



IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

WASAA – Practical machine learning on brain signals 1

Nicolas Farrugia
January 2023

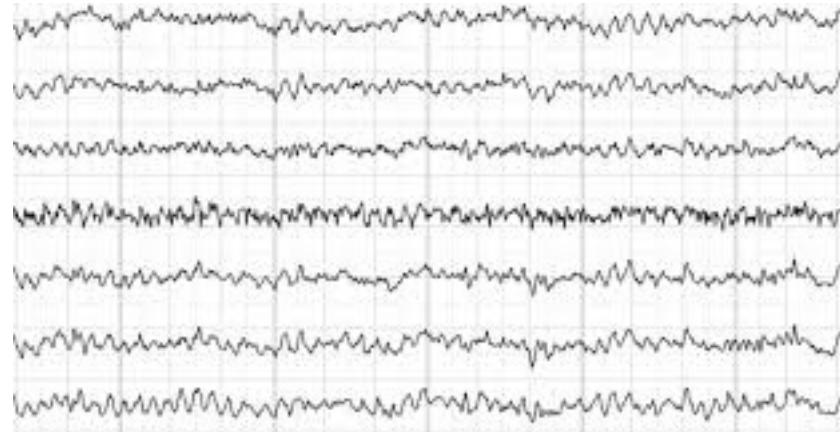
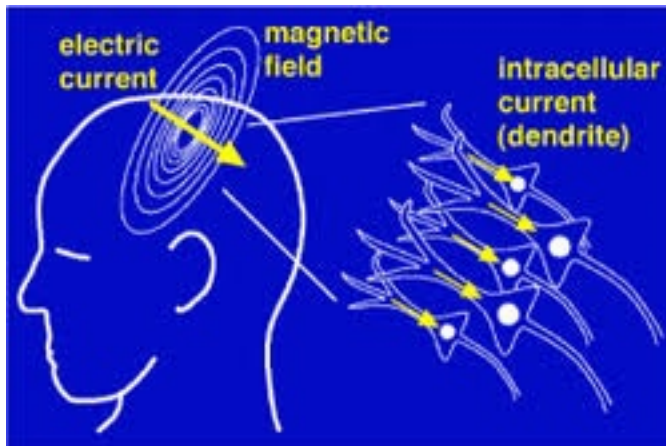
Agenda

1. Neuroimaging techniques
2. Brain Connectivity using MRI
3. Lab session

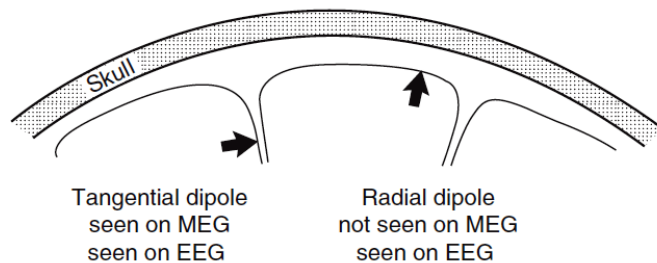


IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

- ▶ Electroencephalography (EEG)
- ▶ Electrical current measured at the scalp level
- ▶ Up to 256 electrodes at 1000 Hz
- ▶ Many sources of artifacts

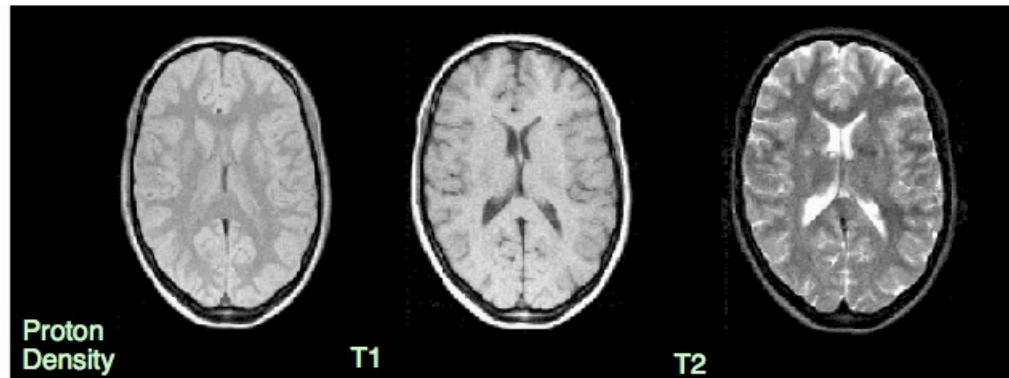


- ▶ Magnetoencephalography (MEG)
- ▶ Magnetic field resulting from neuronal activity
- ▶ Enables better source localization
- ▶ Extremely costly

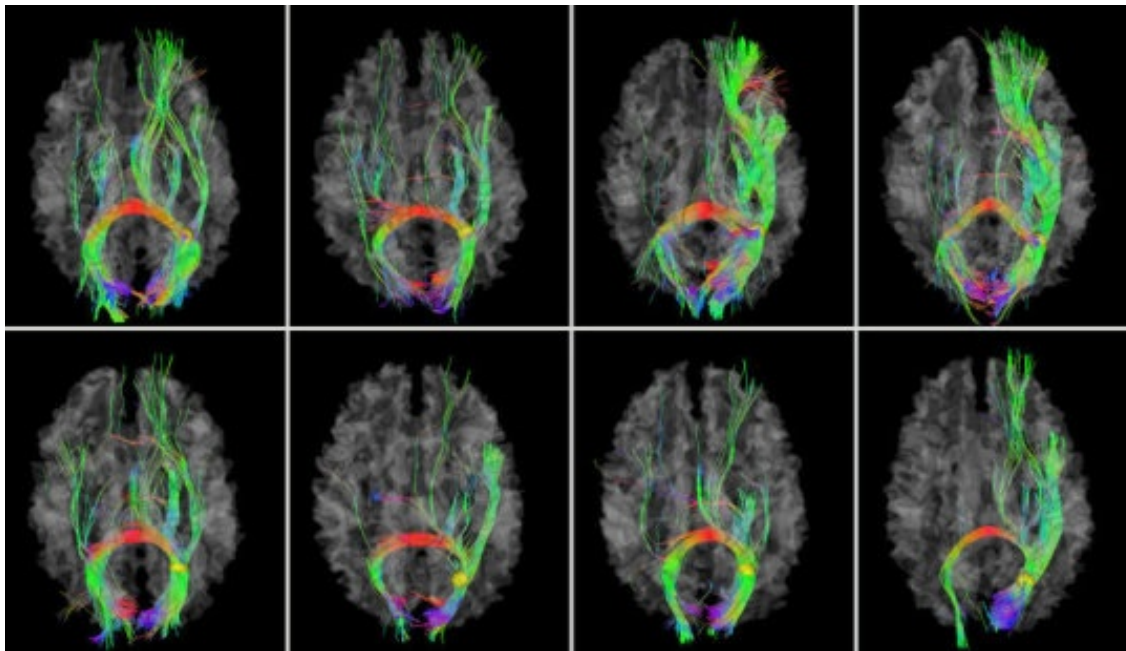


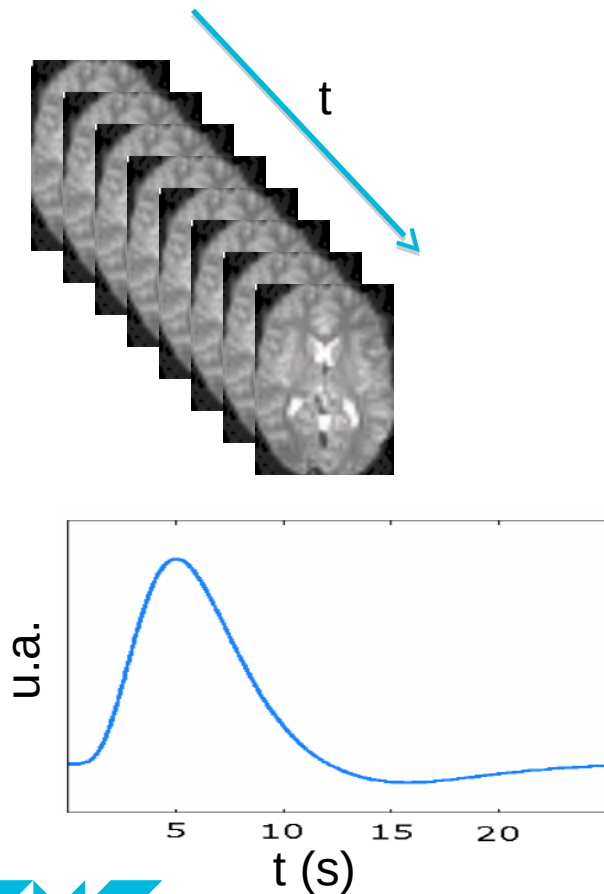


- ▶ 3D brain images -> volumes
- ▶ Different contrast types are generated w.r.t. local tissue properties
- ▶ Structural MRI, Diffusion MRI,
- ▶ Functional MRI.



- ▶ Diffusion MRI
- ▶ Contrast sensitive to the direction of water molecules present around white matter
- ▶ Can be used to estimate brain structural connectivity (fibers of white matter)

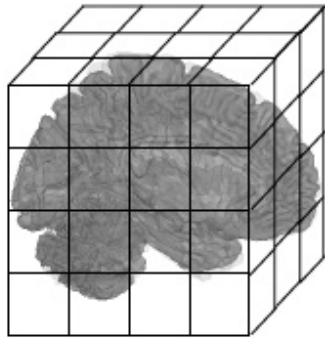




fMRI enables the study of cognitive and affective functions in the brain by an indirect estimation of brain activity

Echo Planar Imaging sequences generate a contrast sensitive to the so-called « Blood-Oxygen Level Dependent » (BOLD) signal

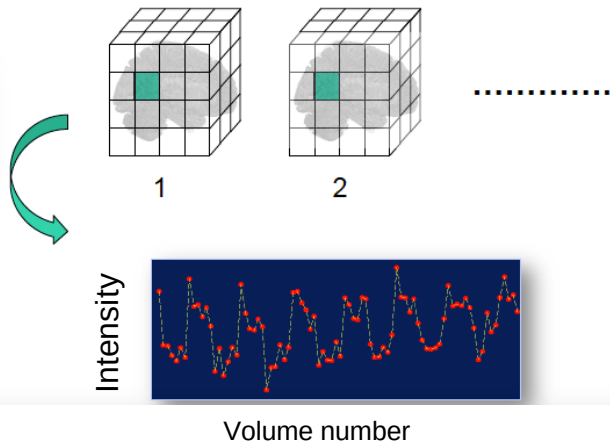
- ▶ Local loss of oxygen in hemoglobin as a result of neuronal activity – Hemodynamic response
- ▶ Subtle variations in the BOLD signal indirectly reflect brain activity (+ several seconds lag)



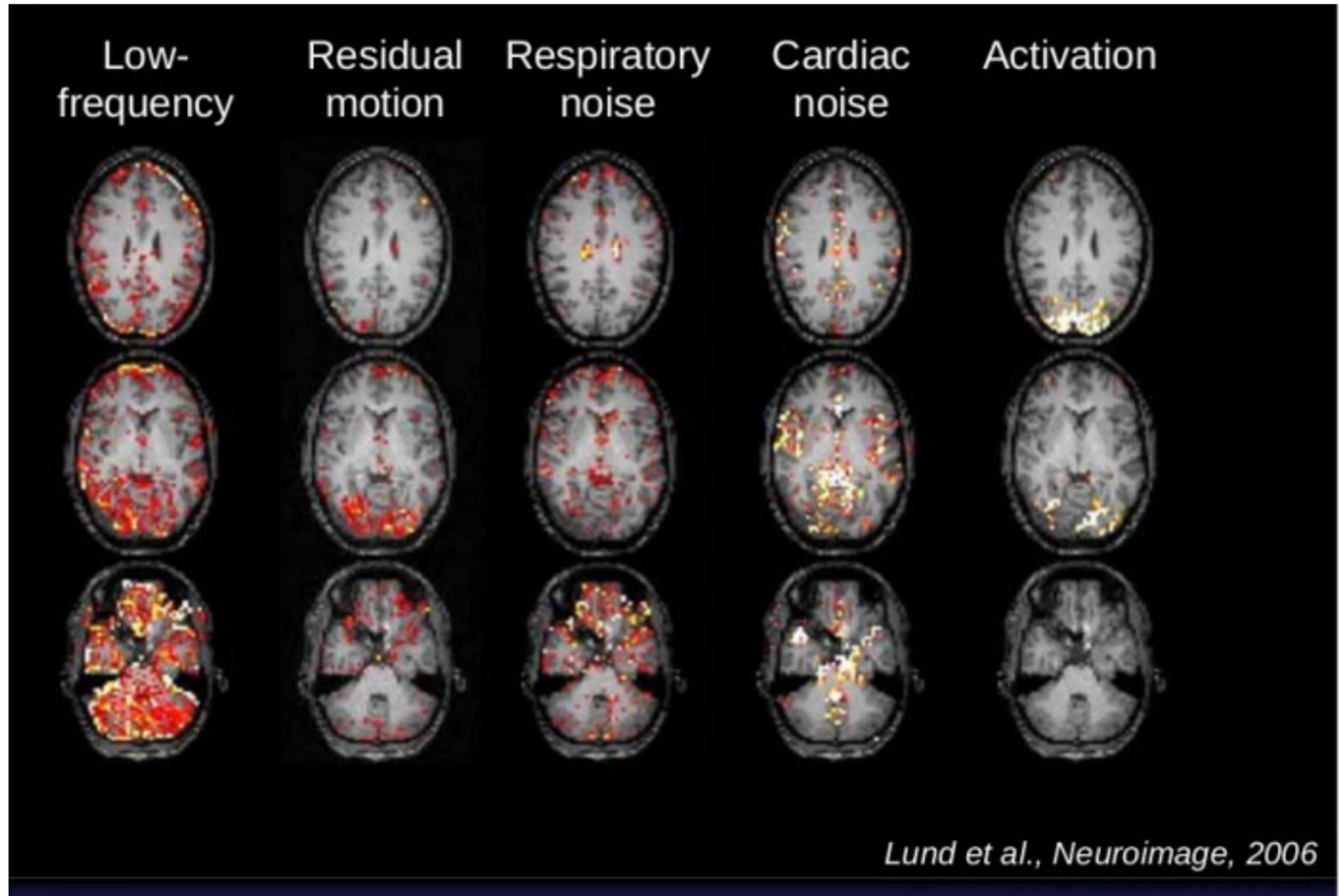
An acquired volume is composed of several thousand volume elements = voxels

Main features

- ▶ Voxels = 1.5 to 3 mm³ cubes -> high spatial resolution
- ▶ A full volume acquired every 1 to 2 seconds -> Low temporal resolution



Functional MRI – Artifacts (aka confounds or nuisance)



Functional MRI - Example

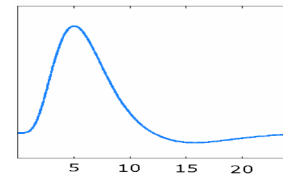
10

Contrast based analysis

Event-related design

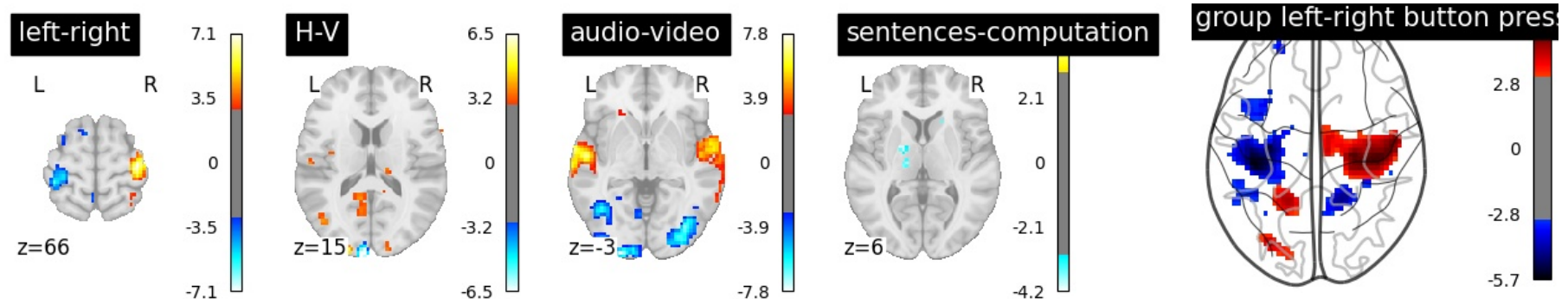
► 5 minutes of stimulation with 80 events of different types

- 'audio_computation',
- 'audio_left_hand_button_press',
- 'audio_right_hand_button_press',
- 'horizontal_checkerboard',
- 'sentence_listening',
- 'sentence_reading',
- 'vertical_checkerboard',
- 'visual_computation',
- 'visual_left_hand_button_press',
- 'visual_right_hand_button_press'

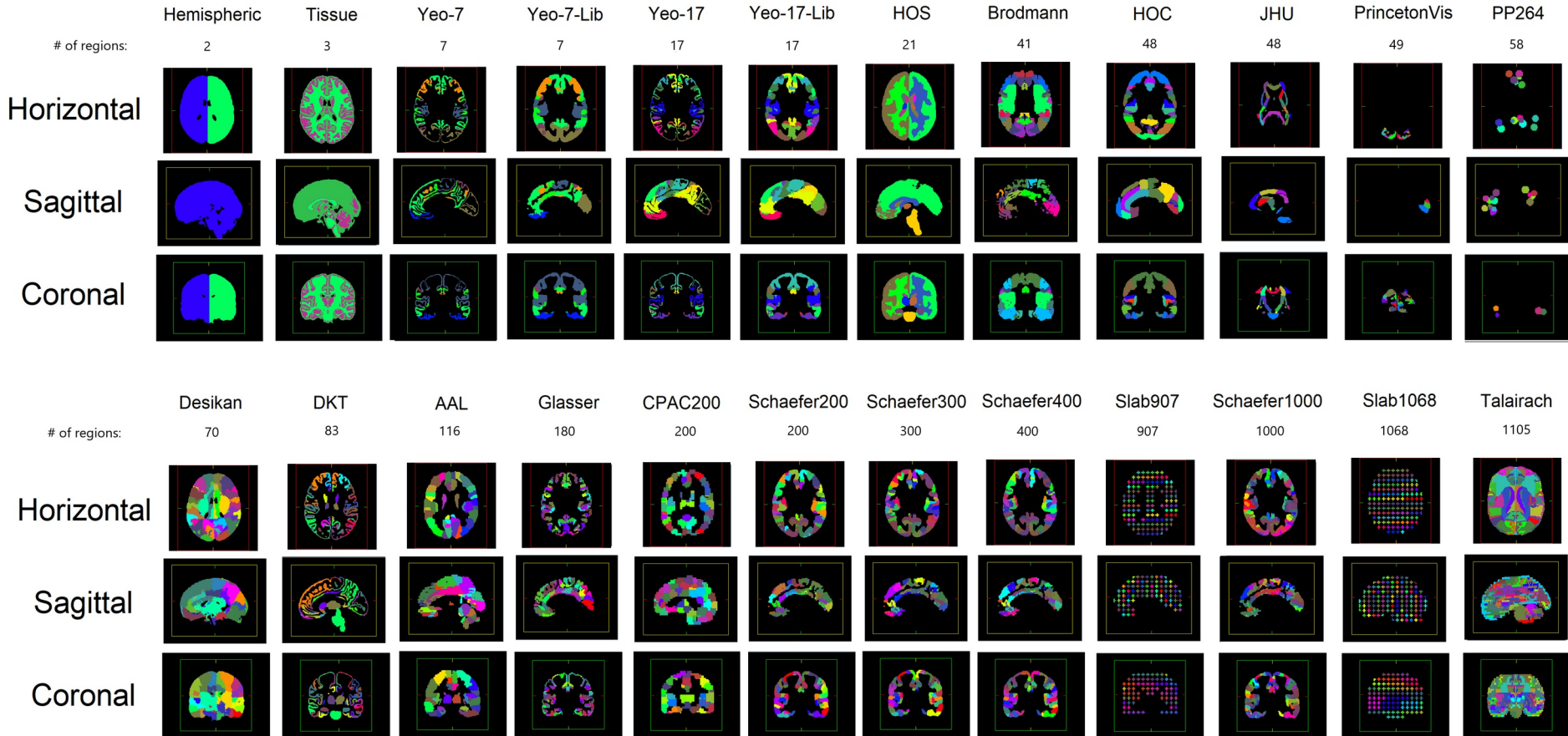


► Linear model of the response to each event

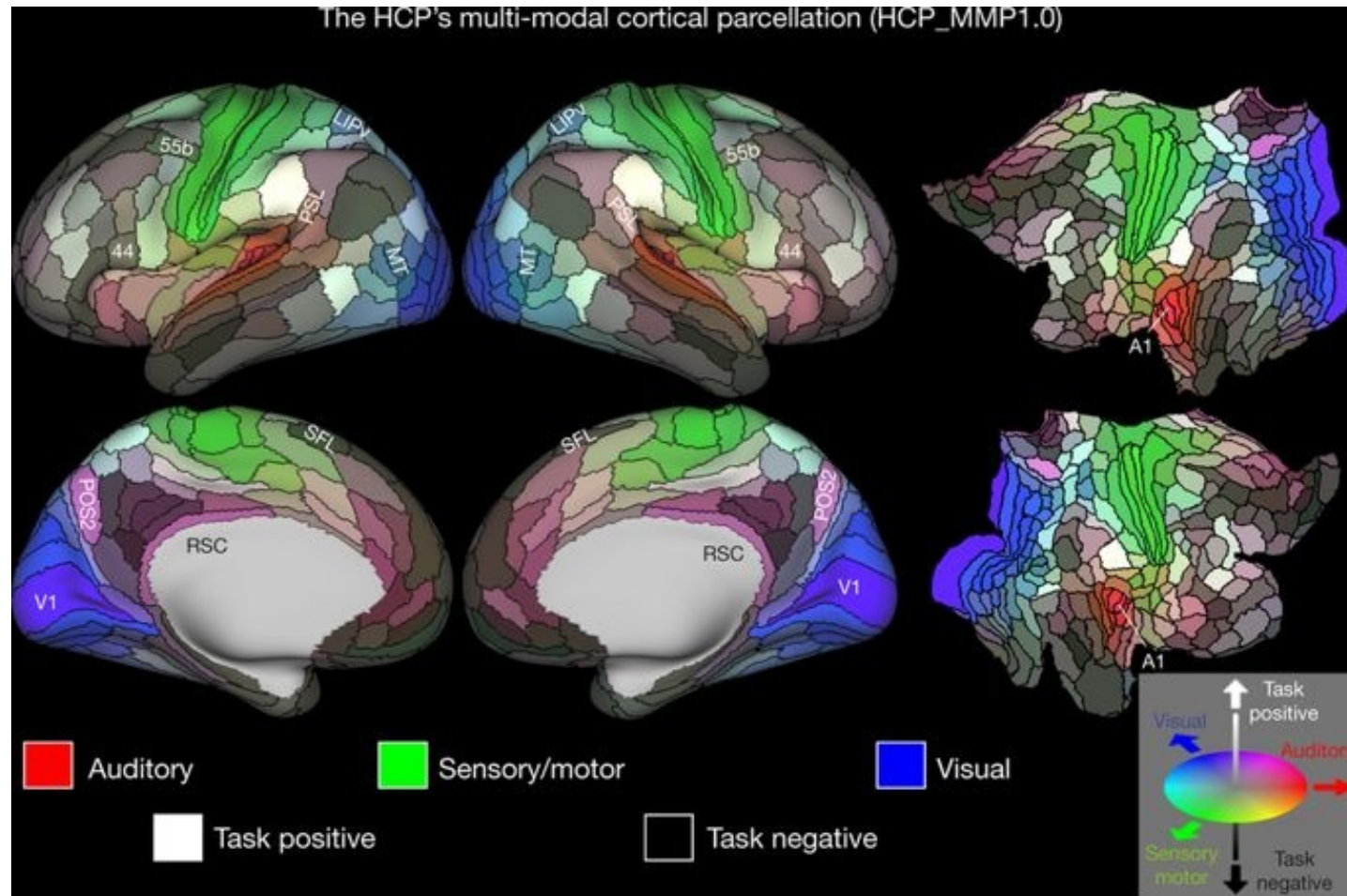
► Contrasts between model fits



Source: nilearn examples



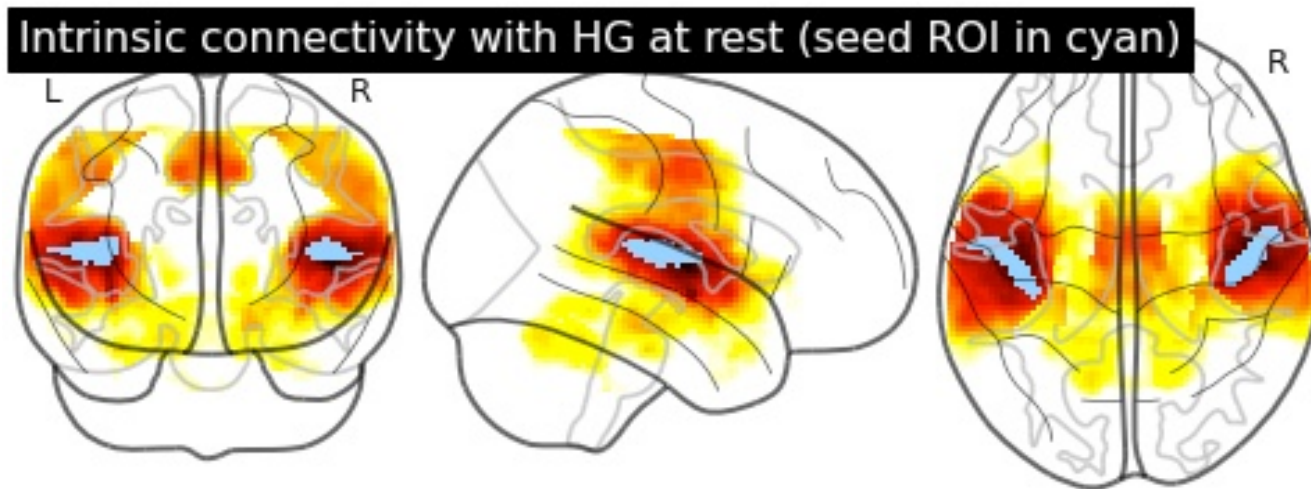
Lawrence et al. (2021). Scientific data, 8(1), 1-9.
<https://github.com/neurodata/neuroparc>

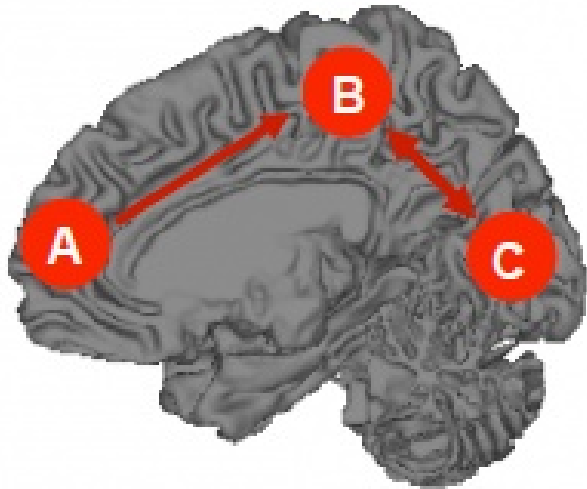


Glasser et al., 2016, Nature

“Seed-based functional connectivity”

“seed” = reference point. How similar is the rest of the brain’s activity compared to this seed ?





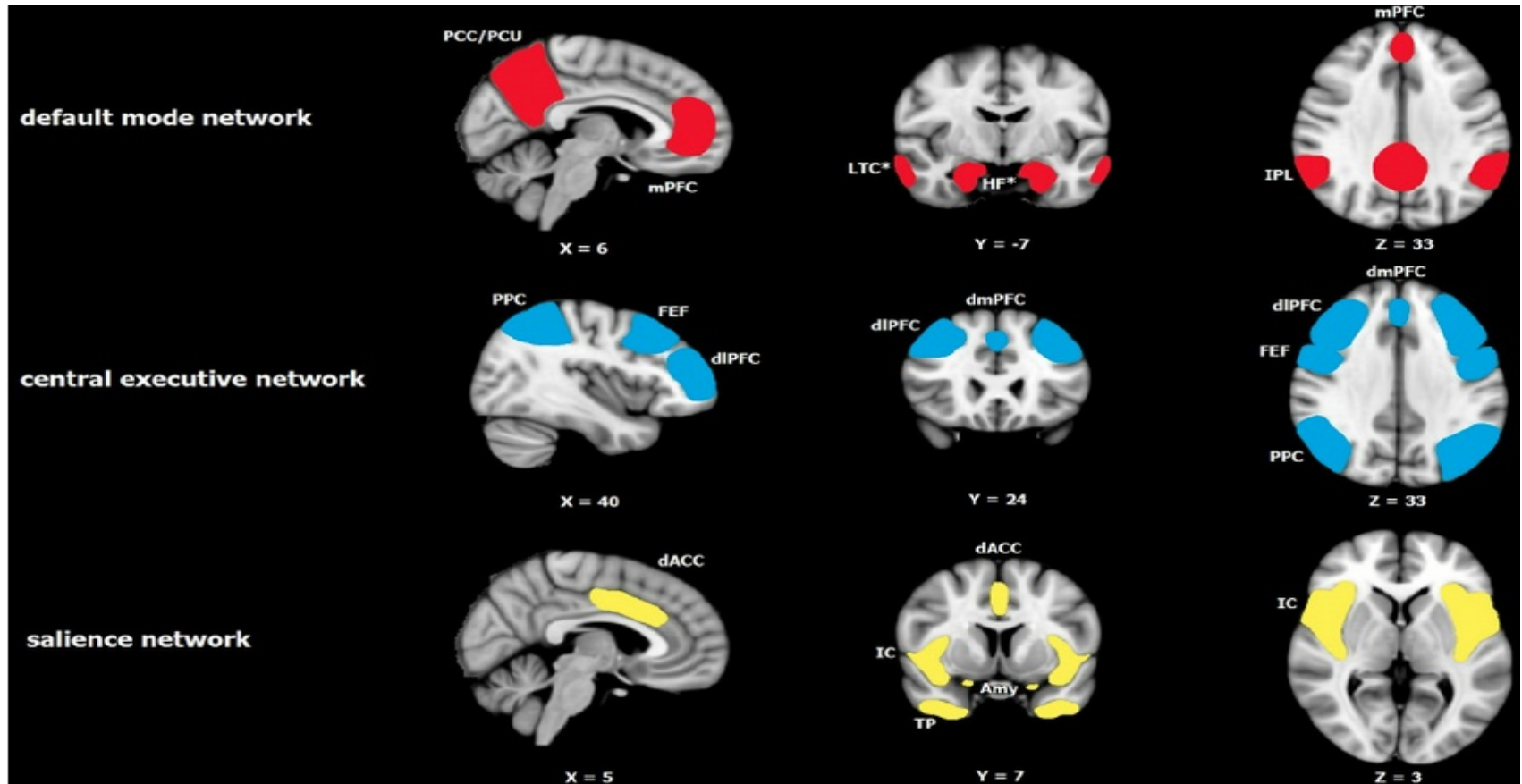
Brain Connectivity

A paradigm shift

Connectivity studies consider the brain as a network of regions interacting with each other, as a function of experimental parameters or subjects.

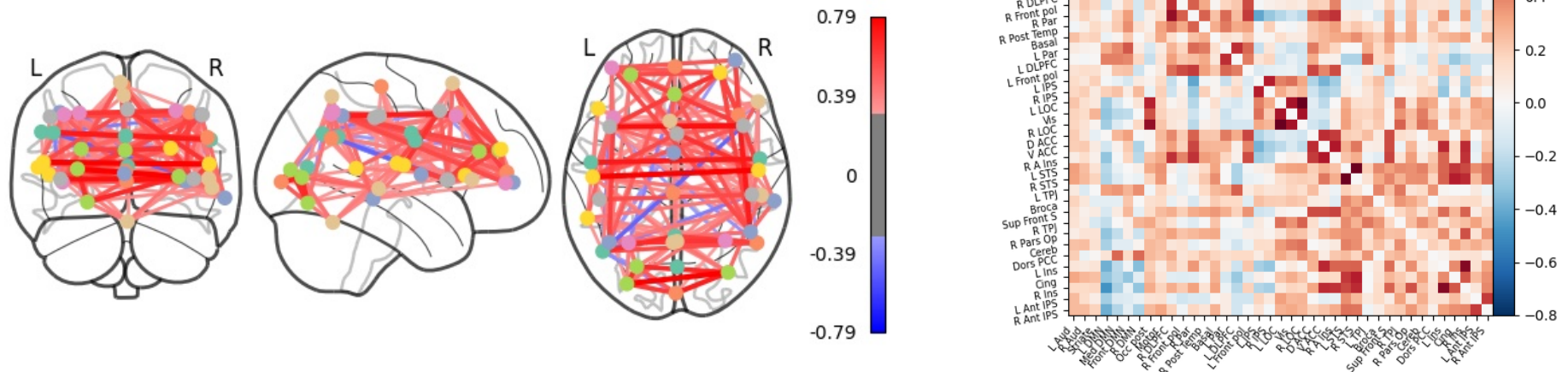
-> Graph theory for topological analysis of networks

Spontaneous networks = « resting-state functional connectivity »

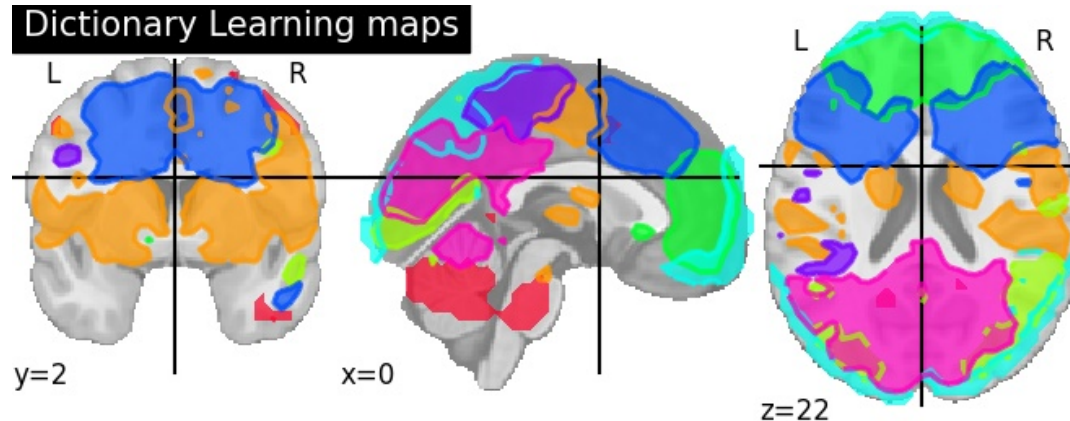


Resting-state functional connectivity

Examples from nilearn



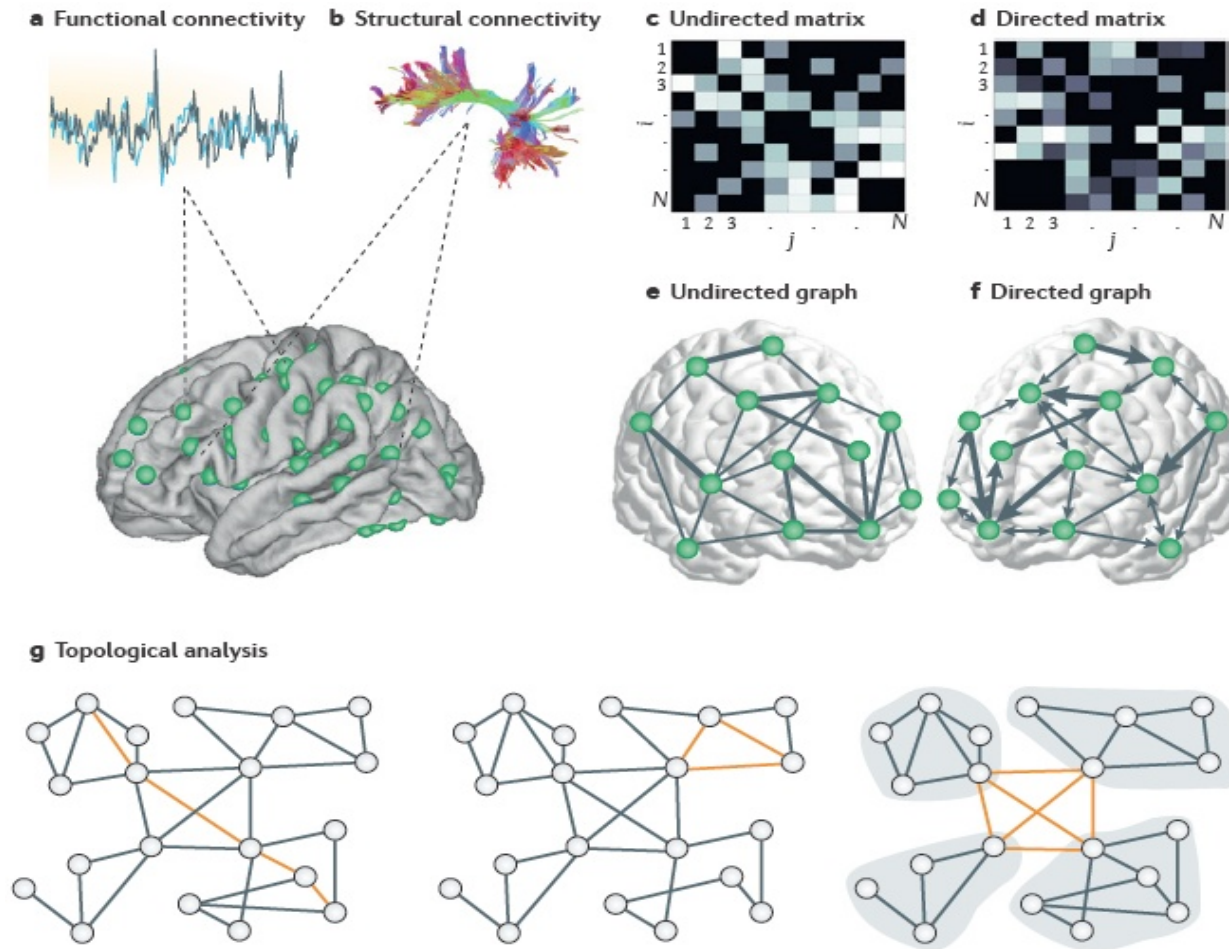
Dictionary Learning maps



Connectivity Graphs

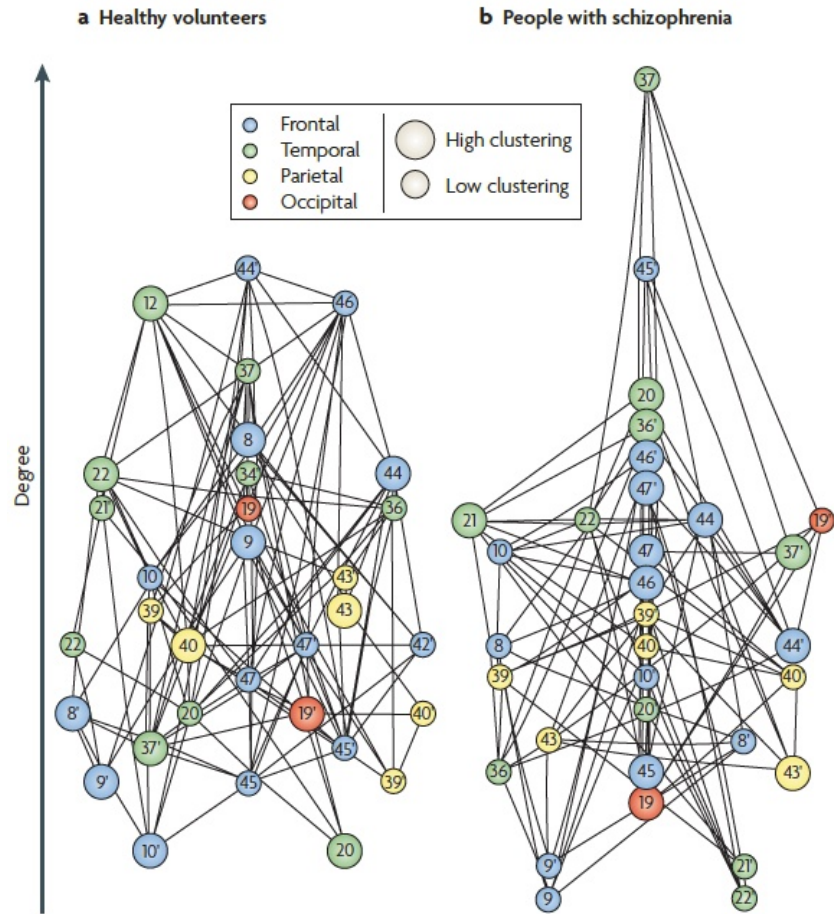
Functional and structural connectivity

17



Fornito et al. 2015
Nature Neuro

Example



Two examples of graph-based measures :

1 – Clustering coefficient

For each vertex, how much are neighbors connected with each other

2- Characteristic path length

The brain as a small world network ?

Agenda

1. Neuroimaging techniques
2. Brain Connectivity
3. Lab session



IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

Questions?

Merci de votre attention!
Nicolas.farrugia@imt-atlantique.fr

www.brain.bzh

Twitter : @milthampton
Facebook : Brain-bzh



IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom