Week 4 – Preprocessing and data quality check 1

L04-09 Preprocessing (1)

Hongji Kim
Ph.D. student in the Cocoan Lab

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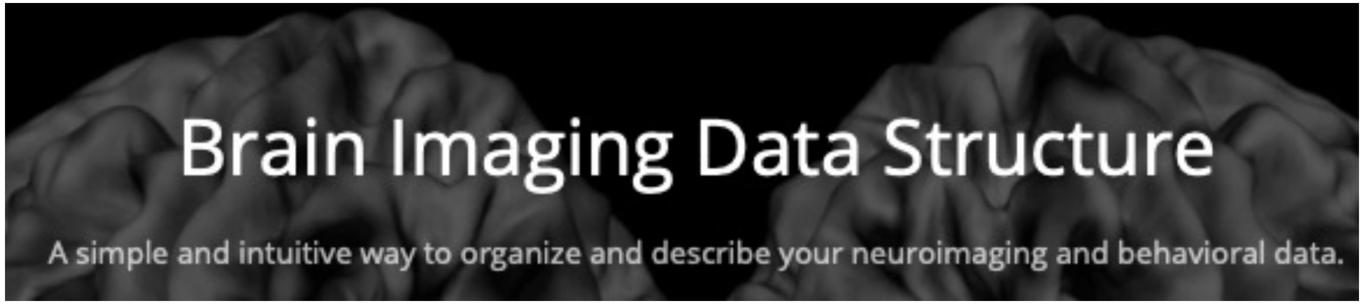
❖ Contents

- A-1 ~ B-1: Moving directories and dicm2nii
  - BIDS form
    - simple and easy to adopt way of organizing neuroimaging and behavioral data
    - BIDS is heavily inspired by the format used internally by the OpenfMRI repository (OpenNeuro.org)
    - Cocoanlab preprocessing pipeline starts with setting directories in BIDS form



- https://bids.neuroimaging.io

❖ A-2 ~ A-4: dicm2nii

```
%% A-2. Dicom to nifti: structural and functional
d=datetime('now');

for i=1:num_sub
    % A-2. Dicom to nifti: anat(T1)

    humanfmri_a2_structural_dicom2nifti_bids(subject_code{1,i}, study_imaging_dir);

    % A-3. Dicom to nifti: functional(Run 1~9)

    %humanfmri_a3_functional_dicom2nifti_bids(subject_code, study_imaging_dir, disdaq_n);
    humanfmri_a3_functional_dicom2nifti_bids(subject_code{1,i}, study_imaging_dir, disdaq_n, 'no_check_disdaq');

    % A-4. Dicom to nifti: fmap(Distortion correction)

    %humanfmri_a4_fieldmap_dicom2nifti_bids(subject_code, study_imaging_dir);
    humanfmri_a4_fieldmap_dicom2nifti_bids(subject_code{1,i}, study_imaging_dir);

    d=[d datetime('now')];
end
```

Set how many images (TRs) you want to exclude as disdaq

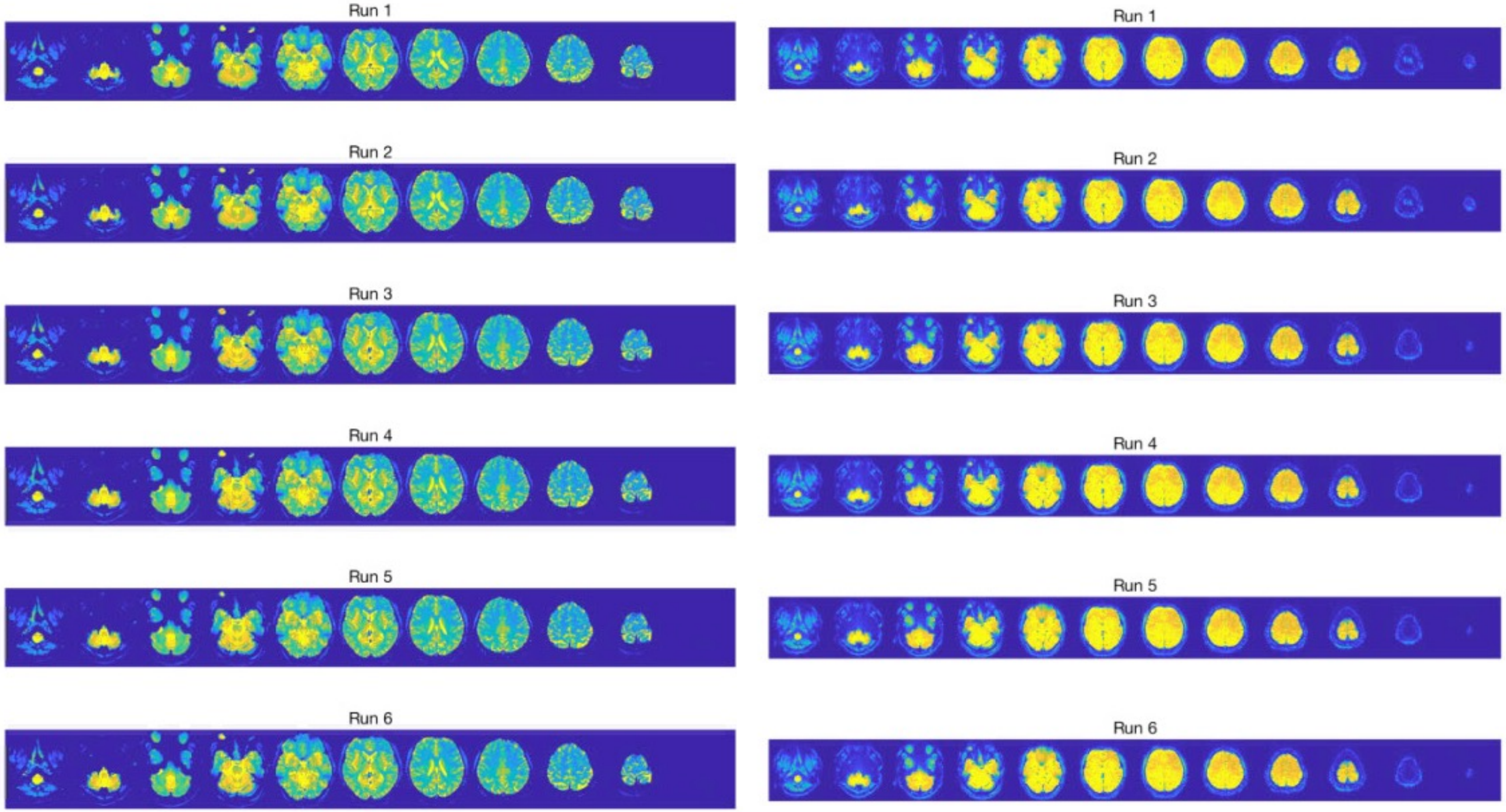
❖ B-2: Implicit mask and mean images

- Brain vs. outside
- Top 95% voxels above the mean value only.
- This function creates and saves implicit mask (top 95% of voxels above the mean value) and mean functional images (before any preprocessing).
- Implicit mask is used to visualize quality check images.

```
%% B-2. Implicit mask and save means

humanfmri_b2_functional_implicitmask_savemean(preproc_subject_dir);
```

- B-2: Implicit mask and mean images (Left: SBREF, right: MB8)
  - Qc plots



❖ B-3: Spike identification (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

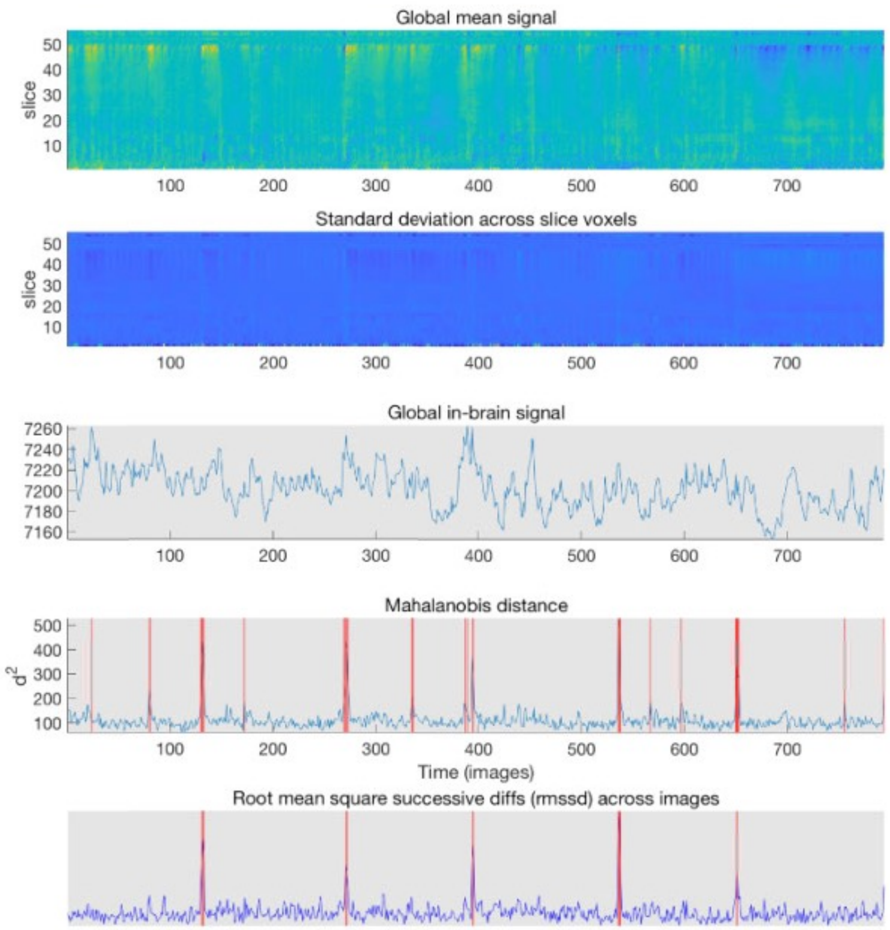
     - The Mahalanobis distance is a measure of the distance between a point P and a distribution D. It is a multi-dimensional generalization of the idea of measuring how many standard deviations away P is from the mean of D.

  2) RMSSD (root-mean-squared successive difference between images)

```
%% B-3. Spike id
humanfmri_b3_spike_id(preproc_subject_dir);
```

❖ B-3: Spike identification (Outlier detection)

- QC plots



Diary:

Session 1:
38 Potential outliers
%Spikes: 4.79
Global SNR (Mean/STD): 253.55

Added 38 global/mahal outlier covariates to covariates field.
Added 38 global/mahal outlier covariates to covariates field.
Outliers in RMSSD images: 0%, 17 imgs.

❖ B-4: Slice timing correction (Optional)

- MR images are typically collected one slice at a time (exception: 3D imaging)
- Delay between slice excitations is typically

  TR / (num. slices)

- Therefore, the time series are time-shifted differently in each slice.
- Correction:
  - Shift each voxel's time series so all voxels in each volume appear to have been acquired at the same time
  - Ideally would be fully integrated with motion correction

- It works with multi-band sequence
- For most of the data collected in Cocoanlab, which uses short TR (0.46 sec), slice timing correction is skipped.

- Slide credit: Tor Wager

Slice acquisition

- Interleaved

- Slide credit: Tor Wager

Slice acquisition

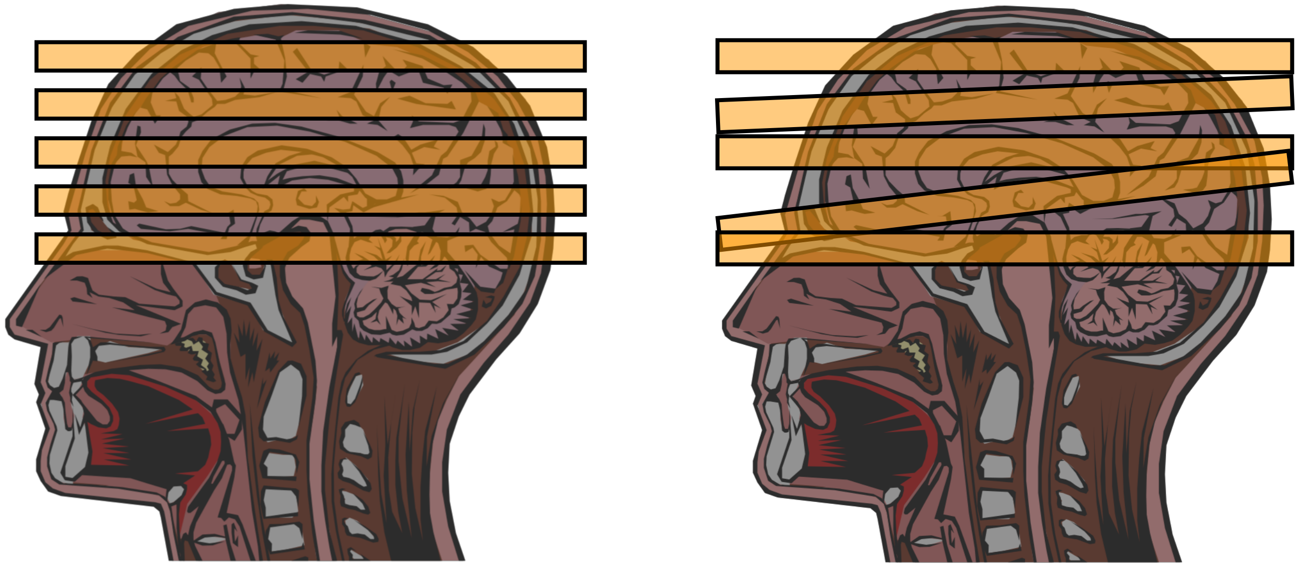
- Sequential

- Slide credit: Tor Wager

Difficulties

- Motion is 3-dimensional

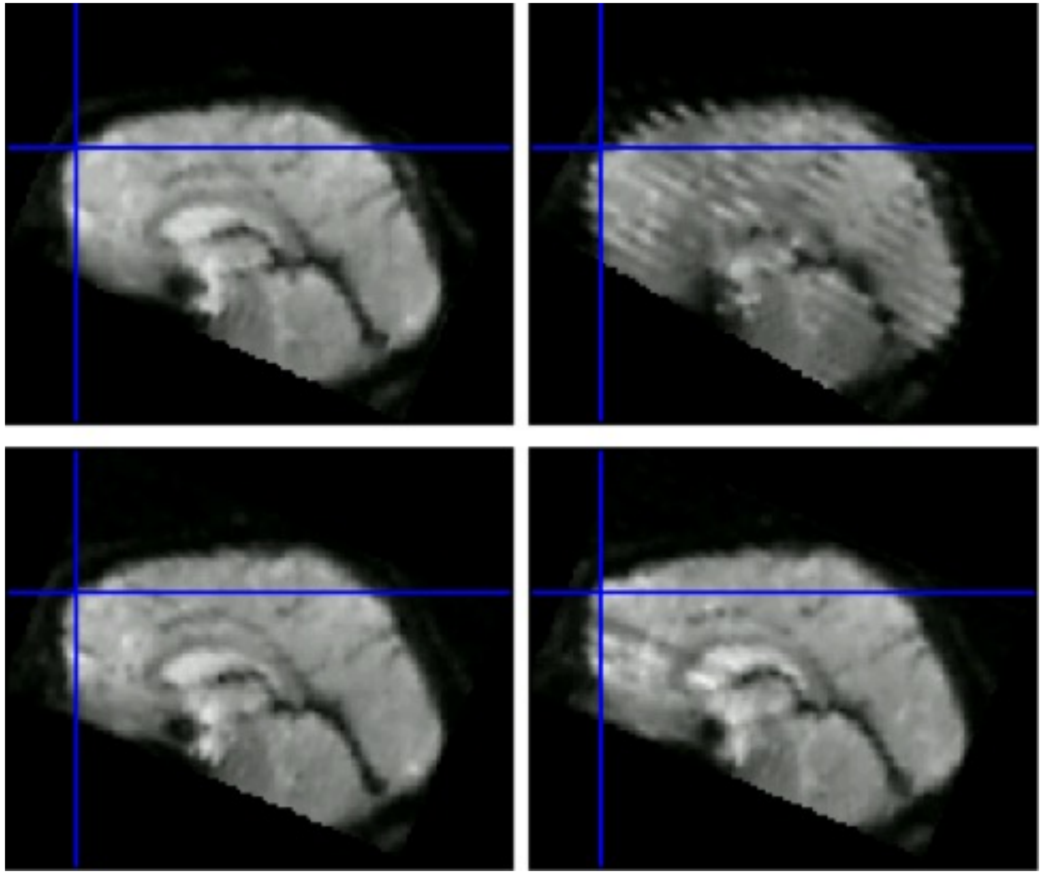
expected acquisition: slices are actually acquired like this…



- Slide credit: Tor Wager

Spin history * head movement artifacts

No head movement | Head movement



Interleaved

Sequential

http://imaging.mrc-cbu.cam.ac.uk/imaging/CommonArtefacts

- Slide credit: Tor Wager

❖ B-5: Motion Correction (Realignment)

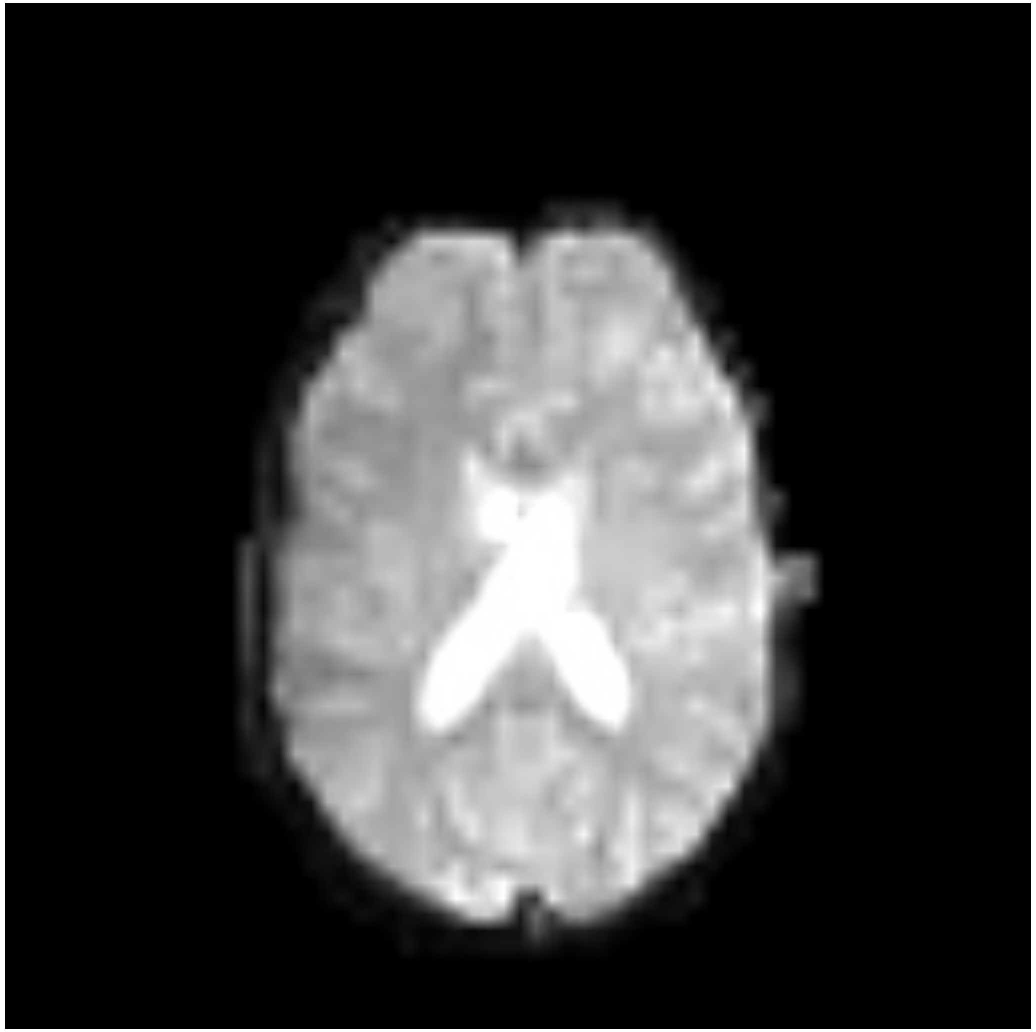
- Head motion can lead to spurious activations or can hinder the ability to find real activations
  - Severity of problem depends on correlation between motion and paradigm (e.g., speech)
- Regions move over time
  - Regions-of-interest (ROI) analysis: ROI may shift
  - Voxel-wise analyses: averages activated and nonactivated voxels
- In this step, we will use SBRef as a reference image, and get 6 movement parameters (x,y,z,pitch,roll,yaw) for each run.
- In step C-3, these 6 movement parameters will be extended into 24 parameters.

```
%% B-5. Motion correction

use_st_corrected_data = false;
use_sbref = true;
humanfmri_b5_motion_correction(preproc_subject_dir, use_st_corrected_data, use_sbref);
```

The first single band reference image is used as the standard of realignment

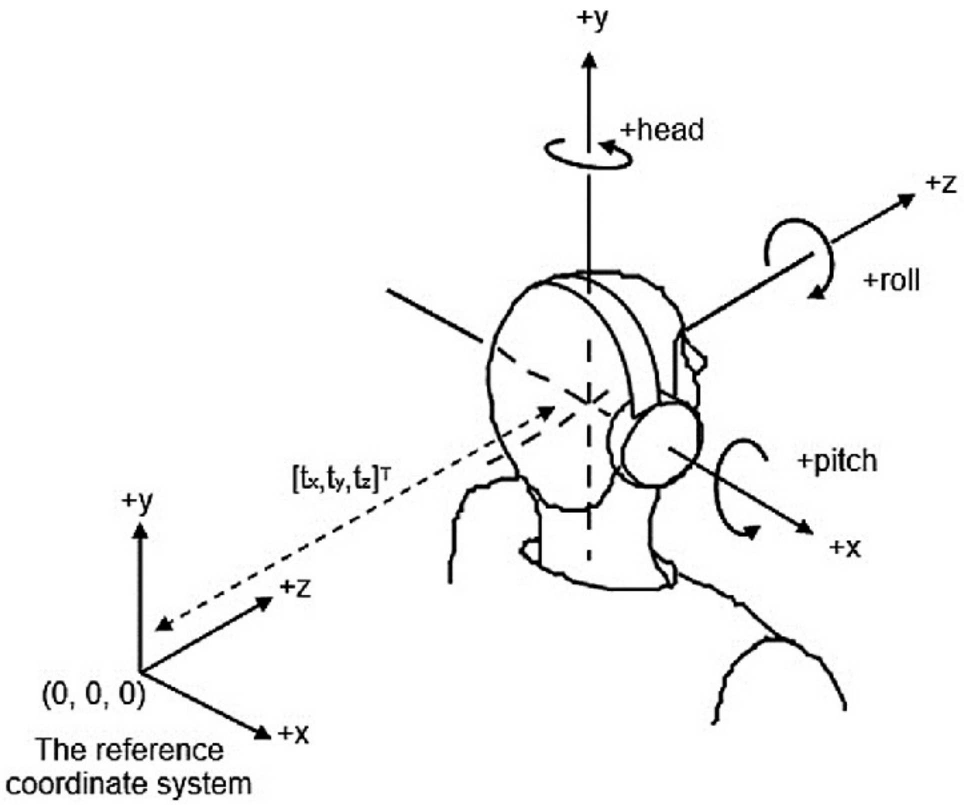
❖ B-5: Motion Correction (Realignment)

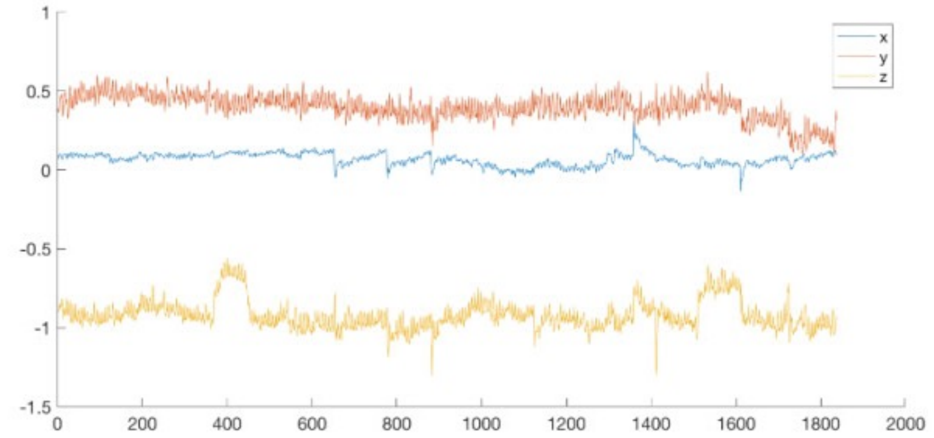


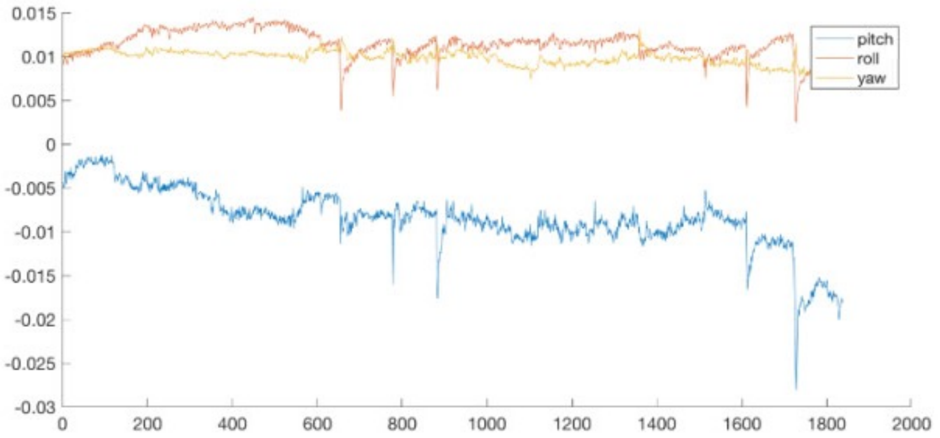
- Slide credit: Tor Wager

❖ B-5: Motion Correction (Realignment)

- QC plots







❖ B-6: Distortion Correction

- Echo-planar imaging can produce large geometric image distortions near areas of high magnetic susceptibility (air/tissue interfaces)
- This can be mathematically corrected using information from field maps and blip up/down acquisitions

```
%% B-6. distortion correction
epi_enc_dir = 'ap';
use_sbref = true;
humanfmri_b6_distortion_correction(preproc_subject_dir, epi_enc_dir, use_sbref, 'run_num', 1:7)
```

- https://fls.fmrib.ox.ac.uk/fslcourse/lectures/reg.pdf

❖ B-6: Distortion Correction

Registration without Correction

Localization of functional information relies on accurate registration of EPI and structural MR, which can be difficult due to EPI distortion caused by B0 field inhomogeneity. Correcting distortion using acquired Fieldmaps has been shown to improve registration [1], but Fieldmaps may not be available or may not be applicable if significant motion is present in the EPI, resulting in sub-optimal registration.

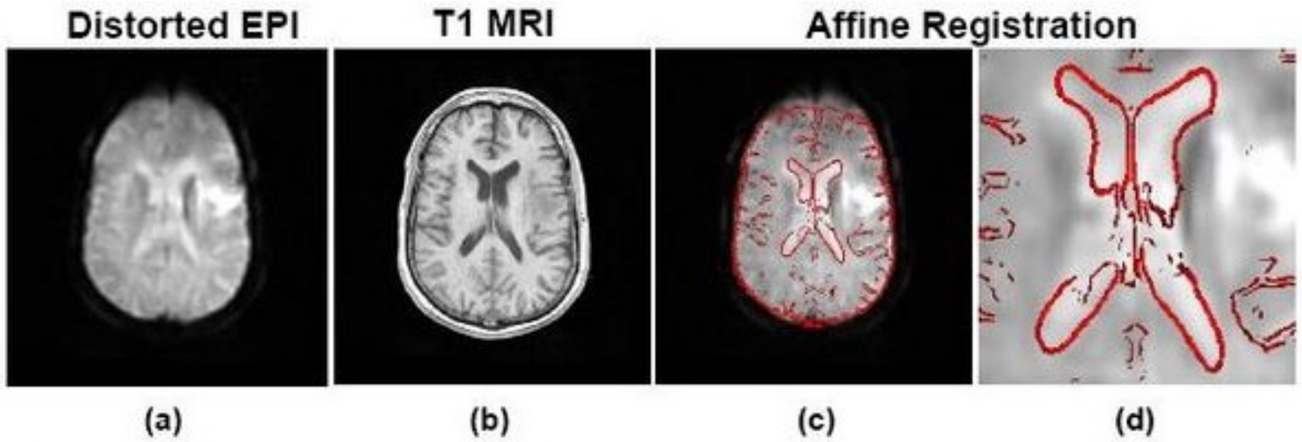


Figure 1. Registration without Distortion Correction.
Registration of Distorted EPI (a) to T1 MRI (b) using a 12 DOF affine transformation results in poor registration (c,d). An edge strength image of the T1 brain (red) is overlaid on the registered EPI for visualization (c,d).

https://www.na-mic.org/wiki/Projects:FieldmapFreeDistortionCorrection

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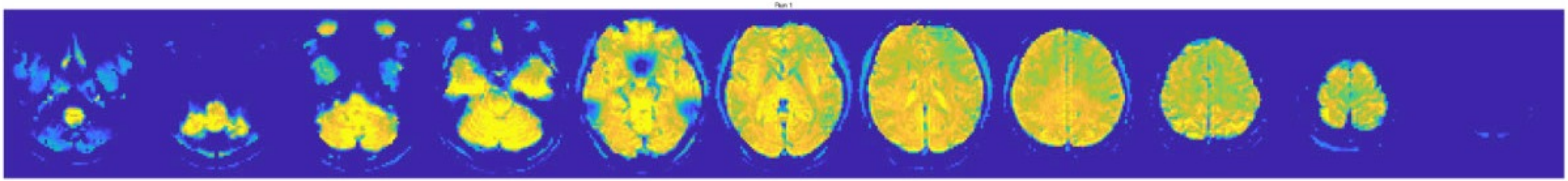
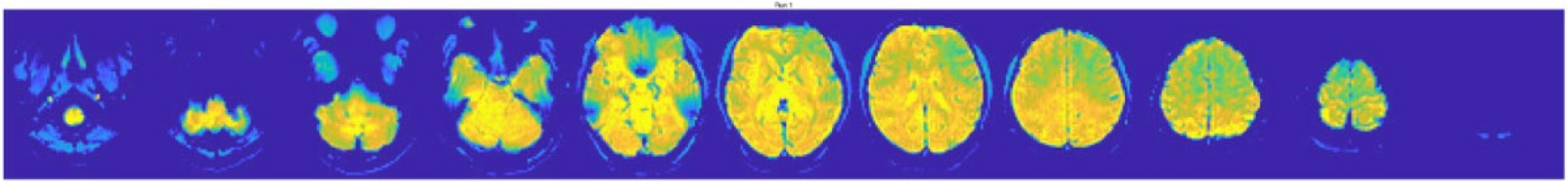
Can you guess which one is before/after distortion correction?





❖ B-7: Coregistration

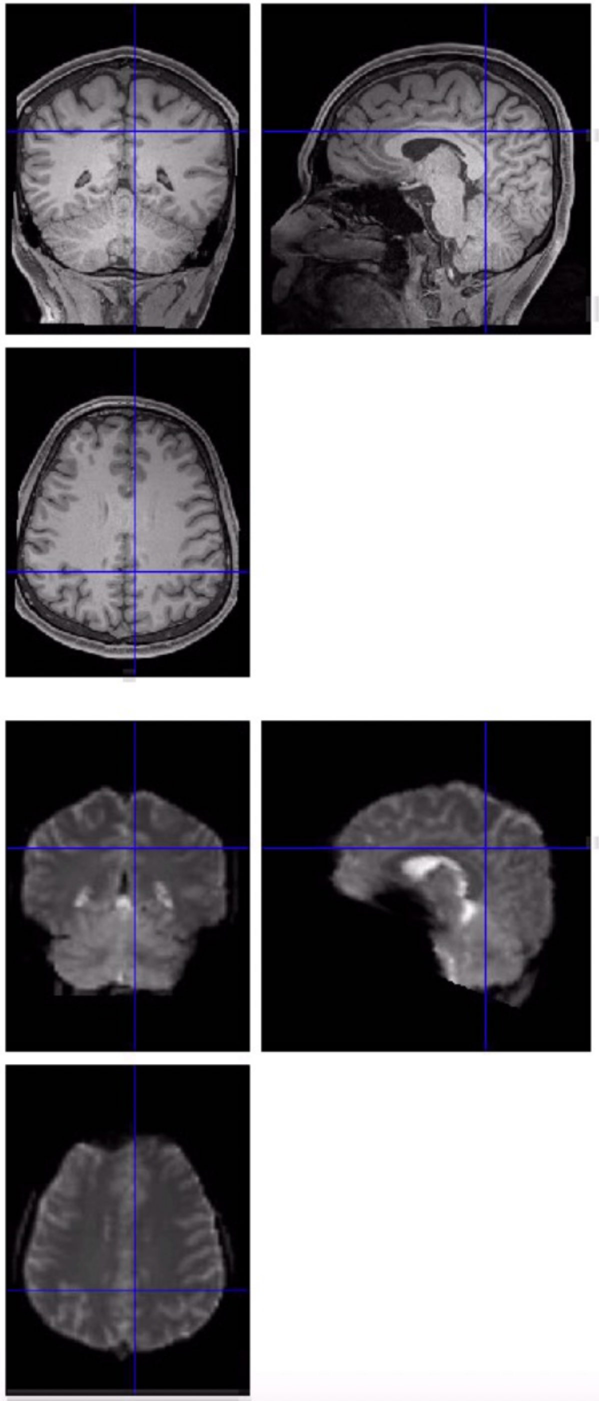
- Lining up functional to anatomical images (correcting for motion between your anatomical and functional images)
- Allows display of activation on anatomical images

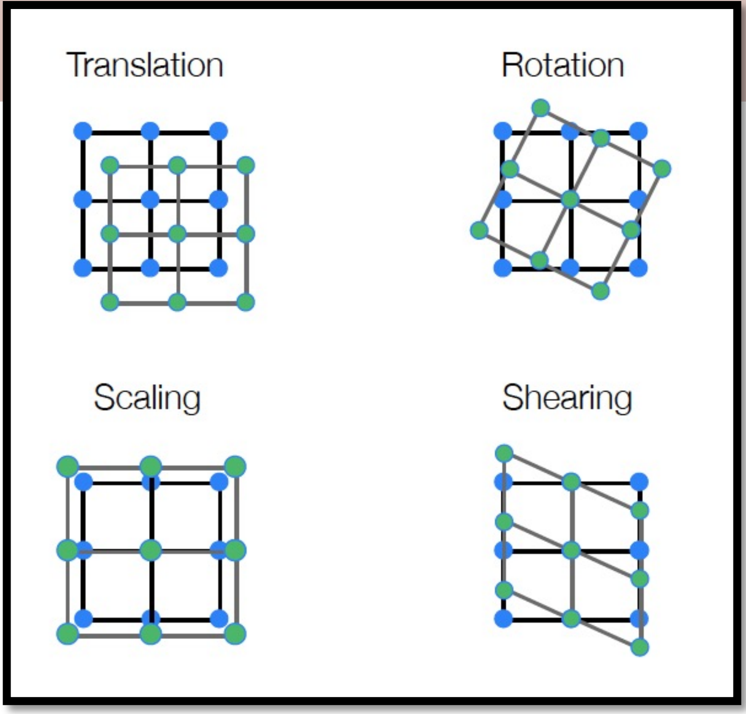
```
%% PART 4
% B-7. coregistration (spm_check_registration.m)

use_sbref = true;
humanfmri_b7_coregistration(preproc_subject_dir, use_sbref);
%humanfmri_b7_coregistration(preproc_subject_dir, use_sbref, 'no_check_reg');
```

L04-09. Preprocessing (1)

❖ B-7: Coregistration

- With ‘spm_check_registration.m’ function, you can visualize how functional and anatomical images are lined up





❖ B-8: Normalization

- Put a brain into a 'standard' brain space
  - Aligns up structural anatomy
- Two-step registration

  1) functional -> structural

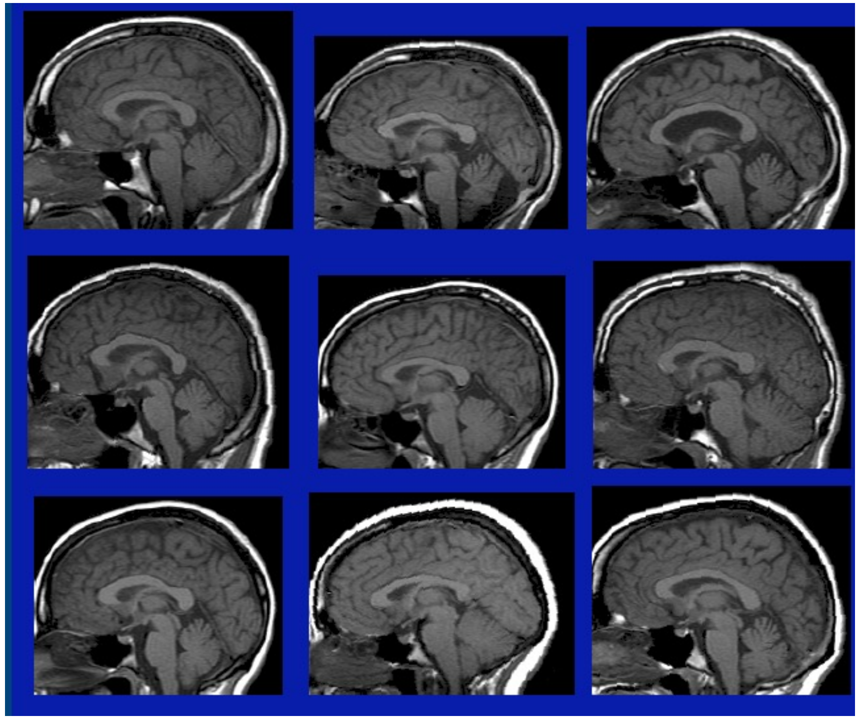
  2) structural -> standard
- Purpose: To warp individual subject brains into a common shape and space
- Goal: To minimize difference between individual brain and template image
- Not always accurate; cannot be used for 'abnormal' brains

```
%% B-8-1. T1 Normalization

use_sbref = true;
humanfmri_b8_normalization(preproc_subject_dir, use_sbref);
% humanfmri_b8_normalization(preproc_subject_dir, use_sbref, 'no_check_reg');
```

Slide credit: Tor Wager

❖ B-8: Normalization

- Benefits of normalization
  - Allows for comparing data across multiple subjects
- Talairach & Tournoux: atlas from 1988, proportional grid system, based on single subject (60 years old, Female, Cadaver), single hemisphere
- MNI (Montreal Neurological Institute) space: combination of many MRI scans on normal controls (all right-handed)



Slide credit: Prof. Shim

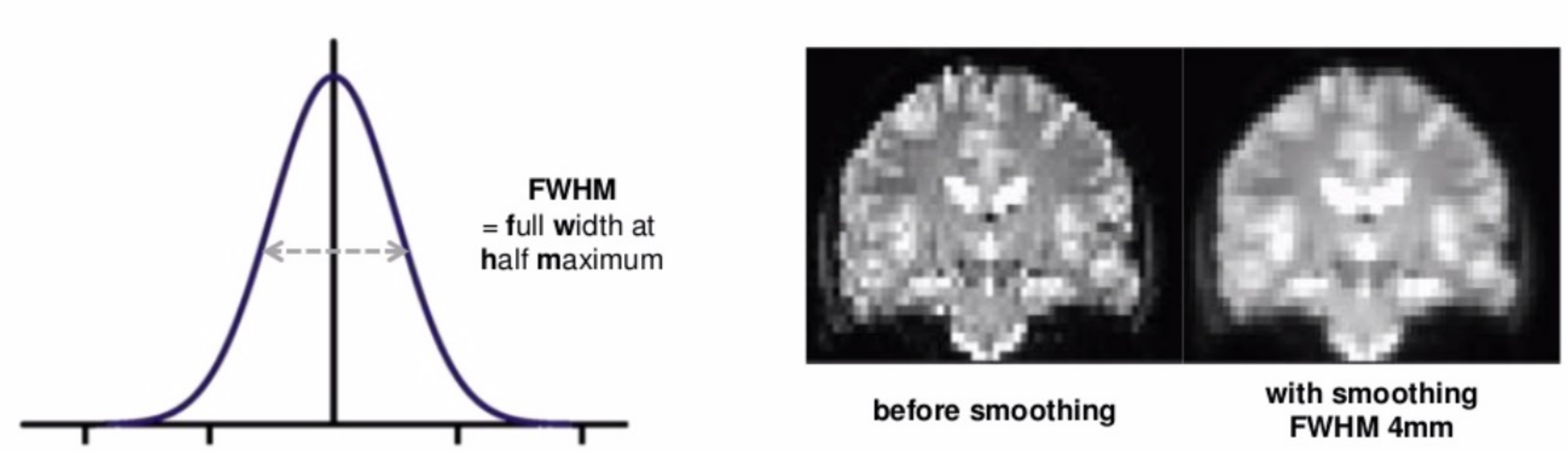
❖ B-9: Smoothing

- Reasons to smooth
  - Increases signal-to-noise ratio
  - Improves ability to make comparisons across subjects
- Pros
  - Suppress noise and effects due to differences in anatomy by averaging over neighboring voxels
  - Achieve better spatial overlap and often enhanced sensitivity
  - Meet assumptions better and reduce effective multiple comparisons when correcting results using Random Field Theory
- Cons
  - You throw away much high-resolution information that can be important
  - Lower signal to noise compared to just acquiring at lower resolution in the first place

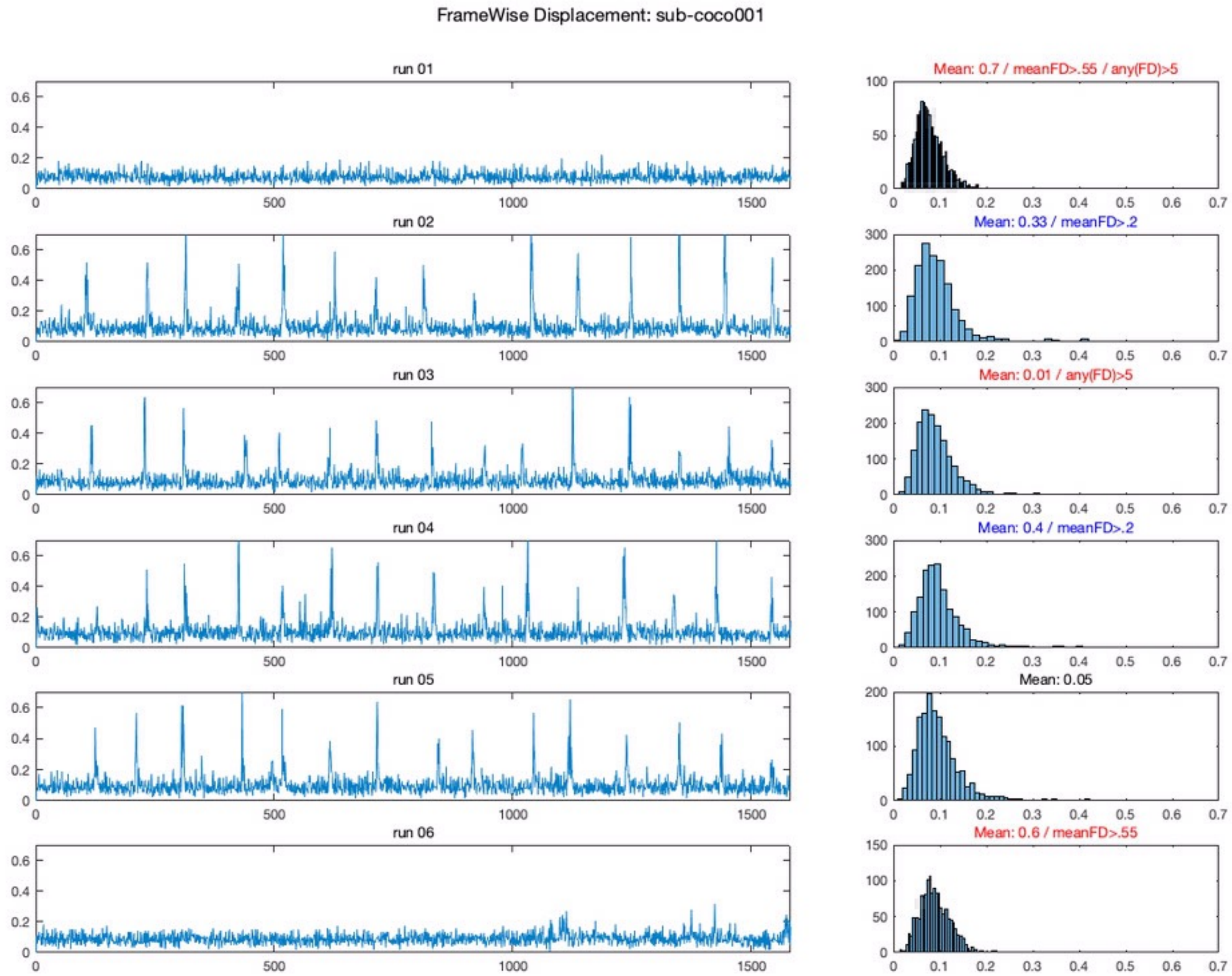
Slide credit: Prof. Shim

❖ B-9: Smoothing

- Apply a Gaussian filter to effectively spread the intensity at each voxel to neighboring voxels
- Increases signal-to-noise ratio: blurring reduces high frequency noise while retaining signal



- C-2: framewise displacement
  - Compute framewise displacement and apply exclusion criteria
  - Three criteria
    - 1) mean FD > 0.55
    - 2) mean FD > 0.2
    - 3) any FD (even one TR) > 5
  - If 1 or 3 -> red flag
  - If 2 -> blue flag
  - If nothing -> black



- C-3: making nuisance matrix
  - Can make various nuisances into one matrix (n * TR matrix)
    - 24 motion parameters (6 movement parameters including x, y, z, roll, pitch, and yaw, and their mean-centered squares, derivatives, and squared derivatives)
    - Spike covariates
    - WM and CSF
    - Linear drift

Cocoan 101

https://cocoanlab.github.io