Realigning and Unwarping MRI data

1. Preprocessing
2. Realigning
3. Unwarping
4. SPM
fMRI data

fMRI data: four-dimensional (3 x space and 1 x time)

- 3D array of voxels repeatedly sampled slice over slice to measure the whole volume of the brain.
- Each voxel has an associated time-series of as many time-points as volumes acquired per session.

Assumptions

1) The voxels at certain position present the same part of the brain over time.
2) All voxels that present a single time point must be acquired simultaneously.
fMRI data pre-processing

→ Correct or adjust our data and prepare it for statistical analysis

Including:

- Take account of time differences between acquiring each image slice
- Correct for head movement during scanning
- Detect anomalous measurements that should be excluded from subsequent analysis
- Align the functional images with the reference structural image
- Normalize the data into a standard space so that data can be compared among several subjects
- Apply filtering to the image to increase the signal-to-noise ratio
Preprocessing pipeline

1. fMRI time series
   - Slice-timing correction
2. Structural MRI
   - Motion correction (and unwarping)
   - Normalization, Co-registration
   - Smoothing

Adapted from Dr. Karl Friston May 2011 SPM workshop presentation
Motion on fMRI

- **Physiological**: heart beat, respiration, blinking
- **Actual movement** of the head
- **Task-related**: moving to press buttons

Possible Solutions:
- Make volunteer comfortable
- Schedule short scanning sessions
- Provide instructions not to move head
- Constrain volunteers’ movement

One voxel: $3\text{mm} \times 3\text{mm} \times 3\text{mm} \rightarrow$ even small head movements lead to unwanted variation in voxels and reduce the quality of data.

Most variance still remains! $\rightarrow$ Motion correction

From previous presentation
Motion Correction: Realigning

- Minimize the influence of movement on the data by aligning the **input image** to a **target image**.

- The target image can be the mean image of all timepoints, the first, or some other time point.

Translation  
Rotation  
Scaling  
Shearing
Types of transformations

Only use linear transformations

- **Rigid body transformation**
  - Principle: assume that all movements are those of a rigid body (the shape of the brain does not change)
  - Translation and rotation

- **Similarity transformation**
  - Translation, rotation and a single global scaling

- **Affine transformation**
  - Translation, rotation, scaling and shearing

□ **Two steps:**
1. Registration (estimate)
2. Re-slicing (resample)
Realigning-Registration

- Determining the 6 parameters that describe the **rigid body transformation** between each image and a reference image.

- The goal is to find the set of parameters which minimizes some cost function.

- Cost function = sum of squared difference between consecutive images.
Realigning-Transformation

“Reslice”, i.e. resample the images $\rightarrow$ apply the transformation parameters

- Need to fill in the gaps
- Determine values of the new voxels

$\Rightarrow$ Interpolation
Interpolation

- Interpolation involves **constructing new data points** based on known data
- Interpolation can be
  - **Nearest neighbour (0-order)**: take the intensity of the closest voxel
  - **Tri-linear (1st-order)**: take the average of the neighbouring voxels
  - **“B-splines” used in SPM**: Approximate all control points, Polynomials of any degree d
Part 2: Unwarping
After realignment

• There is still a lot of variance that is explained by movement

• Movement-related-variance

• This variance is typically large compared to experimentally-induced variance.

• Up to 90% of the variance in fMRI time series after realignment = movement
  • Loss of sensitivity (missing true activations)
  • Loss of specificity (mistake movement-induced variance for true activation)
Why is there still residual variance after realignment?

• Realignment **only** addresses rigid/linear transformations that preserve shape (e.g. shape of the brain)

*However*...

• There are also non-rigid/non-linear transformations that modifies the shape of the image
Non-linear transformations: Inhomogeneities in the magnetic field

• Different tissue types: white matter, grey matter, CSF, blood, air-tissue interfaces
• Different tissue types = different magnetic susceptibilities
• The differences in tissue susceptibility = field inhomogeneity between tissue boundaries because spin dephase faster (= signal loss)
• Areas with air-tissue boundaries are “problem areas”
  • Orbitofrontal cortex
  • Medial temporal lobe
  • Frontal pole
This is what happens in EPI data

- EPI images are not faithful representations of the object (brain) being scanned
- Observed image = warped version of reality
- Funfair mirrors
- An image collected for a given subject position is not identical to that collected at another
- **Susceptibility-by-movement** interaction accounts for a large amount of residual movement-related variance
To summarise...

Image distortion

The image obtained in the scanner is distorted (EPI is not an exact replica)
Participant movement interacts with the image distortions.
So what can I do?

• UNWARP

• UNWARP estimates the changes in distortion caused by movement by:
  • Measuring the distortion field with FieldMap
  • Observing the subject motion parameters (obtained during realignment)
  • Changing the deformation field with subject movement
  • Giving an estimate of the distortion at each time point
Direct and indirect

How much the deformation field changes with movement

Changes in movement

+ Variance in the time series

= Changes in movement

+ Variance in the time series

= How much the deformation field changes with movement
When to use UNWARP

• UNWARP is intended to correct data afflicted by a particular set of problems:
  • Lots of movement in the data (i.e. >1mm or >1 degree)
  • Task-related movements (button press)
  • Studying the “problem areas”
  • Minimises total (across the image volume) variance in the dataset
  • Removes unwanted variance whilst preserving “true” activation

• UNWARP is computationally intense
Select scans for this session.

In the coregistration step, the sessions are first realigned to each other, by aligning the first scan from each session to the first scan of the first session. Then the images within each session are aligned to the first
References

http://mriquestions.com/data-pre-processing.html

http://windstalker.pbworks.com/w/page/55649100/SPM8%20fMRI%20Analyse


https://www.fil.ion.ucl.ac.uk/spm/doc/spm12_manual.pdf

The previous MFD presentations