Data Visualisation in SPM: An introduction

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Visualising results

- After the results table - what next?
- Exploring your results
- Displaying them for publication
Overview

- What to plot?
- Overlays
  - Slices, sections, render in SPM
  - Utilities
- Effect plots
  - Types of plot options in SPM
  - For 1st & 2nd level models
  - Utilities
What to plot?

Golden rule:

- Plot what you are using to make your inferences
- Applies to overlays e.g. thresholding
- Applies to contrast and event-related plots e.g. use of peri-stimulus time histograms
What to plot?

• Overlays
  – Visualisation of regional results on a brain image
  – ‘Big picture’ – distribution, location

• Effect plots
  – Visualisation of effects at a single voxel
Overlay: sections

• From Results
  – Display → overlay

• Sections
  – Plots the current thresholded SPM
  – Superimposes it on orthogonal sections
  – Can use any image for display
Overlay on ‘Canonical brain’?  Overlay on group average EPI?

- The canonical brain T1 (in /spm8/canonical/) looks precise and the location of clusters seems clear
- But data are EPI, not T1!
- …and these were young and older adults combined
- …also, data were smoothed by 10 mm³!
- Beware of mis-localisation and exaggerating precision
- Alternatives e.g. averaged structurals
Overlay: slices

• From Results
  – Display → overlay

• Slices
  – Plots the current thresholded SPM
  – Superimposes it on horizontal slices
  – Can use any image for display
Activity overlaid on slices from a ‘canonical brain’ T1 image

- Plots 3 horizontal slices
- Uses the slices above & below the slice with the index voxel
- Crosshairs (if seen) are at same x and y coordinates
- Distance apart depends on voxel size after normalisation

- NOTE: T values are relative
Overlay: render

• From Results
  – Display ➔ overlay

• Render
  – Plots the current thresholded SPM
  – Projects it onto the surface of the brain
  – Can use any image for display if create your own render file from it
Activity for 2 subject groups for the same contrast rendered on ‘canonical brain’ T1 image

- Here thresholds are $P < 0.001$, 5 voxels (previously FWE)
- Active voxels are projected onto brain surface so highlights surface clusters
- Display is of integral of T values
- Increasing depth $\rightarrow$ exponential decay of intensity (50% at 10 mm)
Overlay guidelines

Show what your inference is based on
• Ideally, thresholds the same for analysis & figures
• Scatterplots for individual differences analysis

Give sufficient details for publication
• e.g. note in legend any ‘masking out’ of some regions in creating overlay

Whole-image inspection & possible publication
• Unthresholded statistical maps & effect size images
• …are non-significant effects really absent?
• Useful for meta-analysis
• Can check brain mask
Plots in SPM

Different options for 1st or 2nd level model

• Single subject plots
  – Show single subject effects
  – Effects fitted to individual timeseries

• Group level plots
  – Show group level effects
  – Effects fitted to group con* images
Single subject plots

At 1\textsuperscript{st} level
- Contrast estimates with 90\% CI
- Fitted/ adjusted responses
- Event-related responses
- Parametric plots
- Volterra plots

At 2\textsuperscript{nd} level
- Contrast estimates with 90\% CI
- Fitted/ adjusted responses
Plots

• From Results
  – Display → plot

• Sections
  – Plots from the current model
  – Plots at the selected location
  – May plot a different regressor/ contrast
Contrast/ CI

- Same for 1\textsuperscript{st} and 2\textsuperscript{nd} level models
- Here, an ‘RFX’ $T$-contrast is plotted
- Shows effect across 2 groups with between-subjects error bar
- Can extract CI info from MATLAB workspace to plot >1 condition outside SPM ("contrast")
Contrast/CI

- Here, a ‘FFX’ $F$-contrast is plotted
- Shows same contrast at single subject level
- But here an $F$-contrast is used to look at effects for the 3 basis functions – canonical, and temporal/dispersion derivatives
- Can do for >1 condition within same model if create $F$ contrast
Fitted & adjusted data

- Raw fMRI timeseries
- Adjusted data
  - Fitted box-car
- High-pass filtered (and scaled)
  - Fitted high-pass filter
- Residuals
**Fitted & adjusted data**

**Raw fMRI timeseries**

**Fitted effects**

= a linear combination of effects $\times$ their parameter estimates

Here, weighted sum of filter cosine set basis functions

**Predicted (fitted) effects**

= effects that have been fitted to data without removing any effects of confounds first
Fitted & adjusted data

- Raw fMRI timeseries
- Adjusted data
- high-pass filtered (and scaled)
- fitted high-pass filter
- fitted box-car

Adjusted data = data that have had effects of confounds fitted and removed – here, effects of the high-pass filter.
A note on units

- Parameter estimate beta (condition) is NOT the percent voxel signal change associated with that condition.
- Data have usually been scaled by multiplying every voxel in every scan by '100/g' where g is the average value over all time points and scans in that session.
- Therefore the time series should have average = 100.
- So beta (condition) is in units of % of 'global' signal, g.
- Can report in units of percent of 'local' signal by dividing by the beta for the session constant, i.e. average signal in that voxel over and above the ‘global’ average.
- (see utilities especially MarsBaR & rfxplot)
Fitted/ adjusted responses

Plot against

• A explanatory variable
  – A variable in the model e.g. behavioural covariate

• (Scan or time)

• A user-specified ordinate
  – Any array of correct size e.g. rescale x-axis to show time (secs) not scan
  – E.g. in 2\textsuperscript{nd} level model…
Fitted/ adjusted

- In factorial model at 2\textsuperscript{nd} level, ‘scan or time’ may not be helpful
- Here scans 1-14 are condition 1, scans 15-28 are condition 2, etc.
- Fitted response shows cross-subject average
- ‘Plus error’ shows individual subject contrast values
Fitted/ adjusted

• In factorial model at 2\textsuperscript{nd} level, ‘scan or time’ may not be helpful
• Instead, try ‘user specified ordinate’ = 1 for condition 1 scans, = 2 for condition 2, etc.
• Fitted response shows cross-subject average
• ‘Plus error’ shows individual subject contrast values

\[ \text{ones(1,14)} \ 2 \times \text{ones(1,14)} \ 3 \times \text{ones(1,14)} \]
Event-related responses are

- To a given event type
- Plotted in peri-stimulus, i.e., onset-centred, time

There are 3 types

- Fitted response and PSTH (Peri-Stimulus Time Histogram): the ‘average’ response to an event type with mean signal +/- SE for each peri-stimulus time bin.
- Fitted response and 90% CI: the ‘average’ response in peri-stimulus time along with a 90% confidence interval.
- Fitted response and adjusted data: plots the ‘average’ response in peri-stimulus time along with adjusted data
PSTH

- Peri-stimulus time: centered around event onset
- Responses to event X are ‘averaged’ over the timeseries
- SPM fits a Finite Impulse Response (FIR) model to do this – often NOT the regressors used in the analysis
- Time bin size = TR
- Confidence intervals are within subject/session
Fitted/90% CI

- Response centered around event onset – again ‘averaged’ over the timeseries
- For fitted responses, unlike PSTH, these always represent the basis functions modelled – all of them
- Confidence intervals are within subject/session

NOTE shape in region selected for effect loading on temporal derivative
Fitted/adjusted

- Response centered around event onset – again ‘averaged’ over the timeseries
- Again, uses the basis functions modelled
- Values of adjusted data in peri-stimulus time indicate the effective sampling of the HRF
- May be ‘bunched’ if a fixed TR/ SOA relationship
Parametric responses

Effect of a ‘parametric modulator’

• Available at 1\textsuperscript{st} level – select for any effect with a pmod

• E.g. RT across trials – how does response vary with speed?

• E.g. effect of time after which a stimulus repeats – analysis of effects of ‘lag’ in trials from face example dataset
Parametric responses

Parametric modulator is ‘lag’ (between repeated faces)
An increase in ‘lag’ is associated with a decrease and then an increase in the BOLD response
Immediate repetition of a face produces a decrease (suppression) – then an increase, maximal for lag ~ = 40
Other tips

- To make across-subject plots of first level responses, e.g. event-related responses, some tweaking is necessary.

- Variables containing fitted & adjusted data are in the MATLAB workspace: “Y” has the fitted data, “y” the adjusted data.

- Other utilities may help here.
Utilities & resources

• FreeSurfer: [http://surfer.nmr.mgh.harvard.edu/](http://surfer.nmr.mgh.harvard.edu/) - cortical models from T1 sMRI for rendering & other functions
• PSTH utility – spm_graph hack for group PSTH with options by RH/AM/DG at [http://www.brain.northwestern.edu/cbmg/cbmg-tools/](http://www.brain.northwestern.edu/cbmg/cbmg-tools/)
• MarsBaR – M Brett’s region of interest toolbox with RFX plot utilities at [http://marsbar.sourceforge.net/](http://marsbar.sourceforge.net/)
• Rfxplot – excellent utility by J Glascher, shortly to be updated for SPM8, at [http://neuro.imm.dtu.dk/wiki/Rfxplot](http://neuro.imm.dtu.dk/wiki/Rfxplot)