Pipeline overview
Generic blueprint

1. Data acquisition
2. Data preprocessing
3. Single-subject analysis
4. Group-level analysis
5. Statistical inference
Generic blueprint

Aims:
- Obtain good quality and consistent data
- Optimise SNR

1. Data acquisition
2. Data preprocessing
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Keep in mind:
- Many trade-offs
- Consider drop-out and distortions
- What are the most important regions?
Generic blueprint

Aims:
● Reduce noise in data
● Prepare data for analysis
● Prepare data for group comparison

Keep in mind:
● Requires careful checking
● Can add additional steps if necessary

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Generic blueprint

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Aims:
● Obtain measure of interest for each subject (often an image)

Keep in mind:
● Differs considerably between modalities
Generic blueprint

Aims:
- Compare single-subject results across group
- Group mean/t-test/correlation

1. Data acquisition
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Keep in mind:
- Can have additional layer to average over sessions
- Account for confounding variables
Generic blueprint

1. Data acquisition
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Aims:
- P-values
- Reliability of results
- Generalise to population

Keep in mind:
- Need enough subjects to have power
- Cannot interpret null results
What we covered so far

**Structural data:**
- Brain extraction
- Bias field correction
- Segmentation
- VBM or vertex analysis
- Registration & unwarping

**Functional data:**
- Motion correction
- Slice timing correction
- Spatial filtering
- Temporal filtering
- Regressors & contrasts
- First level GLM
- Thresholding & correction
Preprocessing

Structural data:
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Functional data:
- Motion correction
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## Structural preprocessing summary

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brain extraction</strong></td>
<td>Remove non-brain tissue to help with registration. Needs to be very precise.</td>
</tr>
<tr>
<td><strong>Bias field correction</strong></td>
<td>Corrects for B1 inhomogeneities</td>
</tr>
<tr>
<td><strong>Registration</strong></td>
<td>Put images into same space (standard space for group analysis)</td>
</tr>
</tbody>
</table>
## fMRI preprocessing summary

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain extraction</td>
<td>Remove non-brain tissue to help with registration</td>
</tr>
<tr>
<td>Motion Correction</td>
<td>Get consistent anatomical coordinates (always do this)</td>
</tr>
<tr>
<td>Slice Timing</td>
<td>Get consistent acquisition timing (use temporal derivative instead)</td>
</tr>
<tr>
<td>Spatial Smoothing</td>
<td>Improve SNR &amp; validate GRF</td>
</tr>
<tr>
<td>Temporal Filtering</td>
<td>Highpass: Remove slow drifts</td>
</tr>
<tr>
<td>Registration &amp; unwarping</td>
<td>Unwarping corrects for B0 inhomogeneities. Registration images into same space (standard space for group analysis)</td>
</tr>
</tbody>
</table>
Single-subject analysis

Structural data:
- Brain extraction
- Bias field correction
- Segmentation
- VBM or vertex analysis
- Registration & unwarping

Functional data:
- Motion correction
- Slice timing correction
- Spatial filtering
- Temporal filtering
- Regressors & contrasts
- First level GLM
# Structural single-subject summary

<table>
<thead>
<tr>
<th>Segmentation</th>
<th>Tissue-type segmentation (FAST), subcortical segmentation (FIRST), white matter hyperintensities (BIANCA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voxel-based morphometry</td>
<td>To detect differences in local grey matter volume. Jacobian modulation and spatial smoothing.</td>
</tr>
<tr>
<td>Vertex analysis</td>
<td>To run shape analysis on subcortical structures. <em>first_utils</em> uses bvars output from FIRST to perform vertex analysis (4D output image of all subject meshes)</td>
</tr>
</tbody>
</table>
## fMRI single-subject summary

<table>
<thead>
<tr>
<th>EVs/ regressors</th>
<th>Design matrix: model of predicted responses based on stimuli presented at each time point</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLM</td>
<td>Estimate parameter estimates for each EV so that the linear combination best fits the data</td>
</tr>
<tr>
<td>Contrasts (F or t)</td>
<td>Maths on parameter estimates to ask research questions. Result is a COPE image per contrast</td>
</tr>
</tbody>
</table>
Group-level analysis

**Structural data:**
- Brain extraction
- Bias field correction
- Segmentation
- VBM or vertex analysis

**Registration & unwarping**

**Functional data:**
- Motion correction
- Slice timing correction
- Spatial filtering
- Temporal filtering

**Regressors & contrasts**

**First level GLM**

**Group level GLM**

**Thresholding & correction**
## Group-level analysis summary

<table>
<thead>
<tr>
<th>EVs/ regressors</th>
<th>Design matrix: one entry per subject. Can describe subject groups, confounds etc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GLM</strong></td>
<td>Structural: inputs are smoothed, modulated GM volumes (VBM) or single subject subcortical meshes (vertex analysis)</td>
</tr>
<tr>
<td></td>
<td>fMRI: inputs are first-level COPE and VARCOPE images.</td>
</tr>
<tr>
<td><strong>Contrasts (F or t)</strong></td>
<td>Structural: tests differences in GM density or shape</td>
</tr>
<tr>
<td></td>
<td>fMRI: Each group-level contrast is tested for each of the subject-level contrasts</td>
</tr>
</tbody>
</table>
Statistical inference

Structural data:
- Brain extraction
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- Segmentation
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- Registration & unwarping

Functional data:
- Motion correction
- Slice timing correction
- Spatial filtering
- Temporal filtering
- Regressors & contrasts
- First level GLM
- Regressors & contrasts
- Group level GLM
- Thresholding & correction

- Bias field correction
- Registration & unwarping
- Structural data:
- VBM or vertex analysis
- Segmentation
- Brain extraction

- Functional data:
- First level GLM
- Temporal filtering
- Spatial filtering
- Slice timing correction
- Motion correction

- Regressors & contrasts
- Group level GLM
- Thresholding & correction
- Regression & contrasts
<table>
<thead>
<tr>
<th>Fixed effects vs mixed effects</th>
<th>Averaging across multiple sessions Generalisation to population</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS vs FLAME vs Randomise</td>
<td>Quick, doesn’t use VARCOPEs Uses COPEs &amp; VARCOPEs Non-parametric</td>
</tr>
<tr>
<td>Multiple comparison correction (FWE/ FDR)</td>
<td>Gaussian Random Field (voxel or cluster based) TFCE</td>
</tr>
</tbody>
</table>
What we covered so far

Preprocessing

Structural data:
- Brain extraction
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Functional data:
- Motion correction
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- Spatial filtering
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Single-subject analysis
- Regressors & contrasts
- First level GLM

Group-level analysis
- Regressors & contrasts
- Group level GLM

Statistical inference
- Thresholding & correction

Registration & unwarping
Looking ahead:
resting state
diffusion
Generic blueprint

1. Data acquisition
2. Data preprocessing
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Resting state analysis

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Consider using multiband
Resting state analysis

1. Data acquisition
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Consider using multiband
Need to apply extra noise-reduction steps (ICA)
Resting state analysis

1. Data acquisition → Consider using multiband
2. Data preprocessing → Need to apply extra noise-reduction steps (ICA)
3. Single-subject analysis → Group ICA+dual regression/Network analysis (FSLnets)
4. Group-level analysis
5. Statistical inference
Diffusion analysis

1. Data acquisition
2. Data preprocessing
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Diffusion directions
Blip-up/blip-down
Multi shell
Diffusion analysis

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- Diffusion directions
  - Blip-up/blip-down
  - Multi shell

- Need to correct for eddy currents
Diffusion analysis

1. Data acquisition
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- Diffusion directions
  - Blip-up/blip-down
  - Multi shell

- Need to correct for eddy currents

- Fractional anisotropy/ mean diffusivity/ tractography
Enjoy the rest of the course!