Dynamic Causal Modelling for fMRI
NITP Summer Course 2015

Pamela K. Douglas
UCLA Semel Institute
Email: pamelita@g.ucla.edu

Overview

1.) Preprocessing your fMRI data for DCM

2.) Running DCM for fMRI

3.) Bayesian Model Selection

Dynamic Causal Modelling (DCM) for fMRI

Introduction

DCM for fMRI is a method for making inferences about neuronal activity that underlie fMRI BOLD time series measurements. Model parameters (i.e., effective connectivity) are estimated via Bayesian model inversion. DCM uses a multi input multi output dynamic state space approach to model neuronal systems along with a modality-specific measurement model (e.g., EEG, fMRI).

This exercise will get you acquainted with the steps in an fMRI-DCM analysis using the graphical user interface. As you will see, it is easy to batch the spm scripts created in the GUI for other subjects. This tutorial exercise was inspired the "attention to visual motion" data set example discussed in the SPM 12 manual. The data are freely available from this website: http://www.fil.ion.ucl.ac.uk/spm/data/attention/.

Typical Preprocessing steps may include:

- Realignment of functional data (Motion Correction)
- Slice Timing Correction
- Coregistration (between functional and structural images)
- Segmentation (into gray and white matter images) and bias regularization
- Spatial Smoothing (Optional for GLM, but recommended for DCM)

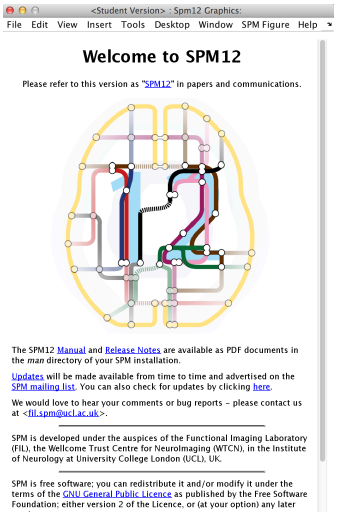
Here, the data have already been preprocessed for you, and are available in the "attention" folder.

1.1 Getting Started:

1.) Start up Matlab, and set your path to the appropriate data directory, for example: /NITP_2015/DCM_Tutorial_2015/attention.

2.) To start spm for fMRI, type the following at the command line. Three windows should open, including the Menu and Graphics windows shown (right).

>> spm fmri



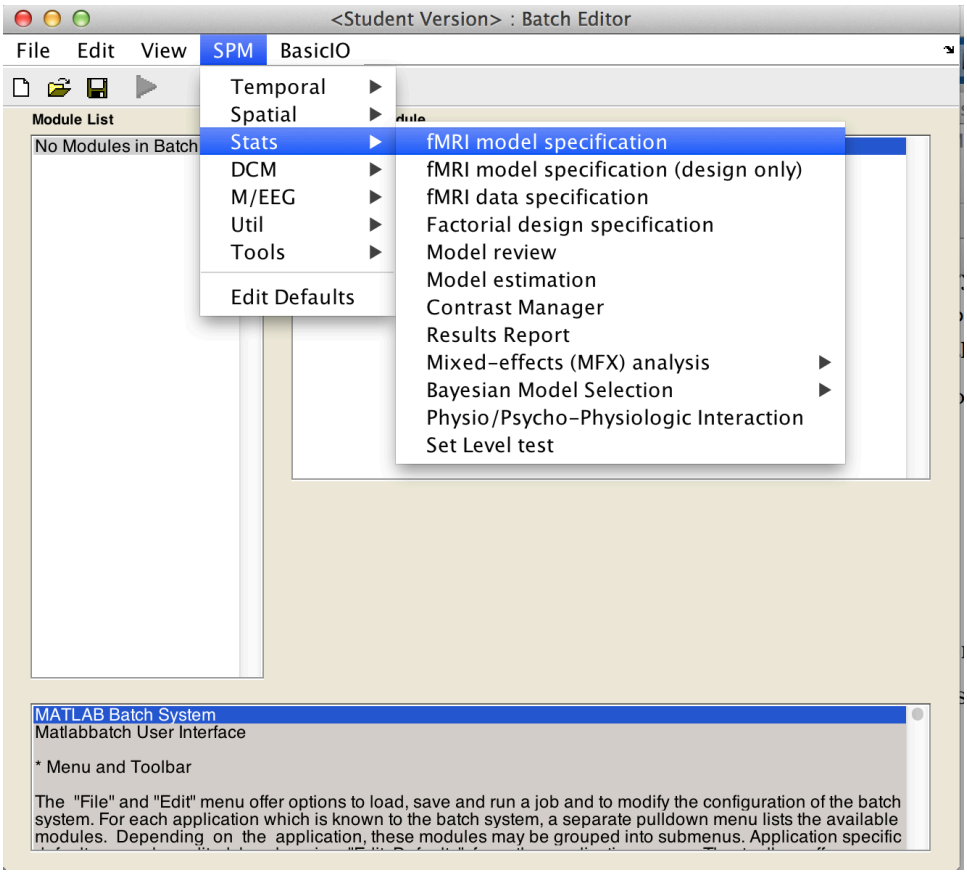
1.2 Setting up your GLM analysis

1.) From the Matlab main window, set up a new directory:

>> mkdir GLM

>> cd GLM

2.) From the SPM Menu window, click on batch. Now Click on SPM > Stats > fMRI model Specification (see below).



3.) Now, specify the following:

a. Units for design [scans]
b. Interscan interval [3.22]

4.) Click Data & Design, Choose New "Subject/Session"

a. Click Scans and choose all the scans snffM00587_00xx.img from the functional directory.

There should be 360 *.img files.

5.) Now you will need to load the file with the experiment timings for each of the 4 conditions (i) fixation (ii) static (iii) radial motion – do not attend, and (iv) radial motion – attend. These conditions are saved in a file called 'factors.mat.' Once you've loaded it, you can type the variable names `stat natt att` to see the onset times for each 10 TR block. Note that the units you specified above were "scans," so these onsets represent the TR that the condition onset occurred.

At the Matlab command line, type:

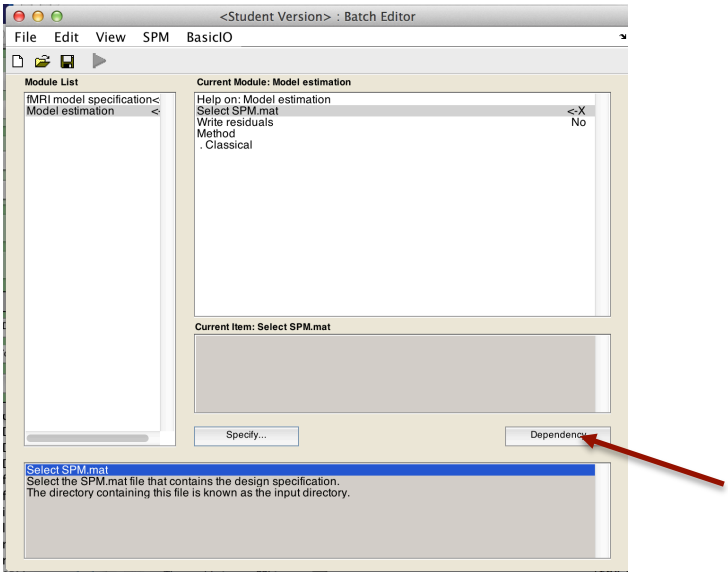
>> load('factors.mat')

6.) Return to the batch editor. Click Conditions then double click New: Condition three times. Enter the following details for each:

a. Condition 1: Name = Photic, Onsets = [att natt stat] and Durations = 10.
b. Condition 2: Name = Motion, Onsets = [att natt] and Durations = 10.
c. Condition 3: Name = Attention, Onsets = att and Durations = 10.

7.) From the SPM menu at the top of the Batch Editor, select "Stats > model estimation".

8.) For Select SPM.mat, click on the Dependency button and choose the proposed item (the output from the previous module).



9.) You should now be able to press the Run green arrow at the top of the Batch Editor window. This will specify and estimate the GLM.

1.3 Extracting Time Series (VOI files)

From the main SPM window, click on the Batch button again.

1. Add a module "SPM > Stats > Contrast manager".
2. For Select SPM.mat, enter the one that has been created in the previous step.
3. Under Contrast Sessions, choose one New: F-contrast and three New: T-contrast and enter
   a. F-contrast: Name = Effects of interest, F weight vector = eye(3). **This sets up an identity matrix of dimension specified.*
   b. T-contrast: Name = Photic, T weight vector = [1 0 0].
   c. T-contrast: Name = Motion, T contrast vector = [0 1 0].
   d. T-contrast: Name = Attention, T contrast vector = [0 0 1].

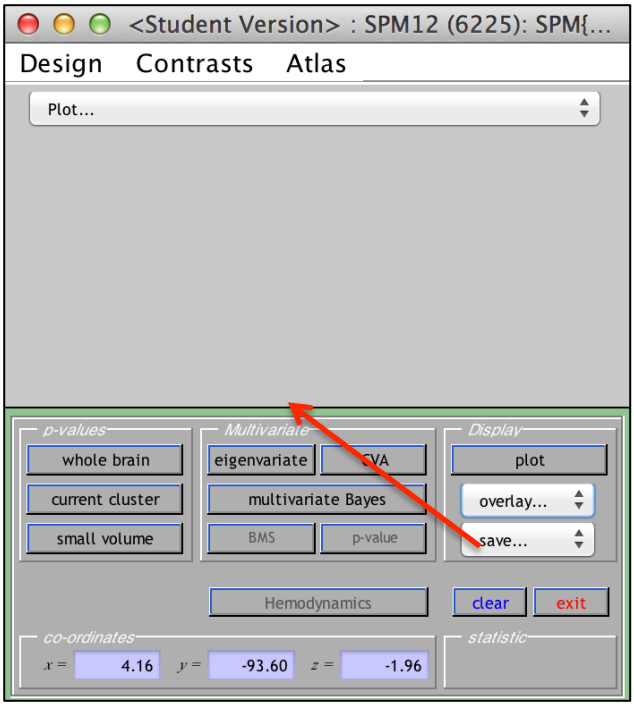
```
EDU>> eye(3)

ans =

     1     0     0
     0     1     0
     0     0     1
```

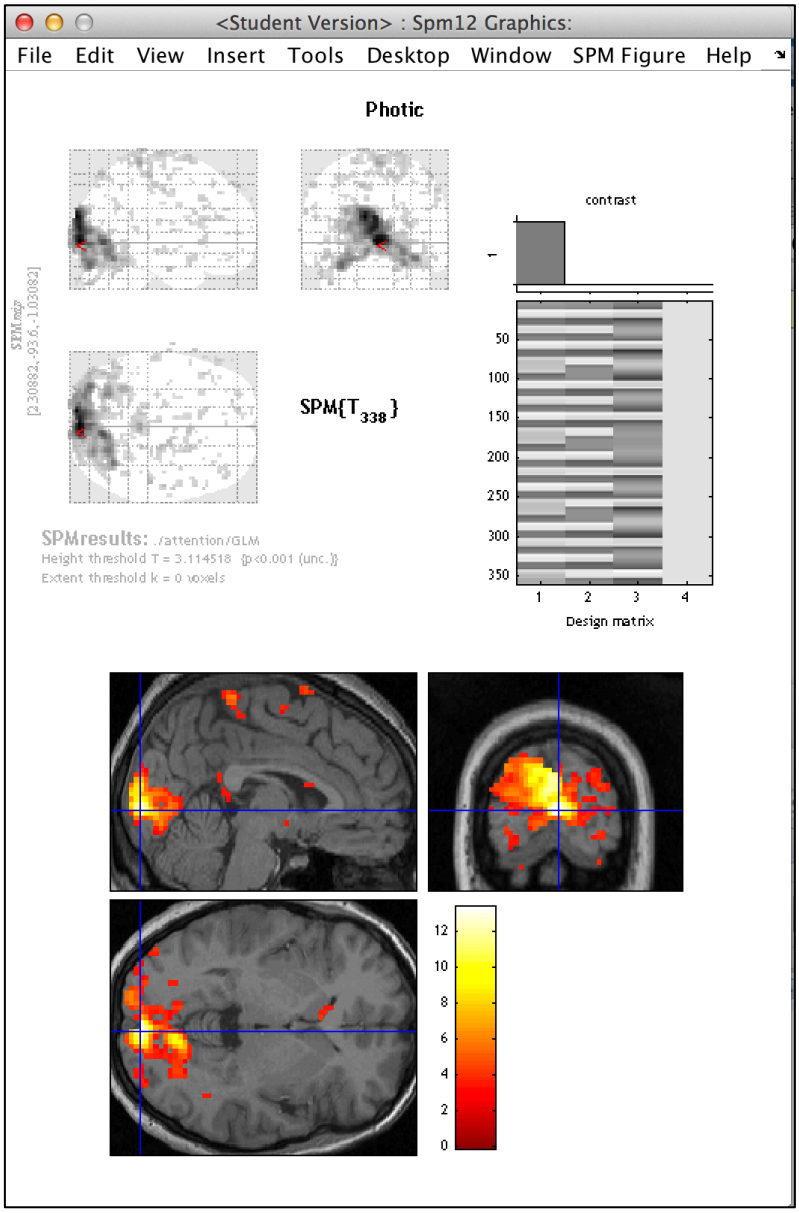
4. Press the Run green arrow at the top of the Batch Editor window. This will specify and estimate these 4 contrasts.

Here is now a step-by-step example for extracting the V1 time series:

1. Press Results.
2. Select the SPM.mat file.
3. Choose the t-contrast for the Photic condition.
4. Apply masking: none.
5. Uncorrected mask p-value p 0.05 and nature of mask: inclusive.
6. p value adjustment to control: none with a threshold of 0.001 and extent 0
7. To overlay these results on a structural scan, click "overlays..." in the SPM Results win- dow, then click "sections". Navigate to the structural folder and select the file named "nsM00587_0002.img".

8. Select the global maxima that looks V5-ish, e.g. [-36 -87 -3].
9. Press the eigenvariate button.
10. Name of region: V1
11. Adjust data for: Effects of interest (this effectively mean-corrects the time series)
12. VOI definition: sphere
13. VOI radius(mm): e.g. 8 mm





SPM now computes the first principal component of the time series from all voxels included in the sphere. The result is stored (together with the original time series) in a file named VOI_V1_1.mat in the working directory (the "1" refers to session 1).

In the interest of time, the other VOI files have been created for you, and are in the GLM folder.

They were created for V5 using the t-contrast for the Motion condition, with the "Apply Masking" turned on using the Attention condition centered on [-36 -87 -3] for a mask. Similarly, the SPC VOI file was created using the Attention contrast, centered at [-27 -84 36].

At this time, you should now copy these files (VOI_V1_1.mat and VOI_SPC_1.mat) into your working directory.

1.4 Running DCM for fMRI

1. Press the large Dynamic Causal Modelling button.
2. Choose specify.
3. Select the SPM.mat file you just created when specifying the GLM.
4. Name for DCM_???.mat: e.g. mod_bwd (for "attentional modulation of backward connection").
5. Select all VOIs in order VOI_V1_1, VOI_V5_1, VOI_SPC_1.
6. Include Photic: Yes
7. Include Motion: Yes
8. Include Attention: Yes
9. Specify slice timings for each area. The default values are set to the last slice of the data, which was the default in the original DCM version. For sequential (as opposed to interleaved) data, this modelling option allows to use DCM in combination with any TR (slice timing differences). Here, we proceed with the default values.
10. Enter 0.04 for "Echo Time, TE[s]".
11. Modulatory effects: bilinear
12. States per region: one
13. Stochastic effects: no
14. Centre input: no

15. Define the following extrinsic connections: V1 to V5, V5 to V1, V5 to SPC, SPC to V5. Extrinsic connections in DCM-fMRI refers to connections between regions.

    a. Note that the columns (1 2 3) specify the source of the connection and the rows specify its target (top left).

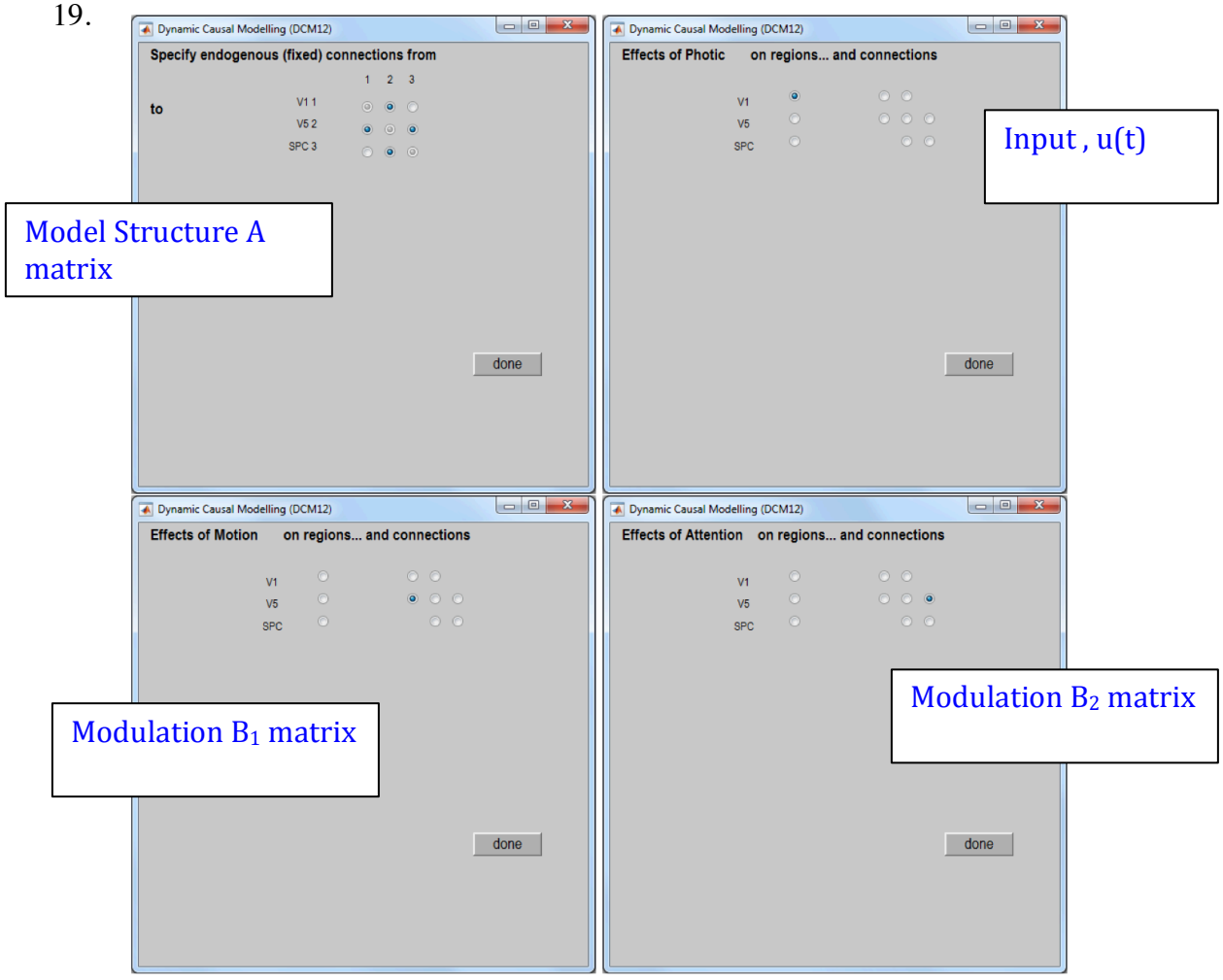
    b. Also note that reciprocal connections are automatically included.

16. Specify Photic as a driving input into V1.

17. Specify Motion to modulate the connection from V1 to V5.

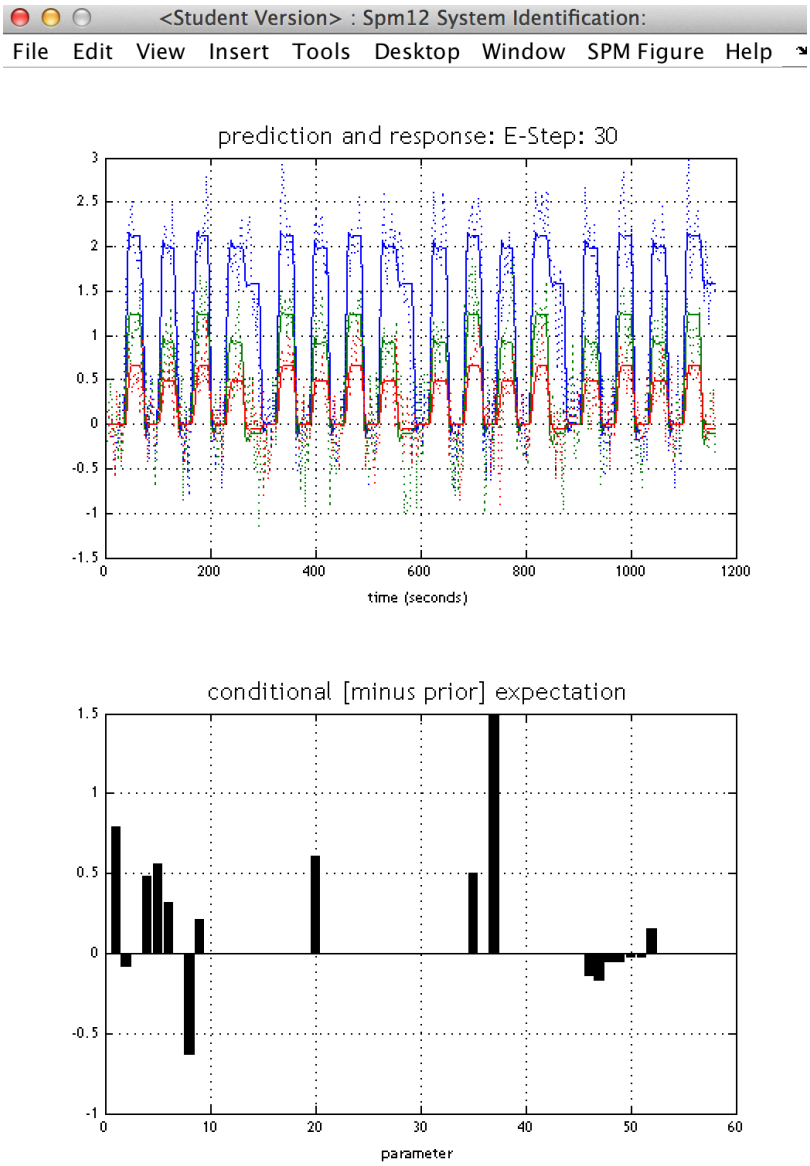
18. Specify Attention to modulate the connection from SPC to V5.

19.



Now its time to run the model.

1. Press the DCM button.
2. Choose estimate (time-series). The model inversion will now proceed.



3. Now you can review the output of your model. Press the DCM button, and Choose review.

4. Select DCM_mod_bwd.mat. You can now review parameter estimates, and other outputs of the model.

Let's now specify an alternate model.

1. Press the DCM button.

2. Choose estimate (time-series). The model inversion will now proceed.

Bayesian Model Selection

Now let's see which model best explains the observed data.

1. Press the "DCM" button.
2. Choose Compare.
3. In the Batch Editor window that opened, fill in the "BMS: DCM" module:

    a. Directory: choose current directory,
    b. Data: add a New Subject with a New Session and select the two models, e.g. in the order DCM_mod_bwd.mat and DCM_mod_fwd.mat,
    c. Inference method: choose "Fixed effects (FFX)".

Press Run (the green triangle in the Batch Editor).

The best model is the one with the highest evidence.

Which one won?