Data Visualisation in SPM: An introduction

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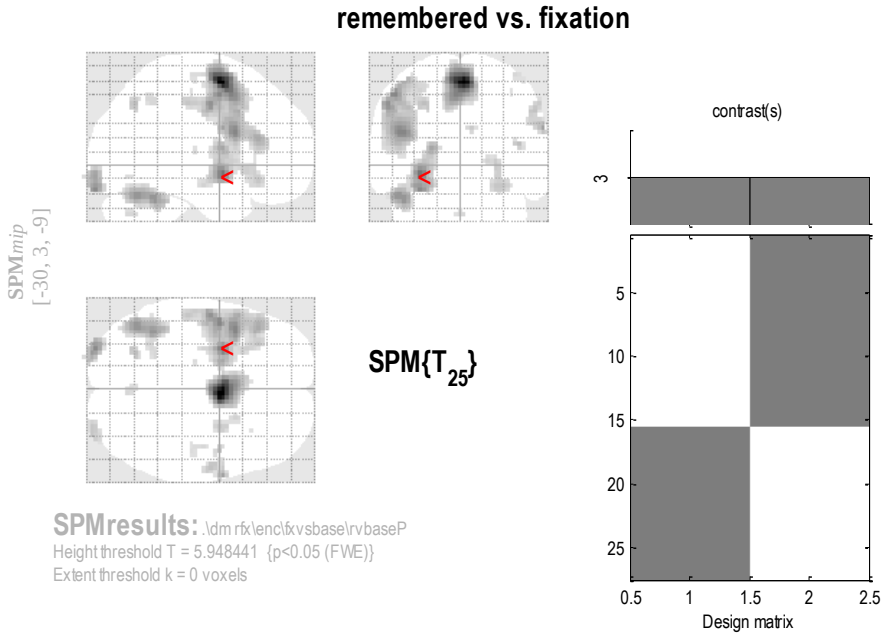
Visualising results

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



Statistics: ***p-values adjusted for search volume***

set-level		cluster-level				peak-level					mm mm mm		
p	*c*	$p_{FWE\text{-}corr}$	$q_{FDR\text{-}corr}$	k_E	p_{uncorr}	$p_{FWE\text{-}corr}$	$q_{FDR\text{-}corr}$	*T*	($Z_{\equiv}$)	p_{uncorr}			
0.000	20	0.000	0.000	460	0.000	0.000	0.000	16.85	7.84	0.000	3	0	60
		0.000	0.000	271	0.000	0.000	0.002	10.99	6.58	0.000	-30	3	-9
						0.000	0.013	8.80	5.88	0.000	-21	3	12
						0.004	0.135	7.25	5.27	0.000	-33	30	-12
		0.000	0.000	816	0.000	0.000	0.003	10.26	6.37	0.000	-45	12	24
						0.000	0.003	10.23	6.36	0.000	-48	0	51
						0.000	0.006	9.57	6.15	0.000	-54	-6	45
		0.000	0.000	90	0.000	0.000	0.003	10.01	6.29	0.000	-30	-93	-18
						0.000	0.013	8.88	5.91	0.000	-30	-93	-9
		0.000	0.000	207	0.000	0.000	0.006	9.51	6.13	0.000	-45	-60	-21
						0.000	0.006	9.41	6.10	0.000	-42	-48	-27
		0.000	0.001	35	0.000	0.000	0.013	8.84	5.90	0.000	63	3	27
		0.002	0.049	9	0.034	0.002	0.076	7.62	5.43	0.000	45	0	15
		0.000	0.013	16	0.007	0.002	0.089	7.51	5.38	0.000	-27	-63	45
		0.000	0.001	32	0.000	0.003	0.108	7.39	5.33	0.000	57	-6	39
		0.000	0.000	55	0.000	0.004	0.138	7.21	5.26	0.000	27	0	0
						0.008	0.243	6.84	5.09	0.000	27	3	-9
						0.016	0.429	6.51	4.94	0.000	21	12	3
		0.000	0.001	33	0.000	0.005	0.151	7.14	5.22	0.000	30	-96	-15
		0.004	0.101	6	0.076	0.005	0.164	7.06	5.19	0.000	9	6	27
		0.000	0.008	19	0.004	0.017	0.429	6.50	4.93	0.000	-27	-48	45

table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 5.95, p = 0.000 (0.050)
Extent threshold: k = 0 voxels, p = 1.000 (0.050)
Expected voxels per cluster, <k> = 1.925
Expected number of clusters, <c> = 0.05
FWEp: 5.948, FDRp: 8.239, FWEc: 1, FDRc: 9

Degrees of freedom = [1.0, 25.0]
FWHM = 14.5 14.7 14.6 mm mm mm; 4.8 4.9 4.9 {voxels}
Volume: 1572858 = 58254 voxels = 457.1 resels
Voxel size: 3.0 3.0 3.0 mm mm mm; (resel = 114.58 voxels)
Page 1

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

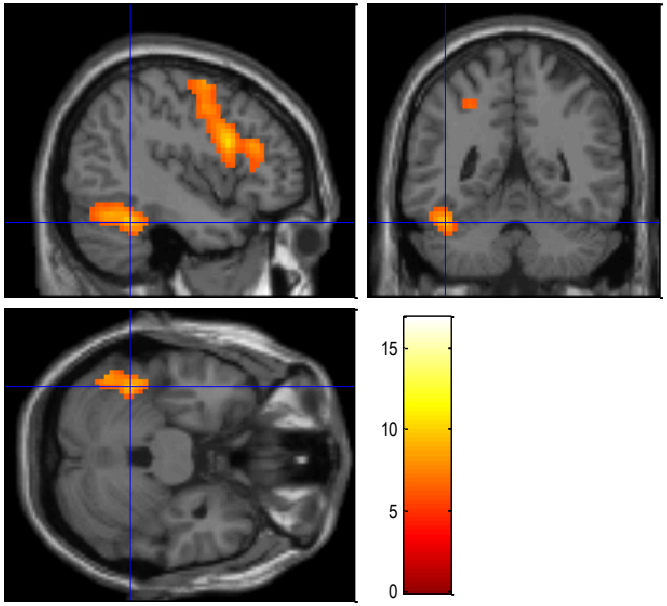
Overlay: sections

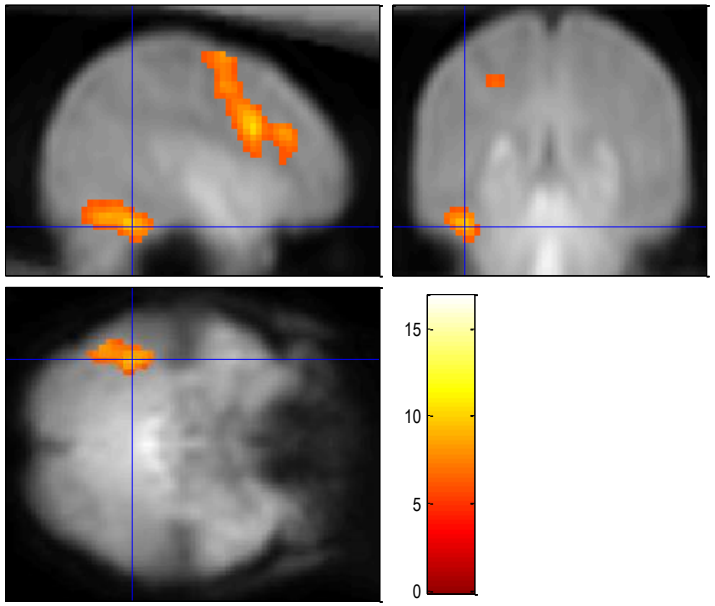
- From Results
  - → overlays → sections
- Sections
  - Plots the current thresholded SPM
  - Superimposes it on orthogonal sections
  - Can use any image for display

  - To remove crosshairs

    >> spm_orthviews('xhairs', 'off')

x = - 48, *y* = - 42, *z* = - 27





Overlay on 'Canonical brain'?

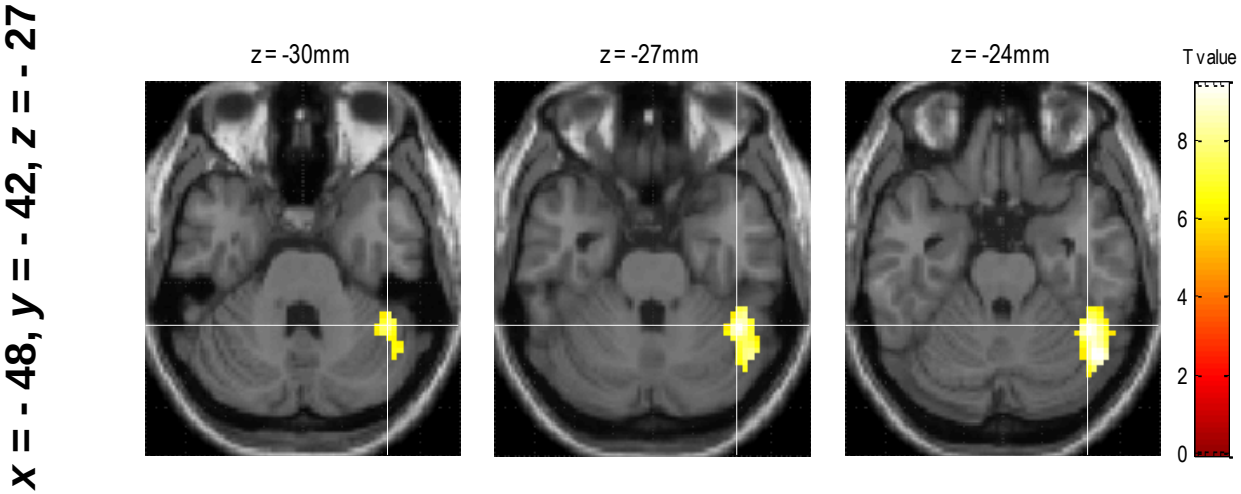
Overlay on group average EPI?

- The canonical brain T1 (in /spm12/canonical/) looks precise and the location of clusters seems clear
- But data are EPI, not T1 !
- …and in my example results were from young and older adults combined
- …also, data were smoothed by 10 mm^3 !
- Beware of mis-localisation and exaggerating precision
- Alternatives e.g. averaged structurals

Overlay: slices

- From Results
  - → overlays → slices

- 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

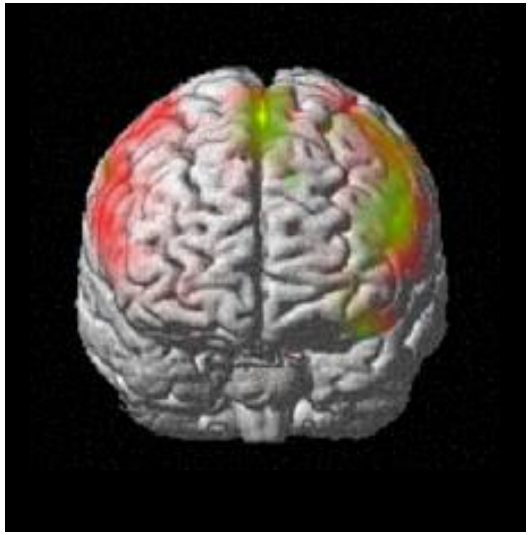
- Plots 3 horizontal slices
- Uses the slices above & below the slice with the index voxel
- Crosshairs (if seen) are at same x and y coordinates
- Distance apart depends on voxel size after normalisation

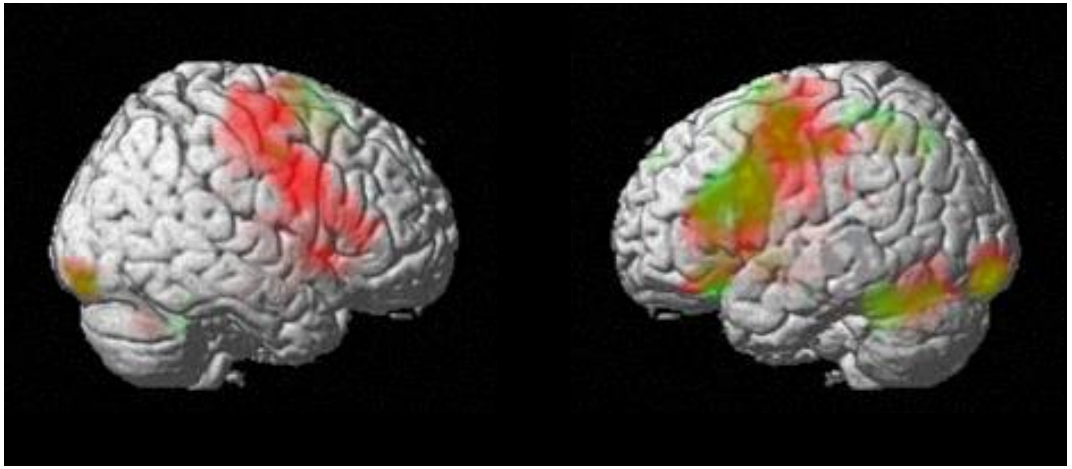
- NOTE: statistic values are relative

Overlay: render

- From Results
  - → overlays → render

- 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 → exponential decay of intensity (50% at 10 mm)

Multiple overlays

- From Main Menu
  - Display OR Check reg → select desired image
  - → Add Overlay

- Can add and threshold by selecting SPM.mat/s
- Or select already thresholded and saved images from Results
- Results → save → (e.g.) thresholded SPM
- Can show multiple contrasts for section and slice overlays as well as render

Overlay guidelines

Show what your inference is based on

- Threshold should be 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 1st level

- Contrast estimates with 90% CI
- Fitted/ adjusted responses
- Event-related responses
- Parametric plots
- Volterra plots

At 2nd level

- Contrast estimates with 90% CI
- Fitted/ adjusted responses

Plots

- From Results
  - → plot

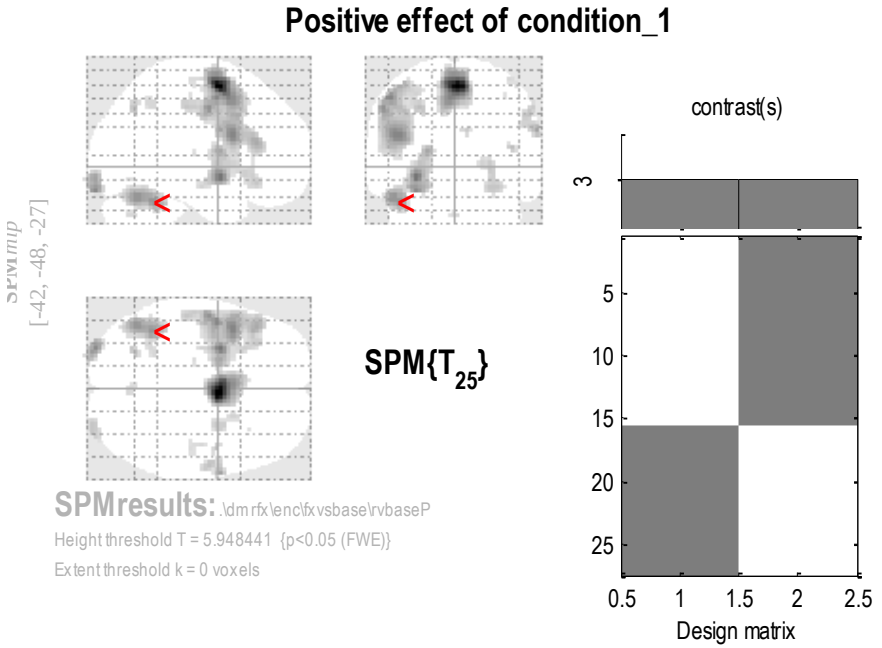
- Plots from the current model
- Plots at the selected location
- May plot a different regressor/ contrast

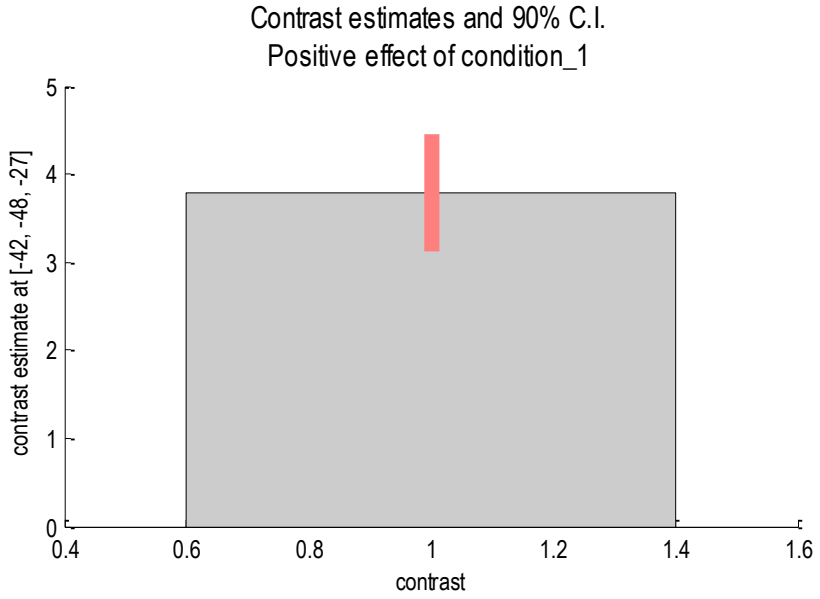
Contrast/ CI

- Same for 1st and 2nd level models
- Here, a group level *T*-contrast is plotted
- Shows average effect across 2 groups with between-subjects error bar
- Can extract CI info from MATLAB workspace to plot >1 condition outside SPM

>> contrast

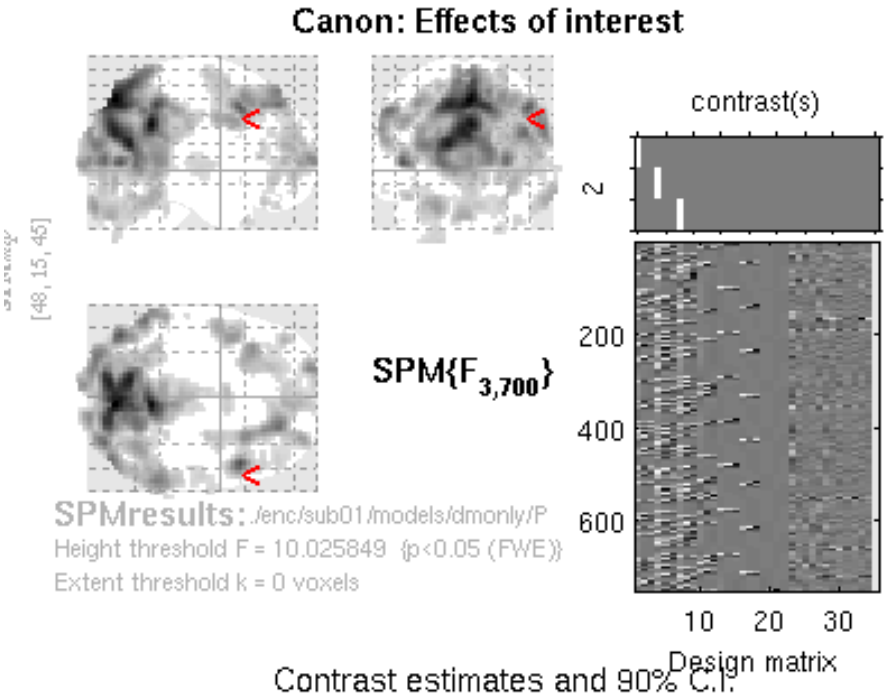
(also all betas, data 'y', etc)

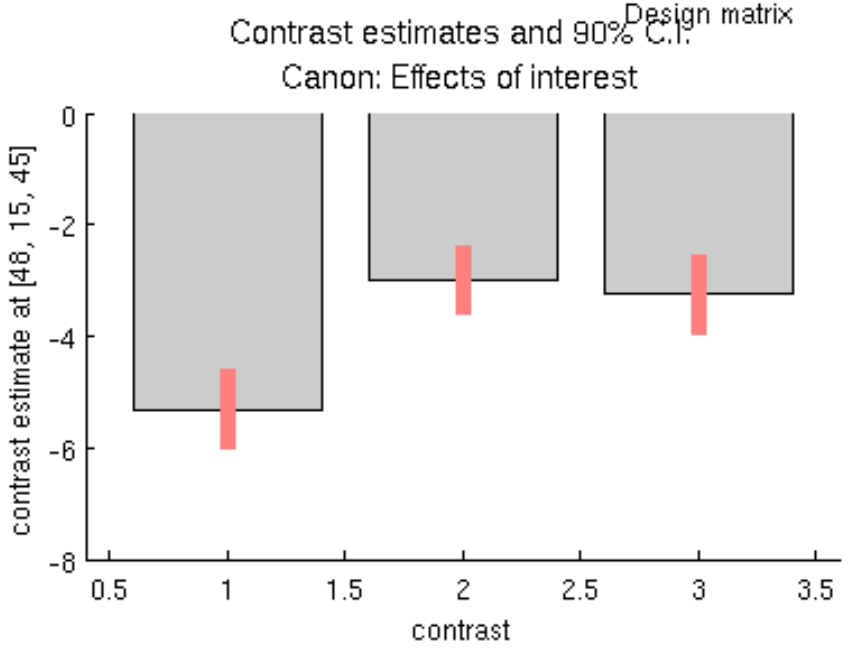




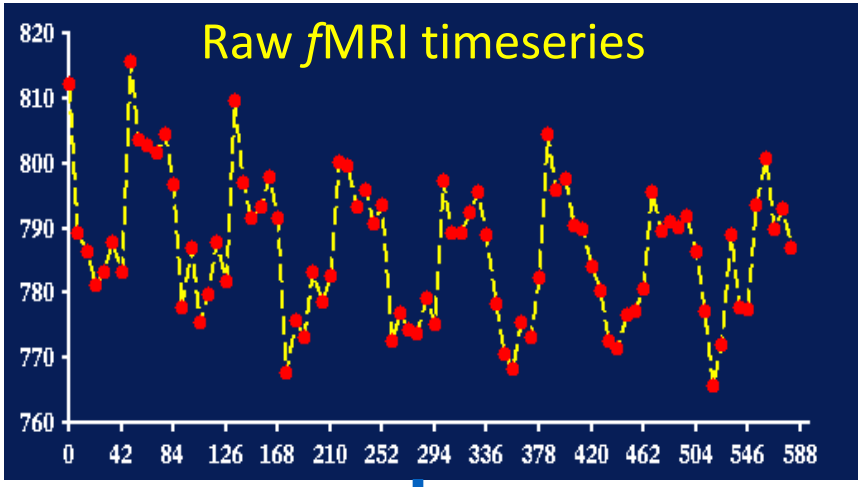
Contrast/CI

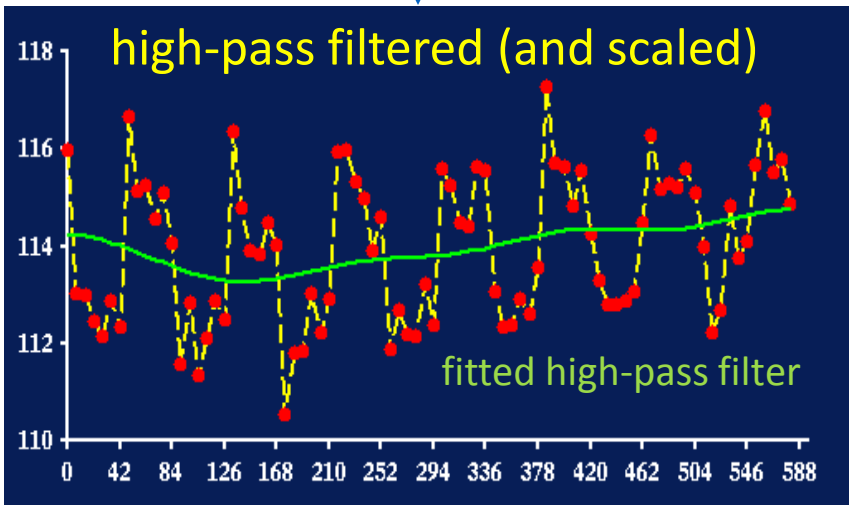
- Here, a 'FFX' *F*-contrast is plotted
- Shows same contrast at single subject level
- But here an *F*-contrast is used to look at effects for the 3 basis functions – canonical, and temporal/ dispersion derivatives
- Can do for >1 condition *within same model* if create F contrast
- E.g. all effects of interest





Fitted and adjusted data





Fitted effects

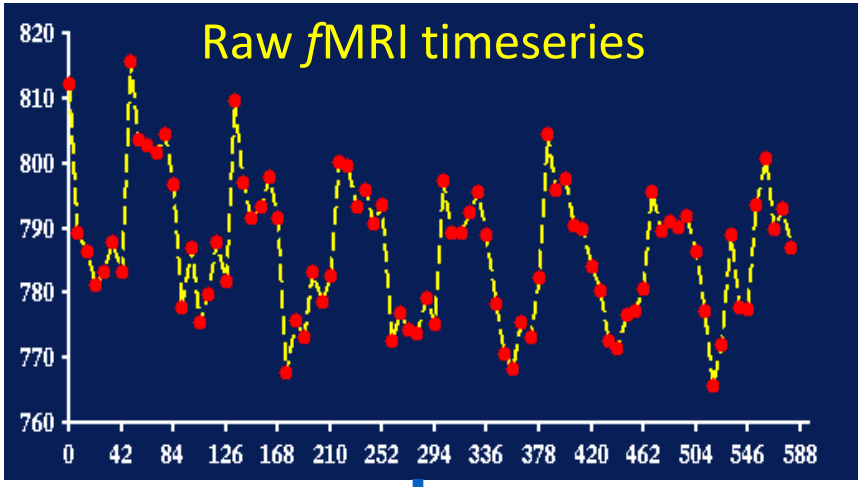
= a linear combination of effects x their parameter estimates

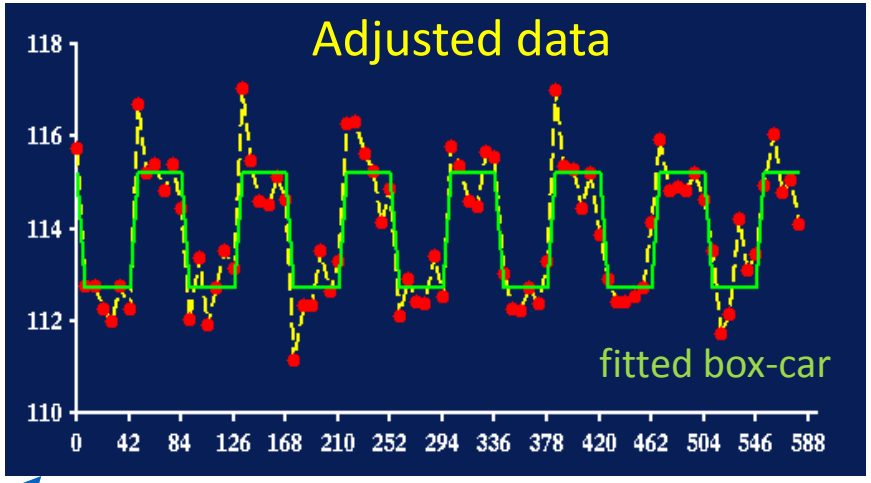
Here, weighted sum of filter cosine set basis functions

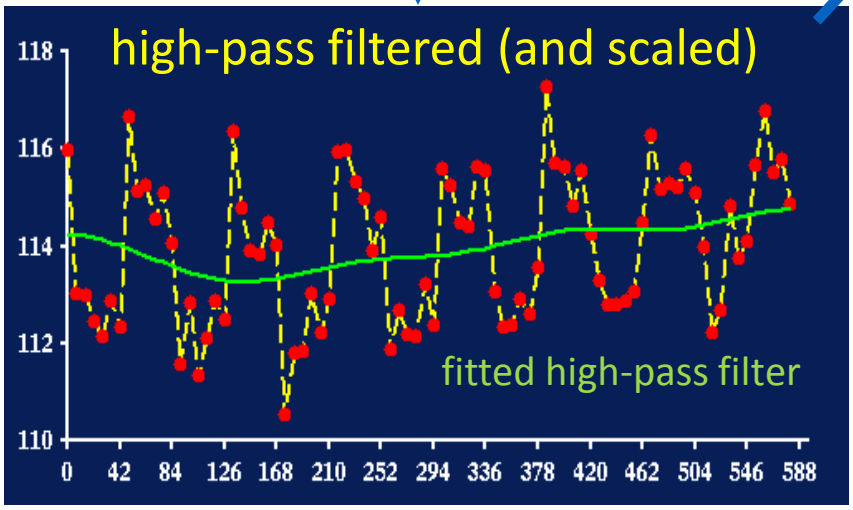
Predicted (fitted) effects

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

Fitted and adjusted data



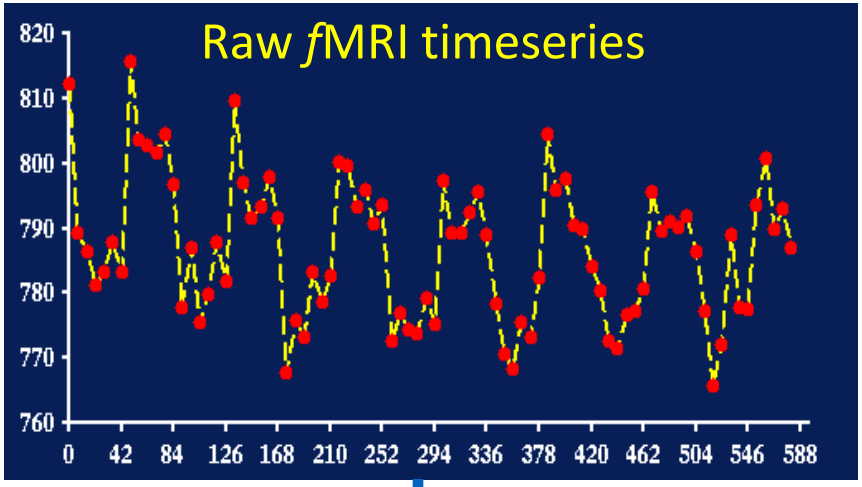


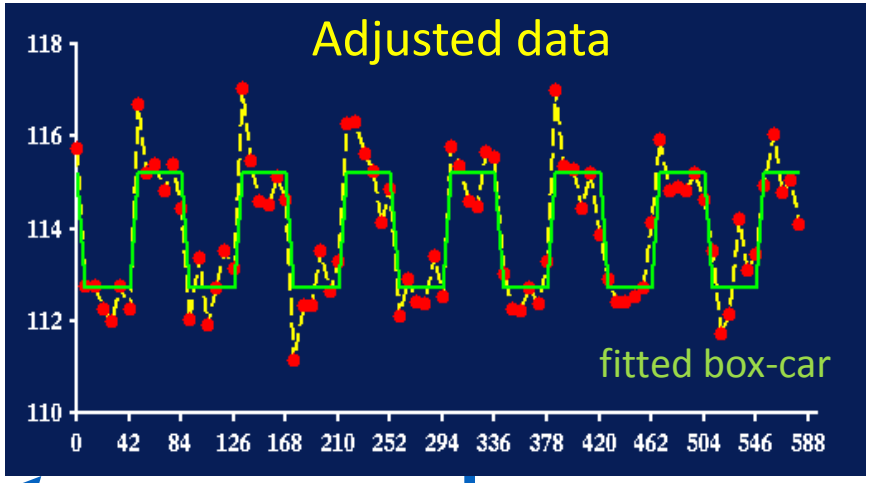


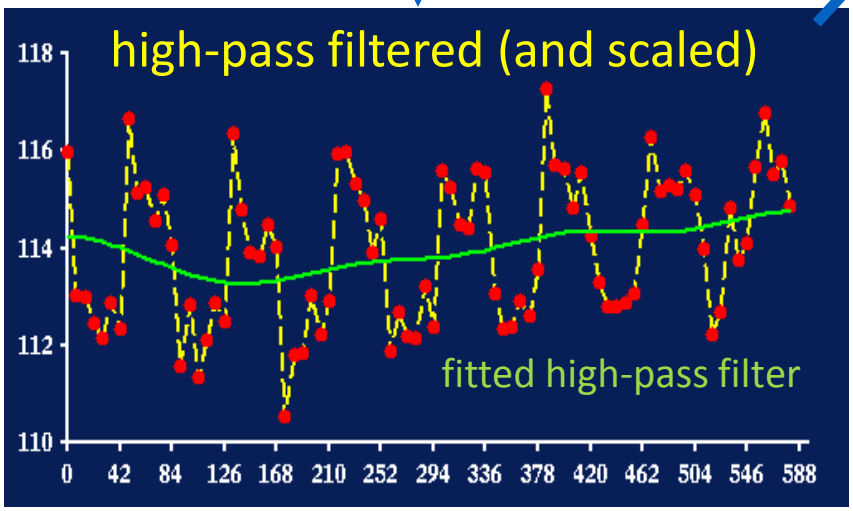
Adjusted data

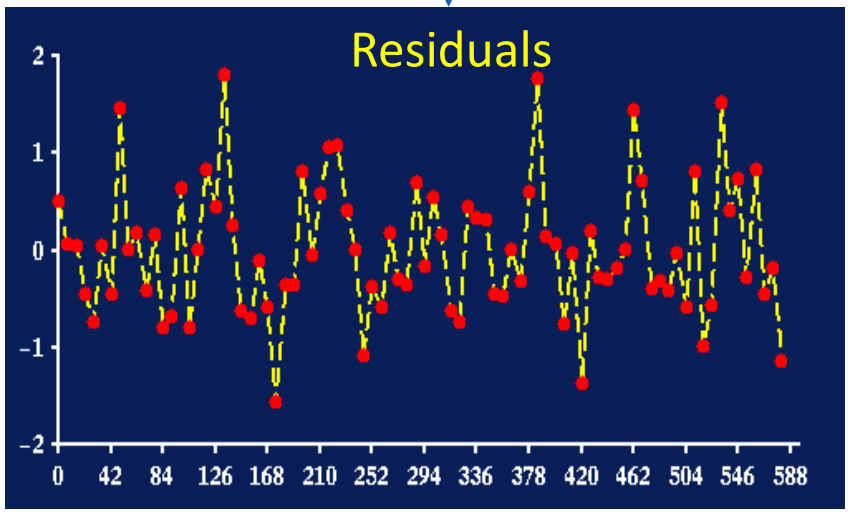
= data that have had effects of confounds fitted and removed – here, effects of the high-pass filter

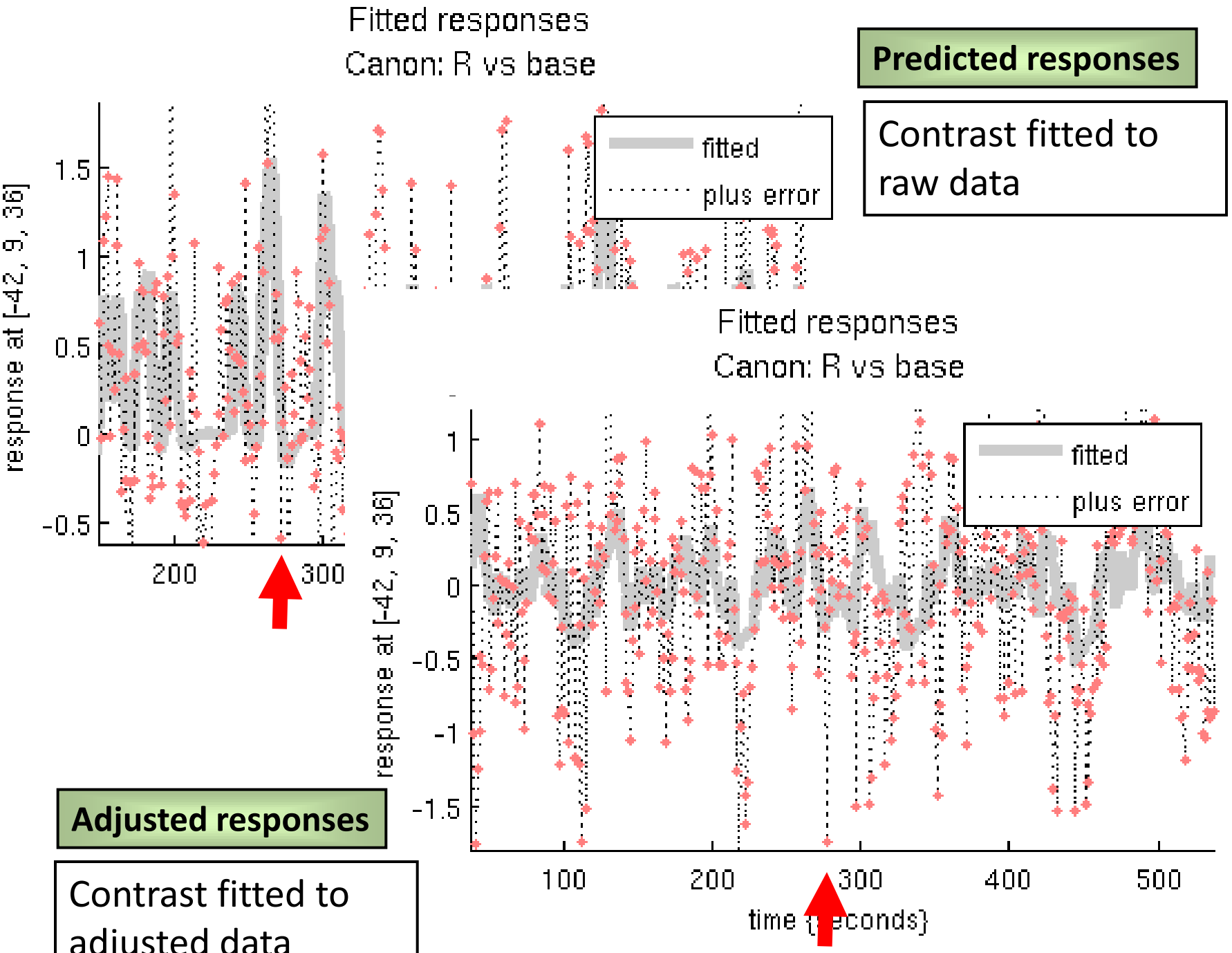
Fitted and adjusted data










Fitted responses
Canon: R vs base
fitted
plus error
response at [-42, 9, 36]
1.5
1
0.5
0
-0.5
200
300
Predicted responses
Contrast fitted to raw data
Fitted responses
Canon: R vs base
fitted
plus error
response at [-42, 9, 36]
1
0.5
0
-0.5
-1
-1.5
100
200
300
400
500
time {seconds}
Adjusted responses
Contrast fitted to adjusted data

A note on units/ percent signal ch.

- Parameter estimate beta (condition) is NOT the percent voxel signal change associated with that condition
- Data usually 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)

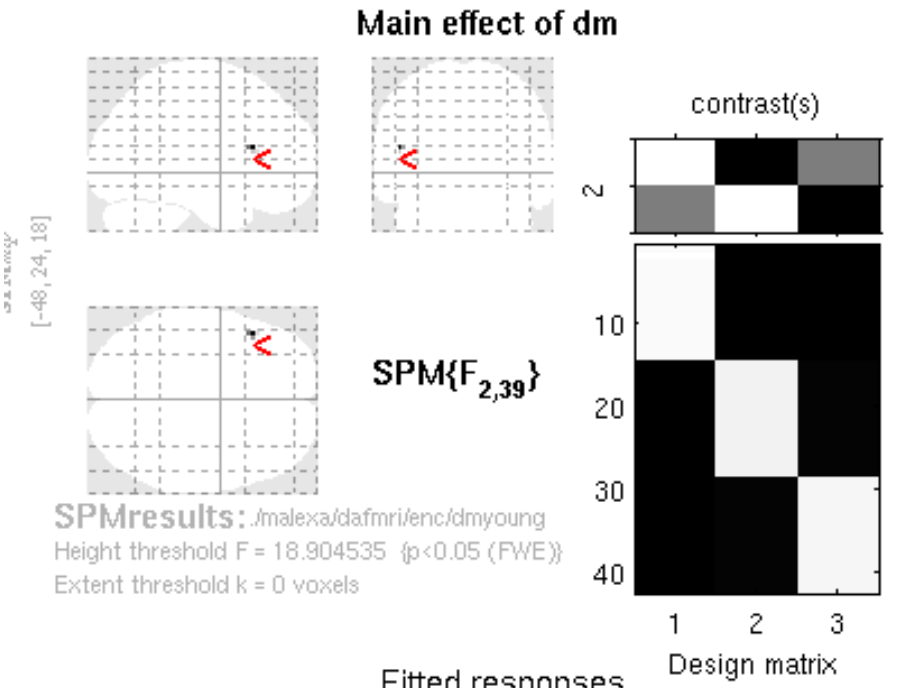
Fitted and adjusted responses

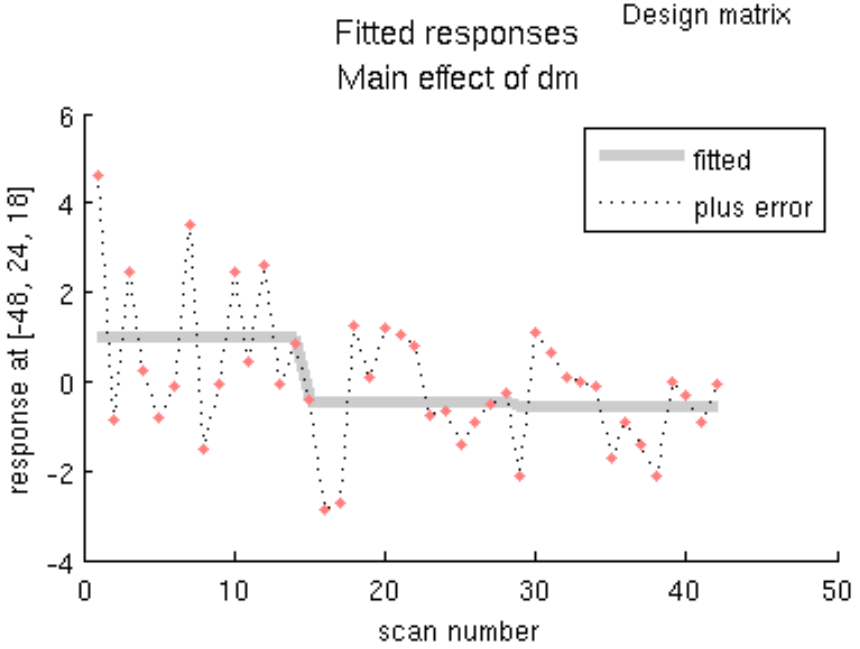
Plot against

- 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 2nd level model…

Fitted/ adjusted

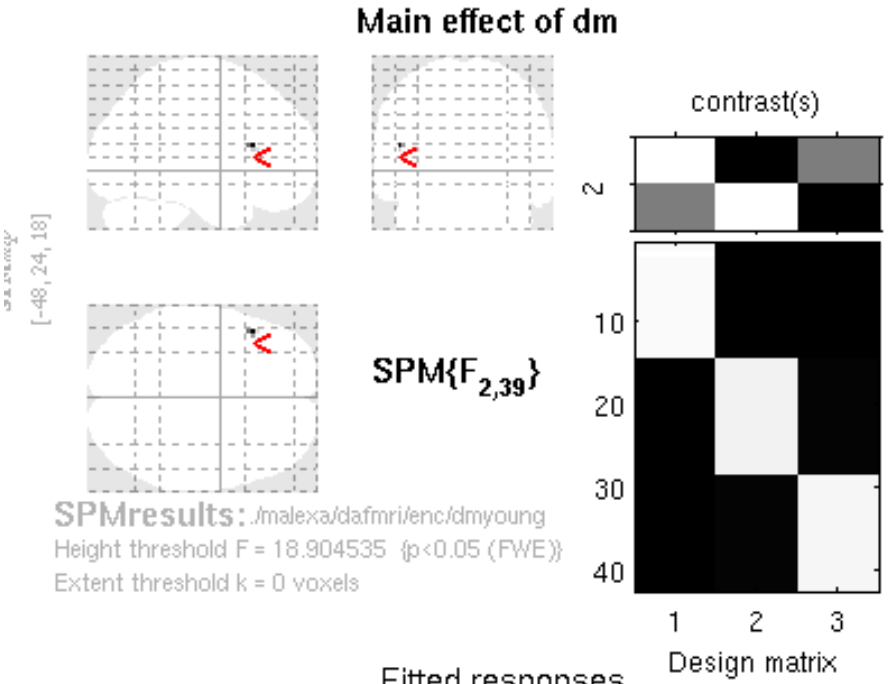
- In factorial model at 2nd level, ‘scan or time’ may not be helpful
- Here scans 1-14 are condition 1, scans 15-28 are condition 2, etc.
- Fitted response shows cross-subject average
- ‘Plus error’ shows individual subject contrast values

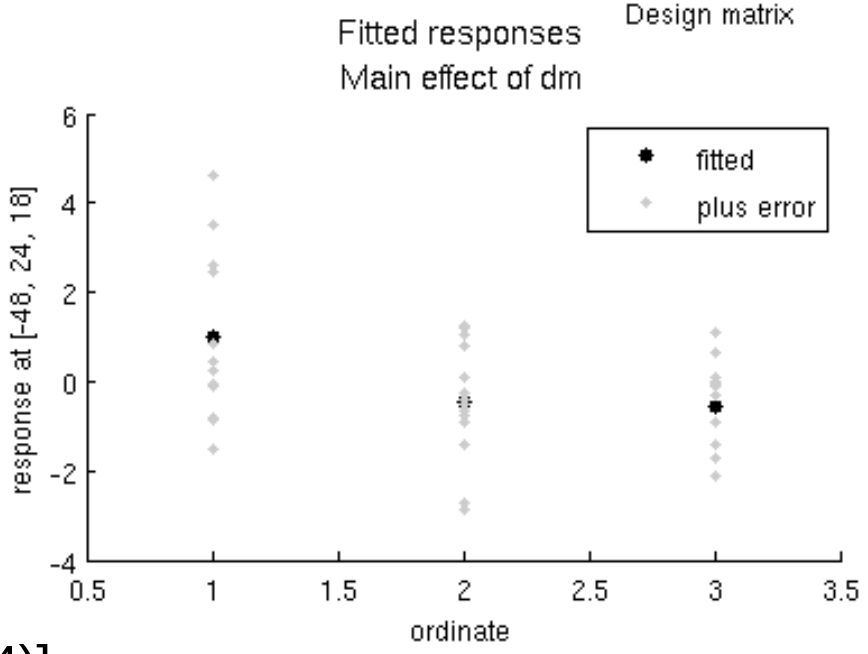




Fitted/ adjusted

- In factorial model at 2nd level, ‘scan or time’ may not be helpful
- 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





[ones(1,14) 2*ones(1,14) 3*ones(1,14)]

Event-related responses

Event-related responses are

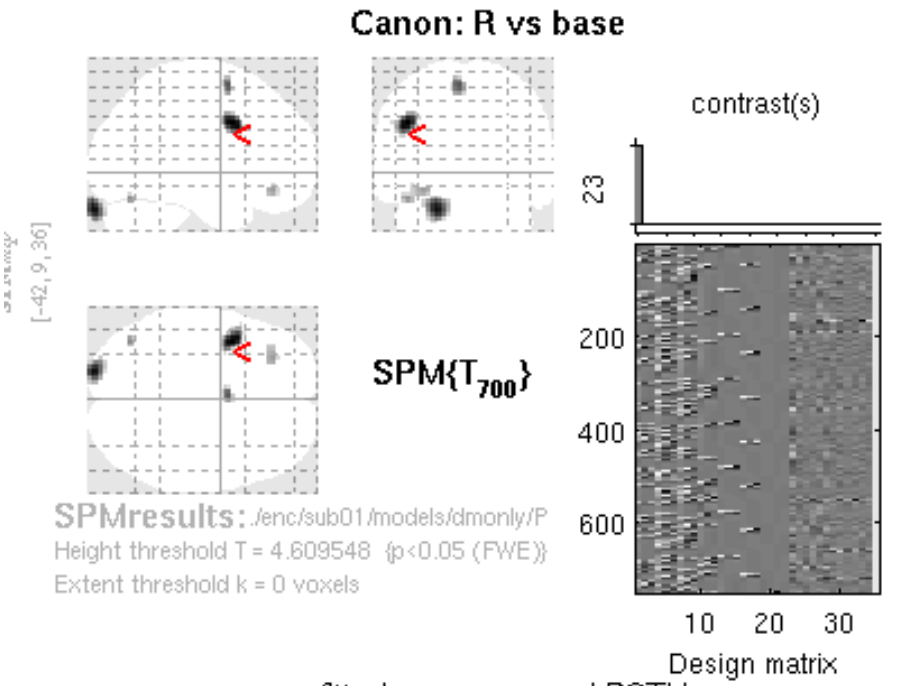
- To a given event type
- Plotted in peri-stimulus, i.e., onset-centred, time

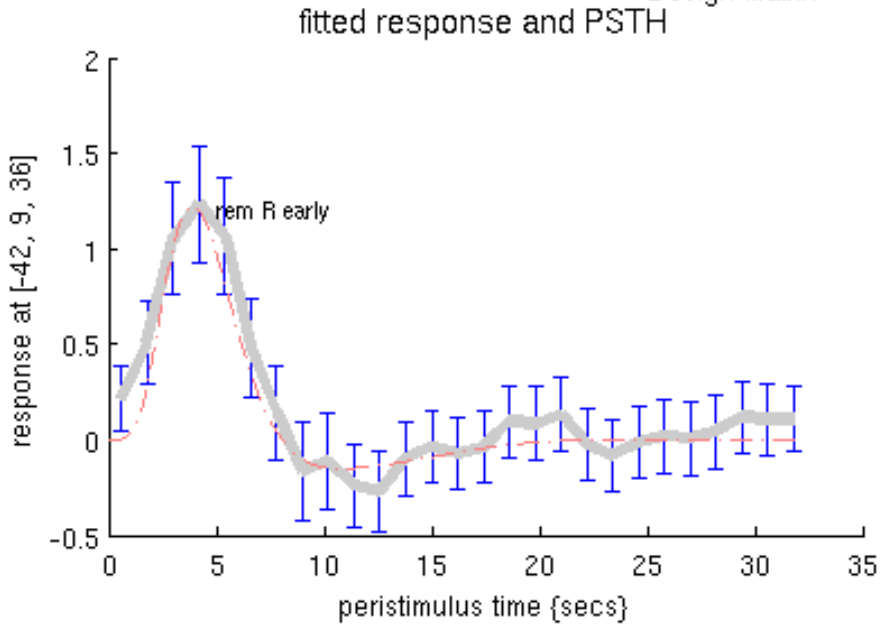
There are 3 types

- 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

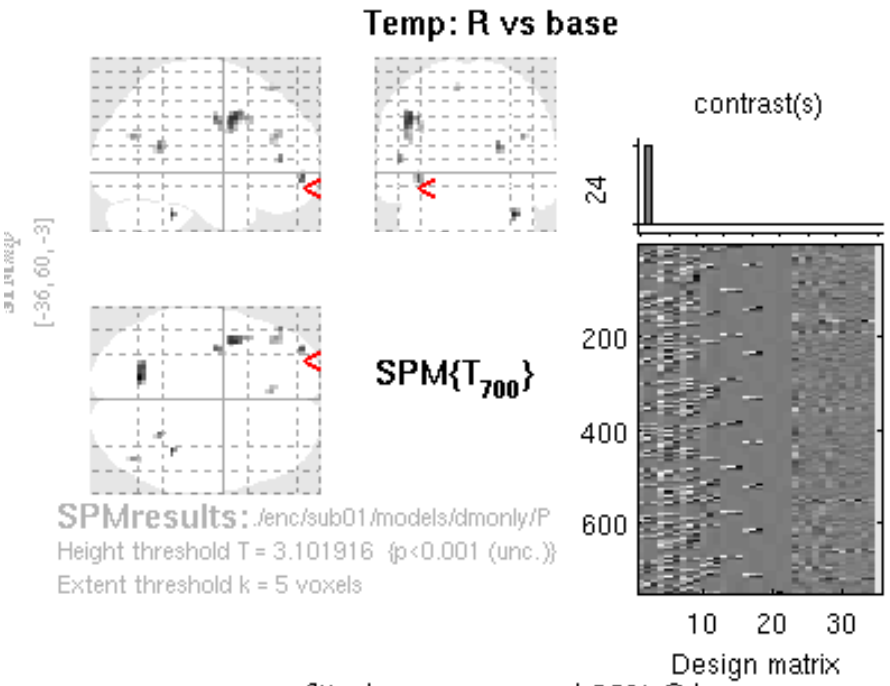
- Peri-stimulus time: centered around event onset
- Responses to event X are 'averaged' over the timeseries
- SPM fits a Finite Impulse Response (FIR) model to do this – often NOT the regressors used in the analysis
- Time bin size = TR
- Confidence intervals are within subject/session

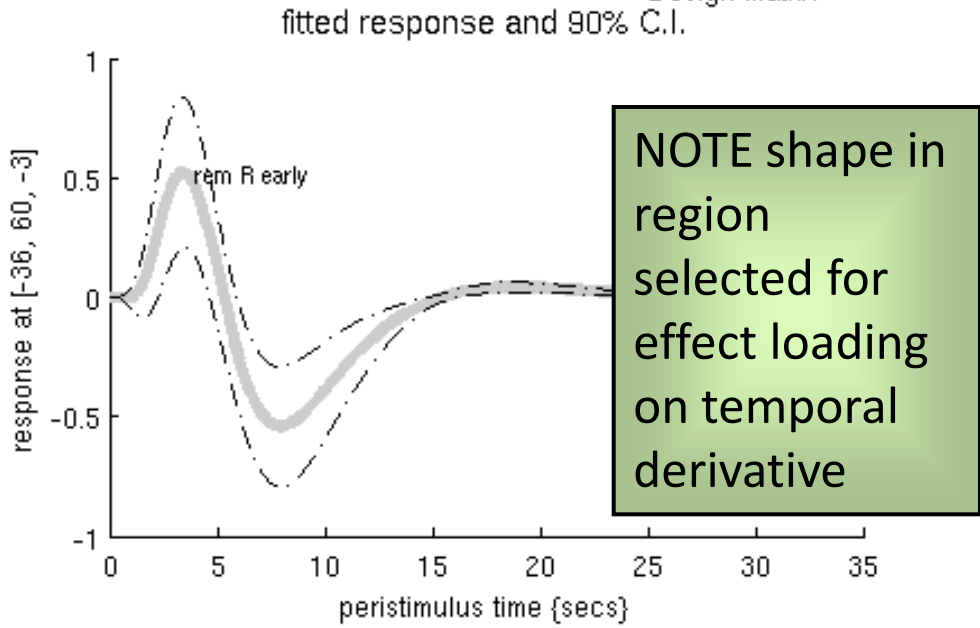




Fitted/90% CI

- 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

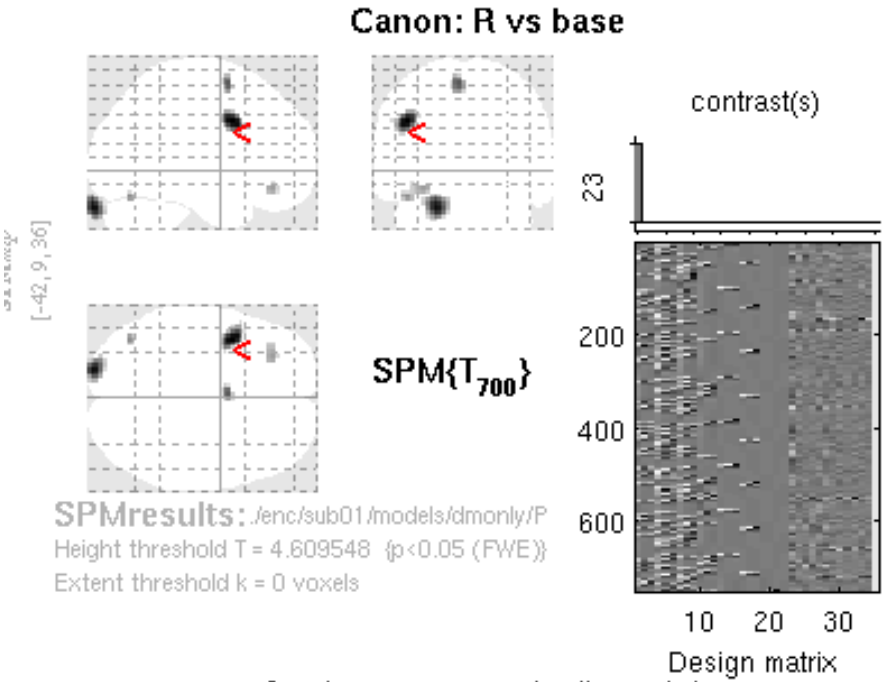


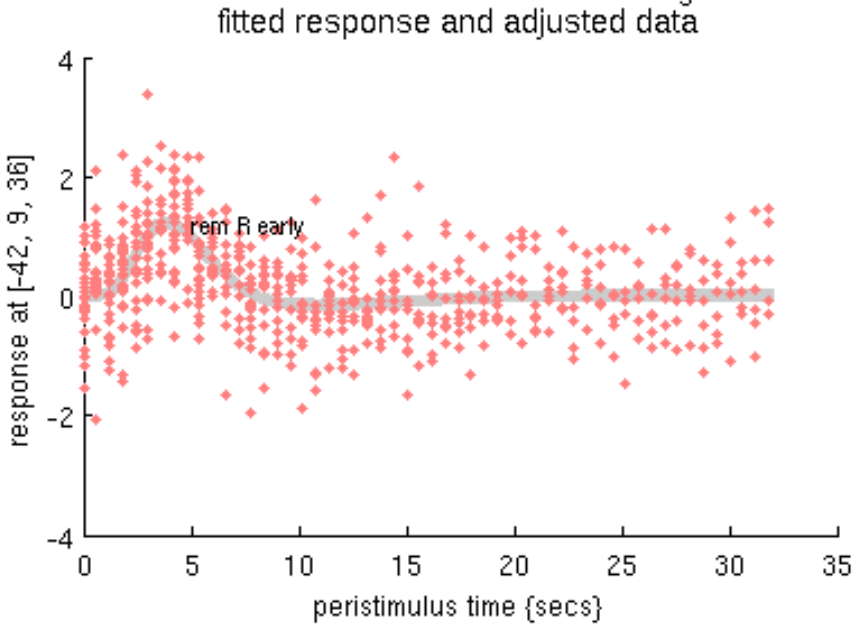


NOTE shape in region selected for effect loading on temporal derivative

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



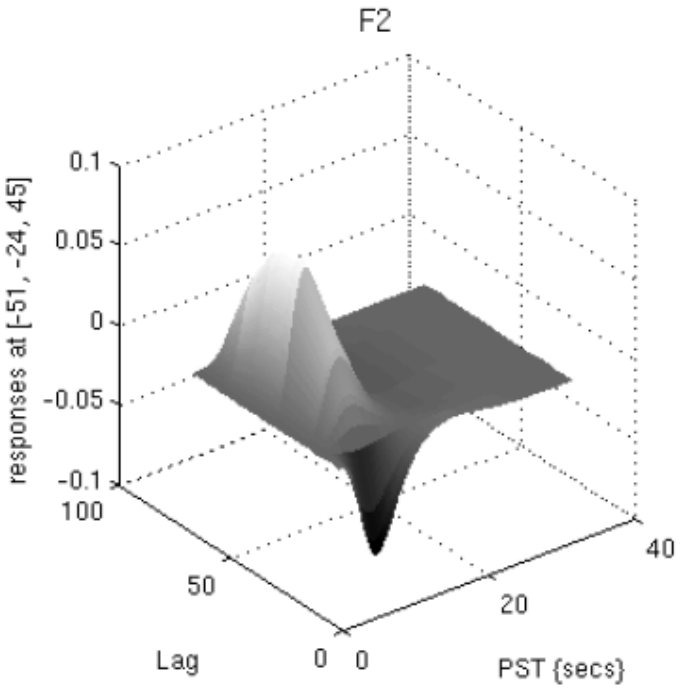


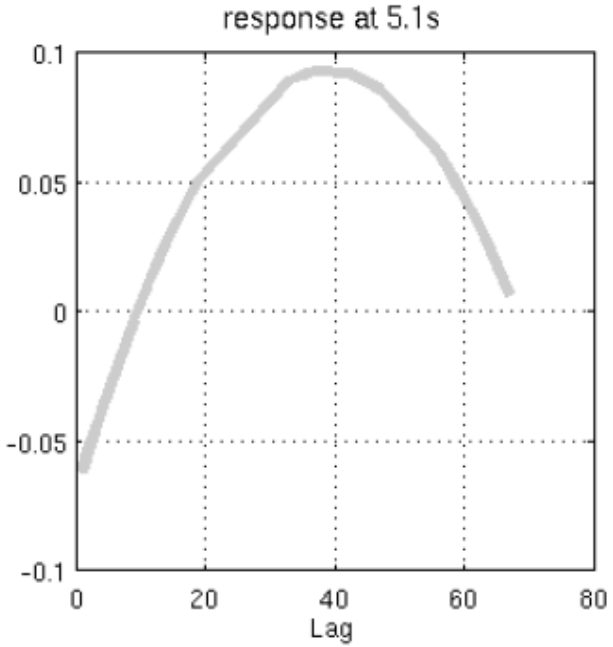
Parametric responses

Effect of a ‘parametric modulator’

- Available at 1st 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 an 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, “contrast” the contrast and data information (etc)
- Other utilities may help here
- E.g. Extracting betas from your voxel or region of interest for all your basis functions (e.g., canonical, temporal derivative) and plotting a fitted response

Utilities & resources

- FreeSurfer: 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/
- MarsBaR – M Brett's region of interest toolbox with RFX plot utilities at http://marsbar.sourceforge.net/
- Rfxplot – excellent utility by J Glascher, but may only apply as far as SPM5, at http://neuro.imm.dtu.dk/wiki/Rfxplot
- Short guidelines: Poldrack RA, Fletcher PC,Henson RN, Worsley KJ, Brett M,Nichols TE. Guidelines for reporting an fMRI study. Neuroimage. 2008 40(2): 409–414. Unthresholded maps: Jernigan TL, Gamst AC, Fennema-Notestine C, Ostergaard AL. More "mapping" in brain mapping: statistical comparison of effects. Hum Brain Mapp. 2003. 19(2):90-5.
- On error bars: Masson, M. E. J., & Loftus, G. R. Using confidence intervals for graphically based data interpretation. Can J Exp Psychol. 2003. 57*:* 203-220.