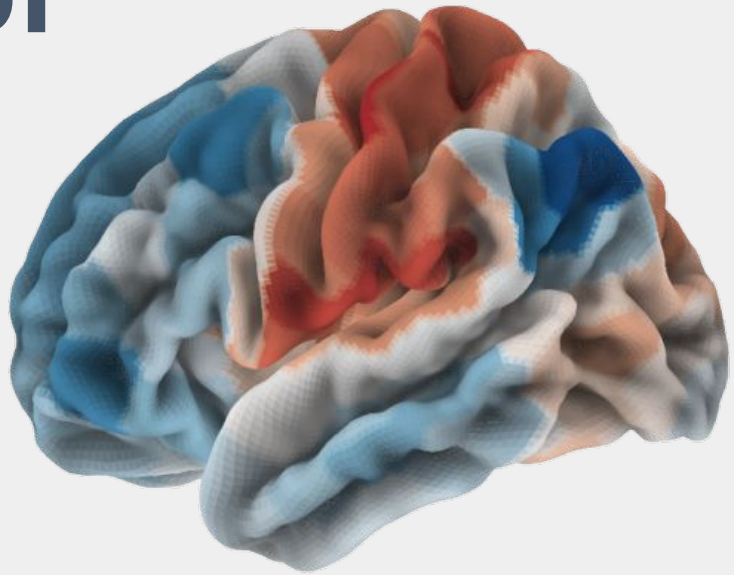
Fundamentals of fMRI data analysis



Karolina Finc

Centre for Modern Interdisciplinary Technologies

Nicolaus Copernicus University in Toruń

COURSE #1: Reproducible neuroimaging

Study plan

BEFORE

Open science & neuroimaging

fMRI data manipulation in python

fMRI data preprocessing

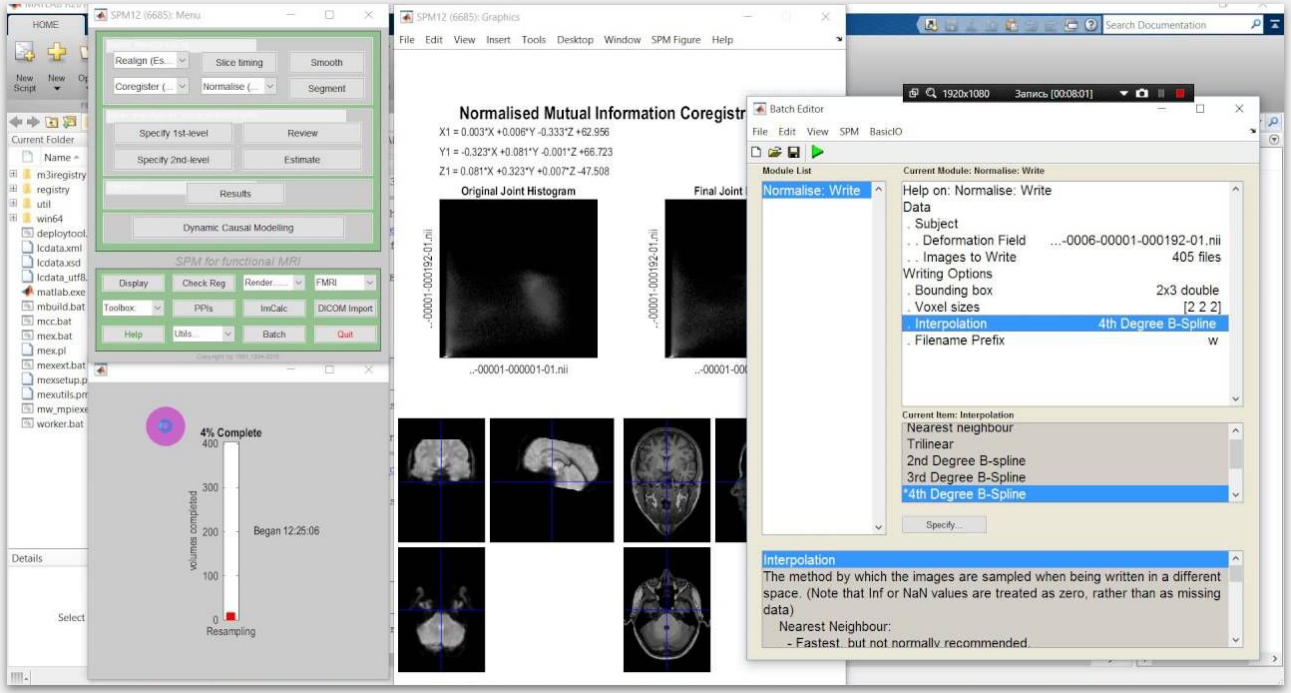
General Linear Model

Functional connectivity

AFTER

Machine Learning on fMRI data

My story



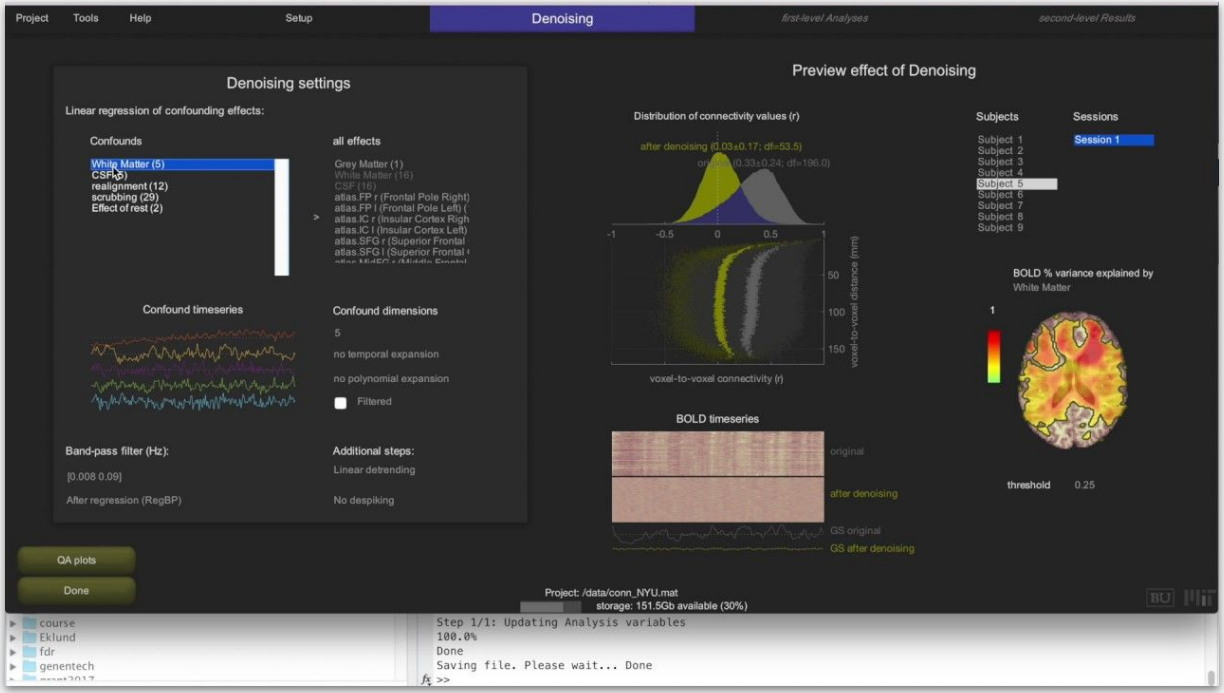
2014

Learning brain activity analysis in SPM.

MATLAB

Statistical Parametric Mapping: `https://www.fil.ion.ucl.ac.uk/spm/`

My story



2014

Learning functional connectivity & graph theory analysis in CONN & BCT.

MATLAB

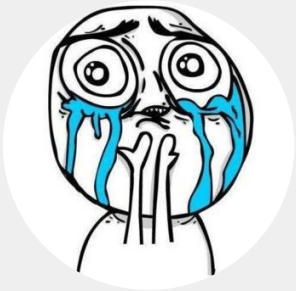
Functional connectivity toolbox: `https://web.conn-toolbox.org/`
Brain Connectivity Toolbox: `https://sites.google.com/site/bctnet/`

Fast way to scientist's depression

Processing step	Reason	Options [suboptions]	Number of plausible option
Motion correction	Correct for head motion during scanning	• 'Interpolation' [linear or sinc] • 'Reference volume' [single or mean]	4
Slice timing correction	Correct for differences in acquisition timing of different slices	'No', 'before motion correction' or 'after motion correction'	3
Field map correction	Correct for distortion owing to magnetic susceptibility	'Yes' or 'no'	2
Spatial smoothing	Increase SNR for larger activations and ensure assumptions of GRF theory	'FWHM' [4 mm, 6 mm or 8 mm]	3
Spatial normalization	Warps an individual brain to match a group template	'Method' [linear or nonlinear]	2
High-pass filter	Remove low-frequency nuisance signals from data	'Frequency cut-off' [100 s or 120 s]	2
Head motion regressors	Remove remaining signals owing to head motion via statistical model	'Yes' or 'no' [if yes: 6/12/24 parameters or single time point 'scrubbing' regressors]	5
Haemodynamic response	Account for delayed nature of haemodynamic response to neuronal activity	• 'Basis function' ['single-gamma' or 'double-gamma'] • 'Derivatives' ['none', 'shift' or 'dispersion']	6
Temporal autocorrelation model	Model for the temporal autocorrelation inherent in fMRI signals	'Yes' or 'no'	2
Multiple-comparison correction	Correct for large number of comparisons across the brain	'Voxel-based GRF', 'cluster-based GRF', 'FDR' or 'non-parametric'	4
Total possible workflows			69,120

Poldrack et al. (2001), *Nat. Rev. Neurosc.*

- Which software to select?
- Which method to select?
- Which option to select?

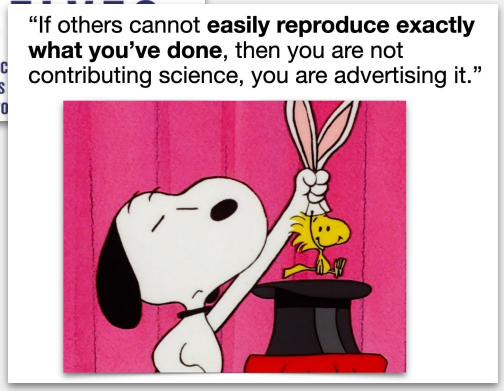


Fast way to scientist's depression cd.

Many results you've read in papers are false positives and are not reproducible.

BAD RESEARCH PRACTICES:

- Not sharing the data
- Not sharing the code
- P-hacking
- HARKing - hypothesis after results are known

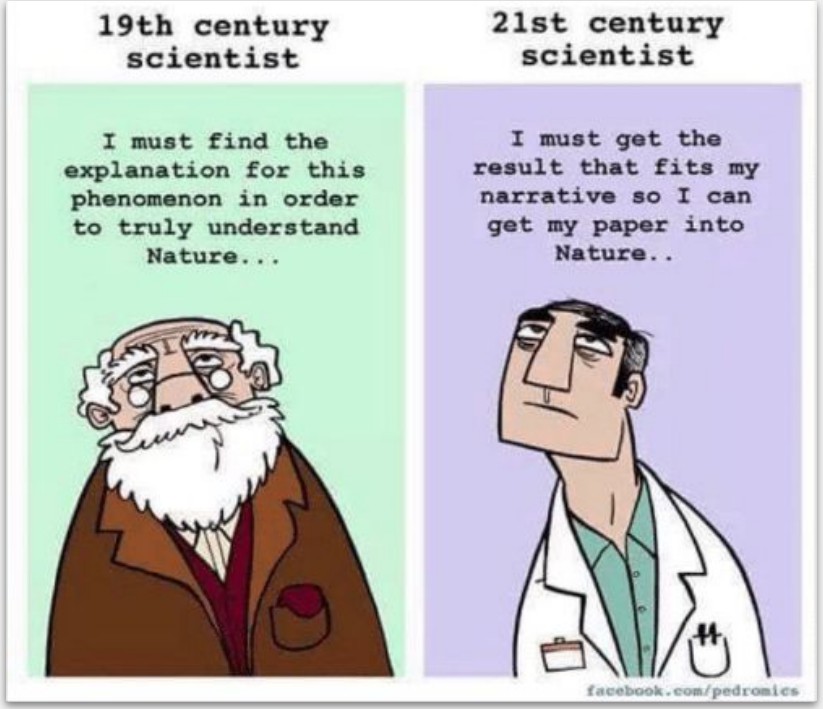


Practical guide to reproducibility

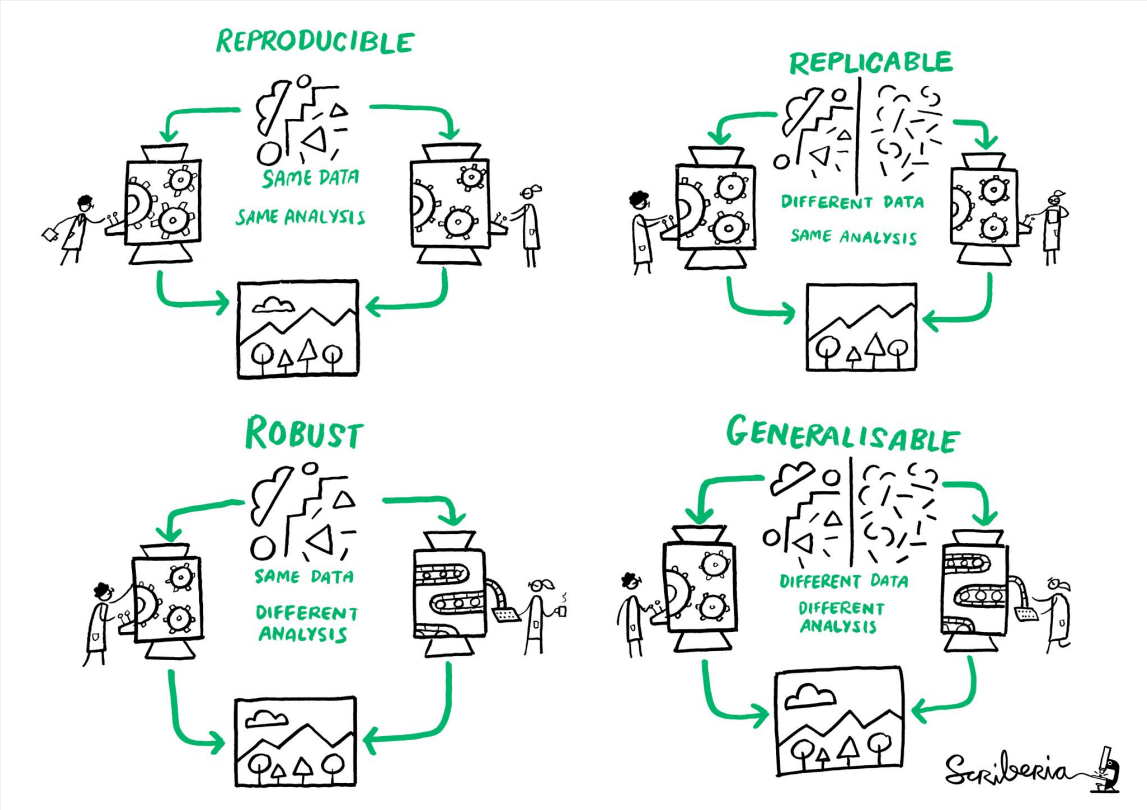
Why?

Some reasons of reproducibility crisis

- Scientists are rewarded based on publications
- Significant results are easier to publish
- Journals are not very open to publish replications (what's new in this?)
- fMRI studies are expensive and time consuming (small sample sizes)
- Learning programming takes time and much effort
- Designing a good experiment and stating a good hypothesis takes time
- etc.

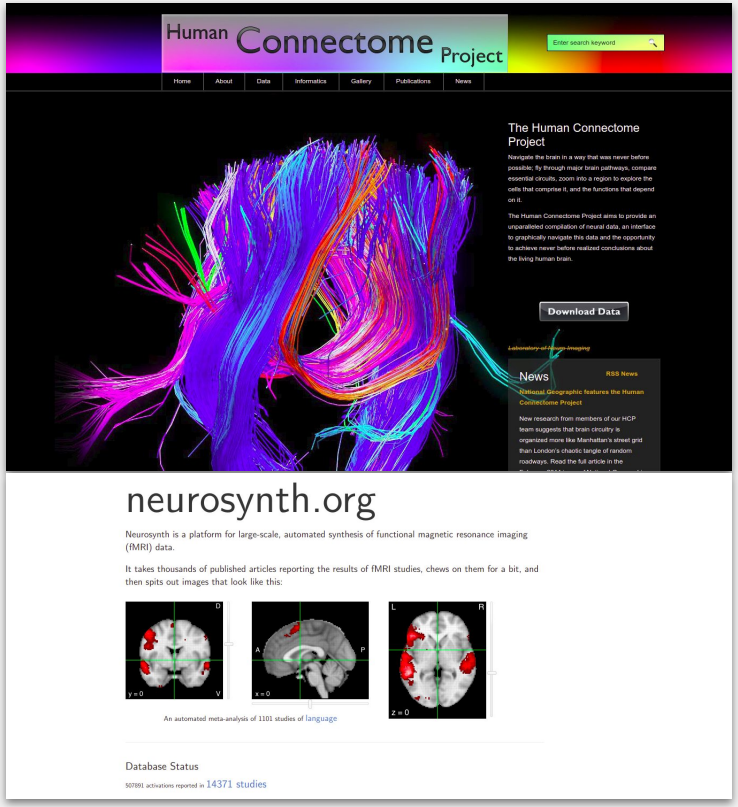


Features of good scientific research



Open science

Open data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The Human Connectome Project
Navigate the brain in a way that was never before possible; fly through major brain pathways, compare essential circuits, zoom into a region to explore the cells that comprise it, and the functions that depend on it.
The Human Connectome Project aims to provide an unparalleled compilation of neural data, an interface to graphically navigate this data and the opportunity to achieve never before realized conclusions about the living human brain.
Download Data
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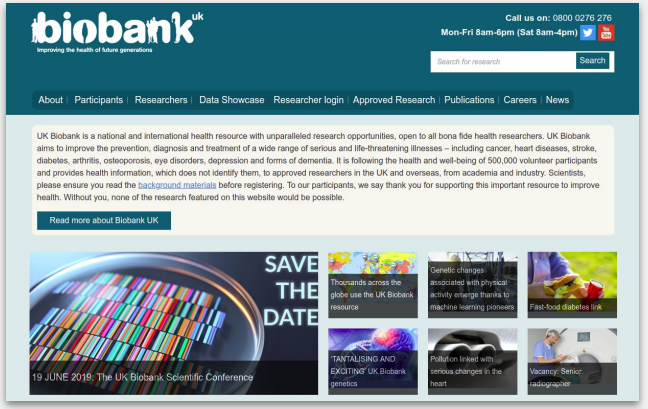
News
RSS News
National Geographic features the Human Connectome Project
New research from members of our HCP team suggests that brain circuitry is organized more like Manhattan's street grid than London's chaotic tangle of random roadways. Read the full article in the
neurosynth.org
Neurosynth is a platform for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data.
It takes thousands of published articles reporting the results of fMRI studies, chews on them for a bit, and then spits out images that look like this:
An automated meta-analysis of 1101 studies of language
Database Status
507891 activations reported in 14371 studies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Read more about Biobank UK
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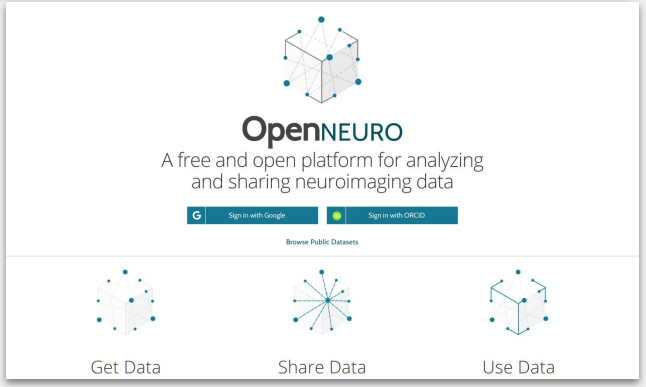
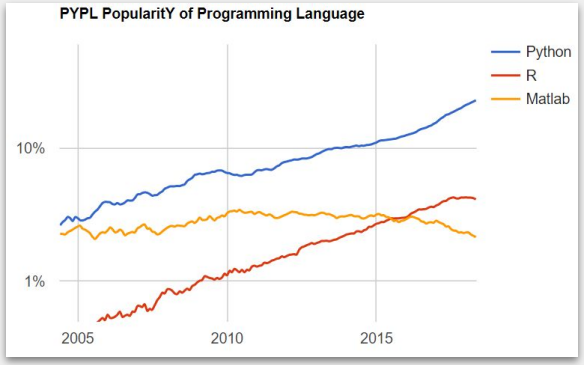
Genetic changes associated with physical activity enlarge thanks to machine learning pioneers
Fast-food diabetes link
'TANTALISING AND EXCITING' UK Biobank genetics
Pollution linked with serious changes in the heart
Vacancy: Senior radiographer


OpenNEURO
A free and open platform for analyzing and sharing neuroimaging data
Sign in with Google
Sign in with ORCID
Browse Public Datasets
Get Data
Share Data
Use Data

Open source

Open programming languages



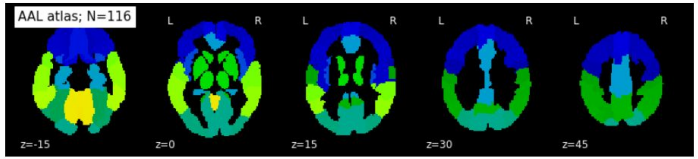
Open source packages

Code sharing platforms

GitHub

Jupyter notebook

In [4]:
```
# Load AAL atlas
aal_dataset = datasets.fetch_atlas_aal(
    data_dir=os.path.join(path_templates, 'aal'))

img_aal = nib.load(aal_dataset.maps)
aal_label_codes = {int(idx): label for idx, label in
                   zip(aal_dataset.indices, aal_dataset.labels)}

plotting.plot_anat(
    img_aal,
    cmap='nipy_spectral',
    cut_coords=cut_coords,
    display_mode='z',
    title=f'AAL atlas; N={len(aal_label_codes)}',
    draw_cross=False)

plt.show()
```

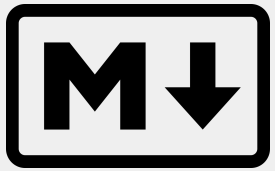


In [5]:
```
# Load Harvard-Oxford cortical atlas
ho_cort_dataset = datasets.fetch_atlas_harvard_oxford(
    atlas_name='cort-maxprob-thr0-1mm',
    data_dir=os.path.join(path_templates, 'harvard_oxford_cortical'))

img_ho_cort = nib.load(ho_cort_dataset.maps)
ho_cort_label_codes = {idx: label
                       for idx, label in enumerate(ho_cort_dataset.labels)}

plotting.plot_anat(
    img_ho_cort,
    cmap='nipy_spectral',
    cut_coords=cut_coords,
    display_mode='z',
    title=f'Harvard-Oxford cortical atlas; N={len(ho_cort_label_codes)}',
    draw_cross=False)

plt.show()
```

Good example: https://github.com/kbonna/decidenet

Getting started with Jupyter notebooks

Jupyter = **Ju**(lia) + **pyt**(hon) + e**R**



Goal of Project Jupyter is to "develop open-source software, open-standards, and services for interactive computing across dozens of programming languages". More: https://en.wikipedia.org/wiki/Project_Jupyter

1. Open terminal
2. Type “jupyter lab”
3. If you don’t have it installed, go to website: https://jupyter.org/try
4. Alternative: https://colab.research.google.com/

Getting started with Git/GitHub

Git - version control system that stores multiple versions of your files over time

GitHub - provides hosting for software development version control using Git

Example:

https://github.com/nipreps/fmriprep

1. Create an account using academic email! (for PRO access)
2. Install Git on your computer (or check if it's already installed)

GitHub

Useful git commands

Step 1: Create a local Git repository (`git init`)

Step 2: Add a new file to the repo (use `git status` to check whether file is tracked)

Step 3: Add a file to the staging environment (`git add <filename>`)

Step 4: Create a local Git repository (`git commit -m “New file added”`)

`git pull` - update local repository to the newest commit
`git push` - push changes to GitHub

Useful git commands

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`git push` - push changes to GitHub

If using terminal is too overwhelming for now you may also want to try **Git client,** e.g. GitKraken

What to install?

1. Git
2. Anaconda 3 (Python distribution)

3. FSL (optional)
4. MATLAB (optional)

Homework

1. **GitHub Classroom**

   fMRI Q&A in Markdown

2. **Data Camp Classroom**

   Intermediate Python

Next

fMRI data manipulation and plotting in Python