



Introduction to fMRIPrep

Oliver Xie
University of Maryland
Brainhack DC 2020



Outline

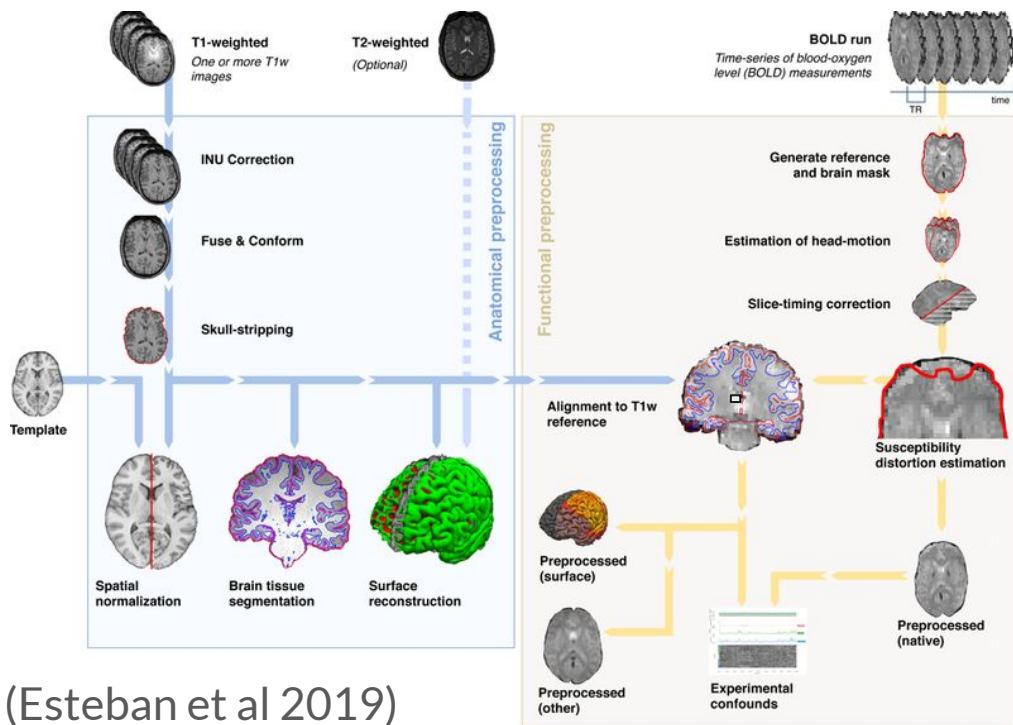
1. **What** is fMRIPrep?
2. **Why** do I want to use fMRIPrep?
3. **How** to use fMRIPrep?

fMRIPrep

a robust preprocessing pipeline for task-based and resting-state fMRI data

What is fMRIPrep?

fMRIPrep is a robust and versatile preprocessing toolbox designed by Poldrack lab at Stanford University to streamline (f)MRI data analysis.



What is fMRIPrep?

Table 1. State-of-art neuroimaging offers a large catalog of readily available software tools. *fMRIPrep* integrates best-in-breed tools for each of the preprocessing tasks that its workflow covers.

Preprocessing task	<i>fMRIPrep</i> includes	Alternatives (not included within <i>fMRIPrep</i>)
Anatomical T1w brain-extraction	antsBrainExtraction.sh (ANTs)	bet (FSL), 3dSkullstrip (AFNI), MRTOOL (SPM Plug-in)
Anatomical surface reconstruction	recon-all (FreeSurfer)	CIVET, BrainSuite, Computational Anatomy (SPM Plug-in)
Head-motion estimation (and correction)	mcflirt (FSL)	3dvolreg (AFNI), spm_realign (SPM), cross_realign_4dfp (4dfp), antsBrainRegistration (ANTs)
Susceptibility-derived distortion estimation (and unwarping)	3dqwarp (AFNI)	fugue and topup (FSL), FieldMap and HySCO (SPM Plug-ins)
Slice-timing correction	3dTshift (AFNI)	slicetimer (FSL), spm_slice_timing (SPM), interp_4dfp (4dfp)
Intra-subject registration	bbregister (FreeSurfer), flirt (FSL)	3dvolreg (AFNI), antsRegistration (ANTs), Coregister (SPM GUI)
Spatial normalization (inter-subject co-registration)	antsRegistration (ANTs)	@auto_tlrc (AFNI), fnirt (FSL), Normalize (SPM GUI)
Surface sampling	mri_vol2surf (FreeSurfer)	MNE, Nilearn
Subspace selection methods	melodic (FSL), ICA-AROMA	Nilearn, LMGS (SPM Plug-in)
Confounds	<i>in-house</i> implementation	TAPAS PhysIO (SPM Plug-in)
Steady-state detection	<i>in-house</i> implementation	<i>Ad hoc</i> implementations

fMRIPrep streamlines pipelines by combining tools from many neuroimaging software.

(Esteban et al., 2019)



Why do I want to use fMRIPrep?

- Reproducibility: Limit the researcher degree of freedom
- Transparency: Turn a black box to a glass box
- Robustness & flexibility: Robust to the idiosyncrasies of the input dataset
- Ease-of-use: One line of code



How to use fMRIPrep?

1. Installation
 - a. Docker (workstation)
 - b. Singularity (cluster)
2. Make sure your data is BIDS-compatible
3. fMRIPrep command line
4. Understand the output

Installation

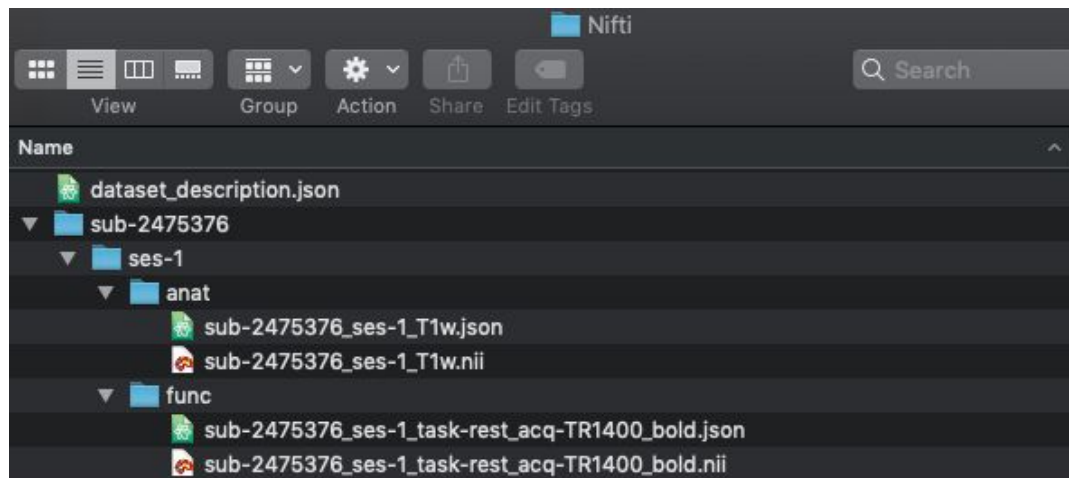
Docker

1. Download Docker and python
 - <https://docs.docker.com/get-docker/>
 - <https://www.python.org/downloads/>
2. Download fMRIPrep Docker image
 - `python -m pip install --user --upgrade fmriprep-docker`
3. Configure your docker environment
 - At least 8GB memory
 - Add fmriprep-docker directory to your PATH



BIDS compatibility

1. Make sure your data is BIDS compatible
 - Newer fmriprep automatically checks BIDS
2. Check json files
 - Phase encoding direction for fieldmap
 - Slice timing
 - “Intended for”



fMRIPrep command line

```
usage: fmriprep [-h] [--version] [--skip_bids_validation]
               [--participant-label PARTICIPANT_LABEL [PARTICIPANT_LABEL ...]]
               [-t TASK_ID] [--echo-idx ECHO_IDX] [--bids-filter-file FILE]
               [--anat-derivatives PATH] [--bids-database-dir PATH]
               [--nprocs NPROCS] [--omp-nthreads OMP_NTHREADS]
               [--mem MEMORY_GB] [--low-mem] [--use-plugin FILE]
               [--anat-only] [--boilerplate-only] [--md-only-boilerplate]
               [--error-on-aroma-warnings] [-v]
               [--ignore {fieldmaps,slicetiming,sbref,t2w,flair} [{fieldmaps,slicetiming,sbref,
               --longitudinal}]]
               [--output-spaces [OUTPUT_SPACES [OUTPUT_SPACES ...]]]
               [--bold2t1w-init {register,header}] [--bold2t1w-dof {6,9,12}]
               [--force-bbr] [--force-no-bbr] [--medial-surface-nan]
               [--dummy-scans DUMMY_SCANS] [--random-seed _RANDOM_SEED]
               [--use-aroma]
               [--aroma-melodic-dimensionality AROMA_MELODIC_DIM]
               [--return-all-components]
               [--fd-spike-threshold REGRESSORS_FD_TH]
               [--dvars-spike-threshold REGRESSORS_DVARS_TH]
               [--skull-strip-template SKULL_STRIP_TEMPLATE]
               [--skull-strip-fixed-seed]
               [--skull-strip-t1w {auto,skip,force}] [--fmap-bspline]
               [--fmap-no-demean] [--use-syn-sdc] [--force-syn]
               [--fs-license-file FILE] [--fs-subjects-dir PATH]
               [--no-submm-recon] [--cifti-output [{91k,170k}] |
               --fs-no-reconall] [--output-layout {bids,legacy}]
               [-w WORK_DIR] [--clean-workdir] [--resource-monitor]
               [--reports-only] [--config-file FILE] [--write-graph]
               [--stop-on-first-crash] [--notrack]
               [--debug {compcor,all} [{compcor,all} ...]] [--sloppy]
               bids_dir output_dir {participant}
```

- `--use-aroma` & `--aroma-melodic-dimensionality`
 - Enable ICA-AROMA based denoising
- `--fs-no-reconall` & `--no-submm-recon` & `--cifti-output`
 - Enable freesurfer, surface-based high-resolution reconstruction, and change freesurfer resolution
- `--output-spaces`
 - Enable alternative volumetric templates (e.g. “MNI152Lin”, “MNI152NLin2009cAsym”, “MNIPediatricAsym”, “fsaverage”, “fsaverage5”, “fsaverage6”)



fMRIPrep command

```
docker run -ti --rm \  
-v Path2InputFolder:/data:ro \  
-v Path2OutputFolder:/out \  
-v Path2Freesurfer/license.txt:/license.txt \  
poldracklab/fmriprep:20.0.5 \  
/data /out participant --participant-label 11111 --no-submm-recon --ignore slicetiming  
--fs-license-file /license.txt
```



Understand the output

- Derivatives (preprocessed data)
 - Anatomical
 - sub-<subject_label>[_space-<space_label>]_desc-preproc_T1w.nii.gz
 - Functional
 - sub-<subject_label>[_specifiers]_space-<space_label>_desc-brain_mask.nii.gz
 - *_desc-preproc_bold.nii.gz
 - *_desc-smoothAROMAnonaggr_bold.nii.gz
- Confounds
 - sub-<subject_label>[_specifiers]_desc-confounds_timeseries.tsv
- Visual QA (HTML) reports

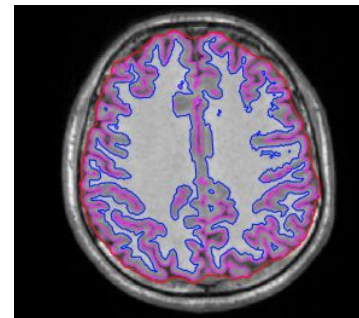
Visual QA

Brain mask and brain tissue segmentation of the T1w

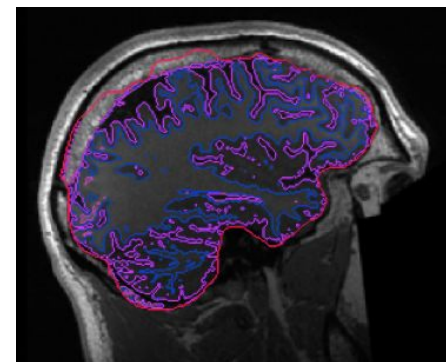
What to look for

Brain mask: make sure the red contour only covers the brain (not skull or dura mater).

Tissue segmentation: make sure the blue line follows the boundary between the white matter and the grey matter.



good



bad

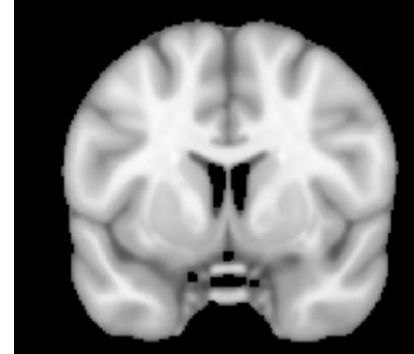
Visual QA

Spatial normalization of the anatomical T1w reference

What to look for

Do the ventricles overlap mostly?

Any artifacts (ghosting, ringing, distortion, stretching)?



MNI152NLin6Asym
template



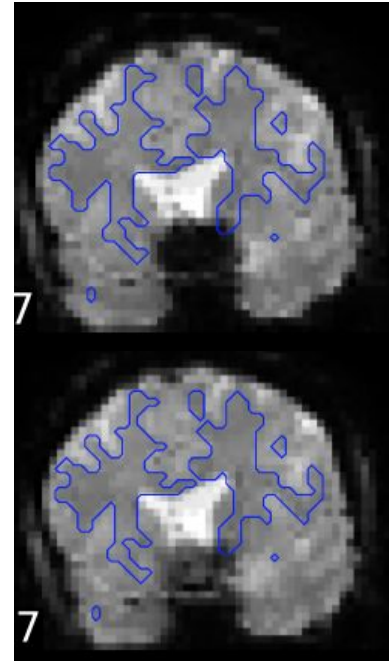
Subject's T1w image

Visual QA

Susceptibility distortion correction

What to look for

Signal dropout and residual distortion in temporal lobes and orbitofrontal cortex is normal, but we should see at least some improvement.



Before

After

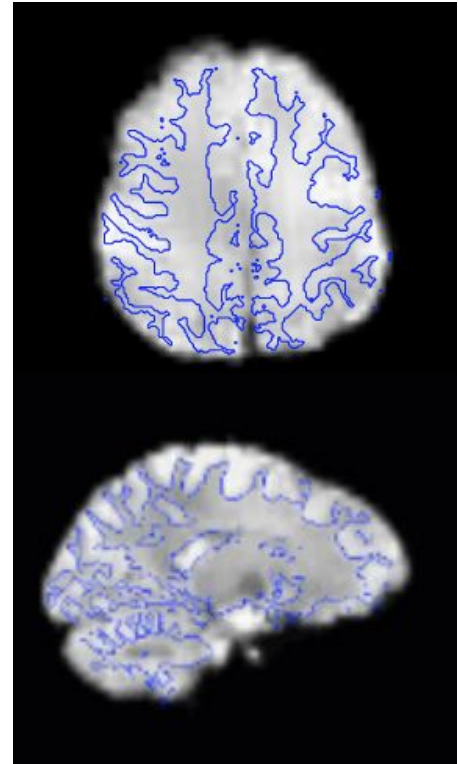
Visual QA

Alignment of functional and anatomical MRI data (surface driven)

What to look for

Blue contour should trace grey/white matter boundary.

Artifacts/signal drop-out area



Visual QA

BOLD Summary

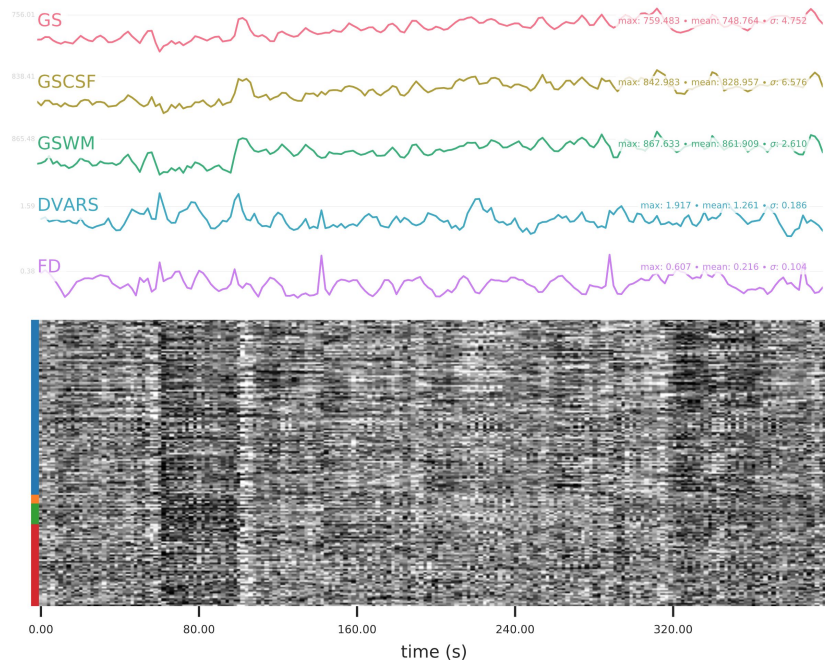
Carpet plot + Confound plots

What to look for

Obvious bands (motion/deep breathing/yawning)

Maximum/average FD

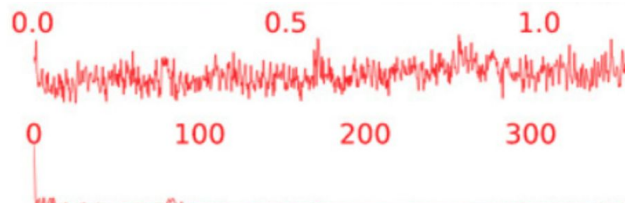
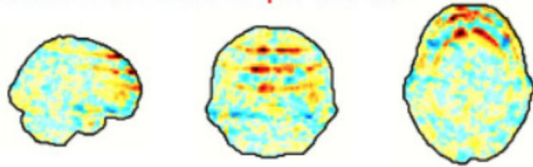
Spikes



Visual QA

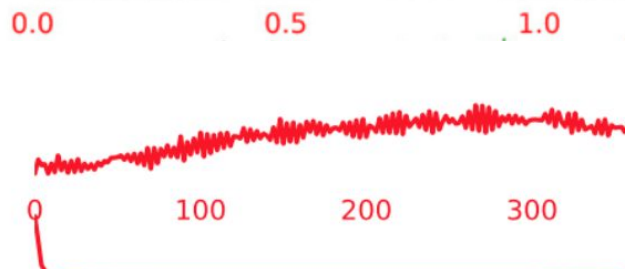
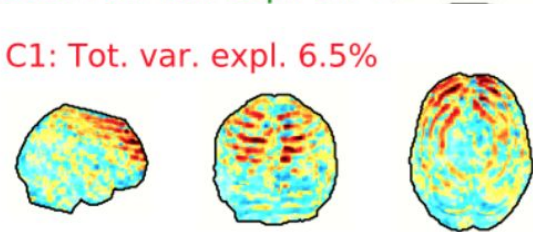
ICA Components classified by AROMA

C33: Tot. var. expl. 0.76%



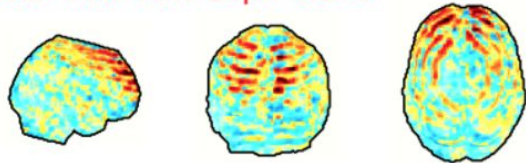
MB artifacts

C35: Tot. var. expl. 0.74%



Slice timing + scanner drift

C1: Tot. var. expl. 6.5%





Visual QA Summary

You should always see your data before any analysis!

- Artifacts/anomalies (should be done before fMRIPrep)
 - ICA-AROMA can reveal potential multiband artifacts and slice timing issues
- Poor skull stripping functional/structural image registration
 - Try a different template
 - Enable freesurf, switch on/off bbregister
- Signal dropout (synthetic susceptibility distortion correction)
 - Check whether your masks include drop-out regions
- Definitely check the carpet plot

Check out this tutorial from Andy for more info: <https://www.youtube.com/watch?v=fQHEKSzFKDc>



More resources

- fMRIPrep documentation
 - <https://fmriprep.org/en/stable/usage.html>
- Questions about fMRIPrep?
 - <https://neurostars.org/tag/fmriprep>
 - <https://github.com/nipreps/fmriprep/issues>
- More tutorial on fMRIPrep
 - https://andysbrainbook.readthedocs.io/en/latest/OpenScience/OS/fMRIPrep_Demo.htm
- Post-fMRIPrep
 - https://github.com/JunaidMerchant/PreThruPostPrep_DSCN