Final Project

Investigation of the relationship between resting-state functional MRI and diffusion MRI data

in course “Imaging in Neuroscience”

by Group 8

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fMRI - data processing + denoising

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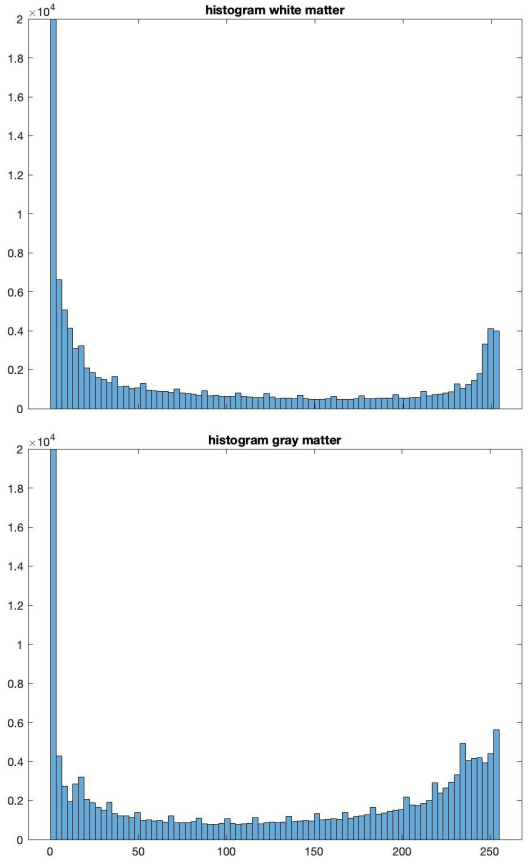

Using **SPM** software, gray matter (**GM**), white matter (**WM**) and cerebrospinal fluid (**CSF**) **probability maps** were obtained.

Binary masks were created by **thresholding** the above probability maps.

- The thresholds for each tissue were selected by **visually inspecting the histograms** of probability maps, trying to discard the majority of errors.
- **0.75 for GM, 0.9 for WM and 0.8 for CSF** were chosen as thresholds.

The resulting binary masks were **eroded to refine the boundaries** of the mask and remove any potential noise or inaccuracies with **a structuring element 2x2**.

fMRI - data processing + denoising

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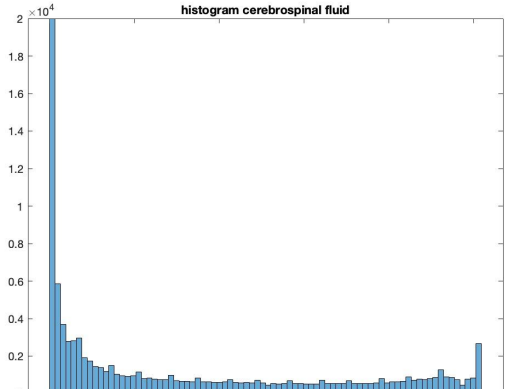
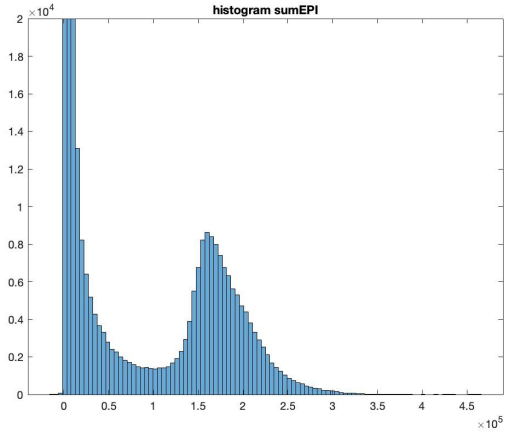
EPI volumes were summed and a **binary mask** was created using **a threshold of 10^5** chosen by a histogram visual inspection.

The **Hammers atlas** was **masked** with **GM** and **sumEPI** binary masks.

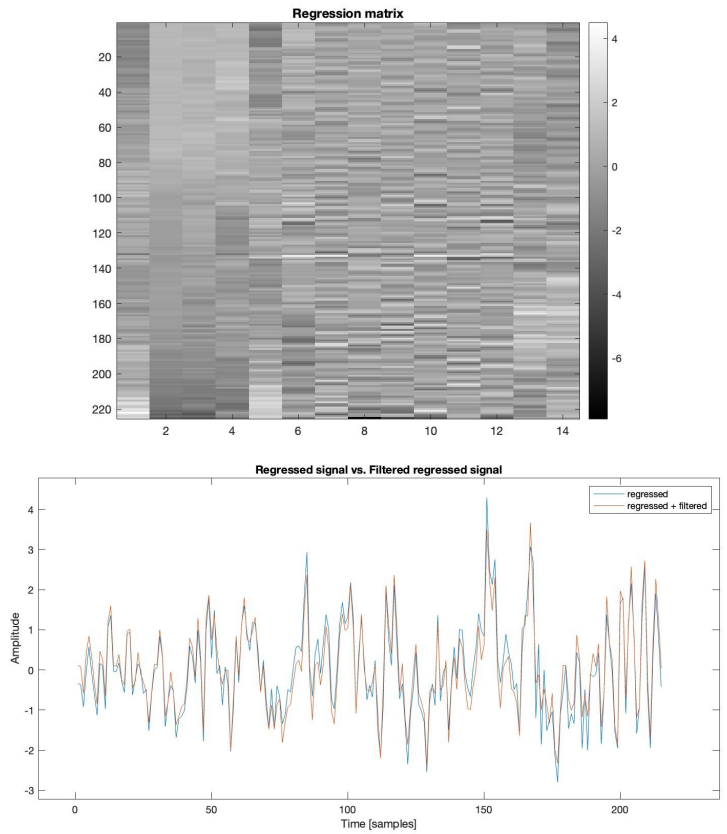
The **mean fMRI signal** was extracted from each masked ROI of the atlas.

- ROIs with **a number of voxels less than 15** were discarded.
- The following region were also removed by default: **amygdala** (3,4), **cerebellum** (17,18), **brainstem** (19), **corpus callosum** (44), **substantia nigra** (74,75), **ventricles** (45,46,47,48,49).





fMRI - data processing + denoising



The figure depicts the denoised averaged ROIs signal before and after temporal filtering.

Using a **linear regression approach**, the non-neural undesired fluctuations were removed.

- Estimated **beta coefficients** associated with **motion correction parameters**, their **temporal derivatives** and the **WM** and **CSF mean signals.**
- Regressed out the **noise from the original signals.**

The regressed signal is then **filtered** with a **band-pass filter** with a **cut-off frequency [0.008-0.15] Hz**.

- **[0.008, 0.08] Hz** is the range related **to neural activity in BOLD signal** of GM areas.
- Band pass from 0.008 to **0.15 Hz** in order to maintain **higher frequencies** that could be potentially **related to hemodynamic response**.

The volumes **affected by motion artifacts** were discarded.

fMRI - check preprocessing step

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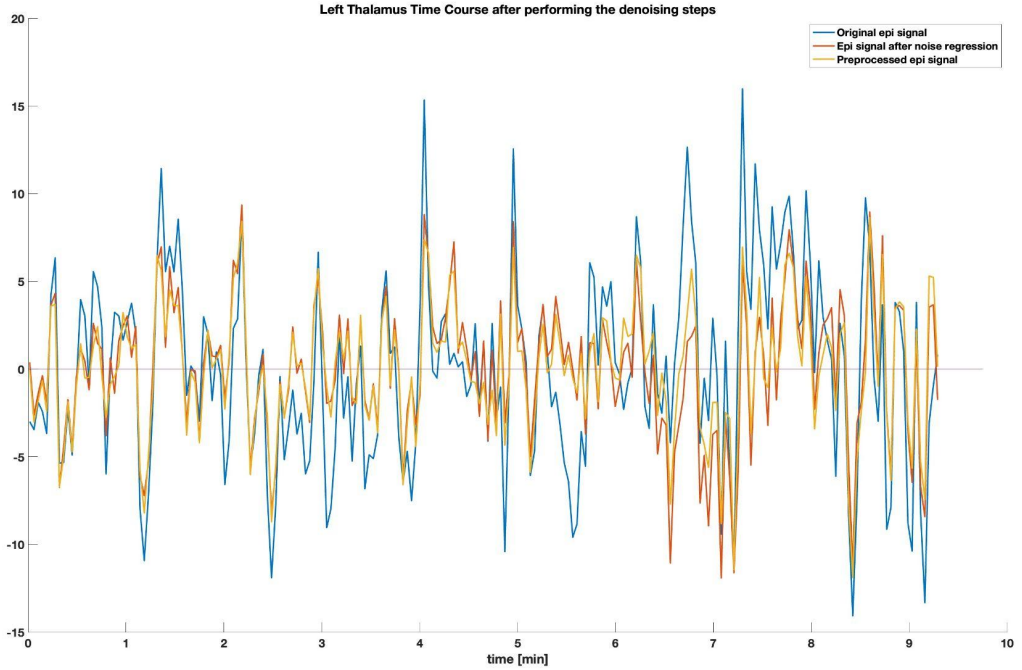
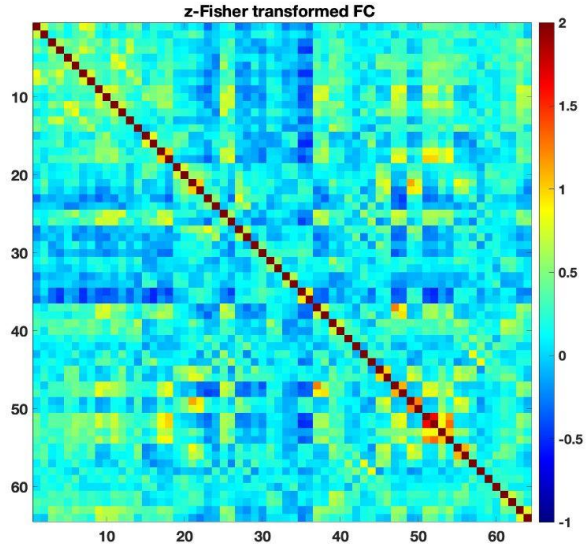
In left thalamus region **there is no visible drift** in the signal. Nevertheless checking other regions of the brain (for example the one of the **hippocampus**) it is **possible to observe** such **drift** that is **corrected by the temporal filtering**.

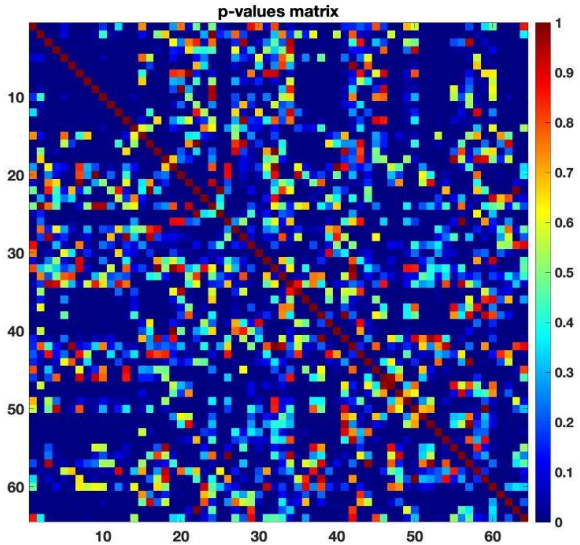


fMRI - FC matrix

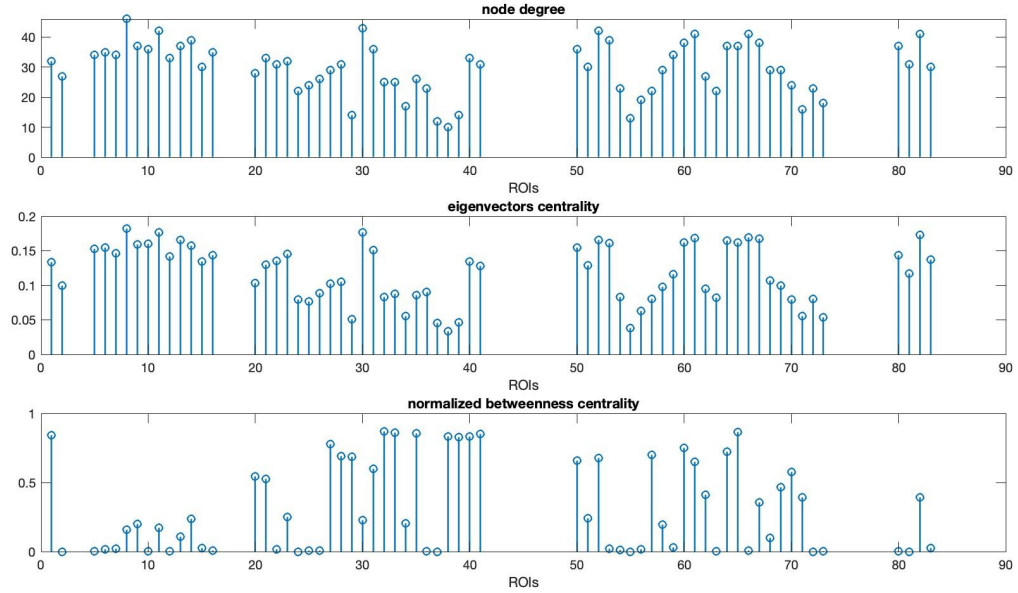
A **pairwise Pearson's correlation** was calculated between the ROIs signals. **Multiple comparison correction** with **Bonferroni** and **False Discovery Rate** was performed.

- **False Discovery Rate** approach was chosen because in this case it is preferable to have better control in the **reduction of the type II error** (when an active voxel is marked as not active) than controlling the type I error (when a voxel is marked as active but no activation takes place).
- Furthermore **Bonferroni is overly conservative** because it assumes all the **tests** to be **independent**, but that is not the case with fMRI data which usually has some **spatial correlation.**





fMRI - results



To summarize the functional connectivity in terms of **node centrality**, for each ROI the **node degree**, the **eigenvector centrality**, and the **normalized betweenness centrality** were computed.

10 ROIs with the highest metrics values

- **Node degree:** [8 30 11 52 61 66 82 14 53 60]
- **Eigenvectors centrality:** [8 30 11 82 66 61 67 13 52 64]
- **Normalized betweenness centrality:** [32 65 33 35 41 1 38 40 39 27]

dMRI - diffusion signal visualization

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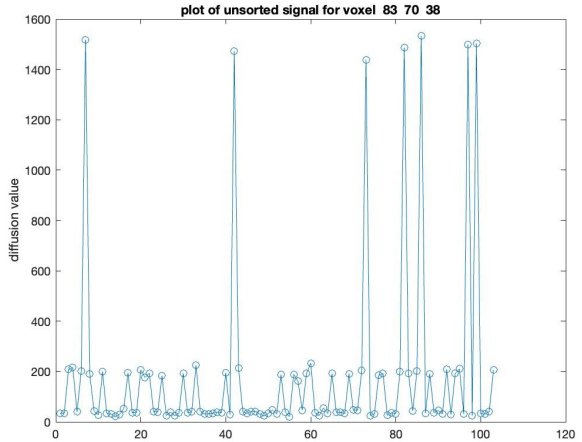
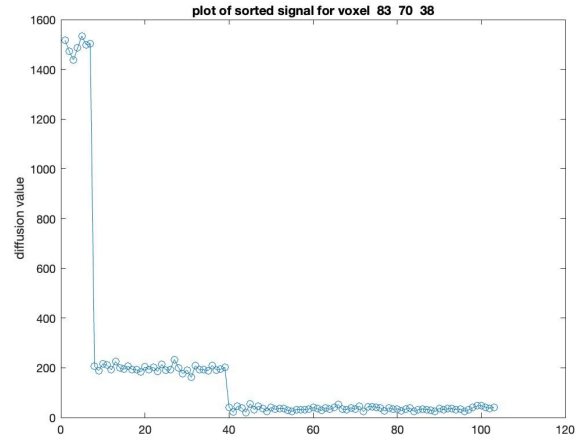
[120×120×90×103] is a size of a single image. The 4th dimension refers to the number of **DWIs,** which in this case is 103.
Excluding b=0, there are **2 diffusion shells** considering a small tolerance α=±20 s/mm2 in the shell definition.
The process of selecting a voxel that is likely populated with cerebrospinal fluid (CSF) based on several aspects.

- **DTI Metrics (FA): 0.0368.** A low FA value is expected in a voxel populated principally with CSF because CSF exhibits **isotropic diffusion** (FA<0.18 for isotropic tissues).
- **Anatomical Atlas: 46.** It corresponds to the **lateral ventricle**. The ventricles are regions in the brain where the cerebrospinal fluid flows, indicating a higher likelihood of CSF presence in this voxel.

By visually inspecting the sorted diffusion signal, we can observe both **inter-b-value** and **intra-b-value** variabilities.

- The inter-b-value variability is due to the relationship between the diffusion MRI signal and the b-value.
- noise and imaging artifacts in the diffusion MRI acquisition process can introduce random fluctuations in the signal, causing intra-b-value variability.





dMRI - diffusion tensor computation

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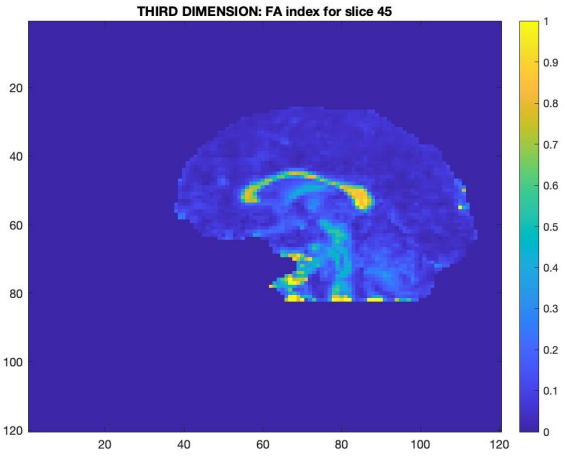
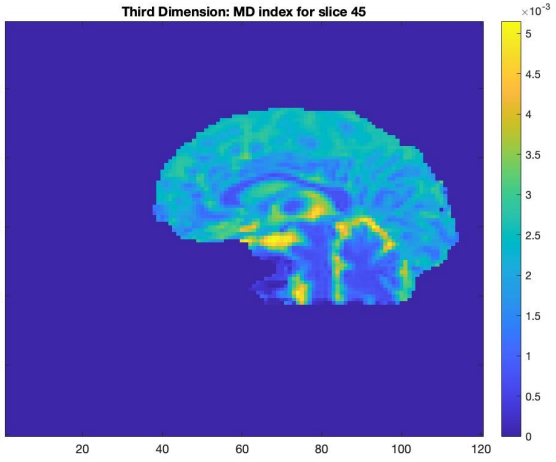
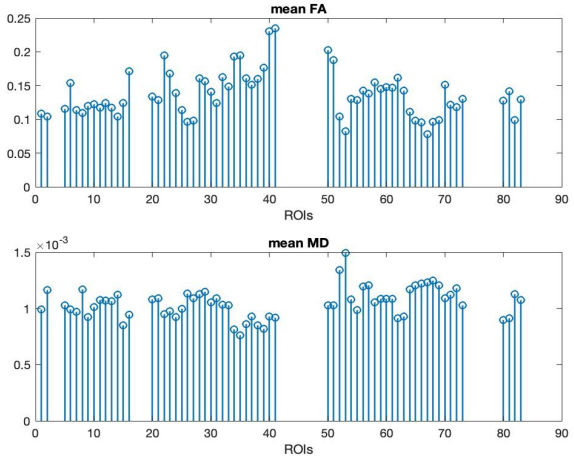
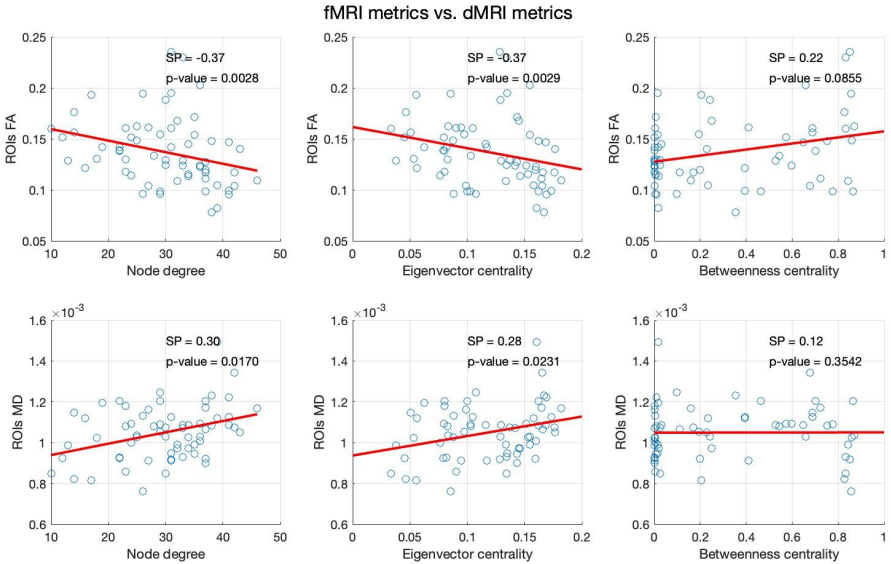
A new **4D matrix** containing only the volumes corresponding to b=0 s/mm2 and to the shell closest to b=1000 s/mm^2 was constructed. Some **voxels** for which the signal is constant and equal to 0 were **removed**. **Eigenvector / eigenvalue decomposition** was used to recover the **FA / MD / RD indices**. The visualization for the FA and MD maps for a **central slice** is provided. **FA and MD maps** were **masked** and the **mean value** in each ROI extracted.

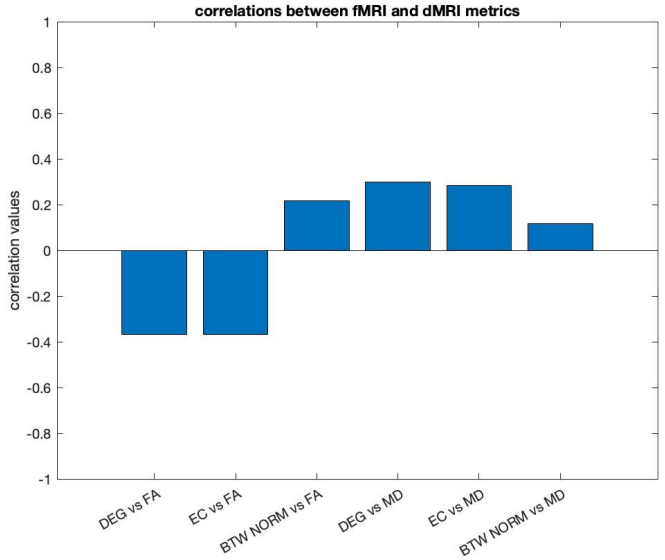






dMRI & fMRI integration





The visual inspection of the **fMRI metrics and dMRI metrics** was performed. **Spearman correlation** was computed between six pairs of variables.

- Fractional Anisotropy (FA) is **negatively correlated** with the Node Degree (DEG)
- Fractional Anisotropy is **negatively correlated** with the Eigenvector Centrality (EC)
- Mean Diffusivity is **not correlated** with the Normalized Betweenness Centrality