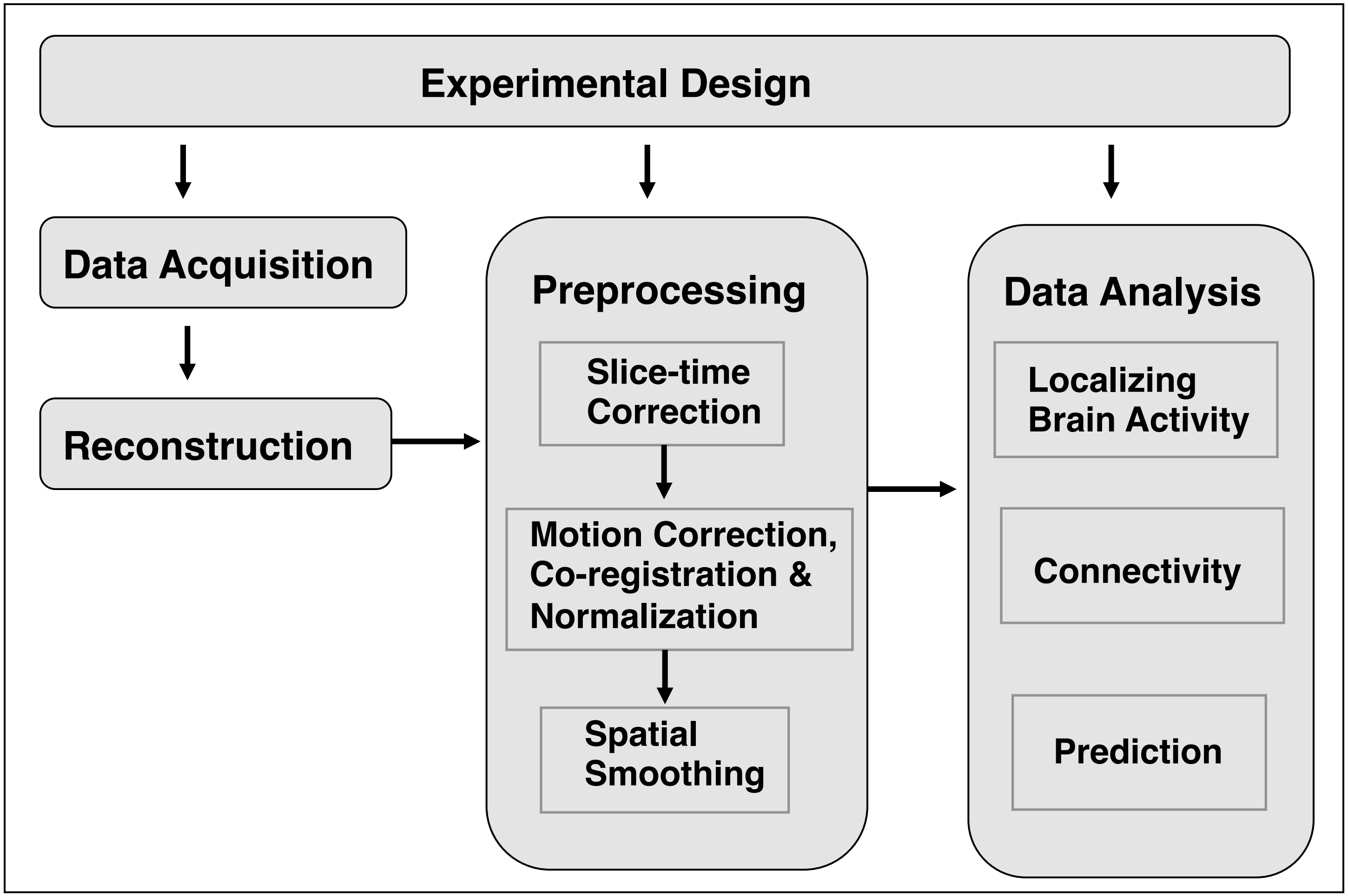
Module 8:
Pre-processing I

Data Processing Pipeline

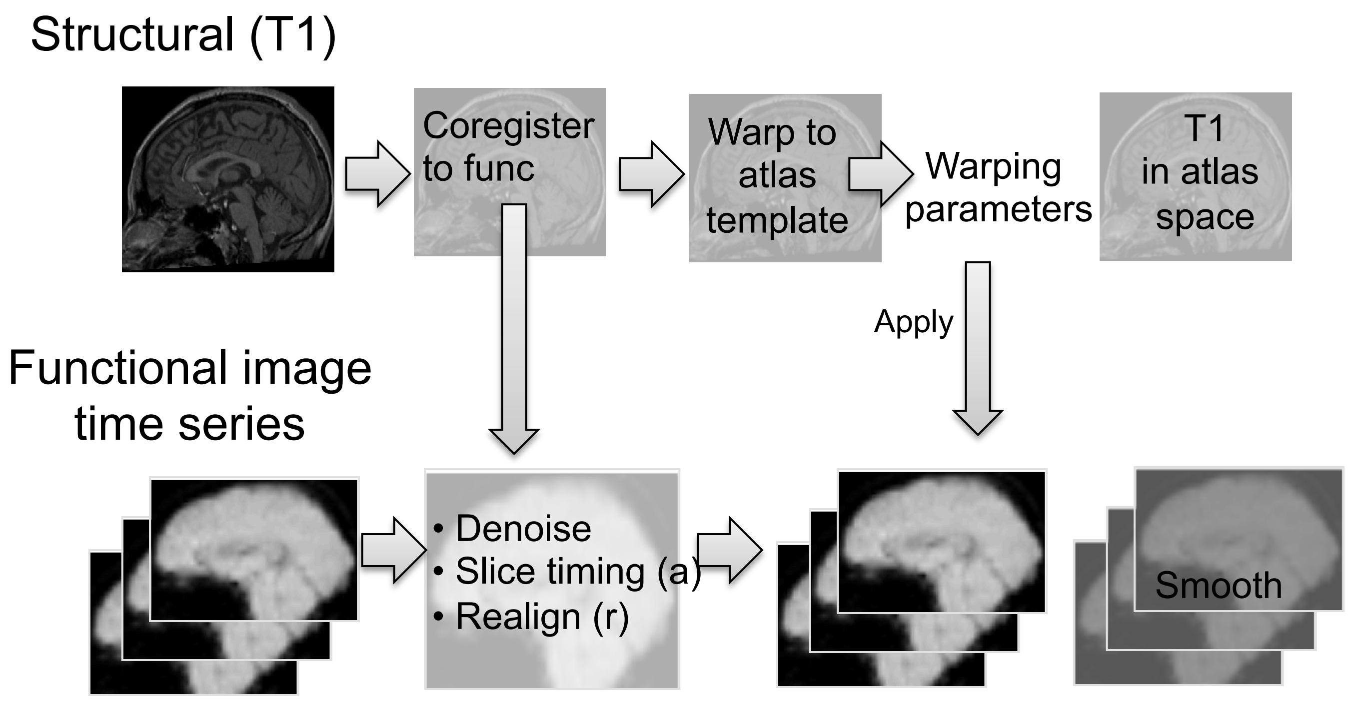


Pre-processing

- Prior to analysis, fMRI data undergoes a series of preprocessing steps aimed at identifying and removing artifacts and validating model assumptions.

- The goals of preprocessing are
  - To minimize the influence of data acquisition and physiological artifacts;
  - To check statistical assumptions and transform the data to meet assumptions;
  - To standardize the locations of brain regions across subjects to achieve validity and sensitivity in group analysis.

Pre-processing Pipeline



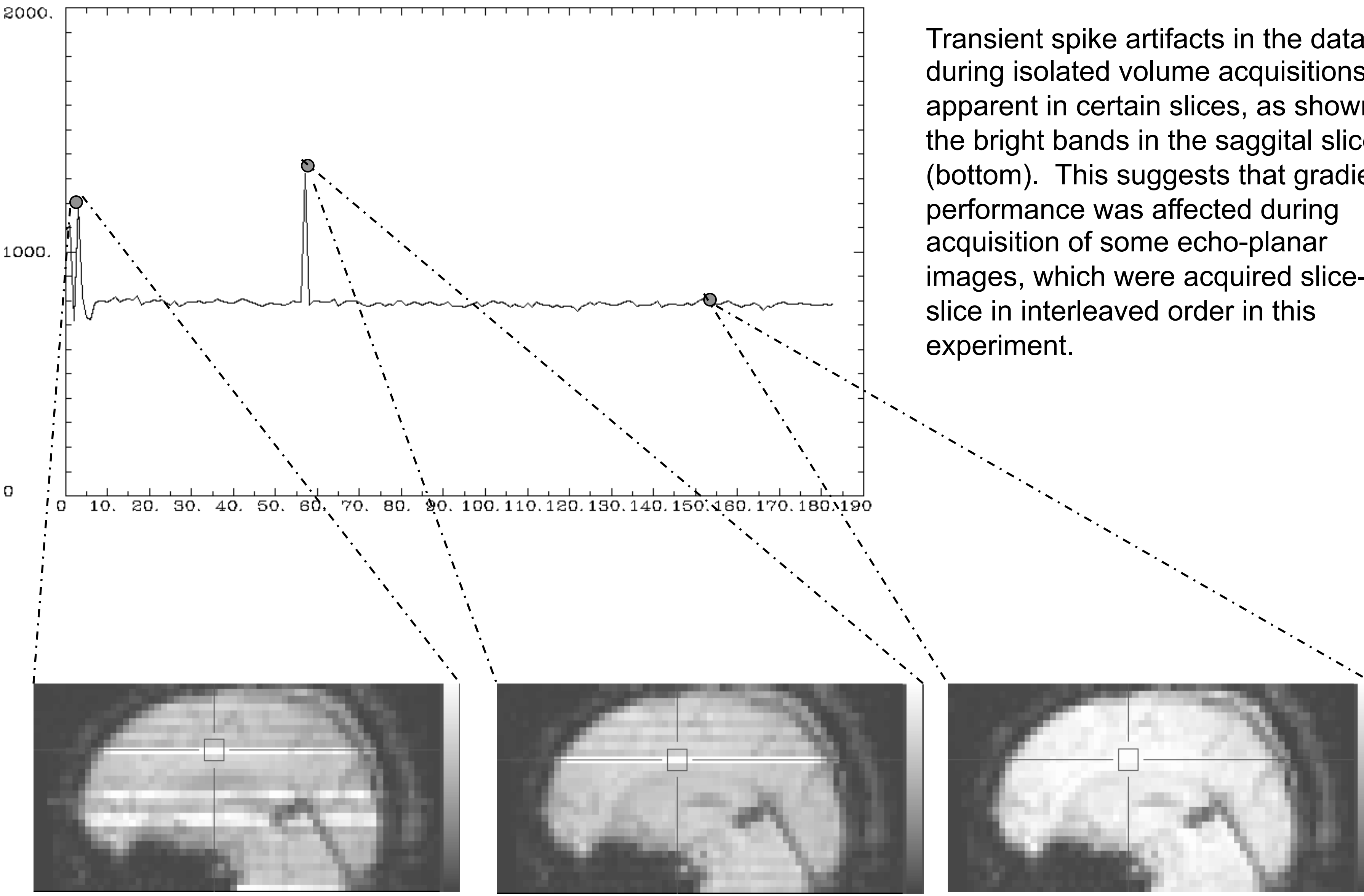
Preprocessing is performed both on the fMRI data and structural scans collected prior to the experiment.

Pre-processing Steps

- Visualization and Artifact Removal
- Slice Time Correction
- Motion Correction
- Physiological Corrections
- Co-registration
- Normalization
- Spatial Filtering
- Temporal Filtering

Visualization & Artifact Removal

- The first part of the preprocessing pipeline is to use exploratory techniques to investigate the raw image data and detect possible problems and artifacts.
- fMRI data often contain transient spike artifacts and slow drift over time.
- An exploratory technique such as principal components analysis (PCA) can be used to look for spike-related artifacts.

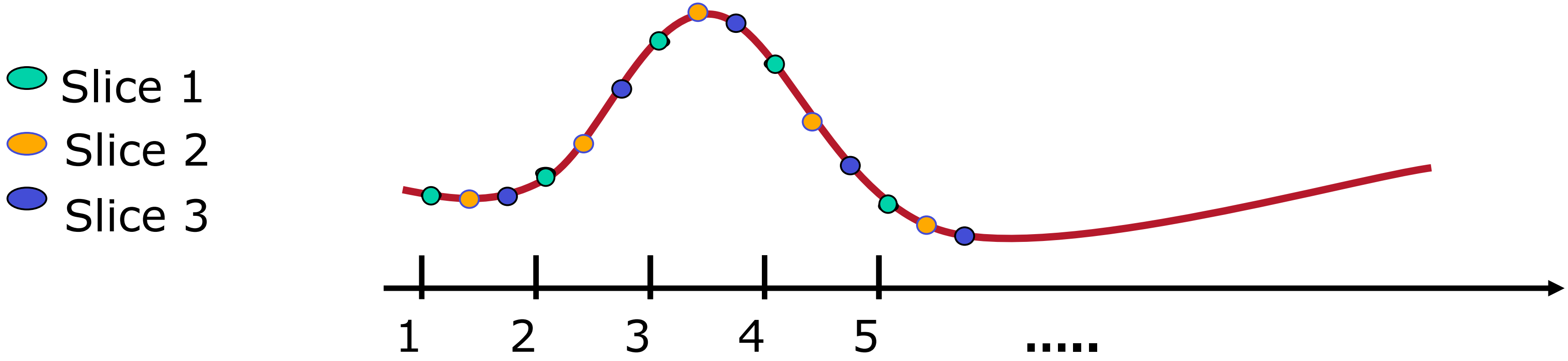


Transient spike artifacts in the data during isolated volume acquisitions are apparent in certain slices, as shown by the bright bands in the saggital slices (bottom). This suggests that gradient performance was affected during acquisition of some echo-planar images, which were acquired slice-by-slice in interleaved order in this experiment.

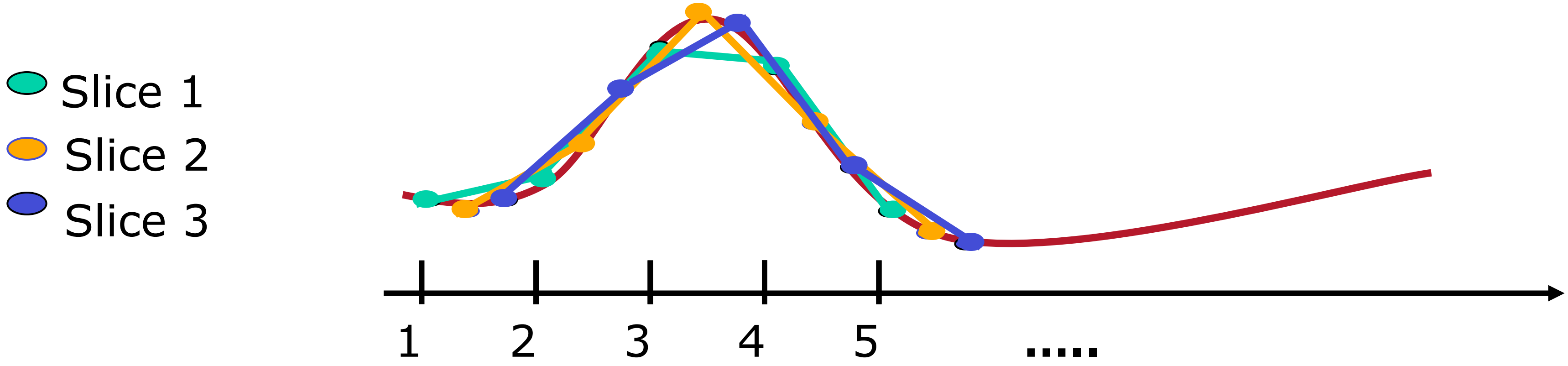
Slice Time Correction

- We often sample multiple slices of the brain during each individual repetition time (TR) to construct a brain volume.
- Typically each slice is sampled at a slightly different time points (i.e., 2D imaging; not 3D).
- Slice time correction shifts each voxel's time series so that they all appear to have been sampled simultaneously.

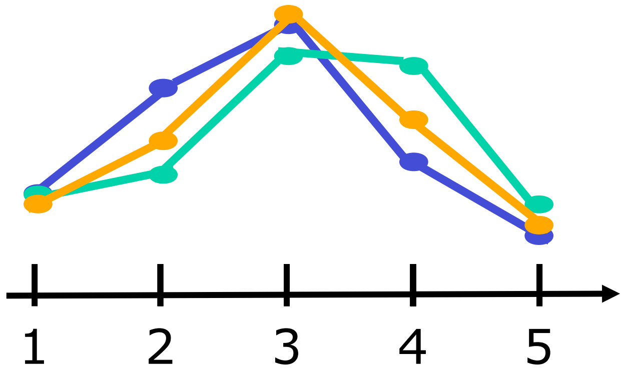
Slice Time Correction



Slice Time Correction



Can be corrected using temporal interpolation.



Temporal Interpolation

- Use information from nearby time points to estimate the amplitude of the MR signal at the onset of the TR.

- Use a linear, spline or sinc function.

Phase Shift

- Slide the time course by applying a phase shift to the Fourier transform of the time course.

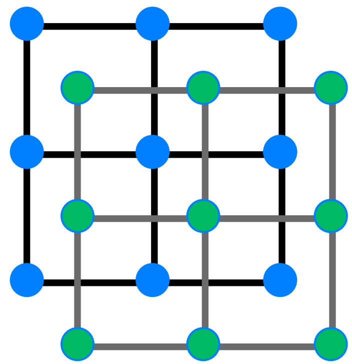
Head Motion

- Very small movements of the head during an experiment can be a major source of error if not treated correctly.
- When analyzing the time series associated with a voxel, we assume that it depicts the same region of the brain at every time point
  - Head motion may make this assumption incorrect.
- Can be corrected using a rigid body transformation.

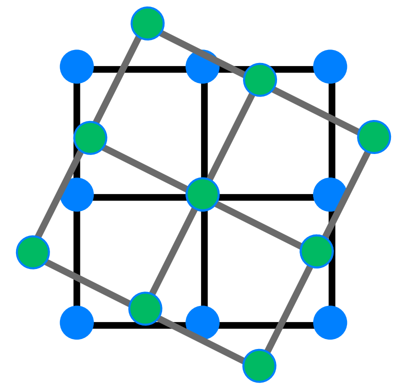
Motion Correction

- The goal is to find the best possible alignment between an input image and some target image.
- To align the two images, one of them needs to be transformed.
- A rigid body transformation is used.
- It involves 6 variable parameters, 3 sets of translations and 3 sets of rotations (6 DOF).

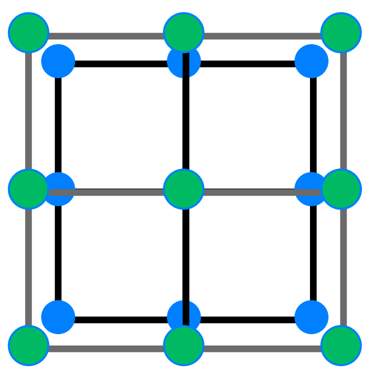
Translation



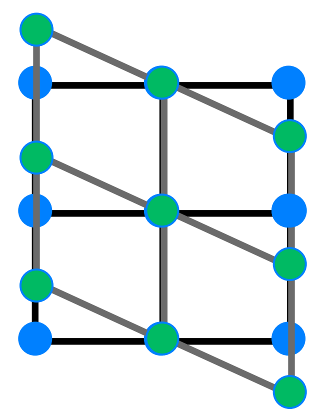
Rotation



Scaling



Shearing



Transformations

Linear transformations

- Rigid body (6 DOF) – translation and rotation
- Similarity (7 DOF) – translation, rotation and a single global scaling
- Affine (12 DOF) – translation, rotation, scaling and shearing.

Warping

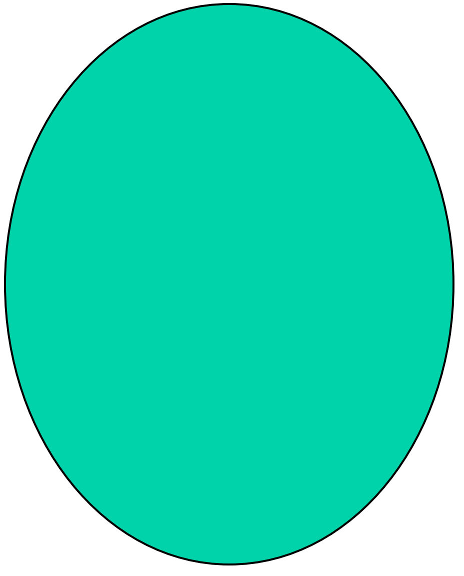
Transformations where the equations relating the coordinates of the images are non-linear.

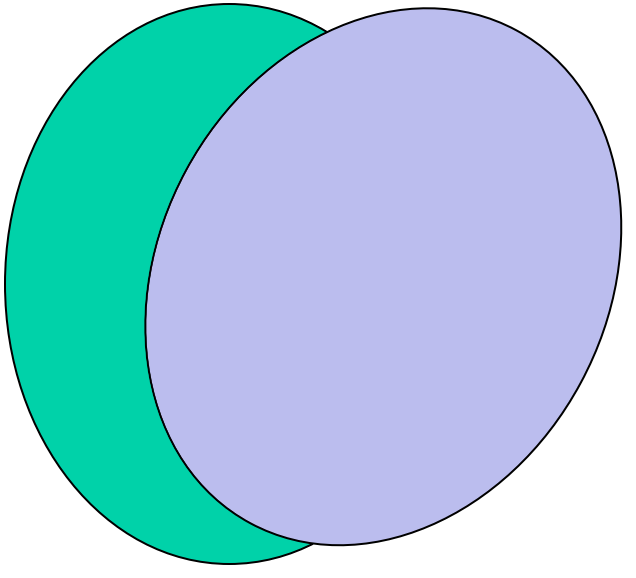
Motion Correction

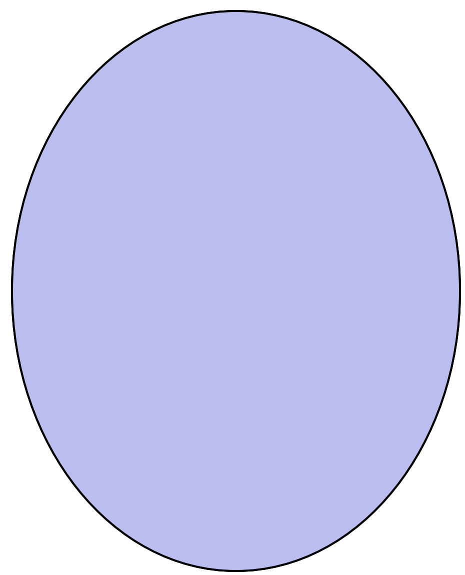
- The target image is usually defined to be the first (or mean) image in the fMRI time series.

- The goal is to find the set of parameters which minimizes some cost function that assesses similarity between the image and the target.

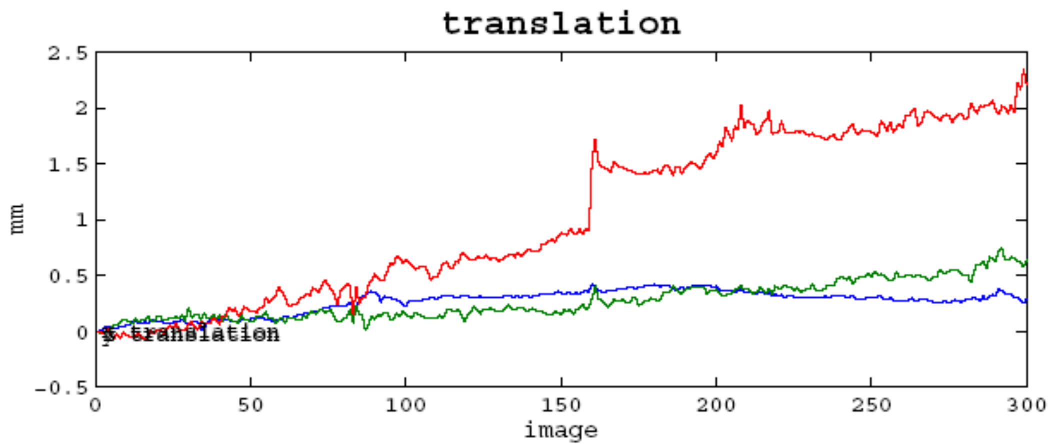
- Examples of cost functions include the sum of squared differences or mutual information.

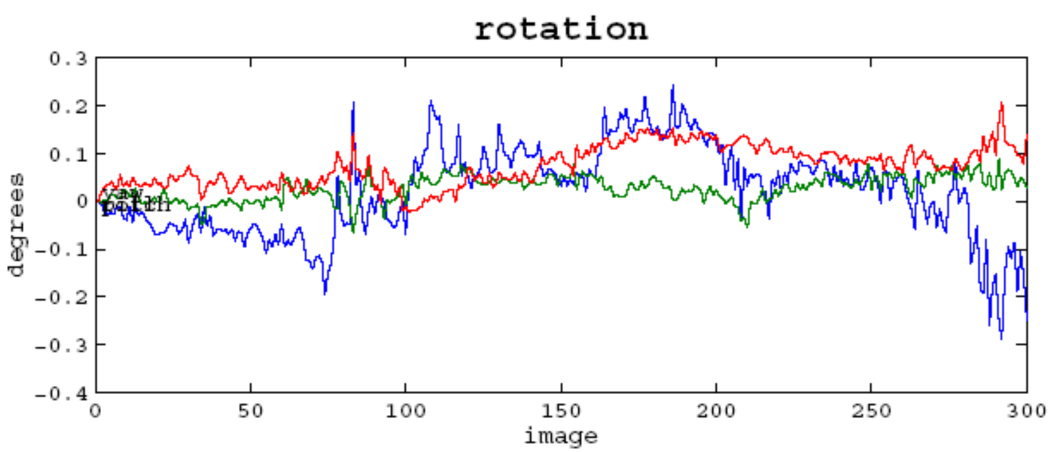






Illustration





Coregistration

- Next, a structural MRI collected in the beginning of the session is registered to the fMRI images in a process referred to as coregistration.
  - Allows one to visualize single-subject task activations overlaid on the individual's anatomical information.
  - Simplifies later transformation of the fMRI images to a standard coordinate system.

Coregistration

- There are certain key differences between co-registration and motion correction.
  - Functional and structural images do not have the same signal intensity in the same areas.
    - They cannot be subtracted.
  - Their shapes may differ.

- Use at least an affine transformation to perform coregistration and the mutual information cost function.

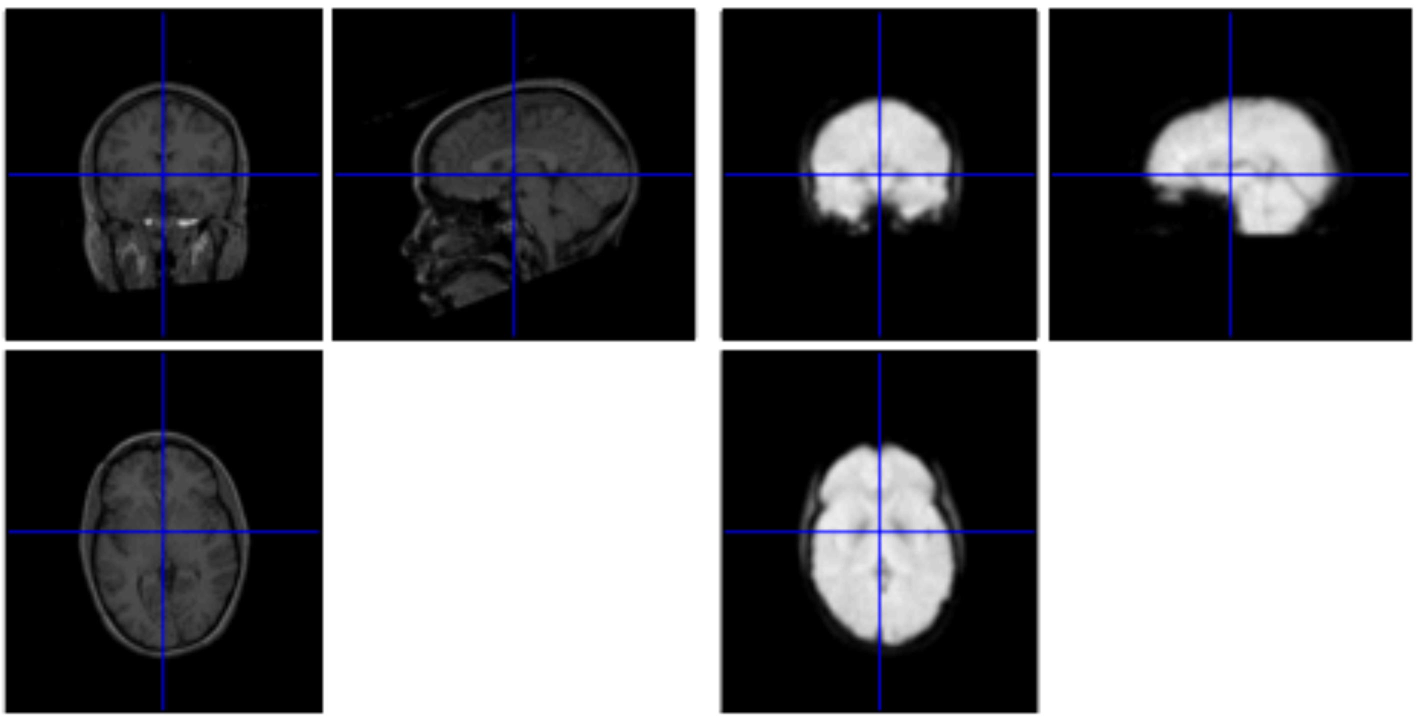
Coregistration

Normalised Mutual Information Coregistration

X1 = 3.492*X +0.123*Y +0.266*Z +6.471

Y1 = -0.041*X +3.269*Y -1.606*Z +40.323

Z1 = -0.237*X +1.244*Y +4.195*Z +2.370



End of Module

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