(Demo-ing) fMRI Connectivity using Dynamic Causal Modelling (DCM)

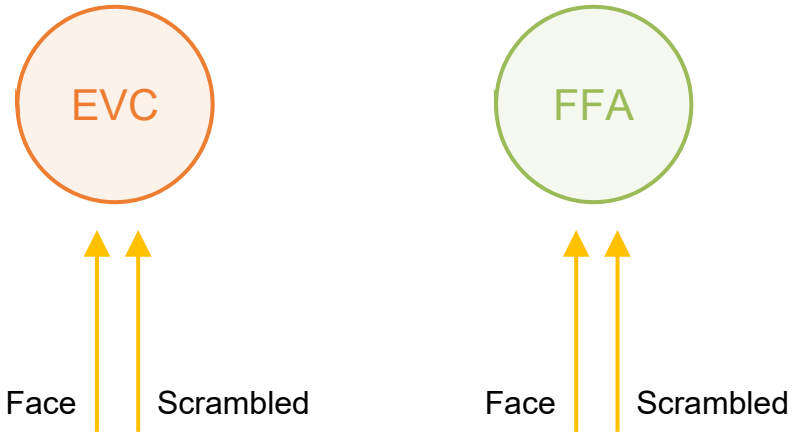
Rik Henson, Pranay Yadav

Theoretical background:

https://www.youtube.com/watch?v=1VOKsWWLgjk

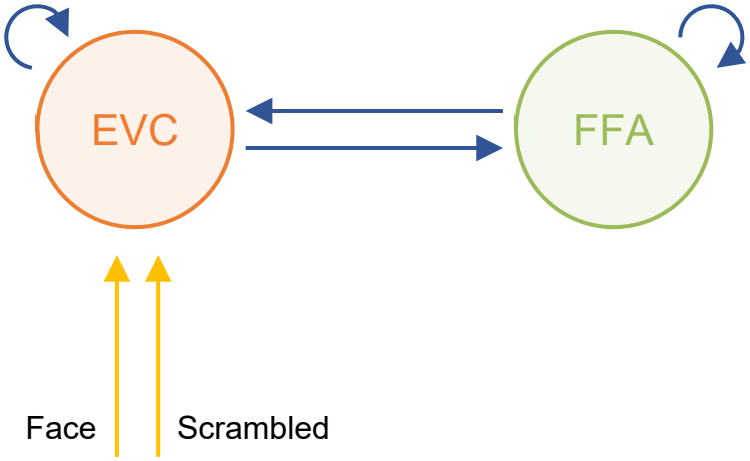
Background

Brain Mapping



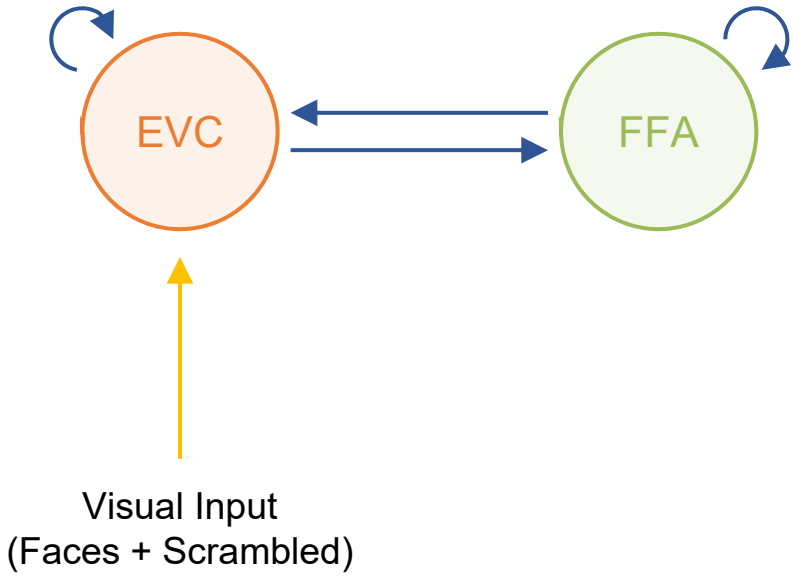
Background

Network Modelling



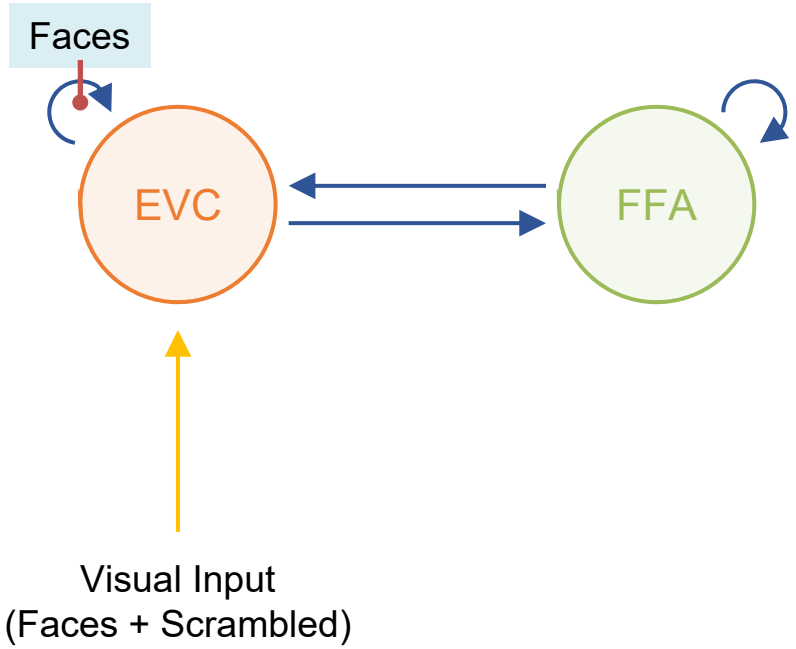
Background

Network Modelling



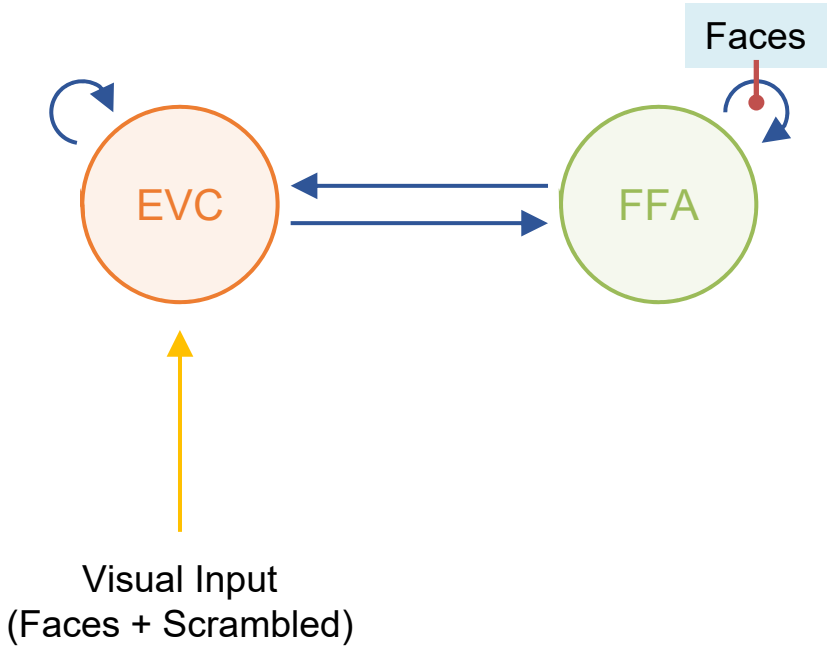
Background

Network Modelling



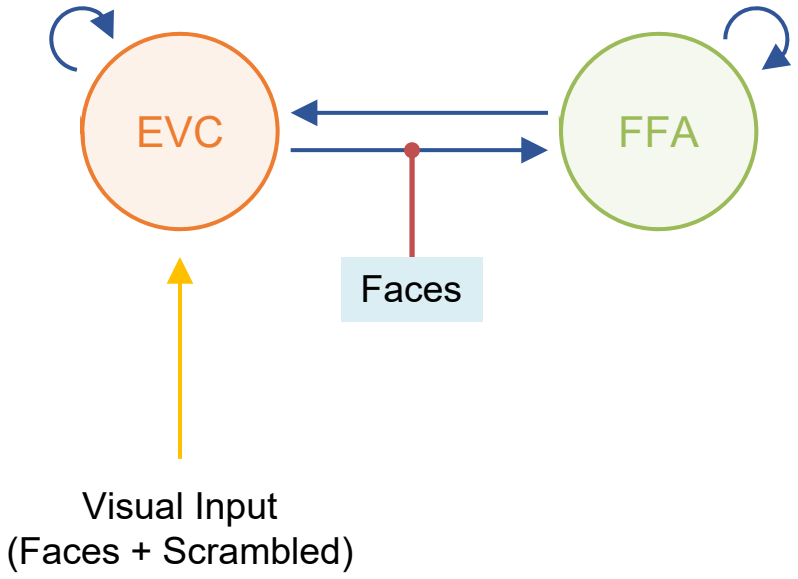
Background

Network Modelling



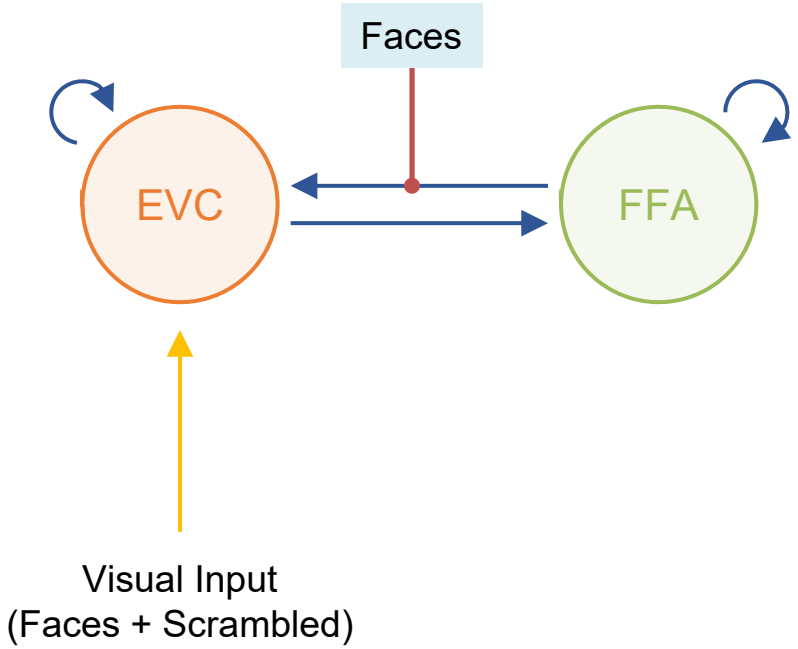
Background

Network Modelling



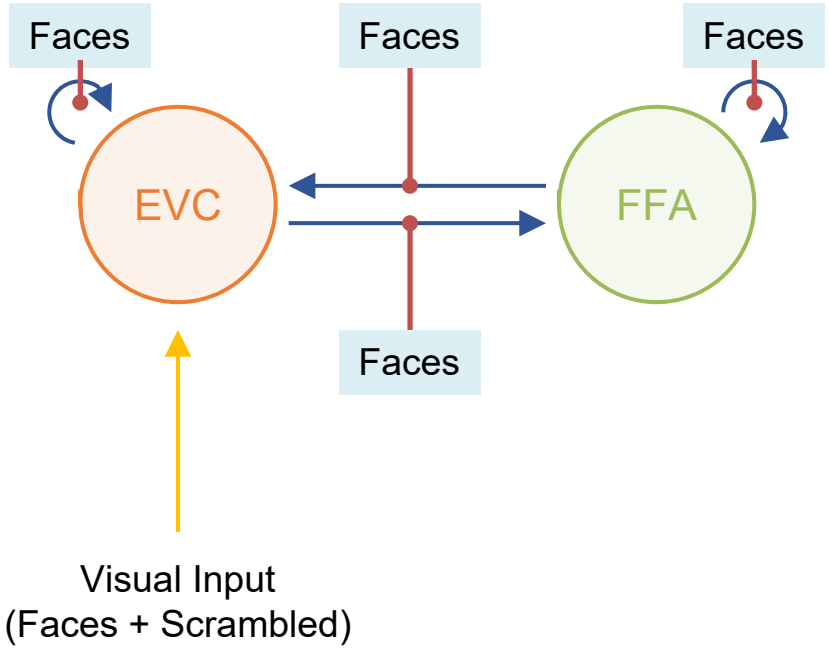
Background

Network Modelling



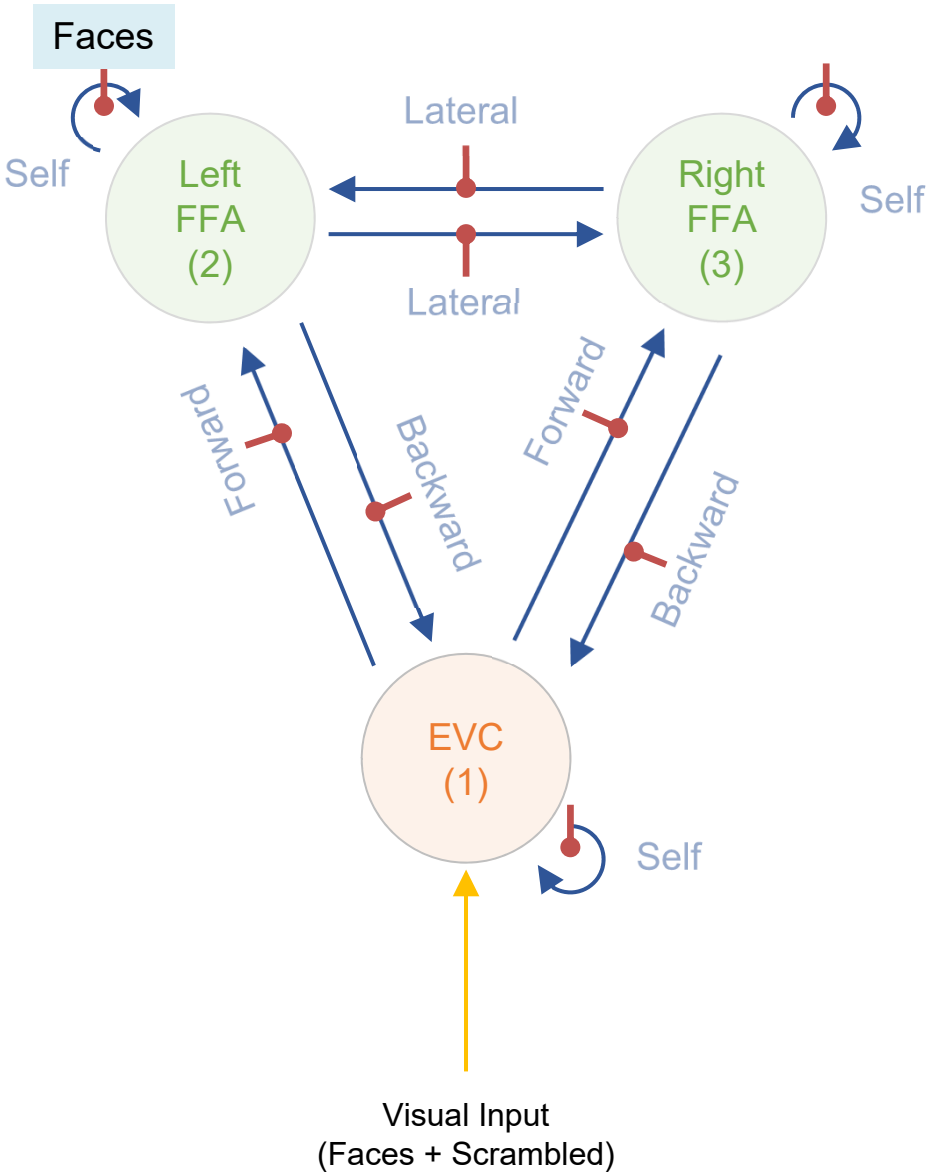
Background

Network Modelling



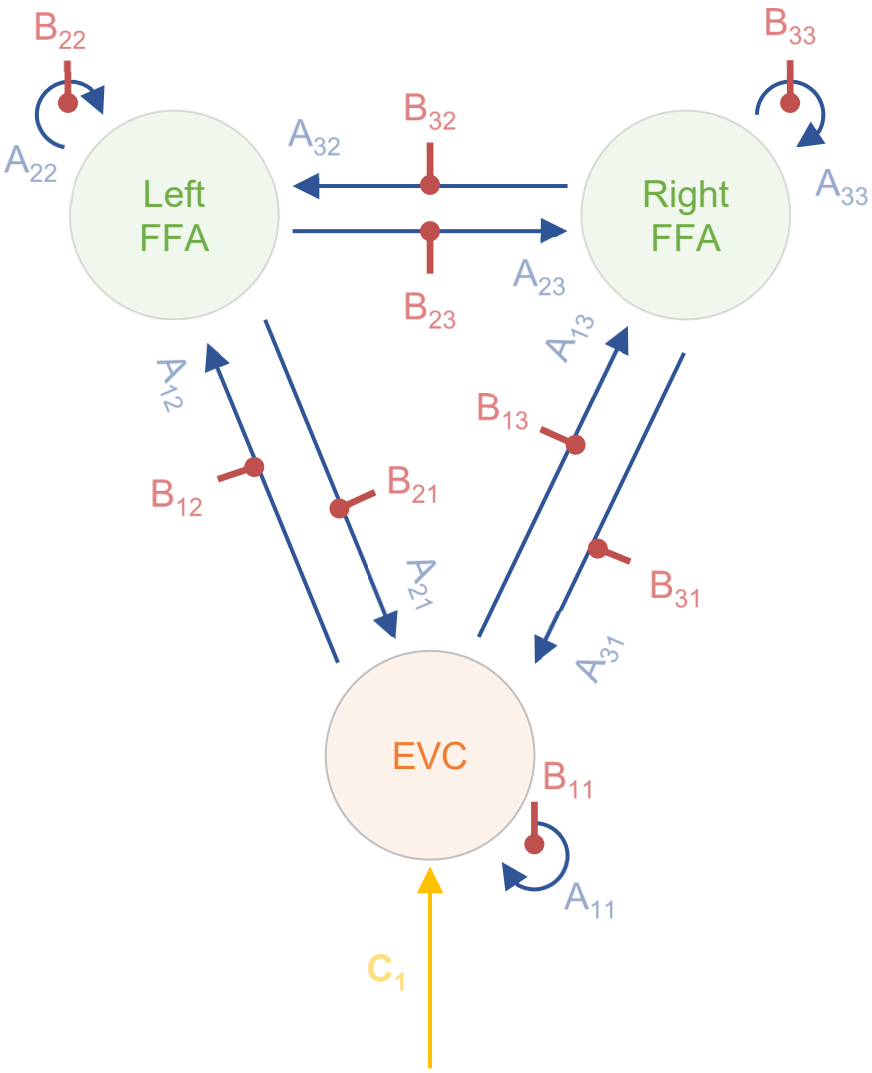
‘Full’ model

Faces modulate both between-region & self connections



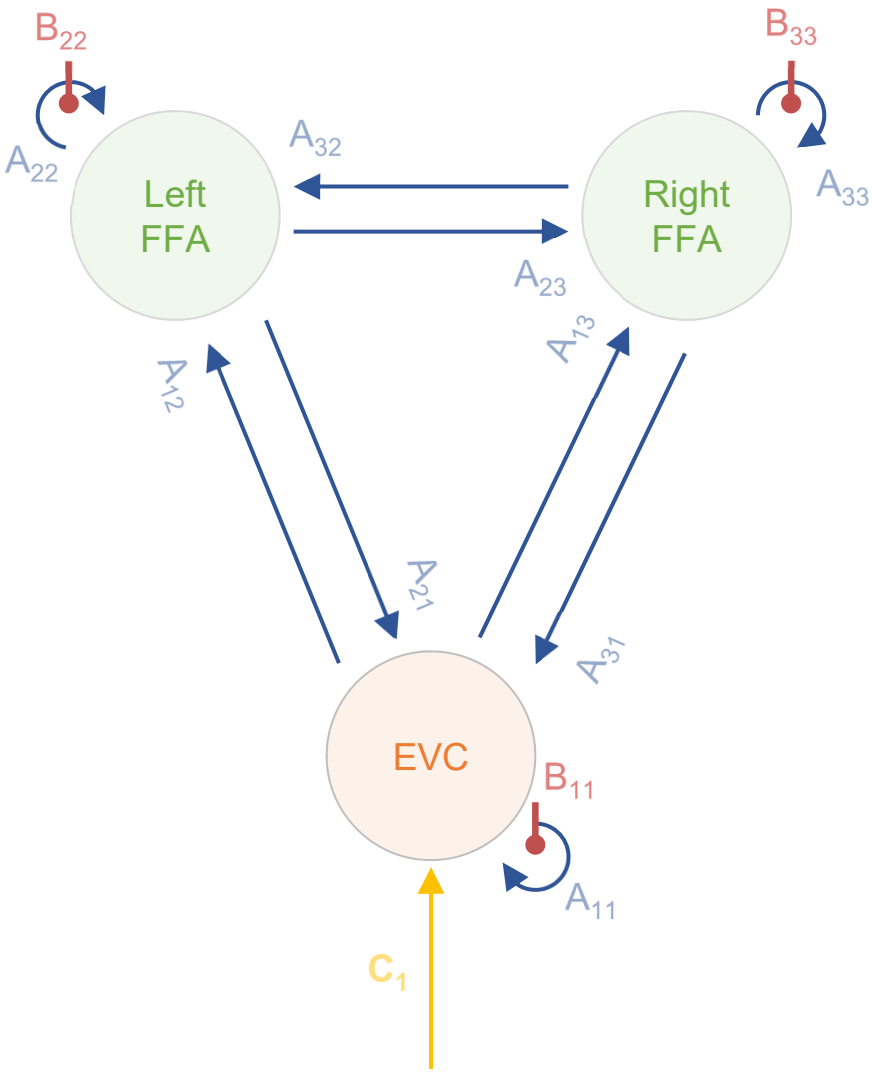
‘Full’ model

Faces modulate both between-region & self connections

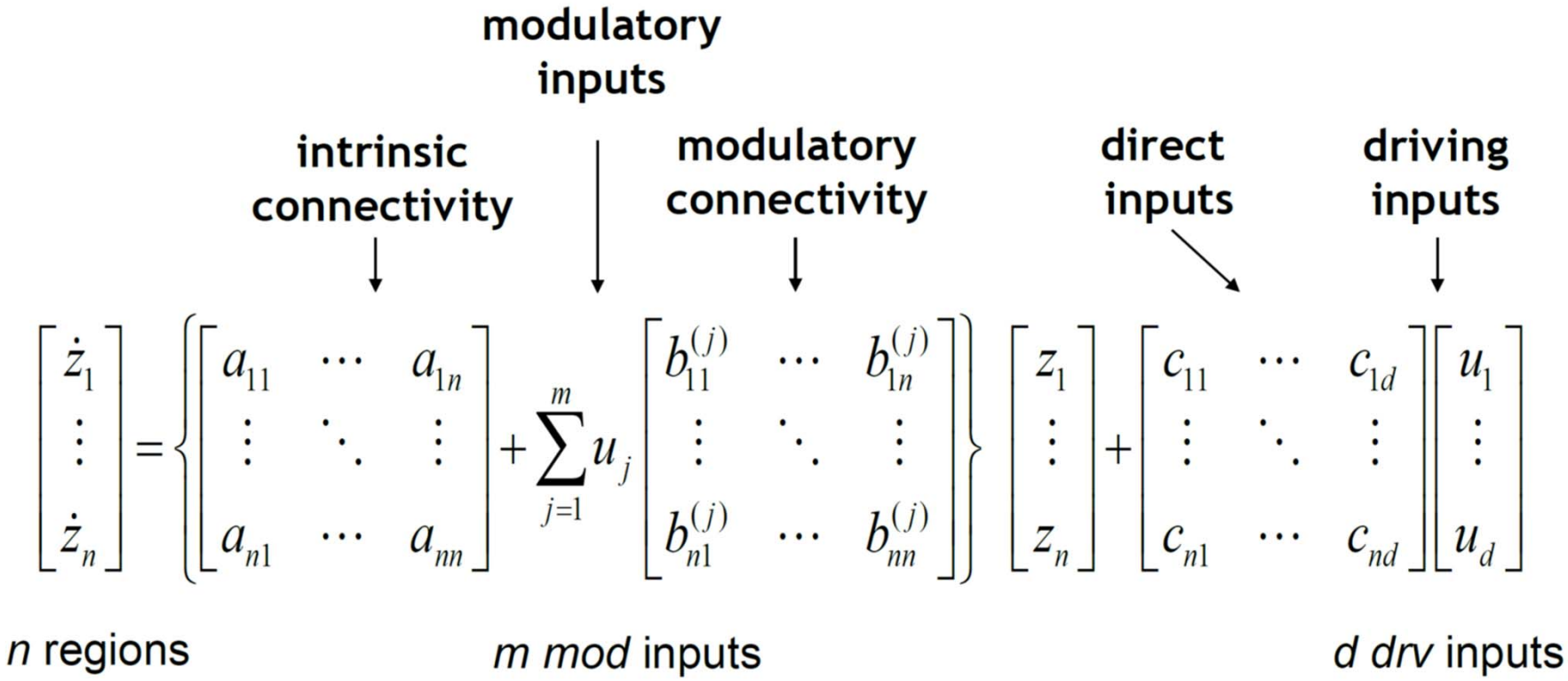


‘Self’ model

Faces modulate only self connections



DCM bilinear model



$$\dot{z} = (A + \sum_{j=1}^{m} u_j B^{(j)}) z + Cu$$

SPM Manual for fMRI+M/EEG

SPM12 Manual

The FIL Methods Group
(and honorary members)

John Ashburner
Gareth Barnes
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Jean Daunizeau
Guillaume Flandin
Karl Friston
Stefan Kiebel
James Kilner
Vladimir Litvak
Rosalyn Moran
Will Penny
Adeel Razi
Klaas Stephan
Sungho Tak
Peter Zeidman

Darren Gitelman
Rik Henson
Chloe Hutton
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Jérémie Mattout
Christophe Phillips

Chapter 42

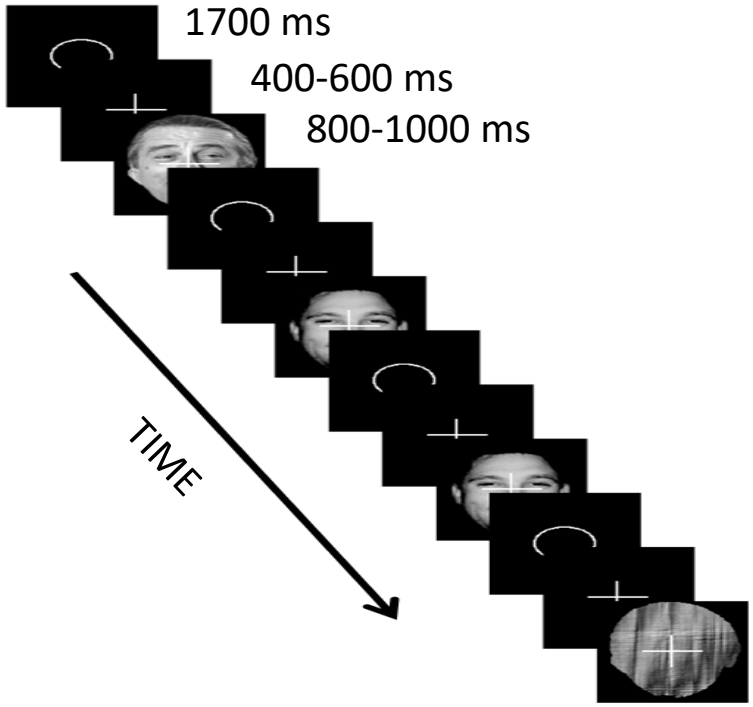
Multimodal, Multisubject data fusion

42.1 Overview

This dataset contains EEG, MEG, functional MRI and structural MRI data from 16 subjects who undertook multiple runs of a simple task performed on a large number of Famous, Unfamiliar and Scrambled faces. It will be used to demonstrate:

1. batching and scripting of preprocessing of multiple subjects/runs of combined MEG and EEG data,
2. creation of trial-averaged evoked responses,
3. 3D scalp-time statistical mapping of evoked responses across trials within one subject,
4. 2D time-frequency statistical mapping of time-frequency data across subjects,
5. preprocessing and group analysis of fMRI data from the same subjects and paradigm,
6. source-reconstruction of the "N/M170" face component (using structural MRI for forward modelling),
7. individual and group-based fusion of EEG and MEG during source reconstruction,
8. statistical mapping across subjects of cortical power in a time-frequency window, using the functional MRI results as spatial priors.

The Dataset



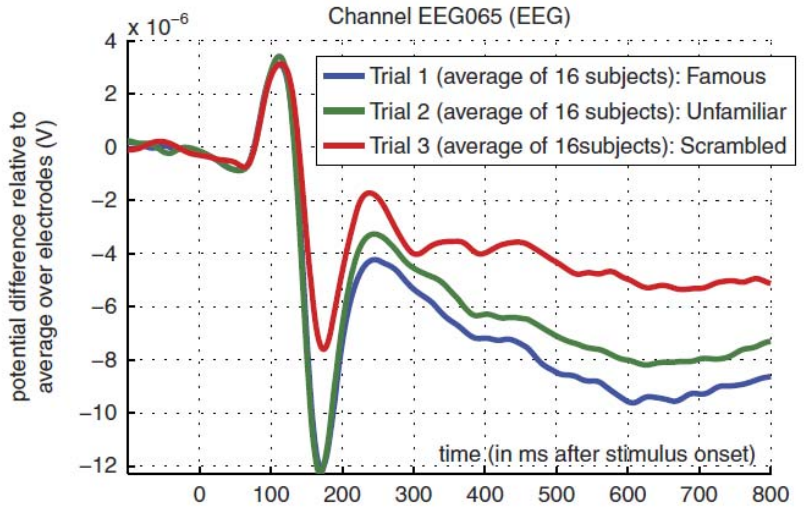
N=16 subjects (BIDS format)

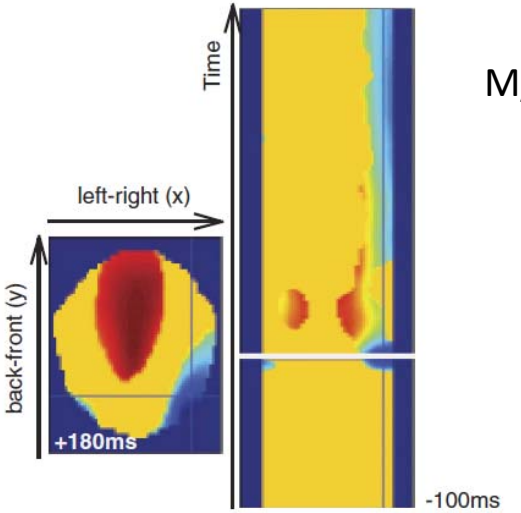
EEG = 70 channels, nose-reference (concurrent with MEG)
MEG = 102 magnetometers + 204 planar gradiometers

fMRI = BOLD EPI 3x3x3mm (3T Siemens Trio)
MRI = T1 MPRAGE 1x1x1mm

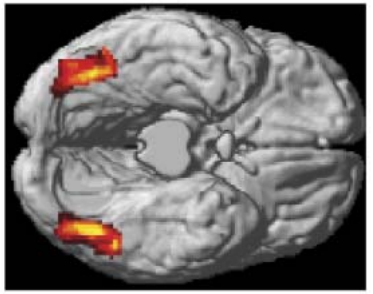
Stimuli: 3 types of greyscale face images:
~300 x Famous
~300 x Nonfamous (previously unseen)
~300 x Phase-scrambled versions of above

Task: Judge left-right symmetry

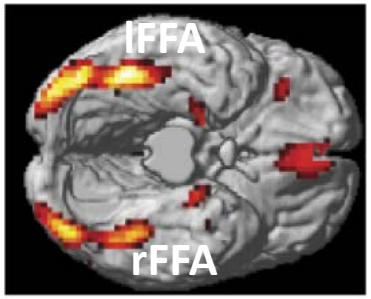




M/EEG



fMRI



Wakeman & Henson (2015), *Scientific Data,* http://www.nature.com/articles/sdata20151

www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES

» Electroencephalography -EEG

» Brain imaging

» Functional magnetic resonance imaging

» Cognitive neuroscience

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Accepted: 05 January 2015
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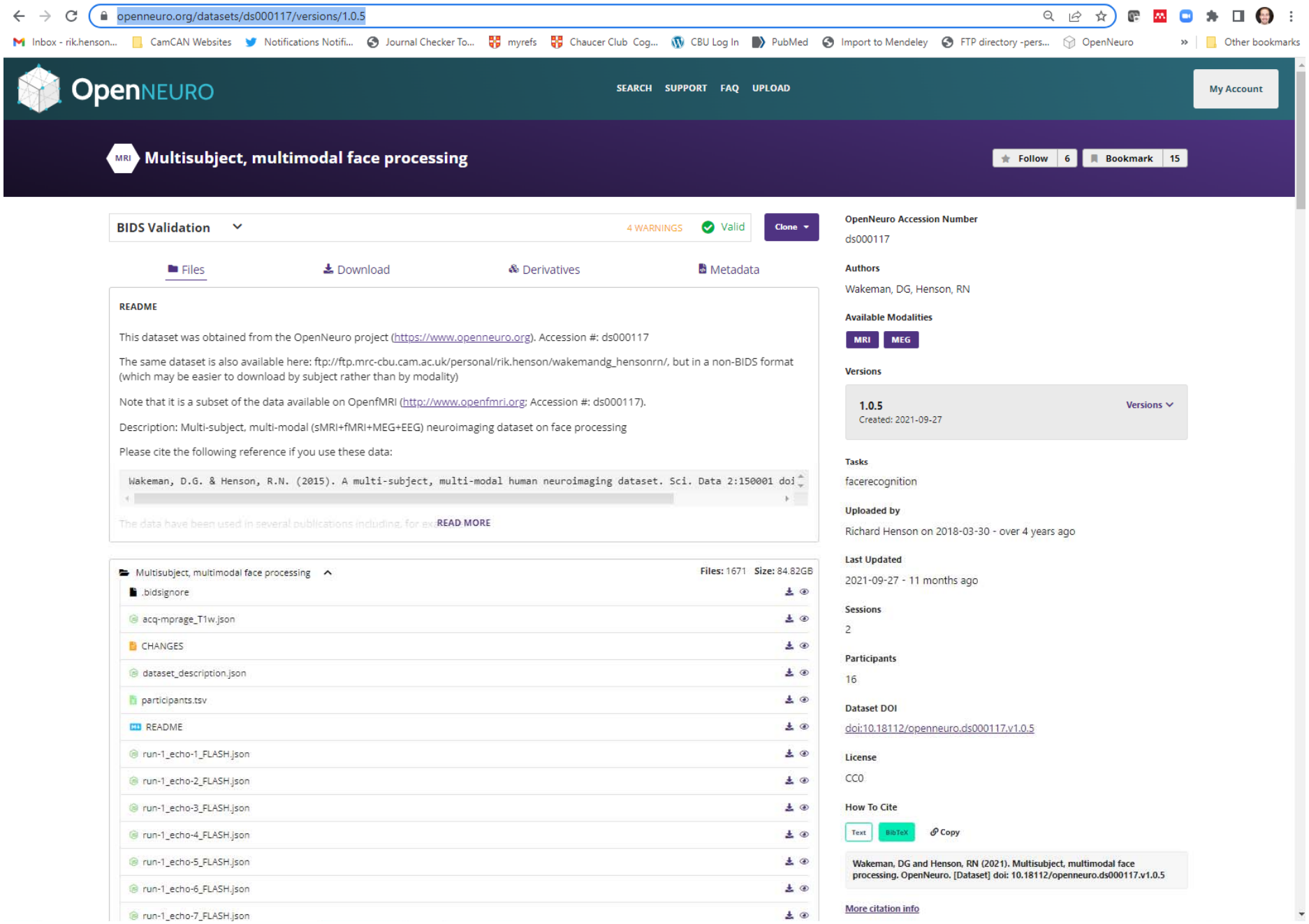
A multi-subject, multi-modal human neuroimaging dataset

Daniel G. Wakeman[1,2] & Richard N. Henson[2]

We describe data acquired with multiple functional and structural neuroimaging modalities on the same nineteen healthy volunteers. The functional data include Electroencephalography (EEG), Magnetoencephalography (MEG) and functional Magnetic Resonance Imaging (fMRI) data, recorded while the volunteers performed multiple runs of hundreds of trials of a simple perceptual task on pictures of familiar, unfamiliar and scrambled faces during two visits to the laboratory. The structural data include T1-weighted MPRAGE, Multi-Echo FLASH and Diffusion-weighted MR sequences. Though only from a small sample of volunteers, these data can be used to develop methods for integrating multiple modalities from multiple runs on multiple participants, with the aim of increasing the spatial and temporal resolution above that of any one modality alone. They can also be used to integrate measures of functional and structural connectivity, and as a benchmark dataset to compare results across the many neuroimaging analysis packages. The data are freely available from https://openfmri.org/.

Wakeman & Henson (2015), *Scientific Data,* http://www.nature.com/articles/sdata20151

https://openneuro.org/datasets/ds000117/versions/1.0.5



Dynamic Causal Modelling of fMRI data in SPM12

Pranay Yadav[1*] & Richard N Henson[1,2]

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[2]Department of Psychiatry, University of Cambridge, Cambridge, UK

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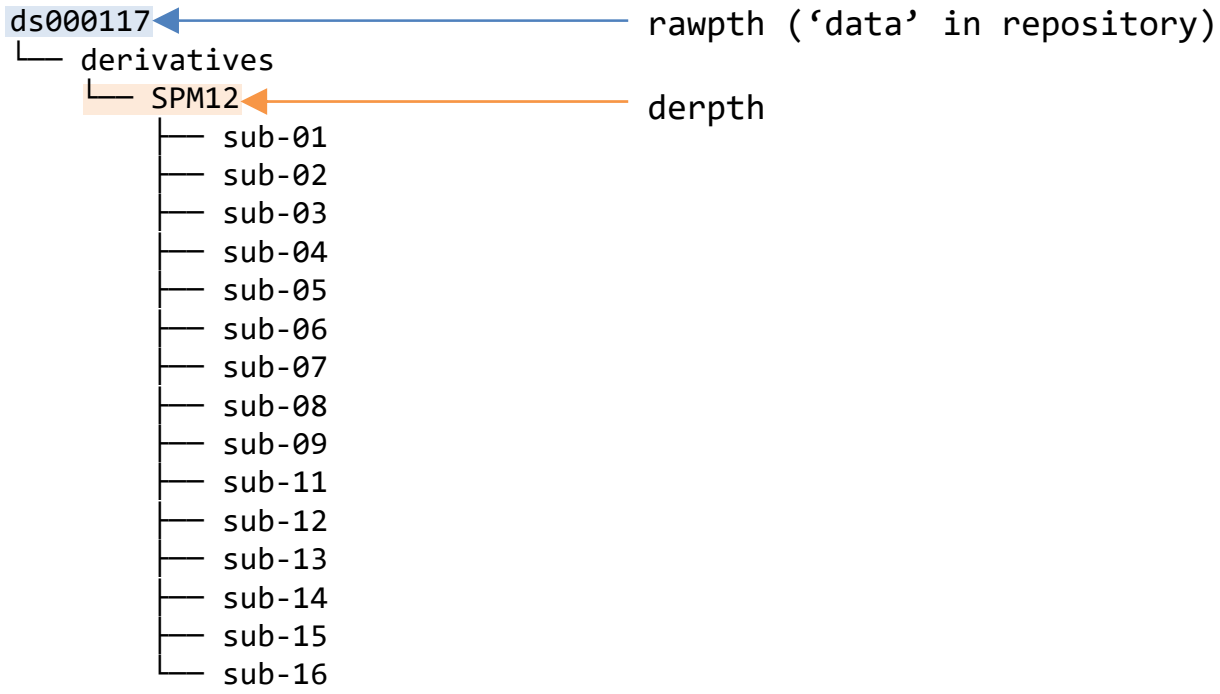
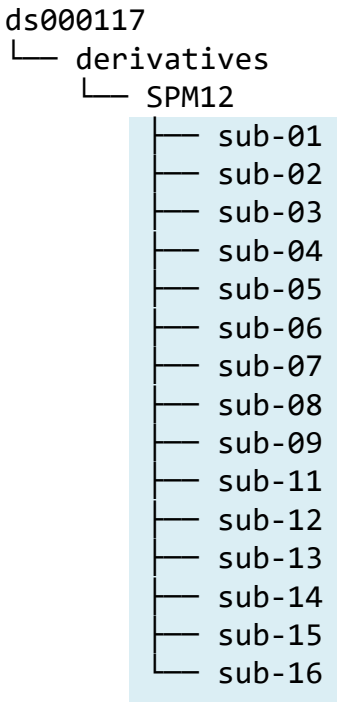
Keywords: MEG, EEG, fMRI, multimodal, fusion, SPM, inversion, faces

Contains links to processed data, batches, scripts…

Data organization



Data organization



These should already be present if you began with raw data and processed as per Henson et al 2019.

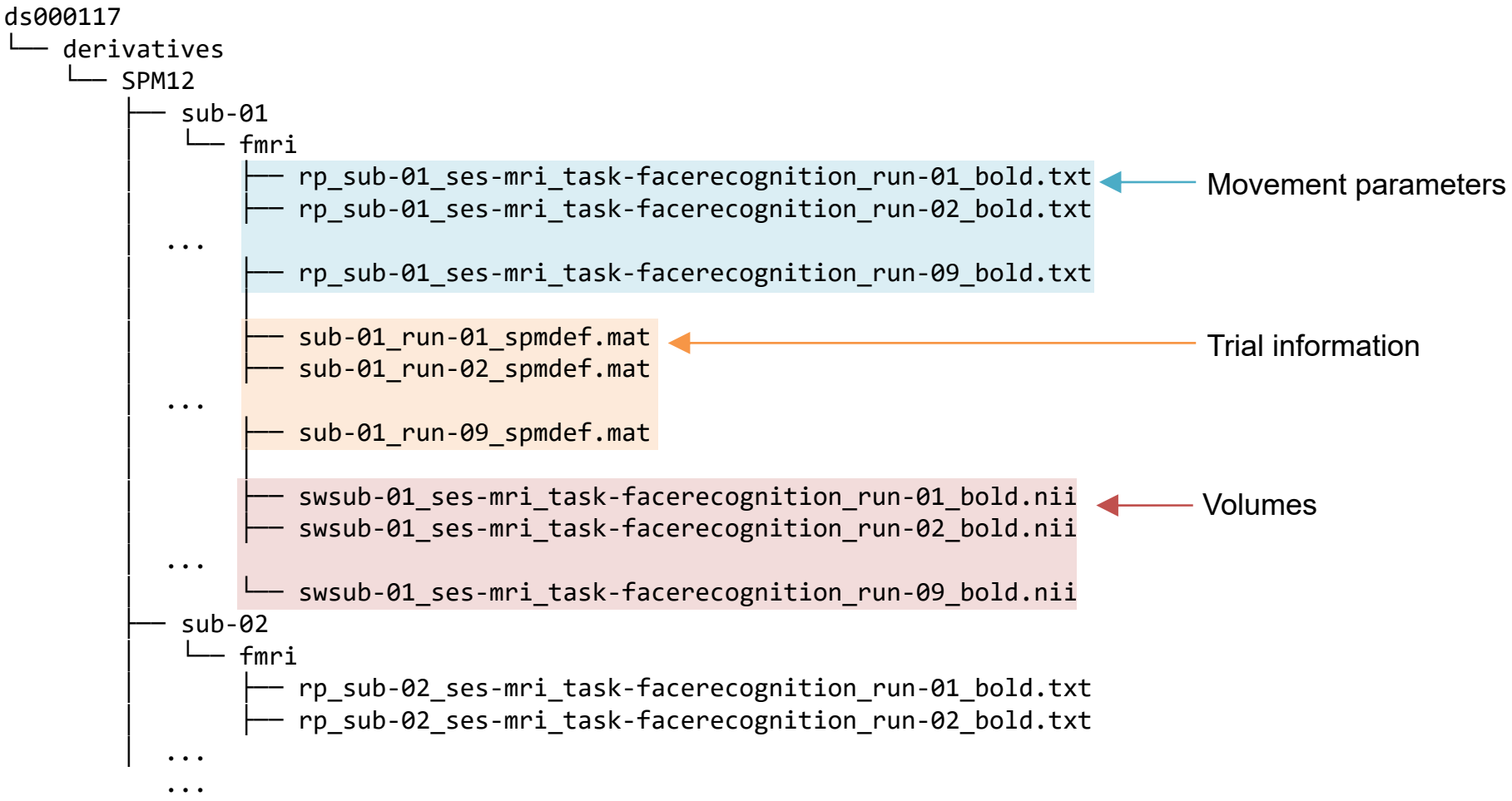
Else, download from figshare and extract here.

Data organization

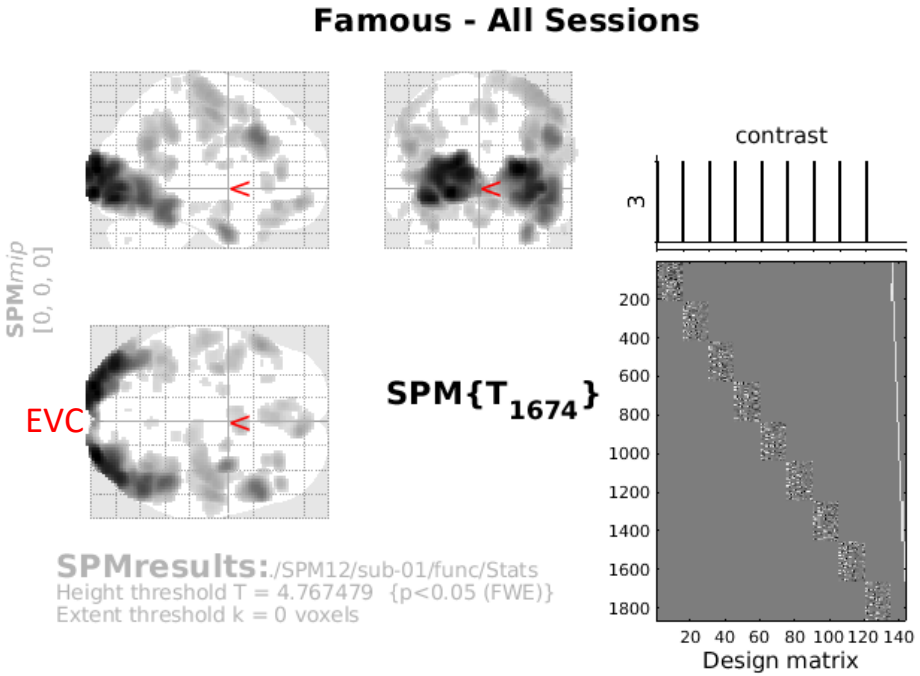
```
ds000117
└── derivatives
    └── SPM12
        ├── sub-01
        │   └── fmri
        │       ├── rp_sub-01_ses-mri_task-facerecognition_run-01_bold.txt
        │       ├── rp_sub-01_ses-mri_task-facerecognition_run-02_bold.txt
        │   ...
        │       ├── rp_sub-01_ses-mri_task-facerecognition_run-09_bold.txt
        │       │
        │       ├── sub-01_run-01_spmdef.mat
        │       ├── sub-01_run-02_spmdef.mat
        │   ...
        │       ├── sub-01_run-09_spmdef.mat
        │       │
        │       ├── swsub-01_ses-mri_task-facerecognition_run-01_bold.nii
        │       ├── swsub-01_ses-mri_task-facerecognition_run-02_bold.nii
        │   ...
        │       └── swsub-01_ses-mri_task-facerecognition_run-09_bold.nii
        ├── sub-02
        │   └── fmri
        │       ├── rp_sub-02_ses-mri_task-facerecognition_run-01_bold.txt
        │       ├── rp_sub-02_ses-mri_task-facerecognition_run-02_bold.txt
        │   ...
        │   ...
```

3 × 9 = 27 files
(per subject)

Data organization



Single-subject (fMRI timeseries) GLM (1st-level) SPM



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

set-level		cluster-level				peak-level					mm	mm	mm
p	c	$p_{FWE-corr}$	$q_{FDR-corr}$	k_E	p_{uncorr}	$p_{FWE-corr}$	$q_{FDR-corr}$	T	(Z_E)	p_{uncorr}			
0.000	**37**	**0.000**	**0.000**	**10065**	**0.000**	**0.000**	**0.000**	**22.70**	**Inf**	**0.000**	**26**	**-98**	**12**
						0.000	0.000	22.38	Inf	0.000	-22	-100	-4
						0.000	0.000	21.81	Inf	0.000	-18	-98	16
		0.000	**0.000**	**816**	**0.000**	**0.000**	**0.000**	**13.75**	**Inf**	**0.000**	**48**	**18**	**34**
						0.000	0.000	6.46	6.42	0.000	46	16	50
		0.000	**0.000**	**278**	**0.000**	**0.000**	**0.000**	**12.79**	**Inf**	**0.000**	**32**	**-4**	**-32**
		0.000	**0.000**	**702**	**0.000**	**0.000**	**0.000**	**10.18**	**Inf**	**0.000**	**-52**	**22**	**28**
						0.000	0.000	7.67	7.60	0.000	-46	4	38
						0.000	0.000	7.47	7.41	0.000	-40	0	34
		0.000	**0.000**	**1754**	**0.000**	**0.000**	**0.000**	**9.50**	**Inf**	**0.000**	**54**	**-12**	**50**
						0.000	0.000	9.24	Inf	0.000	42	-16	64
						0.000	0.000	9.02	Inf	0.000	46	-12	58
		0.000	**0.000**	**652**	**0.000**	**0.000**	**0.000**	**9.21**	**Inf**	**0.000**	**8**	**50**	**-12**
						0.000	0.000	7.35	7.29	0.000	0	30	-26
						0.000	0.000	7.07	7.01	0.000	-10	38	-18
		0.000	**0.001**	**83**	**0.000**	**0.000**	**0.000**	**8.42**	**Inf**	**0.000**	**-36**	**-10**	**-28**
		0.000	**0.000**	**139**	**0.000**	**0.000**	**0.000**	**8.40**	**Inf**	**0.000**	**46**	**36**	**10**
		0.000	**0.000**	**104**	**0.000**	**0.000**	**0.000**	**8.39**	**Inf**	**0.000**	**30**	**34**	**-14**
		0.000	**0.000**	**267**	**0.000**	**0.000**	**0.000**	**8.25**	**Inf**	**0.000**	**-38**	**-60**	**22**
						0.000	0.002	6.09	6.05	0.000	-48	-56	14
		0.000	**0.000**	**294**	**0.000**	**0.000**	**0.000**	**8.01**	**Inf**	**0.000**	**6**	**8**	**52**
						0.000	0.000	6.42	6.38	0.000	-6	4	56

table shows 3 local maxima more than 8.0mm apart

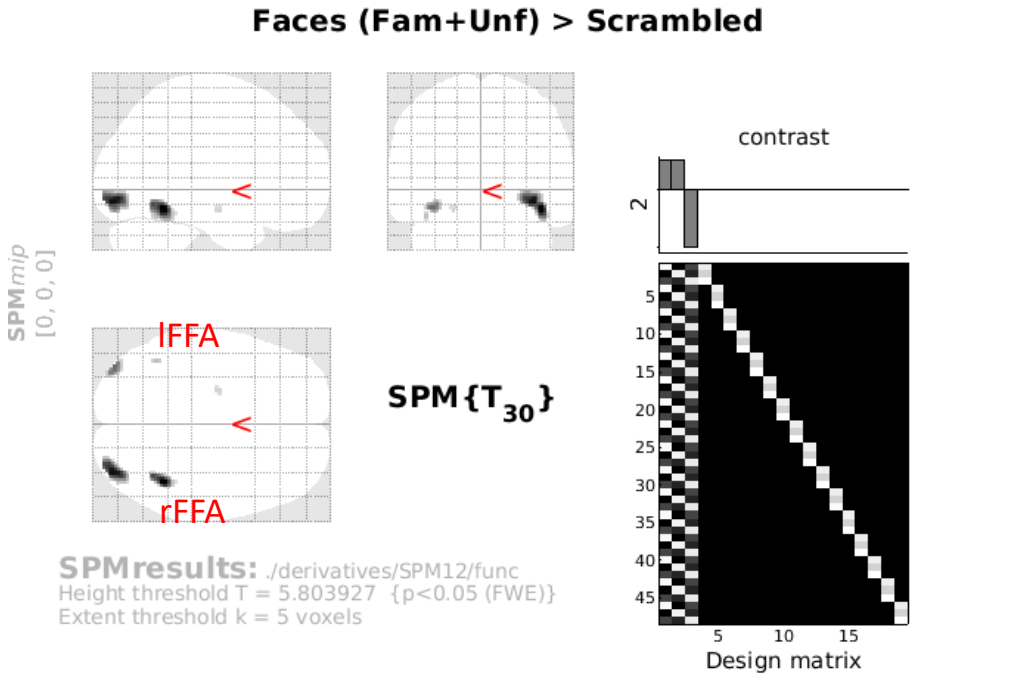
Height threshold: T = 4.77, p = 0.000 (0.050)
Extent threshold: k = 0 voxels
Expected voxels per cluster, <k> = 4.518
Expected number of clusters, <c> = 0.05
FWEp: 4.767, FDRp: 5.503, FWEc: 2, FDRc: 23

Degrees of freedom = [1.0, 1674.0]
FWHM = 10.6 10.5 10.3 mm mm mm; 5.3 5.3 5.1 {voxe
Volume: 1737816 = 217227 voxels = 1415.5 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 142.70 vo

Page 1

1

Group GLM (2^{nd}-level) SPM



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_E)	p_{uncorr}	
0.000	5	0.000	0.000	122	0.000	0.000	0.005	9.00	6.22	0.000	42 -52 -14
		0.000	0.000	180	0.000	0.000	0.005	8.68	6.09	0.000	36 -88 -10
		0.000	0.012	39	0.007	0.001	0.042	7.42	5.55	0.000	-38 -86 -14
		0.014	0.284	5	0.284	0.017	0.399	6.27	4.97	0.000	-42 -56 -20
		0.012	0.284	6	0.242	0.031	0.624	6.01	4.83	0.000	-22 -10 -16

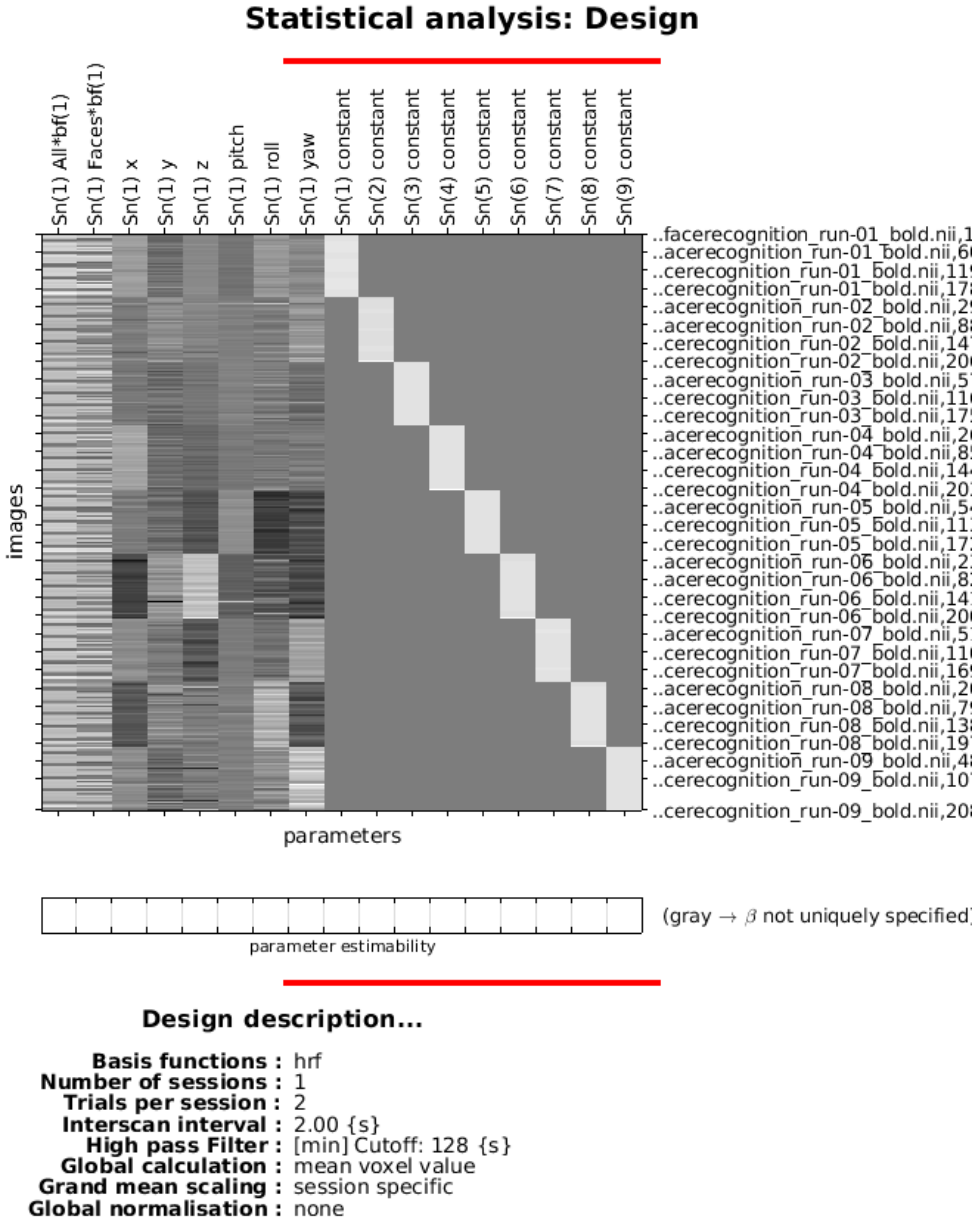
table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 5.80, p = 0.000 (0.050) Degrees of freedom = [1.0, 30.0]
Extent threshold: k = 5 voxels, p = 0.284 (0.014) FWHM = 13.0 12.9 12.6 mm mm mm; 6.5 6.4 6.3 {voxe
Expected voxels per cluster, <k> = 4.709 Volume: 1515968 = 189496 voxels = 671.9 resels
Expected number of clusters, <c> = 0.01 Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 261.78 vo
FWEp: 5.804, FDRp: 7.424, FWEc: 5, FDRc: 39

Concatenation

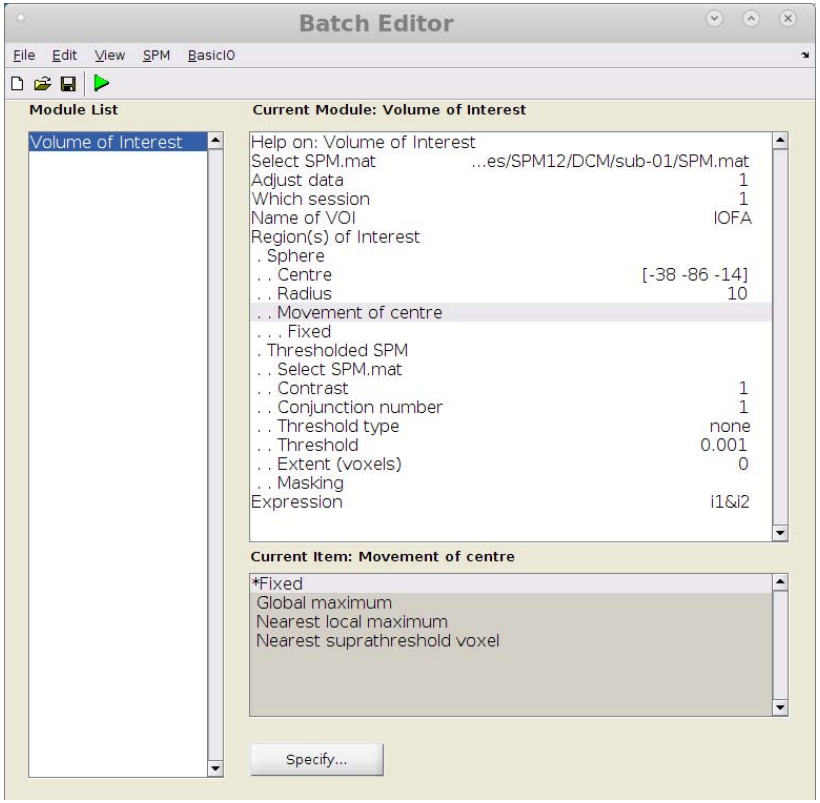
- Could estimate each run separately, but easier to concatenate into one run

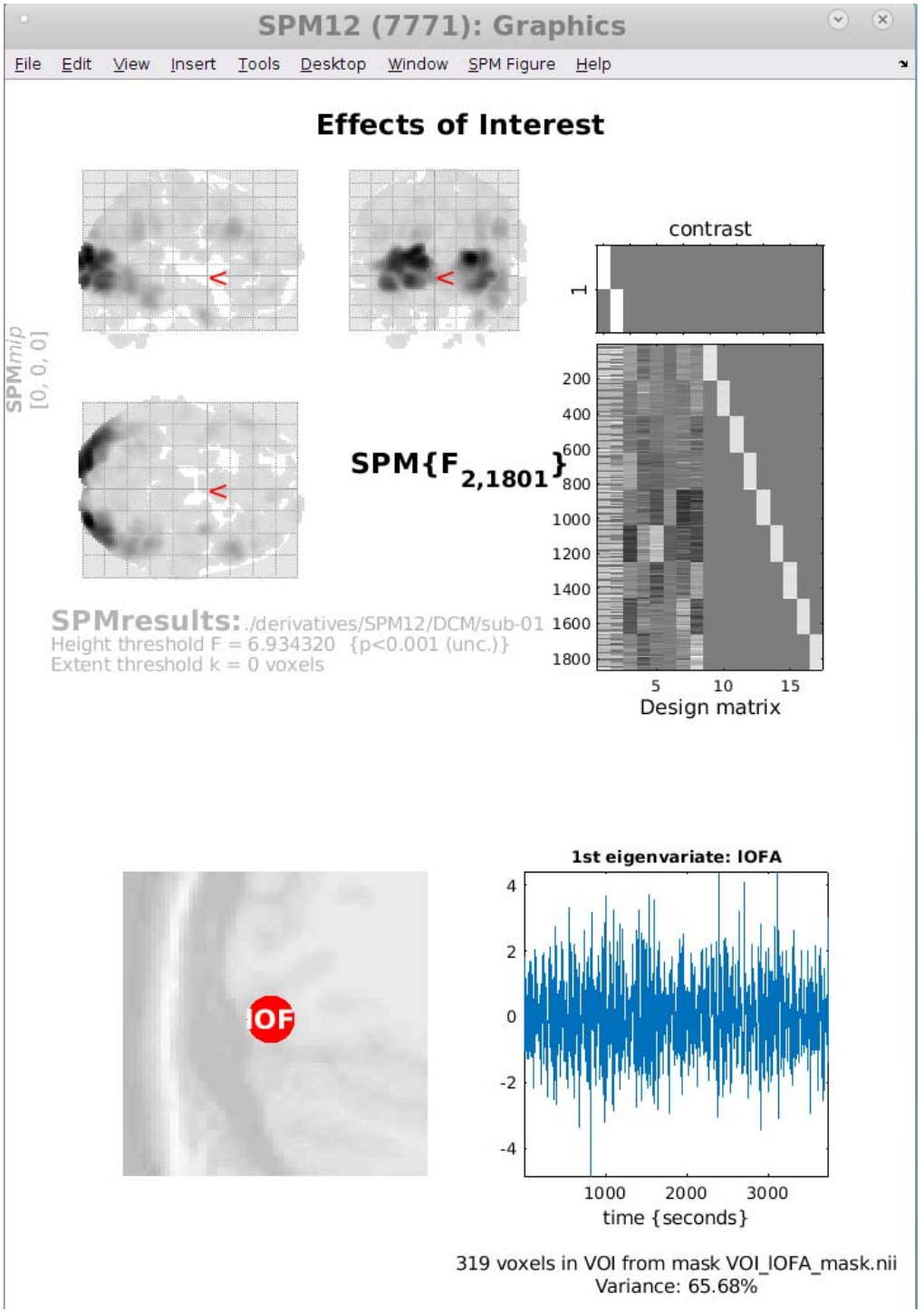
- Re-parametrise conditions by:
  - Collapsing famous and nonfamous faces
  - Defining two conditions: 1) Faces + Scrambled, 2) Faces only
  - 838 trials in total
  - 1872 volumes (TRs) per subject



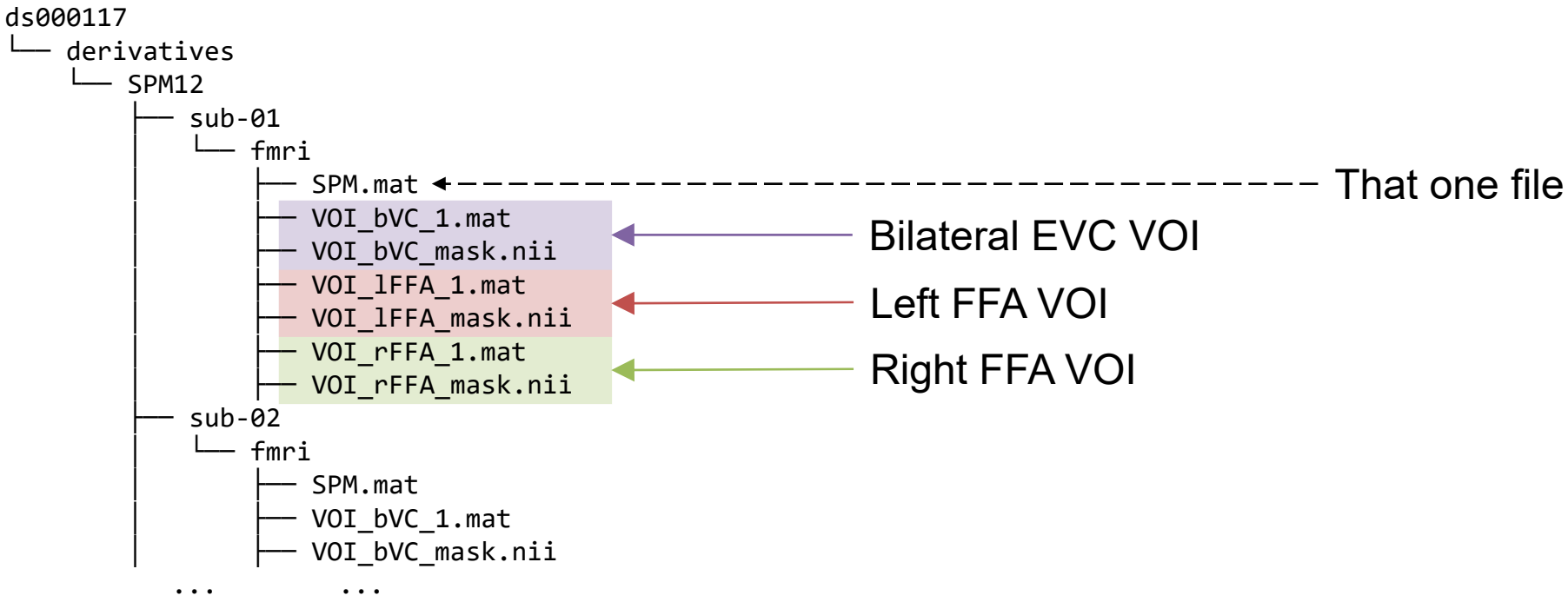
Extract data from VOIs

- bEVC, lFFA, rFFA (order important)





Data organization



Tomorrow

- DCM for evoked M/EEG responses:

Talk by Pranay: https://www.youtube.com/watch?v=HNaAvKmVCYo

Feedback

https://www.surveymonkey.com/r/X525RCT