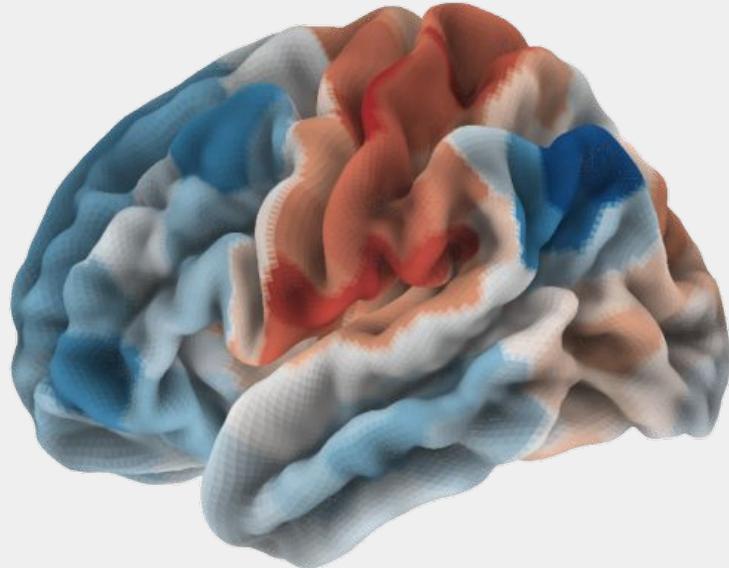


Fundamentals of fMRI data analysis

Karolina Finc

Centre for Modern Interdisciplinary
Technologies Nicolaus Copernicus University
in Toruń



COURSE #5: Functional Connectivity | 1st February 2021

Study plan

Open science & neuroimaging



BEFORE

fMRI data preprocessing



fMRI data manipulation
in python

Functional connectivity



5



4

General Linear Model



AFTER

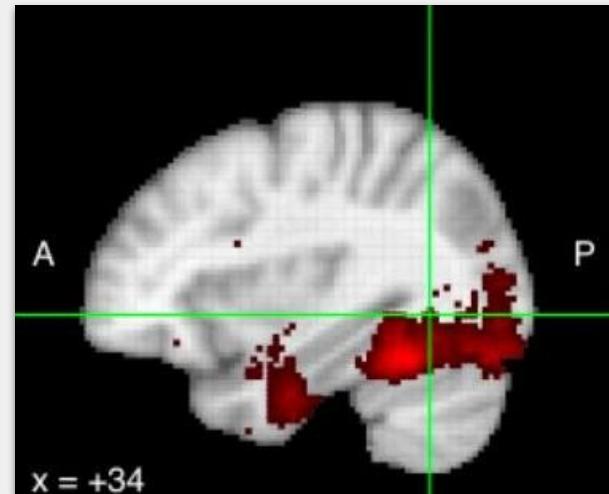


6

Machine Learning
on fMRI data

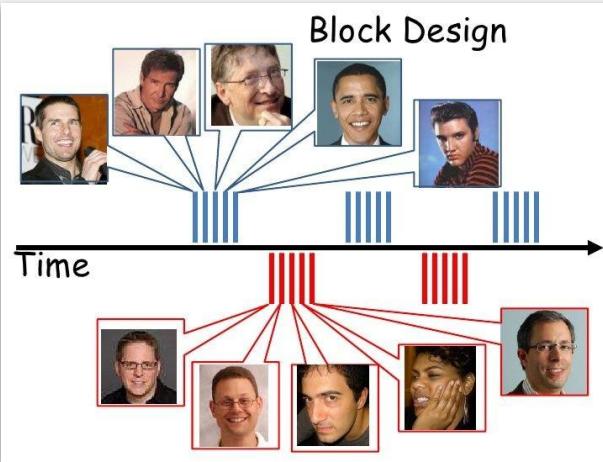
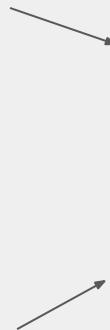
Goals of task-based fMRI

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.

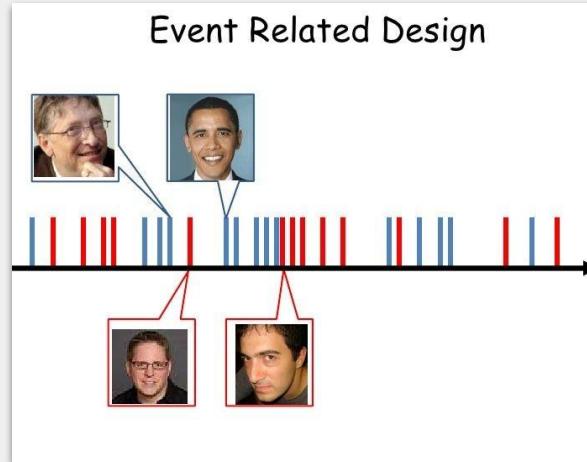


Task designs

Famous people

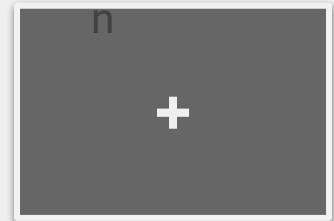
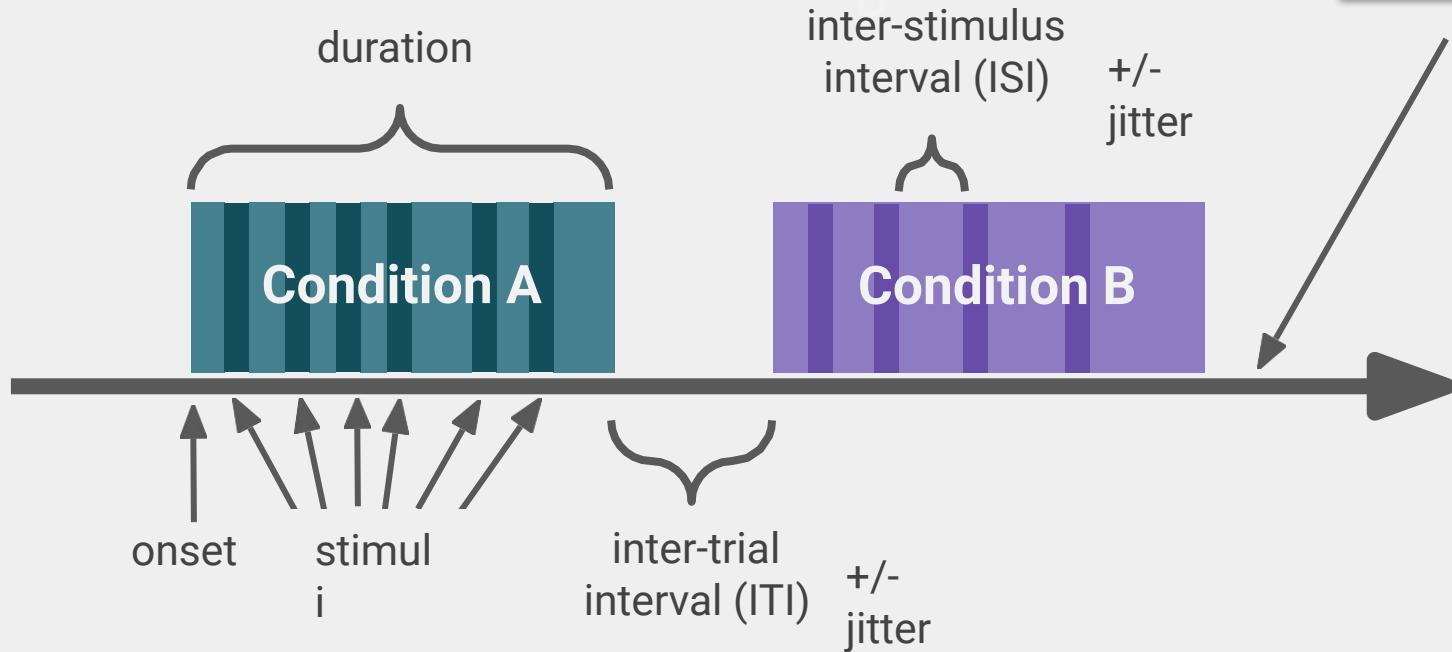


Block design
similar events are
grouped



Event-related design
events are mixed

Events parameters



Condition

P

inter-stimulus
interval (ISI)

+/-
jitter

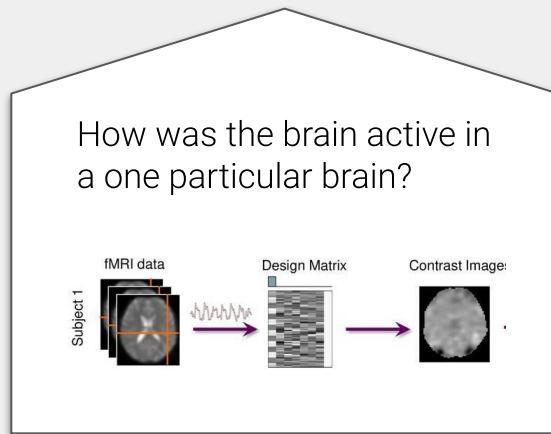
Fixatio

n

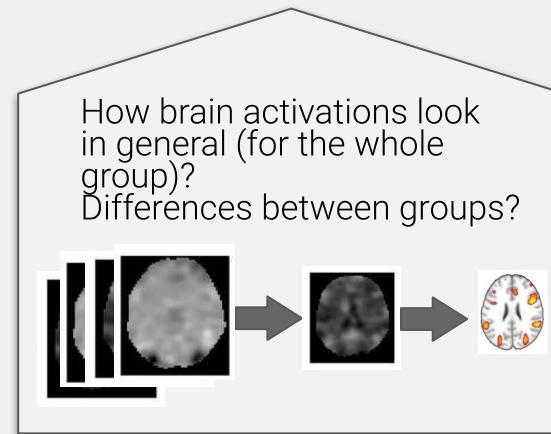
+

Analysis steps

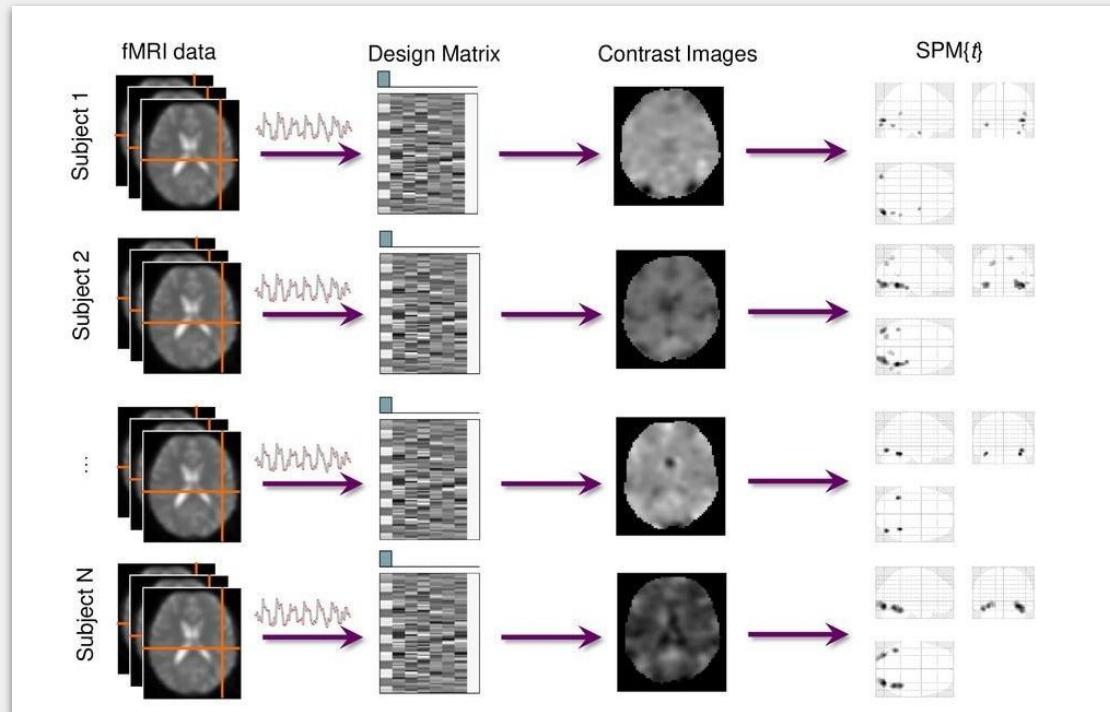
1-level analysis
(within-subject; individual)



2-level analysis
(across-subject; group)



1-level analysis



Study plan

Open science & neuroimaging



BEFORE

fMRI data manipulation
in python



fMRI data
preprocessing



Functional
connectivity



AFTER



General
Linear Model



Machine Learning
on fMRI data

Study plan

Open science &
neuroimaging



BEFORE

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preprocessing



fMRI data manipulation
in python

Functional
connectivity



AFTER

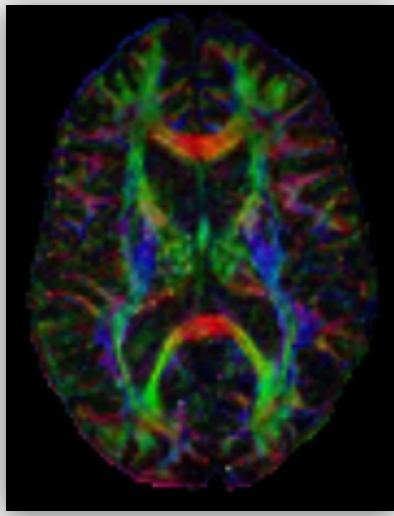


General
Linear Model



Machine Learning
on fMRI data

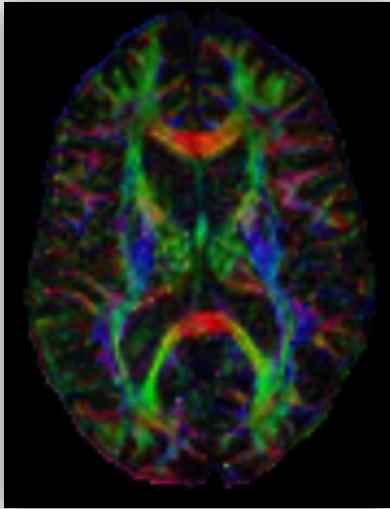
Structural connectivity



Diffusion MRI

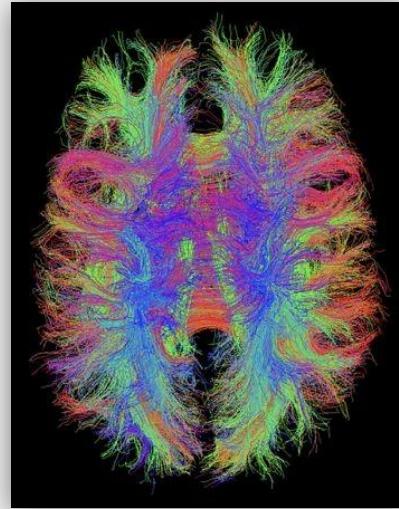
image contrast is determined by
the random microscopic motion
of water protons

Structural connectivity



Diffusion MRI

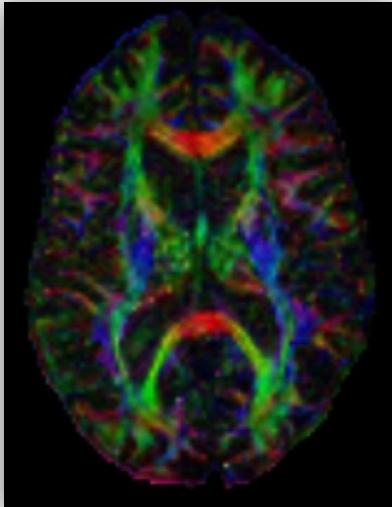
image contrast is determined by the random microscopic motion of water protons



Tractography

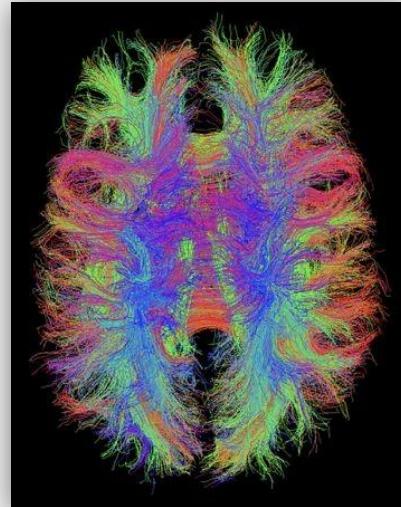
is a modeling technique used to visually represent nerve tracts using data collected by diffusion MRI.

Structural connectivity



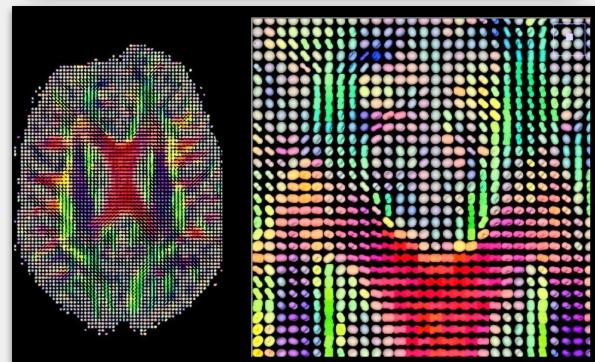
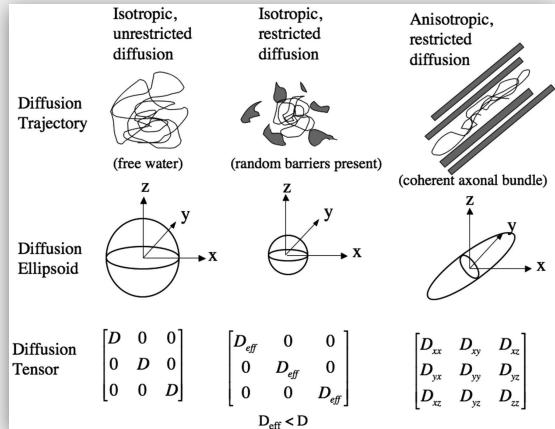
Diffusion MRI

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



Tractography

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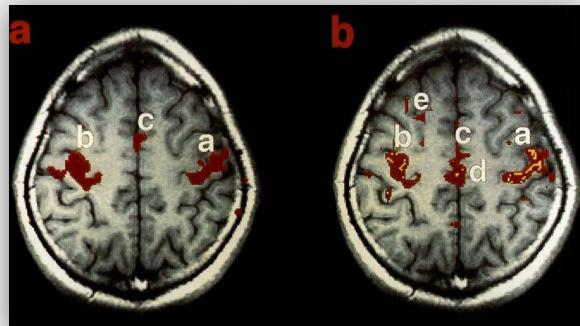


[Explore DTI animations](#)

Functional connectivity

Motor task

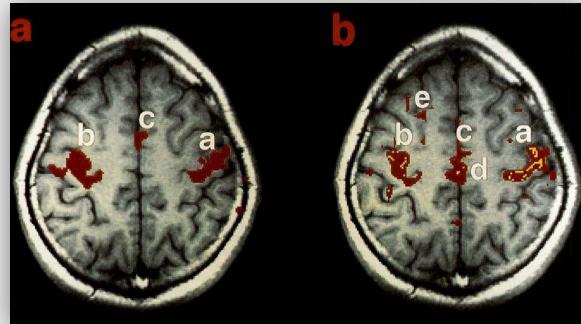
Resting state



Biswal et al. (1995)

Functional connectivity

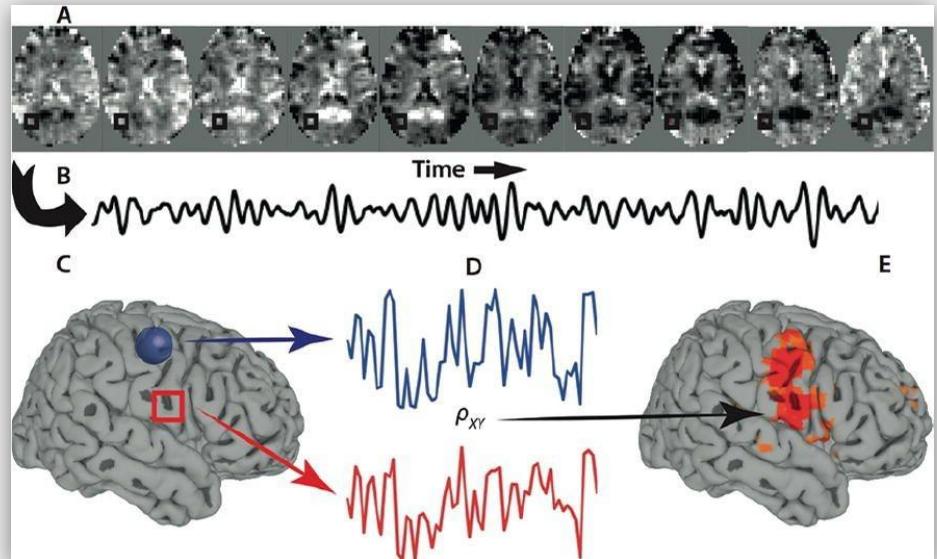
Motor task



Biswal et al. (1995)

Resting state

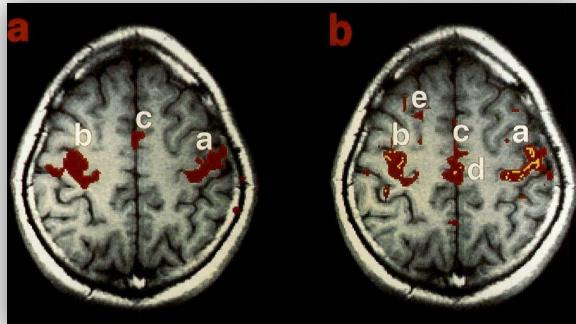
Seed-based approach



Hart et al. (2016)

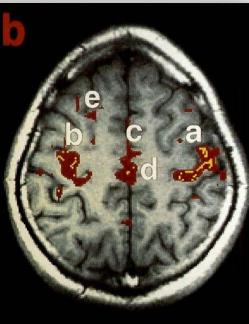
Functional connectivity

Motor task

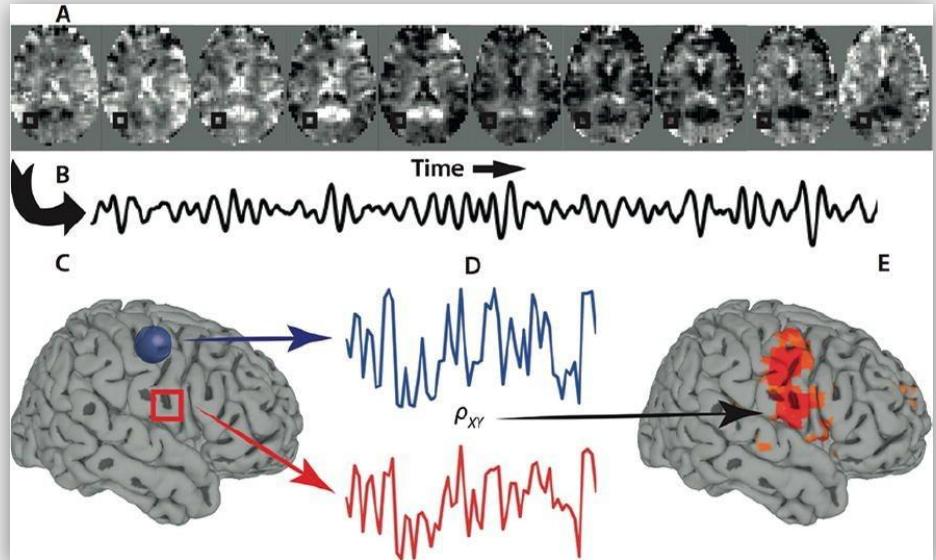


Biswal et al. (1995)

Resting state



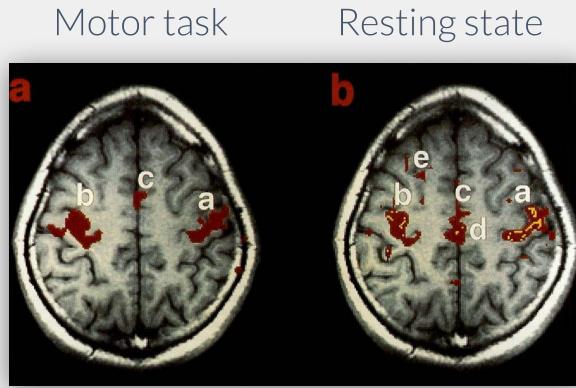
Seed-based approach



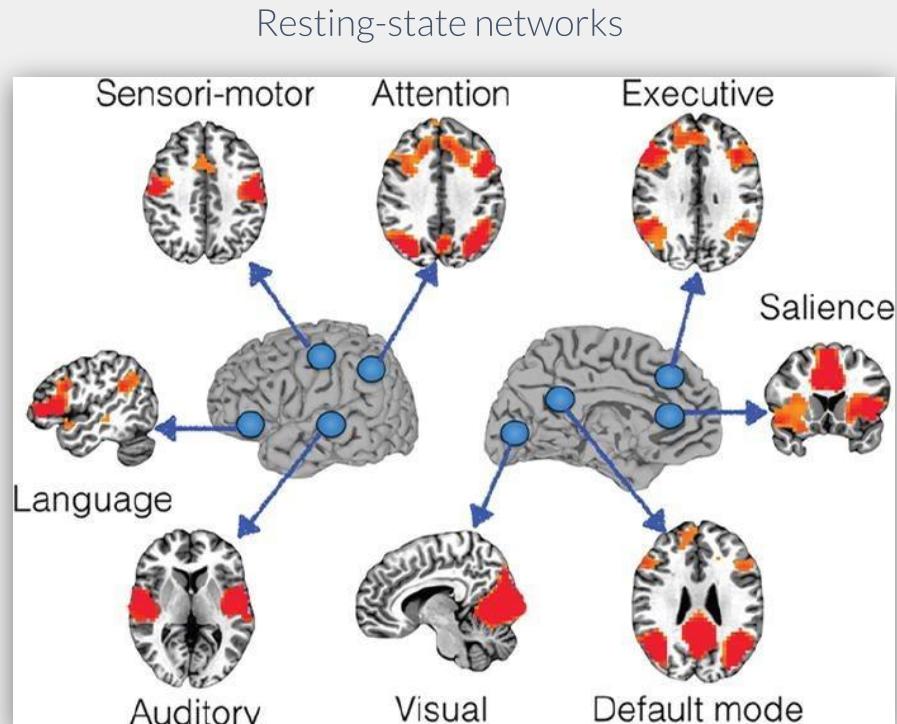
Hart et al. (2016)

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

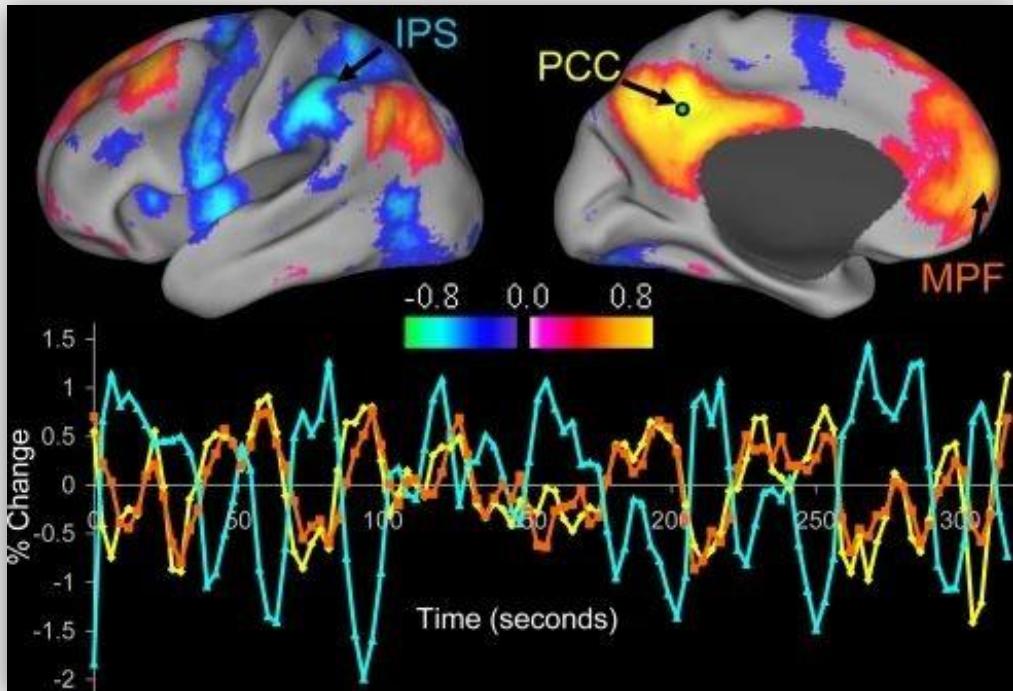
Functional connectivity



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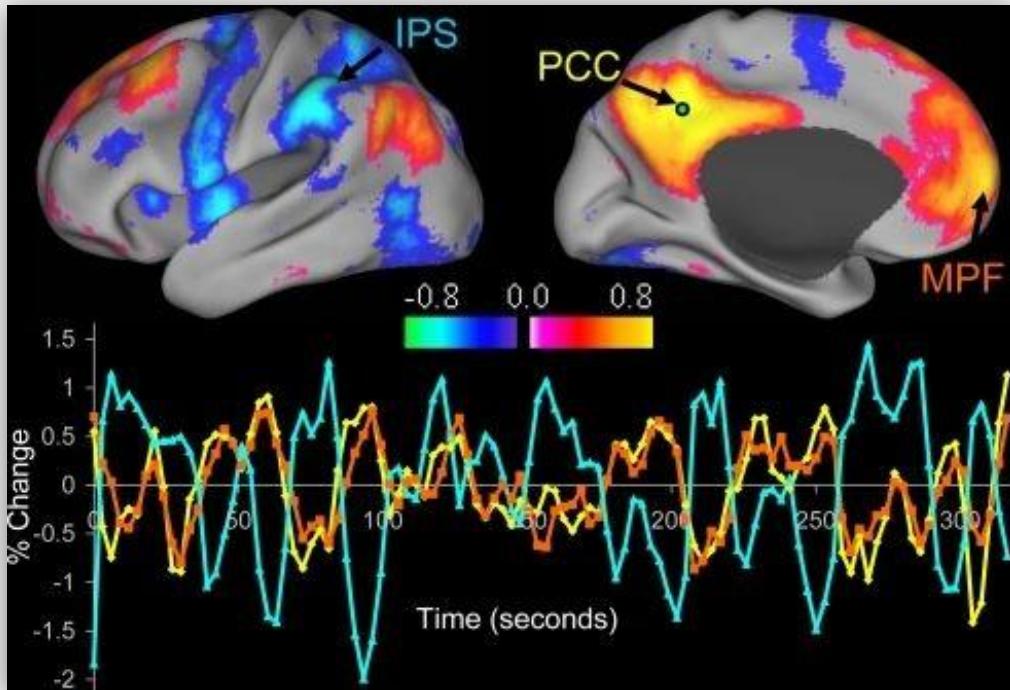
Anticorrelated networks



Fox et al. (2005)

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

Anticorrelated networks

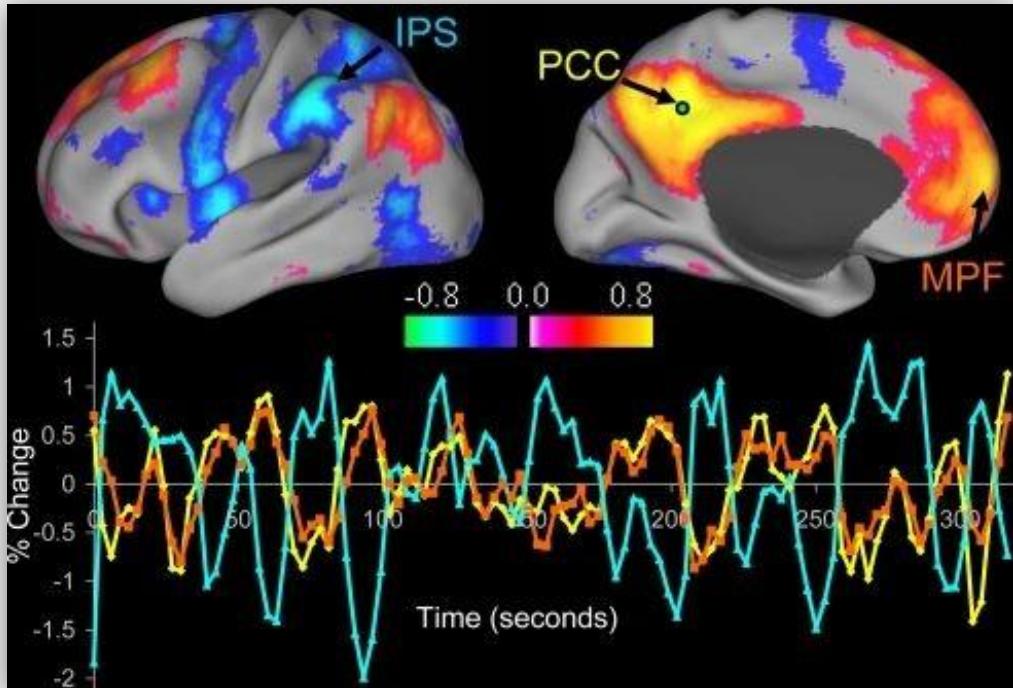


Fox et al. (2005)

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



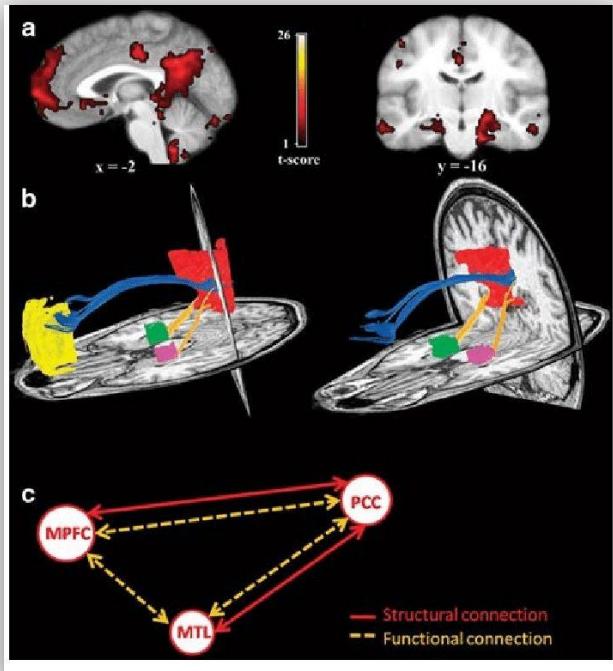
Fox et al. (2005)

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

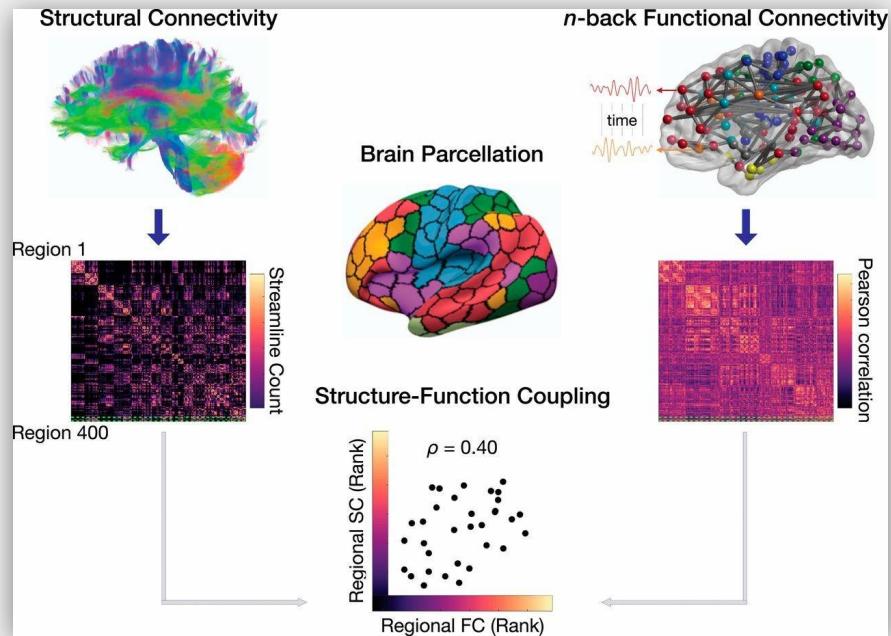
Task-negative networks that are inactive during cognitively demanding tasks (e.g. default mode network).

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

Functional connectivity vs structural connectivity

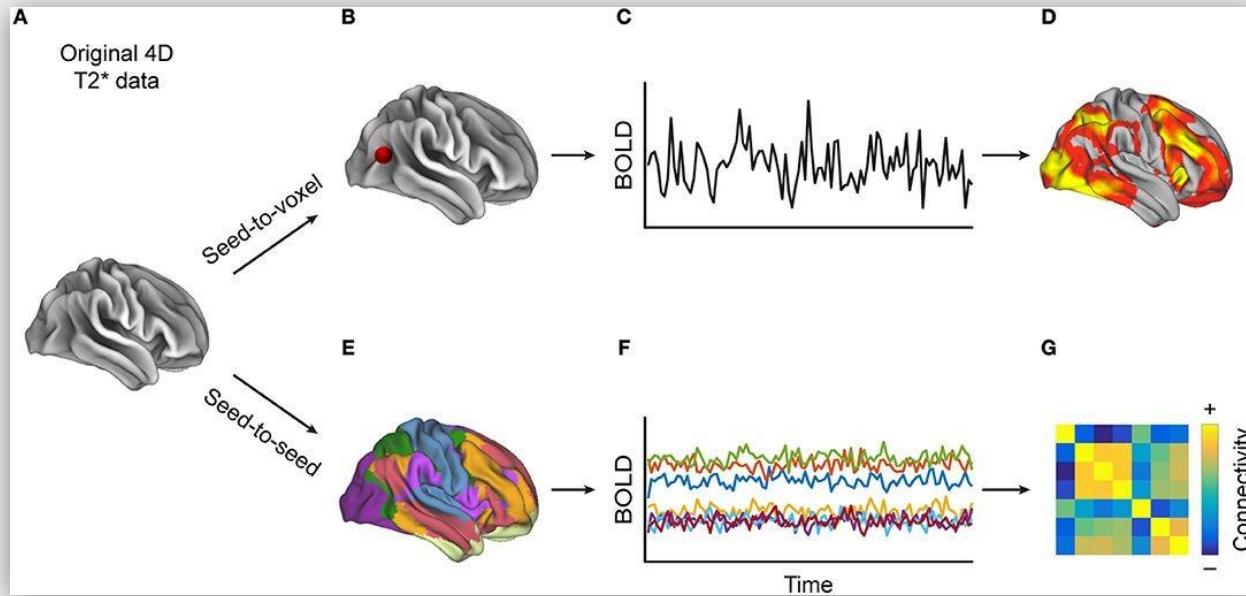


Greicius et al. (2009)



Baum et al. (2019)

Functional connectivity: methods



Seed - predefined region of the brain.

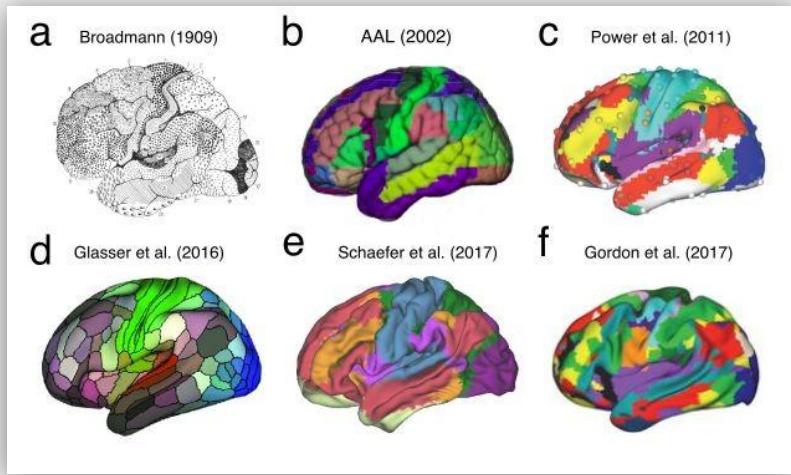
Seed-to-voxel - calculating correlations between seed and all voxels in the brain.

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

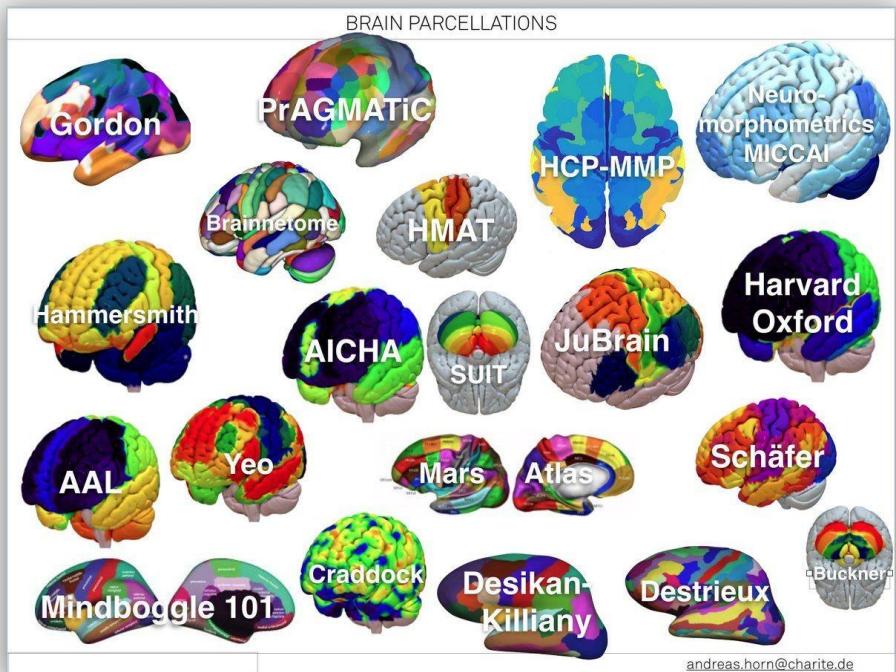
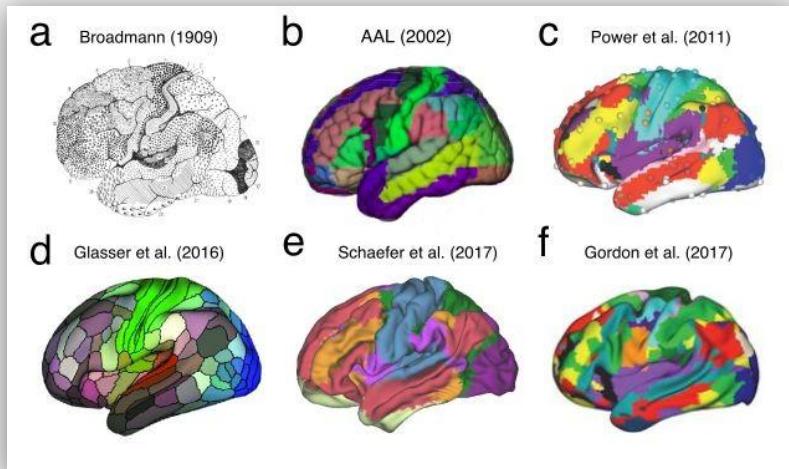
Where to get brain parcellation?



Brain parcellations



Brain parcellations



Atlas resources

Correlation

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

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

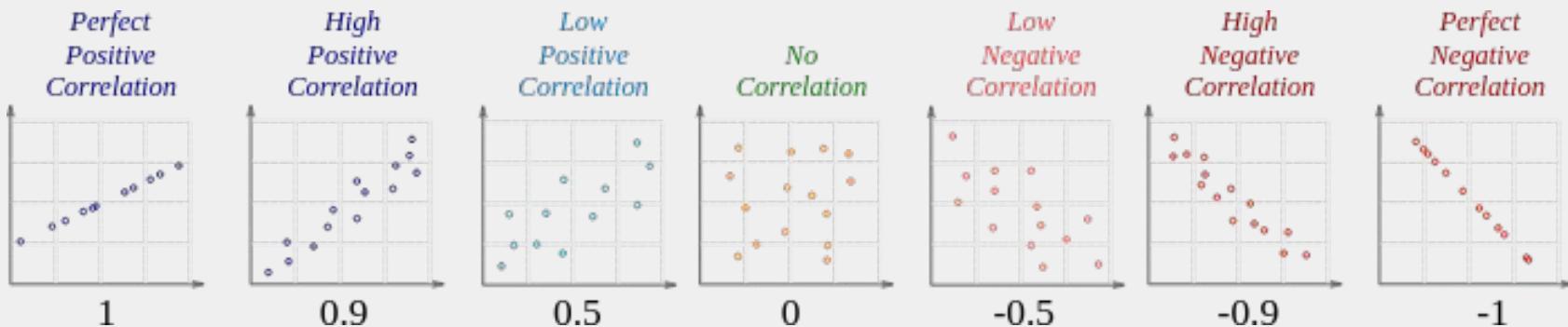
Where, \bar{X} =mean of X variable
 \bar{Y} =mean of Y variable

Covariance

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

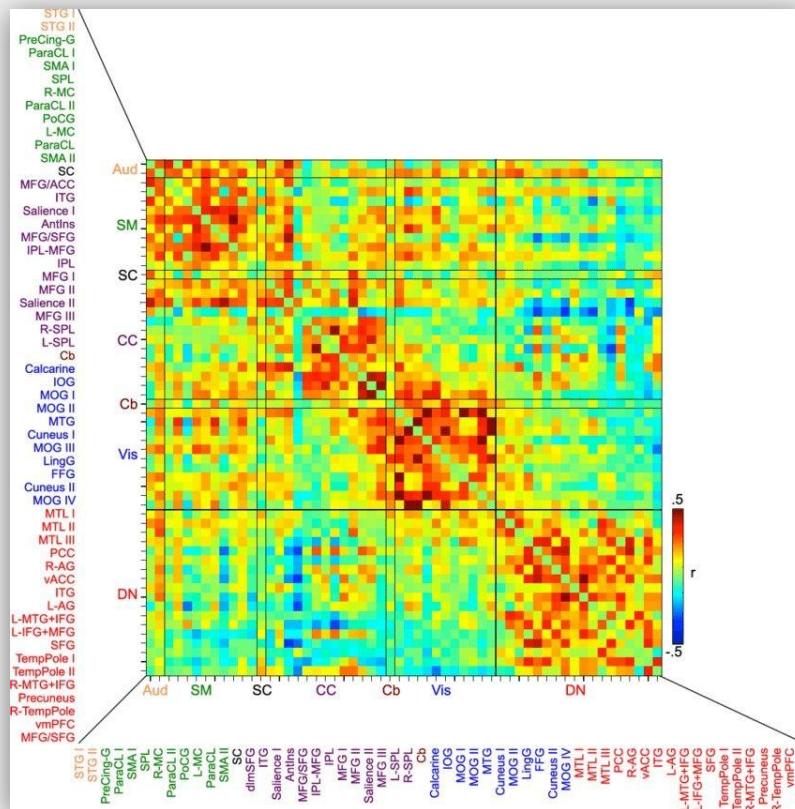


Standard deviation



Correlation matrix

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

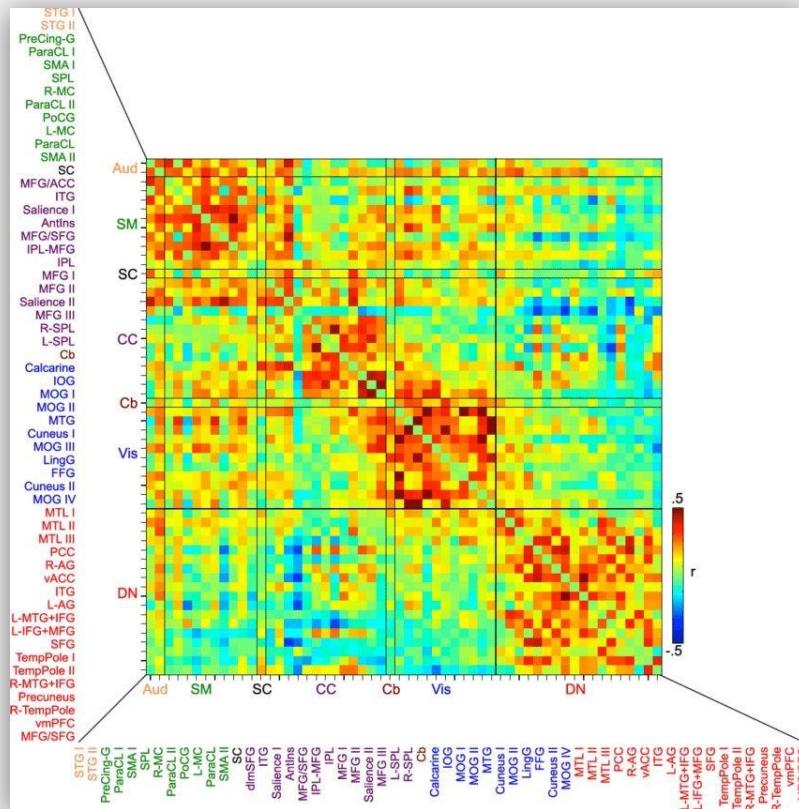


Hutchison & Morton, 2015

Correlation matrix

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

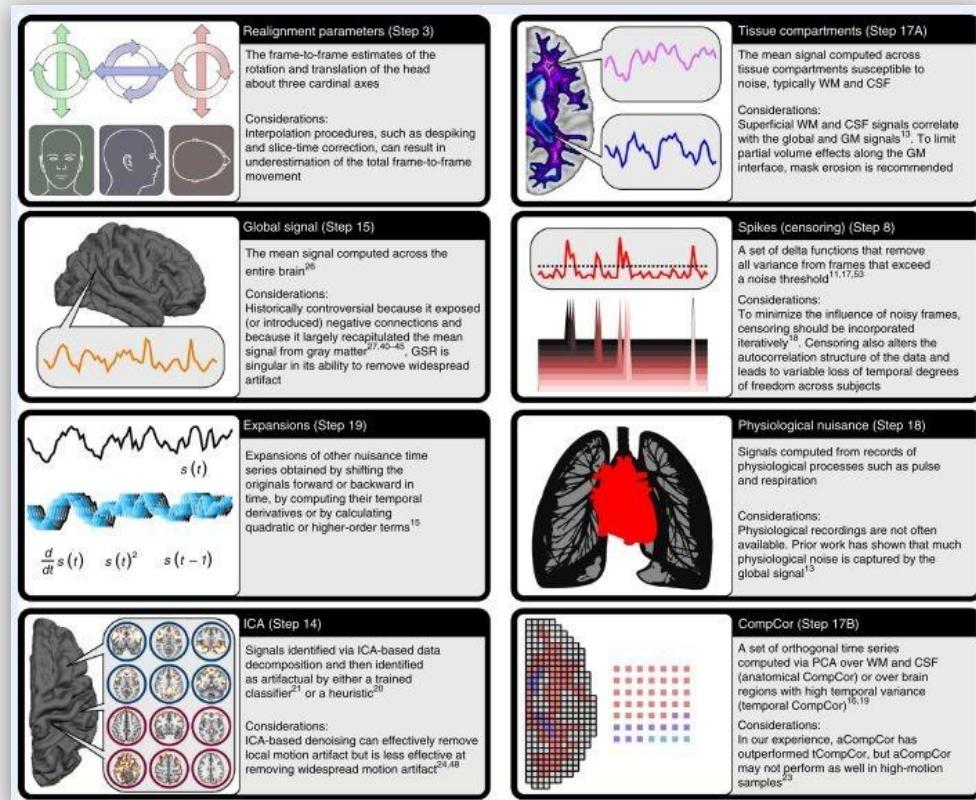
Clusters on a correlation matrix represents brain subnetworks (also known called **modules** or **large-scale systems**).



Hutchison & Morton, 2015

Spurious correlations

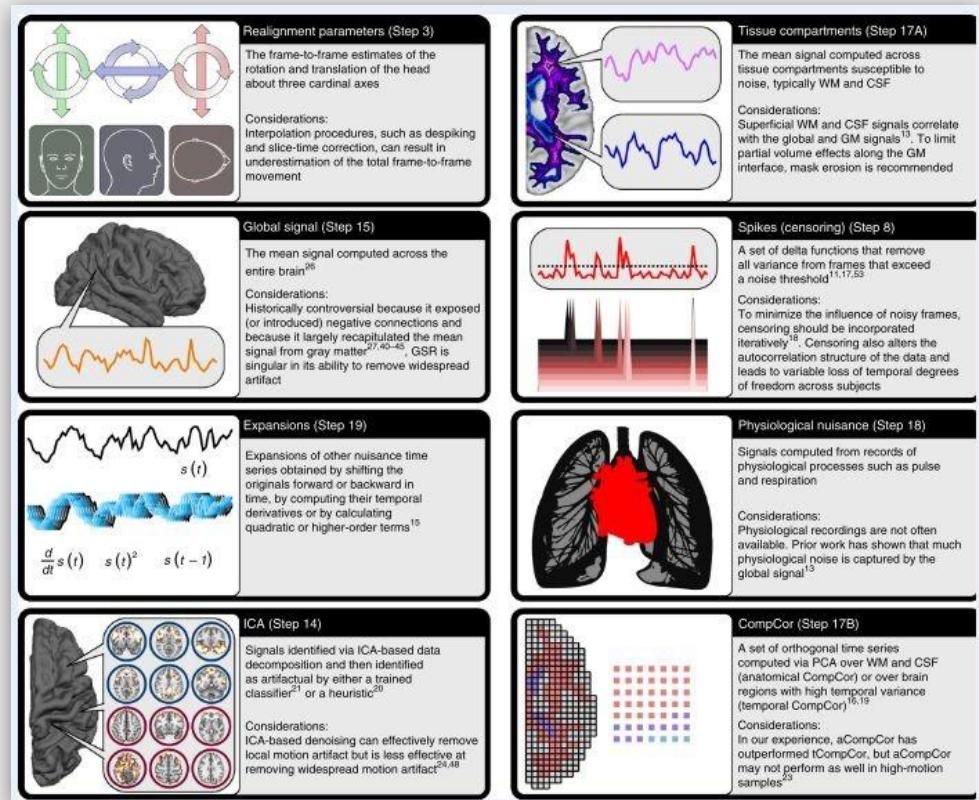
Signal of **non-neuronal origin**
(motion, physiological effects)
can pump the correlation values
between BOLD time-series.



Spurious correlations

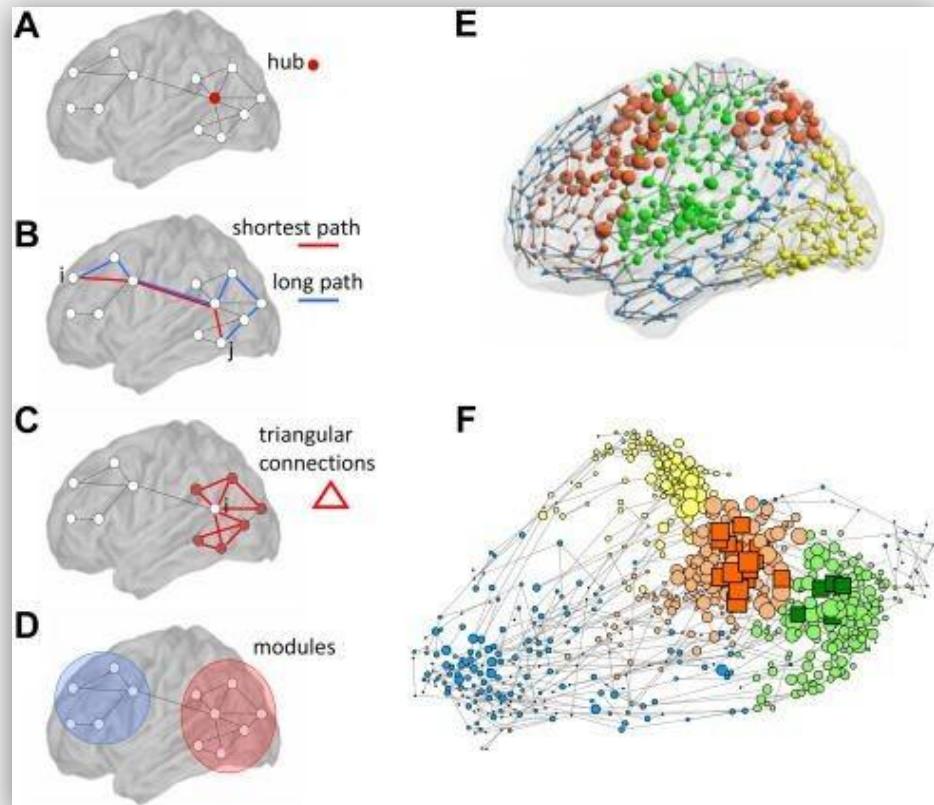
Signal of **non-neuronal origin**
(motion, physiological effects)
can pump the correlation values
between BOLD time-series.

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



Network neuroscience

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

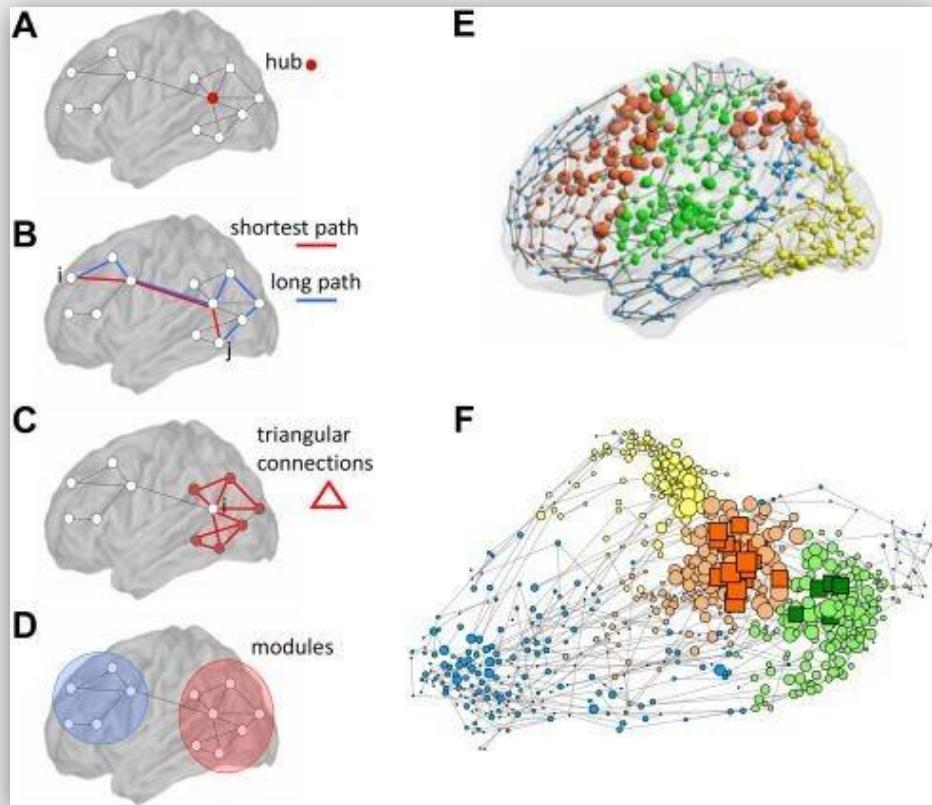


Morgan et al., 2018

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.

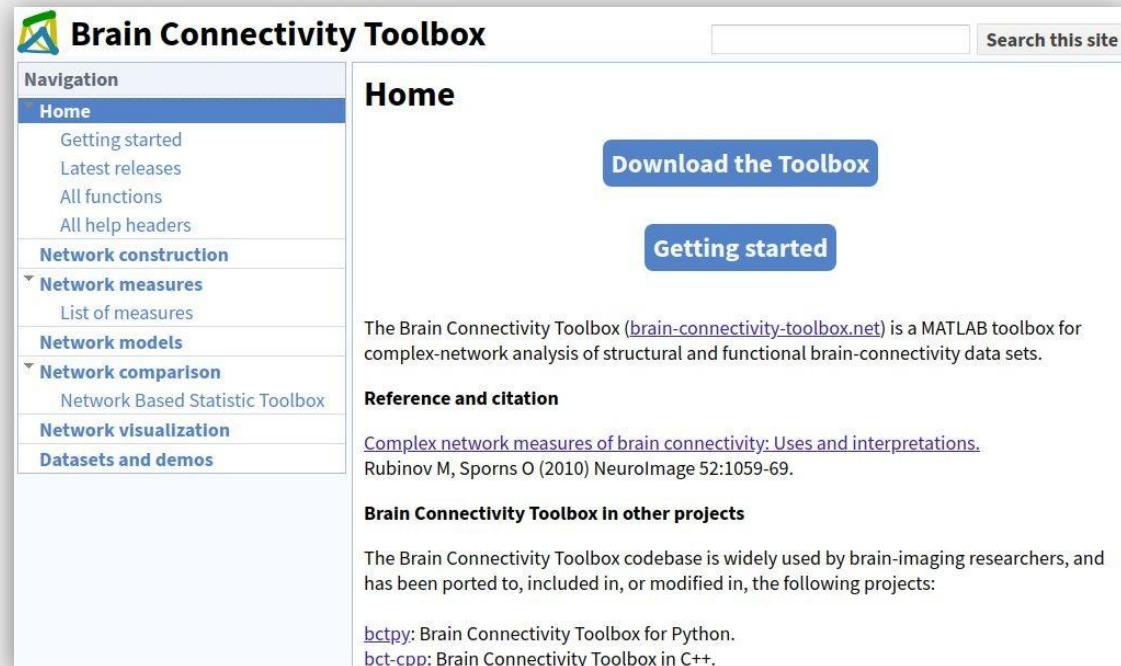


Morgan et al., 2018

Network neuroscience

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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 "Download the Toolbox" button, a "Getting started" button, and a paragraph about the toolbox. Below this are sections for "Reference and citation" (linking to a paper by Rubinov & Sporns), "Brain Connectivity Toolbox in other projects" (mentioning bctpy and bct-cpp), and a note about its use in other projects.

Brain Connectivity Toolbox

Search this site

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.

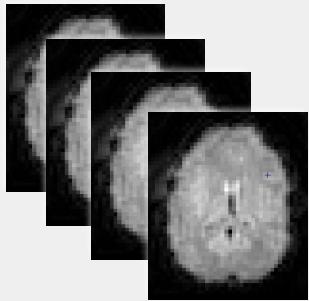
Brain Connectivity Toolbox in other projects

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++.

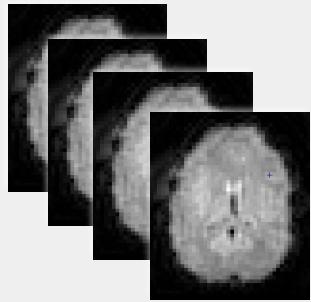
Workflow

fMRI data



Workflow

fMRI data

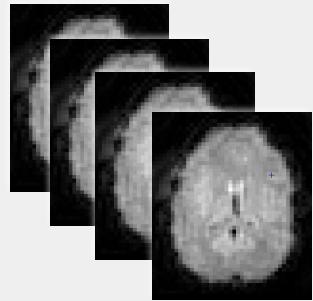


Denoising

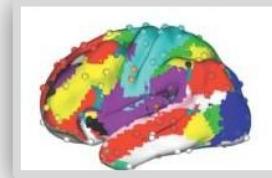
Workflow

Definition of brain regions

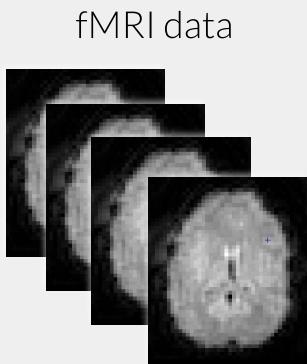
fMRI data



Denoising



Workflow

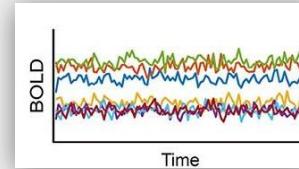
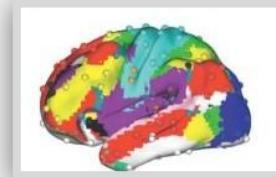


Denoising

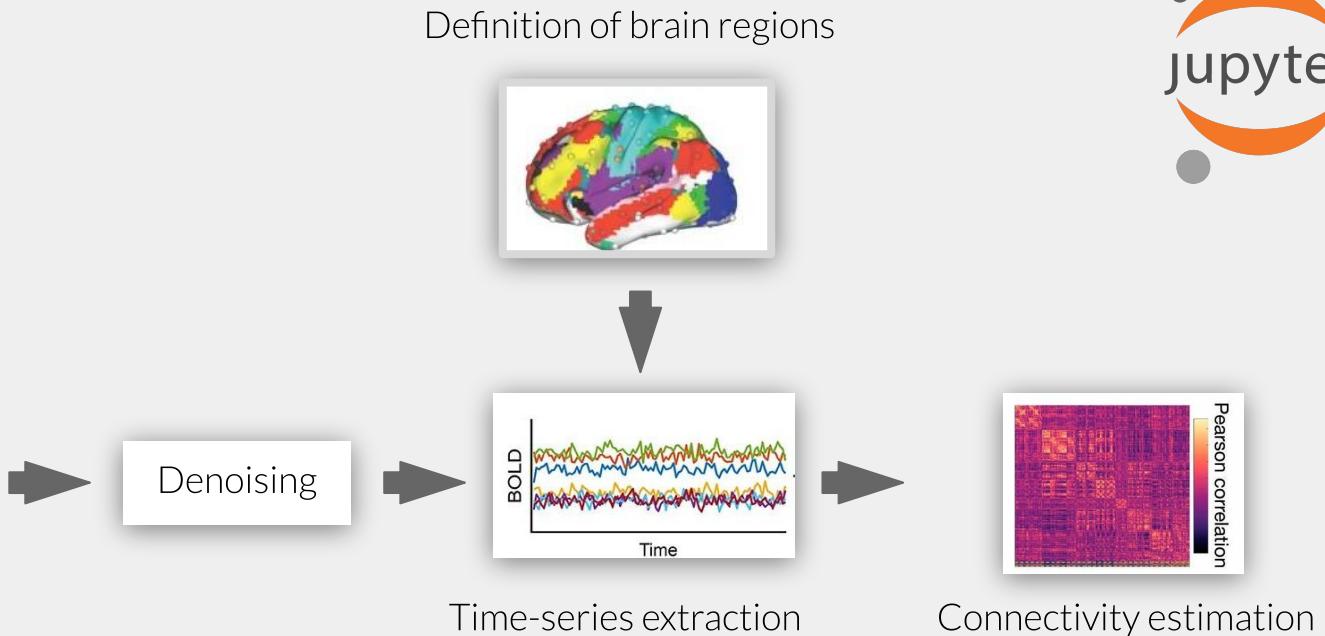
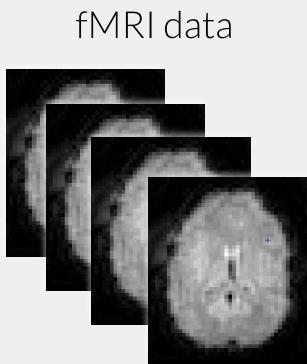


Time-series extraction

Definition of brain regions



Workflow



Homework

1. GitHub Classroom

Functional connectivity

Deadline: **12-02-2020**



Next



Machine learning