

# Data Visualisation in SPM: An introduction

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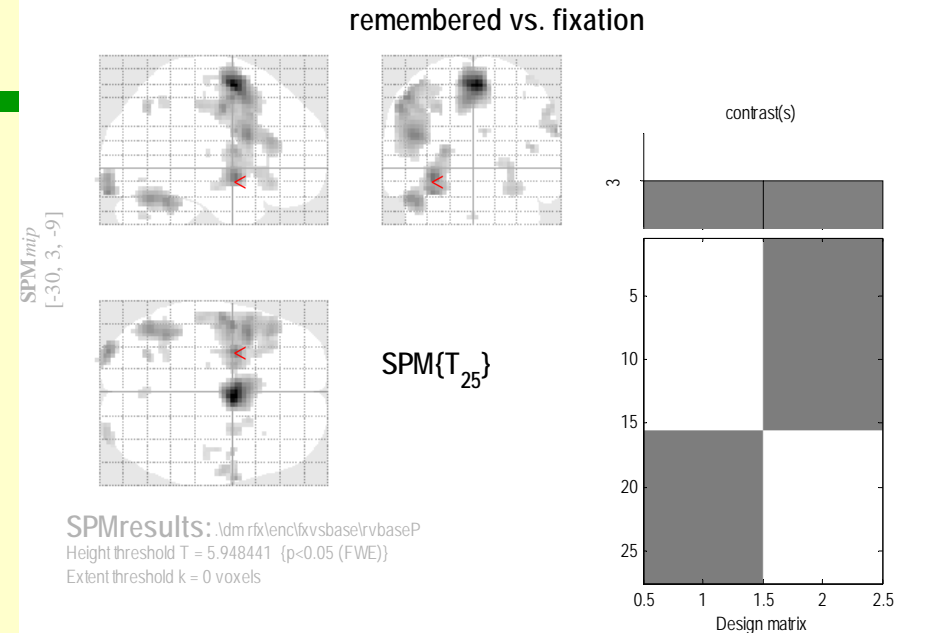
Edinburgh SPM course, April 2010

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Department of Psychology  
University of Edinburgh



# Visualising results

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



SPMresults: .\dm rfx\enclfxvsbase\rbaseP  
Height threshold T = 5.948441 (p<0.05 (FWE))  
Extent threshold k = 0 voxels

Statistics: *p-values adjusted for search volume*

set-level		cluster-level				peak-level					mm mm mm		
<i>p</i>	<i>C</i>	<i>p</i> <sub>FWE-corr</sub>	<i>q</i> <sub>FDR-corr</sub>	<i>k</i> <sub>E</sub>	<i>p</i> <sub>uncorr</sub>	<i>p</i> <sub>FWE-corr</sub>	<i>q</i> <sub>FDR-corr</sub>	<i>T</i>	<i>Z</i>	<i>p</i> <sub>uncorr</sub>			
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

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



# What to plot?

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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?

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- Overlays
  - Visualisation of regional results on a brain image
  - ‘Big picture’ – distribution, location
- Effect plots
  - Visualisation of effects at a single voxel



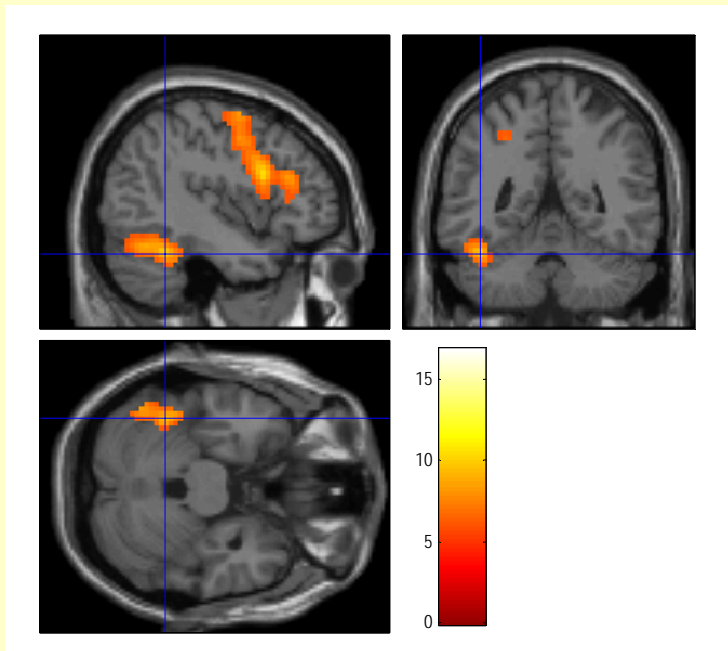
# Overlay: sections

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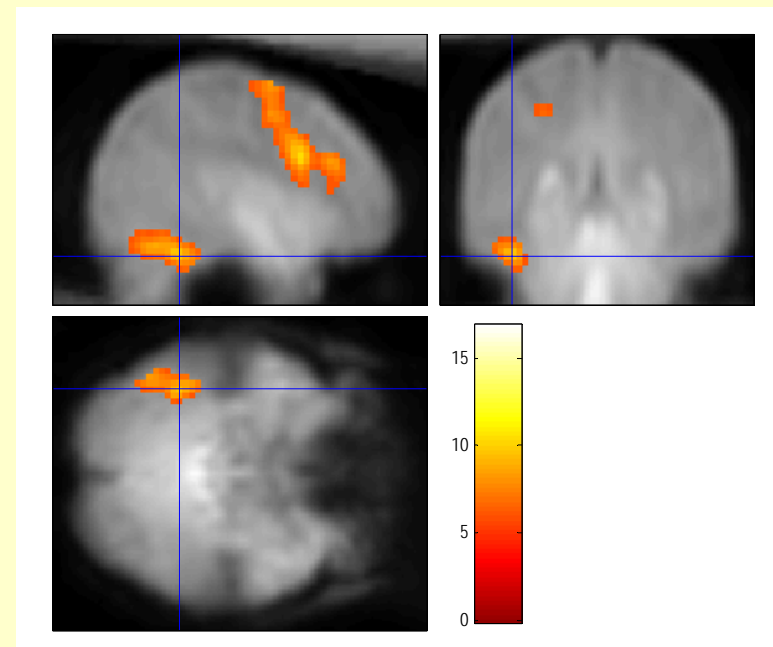
- From Results
  - Display → overlay
- Sections
  - Plots the current thresholded SPM
  - Superimposes it on orthogonal sections
  - Can use any image for display



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



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 mm<sup>3</sup> !
- Beware of mis-localisation and exaggerating precision
- Alternatives e.g. averaged structurals

# Overlay: slices

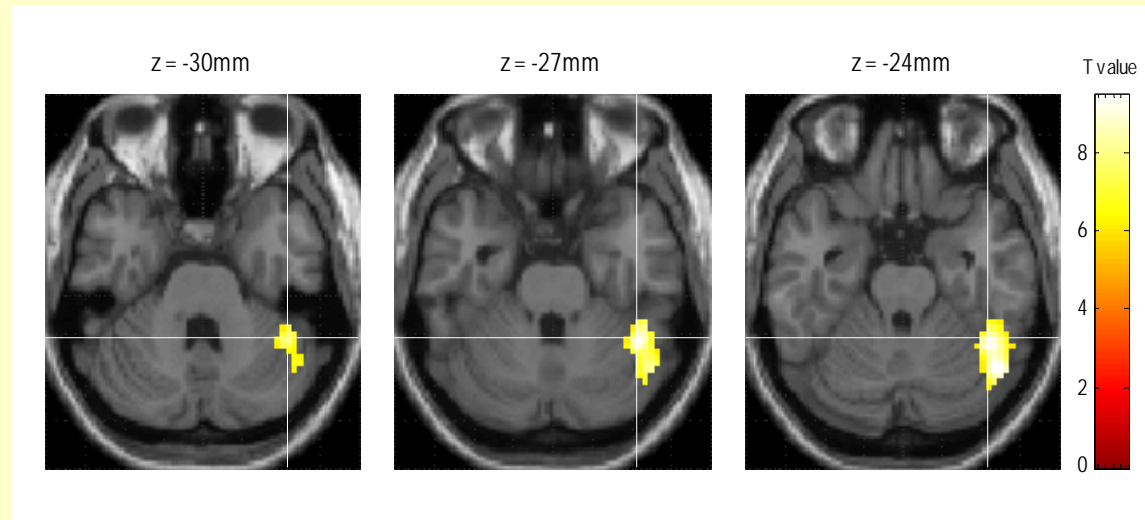
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- From Results
  - Display → overlay
- Slices
  - Plots the current thresholded SPM
  - Superimposes it on horizontal slices
  - Can use any image for display





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



Activity overlaid on slices from a 'canonical brain' T1 image

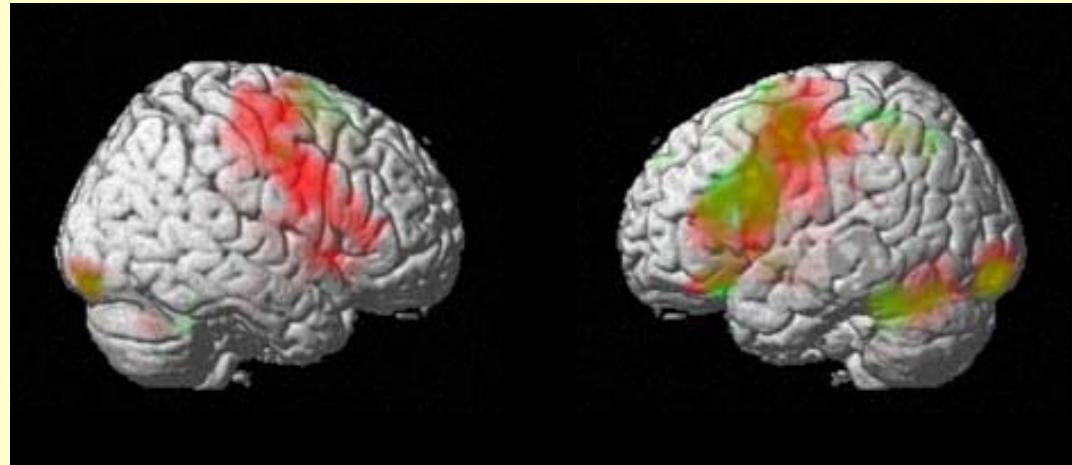
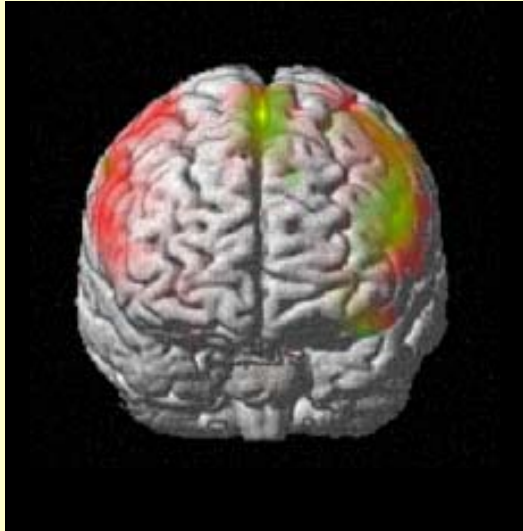
- Plots 3 horizontal slices
- Uses the slices above & below the slice with the index voxel
- Crosshairs (if seen) are at same x and y coordinates
- Distance apart depends on voxel size after normalisation
- NOTE: T values are relative

# Overlay: render

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- 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

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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

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Different options for 1<sup>st</sup> or 2<sup>nd</sup> 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

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At 1<sup>st</sup> level

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

At 2<sup>nd</sup> level

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



# Plots

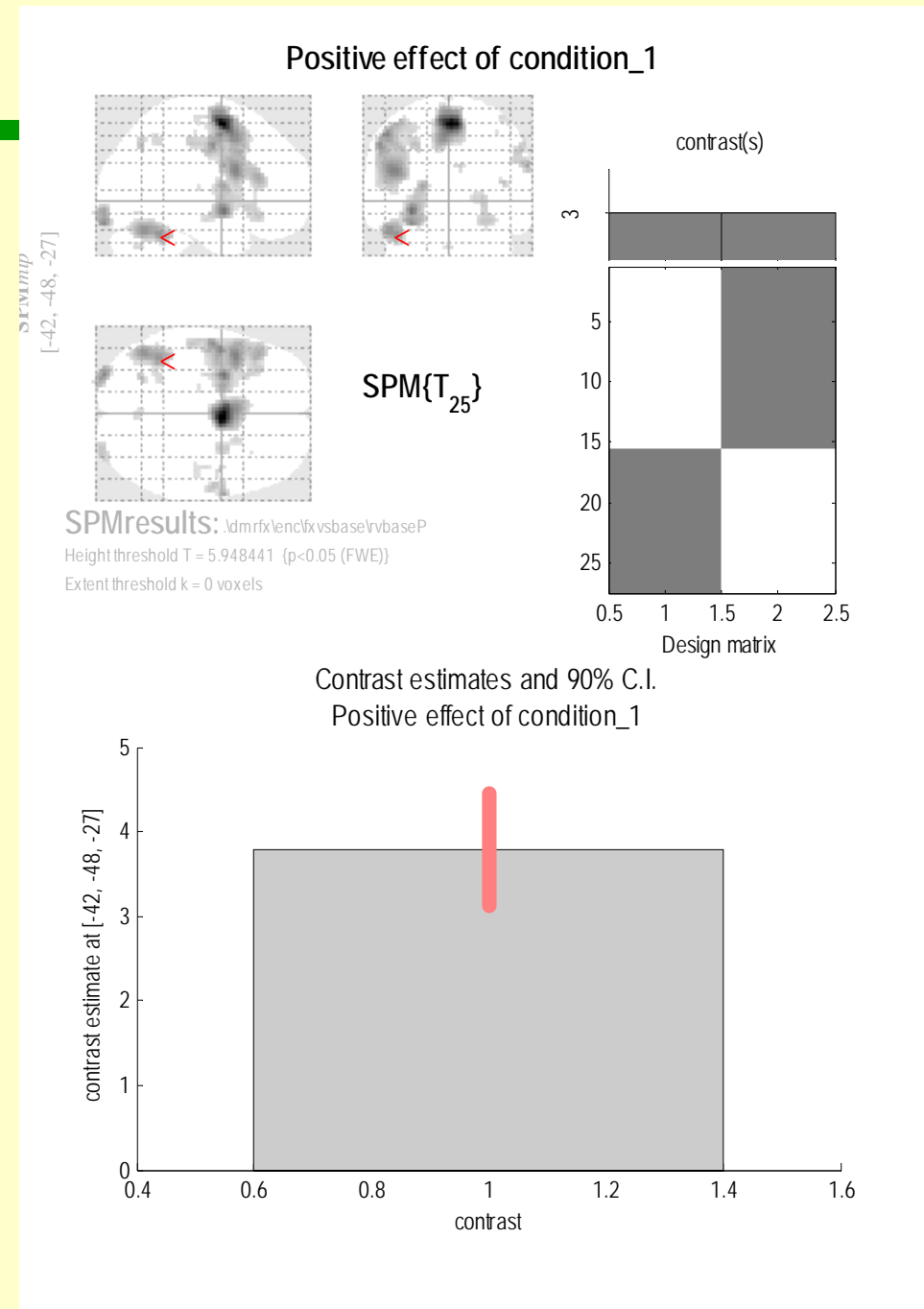
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- From Results
  - Display → plot
- Sections
  - Plots from the current model
  - Plots at the selected location
  - May plot a different regressor/ contrast



# Contrast/ CI

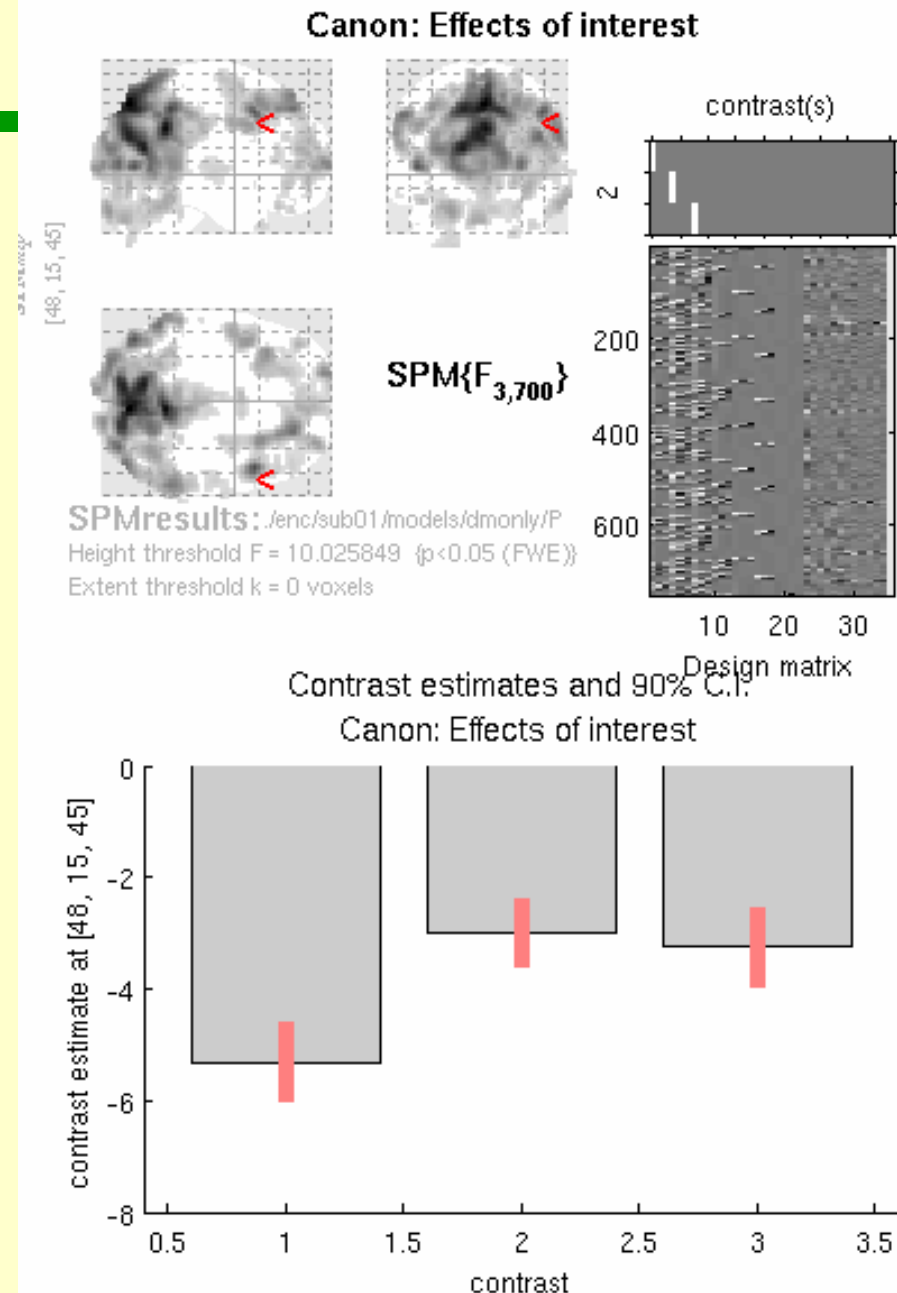
- Same for 1<sup>st</sup> and 2<sup>nd</sup> level models
- Here, an 'RFX'  
 $T$ -contrast is plotted
- Shows effect across 2 groups with between-subjects error bar
- Can extract CI info from MATLAB workspace to plot >1 condition outside SPM ("contrast")



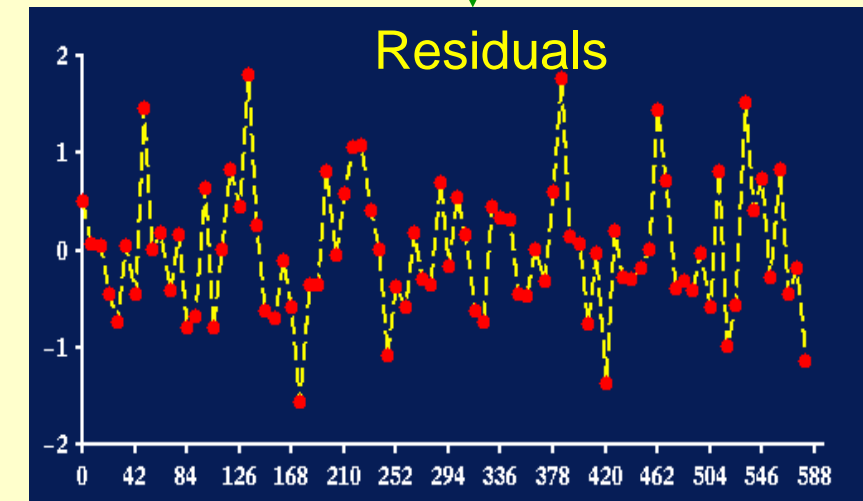
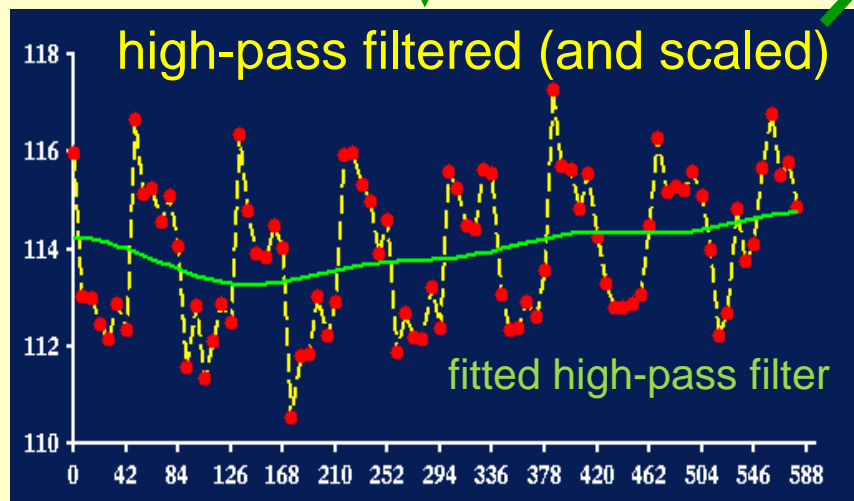
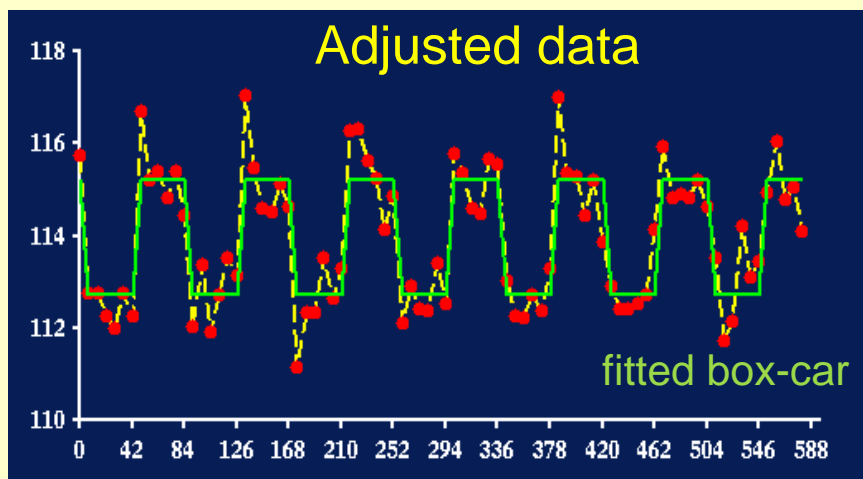
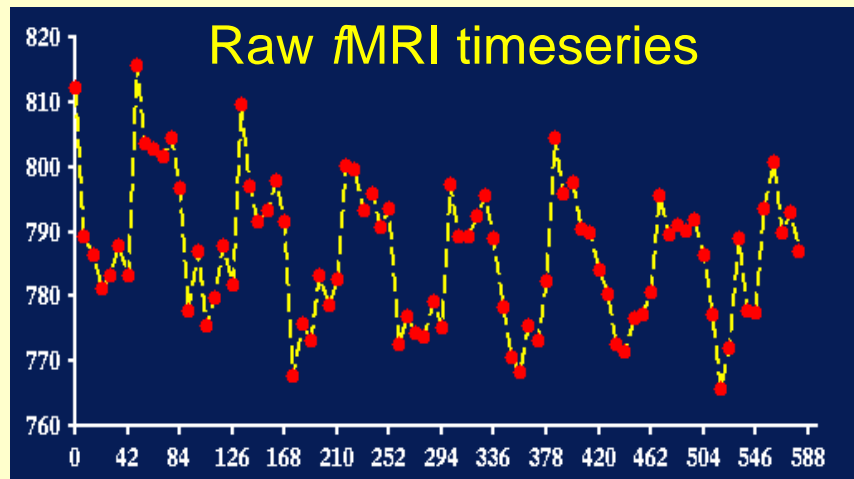


# Contrast/CI

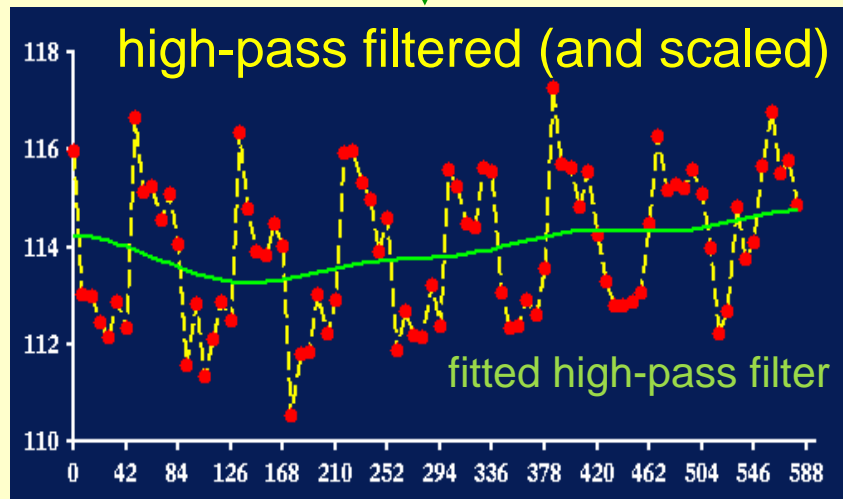
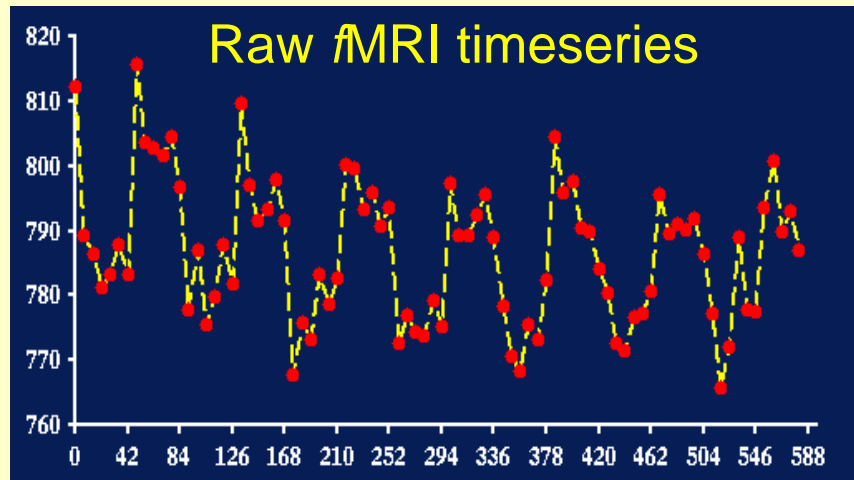
- Here, a 'FFX'  $F$ -contrast is plotted
- Shows same contrast at single subject level
- But here an  $F$ -contrast is used to look at effects for the 3 basis functions – canonical, and temporal/dispersion derivatives
- Can do for  $>1$  condition *within same model* if create  $F$  contrast



# Fitted & adjusted data



# Fitted & adjusted data



## Fitted effects

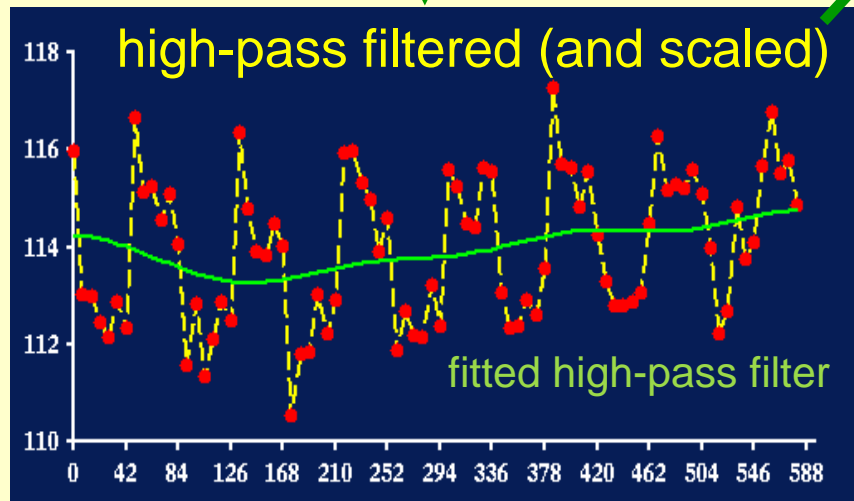
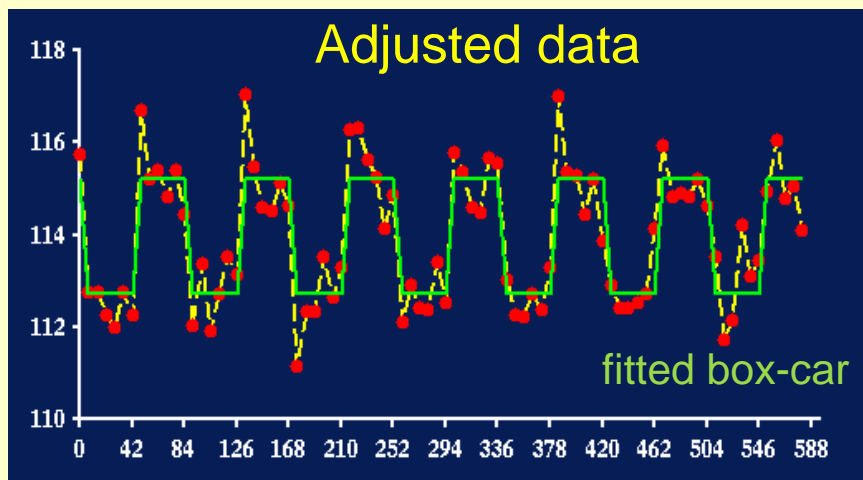
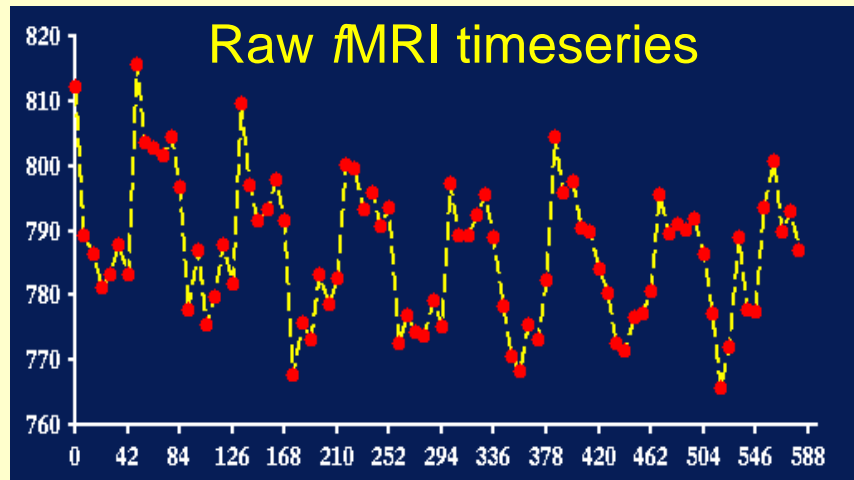
= a linear combination of effects x their parameter estimates

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 & adjusted data



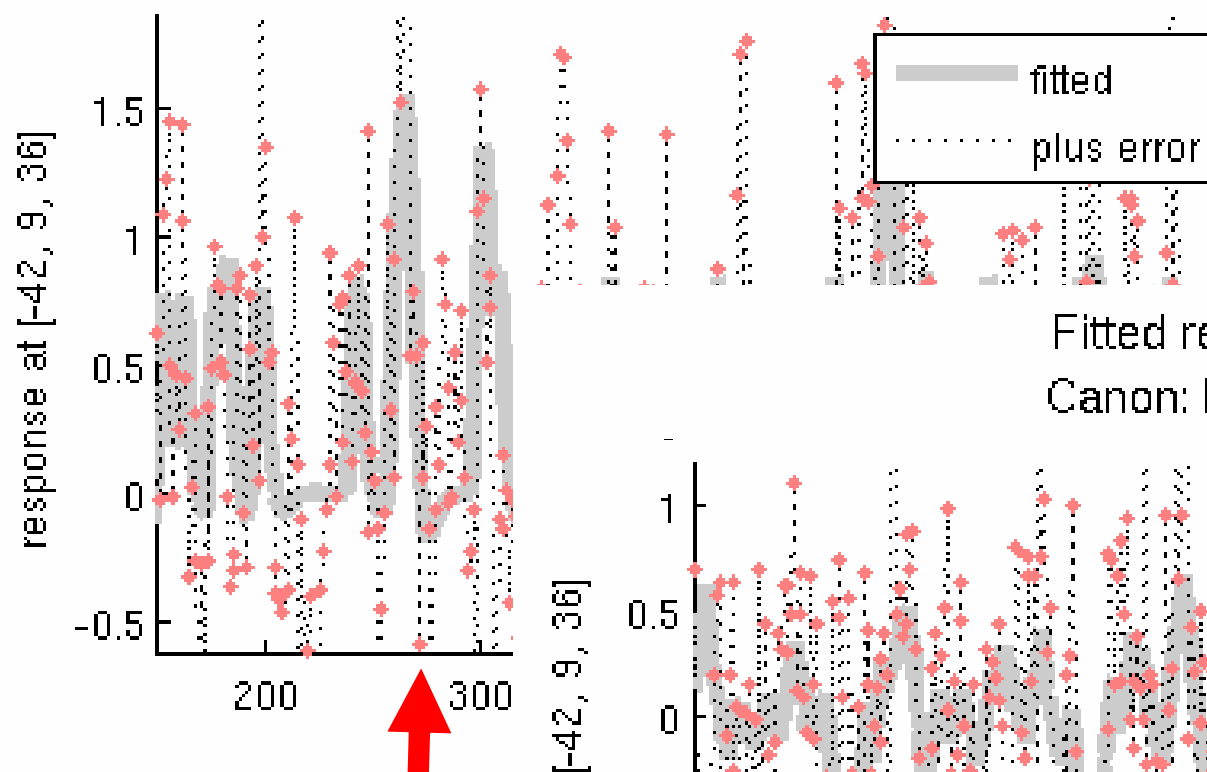
Adjusted data

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

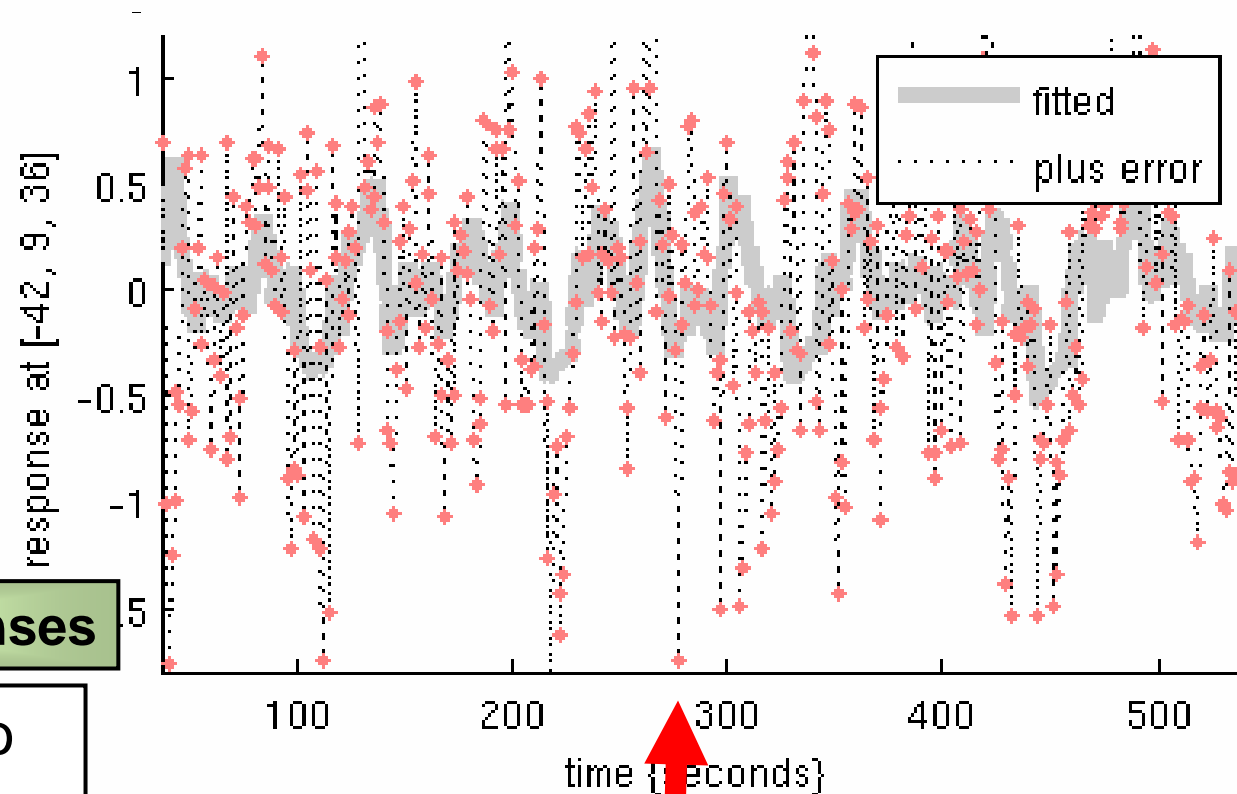
Fitted responses  
Canon: R vs base

Predicted responses

Contrast fitted to  
raw data



Fitted responses  
Canon: R vs base



Adjusted responses

Contrast fitted to  
adjusted data

# A note on units

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- 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

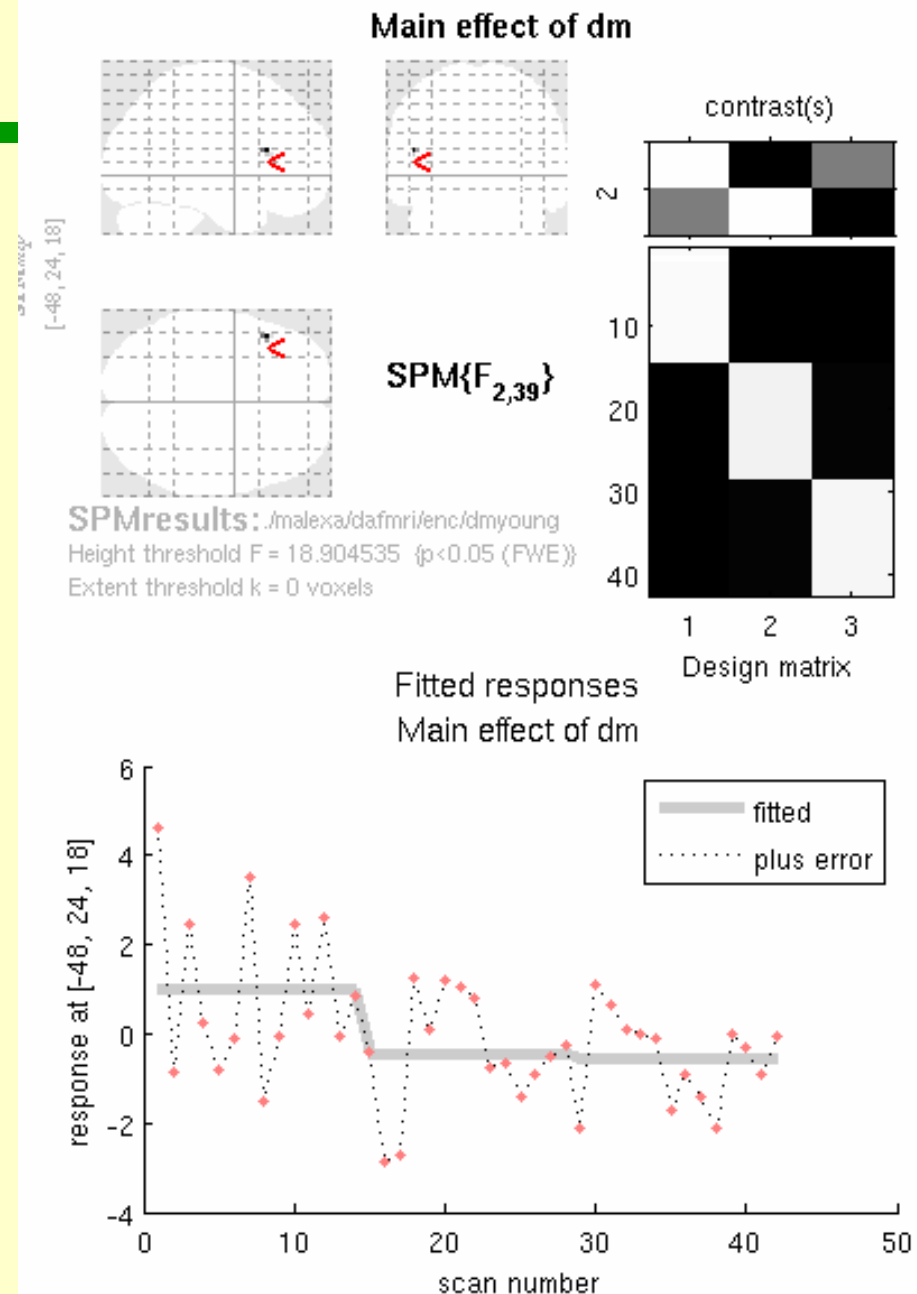
Plot against

- 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<sup>nd</sup> level model...



# Fitted/ adjusted

- In factorial model at 2<sup>nd</sup> 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

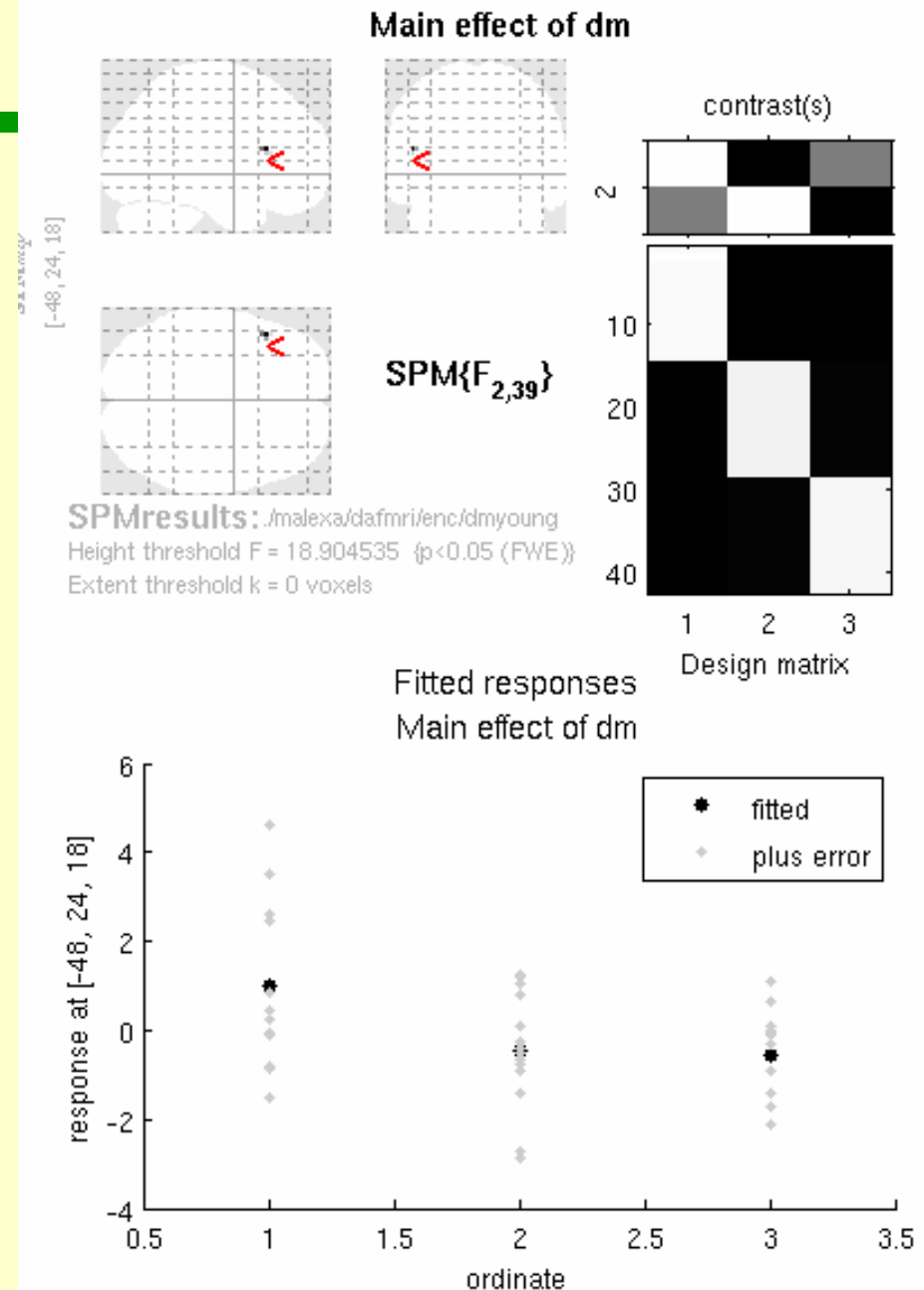




# Fitted/ adjusted

- In factorial model at 2<sup>nd</sup> 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

[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

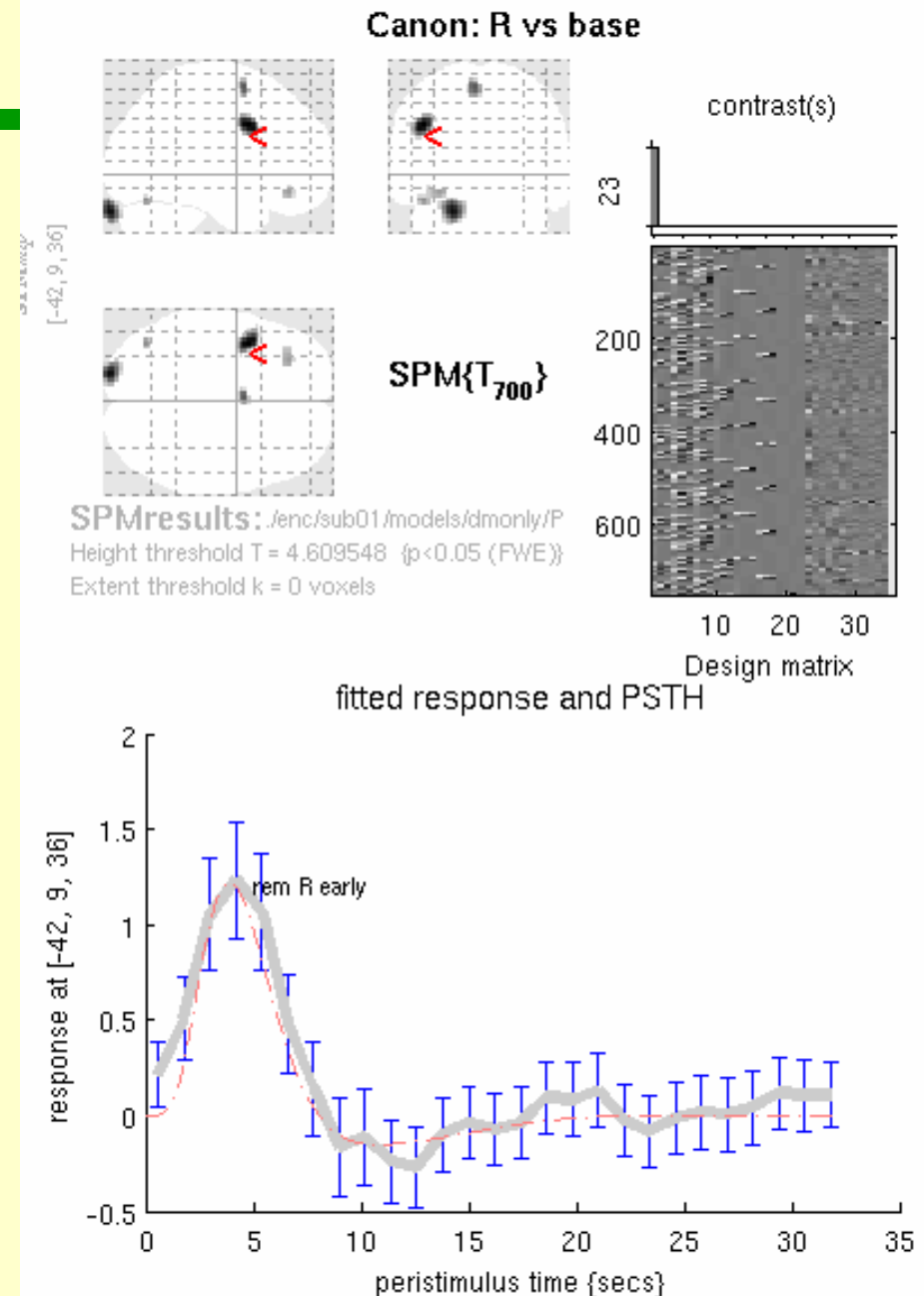
There are 3 types

- Fitted response and PSTH (Peri-Stimulus Time Histogram): the 'average' response to an event type with mean signal  $\pm$  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



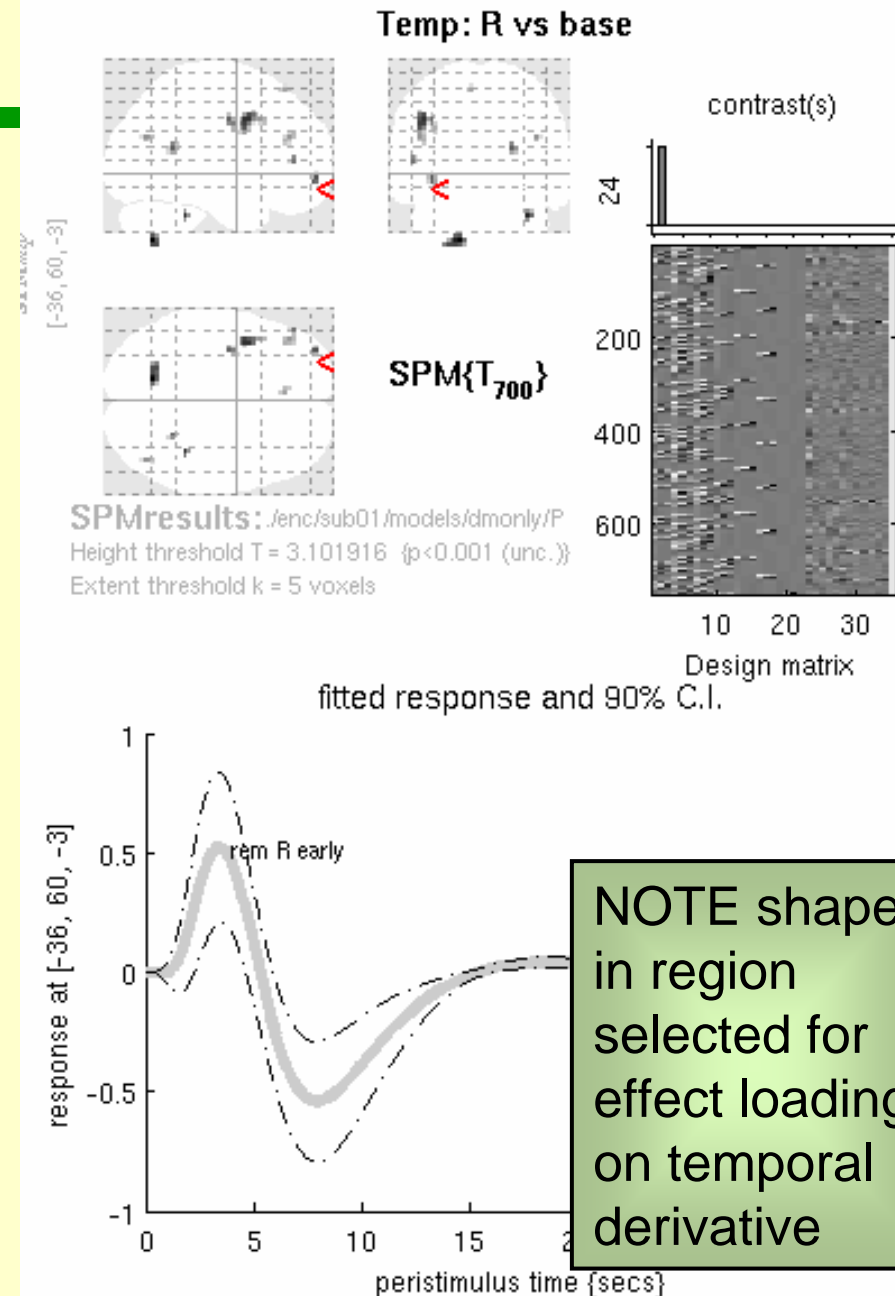
# PSTH

- 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



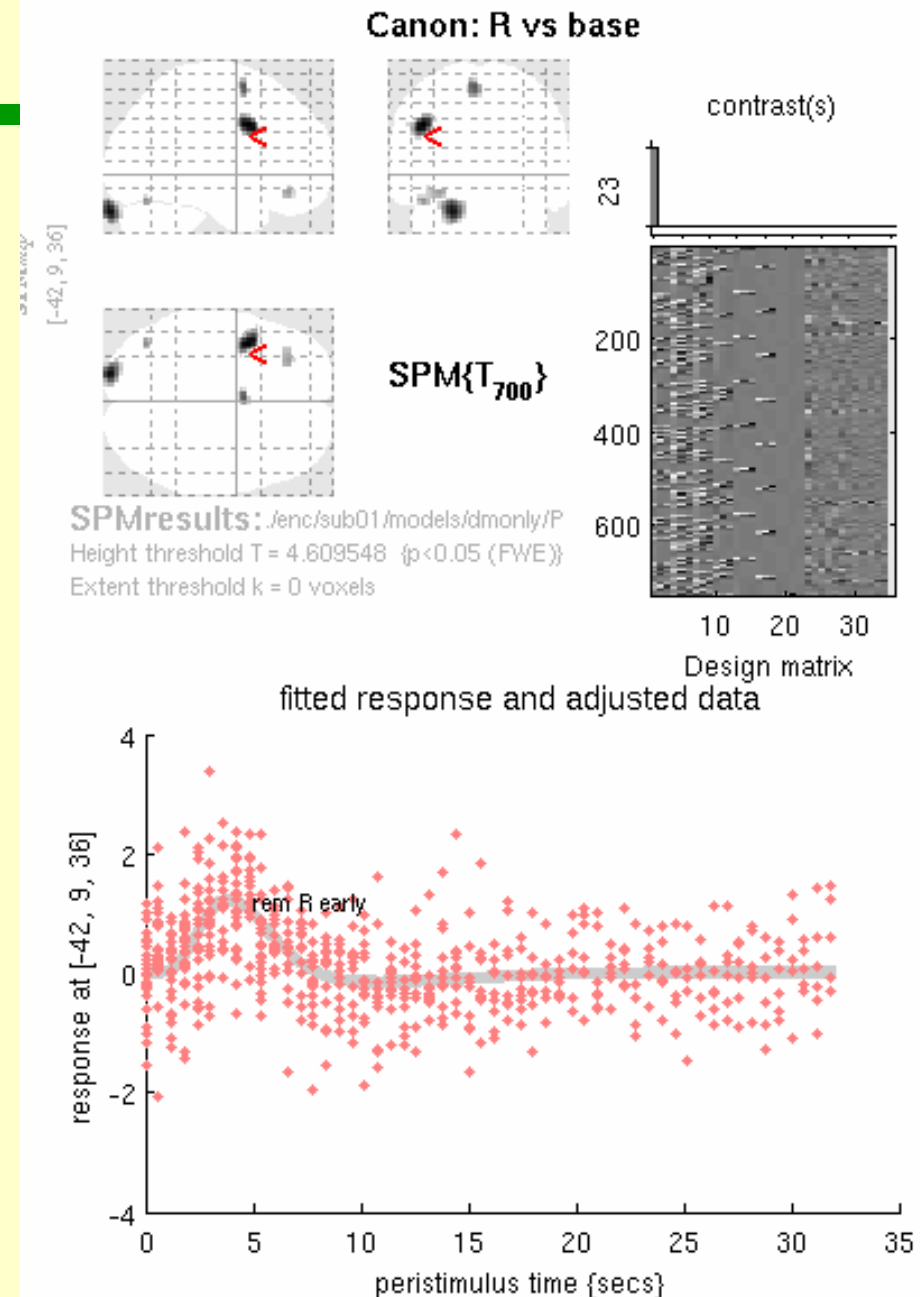
# Fitted/90% CI

- 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



# 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

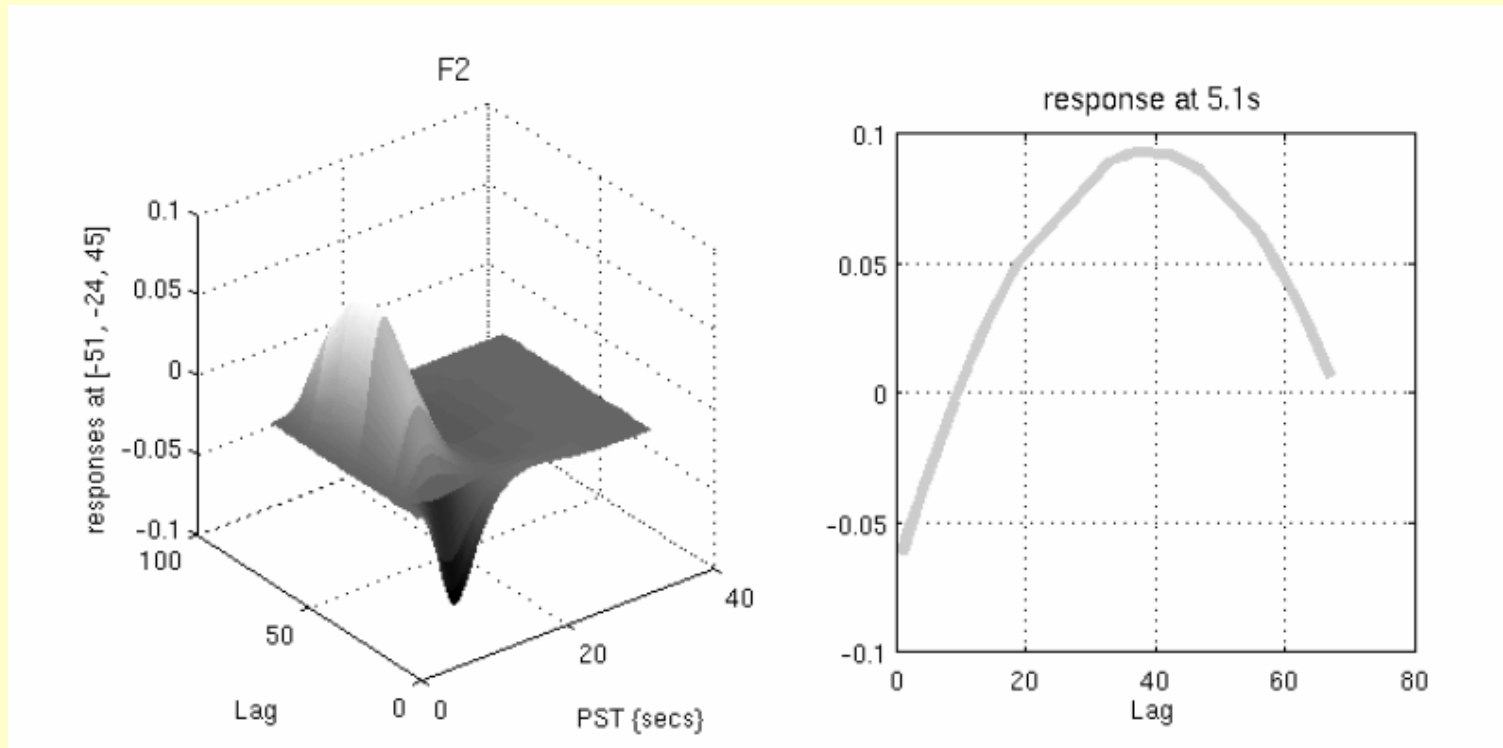
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## Effect of a 'parametric modulator'

- Available at 1<sup>st</sup> 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  $\approx 40$

# Other tips

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- 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

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- 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/cbm/cbm-tools/>
- MarsBaR – M Brett's region of interest toolbox with RFX plot utilities at <http://marsbar.sourceforge.net/>
- Rfxplot – excellent utility by J Glascher, shortly to be updated for SPM8, 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.

