

FMRIPower: A Power Calculation Tool for 2-Stage fMRI models

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Introduction

- **Problem:** Power analyses for fMRI data are difficult to carry out due to the complexities of the group fMRI model, but power calculations are often required in grant applications and can help plan more efficient studies.
- **Solution:** FMRIPower [1]
 - Calculates power for a future analysis based on previous analysis results obtained using the FMRIB Software Library (FSL) [2].
 - Power for different group level designs, eg. power for different sample sizes.
 - Can be used on group models estimated in 2 or 3 stages.
 - Region of interest (ROI) based approach.
 - Matlab based program (requires SPM5).

Methods

FSL Model

- **Group Model:** $\hat{\beta}_{cont} = X_g \beta_g + \epsilon_g$
 - $\hat{\beta}_{cont} = [c\hat{\beta}_1, \dots, c\hat{\beta}_N]'$, c a vector of contrasts, usually 1 for each subject, from the subject-specific models at the previous stage (N -subjects).
 - X_g : $N \times p_g$ design matrix.
 - $\epsilon_g \sim N(0, V_g)$, $V_g = \text{diag}(\sigma_{win_k}^2 + \sigma_{btwn}^2)$, $\sigma_{win_k}^2$ is the within-subject variance for subject k , σ_{btwn}^2 is the between-subject variance.

Hypothesis Test

- $H_0 : c_g \beta_g = 0 \leftrightarrow H_A : c_g \beta_g = \Delta$, c_g is a contrast vector of length p_g .
- **Test Statistic:** $t = (c_g \beta_g) / \sqrt{c_g (X_g^T V_g^{-1} X_g)^{-1} c_g^T}$
 - Under H_0 , $t \sim T_{N-p_g}$ Central T with $N - p_g$ degrees of freedom.
 - Under H_A , $t \sim T_{N-p_g, NCP}$; noncentral T with $N - p_g$ degrees of freedom and noncentrality parameter, $NCP = \Delta / \sqrt{c_g (X_g^T V_g^{-1} X_g)^{-1} c_g^T}$.

Power

Power is the probability of rejecting the null under the alternative distribution,

$$\text{Power} = Pr(T_{N-p_g, NCP} > t_{1-\alpha, N-p_g}),$$

where $t_{1-\alpha, N-p_g}$ is the threshold corresponding to a false positive rate of α .

FMRIPower

Assumptions

- Assume first level design is same for all subjects and the same as the original analysis.
- Assume within subject covariance is the same across subjects.

Impact of assumptions

- Variance is the same across subjects so $V_g = (\sigma_{win}^2 + \sigma_{btwn}^2) I_N$.
- $NCP = \Delta / \sqrt{\sigma^{*2} c_g (X_g^T X_g)^{-1} c_g^T}$, where $\sigma^{*2} = \sigma_{win}^2 + \sigma_{btwn}^2$.
- Allows model to generalize to different sample sizes.

ROI parameter estimates

- Average the contrast estimate, $c\hat{\beta}_g$ (copes) from group level FSL analysis over ROI to get ROI mean effect size, Δ_{ROI} .
- Average the variance, $\hat{\sigma}_{win}^2 + \hat{\sigma}_{btwn}^2$ over ROI to get the ROI mean variance, σ_{ROI}^2 . $\hat{\sigma}_{win}^2$ is the average of $\sigma_{win_k}^2$ over subjects (previous level varcopes) and $\hat{\sigma}_{btwn}^2$ is saved in group FSL analysis.
- Calculate average voxel within the ROI's power for specified design matrix X_g , so $NCP = \Delta_{ROI} / \sqrt{\sigma_{ROI}^2 c_g (X_g^T X_g)^{-1} c_g^T}$.

Using the FMRIPower graphical user interface

- Download beta version at www.fmrpower.org. Matlab based GUI, that uses some SPM5 functions.
- Construct design matrices and save as .mat ascii files.
- Make sure the directory with the FMRIPower code and SPM5 are in the Matlab path. Start GUI by typing "fmrpower" at Matlab prompt (Figure 1).

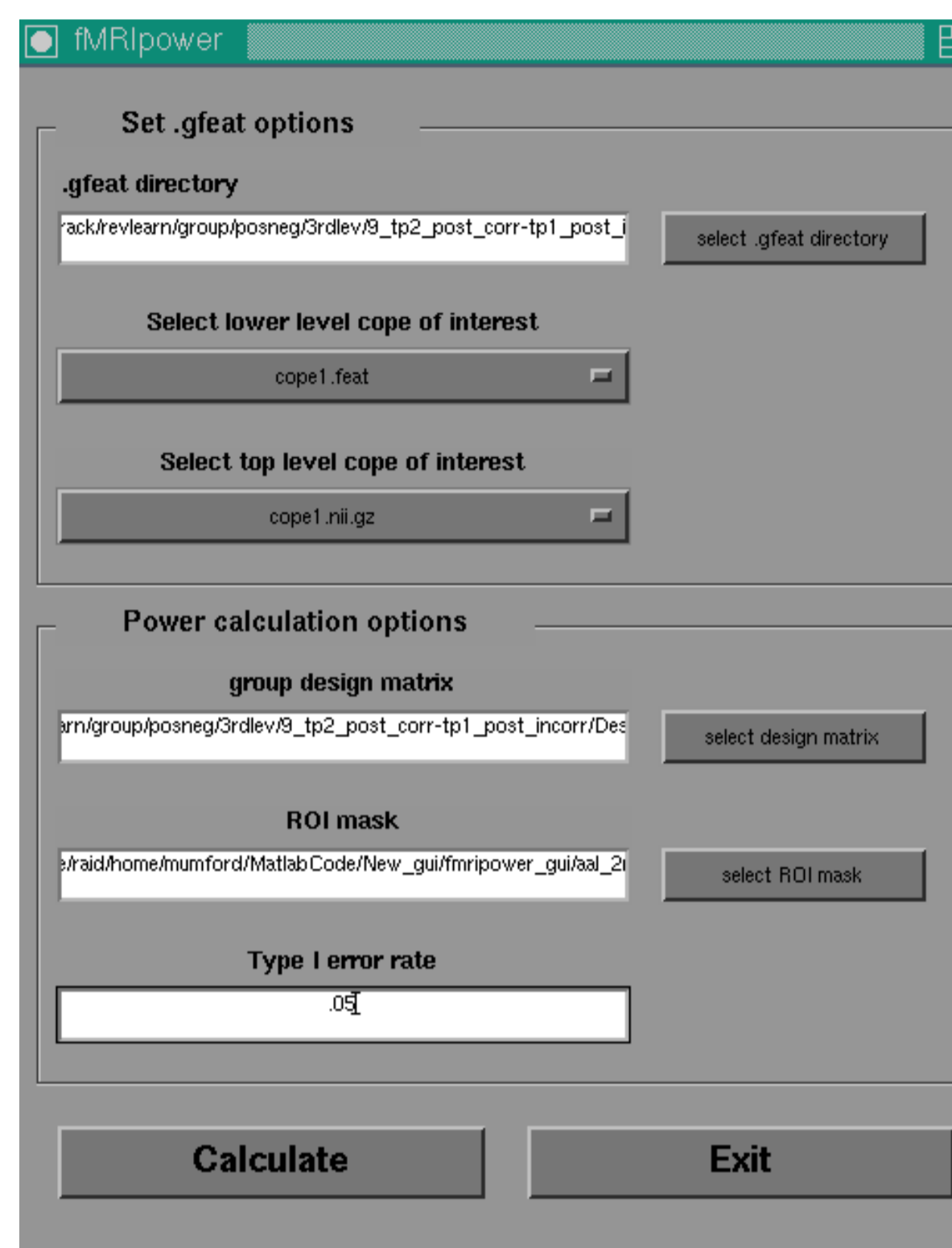


Figure 1: Main FMRIPower gui. Top set of options sets the .gfeat options. Bottom options specify rest of model for power calculation.

- Select the top level (group) .gfeat directory. Lower level copes and top level copes will load into listboxes.
 - **Lower level copes of interest:** The .feat directories within the .gfeat directory. If the group analysis was based on lower level copes, there is only a single cope1.feat directory. If the .gfeat analysis used lower level .feat directories as inputs, each cope#.feat directory corresponds to the lower level copes.
 - **Top level copes of interest:** Group contrasts, within the .feat/stats directory.
- Select design matrix you would like to calculate power for. This must be a .mat file saved in ascii format. The "Check Design" window (Figure 2) will pop up so you can check that your design matrix and contrast are what you intended.

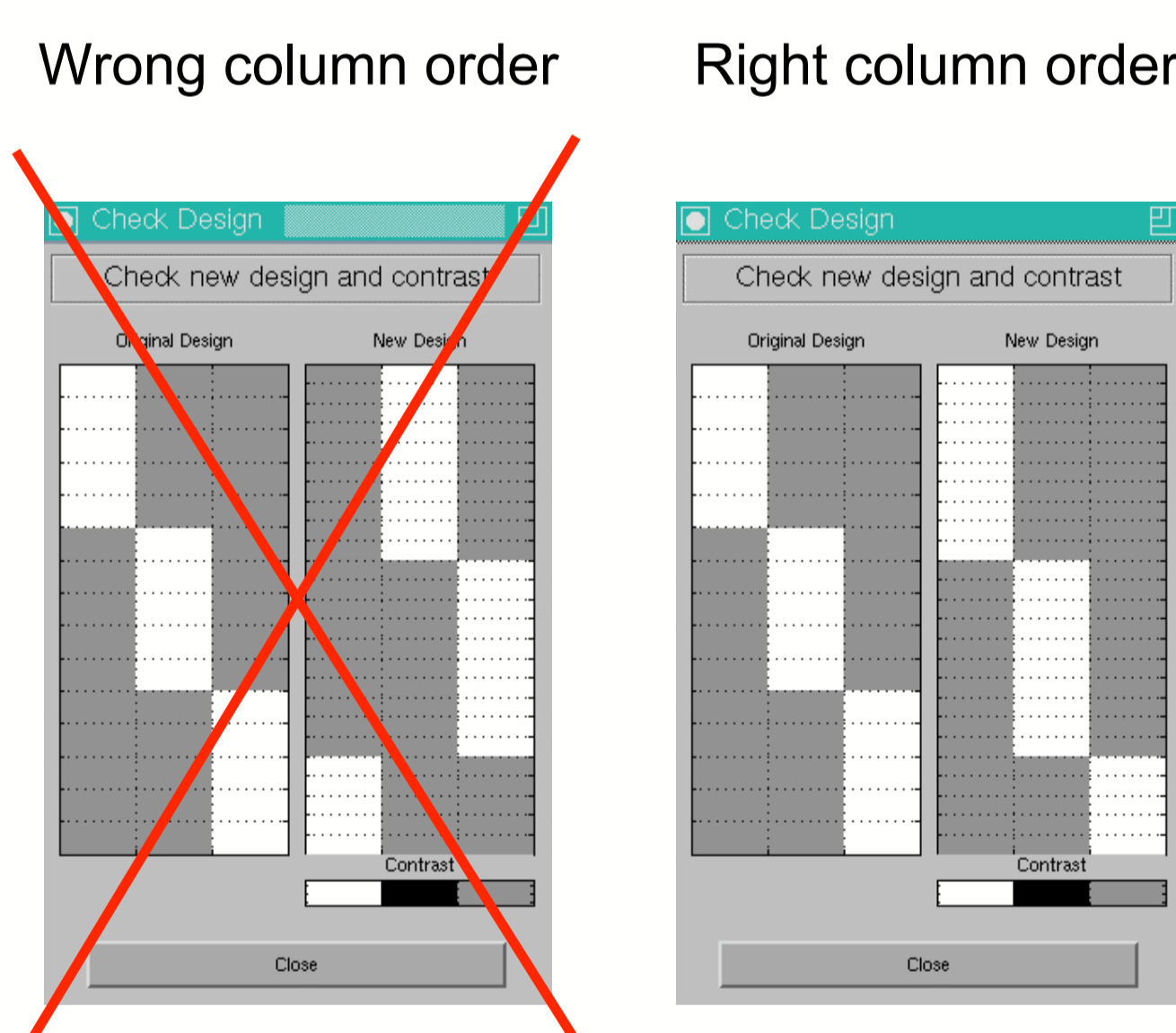


Figure 2: Examples of the "Check Design" window. Assume we had three groups, a, b, and c designated by columns 1, 2, and 3 in the original design matrix (5 subjects per group). If we wanted to calculate power for $H_0 : a - b = 0$, with 10 subjects in each of groups a and b, the example on the left shows an incorrectly specified design, since the columns are not in the correct order. The example on the right shows the correct design matrix to be used in the power analysis.

- Select the ROI mask of your choice. The default is the Anatomical Automated Labeling (AAL) mask described in [3], but any mask where ROI's are indicated by integer values can be used (analyze or nifti format).
- Specify Type I error rate and hit Calculate button.
- View results (Figure 3).
- Results are saved in cope#.feat/Power/mask_name/contrast_name/
 - mn.nii, sd.nii, and mn_sd.nii are the mean, standard deviation and mean in standard deviation units images.
 - pow_tmp.nii is the power image from the most recent power analysis.
 - pow_result.mat is a Matlab structure that stores all information from each power calculation. This can be used to create a plot of power as a function of sample size in Matlab (Figure 4).

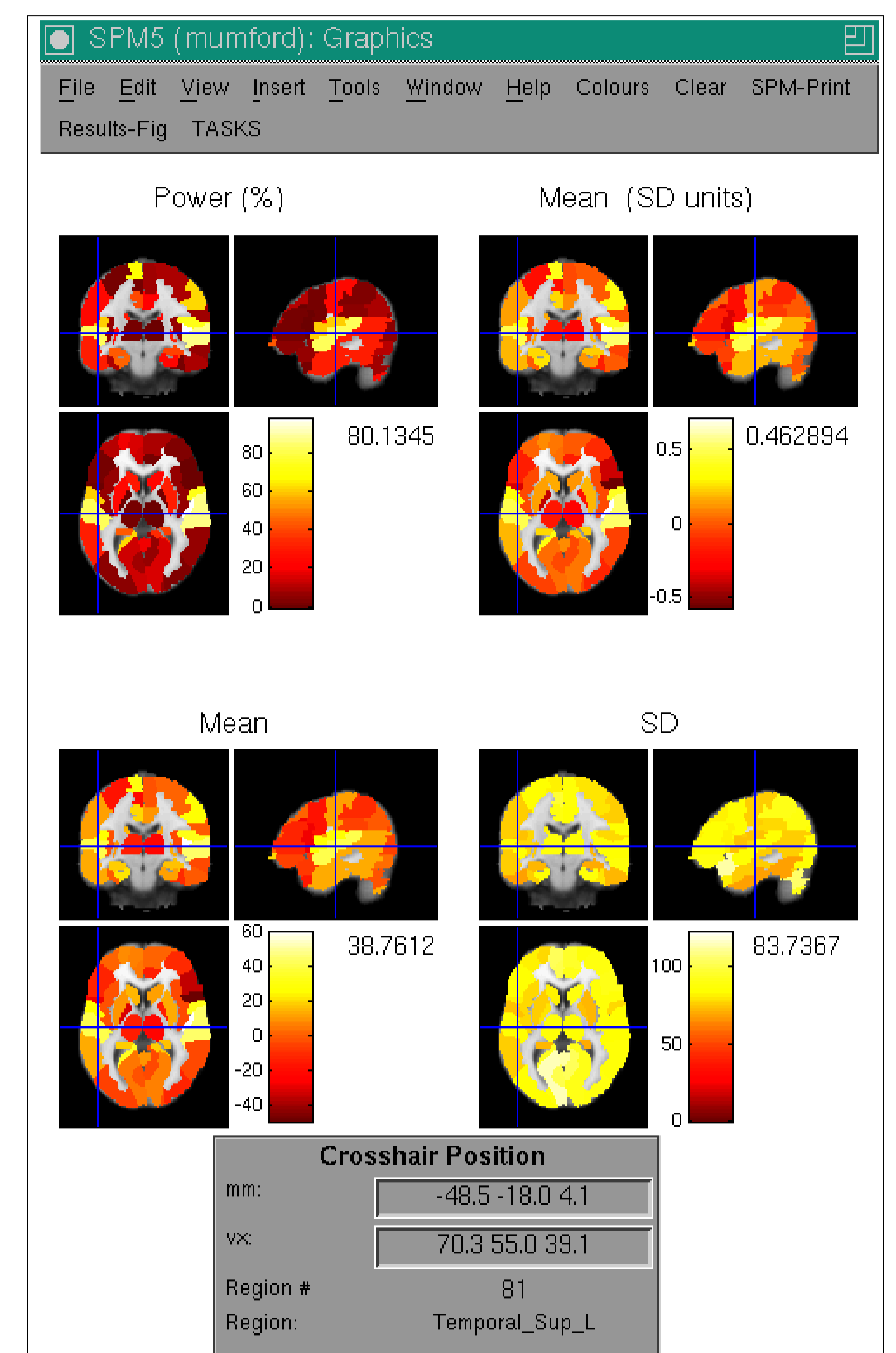


Figure 3: FMRIPower results window. The power estimate for each ROI, mean in standard deviation units, mean and standard deviation are shown in the 4 sets of images. Since the copes and their variances typically are not scaled to reflect a particular unit, the mean and sd maps are not expressed in a particular unit. The numbers next to the colorbars indicate the values at the chosen voxel for that map. The "Crosshair Position" box displays the location of the crosshairs in mm and in voxel units as well as the region # that corresponds to the ROI mask used. If the AAL mask was used, the name of the region.

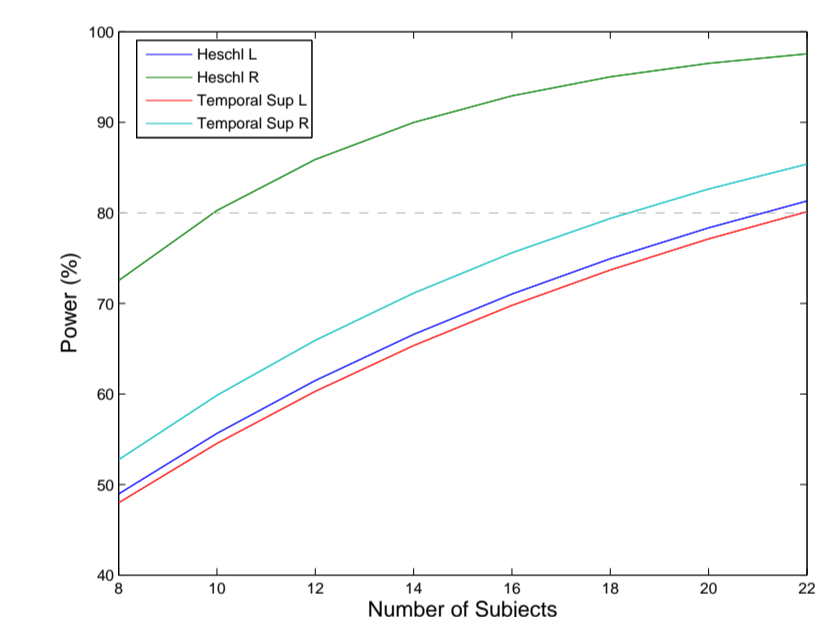


Figure 4: Power curves for detecting overall group mean in four ROI's as a function of sample size.

Conclusions

We have introduced a power calculation tool that can be used to carry out power analyses of group level fMRI models based on prior FSL analyses. The current version of this application allows the user to change the group level design matrix and calculate the power for this design. The power calculations are carried out on a region of interest basis where the estimate indicates the power for the average voxel within that ROI. Future additions to FMRIPower will include

- Capability to change lower level design matrix (for each run).
- Command line version of software.
- Power calculations when multiple variance groups are specified in the model (current version assumes variances are same across subjects).
- Power calculation for group analyses based on previous SPM analyses.

References

- [1] FMRIPower: www.fmrpower.org
- [2] FSL: www.fmrib.ox.ac.uk/fsl
- [3] Tzourio-Mazoyer, N., et al., Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. Neuroimage, 2002;15(1): p. 273-89.