

Group Analysis of fMRI

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Teaching Materials (25 videos & handouts)

http://www.ym.edu.tw/~cflu/CFLu_course_fmriana.html



- Week 1 : Course Introduction and Overview***
- Week 2 : Principles of BOLD fMRI***
- Week 3 : Experimental Design of BOLD fMRI***
- Week 4 : Neuroanatomy and Image Atlas***
- Week 6 : Image Preprocessing of fMRI***
- Week 7 : Brain Activation - General Linear Model: Part I***
- Week 8 : Brain Activation - General Linear Model: Part II***
- Week 9 : Resting-State Brain Activity - ReHo and ALFF***
- Week 10 : Brain Network - Independent Component Analysis***
- Week 11 : Brain Network - Functional Connectivity***
- Week 12 : Brain Network - Dynamic Casual Modeling***
- Week 13 : Brain Network - Dynamic Functional Connectivity***
- Week 14 : Brain Network - Graph Theory and Topological***
- Week 15 : Brain Decoding - Multivariate Pattern Analysis***

Analysis of Functional Magnetic Resonance Imaging

(Graduate)

Elective Course for the Graduate Students
Lecturer: Chia-Feng Lu (alvin4016@ym.edu.tw)
功能性磁振影像分析 (醫放系研究所)
授課教師：盧家鋒

NBA

Laboratory of Neuroimage Biomarker Analysis

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Relevant Links

MRI (UG)
MRM (UG)
MRI Research (G)
MATLAB programming (UG)
MATLAB GUI (G)
Signal Processing (G)
Computer Sci. (UG)
Computer Arch. (UG)
fMRI Analysis (G)
rs-fMRI Analysis (G)
fNIRS Basics (G)
fNIRS Workshop (G)
Human Dissection (UG)
Neuroanatomy (UG)
Image Processing (R)
Invited Talks

Teaching Materials

- http://www.ym.edu.tw/~cflu/CFLu_course_fMRlana.html
- Please download...
 - **Week 8: Brain Activation – General Linear Model II**
<Materials > [fMRlana08_materials.zip](#)
 - **The same fMRI data in Week 6**
<Materials > [fMRlana06_materials.zip](#)

Employed Softwares

- **MRICro**

- <https://people.cas.sc.edu/rorden/mricro/mricro.html#Installation>
- <https://www.mccauslandcenter.sc.edu/crnl/mricro>

- **Statistical Parametric Mapping (SPM 12)**

- <http://www.fil.ion.ucl.ac.uk/spm/>

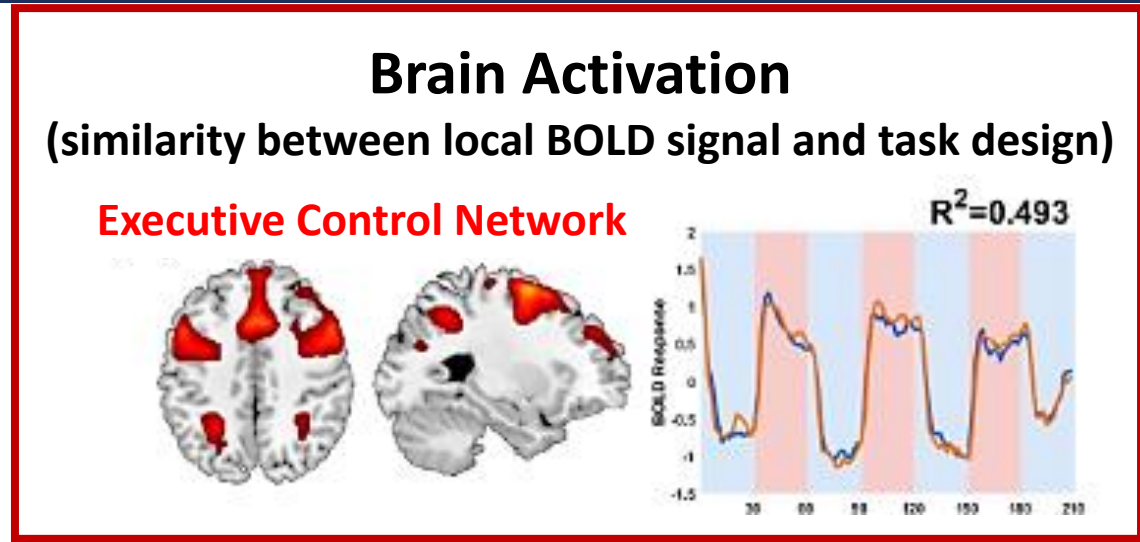
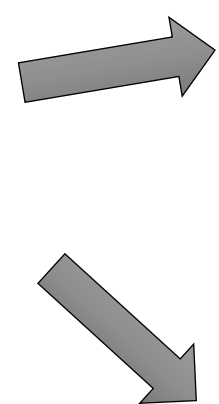
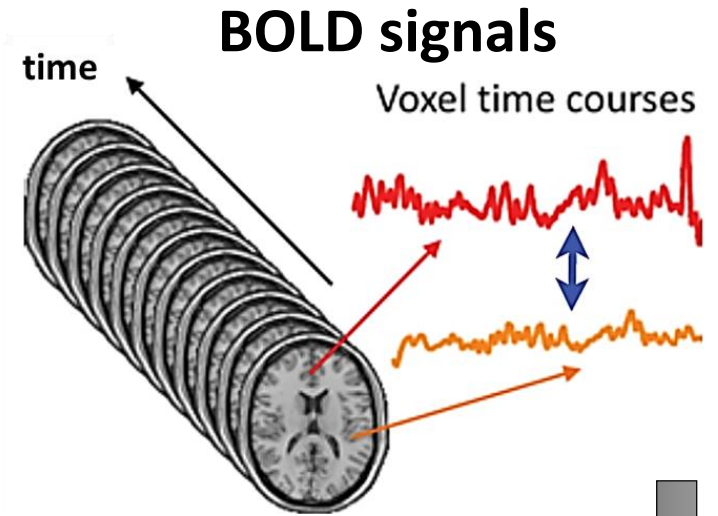


- **xjView (A viewing program for SPM)**

- <http://www.alivelearn.net/xjview/download/>

[Caution] File name\path contains Chinese character or space may cause error!

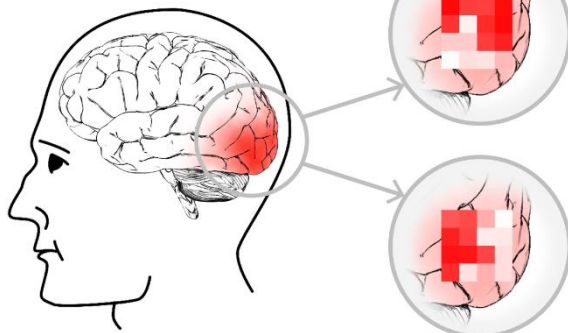
fMRI Analysis



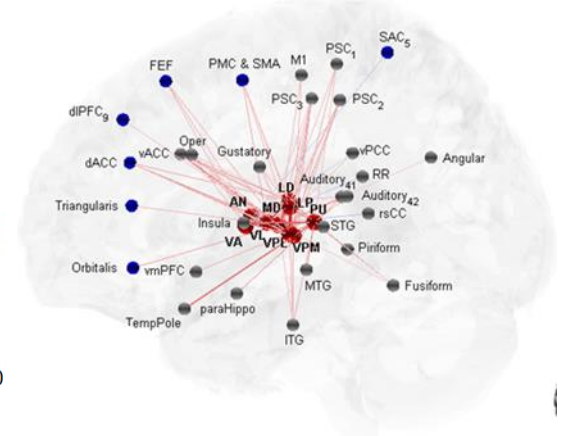
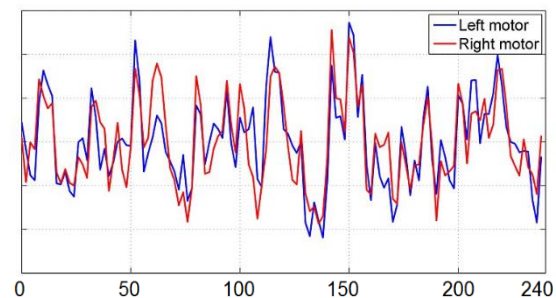
Brain Activity Pattern
(classification or similarity analysis)



Little activity  Much activity



Brain Connectivity
(dependencies of BOLD signals between brain regions)



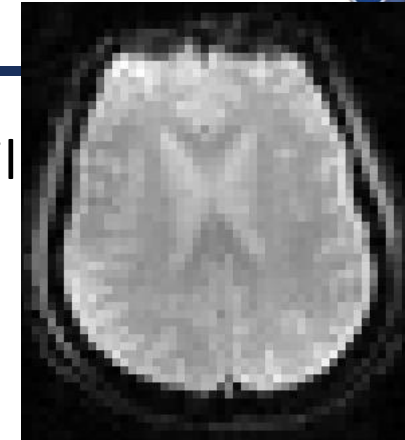
SPM Subject Analysis – 1st-level

http://www.ym.edu.tw/~cflu/CFLu_course_fMRIana.html

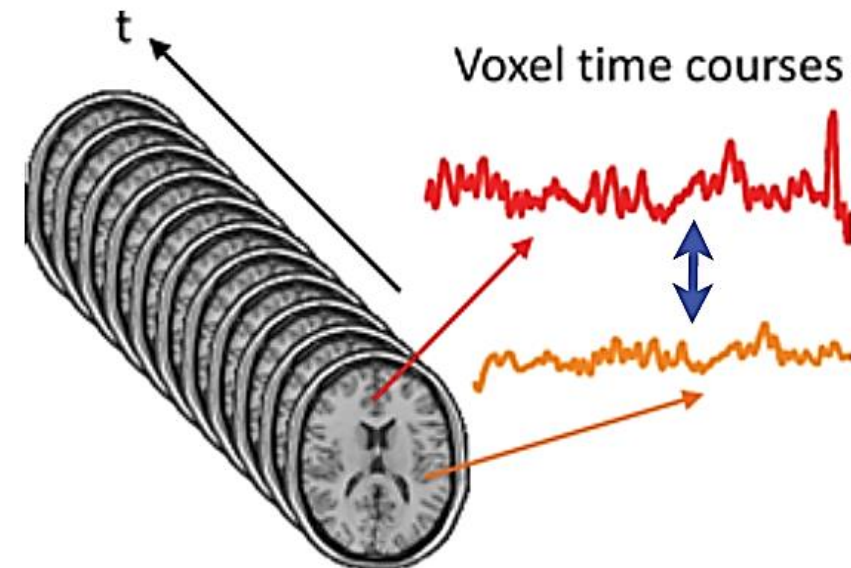
Week 7: Brain Activation – General Linear Model I

fMRI Protocol

- Siemens 3T MAGNETOM Trio Scanner @ NYMU, 32-channel head coil
- Single-Shot 2D EPI (GRE-EPI), T2* weighting
- Repetition Time = 2000 ms
- Echo Time = 20 ms
- Flip Angle = 70~90°
- NEX = 1
- Slice thickness = 3.4 mm
- Field of View = 220 x 220 mm²
- Matrix size = 64 x 64
- Slice number = 40
- Volume number (**depends on experiment design**)



3.44 x 3.44 x 3.40 mm³



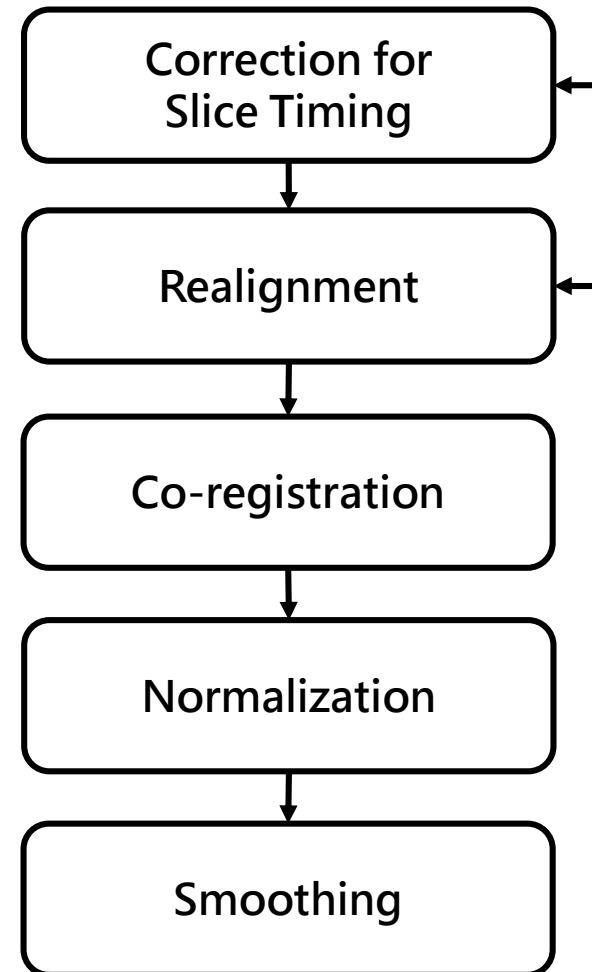
BOLD-fMRI Preprocessing

http://www.ym.edu.tw/~cflu/CFLu_course_fMRIana.html

Week 6: Image Preprocessing of fMRI

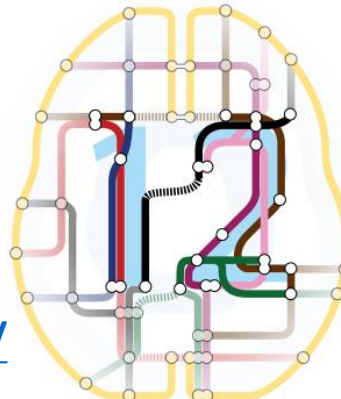


- Standard preprocessing steps for fMRI
 - Slice timing
 - Realignment
 - Co-registration (with anatomical images)
 - Normalization
 - Smoothing
 - Segment (tissue classification; optional)

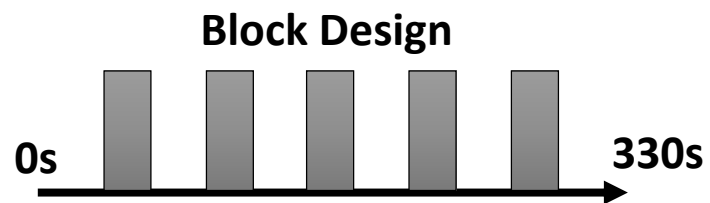
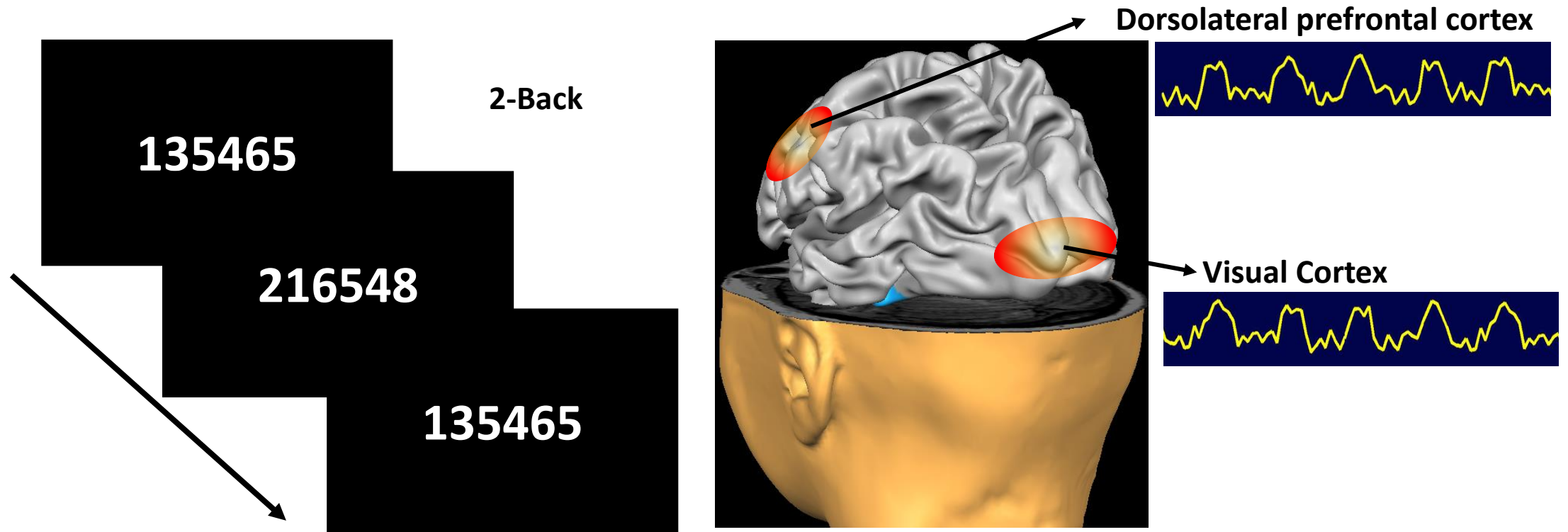


SPM

<https://www.fil.ion.ucl.ac.uk/spm/>



N-Back fMRI Data Acquisition



5 tasking blocks (duration = 30s) with resting interval (30s)

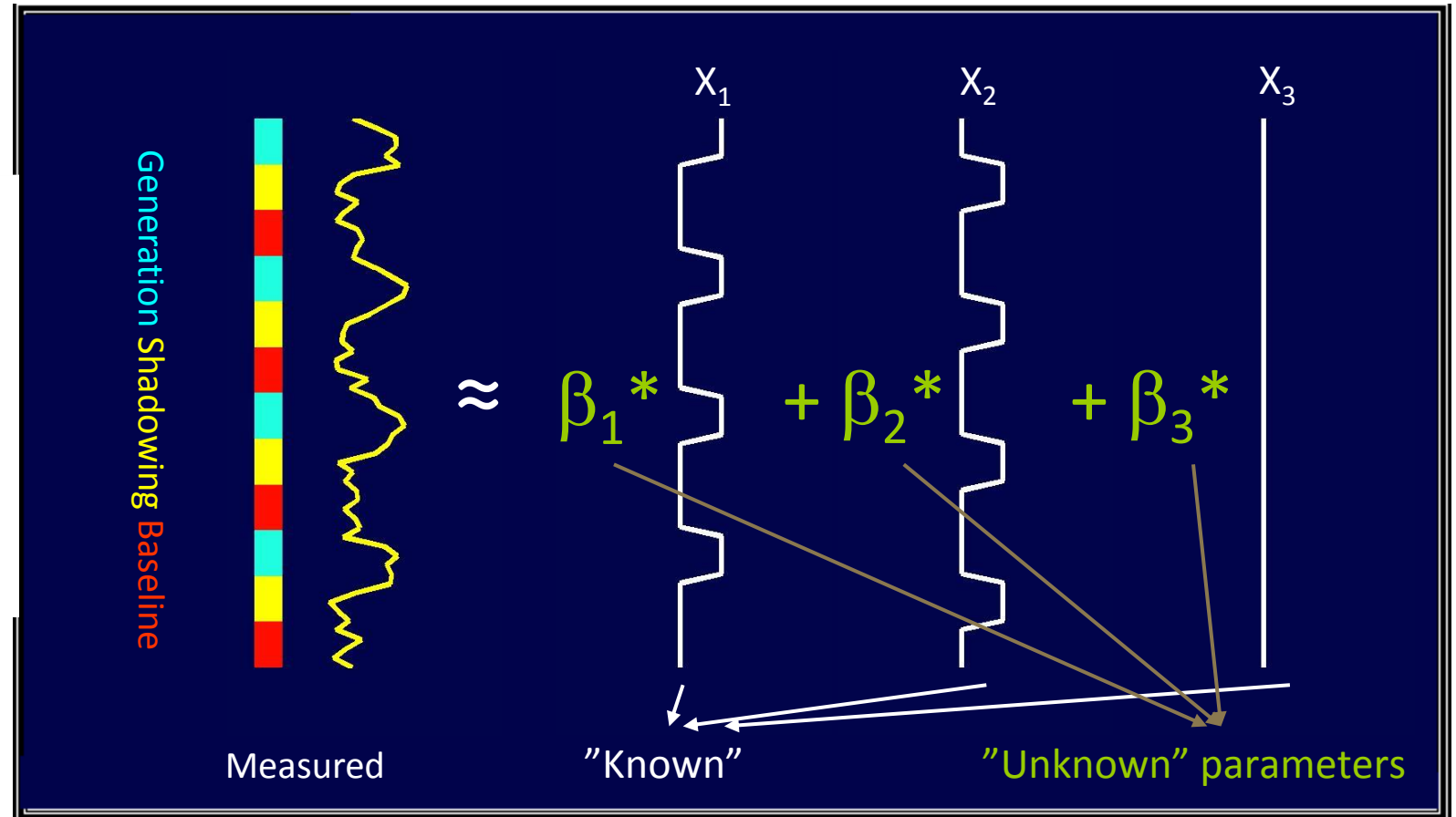
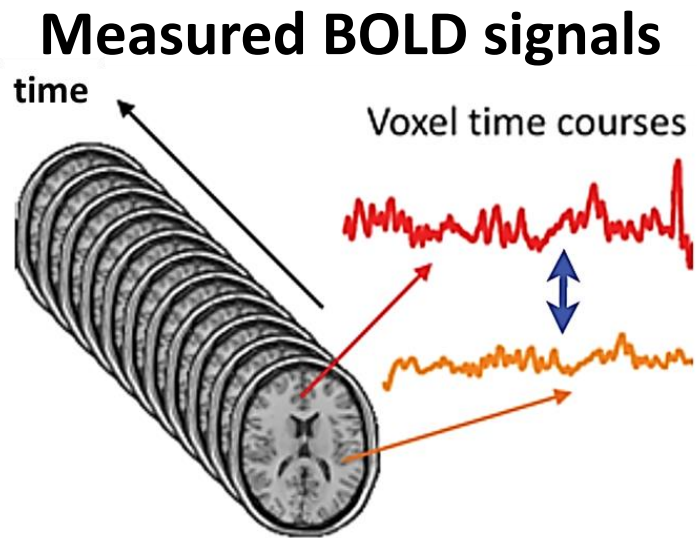
MRI

- BOLD fMRI:
One session of **task**
(visual stimuli)

The Model of General Linear Model (GLM)

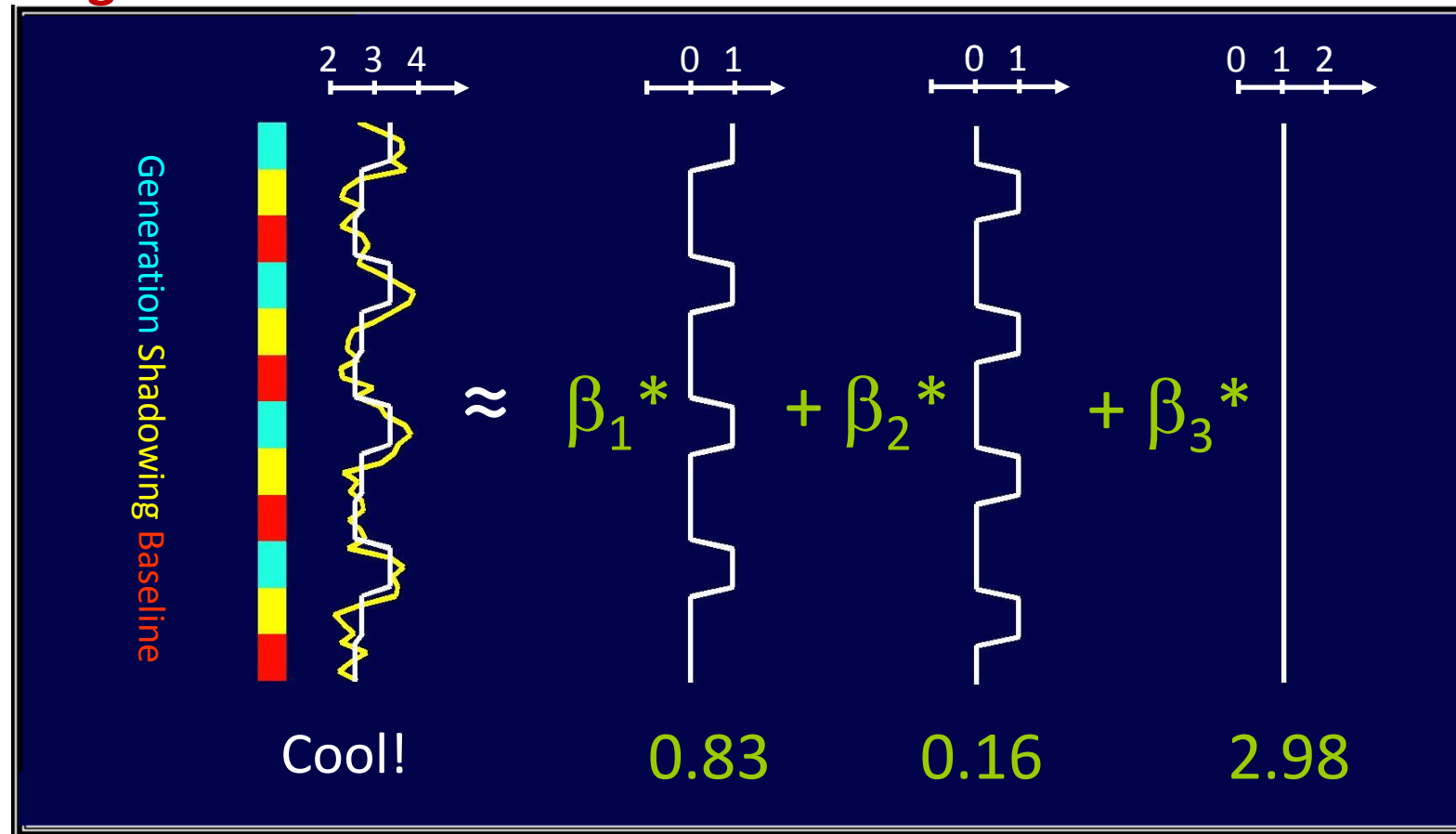


Finding the linear combination of these hypothetical time series "best" fits the data.



Parameter Estimation

Beta value represents the association between a condition design and the measured BOLD signal.

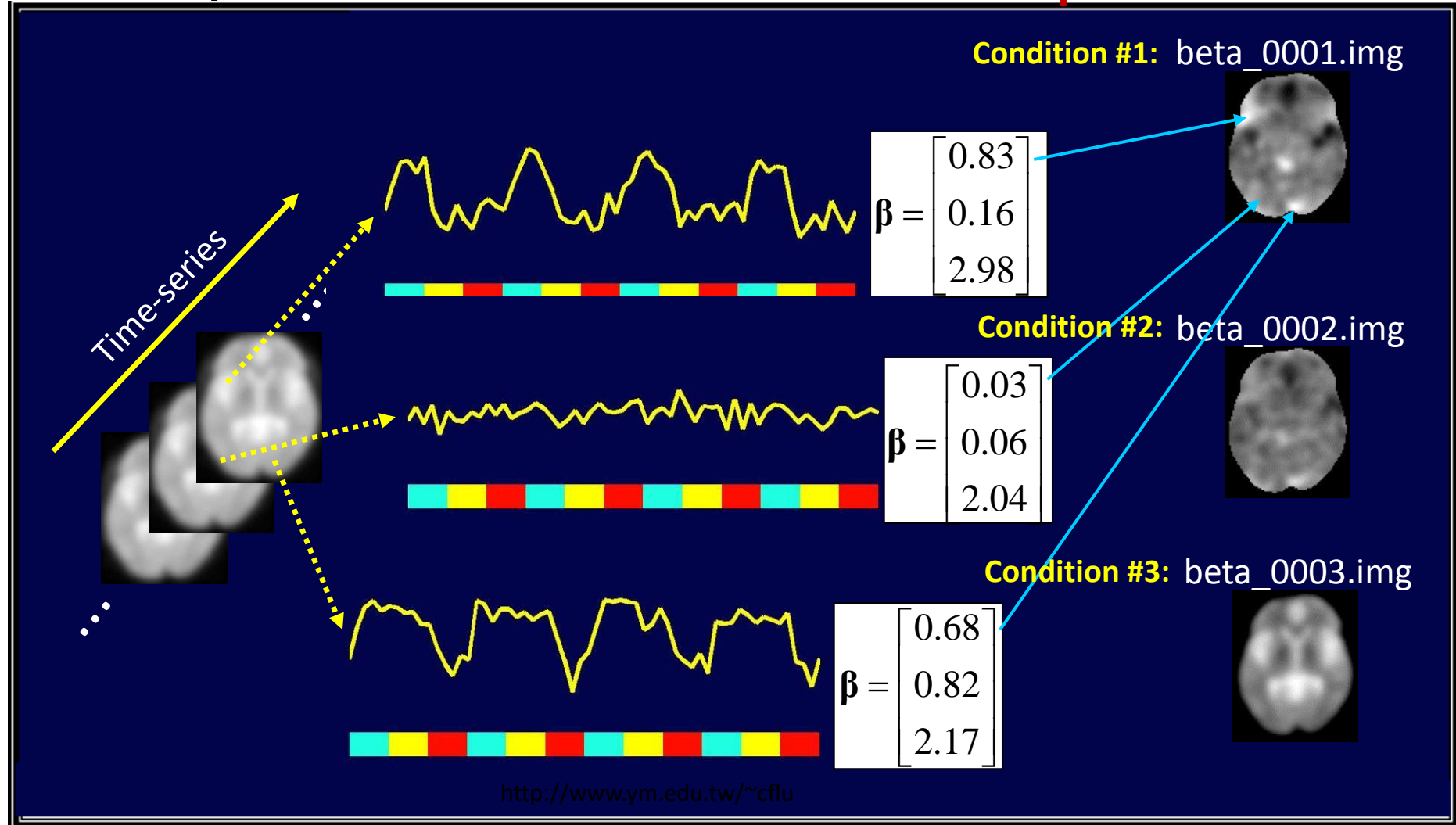


Parameter Estimation

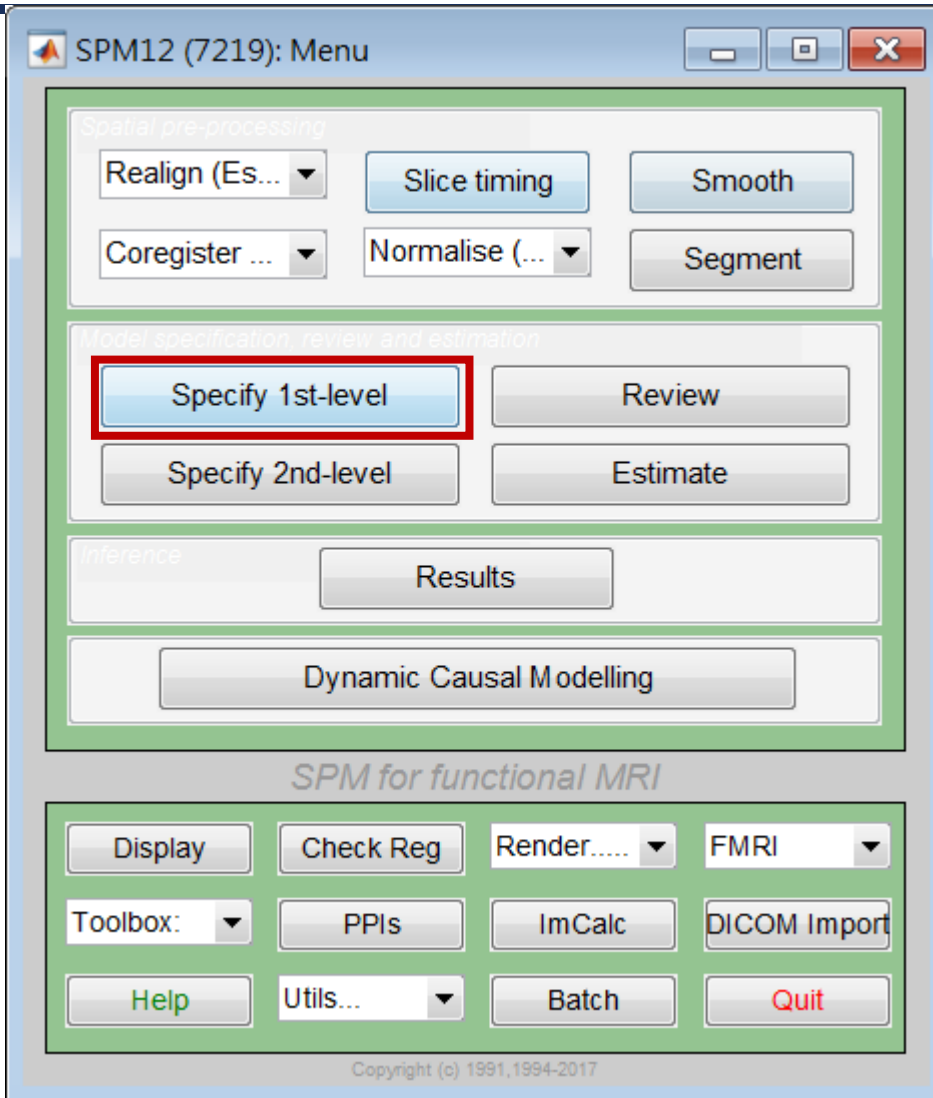
Same model for all voxels.

Different parameters for each voxel.

Beta map for each task condition



Specify 1st-level Model



SPM12 (7219): Menu

Spatial pre-processing

Realign (Es... | Slice timing | Smooth

Coregister ... | Normalise (... | Segment

Model specification, review and estimation

Specify 1st-level | Review

Specify 2nd-level | Estimate

Inference

Results

Dynamic Causal Modelling

SPM for functional MRI

Display | Check Reg | Render..... | FMRI

Toolbox: | PPIs | ImCalc | DICOM Import

Help | Utils... | Batch | Quit

Copyright (c) 1991,1994-2017

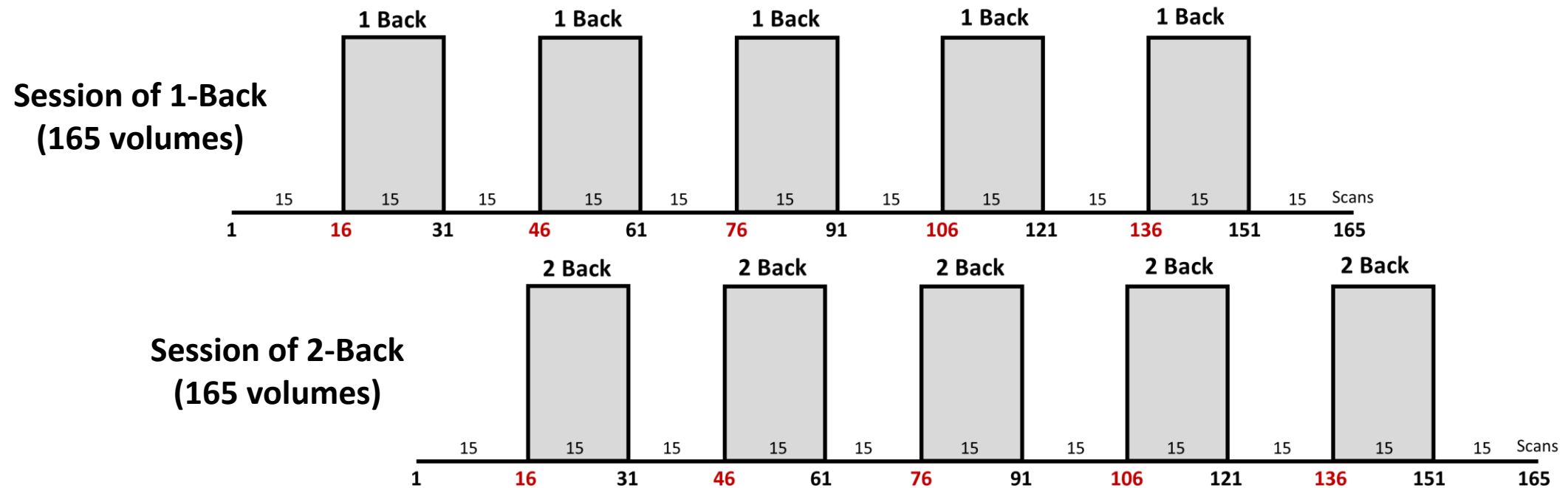
Current Module: fMRI model specification

Help on: fMRI model specification

Directory	<-X
Timing parameters	
. Units for design	<-X
. Interscan interval	<-X
. Microtime resolution	16
. Microtime onset	8
Data & Design	<-X
Factorial design	
Basis Functions	
. Canonical HRF	
. . Model derivatives	No derivatives
Model Interactions (Volterra)	...model Interactions
Global normalisation	None
Masking threshold	0.8
Explicit mask	
Serial correlations	AR(1)

Specify 1st-level Model

- Units for design = Scans
- Interscan interval = 2
- Microtime resolution = 40 (Slice number)
- Microtime onset = 1 (Reference Slice)
- Condition
 - Name = 1-Back or 2-Back
 - Onsets = [16 46 76 106 136]
 - Durations = 15
- Multiple regressors (rp_*.txt)



Specify 1st-level Model

- Data & Design
 - Subject/Session
 - Conditions

Current Item: Data & Design

New: Subject/Session

Replicate: Subject/Session (1)

Replicate: Subject/Session (2)

Delete: Subject/Session (1)

Delete: Subject/Session (2)

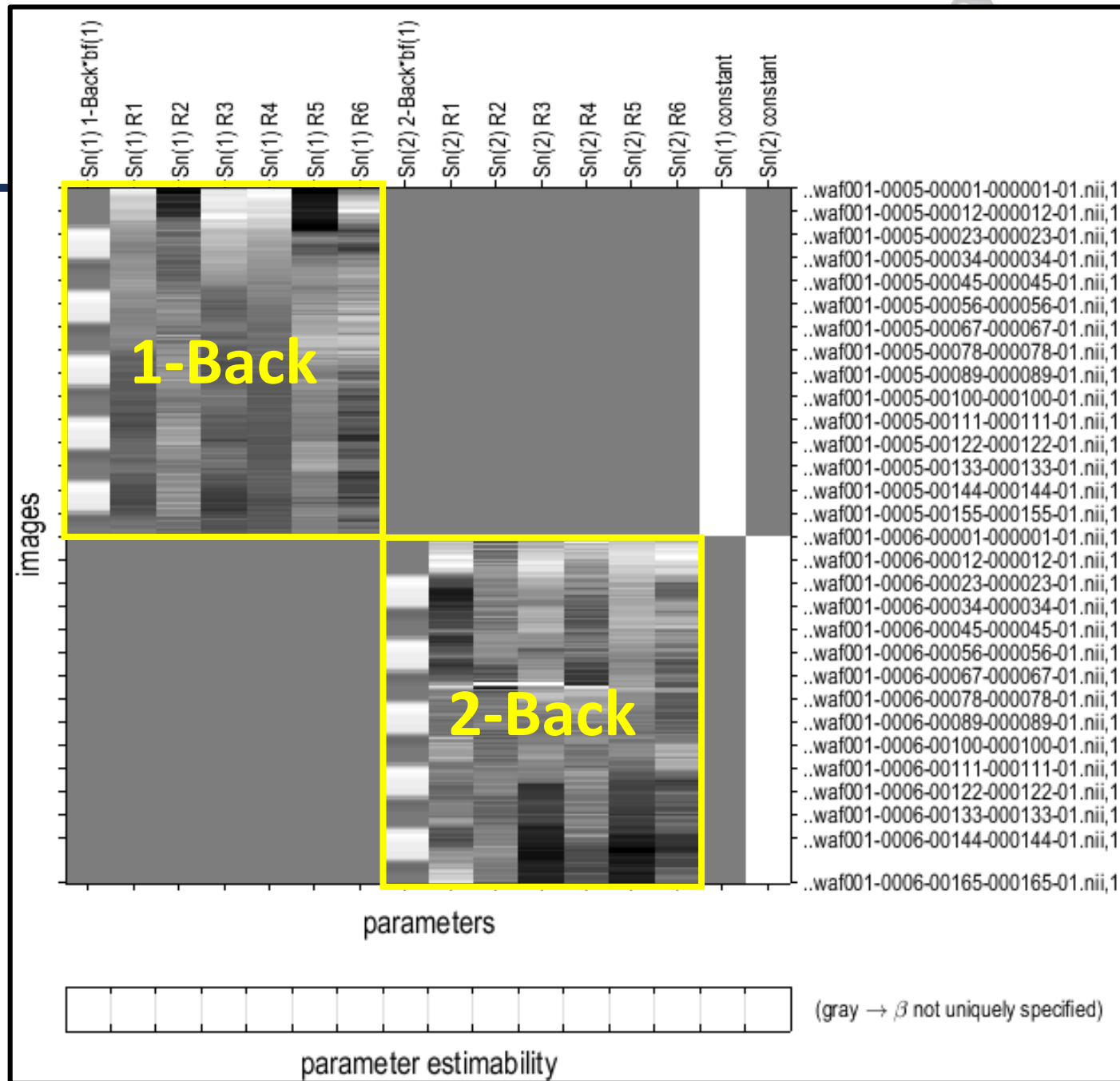
Data & Design	
. Subject/Session	(1)
.. Scans	<-X
.. Conditions	
... Condition	
.... Name	1-Back
.... Onsets	5x1 double
.... Durations	
.... Time Modulation	
.... Parametric Modulations	
.... Orthogonalise modulations	
.. Multiple conditions	
.. Regressors	
.. Multiple regressors	
.. High-pass filter	

. Subject/Session	(2)
.. Scans	<-X
.. Conditions	
... Condition	
.... Name	2-Back
.... Onsets	5x1 double
.... Durations	15
.... Time Modulation	No Time Modulation
.... Parametric Modulations	
.... Orthogonalise modulations	Yes
.. Multiple conditions	
.. Regressors	
.. Multiple regressors	
.. High-pass filter	128

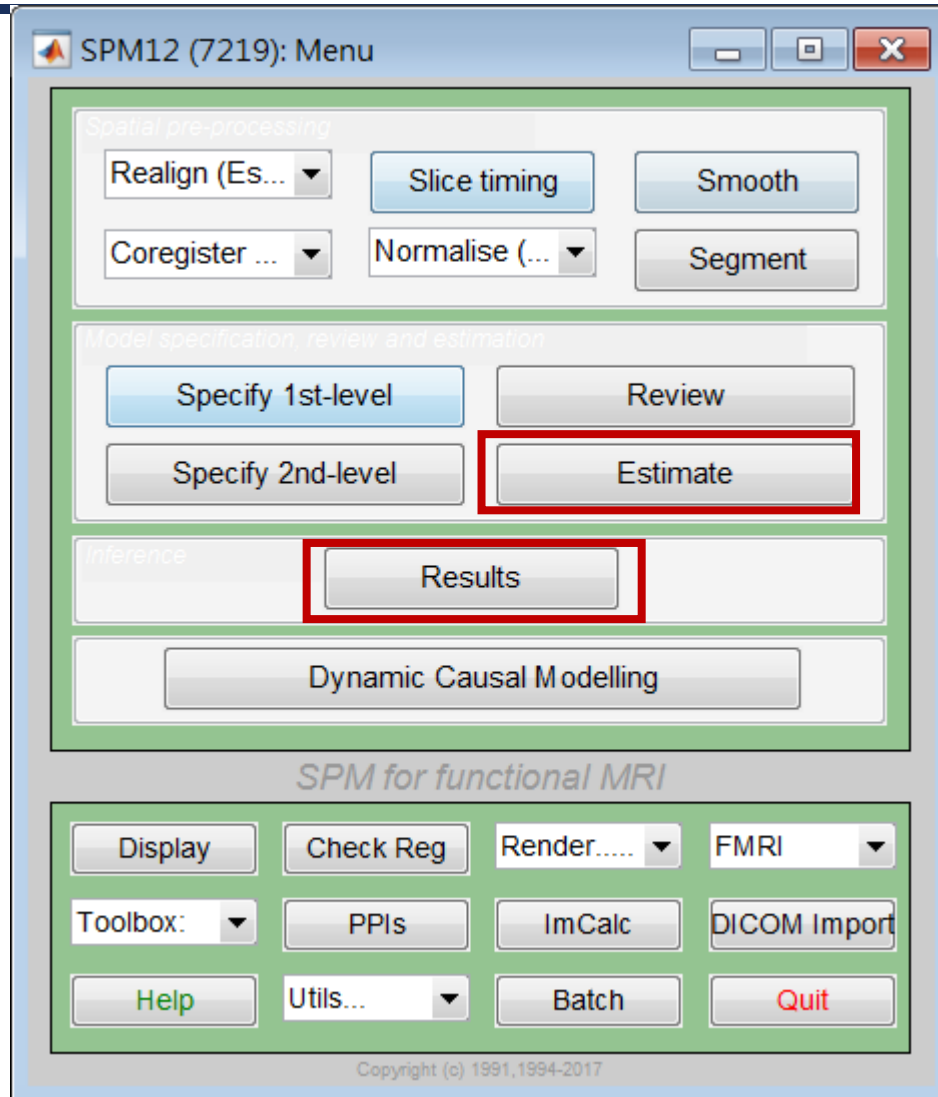
Load Nback_fullmodel.mat

Statistical Analysis: Design

Including both 1-Back and 2-Back datasets.



Estimate Model



Current Module: Model estimation	
Help on: Model estimation	
Select SPM.mat	...process\NBACK\SPM.mat
Write residuals	No
Method	
. Classical	

Review Results

FWE, $p < 0.05$
Cluster > 30 voxels

SPM contrast manager

Select contrasts...

show t-contrasts F-contrasts all

{type}: name

001 {T}: 2 Back - 1 Back

002 {T}: 1 Back & 2 Back

contrast(s)

Design matrix

parameter estimability

Define new contrast... Reset Done

Selected 1 contrast, press "Done" when finished.

2 Back - 1 Back

SPM{ T_{304} }

SPMresults: \process\NBACK
 Height threshold $T = 5.179337$ ($p < 0.05$ (FWE))
 Extent threshold $k = 30$ voxels

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_{\equiv})	p_{uncorr}			
0.000	2	0.000	0.000	92	0.000	0.000	0.027	6.51	6.29	0.000	46	40	26
						0.002	0.226	5.78	5.62	0.000	38	56	30
		0.000	0.000	50	0.000	0.000	0.050	6.18	6.00	0.000	28	2	68
						0.015	0.468	5.42	5.29	0.000	18	-4	78
						0.027	0.646	5.31	5.18	0.000	22	10	68

table shows 3 local maxima more than 8.0mm apart

Height threshold: $T = 5.18$, $p = 0.000$ (0.050)
 Extent threshold: $k = 30$ voxels, $p = 0.000$ (0.000)
 Expected voxels per cluster, $<k> = 0.943$
 Expected number of clusters, $<c> = 0.00$
 FWEp: 5.179, FDRp: 6.184, FWEc: 1, FDRc: 22

Degrees of freedom = [1.0, 304.0]
 FWHM = 6.9 6.8 6.5 mm mm mm; 3.4 3.4 3.3 {voxels}
 Volume: 1970176 = 246272 voxels = 5966.8 resels
 Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 38.17 voxels)

Review Results

FWE, $p < 0.05$
Cluster > 30 voxels

SPM contrast manager

Select contrasts...

show t-contrasts F-contrasts all

{type} : name

001 {T} : 2 Back - 1 Back

002 {T} : 1 Back & 2 Back

contrast(s)

Design matrix

parameter estimability

Define new contrast... Reset Done

Selected 1 contrast, press "Done" when finished.

1 Back & 2 Back

SPM(T₃₀₄)

SPMresults: .\process\NBACK
Height threshold T = 5.179337 { $p < 0.05$ (FWE)}
Extent threshold k = 30 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> _{FWE-corr}	<i>q</i> _{FDR-corr}	<i>k</i> _E	<i>p</i> _{uncorr}	<i>P</i> _{FWE-corr}	<i>q</i> _{FDR-corr}	<i>T</i>	(<i>Z</i> ₌)	<i>p</i> _{uncorr}			
0.000	12	0.000	0.000	8342	0.000	0.000	0.000	12.38	Inf	0.000	12	-62	66
						0.000	0.000	12.23	Inf	0.000	26	-62	52
						0.000	0.000	12.21	Inf	0.000	26	-60	44
		0.000	0.000	2749	0.000	0.000	0.000	11.82	Inf	0.000	60	20	30
						0.000	0.000	9.20	Inf	0.000	46	26	24
						0.000	0.000	9.14	Inf	0.000	50	6	32
		0.000	0.000	1863	0.000	0.000	0.000	9.89	Inf	0.000	-60	18	36
						0.000	0.000	8.88	Inf	0.000	-56	14	46
						0.000	0.000	8.72	Inf	0.000	-38	2	62
		0.000	0.000	1131	0.000	0.000	0.000	9.55	Inf	0.000	-32	-66	-22
						0.000	0.000	8.21	7.79	0.000	-40	-52	-26
						0.000	0.000	7.83	7.47	0.000	-56	-60	-8
		0.000	0.000	276	0.000	0.000	0.000	8.29	Inf	0.000	2	14	56
						0.002	0.081	5.78	5.63	0.000	-2	20	44
						0.003	0.105	5.72	5.57	0.000	-8	18	56
		0.000	0.000	119	0.000	0.000	0.000	7.29	7.00	0.000	52	-42	18
						0.000	0.004	6.45	6.24	0.000	46	-38	26
		0.000	0.000	120	0.000	0.000	0.000	7.29	6.99	0.000	-34	-68	-52
						0.000	0.000	7.10	6.83	0.000	-22	-66	-48
		0.000	0.000	72	0.000	0.000	0.000	7.21	6.92	0.000	-66	-34	16

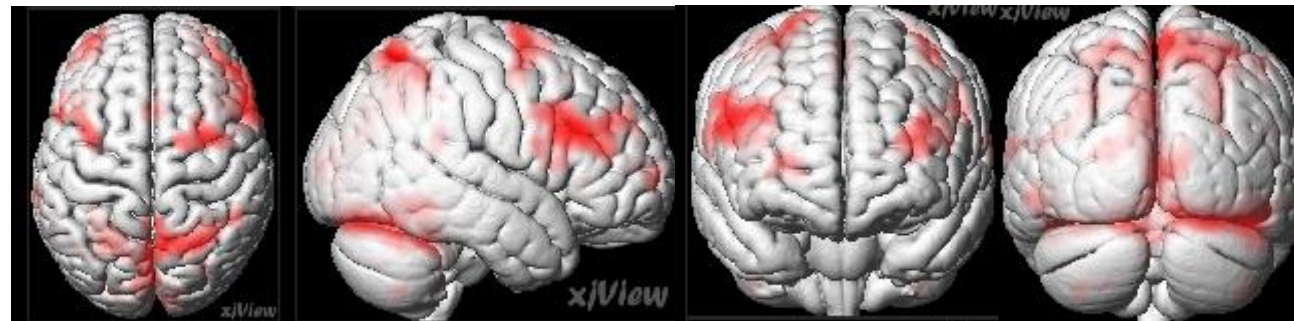
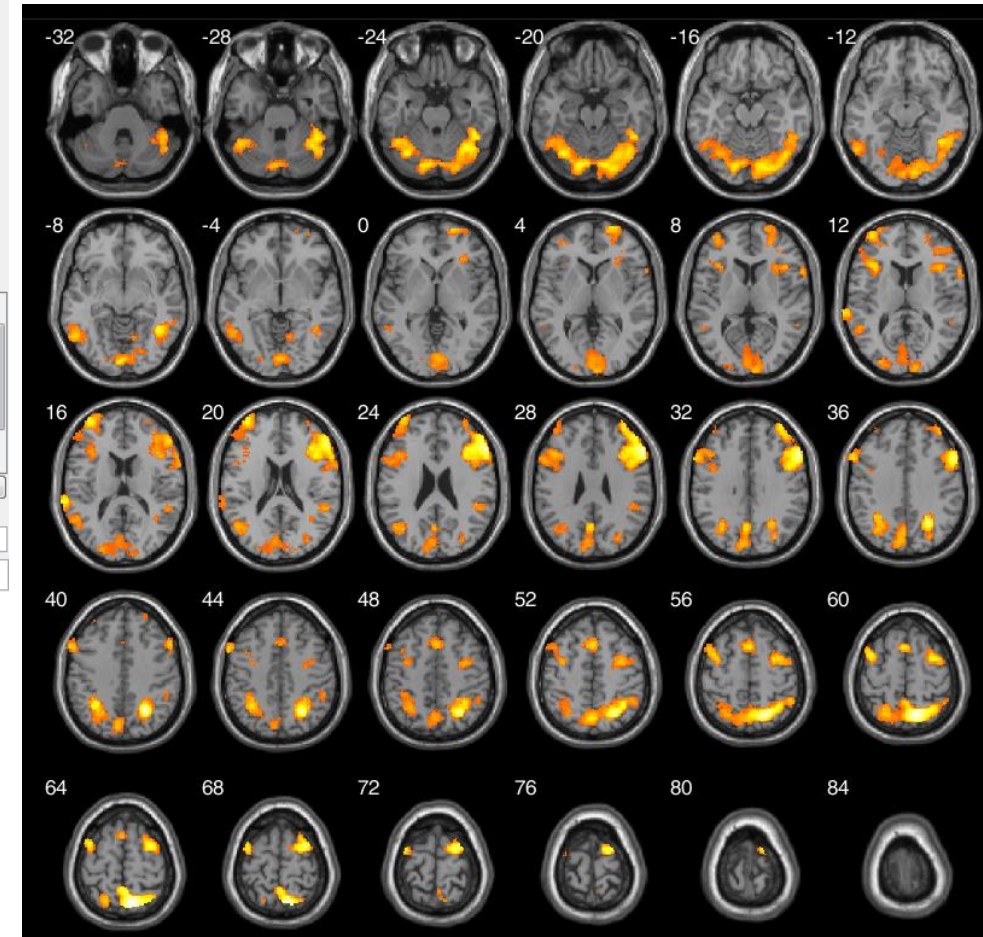
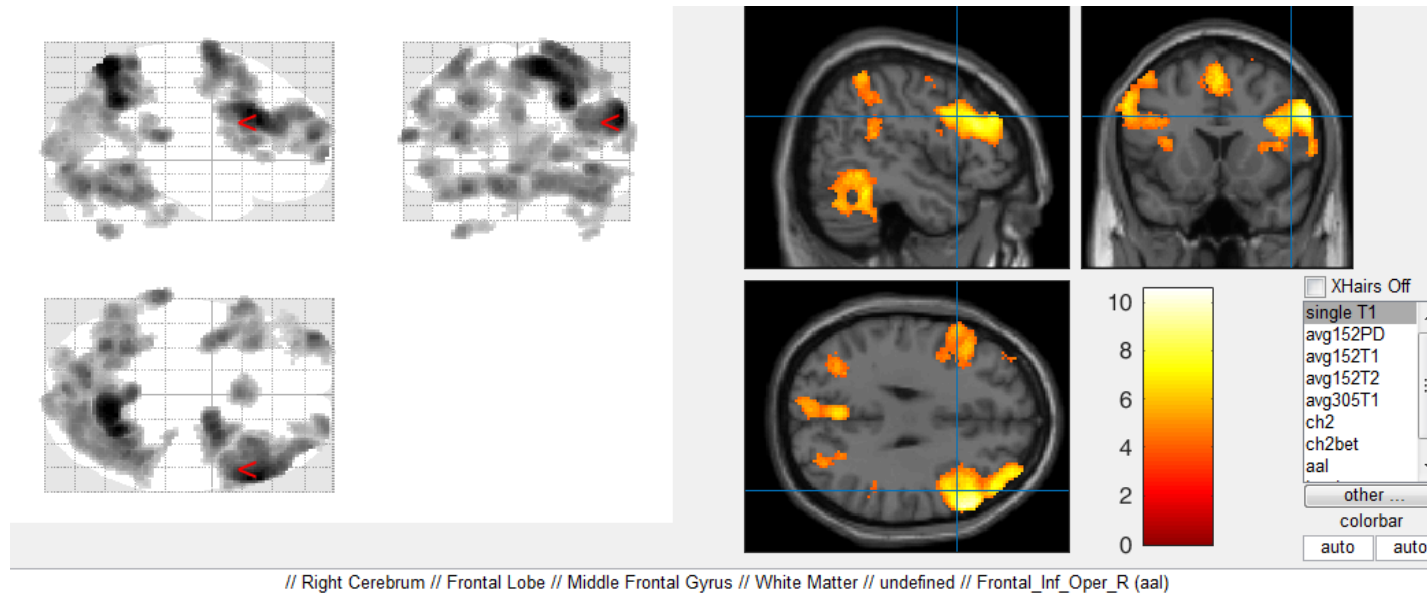
table shows 3 local maxima more than 8.0mm apart

Height threshold: T = 5.18, $p = 0.000$ (0.050)
Extent threshold: k = 30 voxels, $p = 0.000$ (0.000)
Expected voxels per cluster, $<k> = 0.943$
Expected number of clusters, $<c> = 0.00$
FWEp: 5.179, FDRp: 5.903, FWEc: 1, FDRc: 5

Degrees of freedom = [1.0, 304.0]
FWHM = 6.9 6.8 6.5 mm mm mm; 3.4 3.4 3.3 {voxels}
Volume: 1970176 = 246272 voxels = 5966.8 resels
Voxel size: 2.0 2.0 2.0 mm mm mm; (resel = 38.17 voxels)

Page 1

xjview



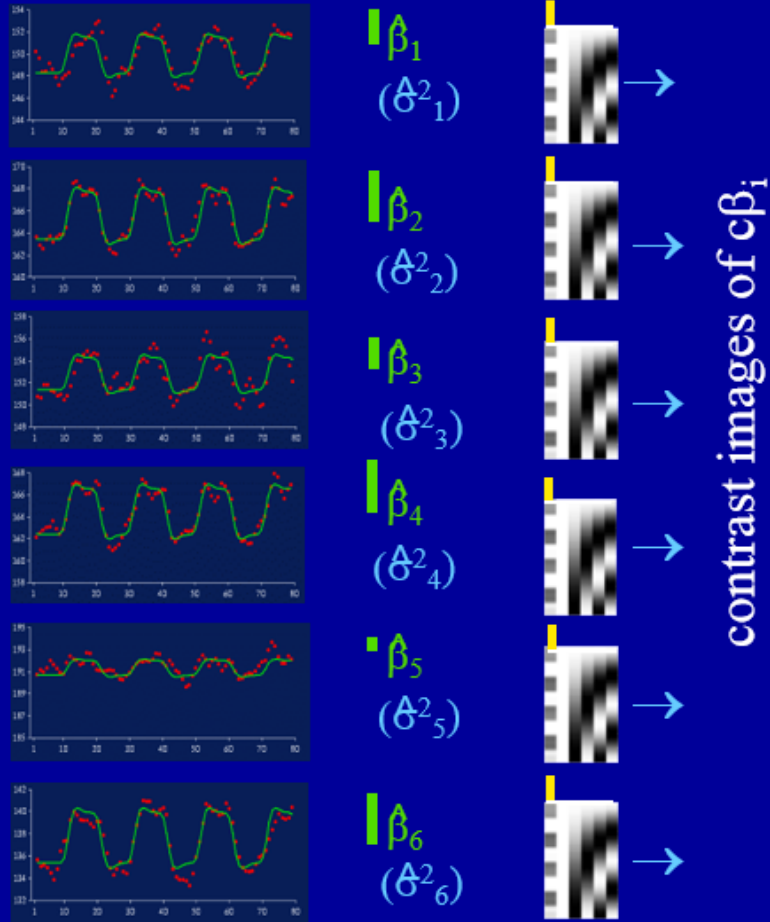
SPM Group Analysis – 2nd-level

http://www.ym.edu.tw/~cflu/CFLu_course_fMRIana.html

Week 8: Brain Activation – General Linear Model II

Two-stage “Summary Statistic” approach

1st-level (within-subject)

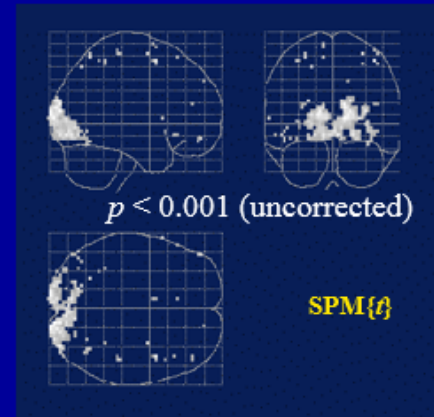
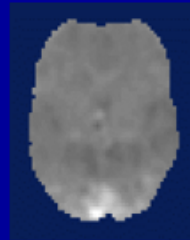


contrast images of $c\beta_i$

2nd-level (between-subject)

One-sample
t-test

N=6 subjects
(error df=5)



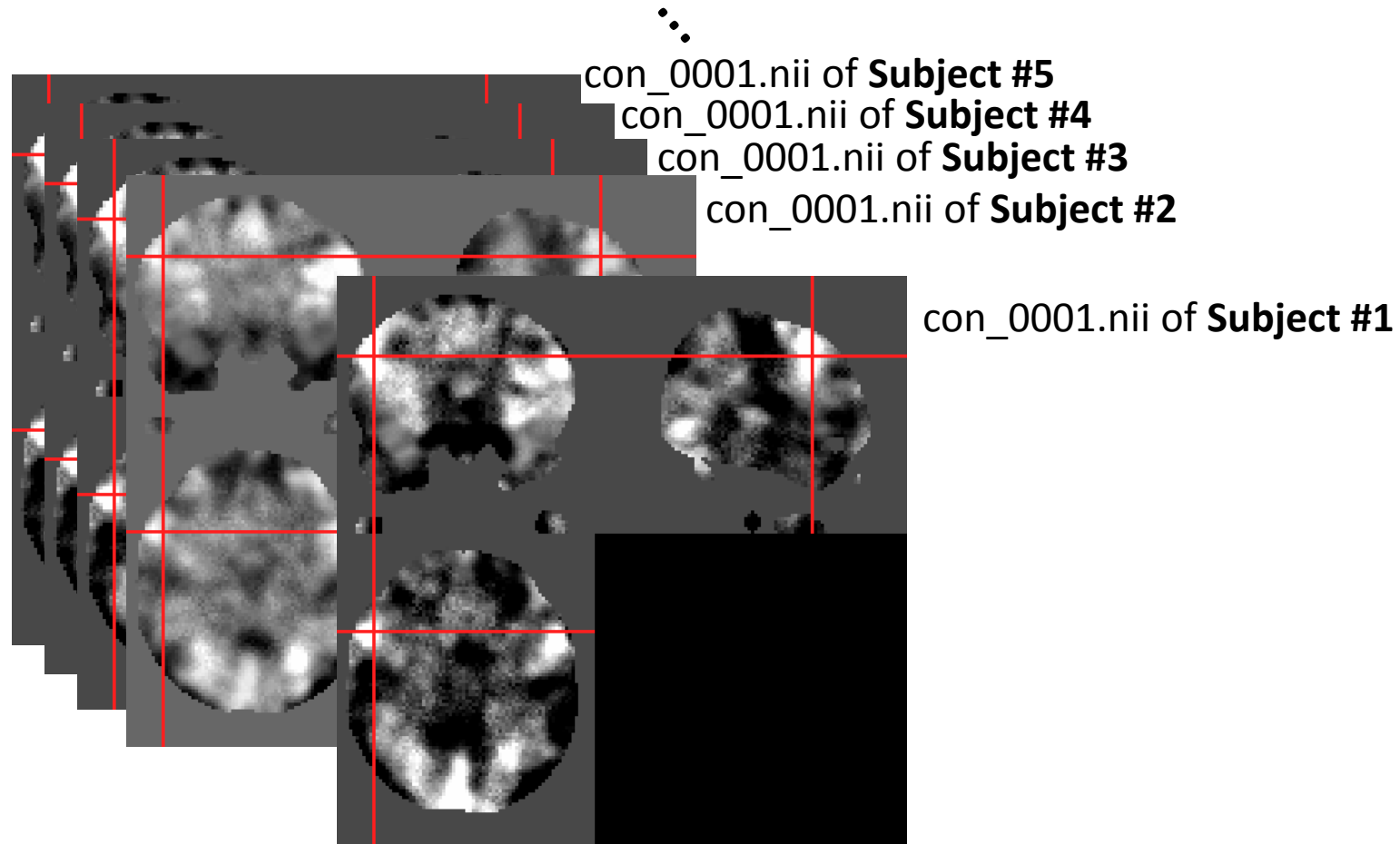
WHEN special case of n
independent observations per
subject:

$$\text{var}(\hat{\beta}_{pc}) = \sigma_b^2 / N + \sigma_w^2 / Nn$$

$\hat{\sigma}_w^2 =$ within-subject error

Quoted from **Irma Kurniawan's lecture**
“2nd level analysis –
design matrix,
contrasts and
inference”

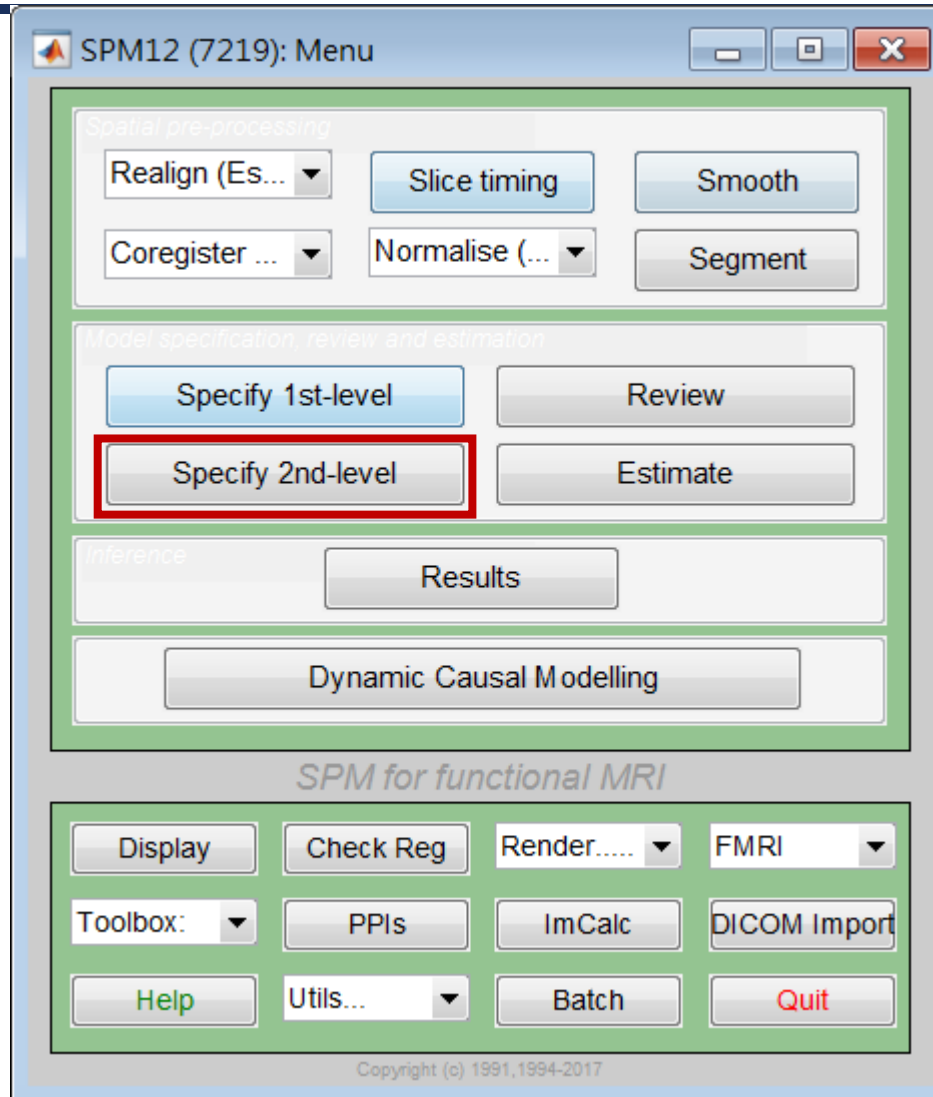
Statistical Inference on Group Data



fMRIana08_materials\Data

- BI_1Back
- BI_2-1Back
- BI_2Back
- HC_1Back
- HC_2-1Back
- HC_2Back

Specify 2nd-level Model



Current Module: Factorial design specification

Help on: Factorial design specification

Directory <-X

Design

- . One-sample t-test
- . . Scans <-X

Covariates

Multiple covariates

Masking

- . Threshold masking
- . . None
- . Implicit Mask Yes
- . Explicit Mask

Global calculation

- . Omit

Global normalisation

- . Overall grand mean scaling
- . . No
- . Normalisation None₂₄

Specify 2nd-level Model

Current Module: Factorial design specification

Help on: Factorial design specification

Directory <-X

Design

. One-sample t-test

. . Scans <-X

Covariates

Multiple covariates

Masking

. Threshold maski

Current Item: Design

***One-sample t-test**

Two-sample t-test

Paired t-test

Multiple regression

One-way ANOVA

One-way ANOVA - within subject

Full factorial

Flexible factorial

To identify the activation maps that consistently present across subjects.

Ex: 2-Back brain activations in healthy controls.

To identify the activation maps that significantly different between two groups.

Ex: Difference of 2-Back brain activations between healthy controls and brain Injury patients.

To identify the activation maps that significantly different between two conditions.

Ex: Difference of brain activations between pre- and post-treatment conditions in brain Injury patients.

Specify 2nd-level Model – one sample

To identify the 2-Back activation that consistently present across HC subjects.

Current Module: Factorial design specification

Help on: Factorial design specification

Directory: ...aterials\Data

Design

- . One-sample t-test
- . Scans** 10 files

Covariates

Multiple covariates

Masking

Data\HC_2Back

SPM contrast manager

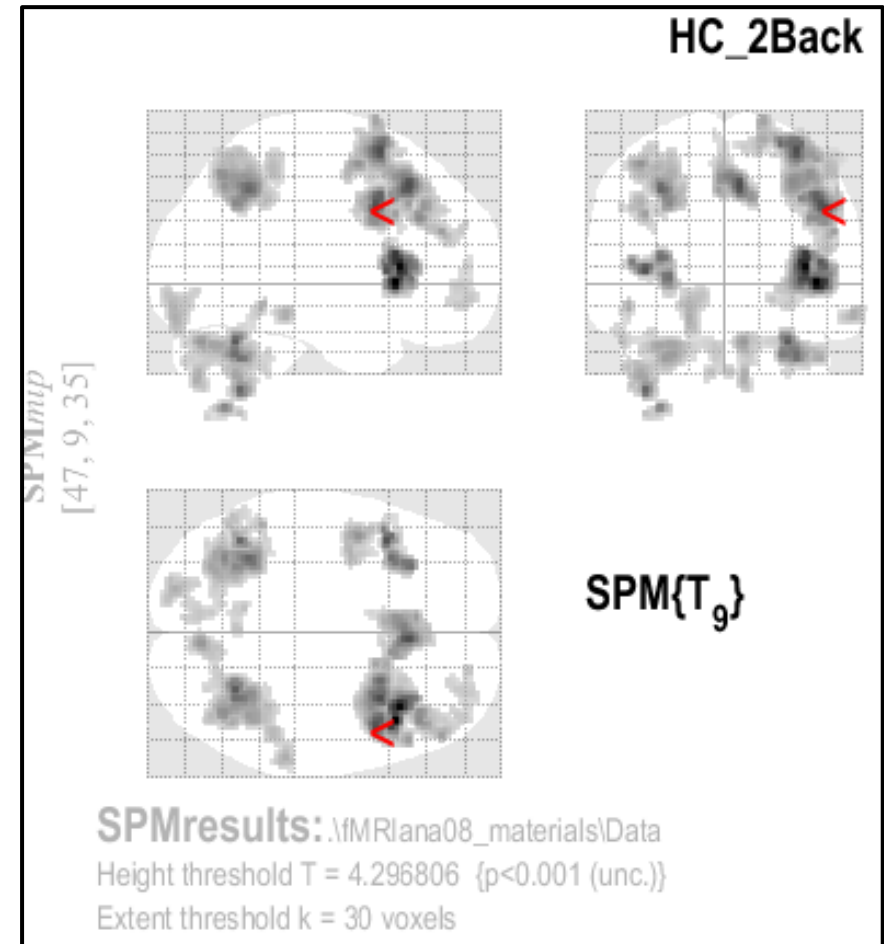
Select contrasts...

show

t-contrasts F-contrasts all

### (type) : name	contrast(s)
001 (T) : HC_2Back	

p<0.001 without FWE
Cluster > 30 voxels



Specify 2nd-level Model – two sample

To identify the difference of 2-Back brain activations between HC and BI subjects.

Current Module: Factorial design specification

Help on: Factorial design specification

Directory <-X

Design

- . Two-sample t-test
- . . Group 1 scans 10 files
- . . Group 2 scans 10 files
- . . Independence
- . . Variance
- . . Grand mean scal
- . . ANCOVA

Covariates

Data\HC_2Back
Data\BI_2Back

SPM contrast manager

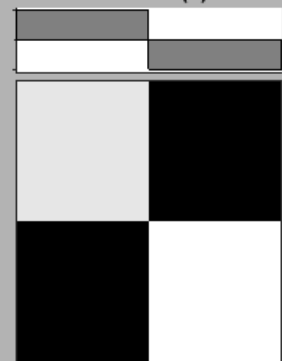
Select contrasts...

show

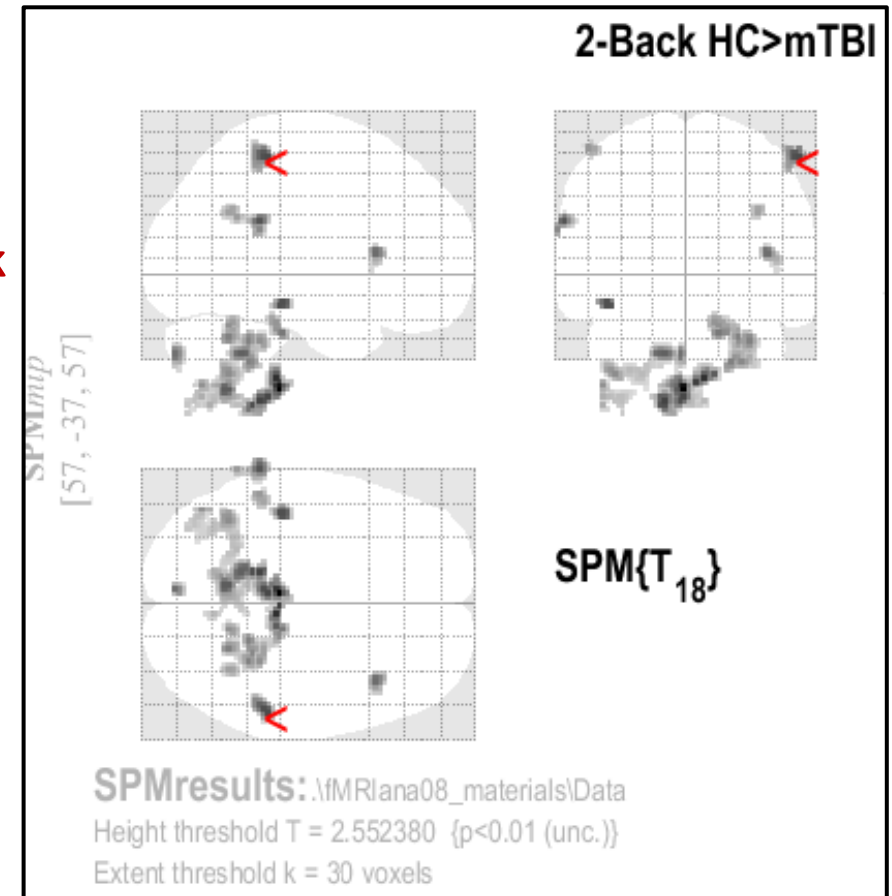
t-contrasts F-contrasts all

###	{type}	name
001	{T}	2-Back HC>mTBI
002	{T}	2 Back HC<mTBI

contrast(s)



p<0.01 without FWE
Cluster > 30 voxels



Specify 2nd-level Model – One-way ANOVA – within subject

Specify 4 files for each subject.

Conditions [1 2 3 4] represent there are four repeated scans for each subject.

Current Module: Factorial design specification

Help on: Factorial design specification

Directory c:\Temp

Design

- . One-way ANOVA - within subject
- .. Subjects
 - ... Subject **Subject #1**
 - Scans 4 files
 - Conditions [1 2 3 4]
 - ... Subject **Subject #2**
 - Scans 4 files
 - Conditions [1 2 3 4]
 - ... Subject **Subject #3**
 - Scans 4 files
 - Conditions [1 2 3 4]
- .. Independence No
- .. Variance Unequal
- .. Grand mean scaling No
- ANCOVA No

Current Item: Subjects

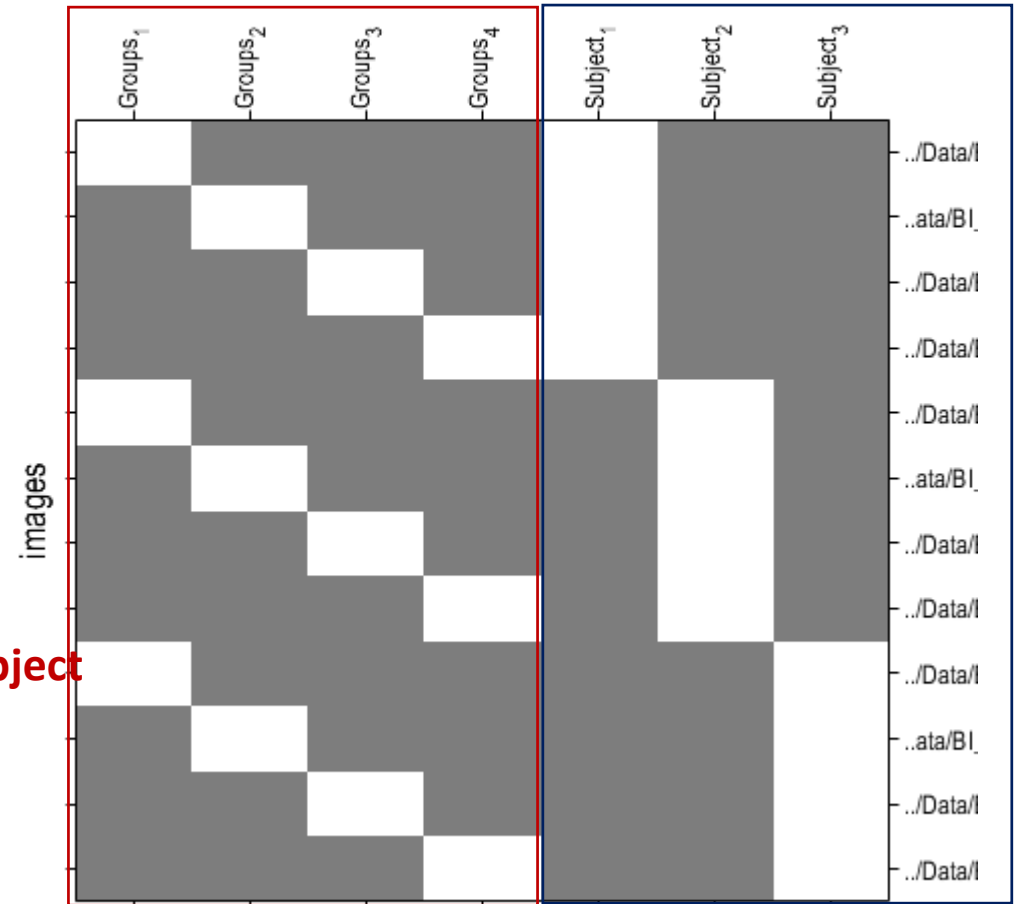
New: Subject

- Replicate: Subject (1)
- Replicate: Subject (2)
- Replicate: Subject (3)
- Delete: Subject (1)
- Delete: Subject (2)

Statistical analysis: Design

Totally 12 files from 4 different conditions (Groups)

Scans for each subject (Repetition)



Press New: Subject to add in a subject (three subjects in this example)

Factorial Design (1/2)

- Combining two or more factors within a task and looking at the effect of one factor on the response to other factor.

- Main effects**

- Main effect of task:
 $(A1+B1) - (A2+B2)$
- Main effect of stimuli:
 $(A1+A2) - (B1+B2)$

N-back Load (1/2)

		Viewing	Naming
Group (A/B)	Gray-level	A1	A2
	Color	B1	B2

Factorial Design (2/2)

- Combining two or more factors within a task and looking at the effect of one factor on the response to other factor.

- Interaction of task and stimuli**

- $(A1 - B1) - (A2 - B2)$
or $(A1 - A2) - (B1 - B2)$

Does not make the assumption of pure insertion.

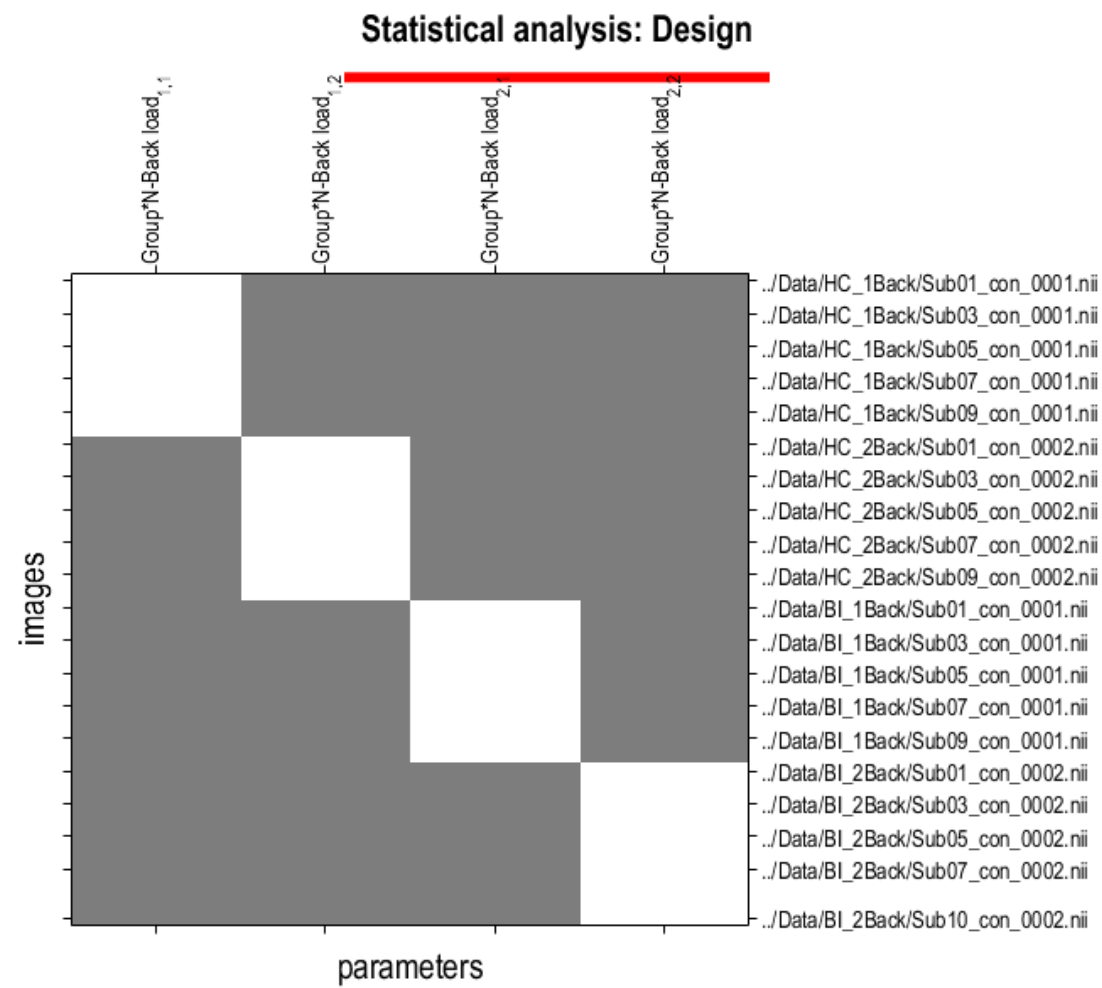
N-back Load (1/2)

		Viewing	Naming
Group (A/B)	Gray-level	A1	A2
	Color	B1	B2

Factorial design

Design	
. Full factorial	
.. Factors	
... Factor	
.... Name	Group
.... Levels	2
.... Independence	Yes
.... Variance	Unequal
.... Grand mean scaling	No
... Factor	
.... Name	N-Back load
.... Levels	2

.... Independence	.. Cells	
.... Variance	... Cell	
.... Grand mean scaling	.... Levels	[1 1]
.... ANCOVA	.... Scans	10 files
	... Cell	
	.... Levels	[1 2]
	.... Scans	10 files
	... Cell	
	.... Levels	[2 1]
 Scans	10 files
	... Cell	
 Levels	[2 2]
 Scans	10 files
	.. Generate contrasts	Yes



THE END

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Teaching Materials: http://www.ym.edu.tw/~cflu/CFLu_course_fMRIana.html