GLM Analysis using FSL (FMRIB Software Library) using (FEAT) (fMRI Expert Analysis Tools)

Some slides from Dr. Scott Huettel &

Chris Petty and FSL website: http://www.fmrib.ox.ac.uk/fsl/

Data Analysis: Main Components

- Within-subjects
  - *Preprocessing*: removal/minimization of task-independent variability
  - General linear model
    - Model specification: creating and evaluating a model for brain function
    - Model evaluation: testing specific hypotheses
- Across-subjects
  - Aggregation of data to increase experimental power
  - Inter-group comparisons
  - Testing of parametric effects

FMRIB Software Library (FSL)

- Created by researchers at the FMRIB in Oxford
- Comprises many tools for analysis of:
  - fMRI data
  - Structural MRI data
  - Diffusion Tensor Imaging data
- Runs natively on Linux/Unix or Mac
  - Runs on Windows with virtual machine (vm-ware)
- Can be run via GUI or via scripts
- Citation
  - S.M. Smith, et al. Advances in functional and structural MR image analysis and implementation as FSL. NeuroImage, 23(S1):208-219, 2004

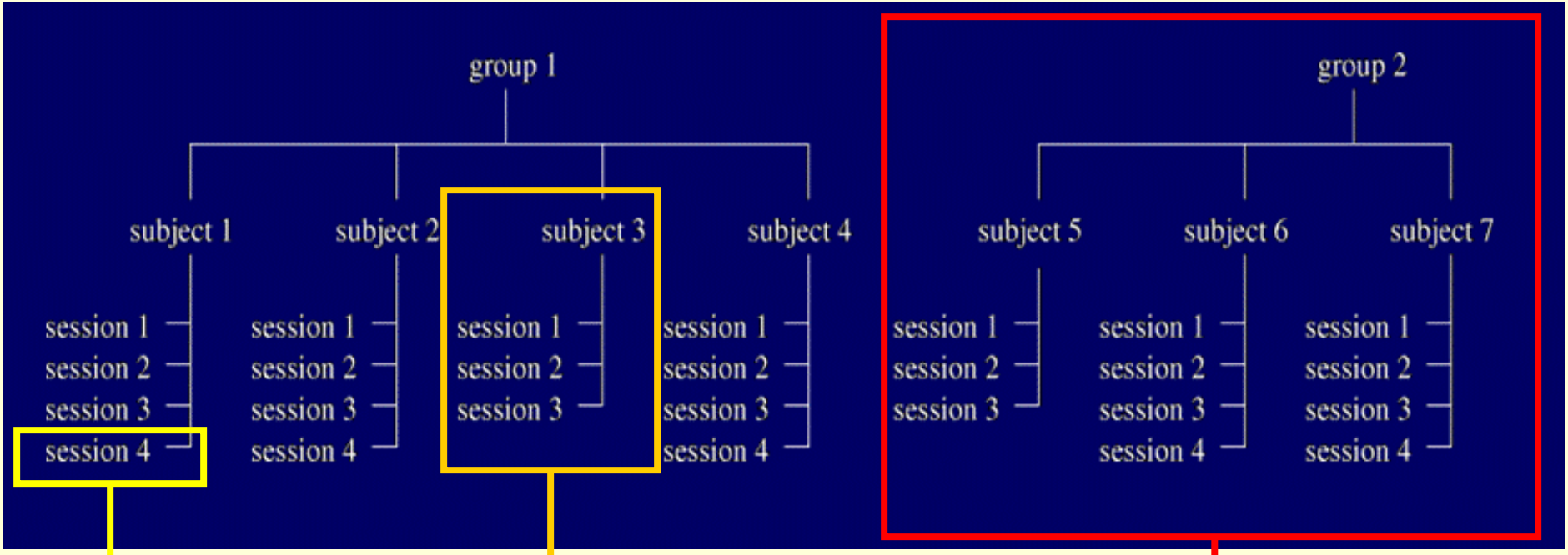
FMRIB Software Library (FSL)

- FEAT: fMRI analysis (subject and group levels), preprocessing
  - MCFLIRT: motion correction
  - FLIRT: registration
  - BET: Brain Extraction Tool
- MELODIC: independent components analysis, for model-free analyses and noise removal
- FSL View: displaying data

Preparing your data for FSL

- Convert functional and anatomical data into correct format (nifti)
- Generate orientation matrix for registration
- Generate “3 column files” for behavior
  - Text files with three columns: (1) When did something happen, (2) how long did it take, (3) how much should it be weighted

Levels of FSL analysis

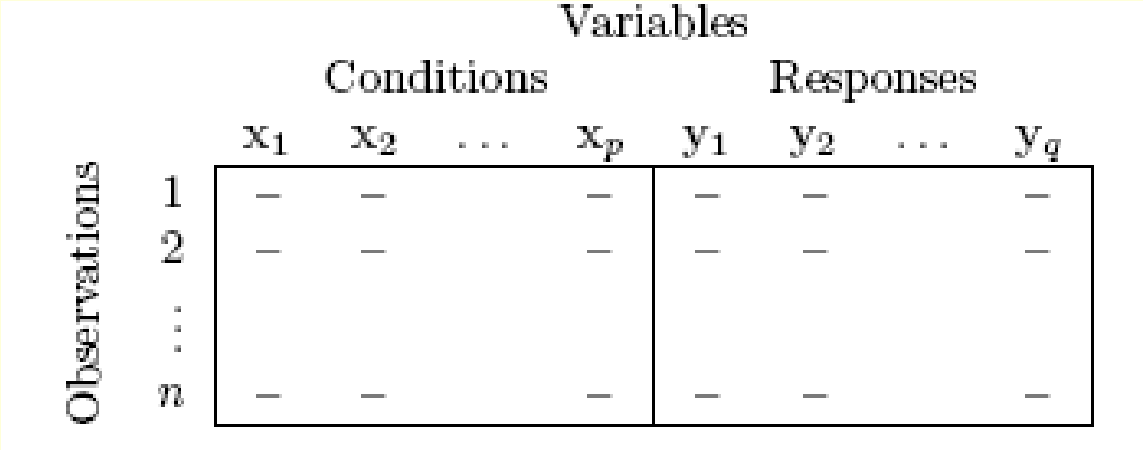


1st level: session

2nd Level: subject

3rd Level: group

GLM model



- The rows (observations) may refer to observations at different times, to different subjects, or to different brain locations
- The columns (**x_j variables) describe the condition in which the observation was made (**it may describe particular response condition, groups, or subjects)
- **y_k are observed measurements, for example activations measured** different locations.

- The basic goal of the analysis is to find a way to describe the **y_k as functions of the x_js**

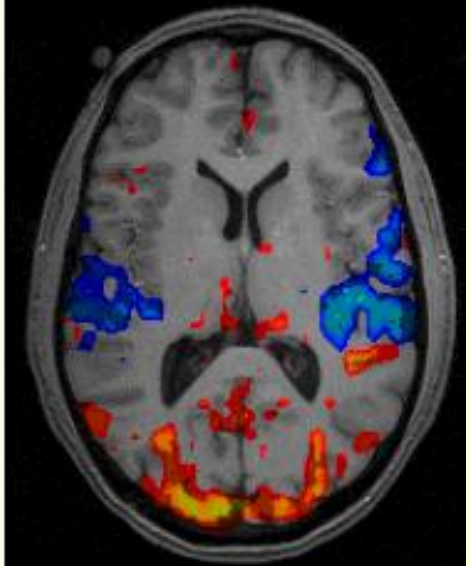
t	Stim	x_0	x_1	x_2	y_1	y_2	y_3	y_4
1	0	1	0	0	9.45	13.25	11.23	16.48
2	0	1	0	0	9.86	10.26	11.13	13.62
3	0	1	0	0	10.17	13.90	11.74	15.13
4	1	1	1	0	12.97	11.76	10.97	16.63
5	1	1	1	0	11.31	13.83	10.65	16.42
6	1	1	1	0	12.70	10.96	10.12	17.85
7	0	1	0	0	11.38	12.95	11.15	13.65
8	0	1	0	0	10.29	12.12	11.56	15.96
9	0	1	0	0	11.82	10.29	12.73	14.27
10	2	1	0	1	10.27	12.45	14.15	19.39
11	2	1	0	1	11.54	13.25	14.33	18.49
12	2	1	0	1	8.93	8.93	14.32	16.73
13	0	1	0	0	11.01	11.69	10.40	17.31
14	0	1	0	0	8.92	11.52	10.87	14.62
15	0	1	0	0	11.04	12.85	11.09	14.00
16	2	1	0	1	9.45	11.65	15.50	17.54
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

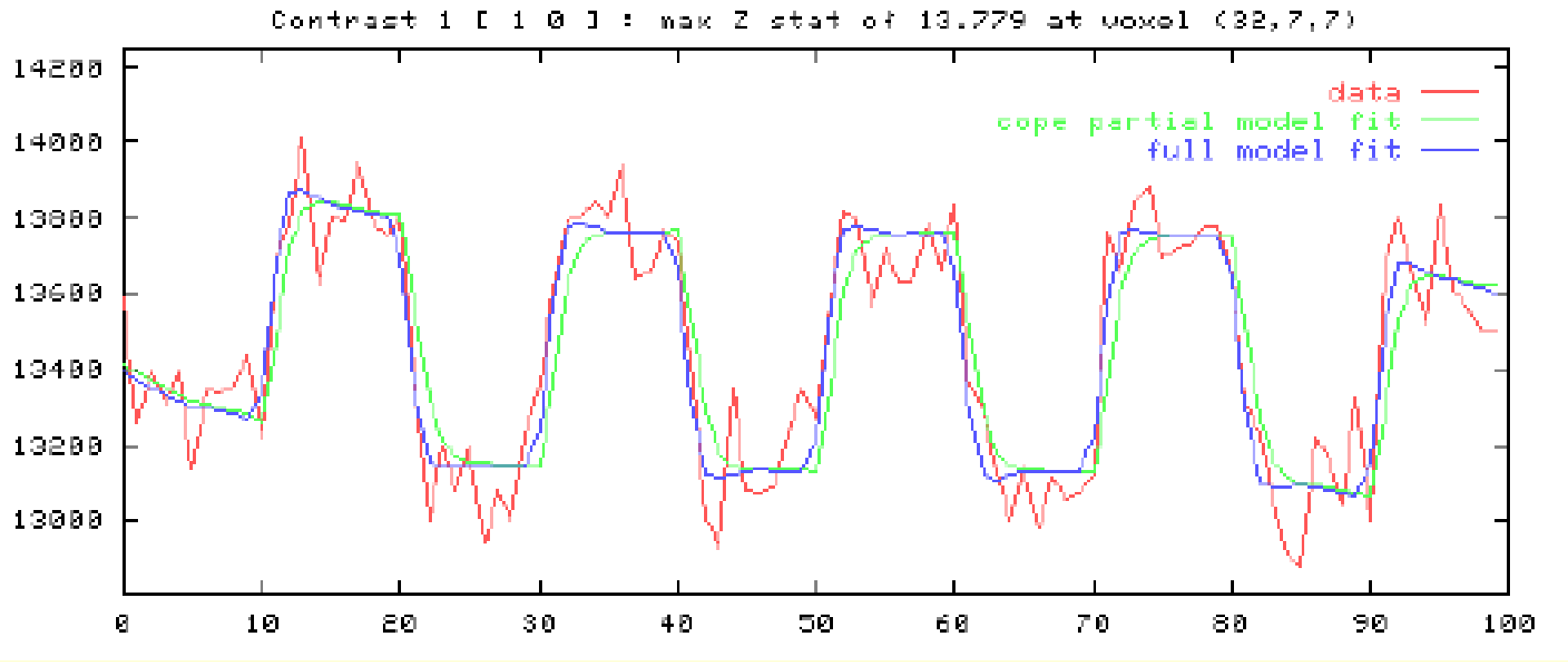
Data from two stimuli presented at different times. Responses are recorded from four locations.

GLM concept

$$Y_j = x_{j1}\beta_1 + \ldots + x_{jl}\beta_l + \ldots + x_{jL}\beta_L + \epsilon_j$$

- GLM explains the activation measure (response variable) Y_j in terms of a linear combination of different stimuli (EV: explanatory variables) plus error term.
- Y_j is activation in a particular voxel at observation (time) j
- X_{jl} is explanatory variable (stimulus) for various stimuli, groups, or subjects l=1,….,L
- β_l is the Parameter Estimate (fitted value for each stimulus)
- ε_j is error for each observation

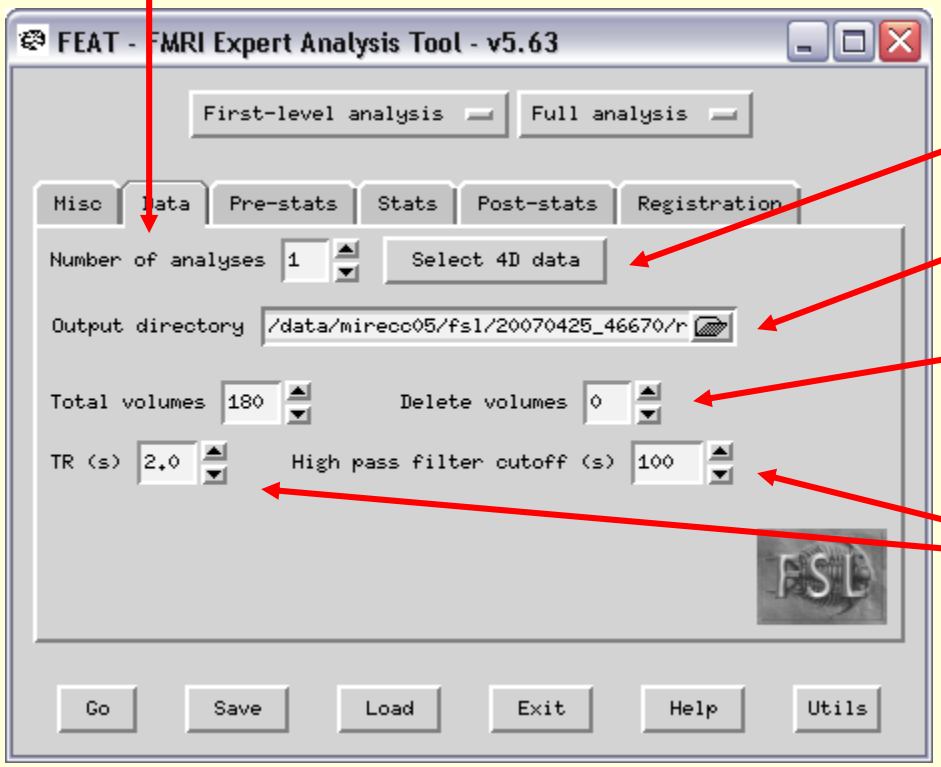



Contrast 1 [1 0] : max Z stat of 13.779 at voxel (32,7,7)
14200
14000
13800
13600
13400
13200
13000
0
10
20
30
40
50
60
70
80
90
100
data
cope partial model fit
full model fit

1st Level: Data Parameters

How many runs:

-Typically do runs individually



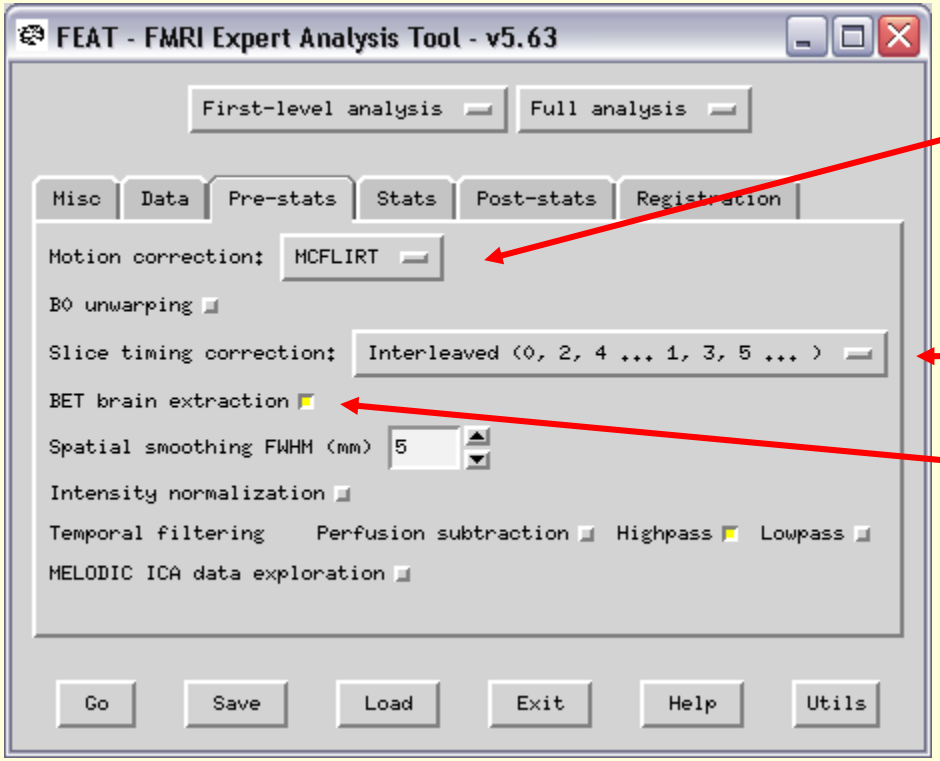
Select the 4-d data for your run

Where will the data be saved?

Are disdaqs already thrown out?

Self explanatory

1st Level: Preprocessing

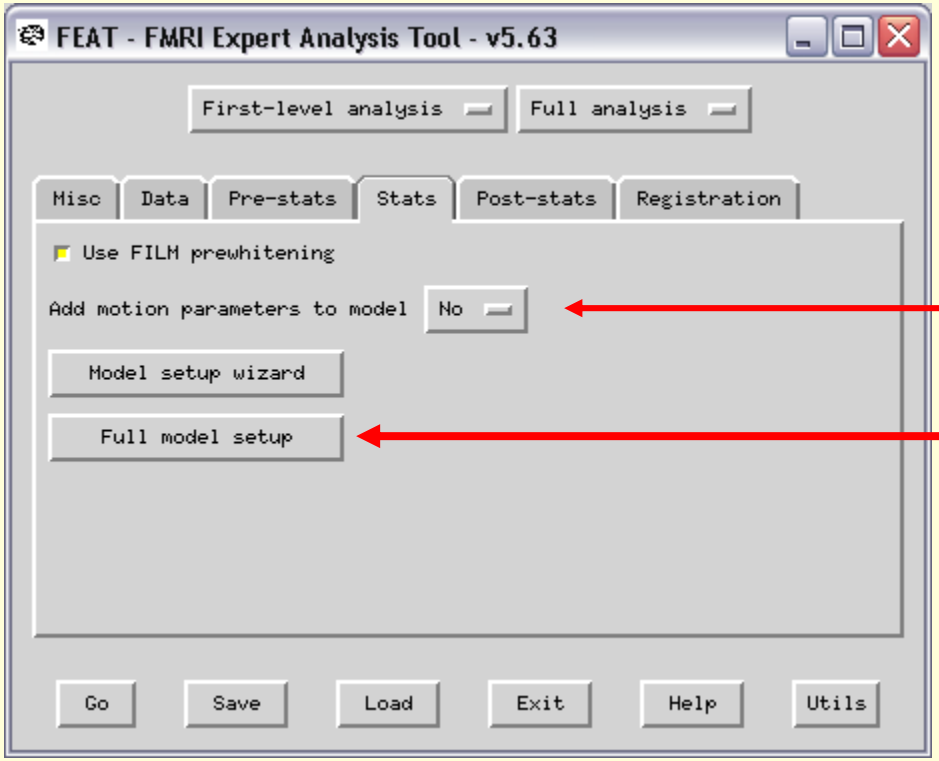


Correct for motion?

Interleaved, ascending, descending, custom order

Brain only voxels

1st Level: Statistics

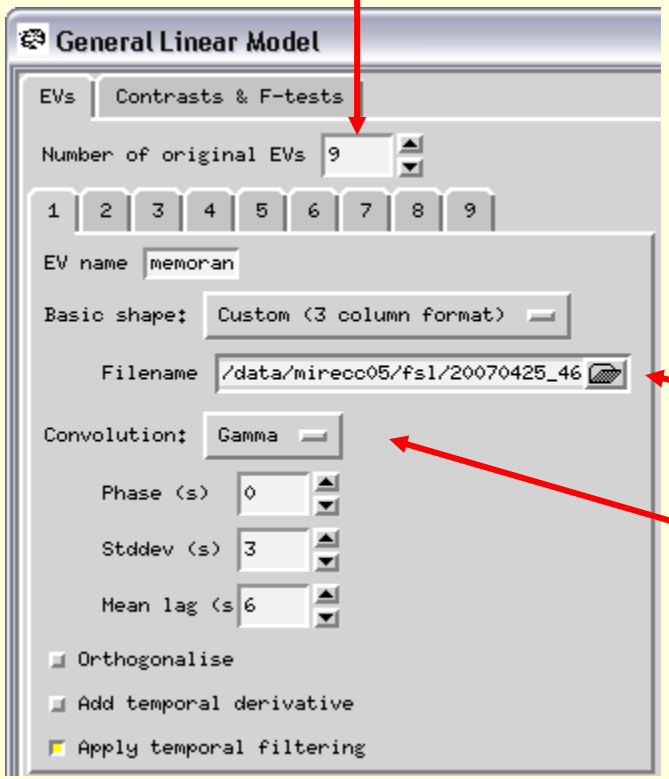


Want to model motion?

This is the only hard part
(i.e., model specification)

1st Level: General Linear Model

How many explanatory variables?

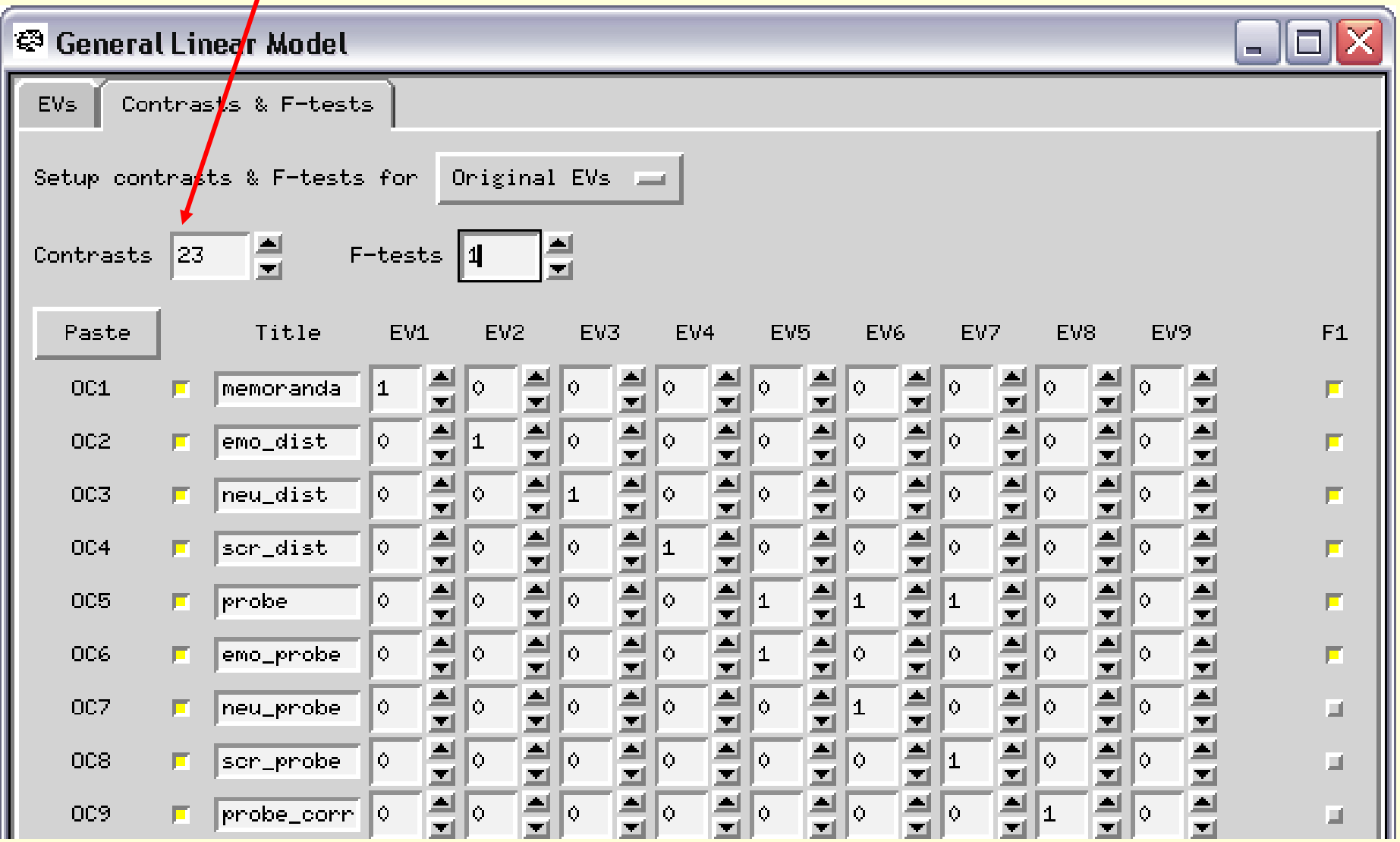


Select your 3 column file

Shape of your correlation waveform

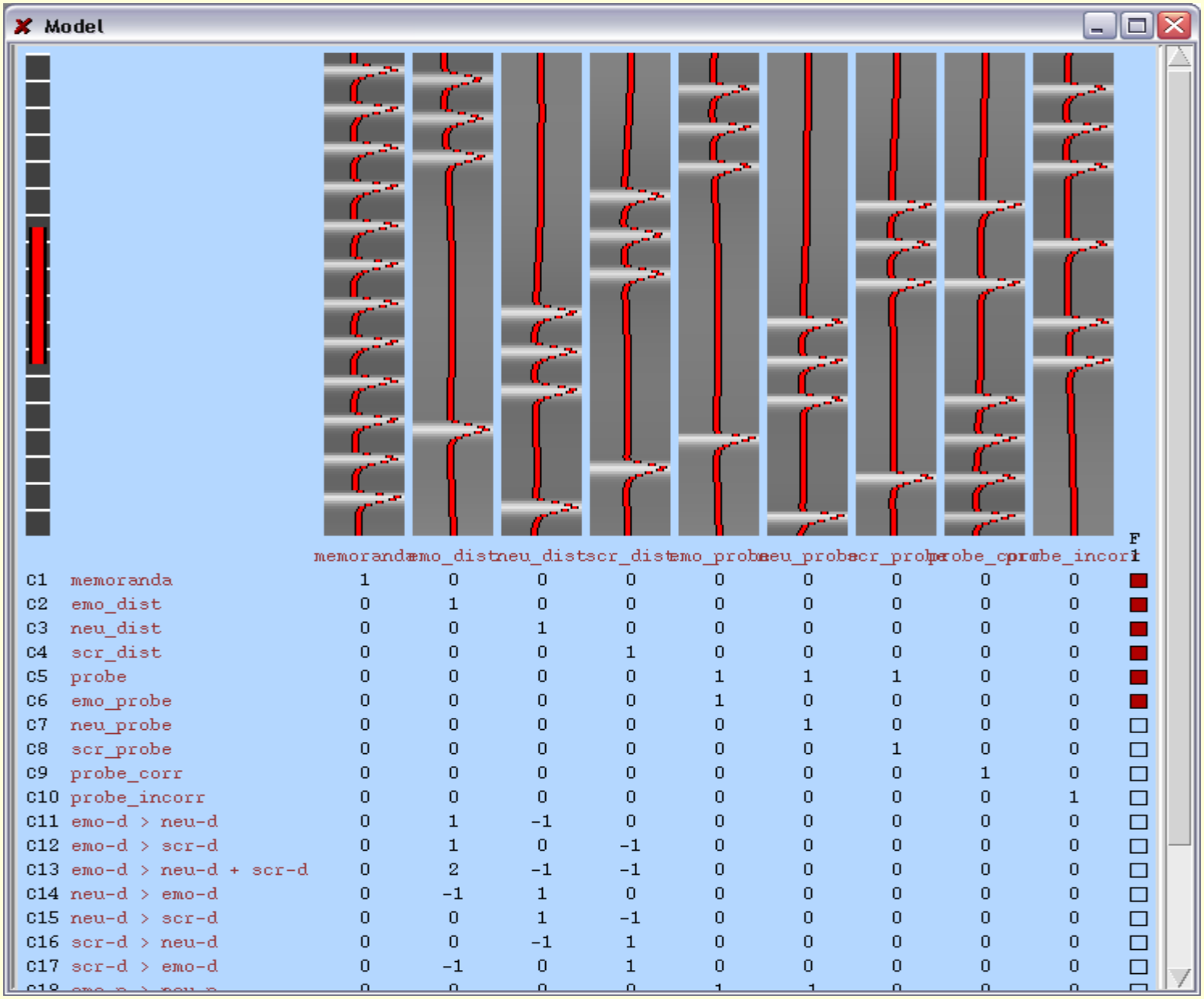
1st Level: Contrasts

How many zmaps? (each condition + contrasts)

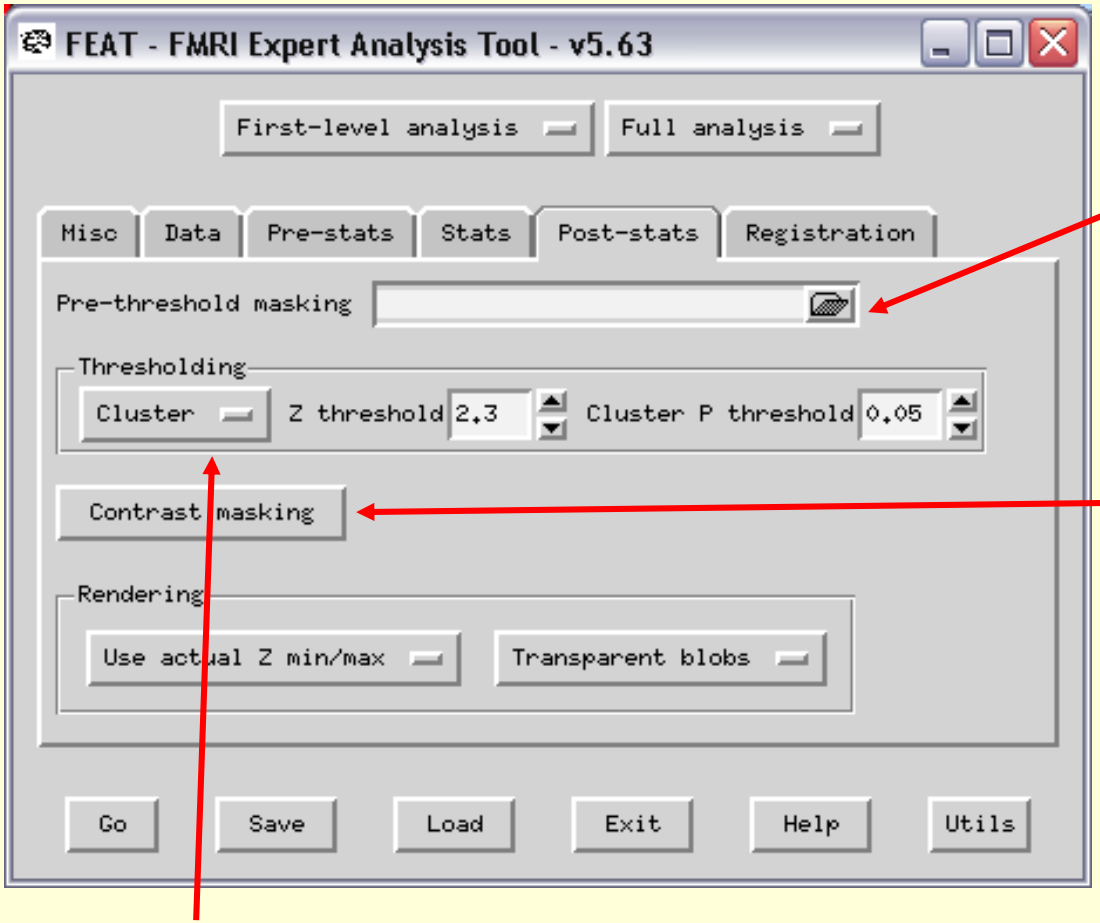


What is a contrast?

- Key concept in fMRI analysis
  - Remember: fMRI provides *relative* measures
- We contrast terms in our analysis model to evaluate whether they modulate the brain differently
  - Faces > Houses
  - “Tapping right hand” > “Tapping left hand”
- Analogous to subtractive techniques in psychology


Model
memoranda
emo_dist
neu_dist
scr_dist
emo_probe
neu_probe
scr_probe
probe_corr
probe_incorr
F
t
C1 memoranda 1 0 0 0 0 0 0 0 0
C2 emo_dist 0 1 0 0 0 0 0 0 0
C3 neu_dist 0 0 1 0 0 0 0 0 0
C4 scr_dist 0 0 0 1 0 0 0 0 0
C5 probe 0 0 0 0 1 1 1 0 0
C6 emo_probe 0 0 0 0 1 0 0 0 0
C7 neu_probe 0 0 0 0 0 1 0 0 0
C8 scr_probe 0 0 0 0 0 0 1 0 0
C9 probe_corr 0 0 0 0 0 0 0 1 0
C10 probe_incorr 0 0 0 0 0 0 0 0 1
C11 emo-d > neu-d 0 1 -1 0 0 0 0 0 0
C12 emo-d > scr-d 0 1 0 -1 0 0 0 0 0
C13 emo-d > neu-d + scr-d 0 2 -1 -1 0 0 0 0 0
C14 neu-d > emo-d 0 -1 1 0 0 0 0 0 0
C15 neu-d > scr-d 0 0 1 -1 0 0 0 0 0
C16 scr-d > neu-d 0 0 -1 1 0 0 0 0 0
C17 scr-d > emo-d 0 -1 0 1 0 0 0 0 0

1st Level: Thresholding



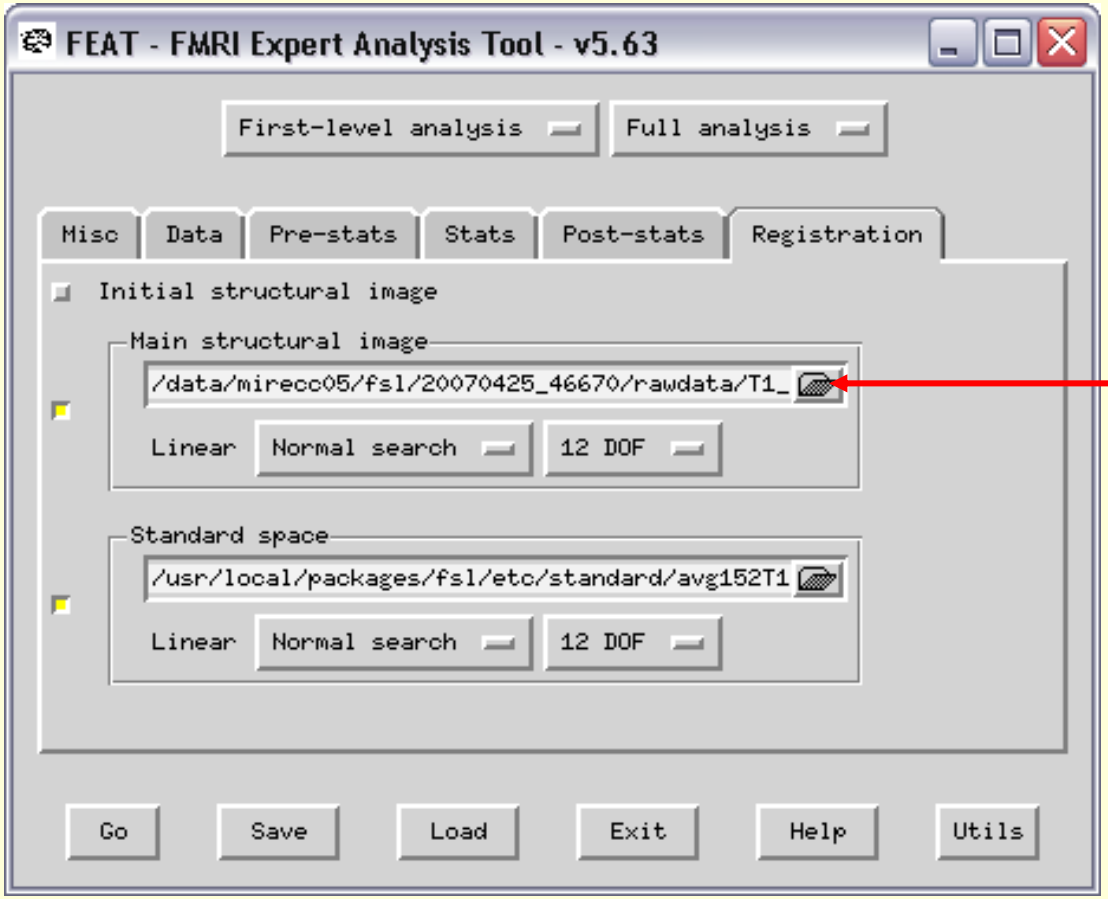
Mask by a bitmap of some specified region

You can mask one cope by another

If **Cluster**: Then each cluster's estimated significance level (from GRF-theory) is compared with the cluster probability threshold.

If **Voxel** thresholding is selected, GRF-theory-based maximum height thresholding is carried out, with thresholding at the level set, using one-tailed testing. This test is less overly-conservative than Bonferroni correction.

1st Level: Registration

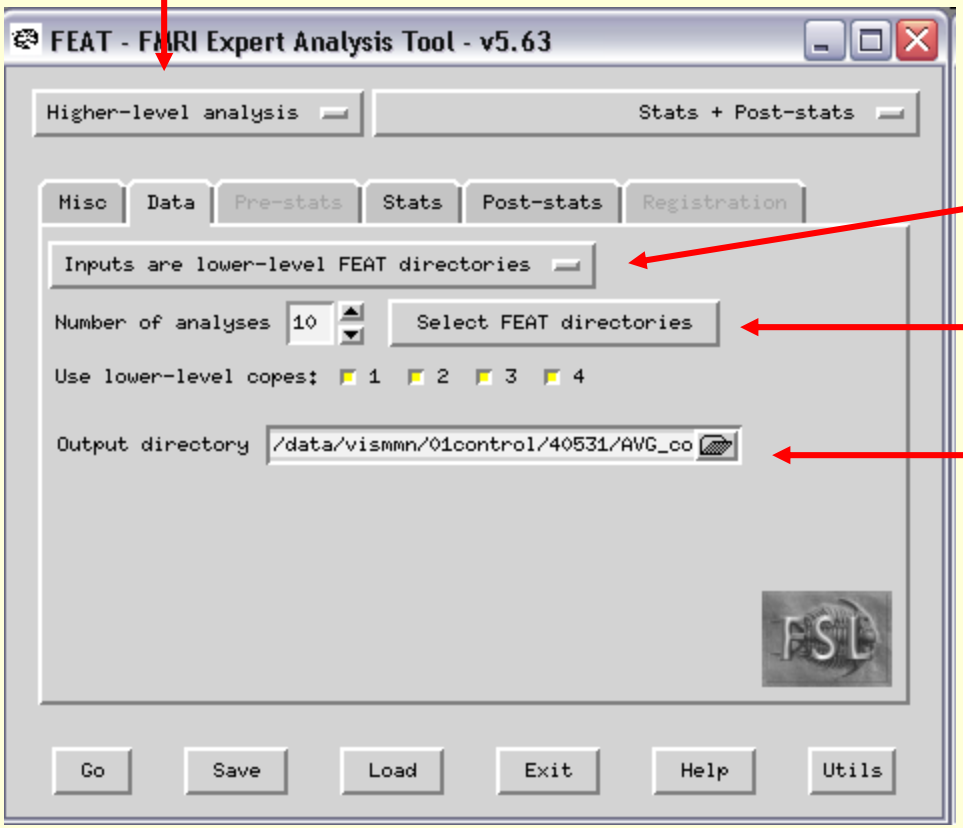


Your skull stripped anatomical

Click **GO** to run FEAT, if you need to insert the orientation matrix, then click **Save**

2nd Level: Within-subject, across-runs

Higher-level analysis – within subject



Inputs are your subject's run directories

# of analyses = # of runs

Where do you want your data saved?

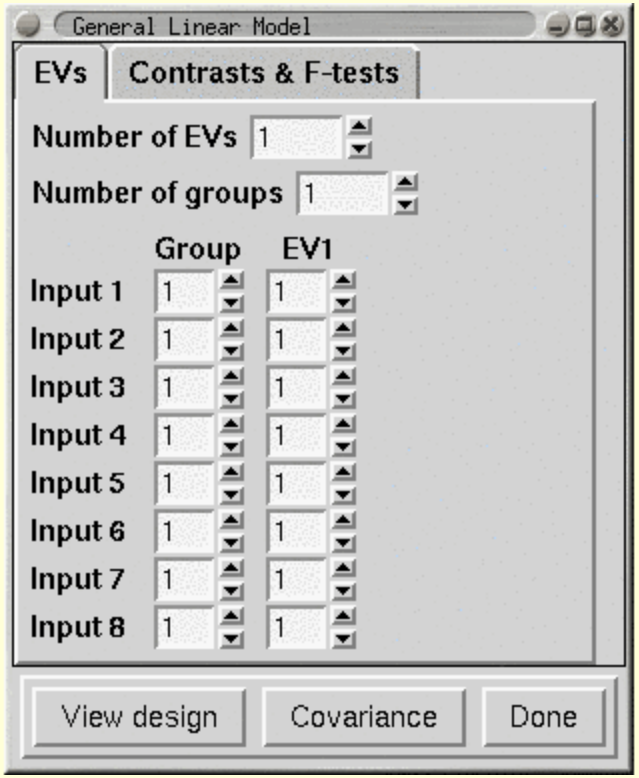
-Individual conditions will be saved within the output directory as separate copes

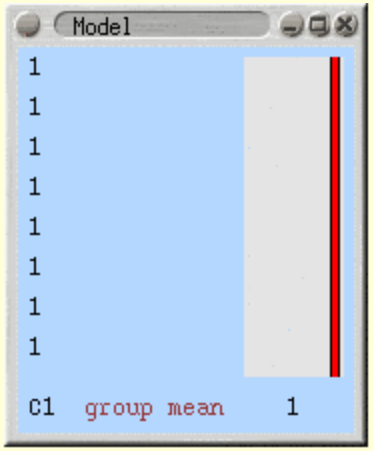
Error in Group Analysis

- Fixed-Effects variance is “the within-session across-time variance” estimated in first level analysis.
- Random-Effects variance is “the cross-session variance” in first level parameter estimates.
- In higher level (group analysis) FEAT uses Mixed Effects (FLAME= FMRIB Local Analysis of Mixed Effects), which is “the sum of fixed-Effects variance and Random-Effects variance.

2nd Level: Across-Runs: Single group Analysis (one-sample t-test)

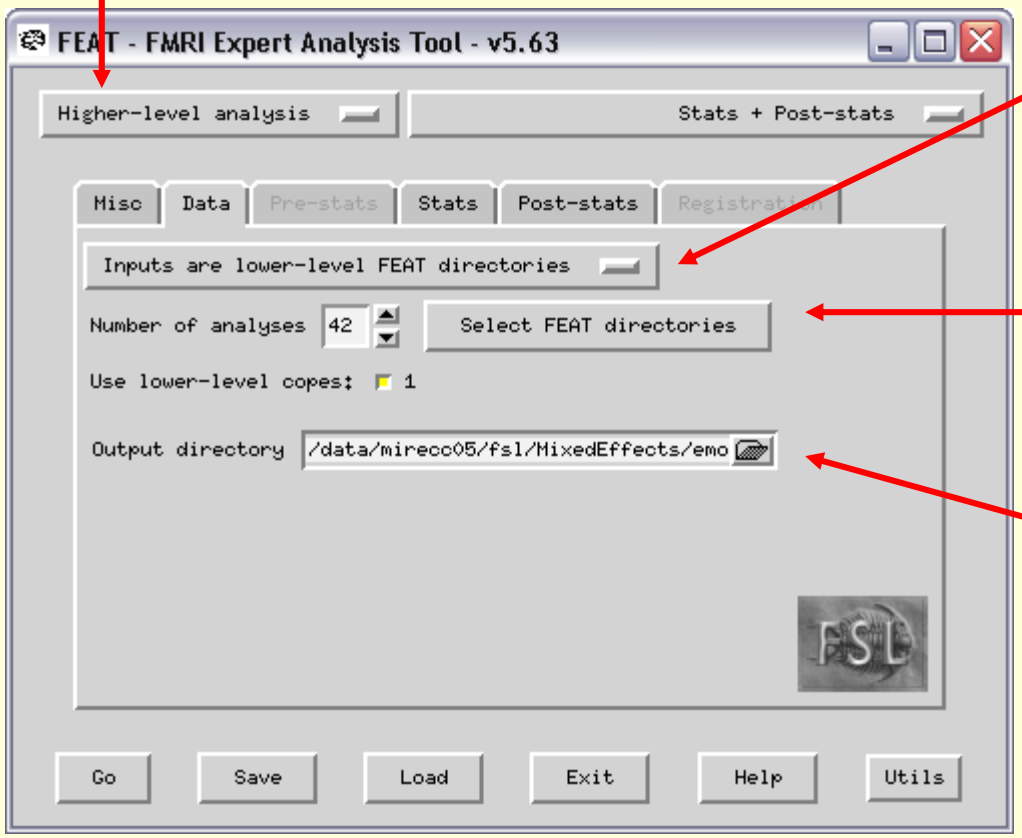
We have 8 subjects in one group and want the mean group effect.





3rd Level: Across Subjects

Higher level - Group



Inputs are now cope#.feat directories from the subject averages (2nd Level)

#analyses = #subjects included
- Select /subj#/AVG.gfeat/cope#.feat

Where to save results, what name?

This step needs to be done separately for every condition you are interested in viewing.

3rd Level: Group Effects

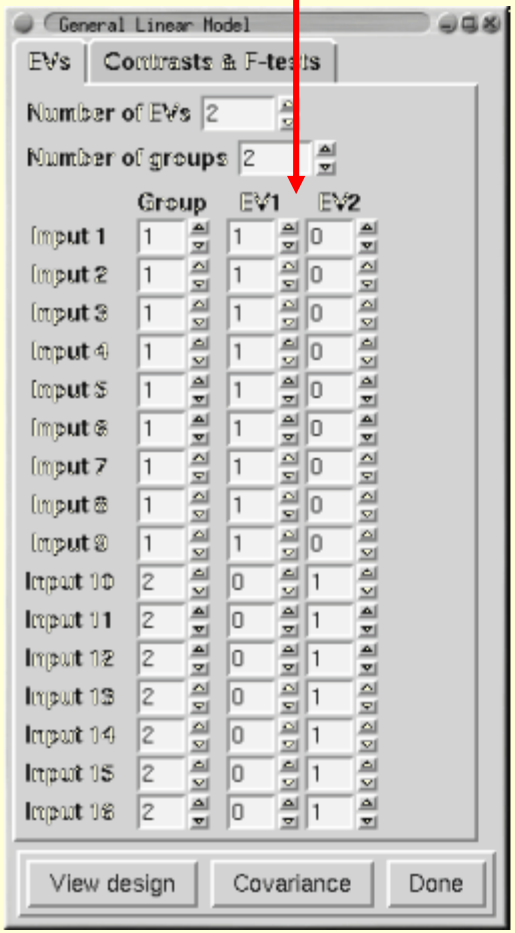
Unpaired two-group differences (Two-sample unpaired T-test)

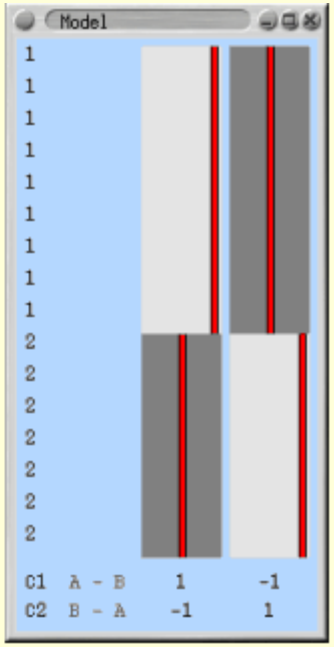
We have two groups of different kinds of subjects (eg. 9 patients and 7 controls)

EV1 = include in group1
EV2 = include in group2

group1

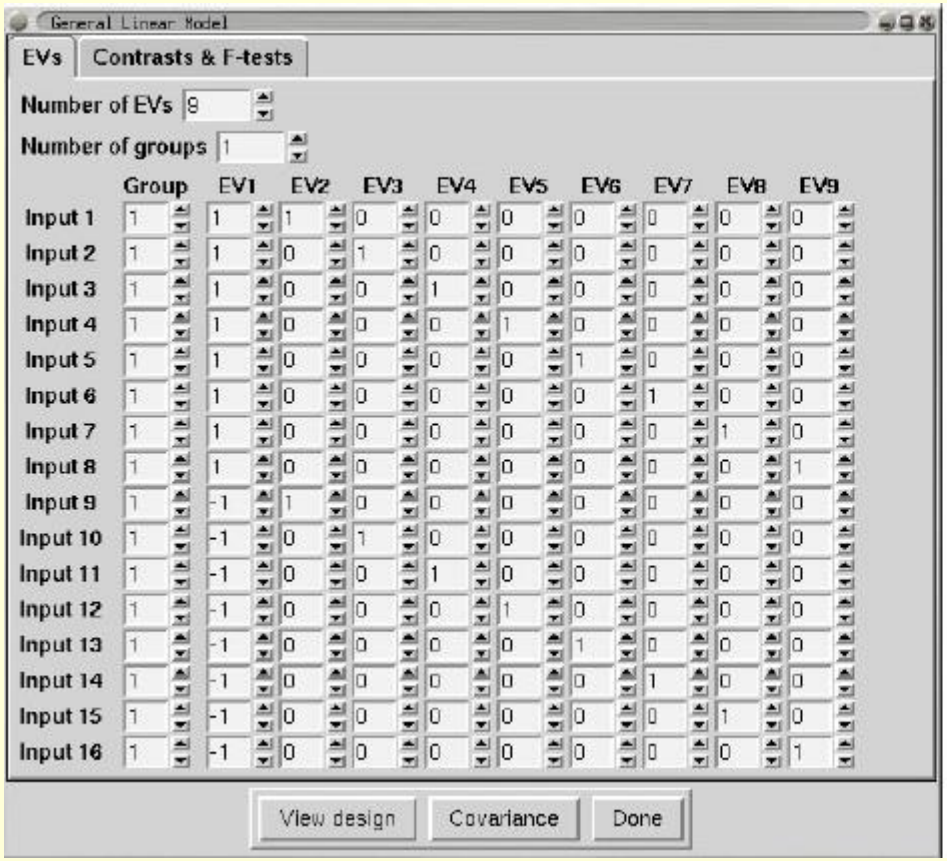
group2

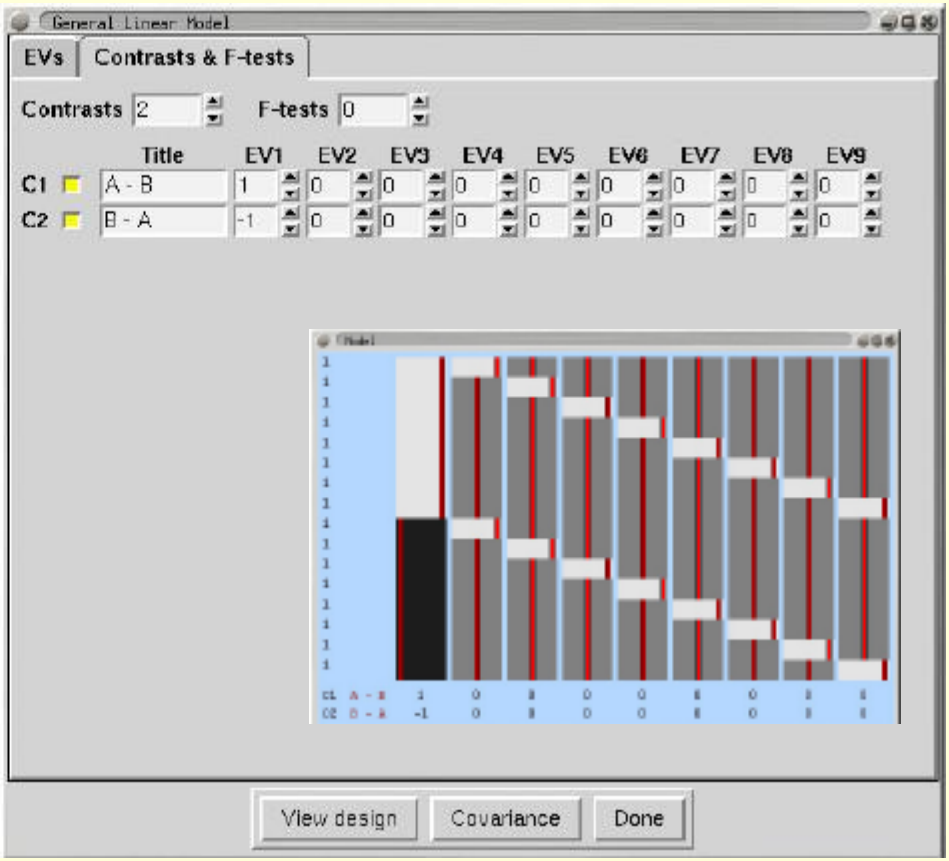




Paired Two-group differences: (Two-sample paired T-test)

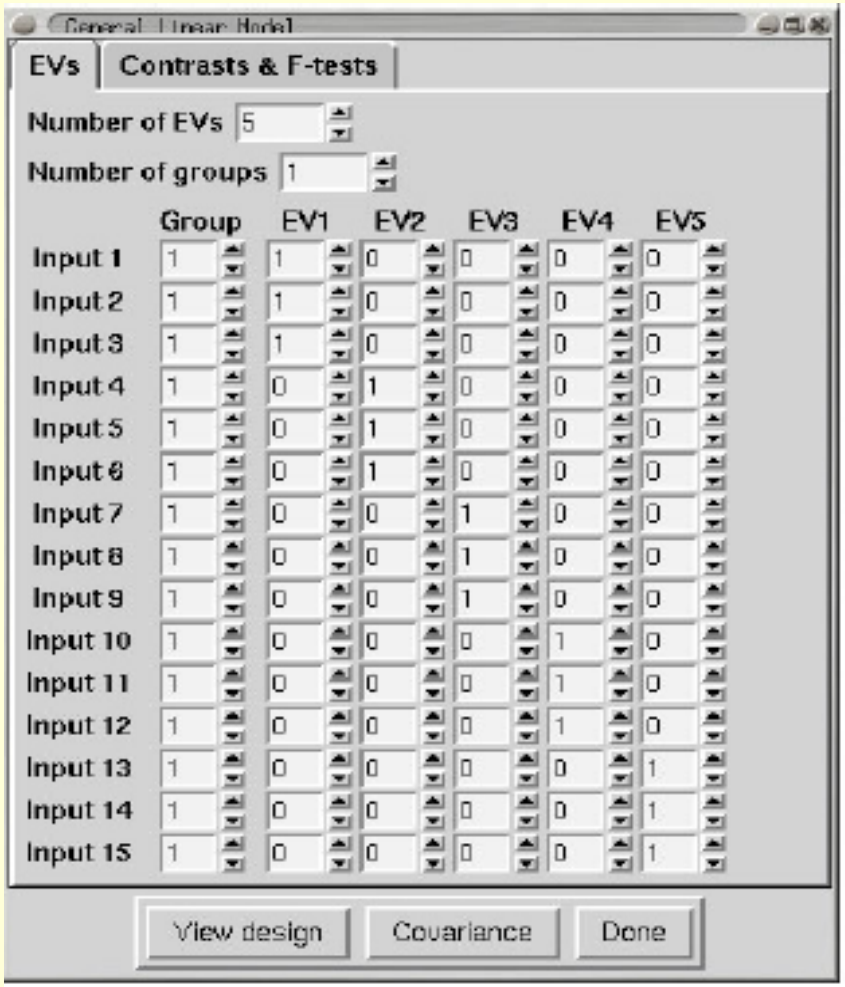
We have a group of 8 subjects scanned under different conditions, A and B

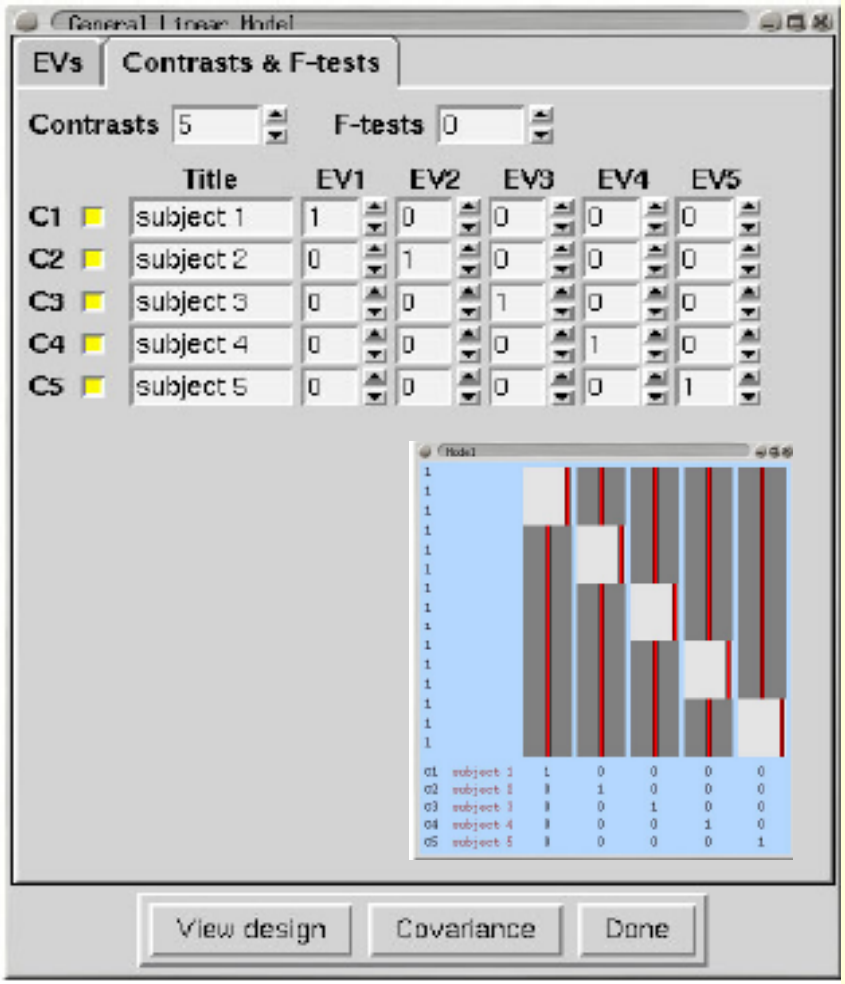




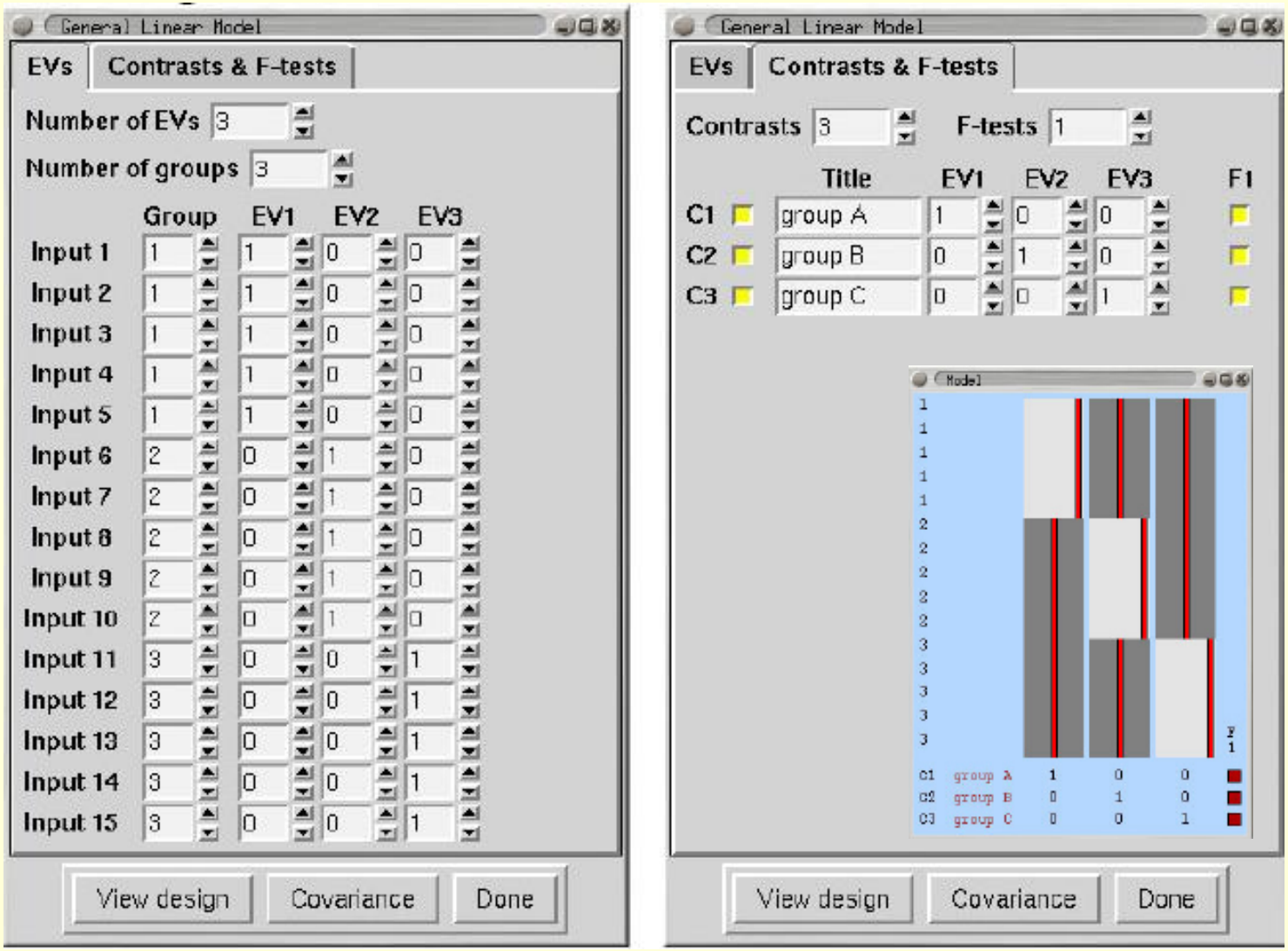
3-Level Analysis: Multi-Session & Multi-Subject

We have 5 subjects each have 3 sessions. Because number of sessions is low, and cross-session variance is required, we can put all subjects into one 2nd-Level analysis.

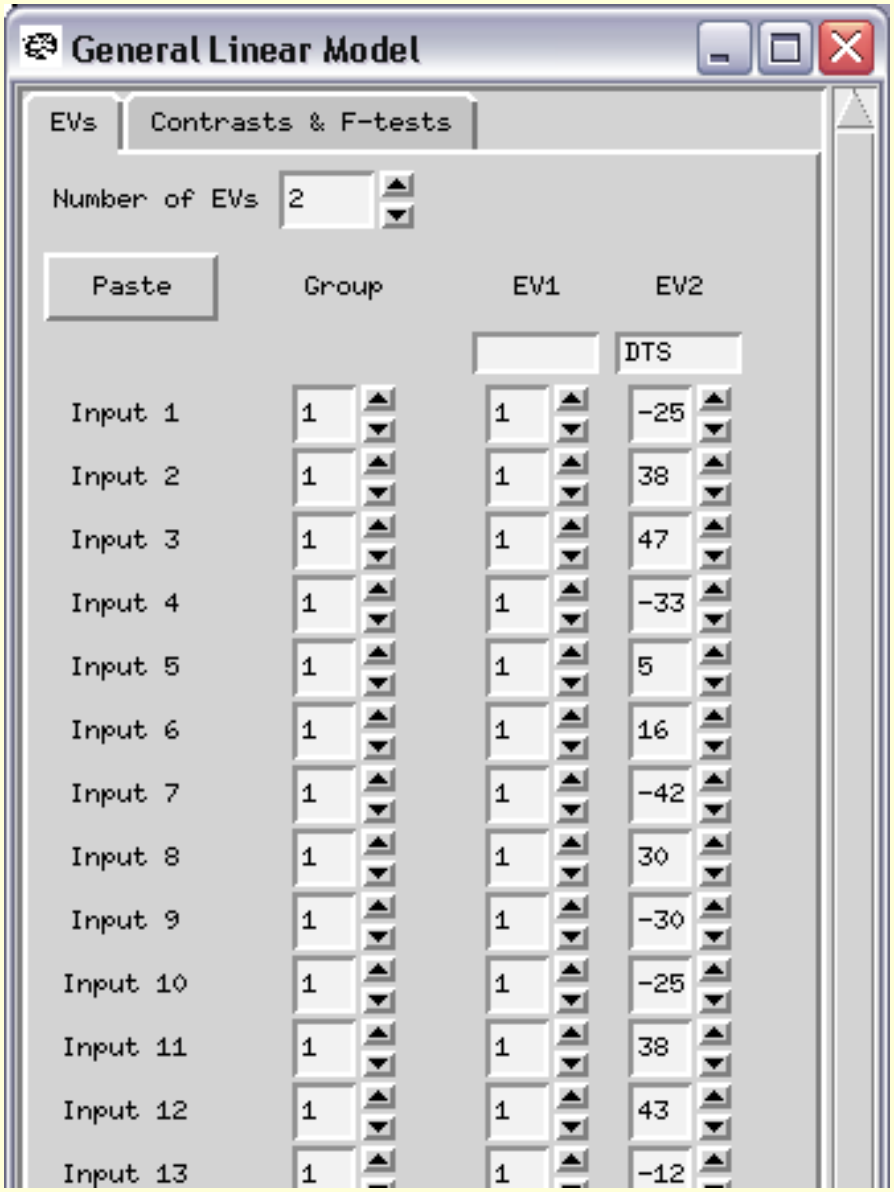




F-Tests: With 3 groups of previous subjects, is any group activating on average?

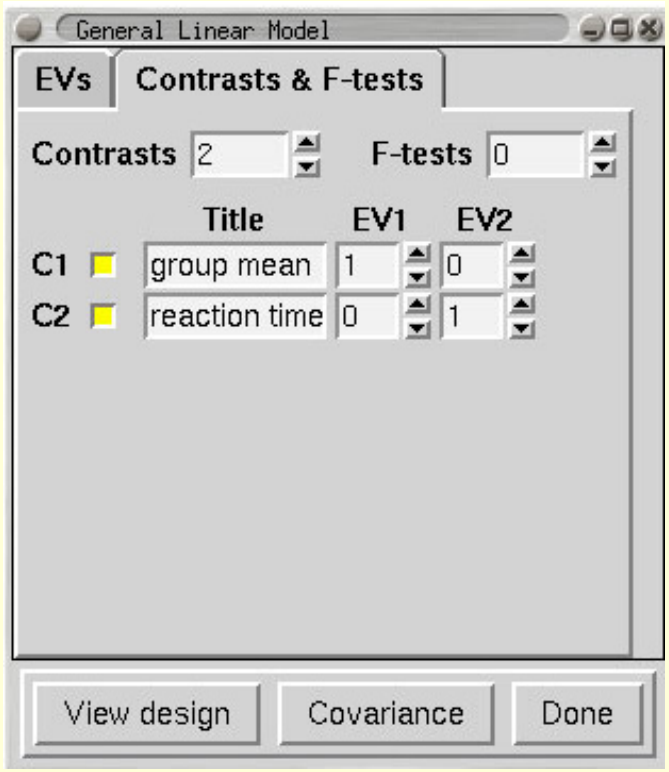


3rd Level: Main and Parametric Effects



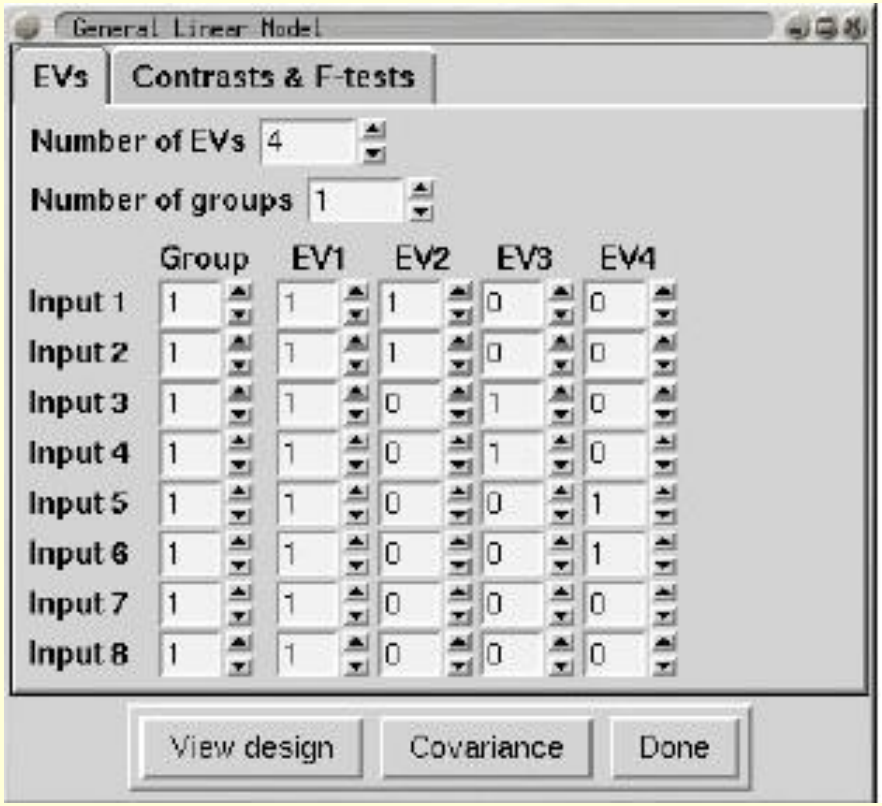
EV1 represents the main effect across subjects.

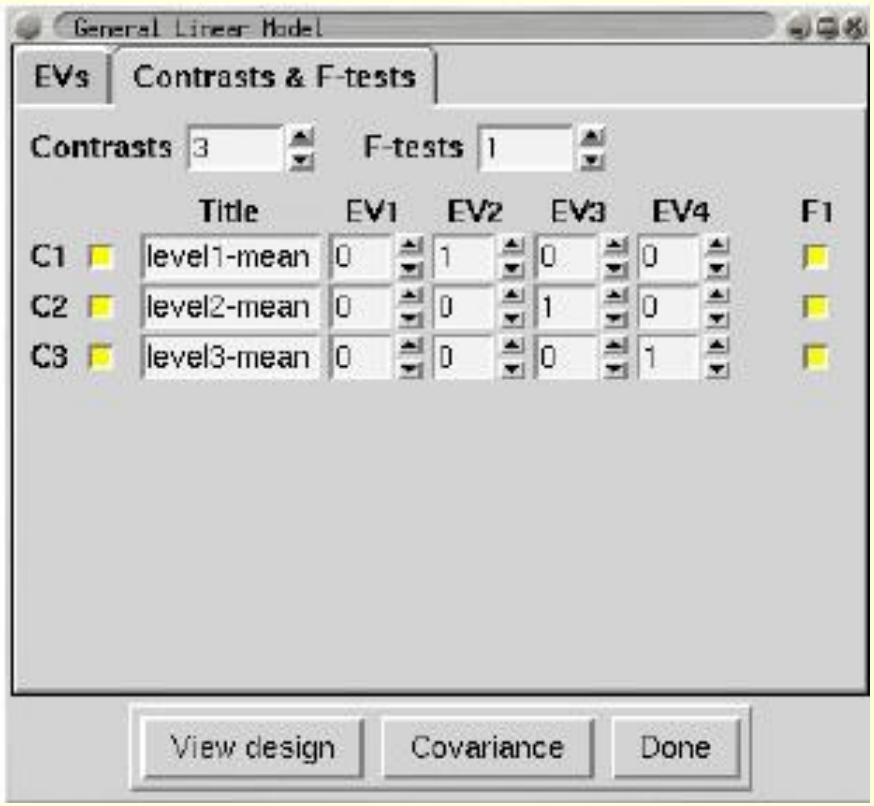
EV2 represents some parameter (e.g., a personality test, age, disability scale, ets) that varies across subjects.



Other groups

- ANOVA: 1-factor 3-level
  - We have 8 subjects with 1 factor at 3 or 4 levels





Rules for Projects

- Safety
  - There should be no risk to the participant.
  - You must behave professionally and conscientiously while running your subjects.
- Simplicity and Robustness
  - The task must be simple and easily programmed.
  - The design should be simple, ideally blocked with few conditions.

Imaging Cognition II: An Empirical Review of 275 PET and fMRI Studies

A review 275 PET and fMRI studies of:

- Attention (sustained, selective, Stroop, orientation, divided)
- Perception (object, face, space/motion, smell),
- Imagery (object, space/ motion)
- Language (written/spoken word recognition, spoken/ no spoken response)
- Working memory (verbal/numeric, object, spatial, problem solving)
- Semantic memory retrieval (categorization, generation),
- Episodic memory encoding (verbal, object, spatial)
- Episodic memory retrieval (verbal, nonverbal, success, effort, mode, context)
- Priming (perceptual, conceptual)
- Procedural memory (conditioning, motor, and nonmotor skill learning).

New feasible Proposals

- Cortical thickness measurement for cognitive status and neuro-degenerative disease
- Connectivity evaluation in cognitive status and neuro-degenerative disease (eg. Epilepsy)
- Evaluation of Pre-frontal dementia for changes in attention, Language, and memory

Much More Info on FSL

FEAT Expert Guide

http://www.fmrib.ox.ac.uk/fsl/feat5/detail.html

FSL Course Slides

http://www.fmrib.ox.ac.uk/fslcourse/

More Expert Guidance

http://fsl.fmrib.ox.ac.uk/fsl/feat5/