Fundamentals of fMRI data analysis

Karolina Finc

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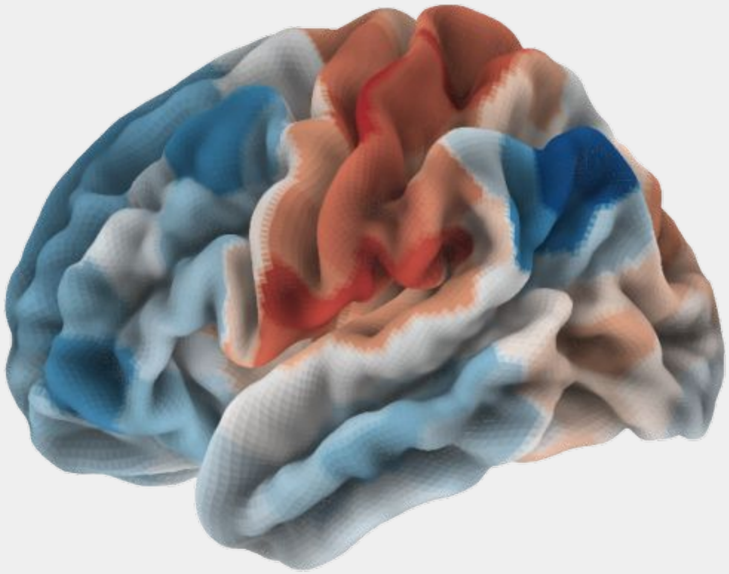


PART #6: Functional connectivity

Study plan

BEFORE

Open science & neuroimaging

fMRI data manipulation in python

fMRI data preprocessing

General Linear Model

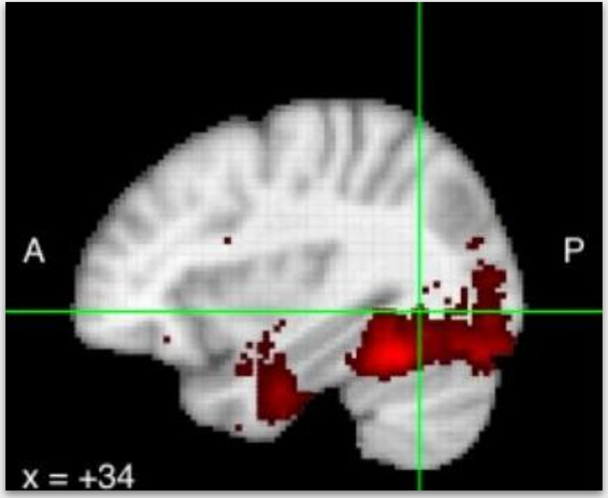
Functional connectivity

Machine Learning on fMRI data

AFTER

Goals of task-based fMRI

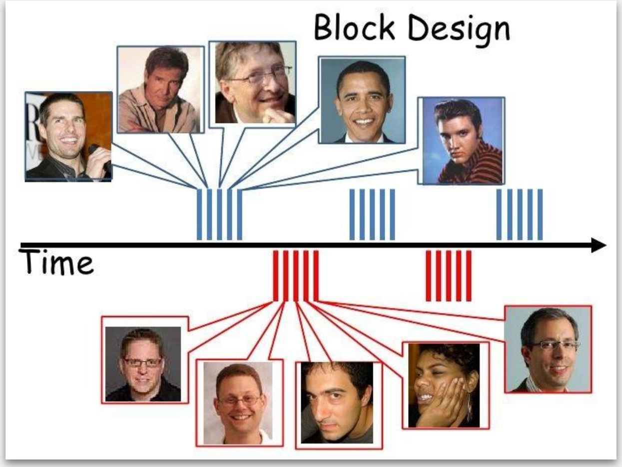
1. Induce in a study participant to do actions or experience cognitive states you're interested in.
2. You want to detect brain signals that are related to this cognitive states or actions.

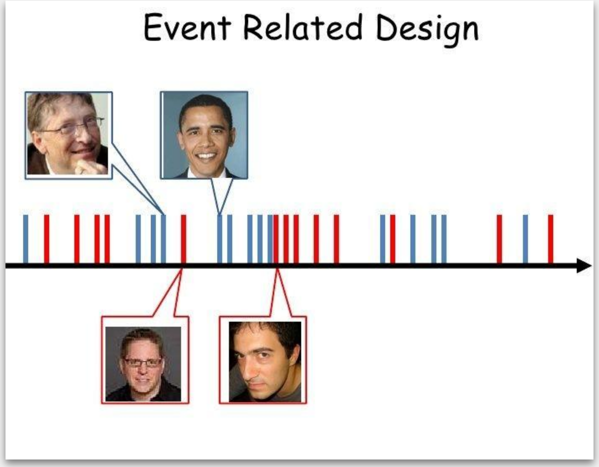


Task designs

Famous people

Non-famous people



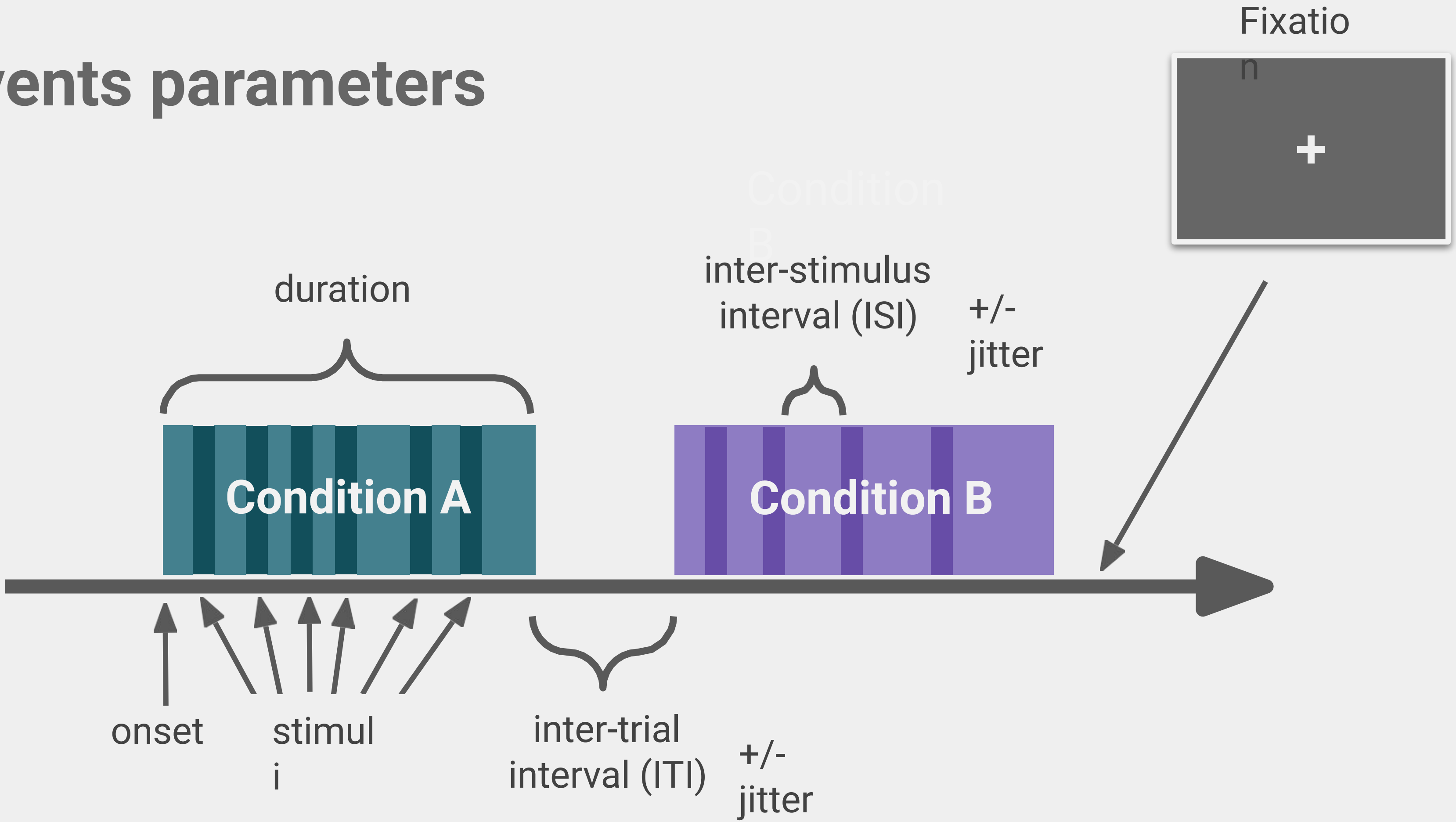


Block design
similar events are grouped

Event-related design
events are mixed

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

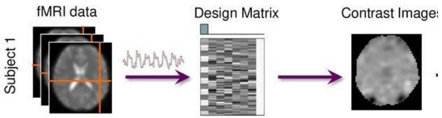
Events parameters



Analysis steps

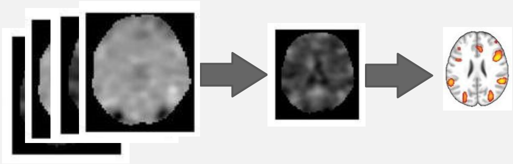
1-level analysis
(within-subject; individual)

How was the brain active in
a one particular brain?

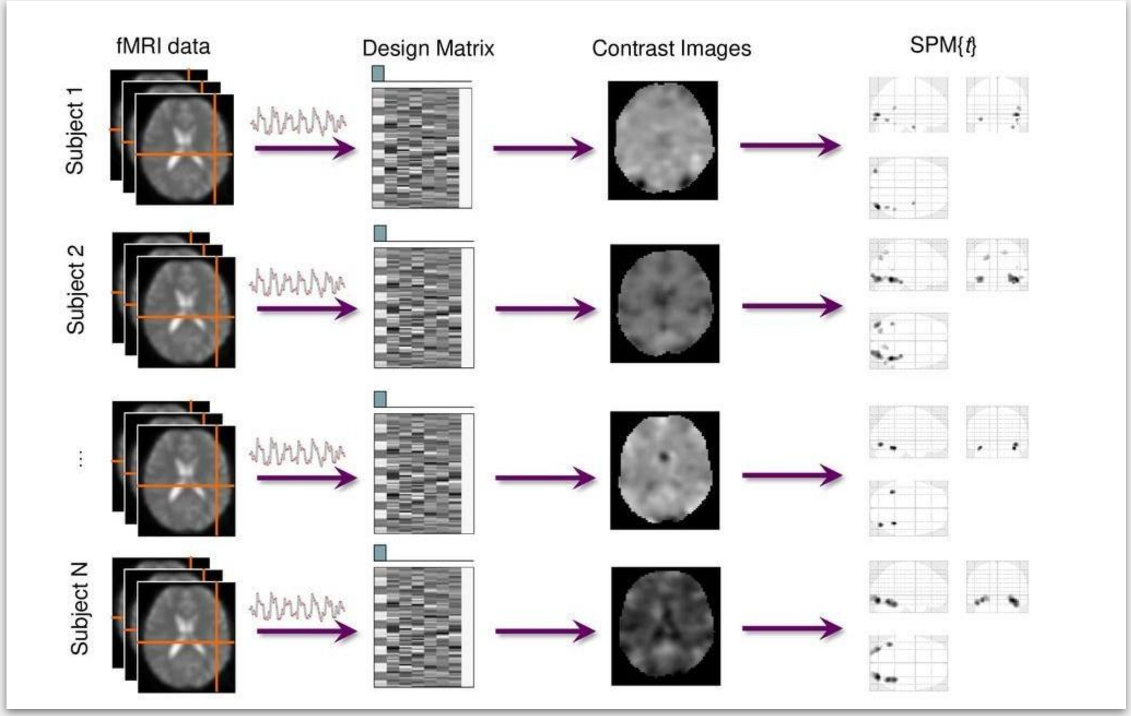


2-level analysis
(across-subject; group)

How brain activations look
in general (for the whole
group)?
Differences between groups?



1-level analysis



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

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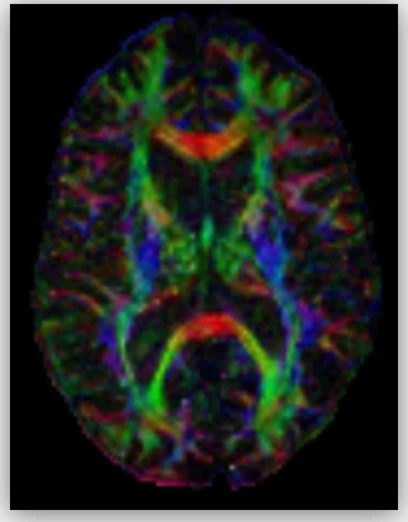
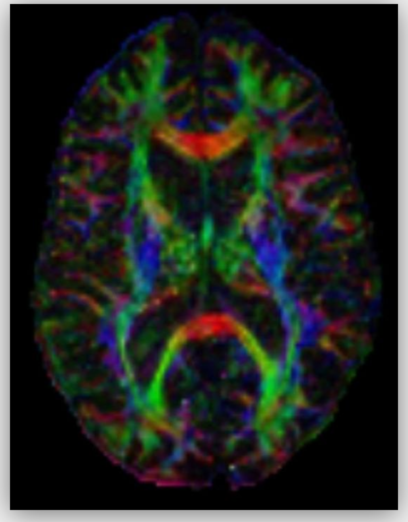
Structural connectivity



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

Structural connectivity



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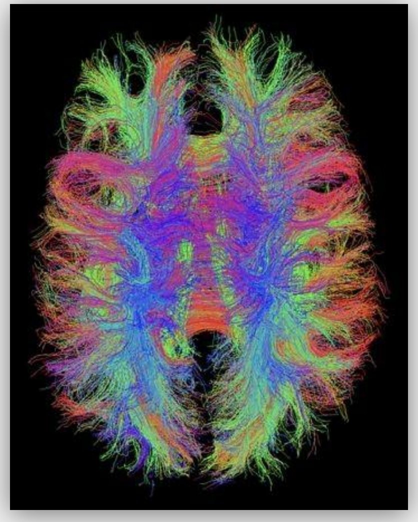
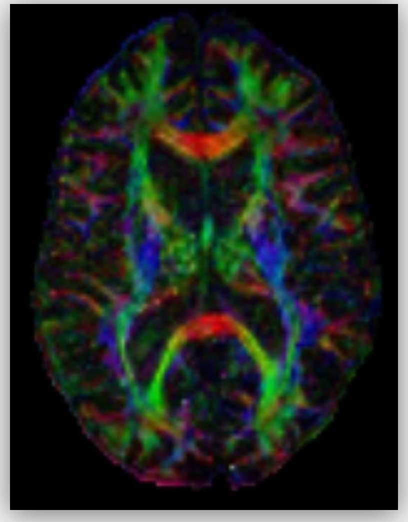


Tractography
is a modeling technique used to visually represent nerve tracts using data collected by diffusion MRI.

Structural connectivity



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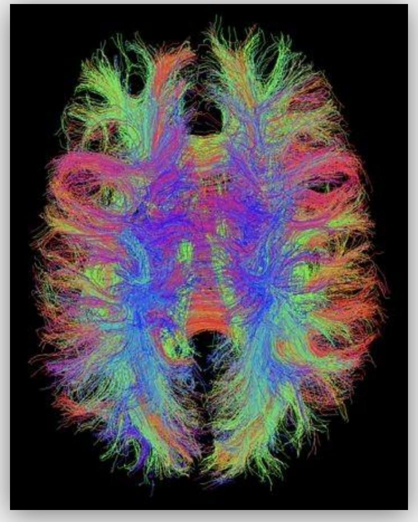

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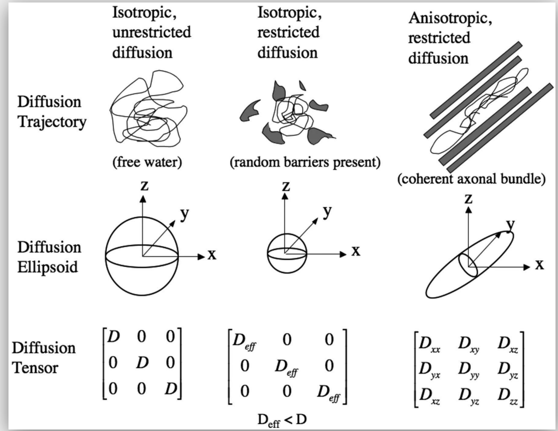
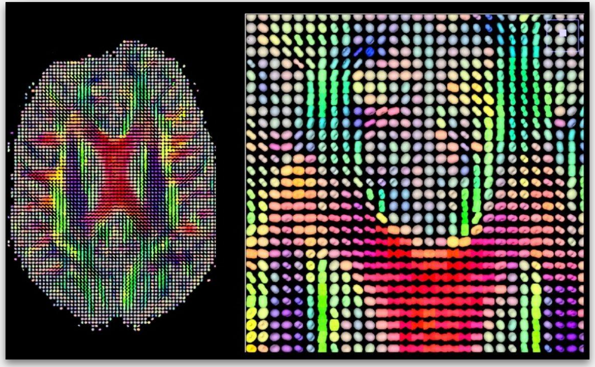
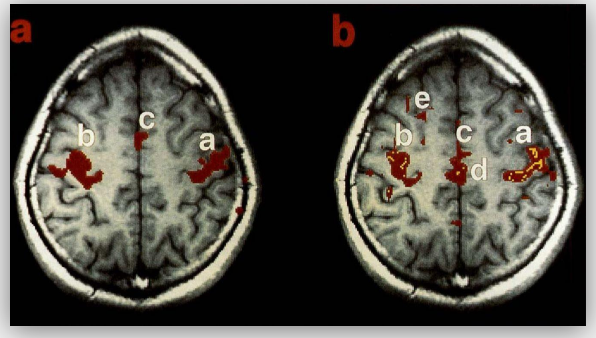




[Explore DTI animations]

Functional connectivity

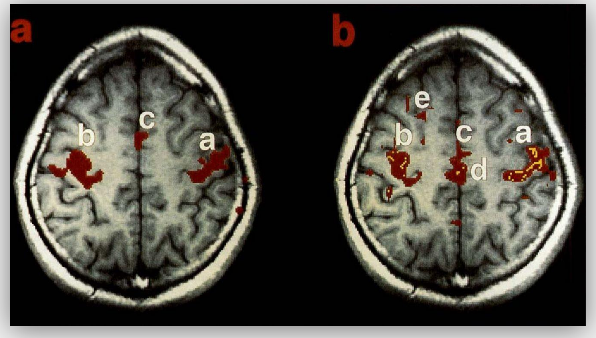
Motor task   Resting state



Biswal et al. (1995)

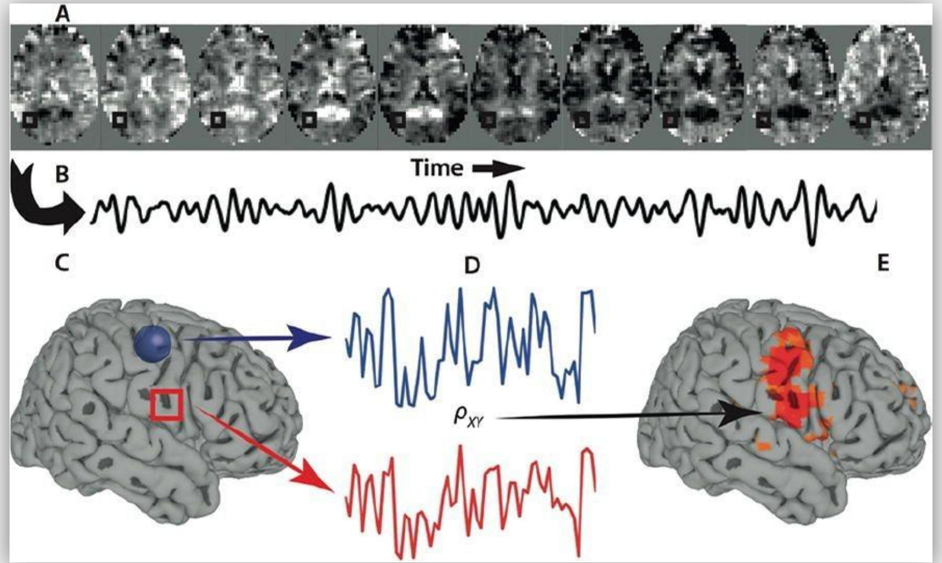
Functional connectivity

Motor task Resting state



Biswal et al. (1995)

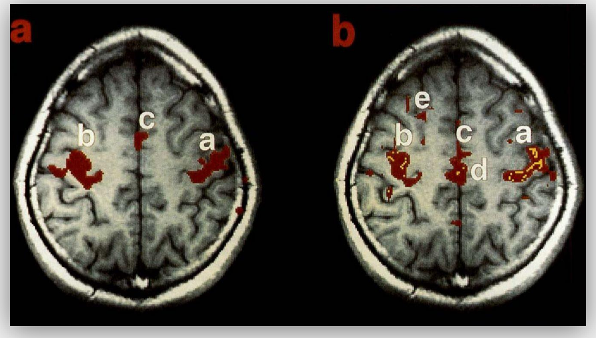
Seed-based approach



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

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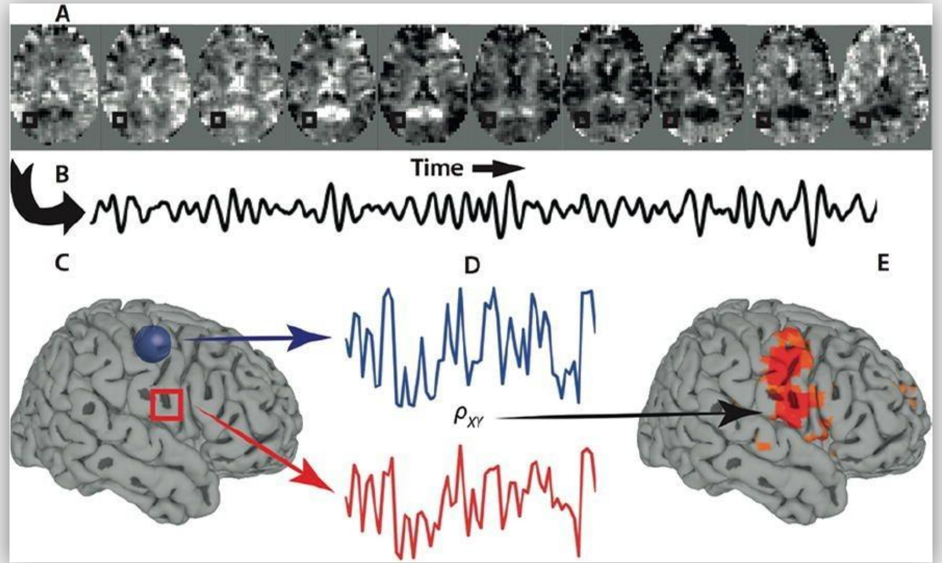

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Functional connectivity

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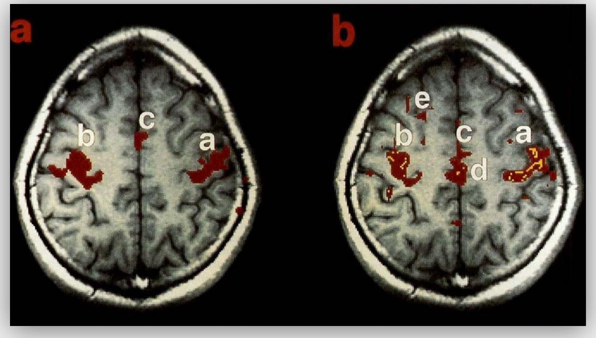

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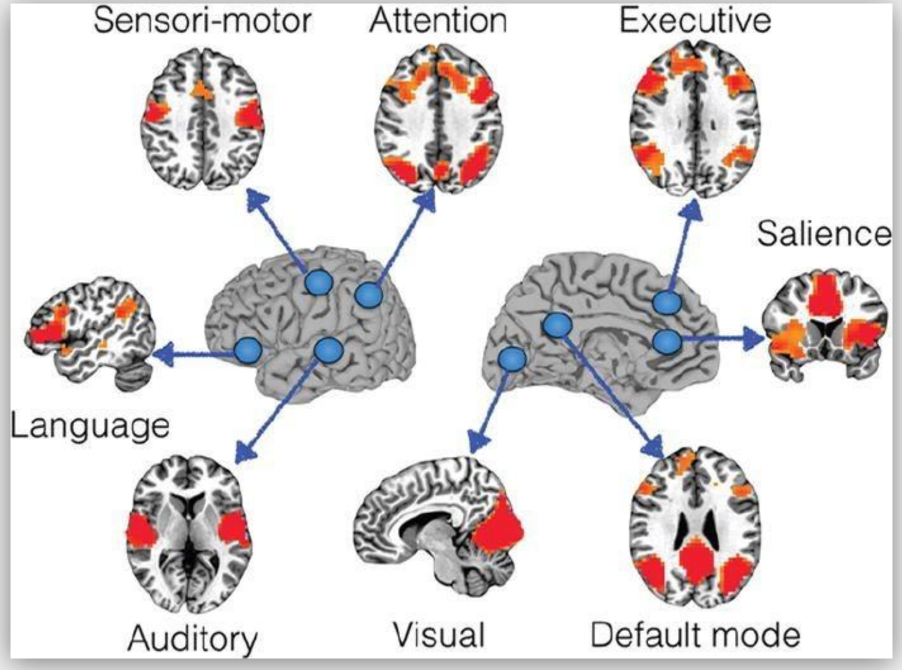
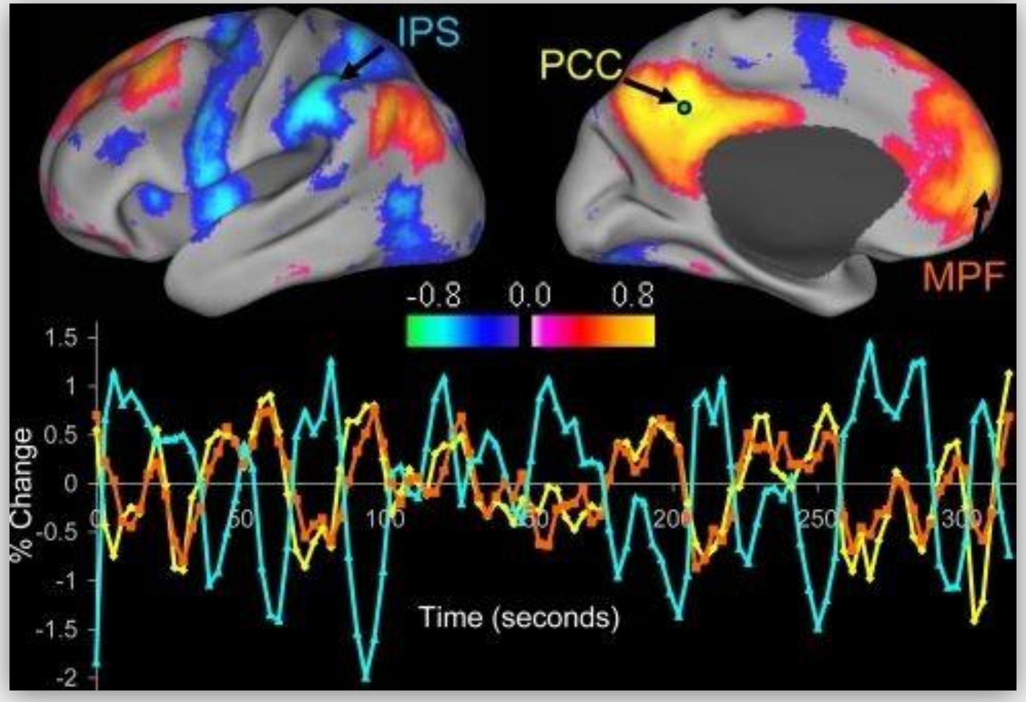
Resting-state networks



Hart et al. (2016)

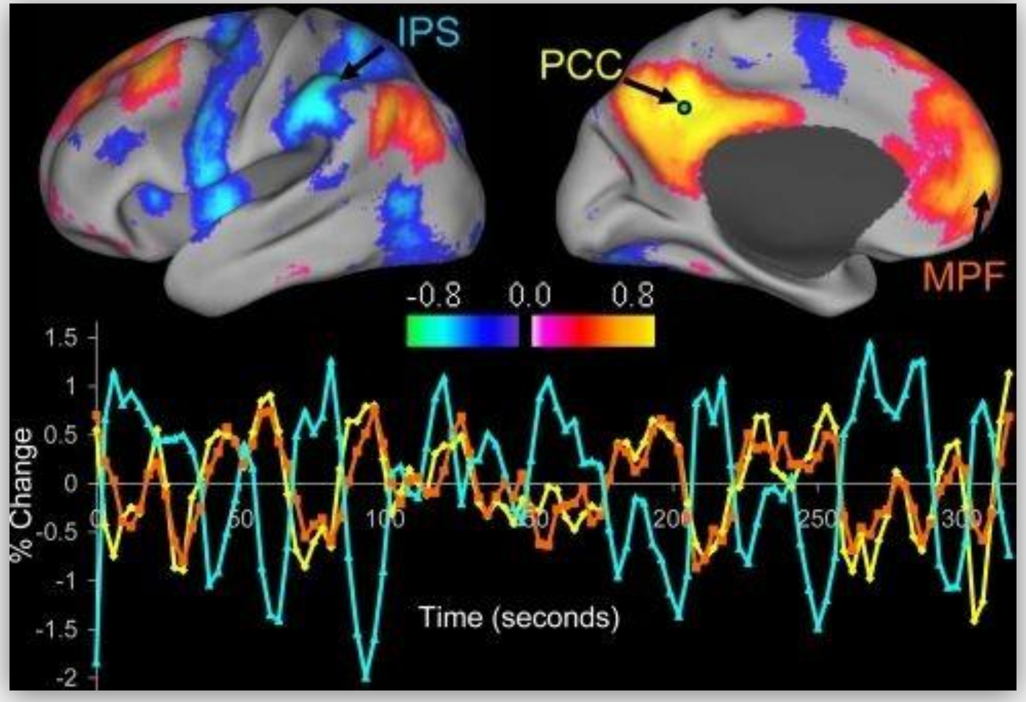
Anticorrelated networks



Fox et al. (2005)

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

Anticorrelated networks



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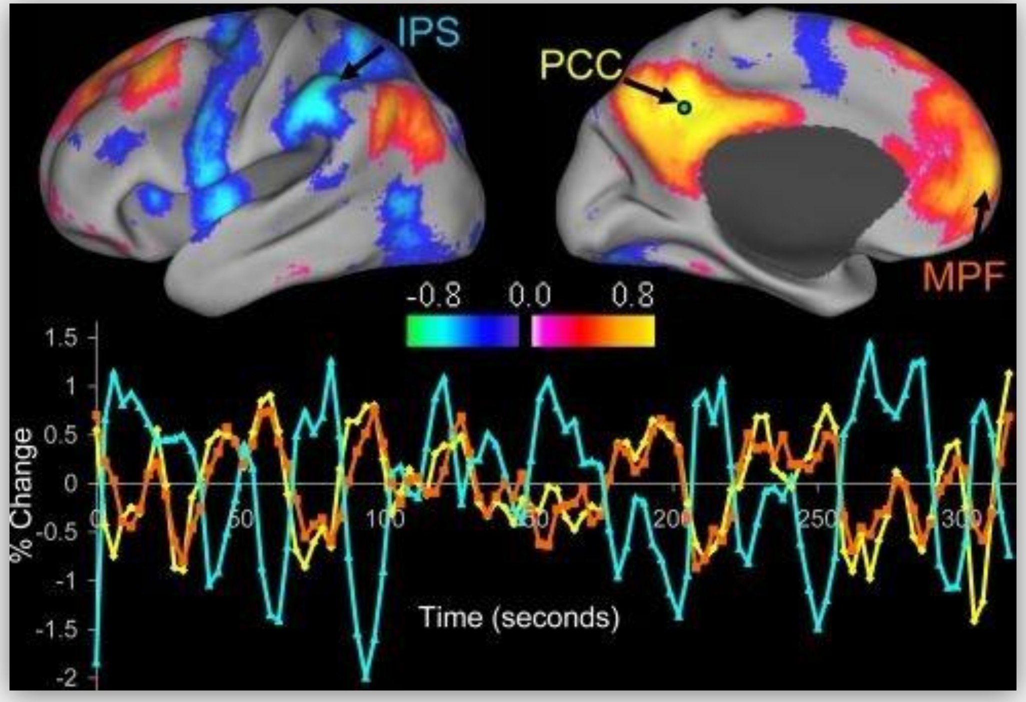
Task-negative networks that are inactive during cognitively demanding tasks (e.g. default mode network).

Anticorrelated networks



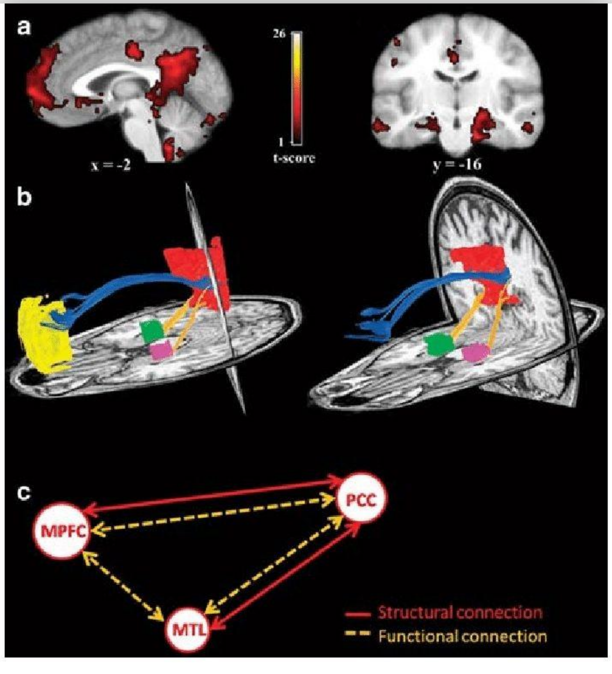
Fox et al. (2005)

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

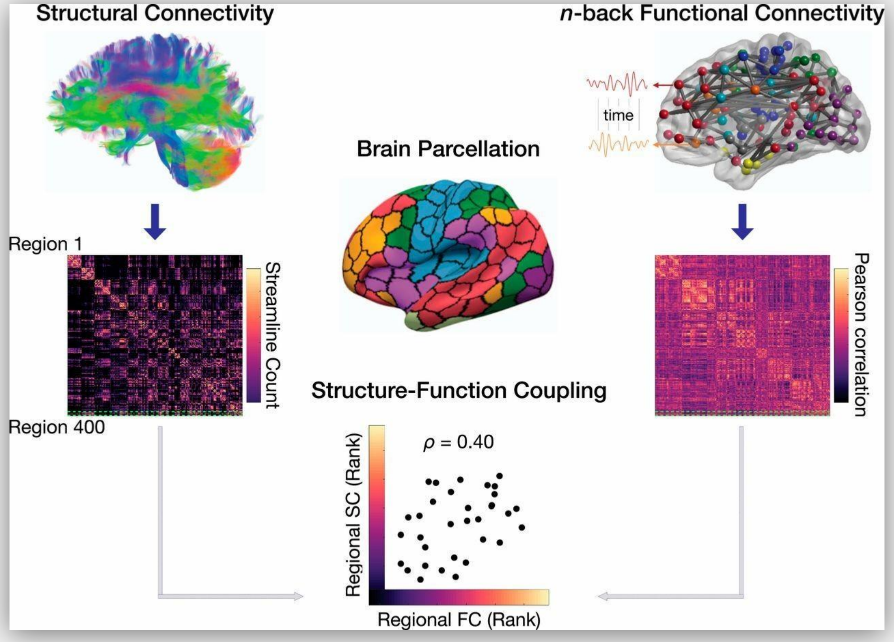
Task-negative networks that are inactive during cognitively demanding tasks (e.g. default mode network).

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

Functional connectivity vs structural connectivity

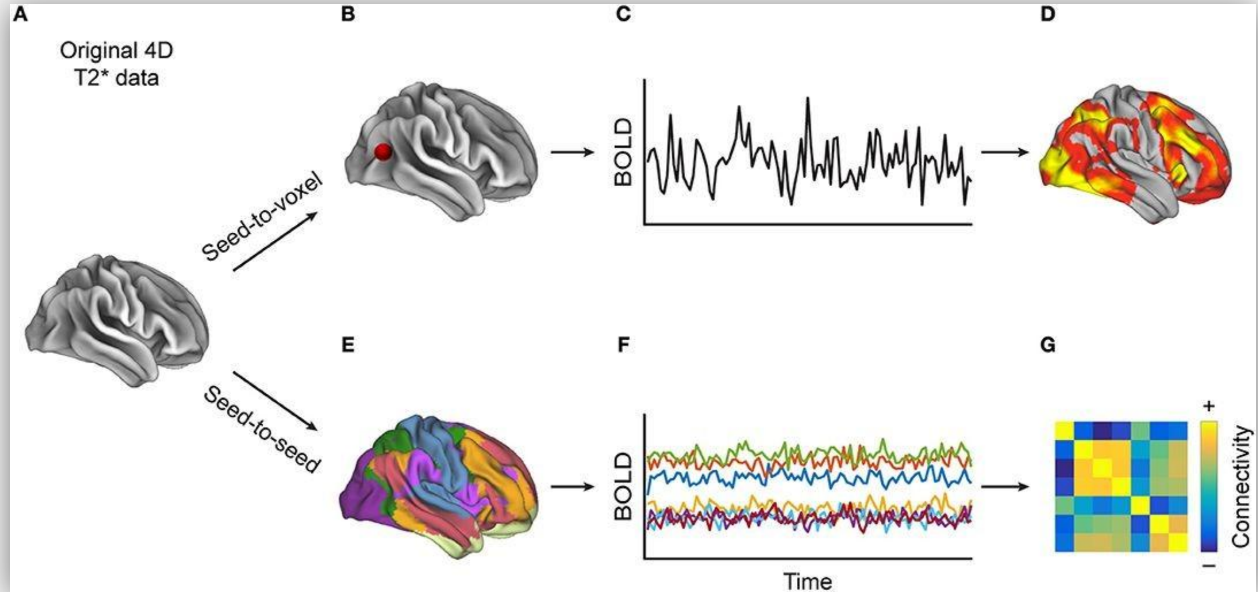


Greicius et al. (2009)



Baum et al. (2019)

Functional connectivity: methods



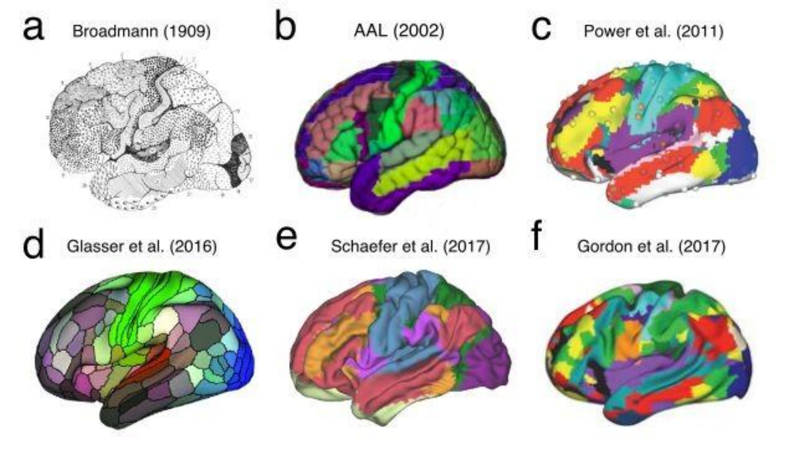
Seed - predefined region of the brain.

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

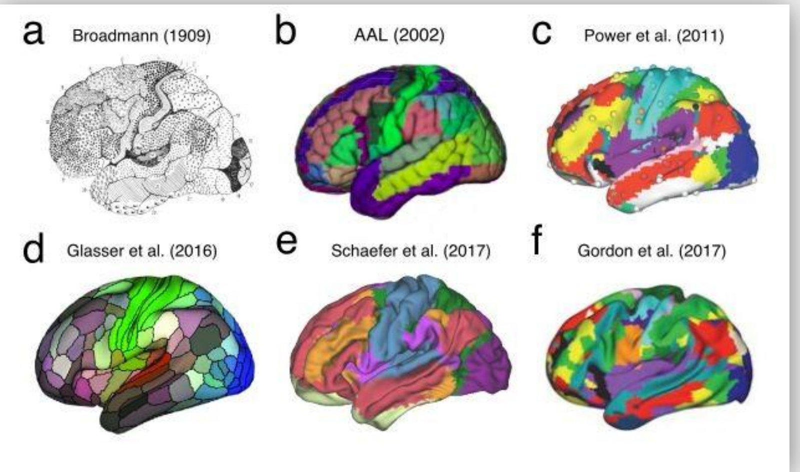
Seed-to-seed - calculating correlations between seed regions.

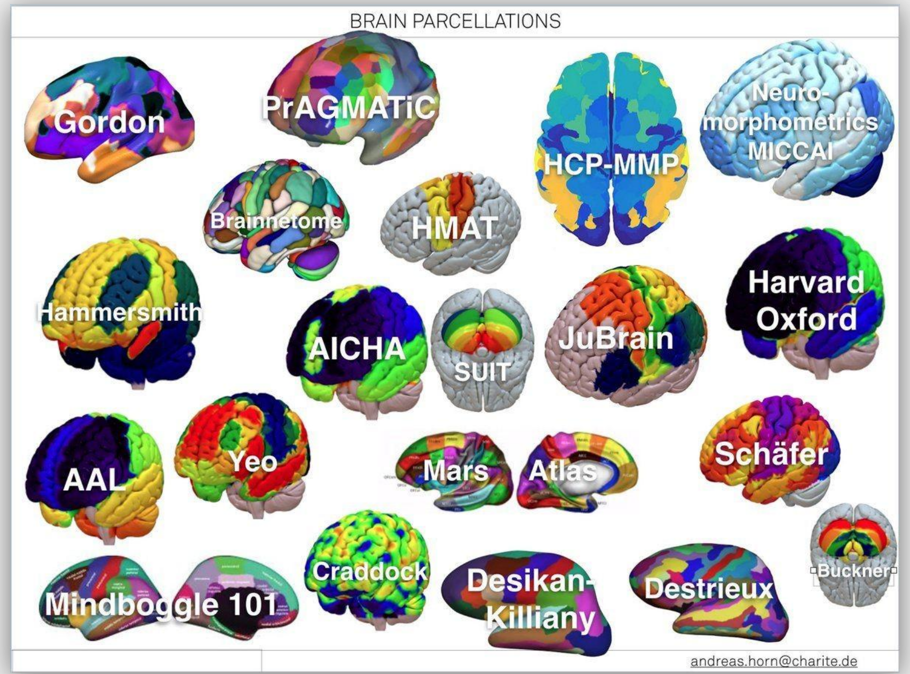
Where to get brain parcellation?

Brain parcellations



Brain parcellations





[Atlas resources]

Correlation

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

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

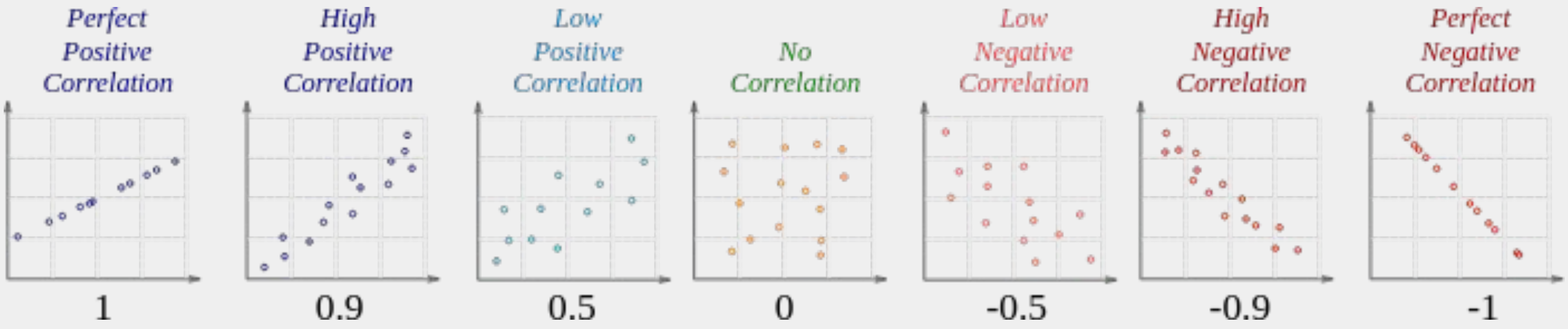
Where, $\overline{X}$ = mean of X variable

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

Covariance

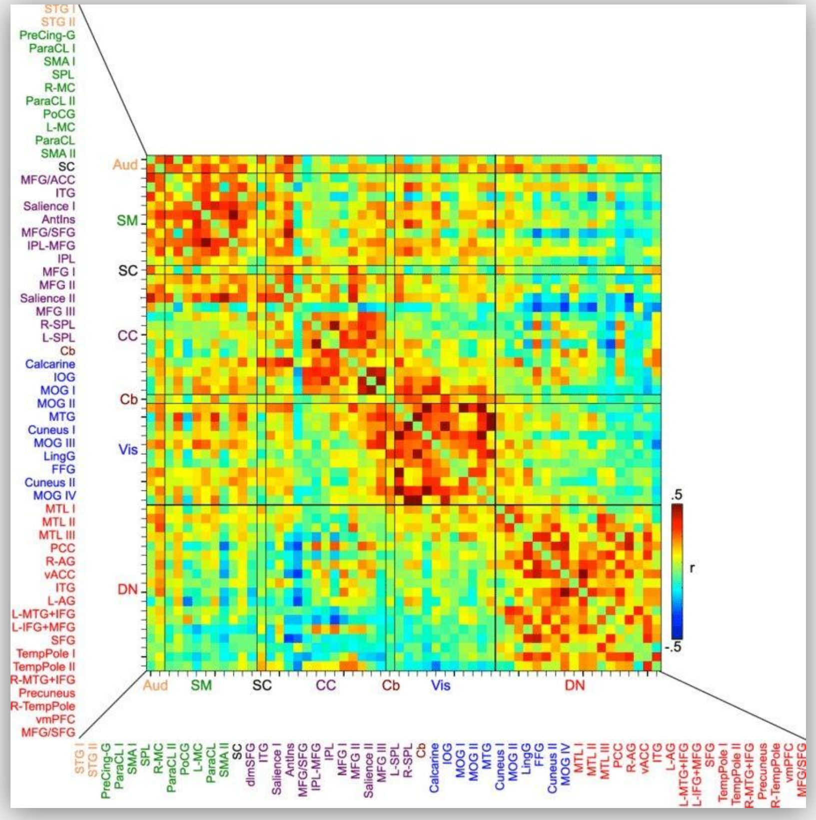
$$Correlation = \frac{Cov\ (x,y)}{\sigma x * \sigma y}$$

Standard deviation



Correlation matrix

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

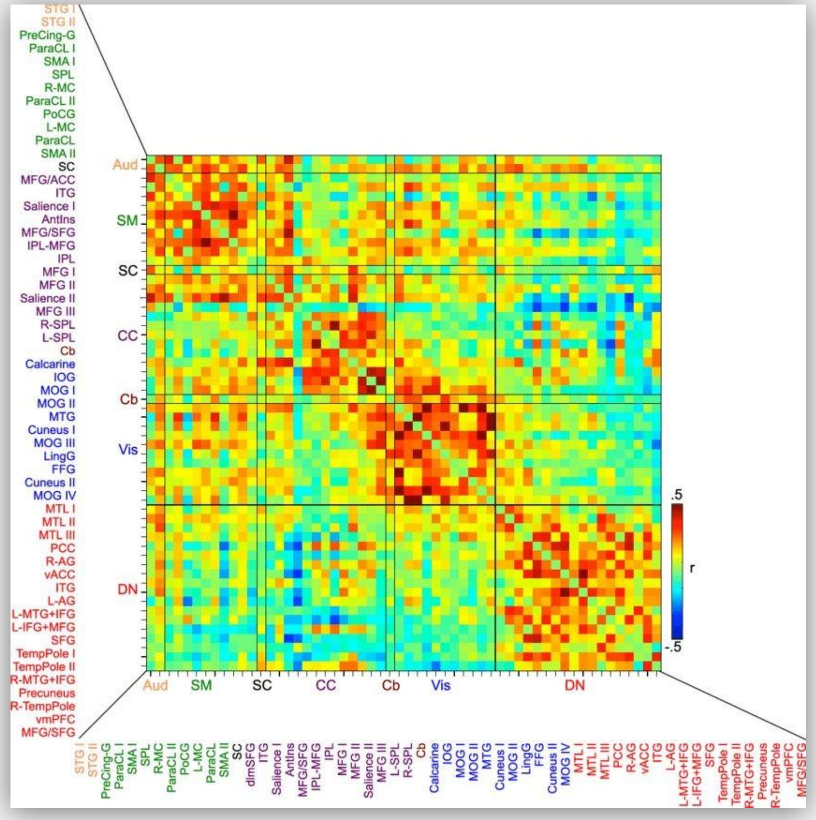


Hutchison & Morton, 2015

Correlation matrix

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

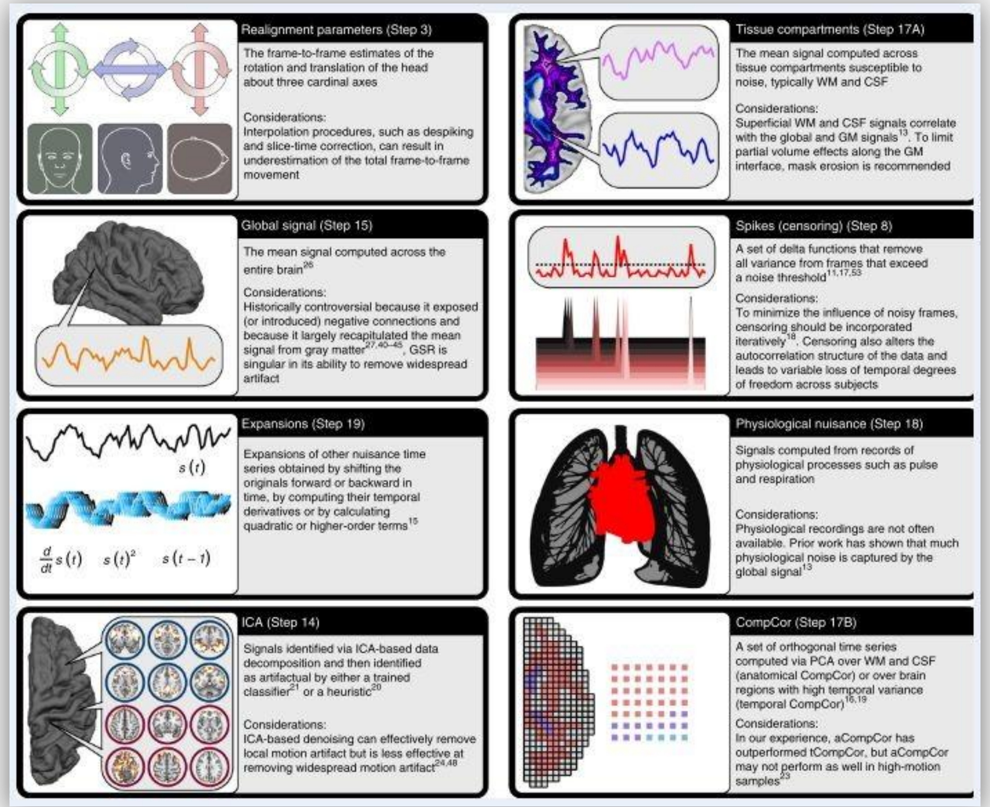
Clusters on a correlation matrix represents brain subnetworks (also known called **modules** or **large-scale systems**).



Hutchison & Morton, 2015

Spurious correlations

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

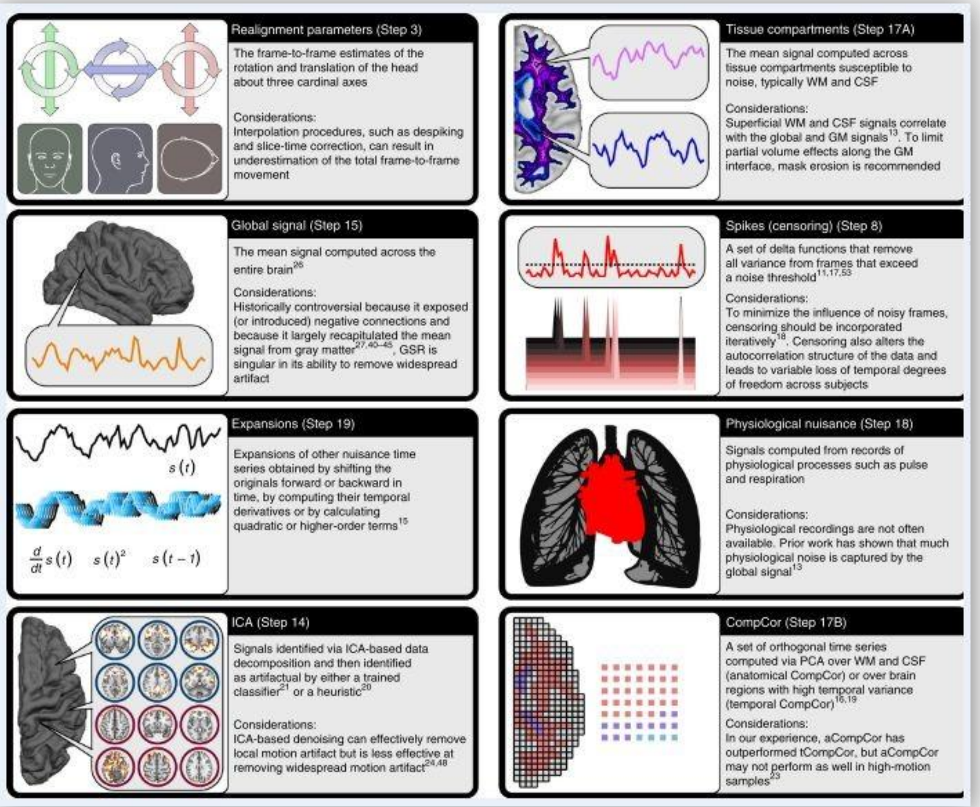


Ciric et al., 2018

Spurious correlations

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

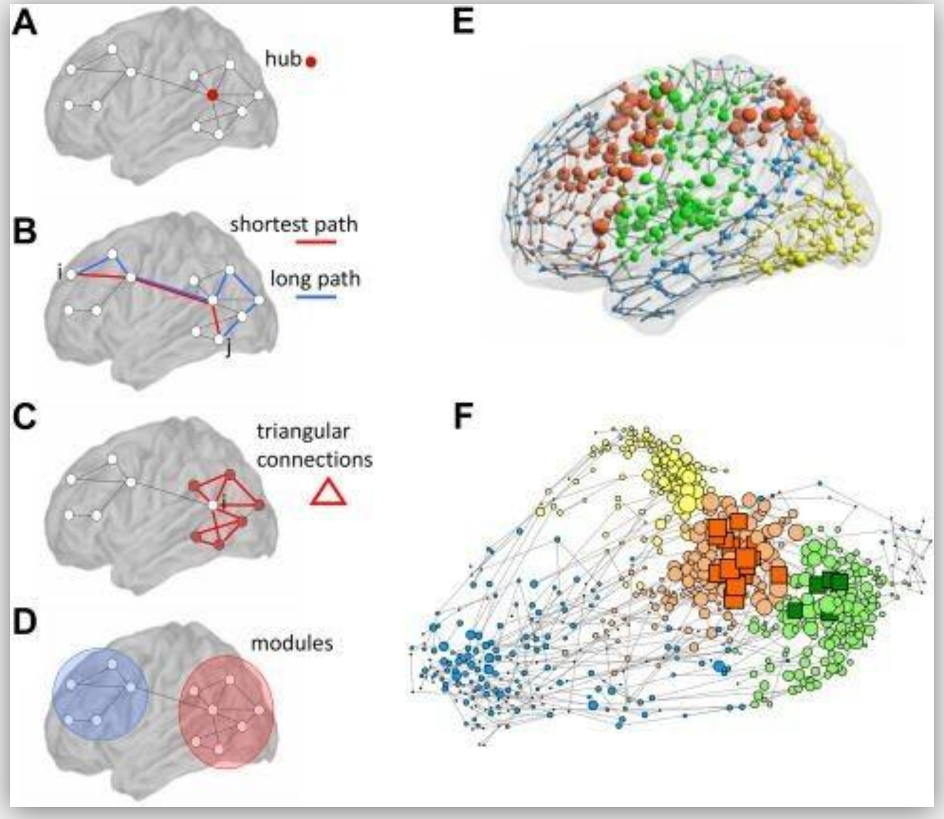
Denoising procedure - regressing out confounding signals might minimise the level of spurious correlations in studies focused on functional connectivity.



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

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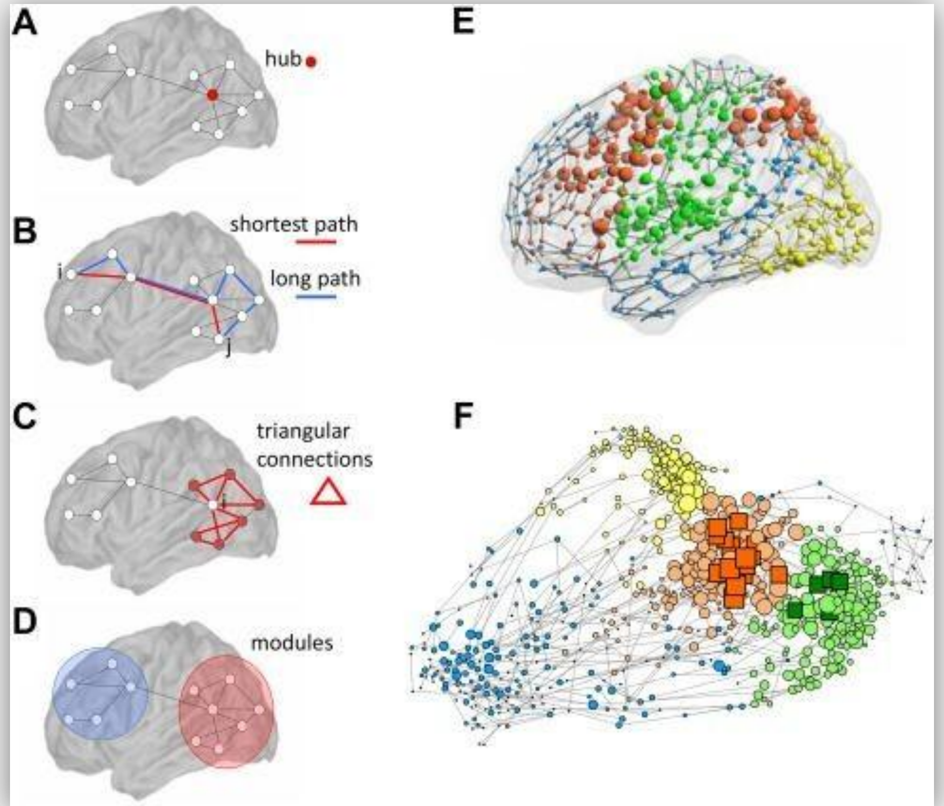
Network science - field which studies complex networks, considering distinct elements represented by **nodes** (or vertices) and the **edges** (or connections) between them.



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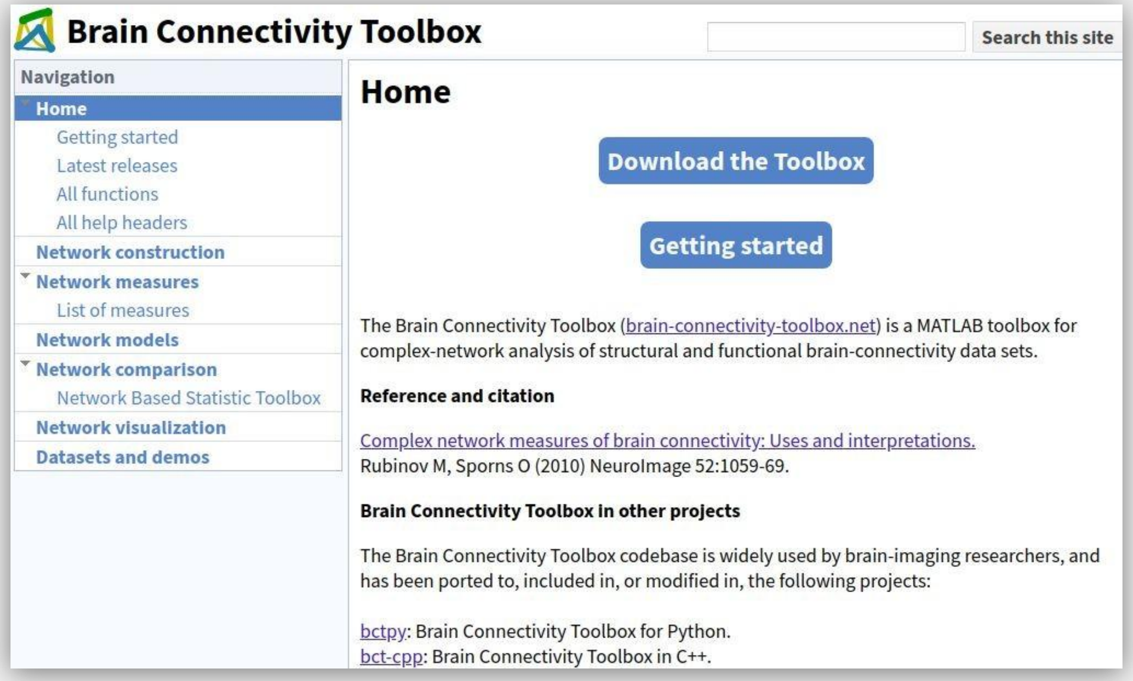
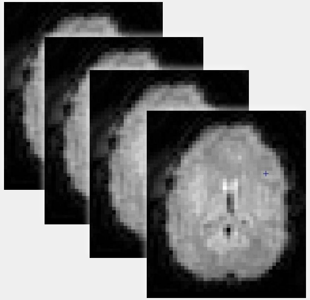


Workflow

fMRI data



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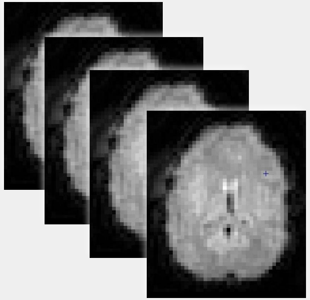
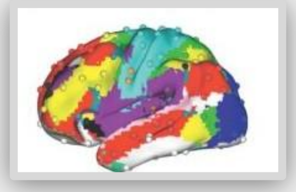


Denoising

Workflow

Definition of brain regions



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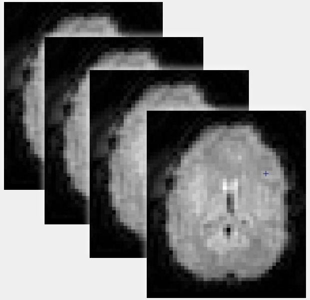

Denoising

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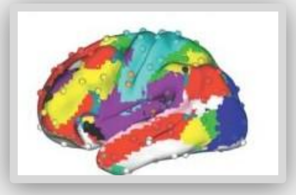

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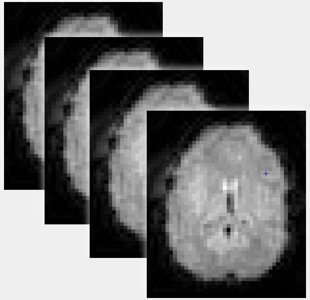

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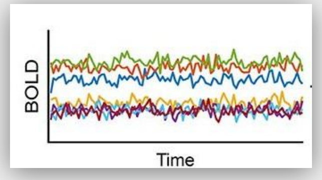
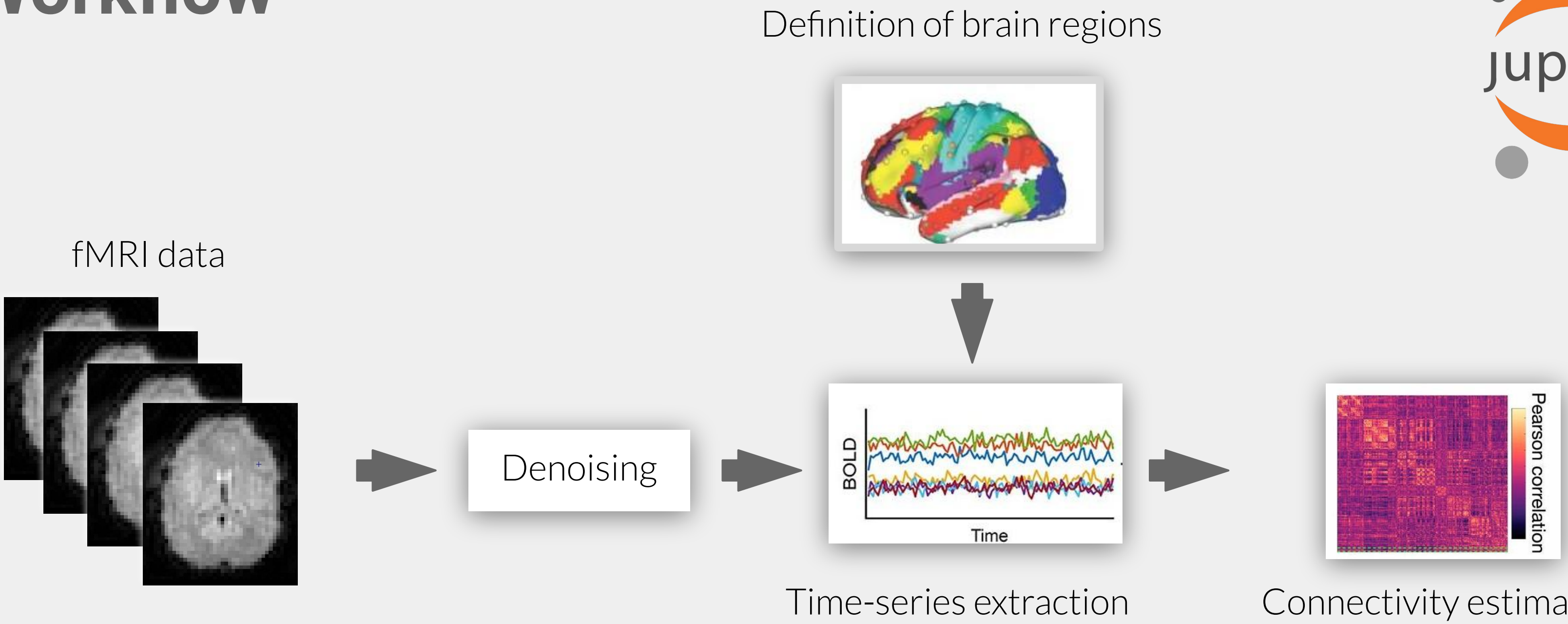
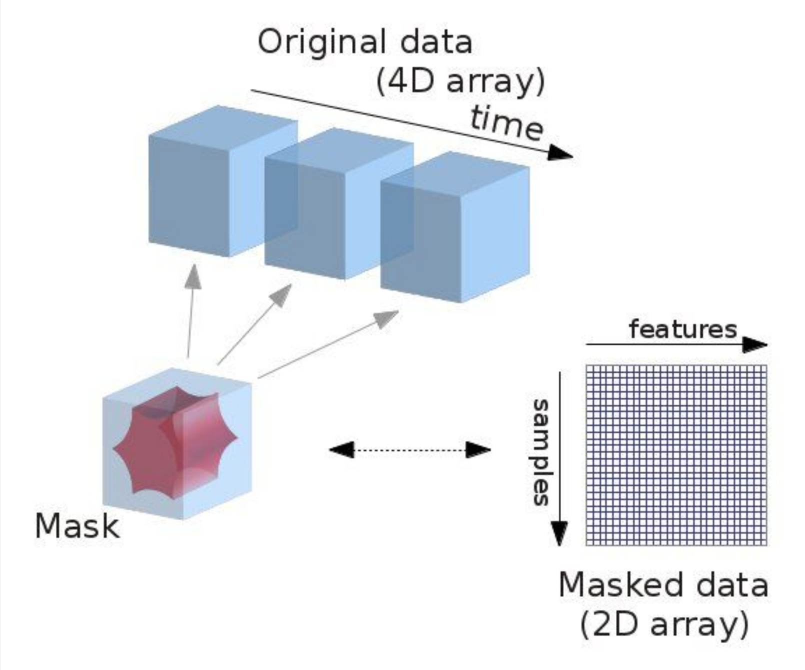


Time-series extraction

Workflow


Definition of brain regions
fMRI data
Denoising
BOLD
Time
Pearson correlation
Time-series extraction
Connectivity estimation

Masking data: from 4D to 2D



Homework

1. **GitHub Classroom**

   Functional connectivity

1.

Next

› Machine learning