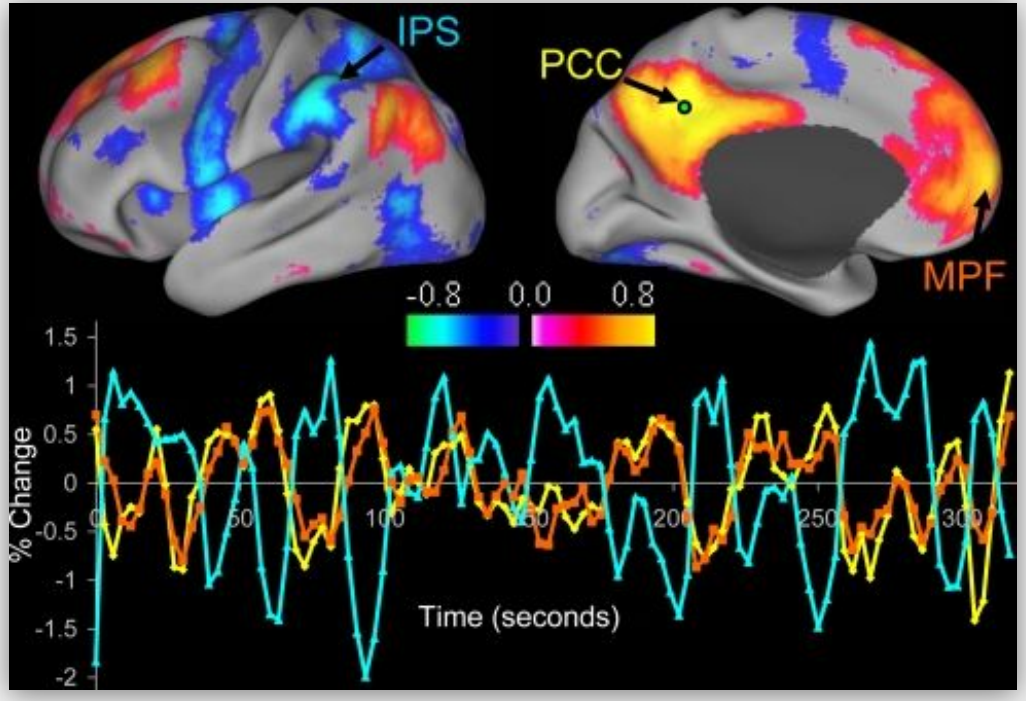



Fox et al. (2005)

**Task-positive** networks - networks that are active during cognitively demanding tasks (e.g. frontoparietal network, dorsal attention network).

**Task-negative** networks that are inactive during cognitively demanding tasks (e.g. default mode network).

# Anticorrelated networks



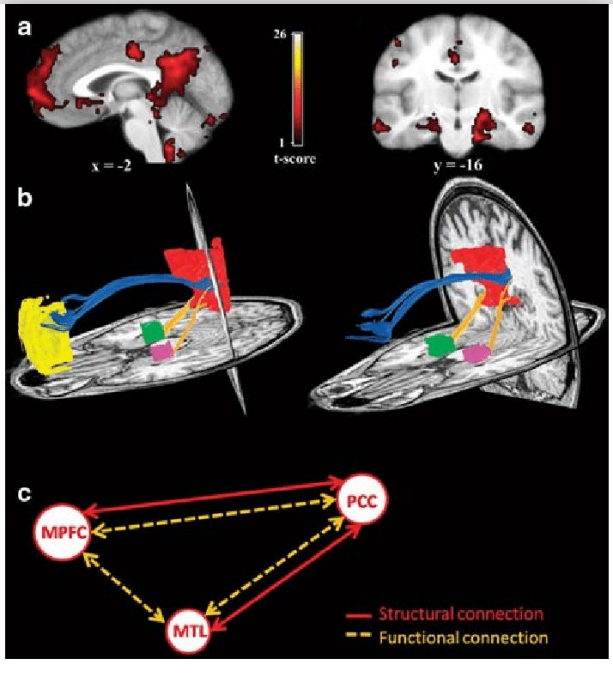

Fox et al. (2005)

**Task-positive** networks - networks that are active during cognitively demanding tasks (e.g. frontoparietal network, dorsal attention network).

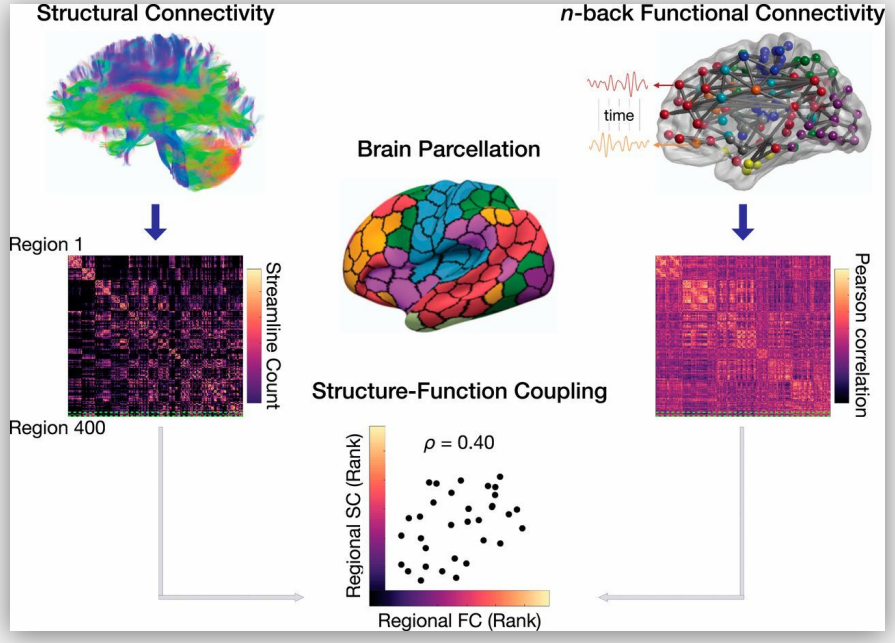
**Task-negative** networks that are inactive during cognitively demanding tasks (e.g. default mode network).

**Task-positive** and **task-negative** networks are *often* **anticorrelated** during task and rest.

# Functional connectivity vs structural connectivity

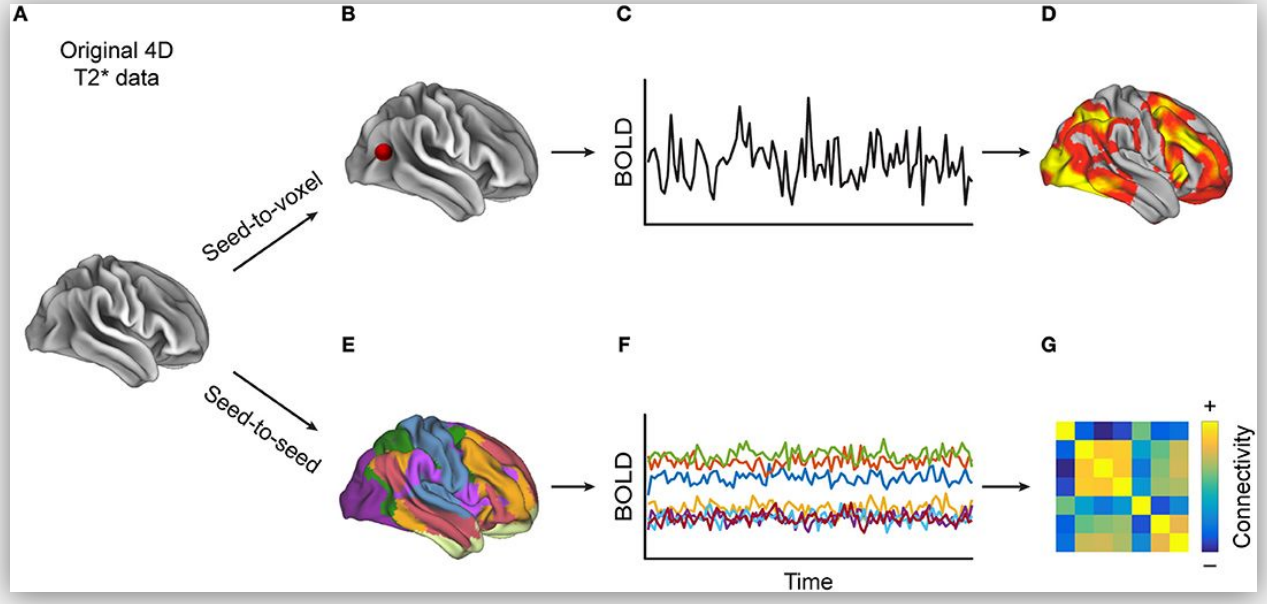



Greicius et al. (2009)




Baum et al. (2019)

# Functional connectivity: methods



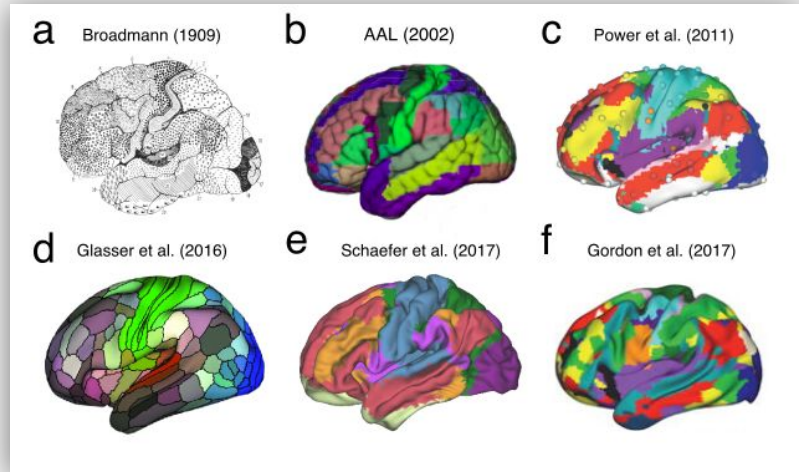

**Seed** - predefined region of the brain.

**Seed-to-voxel** - calculating correlations between seed and all voxels in the brain.

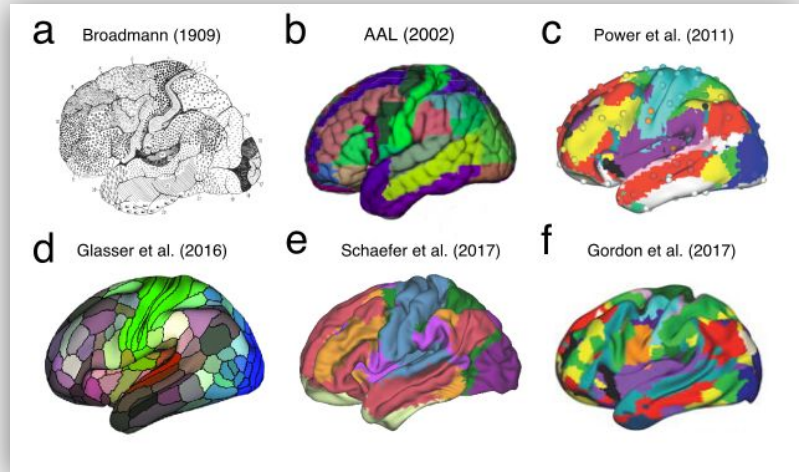
**Seed-to-seed** - calculating correlations between seed regions.

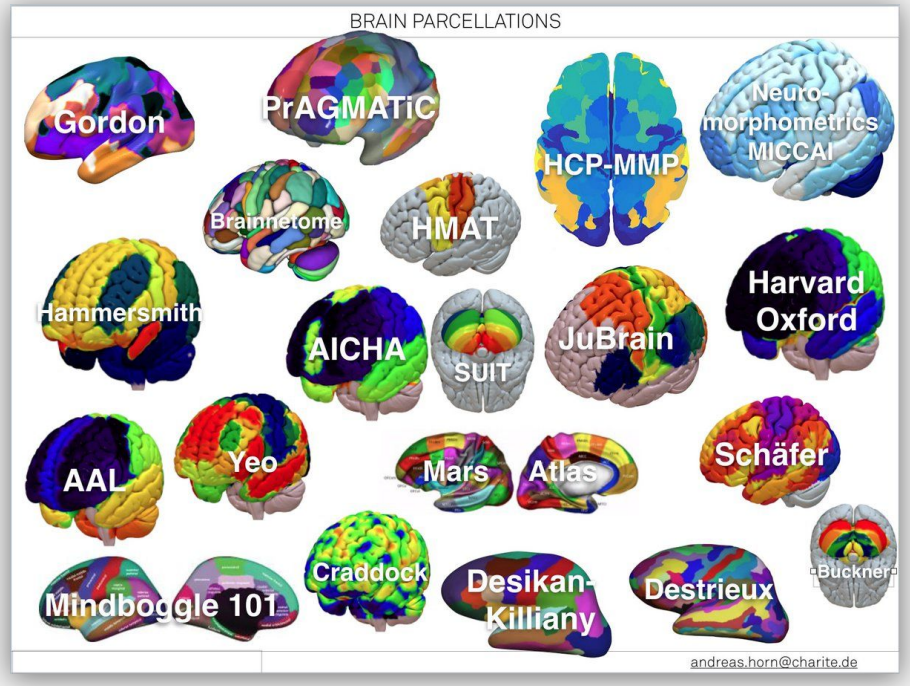
# Where to get brain parcellation?

# Brain parcellations



# Brain parcellations




Atlas resources

# Correlation

**Correlation** is a statistic that measures the degree to which two variables are related to each other.

$$r = \frac{\sum(X-\overline{X})(Y-\overline{Y})}{\sqrt{\sum(X-\overline{X})^2}\sqrt{(Y-\overline{Y})^2}}$$

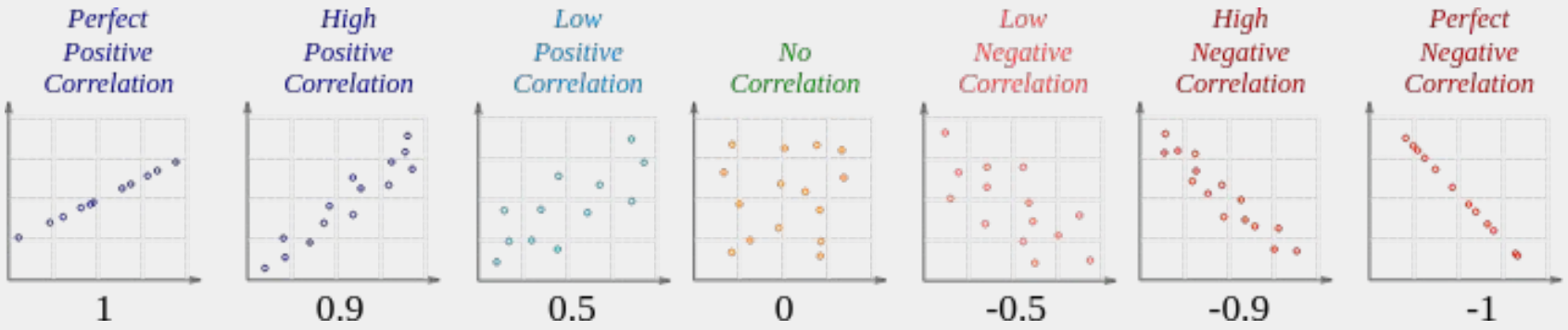
Where, $\overline{X}$ = mean of X variable

$\overline{Y}$ = mean of Y variable

Covariance

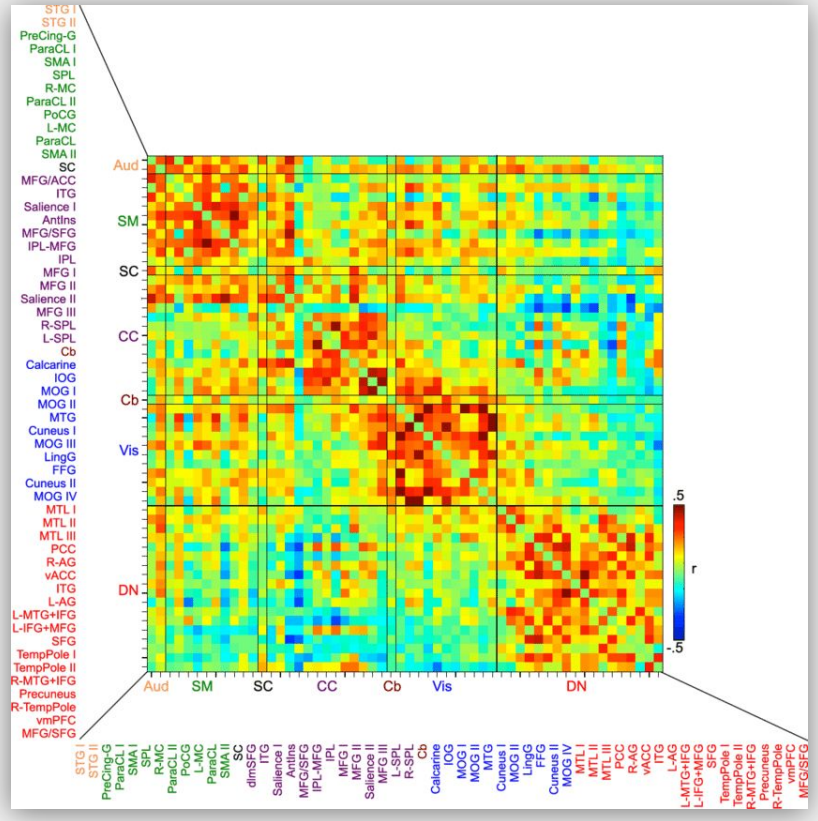
$$Correlation = \frac{Cov\ (x,y)}{\sigma x * \sigma y}$$

Standard deviation



# Correlation matrix

Each ***ij*** element of a matrix represent the **correlation coefficient** (functional connectivity strength) between two regions.

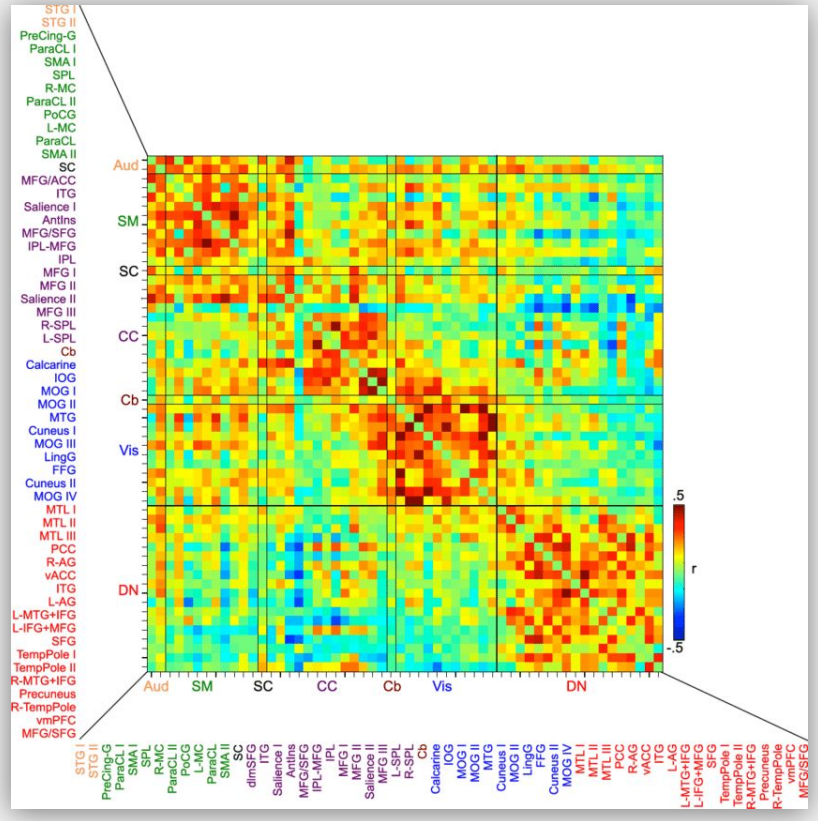



Hutchison & Morton, 2015

# Correlation matrix

Each ***ij*** element of a matrix represent the **correlation coefficient** (functional connectivity strength) between two regions.

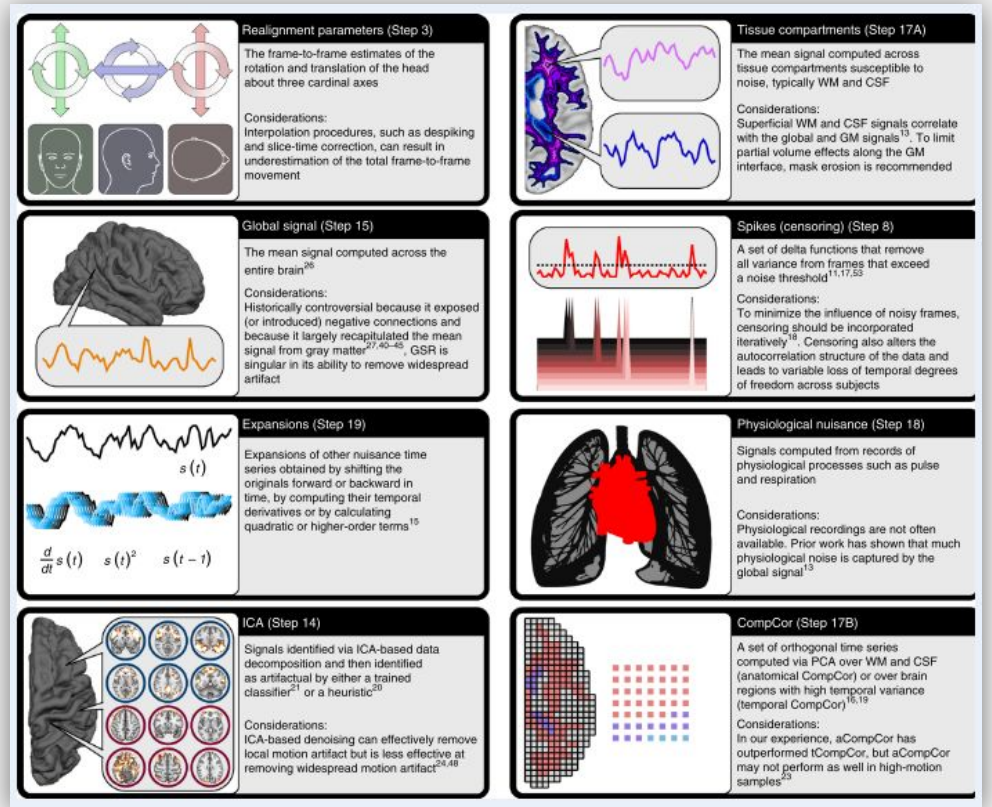
**Clusters** on a correlation matrix represents brain subnetworks (also known called **modules** or **large-scale systems**).




Hutchison & Morton, 2015

# Spurious correlations

Signal of **non-neuronal origin** (motion, physiological effects) can pump the correlation values between BOLD time-series.

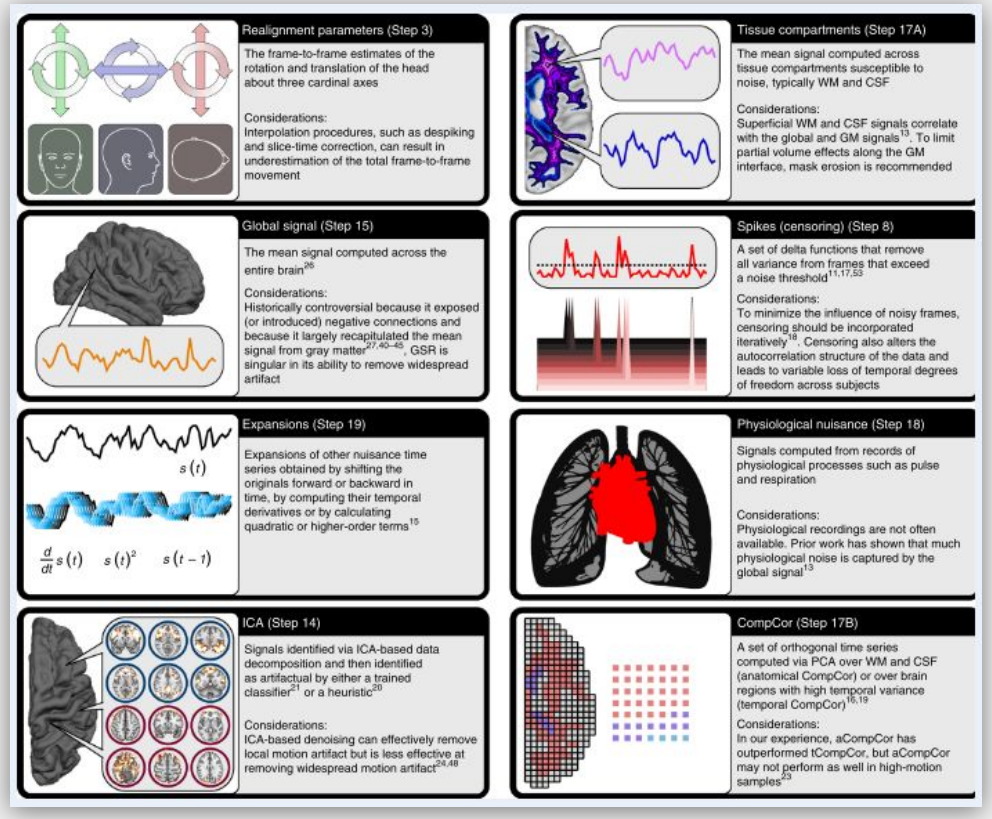



Ciric et al., 2018

# Spurious correlations

Signal of **non-neuronal origin** (motion, physiological effects) can pump the correlation values between BOLD time-series.

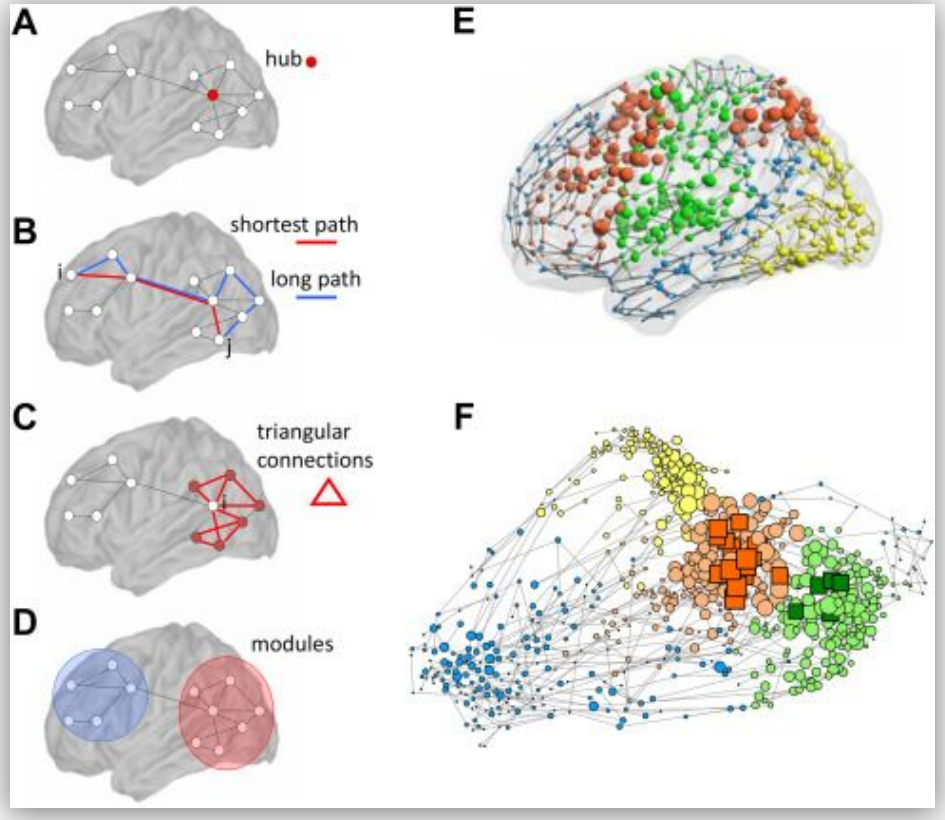
**Denoising procedure** - regressing out confounding signals might minimise the level of spurious correlations in studies focused on functional connectivity.




Ciric et al., 2018

# Network neuroscience

The goal of the **network neuroscience** is to understand properties of brain network reorganization using **network science** tools.

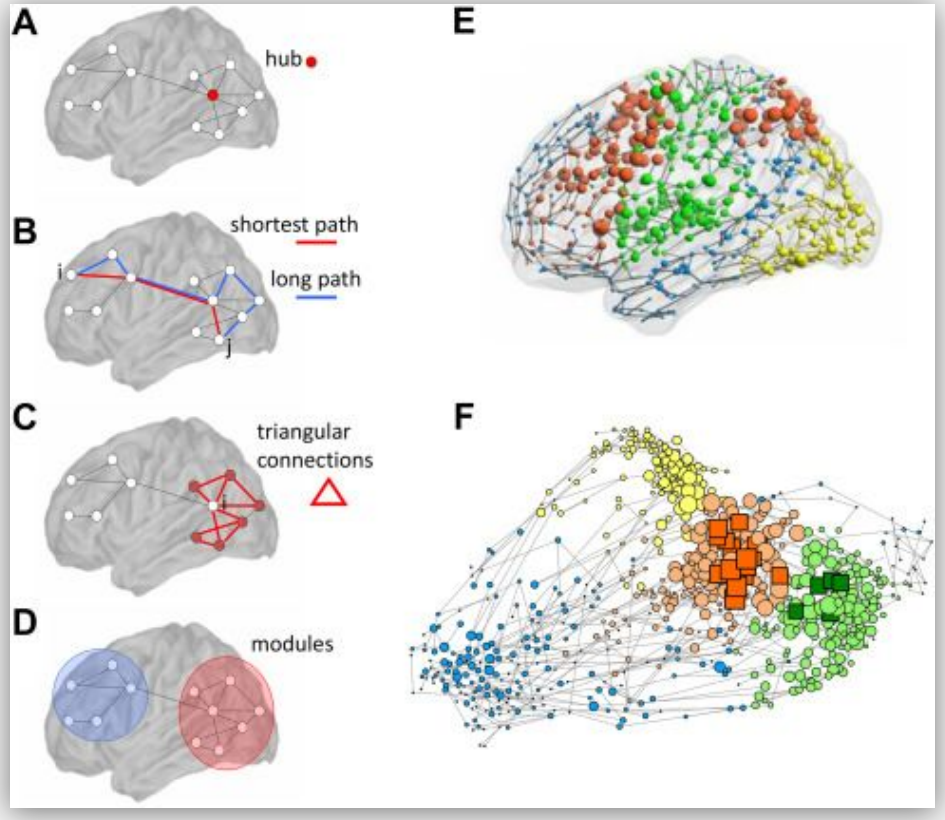



Morgan et al., 2018

# Network neuroscience

The goal of the **network neuroscience** is to understand properties of brain network reorganization using **network science** tools.

**Network science** - field which studies complex networks, considering distinct elements represented by **nodes** (or vertices) and the **edges** (or connections) between them.

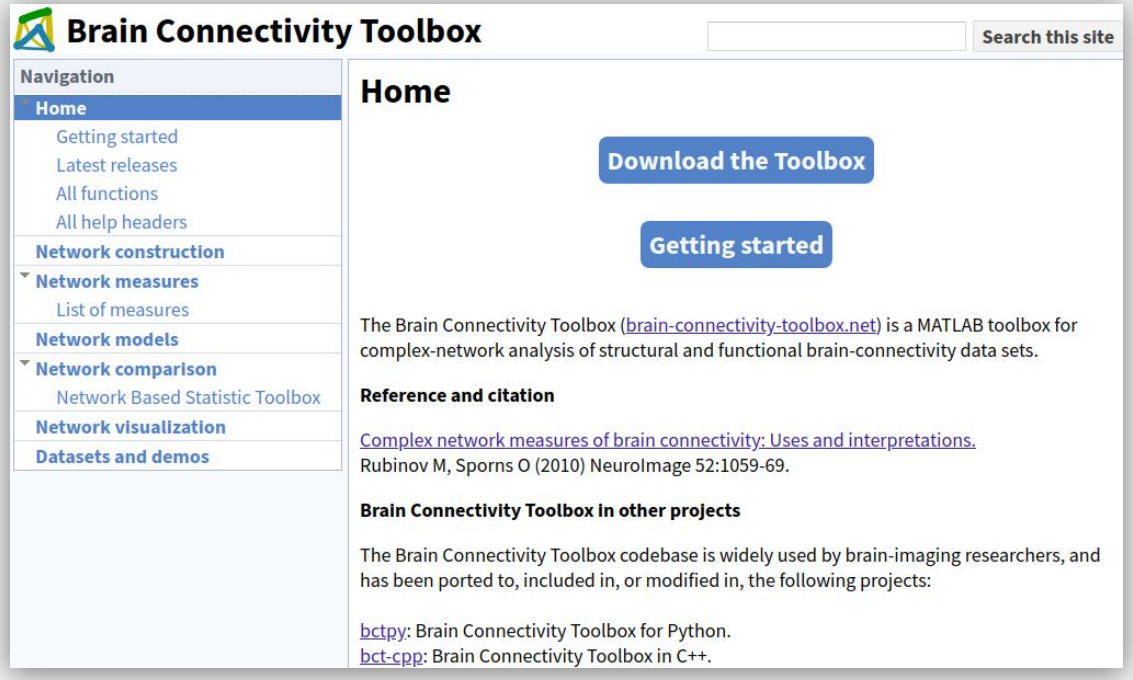



Morgan et al., 2018

# Network neuroscience

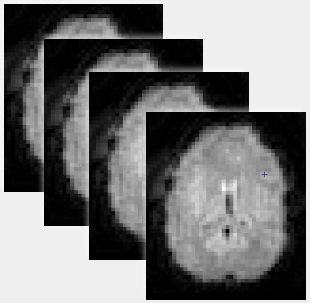
The goal of the **network neuroscience** is to understand properties of brain network reorganization using **network science** tools.

**Network science** - field which studies complex networks, considering distinct elements represented by **nodes** (or vertices) and the **edges** (or connections) between them.



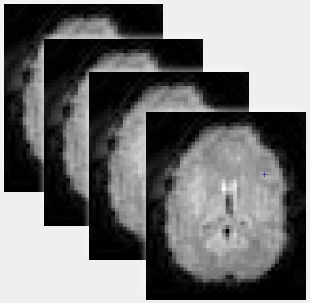
# Workflow

fMRI data



# Workflow

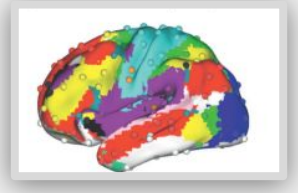
fMRI data



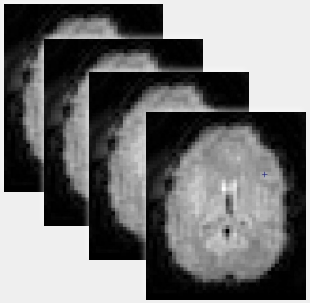
Denoising

# Workflow

Definition of brain regions



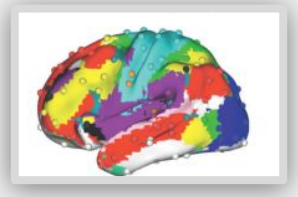
fMRI data



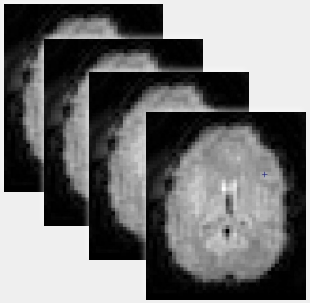
Denoising

# Workflow

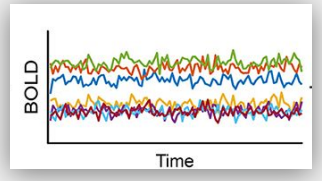
Definition of brain regions



fMRI data



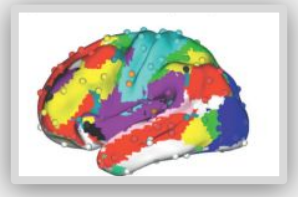
Denoising



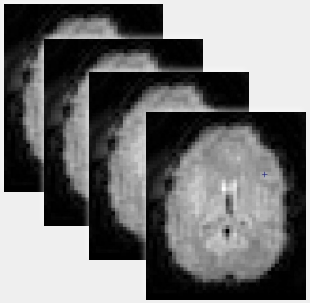

Time-series extraction

# Workflow

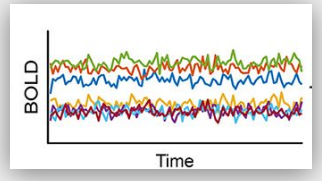
Definition of brain regions



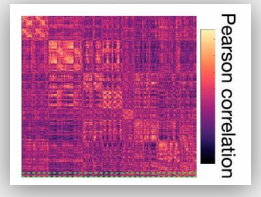
fMRI data



Denoising




Time-series extraction




Connectivity estimation

# Homework

1. **GitHub Classroom**

   Functional connectivity
   Deadline: 19-06-2020


1.

## Next

# Machine learning