Week 4 – Preprocessing and data quality check 1

L04-08. Introduction to Preprocessing

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L04-08. Introduction to preprocessing

- What is preprocessing?
  - Before starting the actual analysis, we need to **PRE**process (here, for the fMRI data)
- Goals of preprocessing
  - Prior to analysis, fMRI data undergoes a series of preprocessing steps aimed at identifying and removing artifacts and validating model assumptions.
  - To minimize the influence of data acquisition and physiological artifacts
    (= to remove uninteresting variability from the data)
  - To standardize the locations of brain regions across subjects to achieve validity and sensitivity in group analysis
  - If done correctly, preprocessing steps can greatly increase the functional resolution of an fMRI experiment.

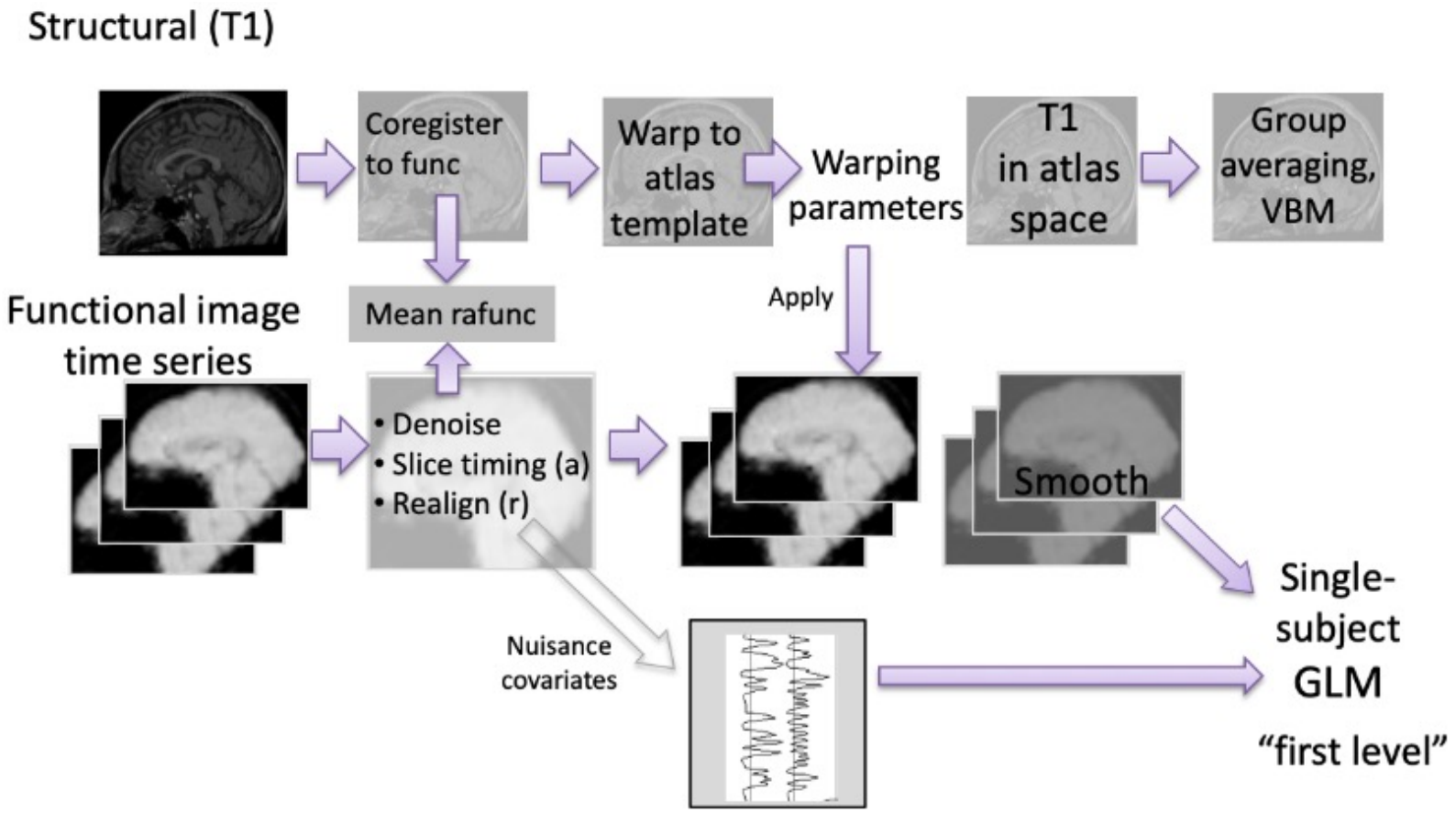
- Huettel et al, Functional Magnetic Resonance Imaging, 3rd edition
- Lindquist and Wager, Principles of fMRI

❖ Sources of noise

1. **Physical** noise
   - Intrinsic thermal noise within subject and scanner electronics
   - System noise associate with imperfections in scanner hardware
2. **Physiological** noise
   - Artifacts (head motion, respiration, heart rate)
   - Variability in neuronal activity associated with non-task factors
   - Changes in behavioral performance and cognitive strategies

- Huettel et al, Functional Magnetic Resonance Imaging, 3rd edition
- Lindquist and Wager, Principles of fMRI

❖ Pre-processing pipelines



- Slide credit: Tor Wager

❖ Cocoanlab preprocessing pipeline (github.com/cocoanlab/humanfrmi_preproc_bids)

Option 1 (default). **T1 normalization**

PART 1 (a1-a4)

DICOM to NIFTI
in a BIDS format

- a1: make directory
- a2: Structural
- a3: Functional
- a4: Fieldmap

PART 2 (b1-b3)

Functional images
QC (outlier detection)

b1: Make directories

b2: implicit mask and mean images
- create an implicit mask image
- save mean images and SBRef (before preproc) as png in qc directories

b3: outlier detection
- outlier detection based on 1) mahalanobis distance across global mean for slices and spatial STD for slices, as in scn_session_spike_id.m 2) root-mean-square successive differences between images

PART 3 (b4-b6)

Functional images
Slice timing, motion, distortion correction

b4: slice timing correction
- It works with multi-band sequence
- It reads the actual acquisition timing from dicom header.

b5: motion correction (realignment)
- It uses the first functional image or SBRef (you can choose) as a reference.
- It saves 6 movement parameters for each run

b6: distortion correction (using FSL's topup)

PART 4 (b7-b8)

Structural and functional images
Coregistration, normalization, smoothing

b7: coregistration
- coregistration between T1 and mean functional images or SBRef image (you can choose).

b8: normalization
- segmentation of the coregistered T1 image using SPM12's tissue probability map (TPM.nii)
- warping segmented (and coregistered) T1 image to MNI template
- applying the warping parameter to the functional images

PART 5 (b9-b10)

Functional images
Smoothing and ICA-AROMA

b9: smoothing
- smoothing functional images with the FWHM 5 mm smoothing kernel.

b10: ICA-AROMA
- A data-driven method to identify and remove motion-related independent components from functional MRI data.
- https://github.com/rhr-pruim/ICA-AROMA

B-2. Implicit mask and mean images
B-3. Outlier detection

B-4. Slice timing correction (optional)
B-5. Motion correction (realignment)
B-6. Distortion correction

B-7. Coregistration
B-8. Normalization

B-9. Smoothing
B-10. ICA-AROMA

C-2. Framewise displacement
C-3. Make nuisance regressors

❖ Useful resources

- Tor Wager & Martin Lindquist's Coursera
  - Principles of fMRI 1: https://www.coursera.org/learn/functional-mri
  - Principles of fMRI 2: https://www.coursera.org/learn/functional-mri-2
  - Want videos only? https://www.youtube.com/channel/UC_BIby85hZmcItMrkAlc8eA

- Mumford's Educational videos
  - https://www.youtube.com/channel/UCZ7gF0zm35FwrFpDND6DWeA/videos

- SPM/FSL mailing list is extremely helpful
  - E.g., SPM: https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=spm

- SPM Manual is also helpful!

❖ Prerequisites

- SPM12 (https://www.fil.ion.ucl.ac.uk/spm/software/download)
- Canlab tools (https://github.com/canlab/CanlabCore)
- Canlab preprocessing codes (https://github.com/canlab/preprocess)
- Cocoanlab tools (https://github.com/cocoanlab/cocoanCORE)
- Cocoanlab preprocessing codes (https://github.com/cocoanlab/humanfmri_preproc_bids)
- Statistical toolbox of Matlab
- FSL (https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FslInstallation)

❖ Example codes are there! (https://github.com/cocoanlab/humanfmri_preproc_bids/tree/master/codes)

master ▾ humanfmri_preproc_bids / codes / Go to file

Hongjikim bug fixed 6a2c561 on 5 Feb History

..		
old	moved distortion correction after motion correction	3 years ago
change_basedir_PREPROC.m	updates	3 years ago
humanfmri_a1_make_directories.m	reorganizing files	3 years ago
humanfmri_a2_structural_dicom2nifti_bids.m	more options for dicom pattern	12 months ago
humanfmri_a3_functional_dicom2nifti_bids.m	more options for dicom pattern	12 months ago
humanfmri_a4_fieldmap_dicom2nifti_bids.m	BUG FIX: DISTORTION CORRECTION	2 years ago
humanfmri_b10_ICA_AROMA.m	bugfix: filenames->fullpath (b10)	7 months ago
humanfmri_b1_preproc_directories.m	minor bug fixed	2 years ago
humanfmri_b2_functional_implicitmask_savemean.m	updates	14 months ago
humanfmri_b3_spike_id.m	added a new functionality(specify run numbers), run_num	3 years ago
humanfmri_b4_slice_timing.m	bugfix:slicetimingcorrection	3 years ago
humanfmri_b5_motion_correction.m	minor bug fix	14 months ago
humanfmri_b5_motion_correction_with_st_correct.m	add new function: motion correction with slice-timing correction	12 months ago
humanfmri_b6_distortion_correction.m	minor bug fix	14 months ago

❖ Example codes are there! (https://github.com/cocoanlab/humanfmri_preproc_bids/tree/master/examples)

example_CAPS2.m	reorganizing files	3 years ago
example_code.m	updates pipeline figures and example codes	3 years ago
example_code2_fast.m	updates pipeline figures and example codes	3 years ago
example_pico_preproc.m	added example of pico and minor bug fixed	2 years ago
example_semic_preproc.m	aadded new function and minor bug fixed	2 years ago
pipeline_overview.pptx	updates	3 years ago
preprocessing_manual_2019Feb.mlx	added manual in examples	2 years ago

Cocoan 101

https://cocoanlab.github.io