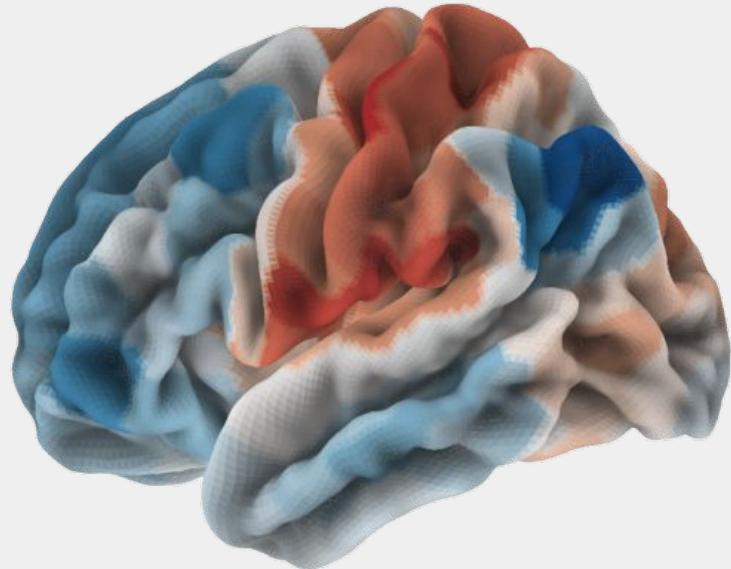


Advanced fMRI data analysis

Karolina Finc

Centre for Modern Interdisciplinary Technologies

Nicolaus Copernicus University in Toruń



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

Study plan

Open science & neuroimaging



BEFORE

fMRI data manipulation
in python



fMRI data
preprocessing



3

Functional
connectivity



5



4

General
Linear Model



AFTER

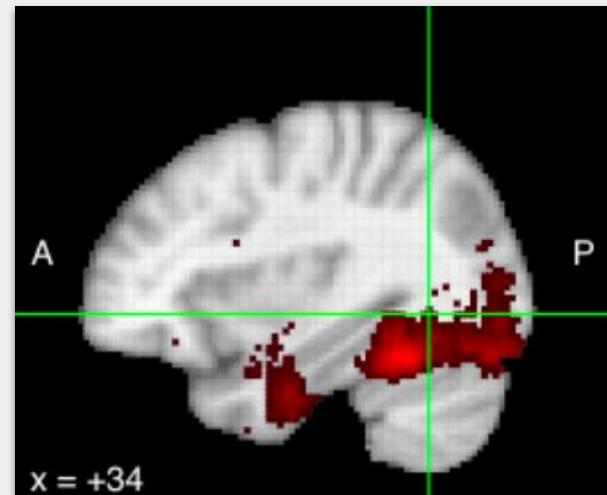


6

Machine Learning
on fMRI data

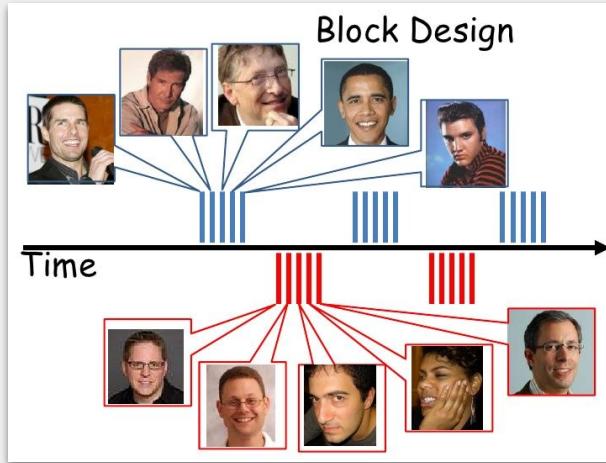
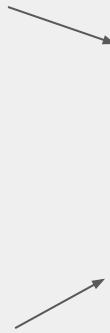
Goals of task-based fMRI

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.



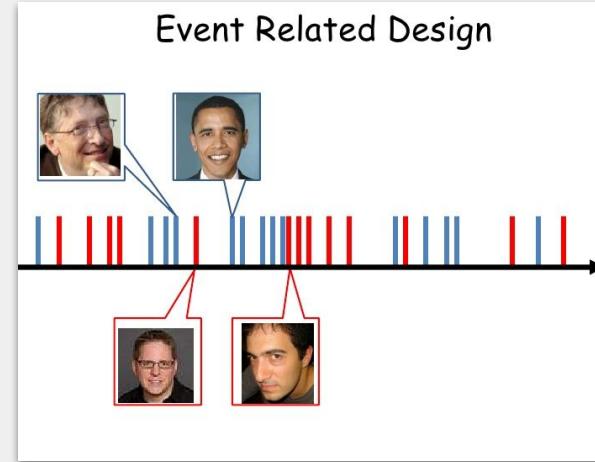
Task designs

Famous people



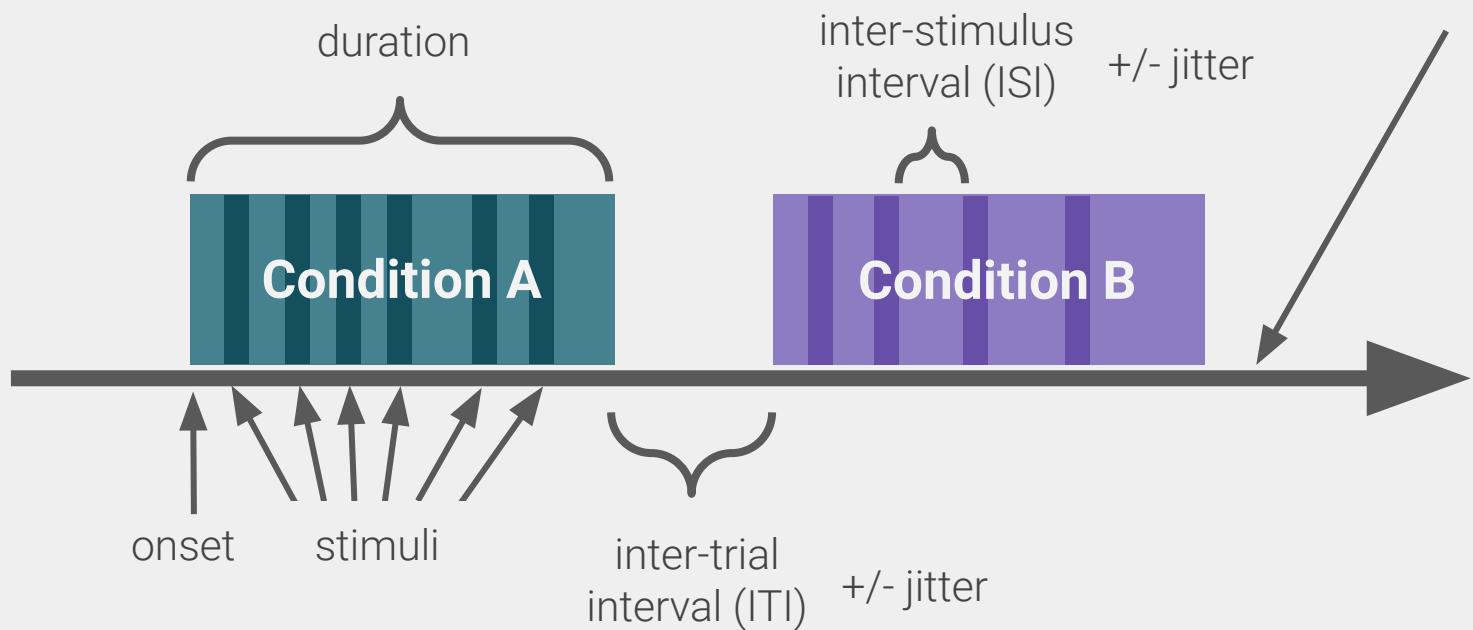
Non-famous people

Block design
similar events are grouped



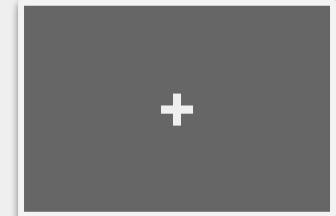
Event-related design
events are mixed

Events parameters



Condition B

Fixation



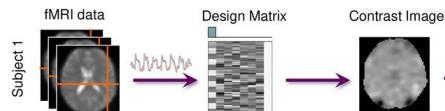
Analysis steps

1-level analysis (within-subject; individual)

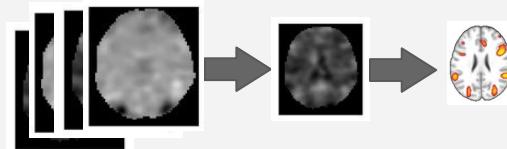


2-level analysis (across-subject; group)

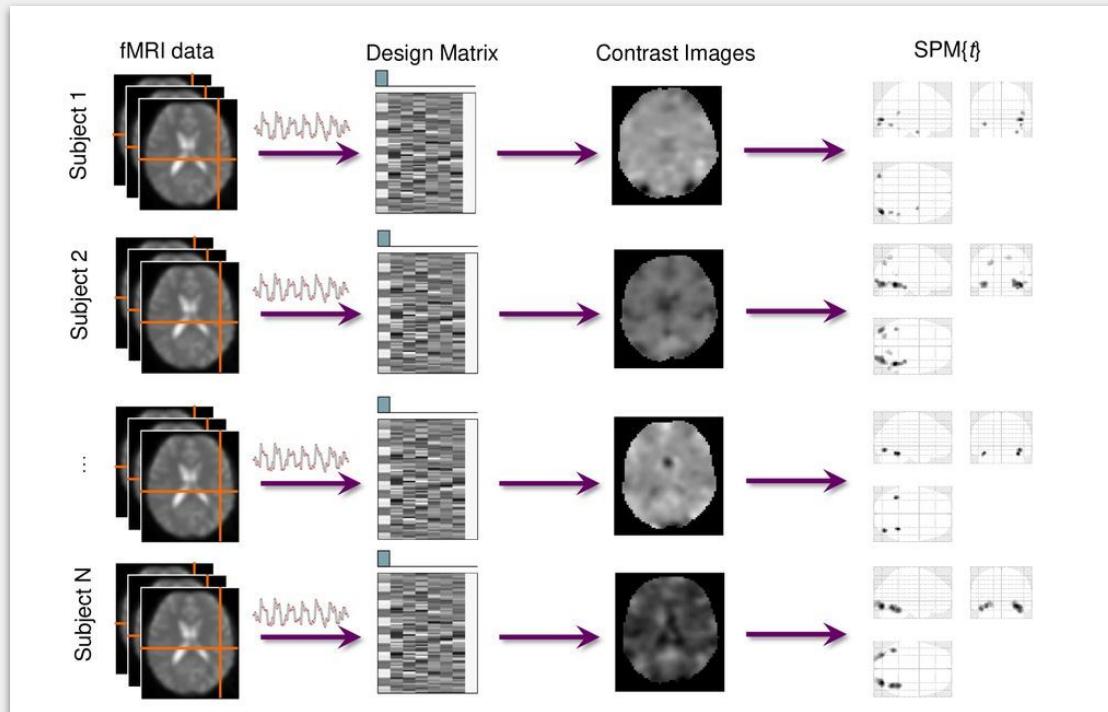
How was the brain active in a one particular brain?



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



1-level analysis



Study plan

Open science & neuroimaging



BEFORE

fMRI data manipulation
in python



fMRI data
preprocessing



3

General
Linear Model



5

Functional
connectivity



AFTER



6

Machine Learning
on fMRI data

Study plan

Open science & neuroimaging



BEFORE

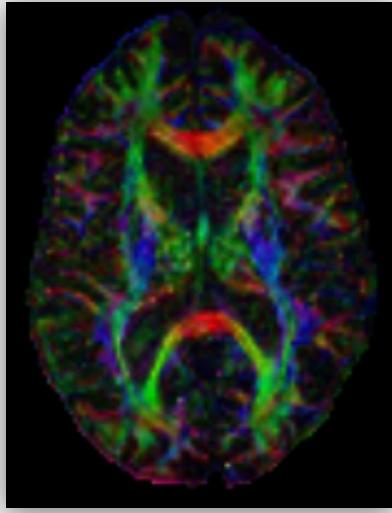
fMRI data manipulation
in python



fMRI data
preprocessing



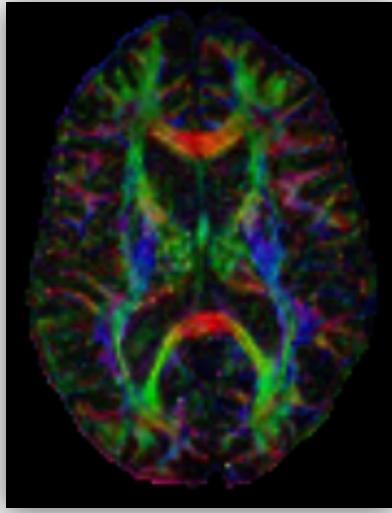
Structural connectivity



Diffusion MRI

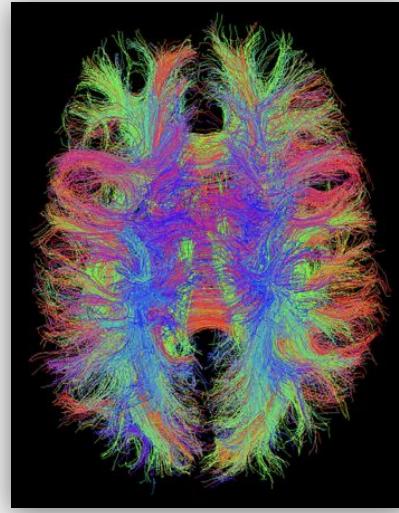
image contrast is determined by
the random microscopic motion
of water protons

Structural connectivity



Diffusion MRI

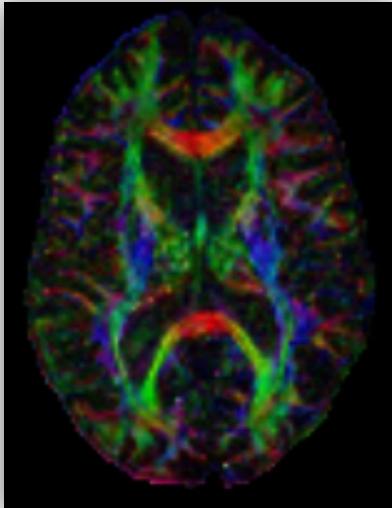
image contrast is determined by
the random microscopic motion
of water protons



Tractography

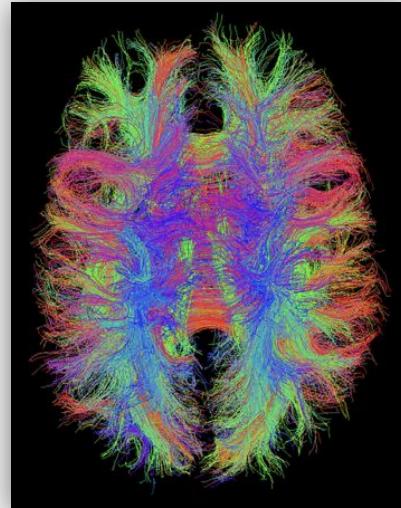
is a modeling technique used to
visually represent nerve tracts using
data collected by diffusion MRI.

Structural connectivity



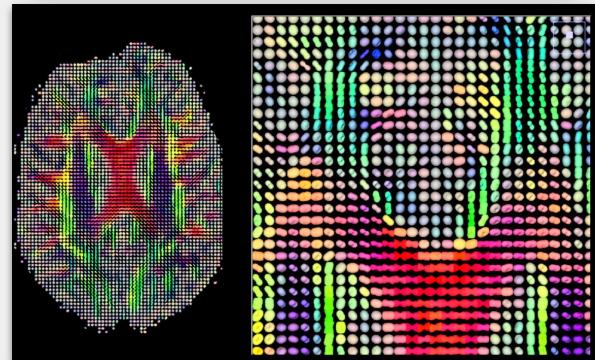
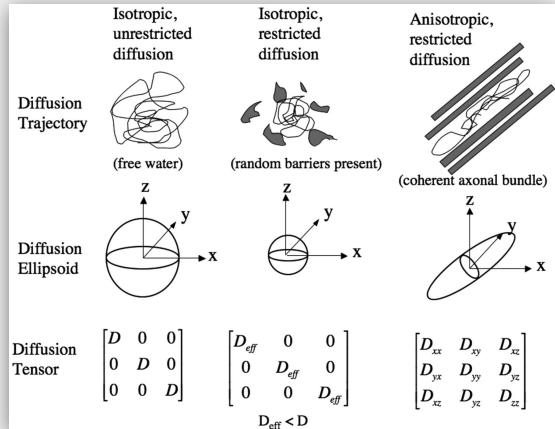
Diffusion MRI

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.

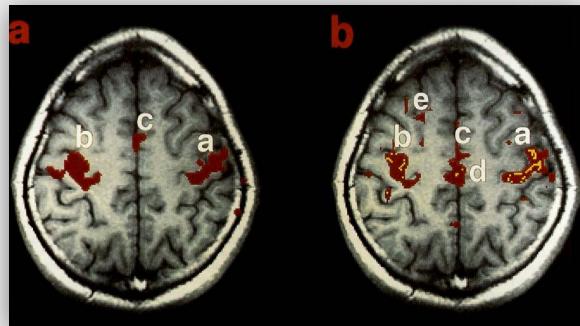


[Explore DTI animations](#)

Functional connectivity

Motor task

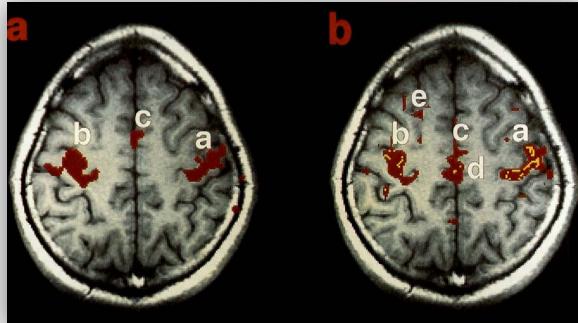
Resting state



Biswal et al. (1995)

Functional connectivity

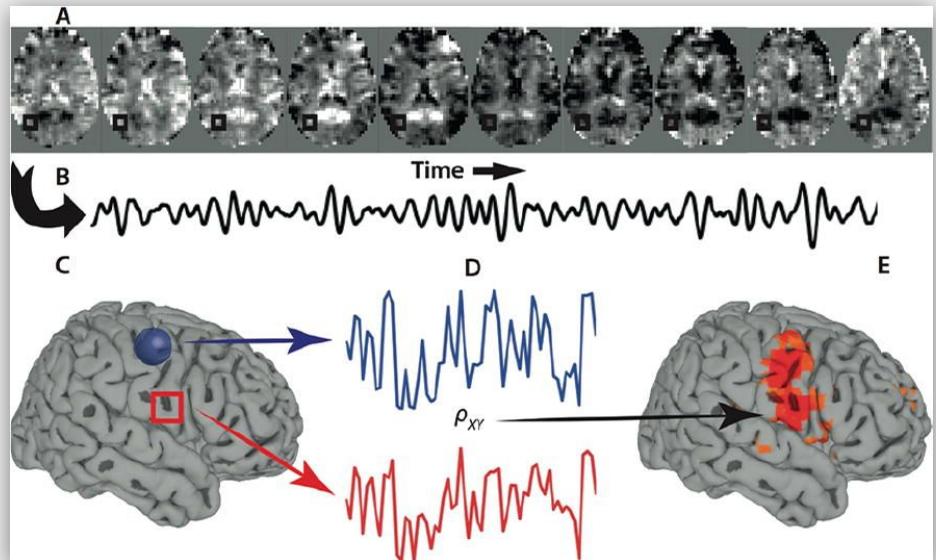
Motor task



Biswal et al. (1995)

Resting state

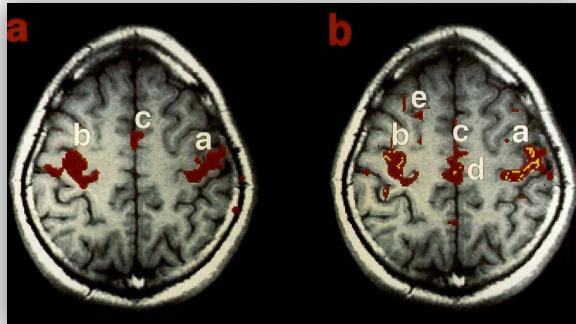
Seed-based approach



Hart et al. (2016)

Functional connectivity

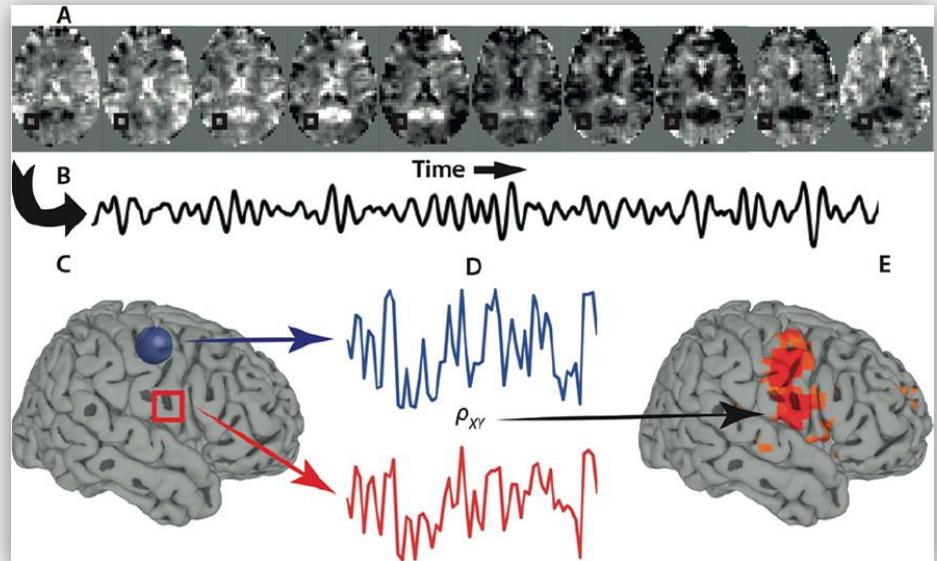
Motor task



Biswal et al. (1995)

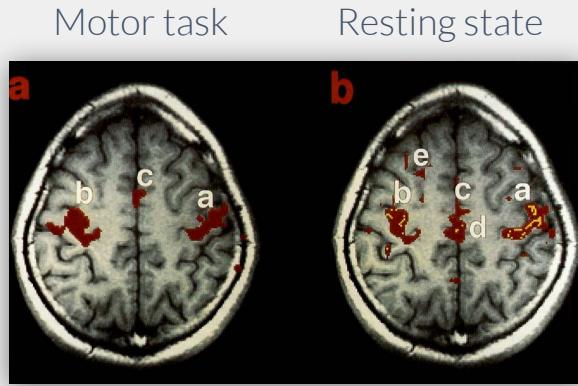
Resting-state functional connectivity measures temporal correlation of spontaneous BOLD signal among spatially distributed brain regions, with the assumption that regions with correlated activity form functional networks

Seed-based approach



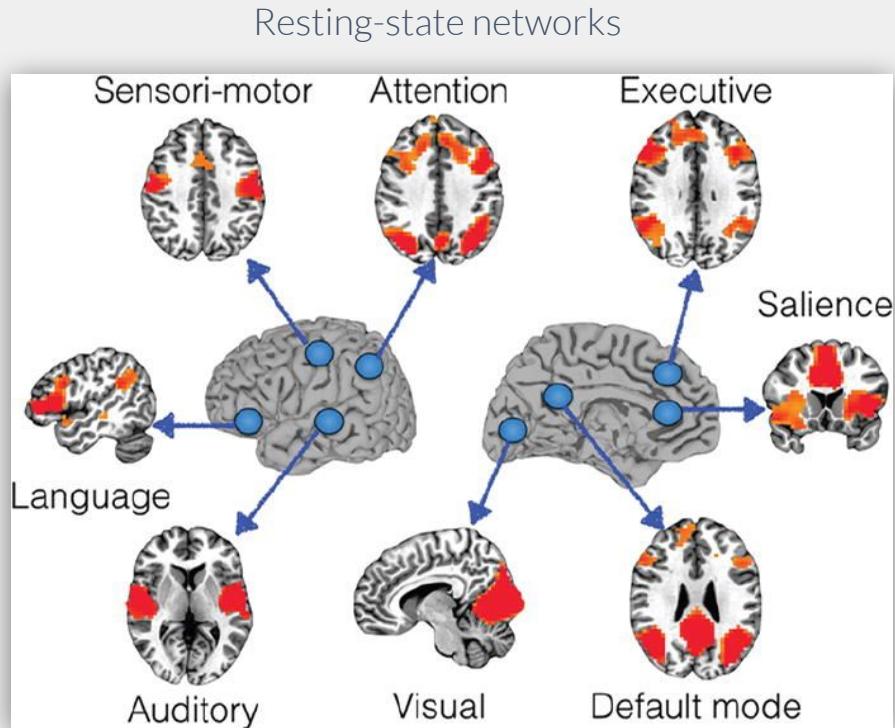
Hart et al. (2016)

Functional connectivity



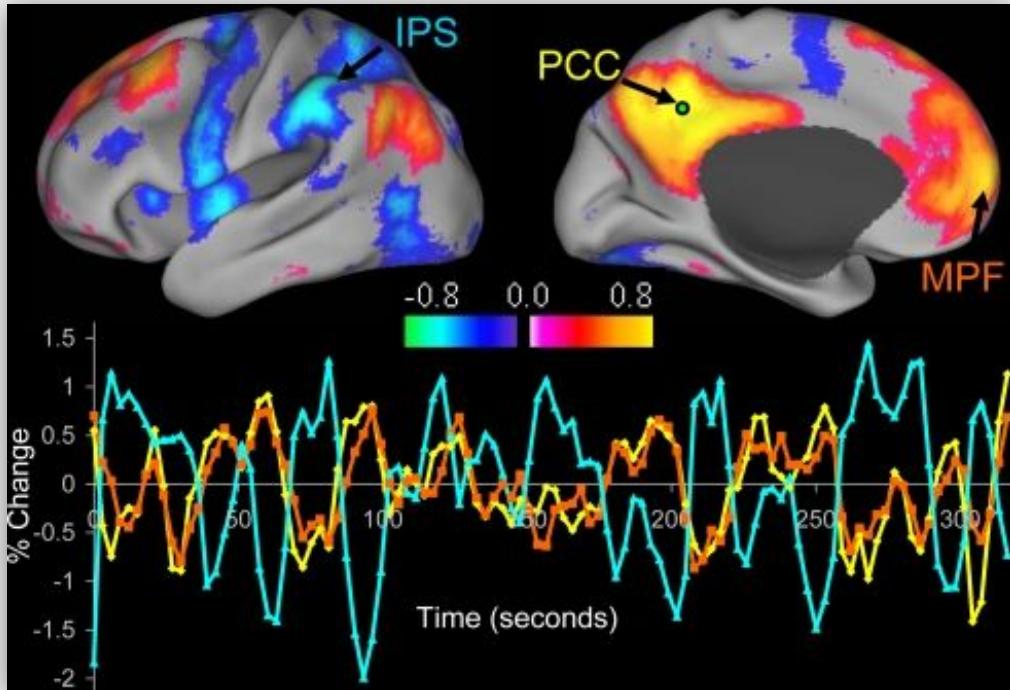
Biswal et al. (1995)

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



Hart et al. (2016)

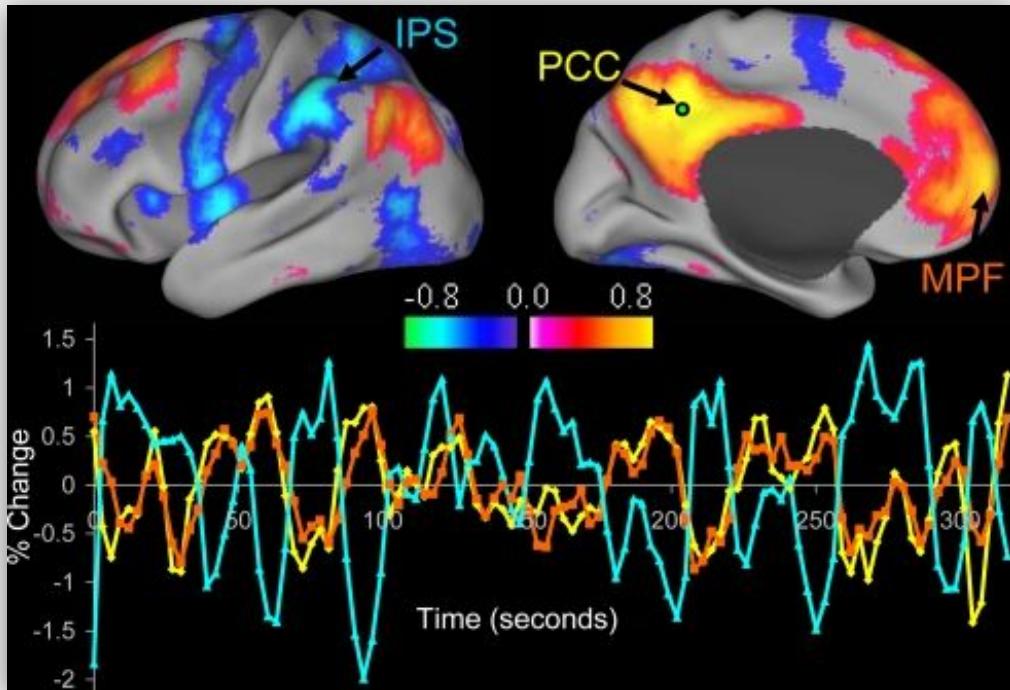
Anticorrelated networks



Fox et al. (2005)

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

Anticorrelated networks

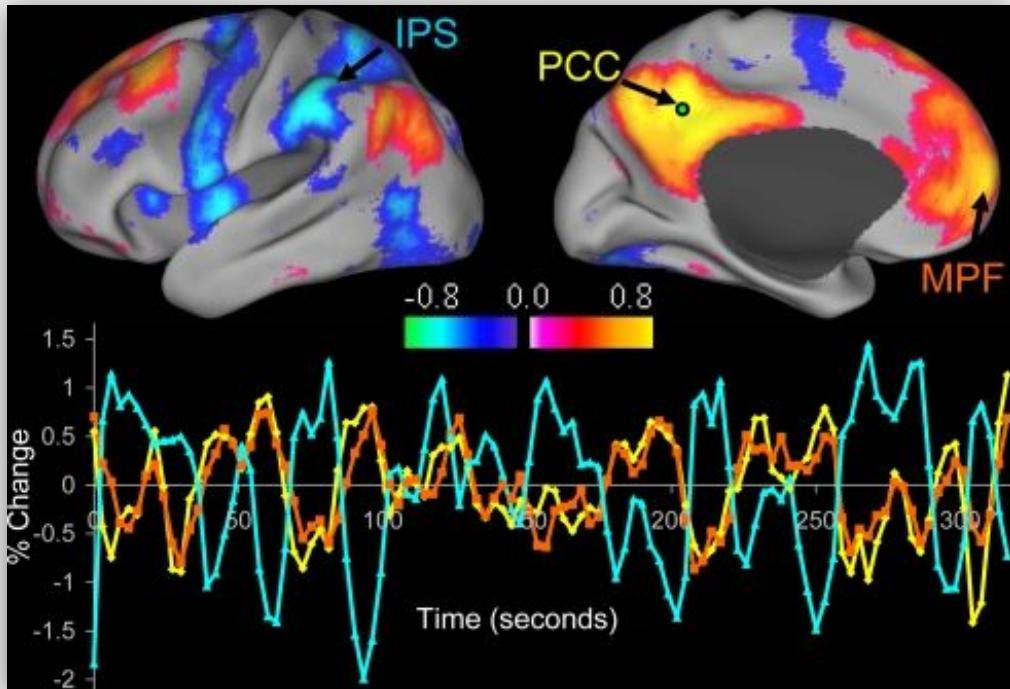


Fox et al. (2005)

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



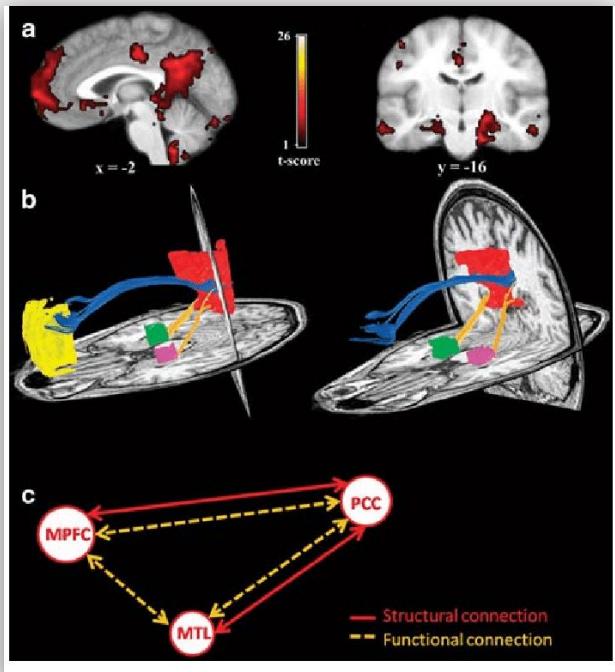
Fox et al. (2005)

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

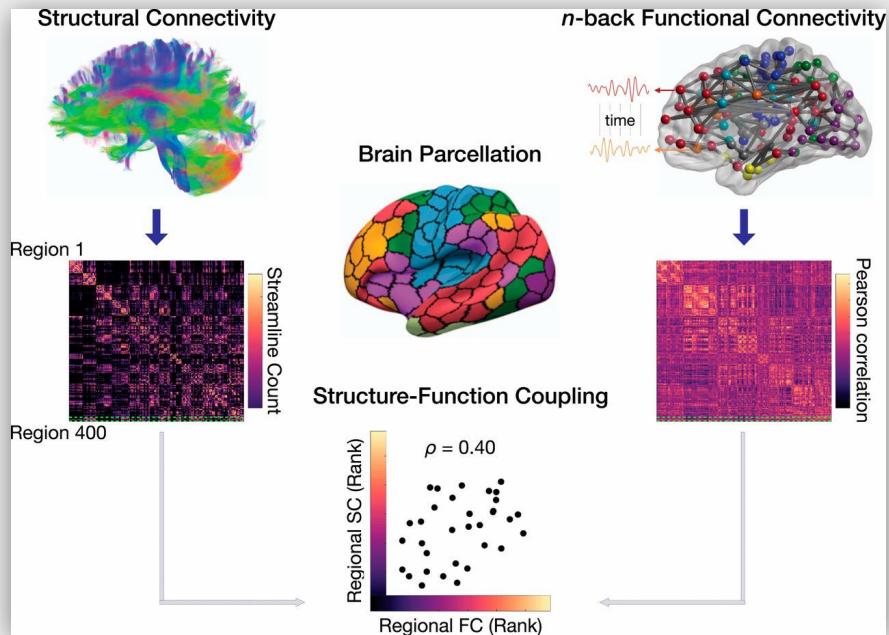
Task-negative networks that are inactive during cognitively demanding tasks (e.g. default mode network).

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

Functional connectivity vs structural connectivity

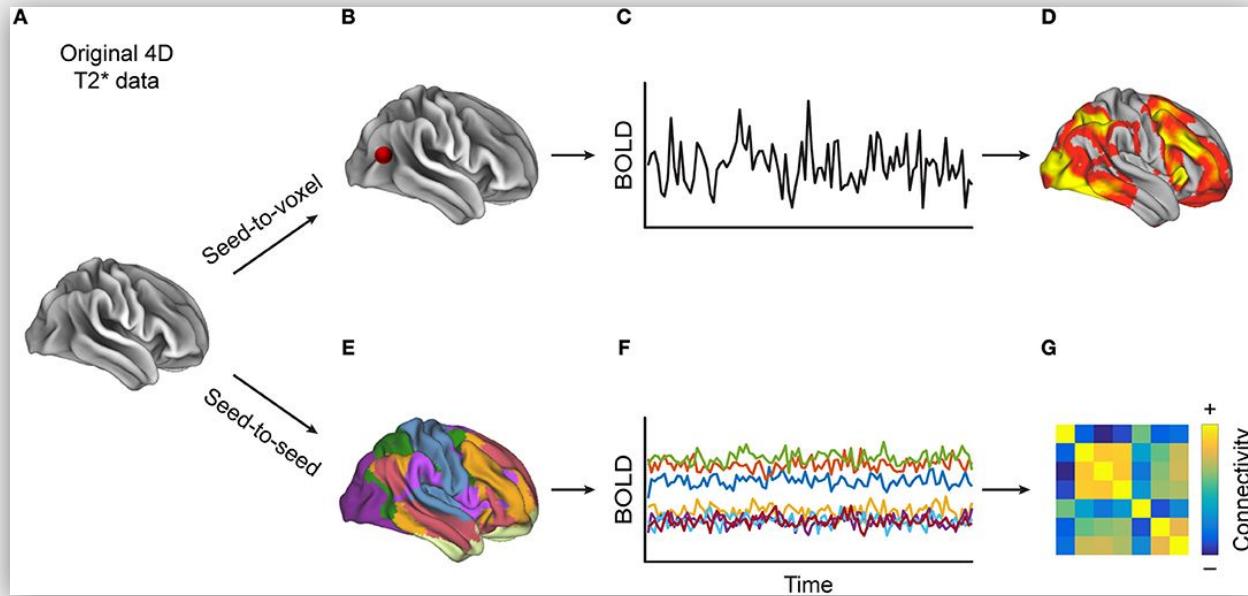


Greicius et al. (2009)



Baum et al. (2019)

Functional connectivity: methods



Seed - predefined region of the brain.

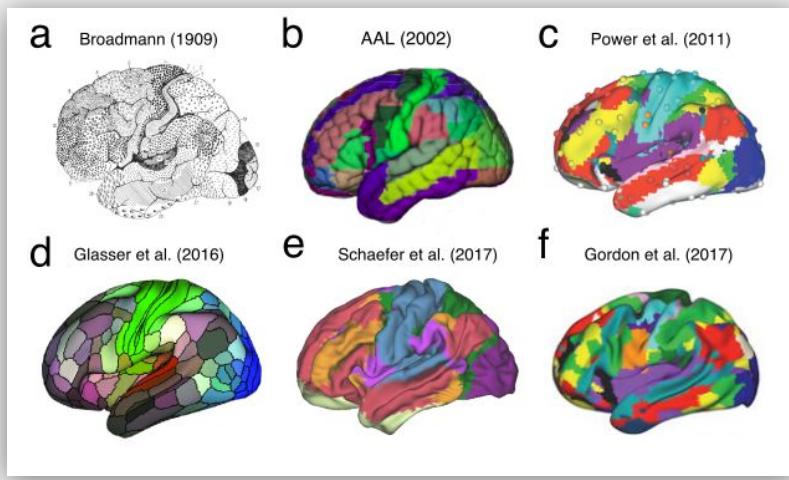
Seed-to-voxel - calculating correlations between seed and all voxels in the brain.

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

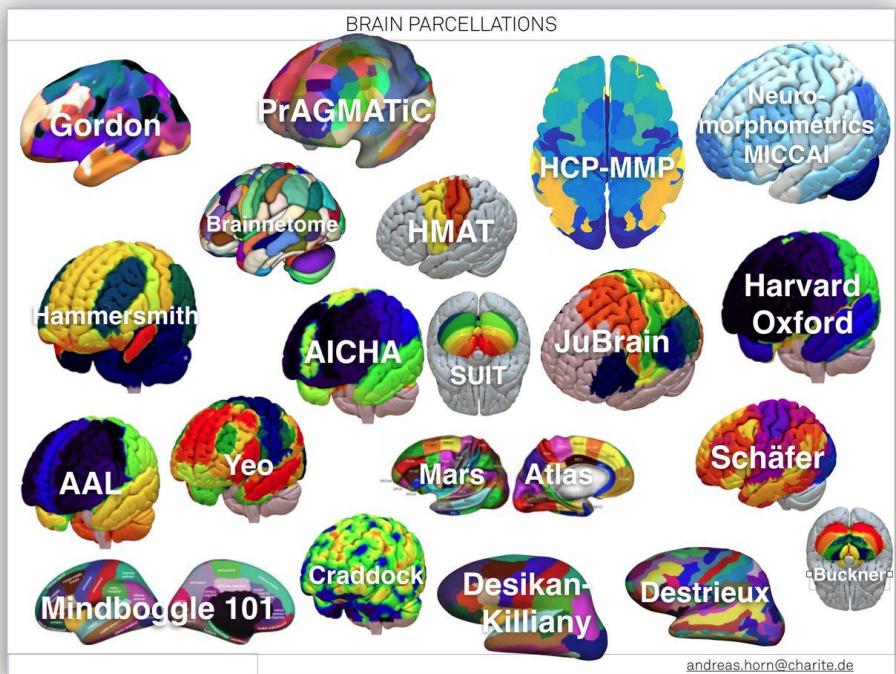
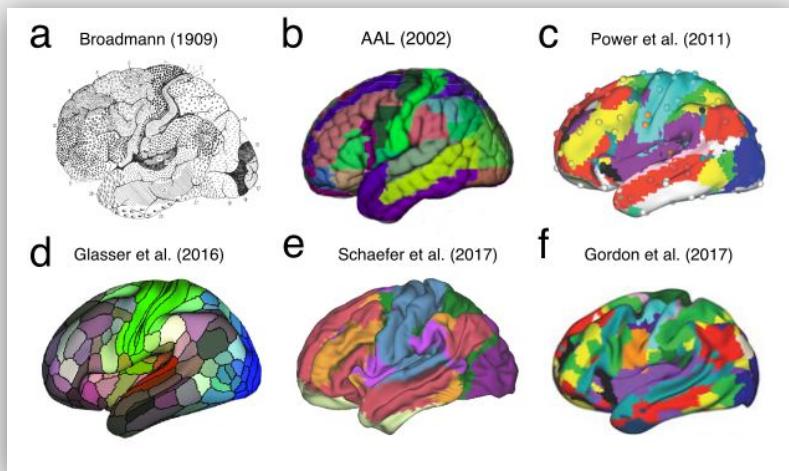
Where to get brain parcellation?



Brain parcellations



Brain parcellations



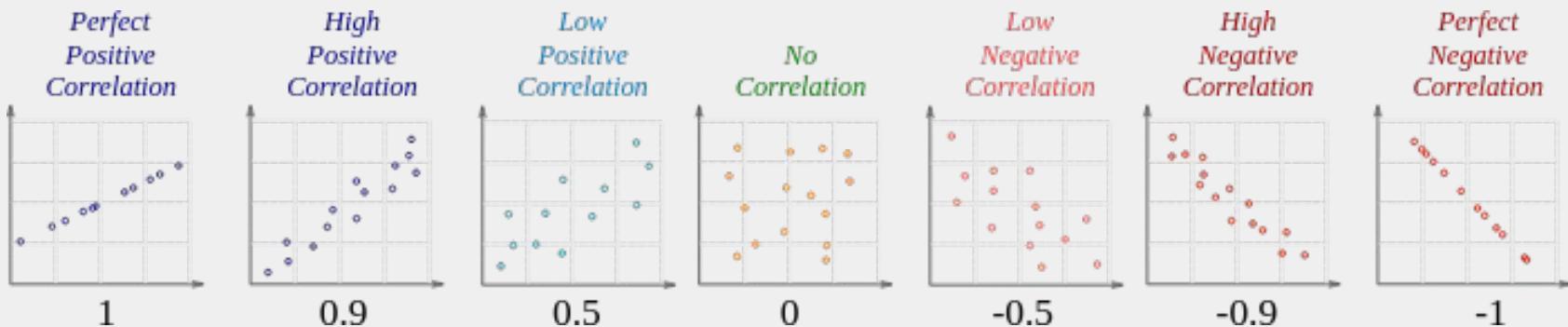
Atlas resources

Correlation

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

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

Where, \bar{X} =mean of X variable
 \bar{Y} =mean of Y variable



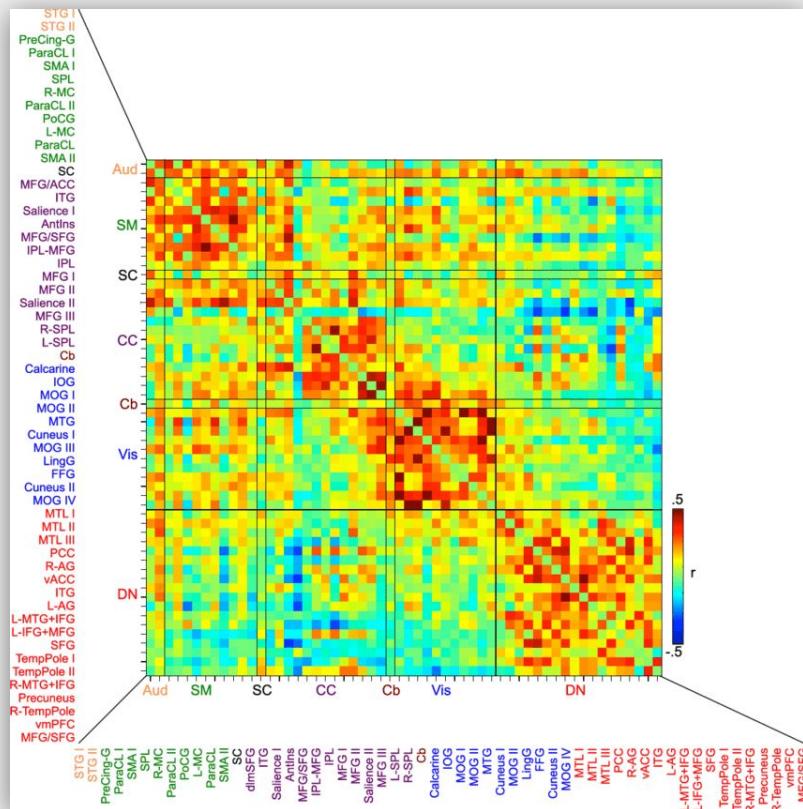
Covariance

$$\text{Correlation} = \frac{\text{Cov}(x, y)}{\sigma_x * \sigma_y}$$

Standard deviation

Correlation matrix

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

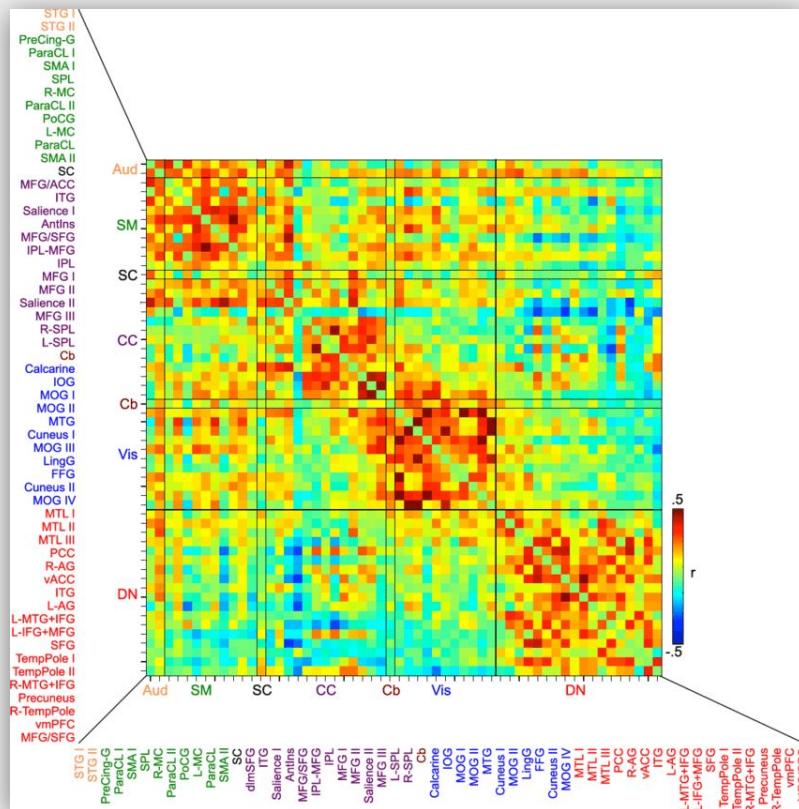


Hutchison & Morton, 2015

Correlation matrix

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

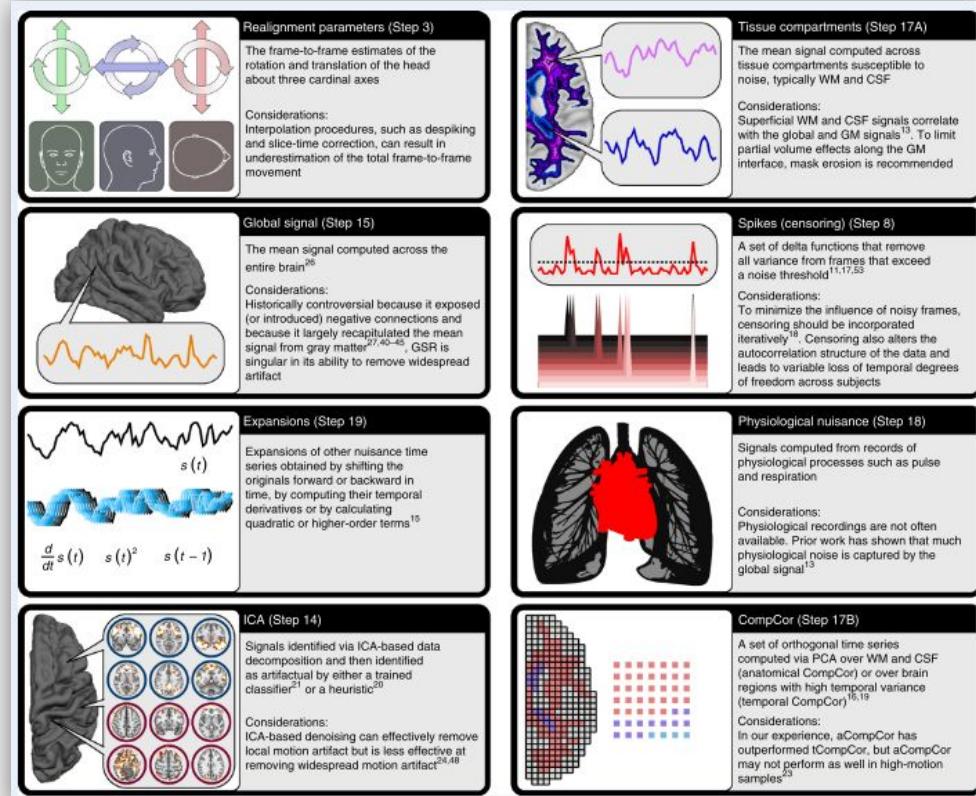
Clusters on a correlation matrix represents brain subnetworks (also known called **modules** or **large-scale systems**).



Hutchison & Morton, 2015

Spurious correlations

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

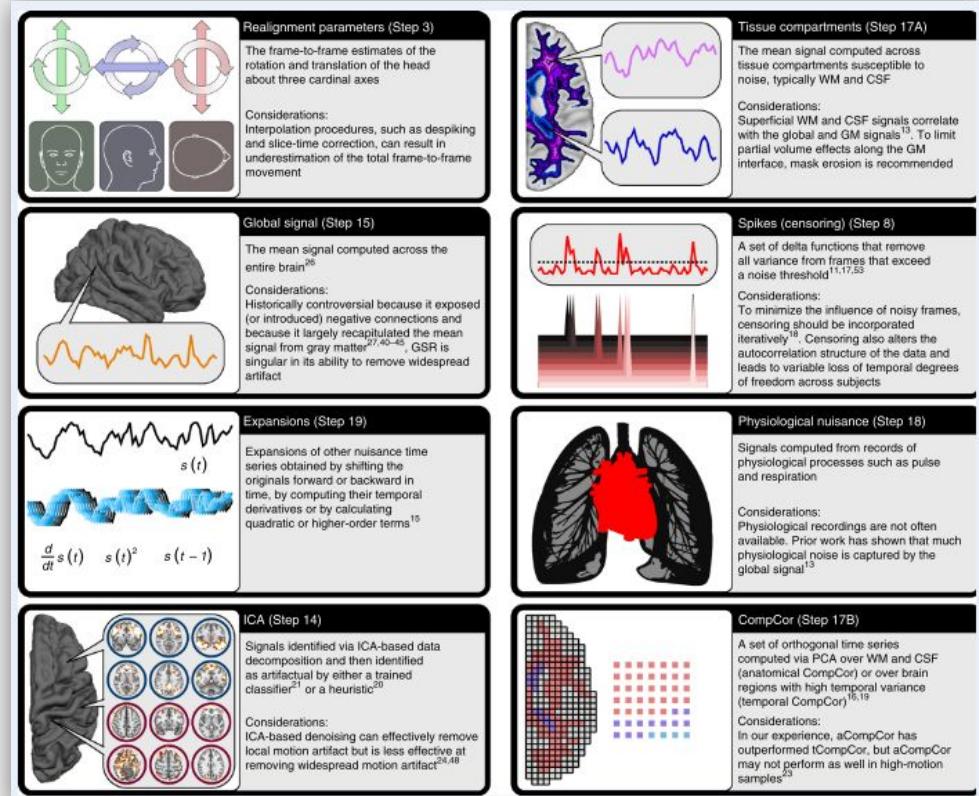


Ciric et al., 2018

Spurious correlations

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

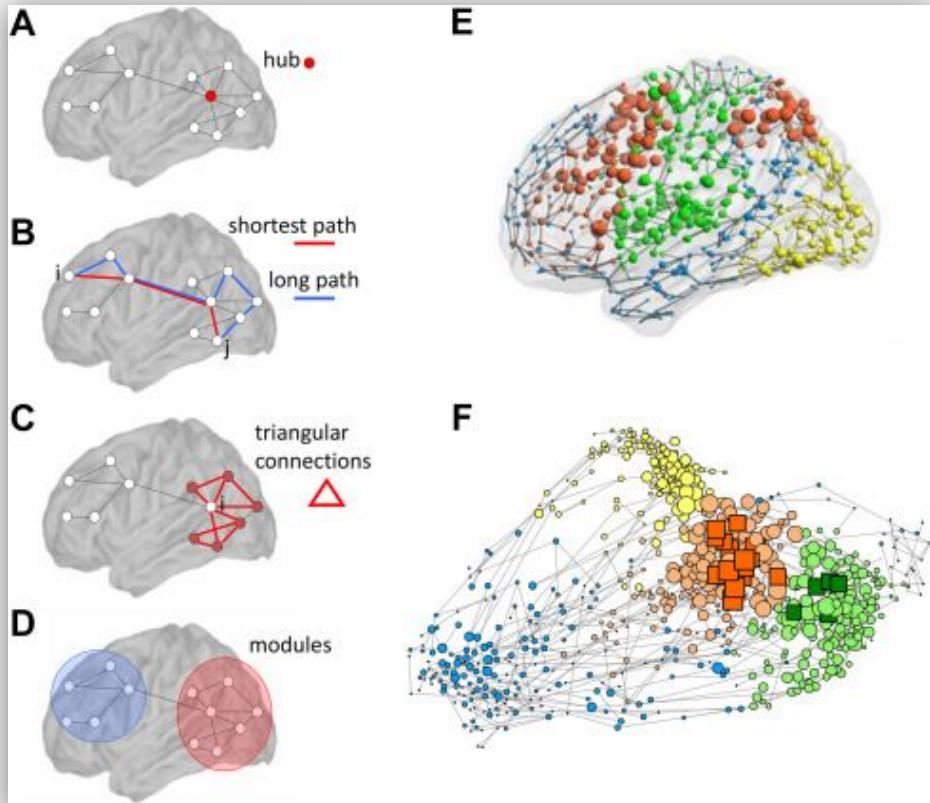
Denoising procedure -
regressing out confounding
signals might minimise the level
of spurious correlations in
studies focused on functional
connectivity.



Ciric et al., 2018

Network neuroscience

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

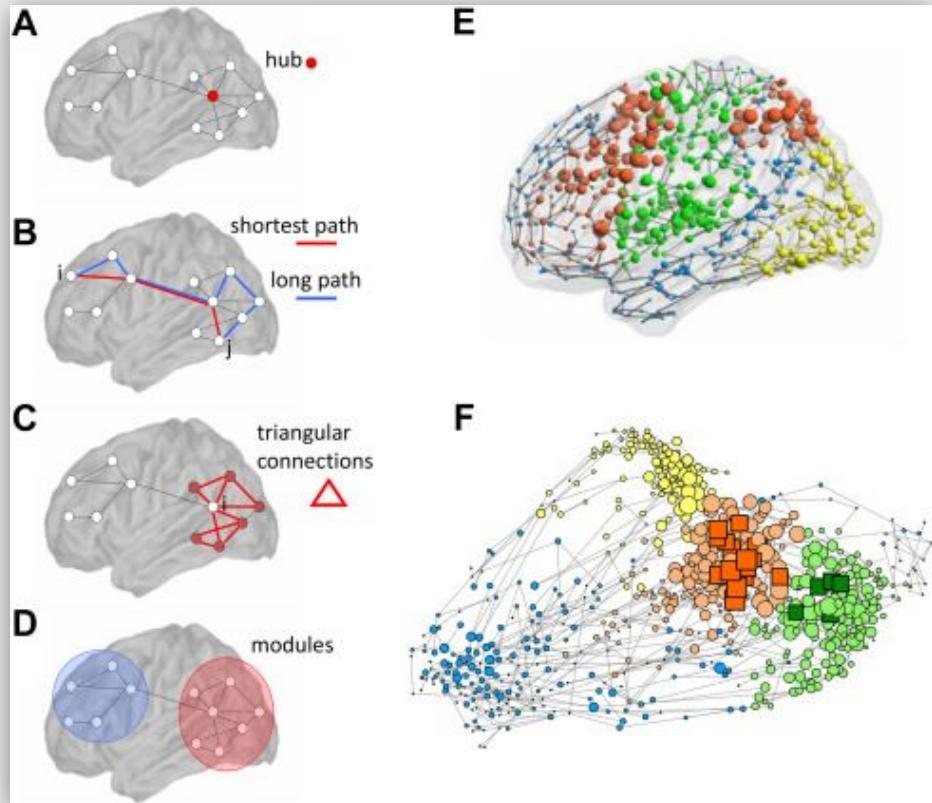


Morgan et al., 2018

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.

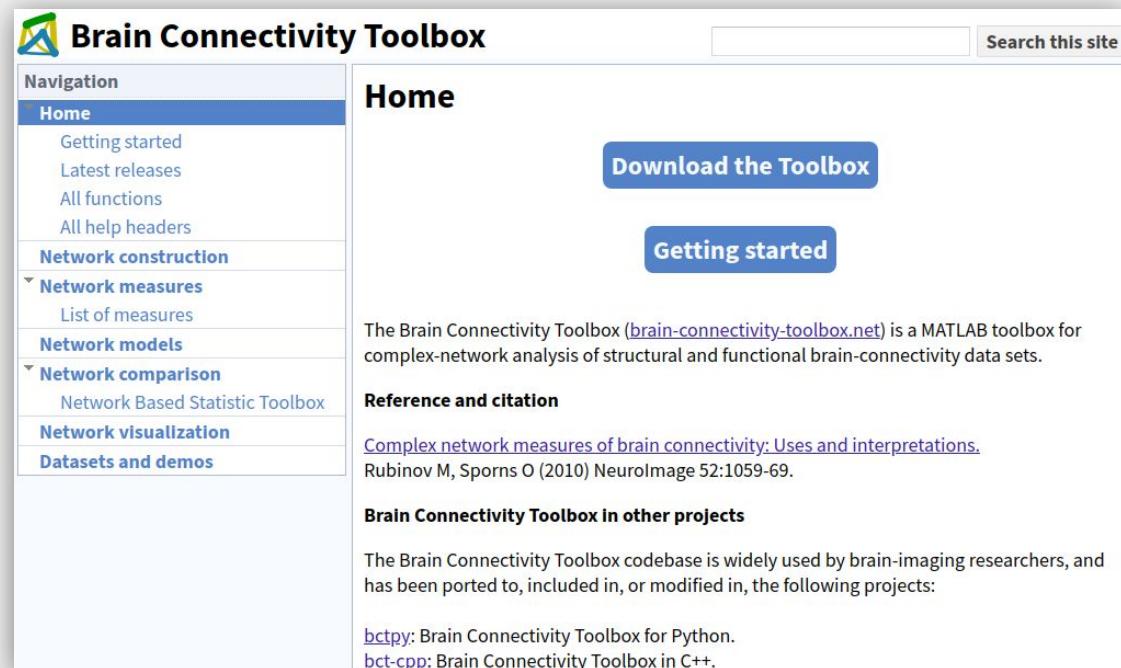


Morgan et al., 2018

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.



The screenshot shows the homepage of the Brain Connectivity Toolbox. The header features the toolbox's logo and the text "Brain Connectivity Toolbox". A search bar and a "Search this site" button are on the right. The left sidebar is titled "Navigation" and includes links for "Home", "Getting started", "Latest releases", "All functions", "All help headers", "Network construction", "Network measures" (with a "List of measures" link), "Network models", "Network comparison" (with a "Network Based Statistic Toolbox" link), "Network visualization", and "Datasets and demos". The main content area is titled "Home" and contains a large blue button "Download the Toolbox", a blue button "Getting started" (which is highlighted), and a paragraph about the toolbox. Below this is a section titled "Reference and citation" with a link to a paper: "Complex network measures of brain connectivity: Uses and interpretations." by Rubinov M, Sporns O (2010) NeuroImage 52:1059-69. The final section is "Brain Connectivity Toolbox in other projects" with links to "bctpy" and "bct-cpp".

Brain Connectivity Toolbox

Home

Download the Toolbox

Getting started

The Brain Connectivity Toolbox ([brain-connectivity-toolbox.net](#)) is a MATLAB toolbox for complex-network analysis of structural and functional brain-connectivity data sets.

Reference and citation

[Complex network measures of brain connectivity: Uses and interpretations.](#)
Rubinov M, Sporns O (2010) NeuroImage 52:1059-69.

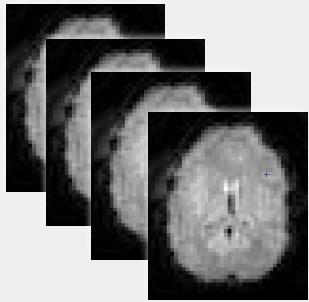
Brain Connectivity Toolbox in other projects

The Brain Connectivity Toolbox codebase is widely used by brain-imaging researchers, and has been ported to, included in, or modified in, the following projects:

[bctpy](#): Brain Connectivity Toolbox for Python.
[bct-cpp](#): Brain Connectivity Toolbox in C++.

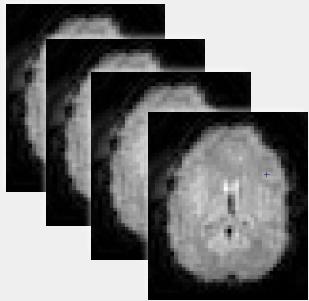
Workflow

fMRI data



Workflow

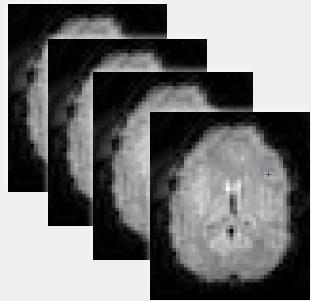
fMRI data



Denoising

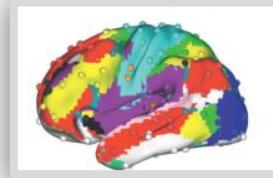
Workflow

fMRI data



Denoising

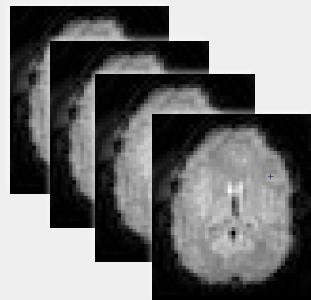
Definition of brain regions



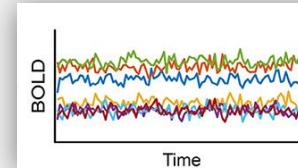
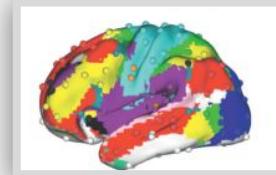
Workflow

Definition of brain regions

fMRI data

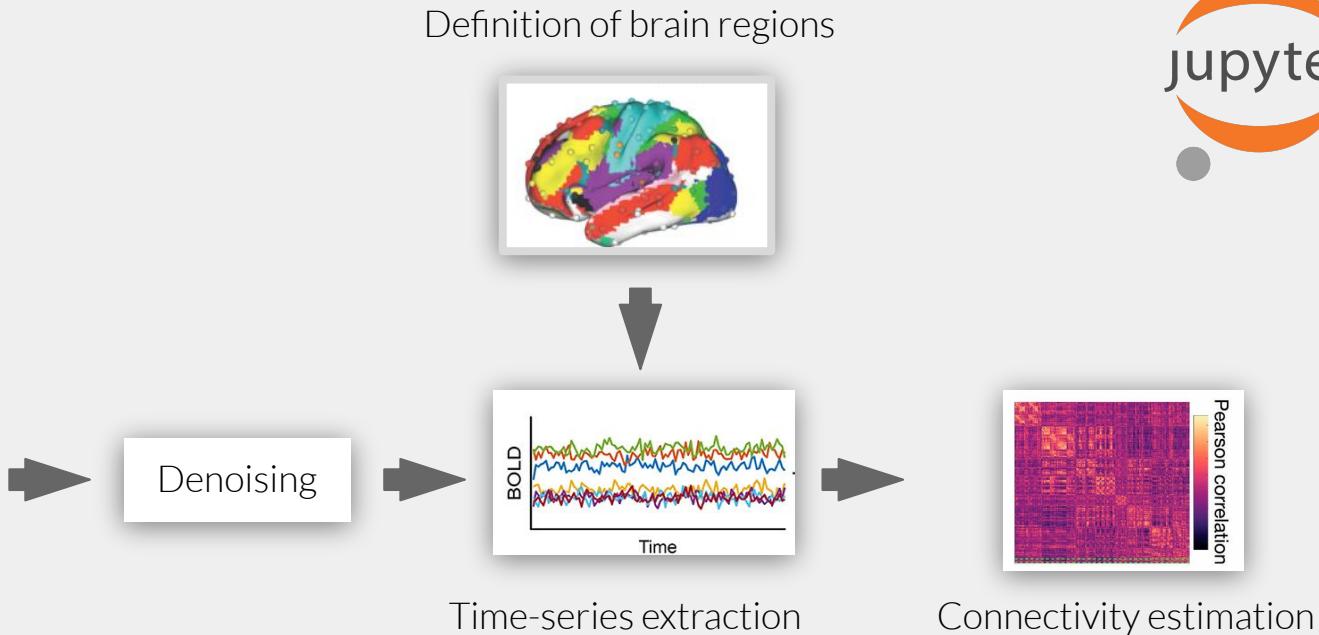
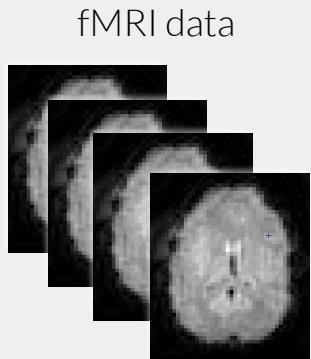


Denoising

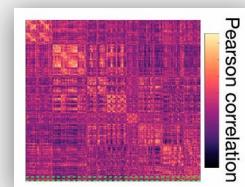
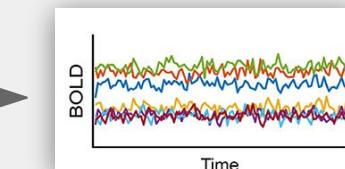
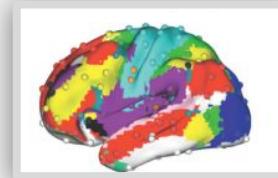


Time-series extraction

Workflow



Definition of brain regions



Homework

1. GitHub Classroom

Functional connectivity
Deadline: 19-06-2020



Next



Machine learning