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# First level fMRI data analysis

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# Outline

- We learned the general linear model (GLM), preprocessing, and experimental design

- What is next:

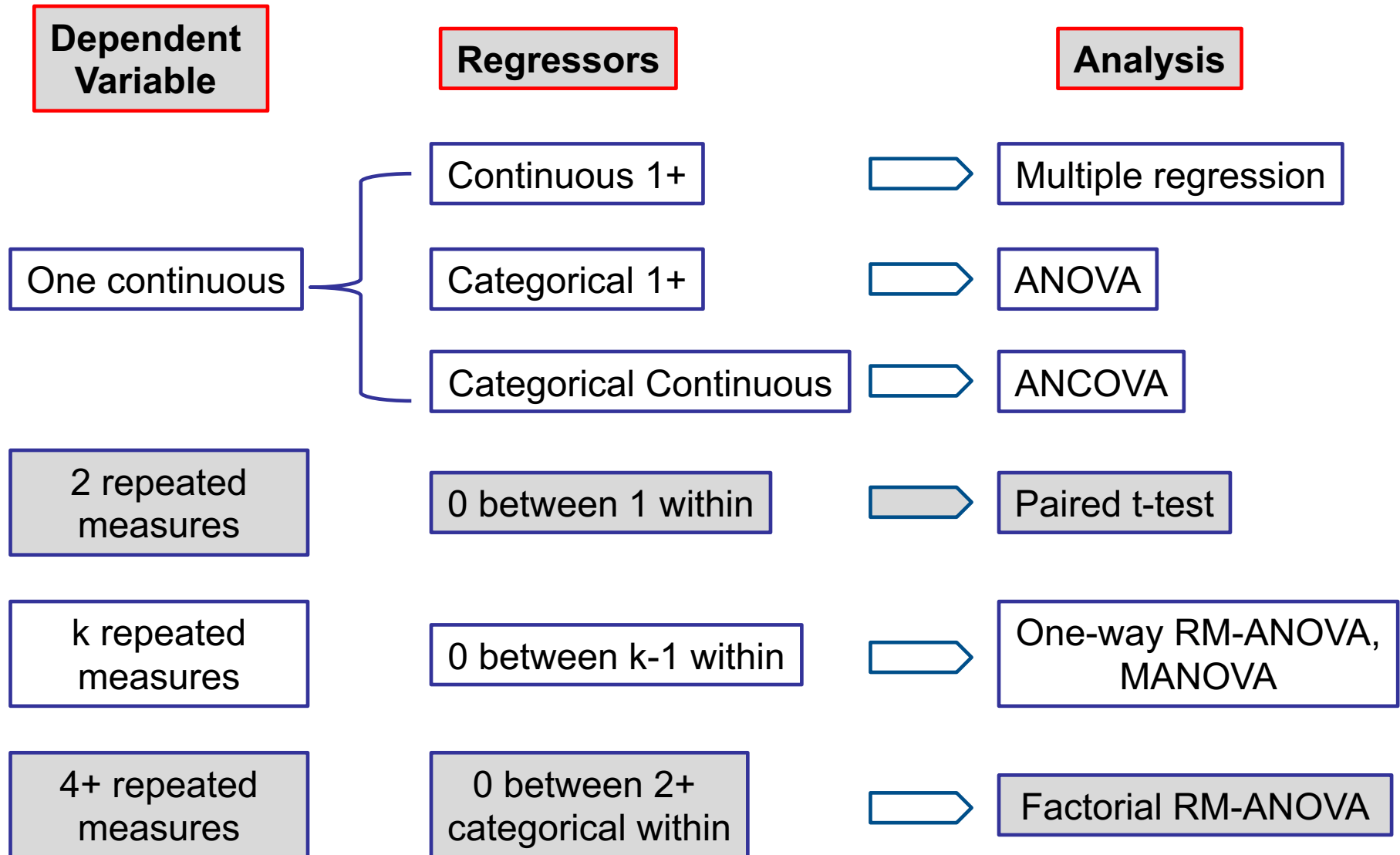
Apply the GLMs to the preprocessed data

**Note:** 1st level analysis = within subject analysis

# Outline

- Statistical models according to experiment design
- Contrasts
- Operation in SPM12
  - To set the parameters
  - To make contrasts: T contrasts

# The general linear model (GLM) family



# Mass univariate approach

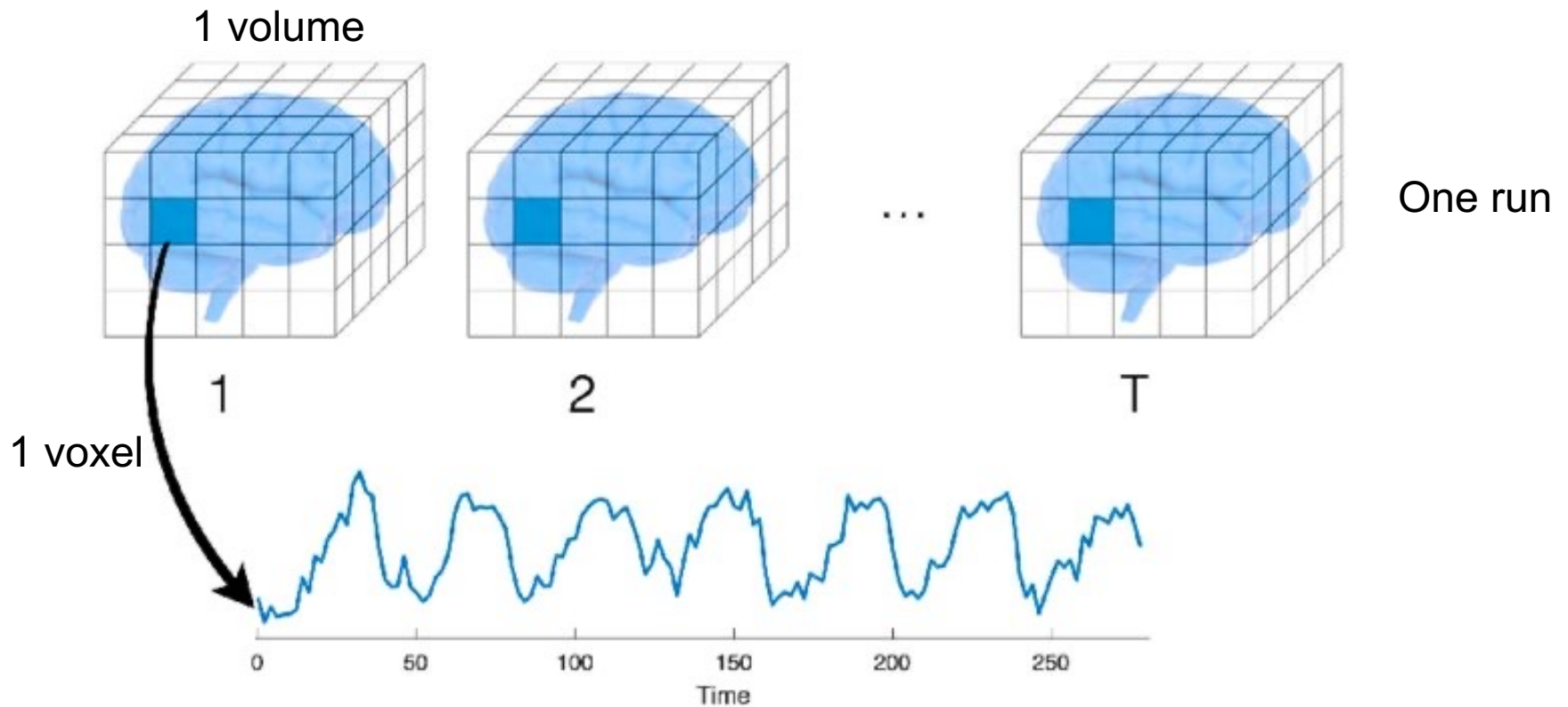
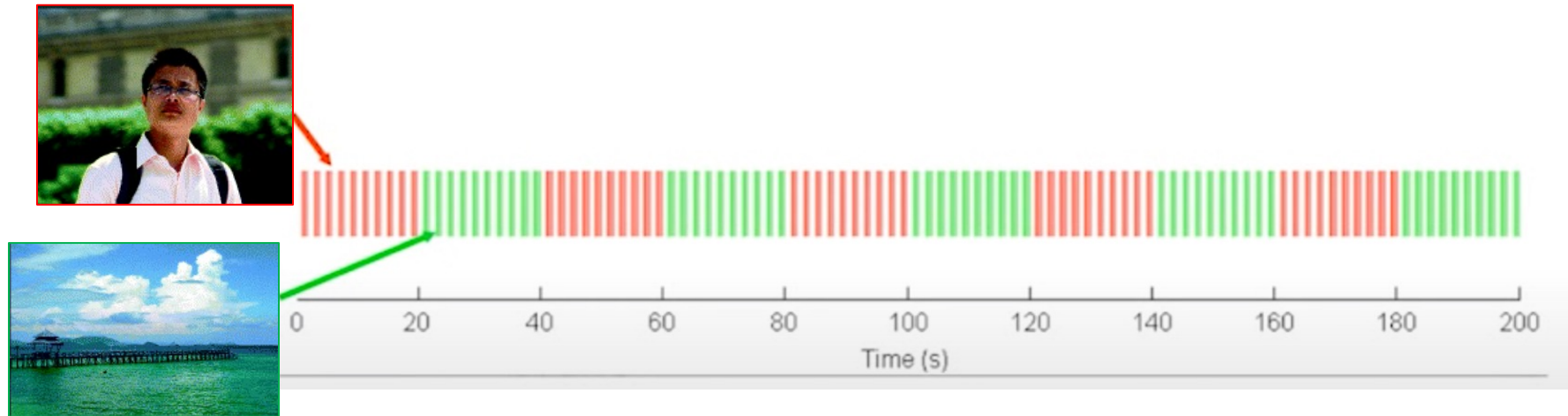


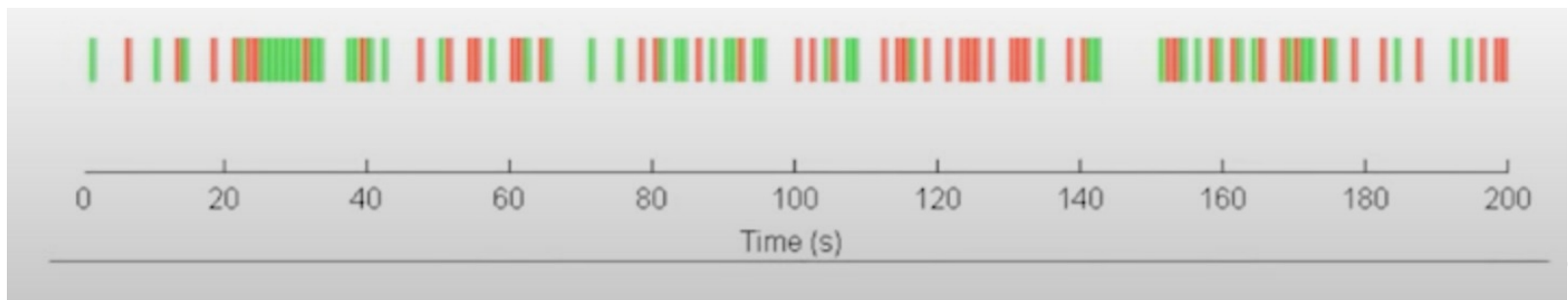
Image available via license: [CC BY-NC 4.0](https://creativecommons.org/licenses/by-nc/4.0/)

# 1<sup>st</sup> level GLM: single-voxel, signal subject

## 1. Block design



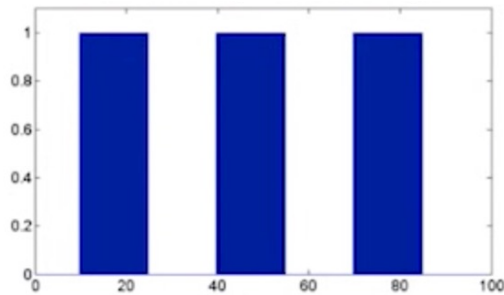
## 2. Event-related design



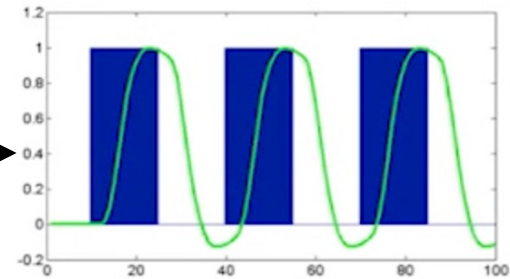
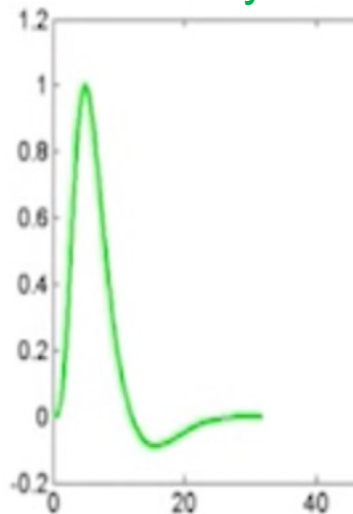
# How to build a regressor?

- BOLD responses are delayed: **peak at 4-6 s** and **baseline 20-30 s**.
- Convolved with the hemodynamic response function (HRF)
- The linear time-invariant (LTI) system

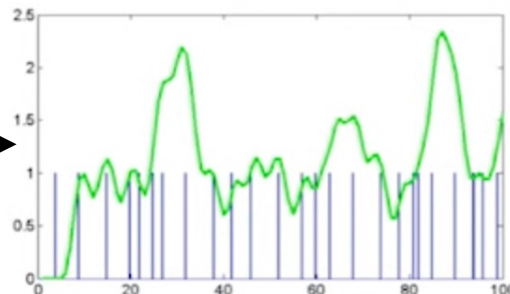
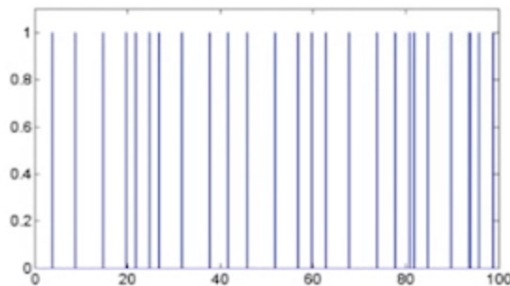
Block design



Hemodynamic  
delay

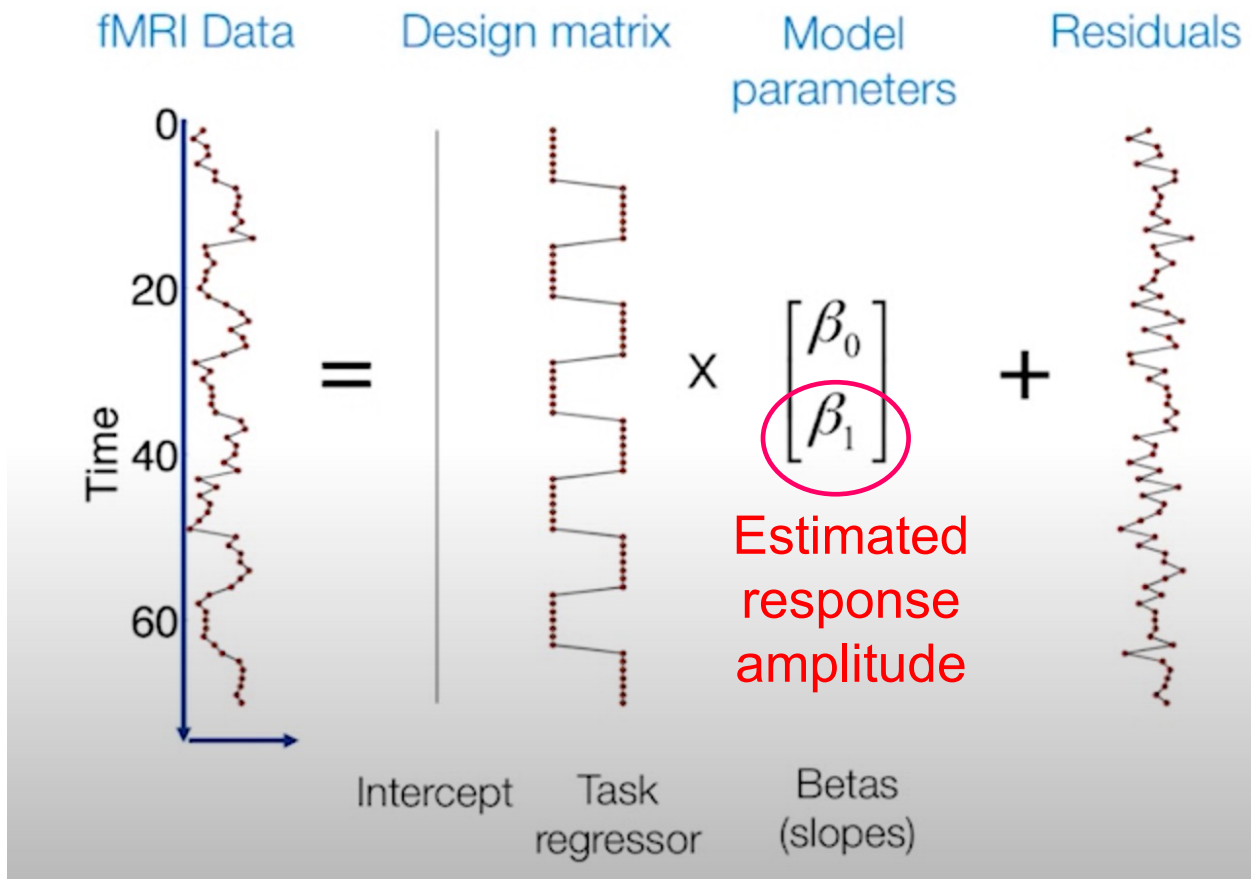


Event-related design





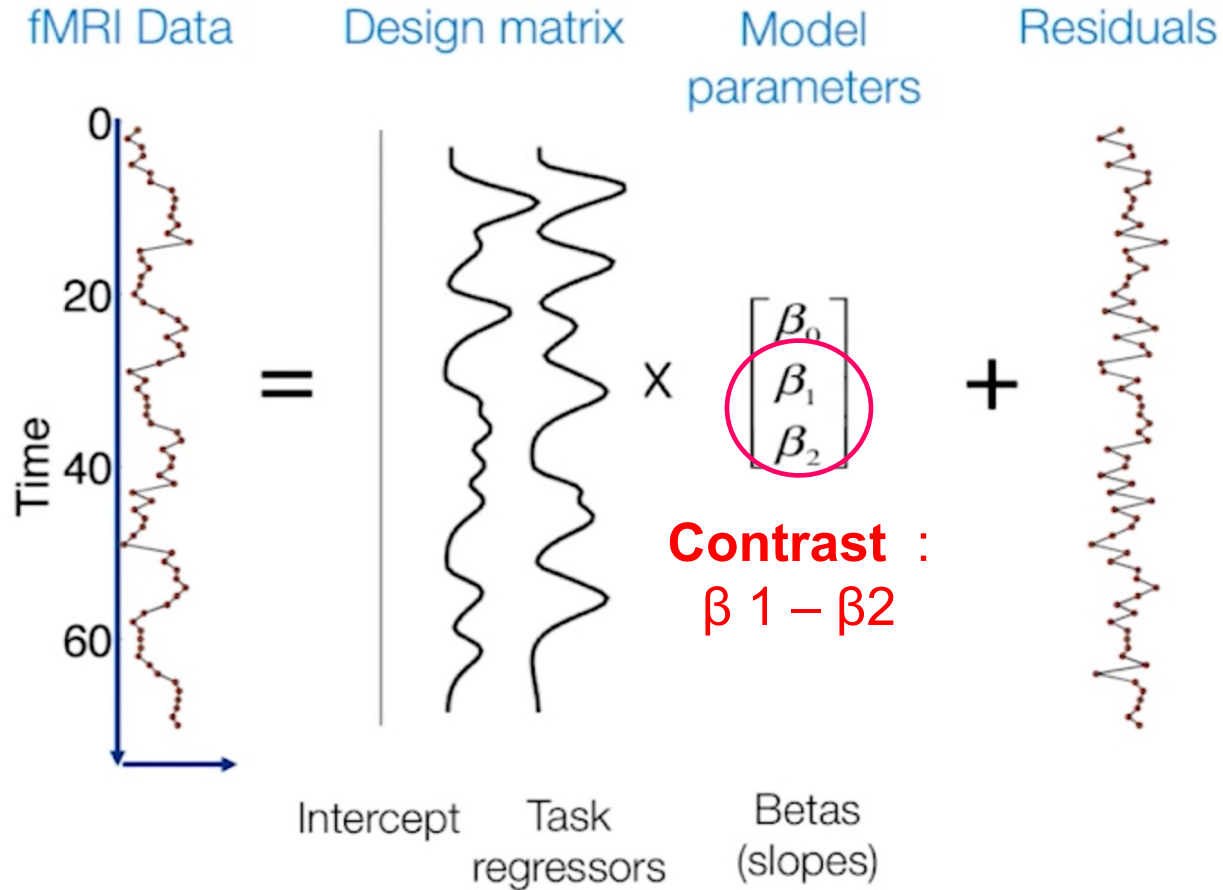
# Block design: one regressor of interest (e.g. people vs. landscape)







# Event-related design: two continuous regressors (people vs. landscape)



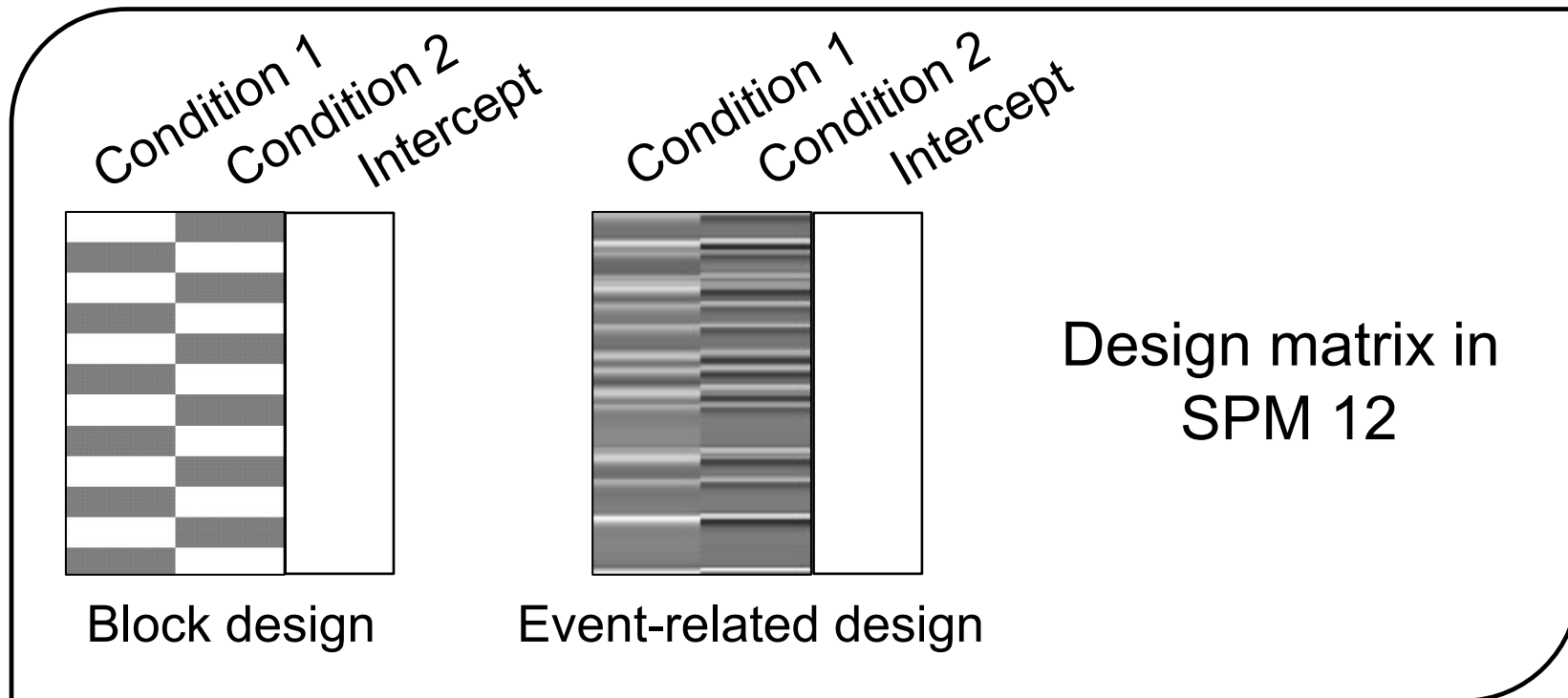
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# Contrasts

Experimental conditions: people vs. landscape

- Your interest is often the difference between the two conditions, which is “contrast”
  - You can calculate the difference, sum or separately each conditions, which are calculated by different linear contrasts.
- 
- We only focus on T contrast in this lecture ! !



**Difference between conditions**

$[ 1 -1 ] = \text{“Con1 > Con2”}$

$[ -1 1 ] = \text{“Con1 < Con2”}$

**Separately**

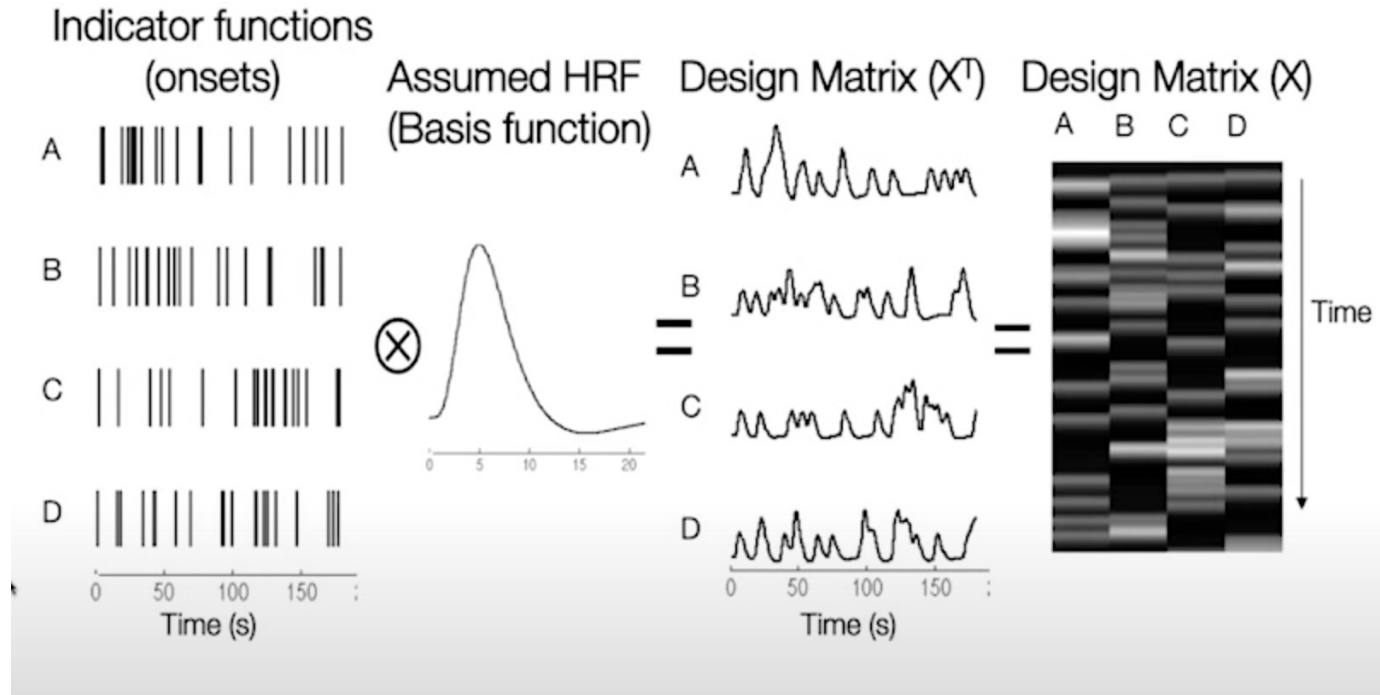
$[ 1 0 ]$  or  $[ -1 0 ] = \text{“main effect Con1”}$

$[ 0 1 ]$  or  $[ 0 -1 ] = \text{“main effect Con2”}$

**Sum**

$[ 1 1 ]$  or  $[ -1 -1 ]$

# More regressors



- [ 1 1 -1 -1 ] : (A+B) > (C+D)
- [ 1 -1 1 -1 ] : (A+C) > (B+D)
- [ 1 0 0 0 ] : main effect of A
- [ 1 1 0 0 ] : Sum of (A+B) vs the mean of the signal
- .....

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# Simple or multiple regression, t-tests, ANOVA, ANCOVA

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

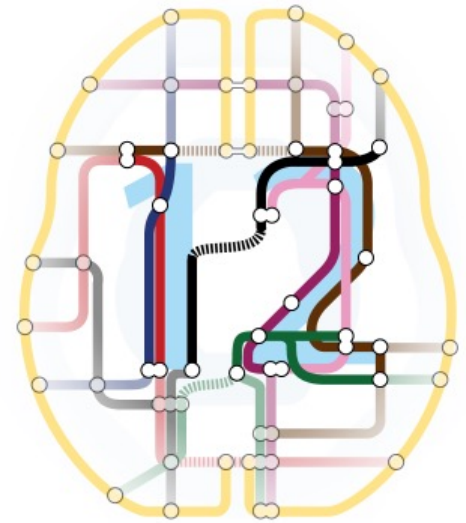
The diagram illustrates the regression equation  $\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$  with the following components and labels:

- Observed Data:** A column vector  $\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}$  with an arrow pointing to it from the label "Observed Data".
- Design matrix:** A matrix  $\begin{bmatrix} 1 & X_{11} & \cdots & X_{1p} \\ 1 & X_{21} & \cdots & X_{2p} \\ \vdots & \vdots & & \vdots \\ 1 & X_{np} & \cdots & X_{np} \end{bmatrix}$  with an arrow pointing to it from the label "Design matrix".
- Model parameters:** A column vector  $\begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_p \end{bmatrix}$  with an arrow pointing to it from the label "Model parameters".
- Residuals:** A column vector  $\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$  with an arrow pointing to it from the label "Residuals".

The equation is shown as  $\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & \cdots & X_{1p} \\ 1 & X_{21} & \cdots & X_{2p} \\ \vdots & \vdots & & \vdots \\ 1 & X_{np} & \cdots & X_{np} \end{bmatrix} \times \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_p \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$ .

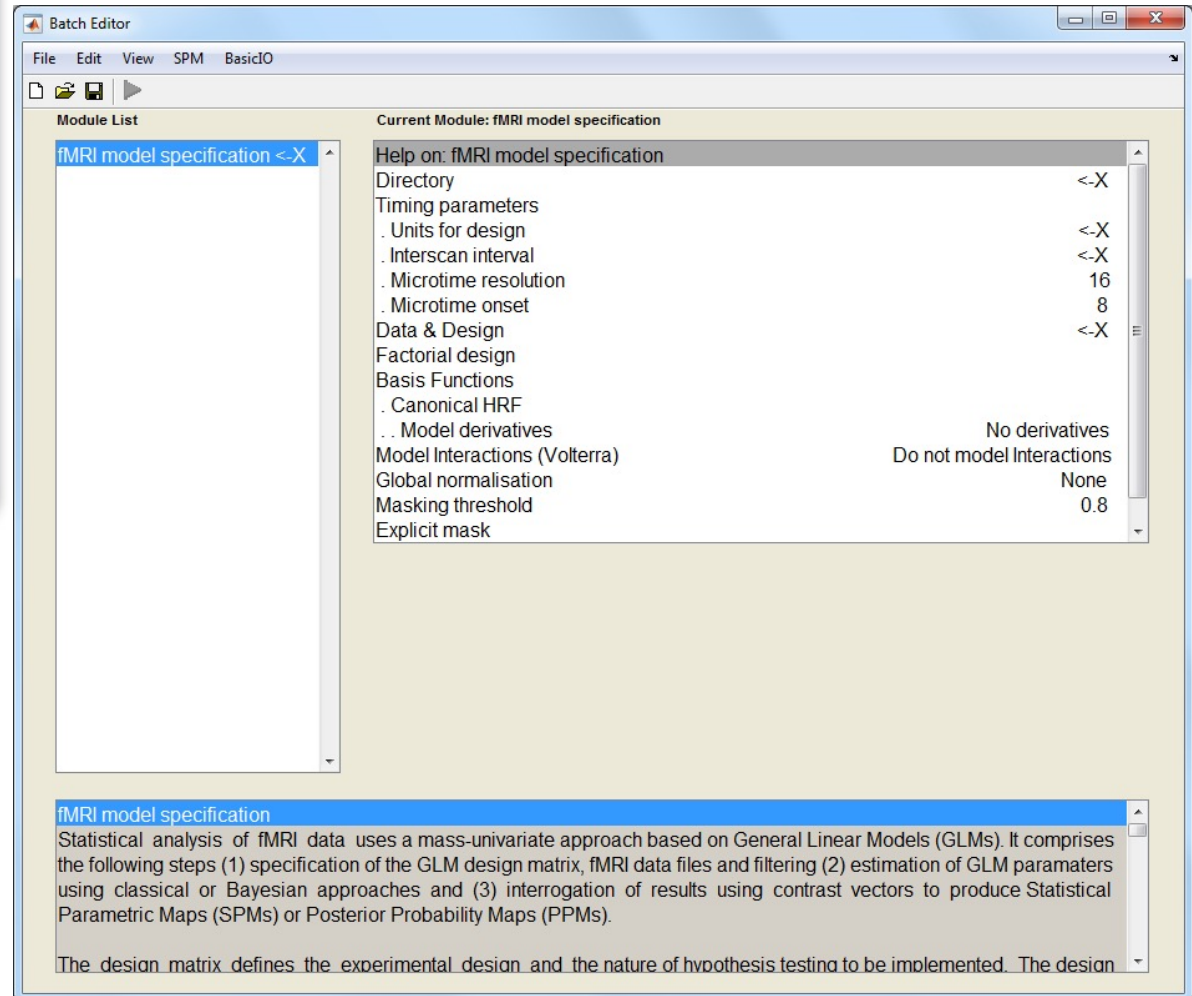
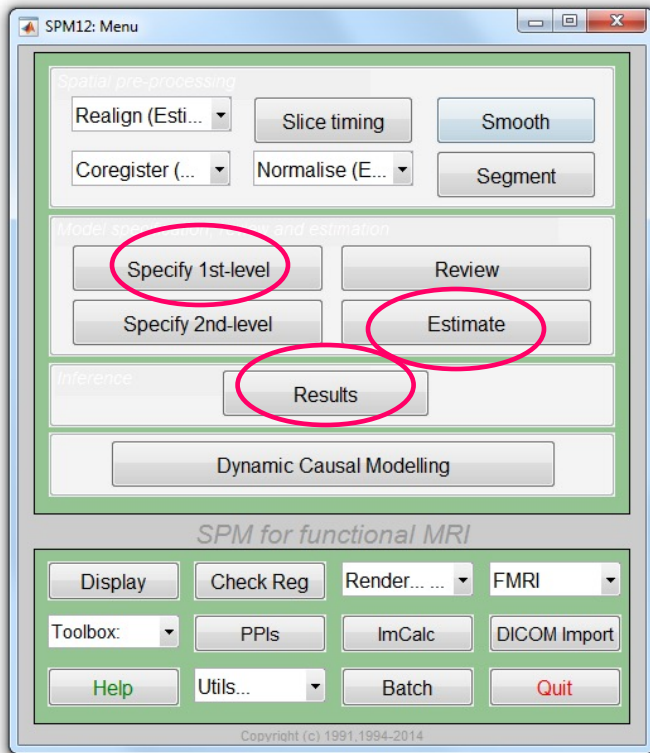
# SPM12

- SPM - theoretical concepts of Statistical Parametric Mapping in a complete analysis package.
- Run in matlab
- See more information:  
<https://www.fil.ion.ucl.ac.uk/spm/software/spm12/>





# Operation in SPM12



# SPM12: parameter setting

Current Module: fMRI model specification

Help on: fMRI model specification

Directory

Timing parameters

- . Units for design
- . Interscan interval
- . Microtime resolution
- . Microtime onset

Data & Design

Factorial design

Basis Functions

- . Canonical HRF
- . . Model derivatives

Model Interactions (Volterra)

Global normalisation

Masking threshold

Explicit mask

Result folder

Basic imaging parameters

Design matrix: **sessions & conditions**

Leave as default,  
or specify if necessary

**Current Module: fMRI model specification**

Data & Design		
. Subject/Session		
. . Scans	→ All scan volumes	<-X
. . Conditions		
. . . Condition	→ Condition 1	
. . . . Name		humans
. . . . Onsets		<-X
. . . . Durations		<-X
. . . . Time Modulation		No Time Modulation
. . . . Parametric Modulations		
. . . . Orthogonalise modulations		Yes
. . . Condition		
. . . . Name		landscape
. . . . Onsets		<-X



Data estimation

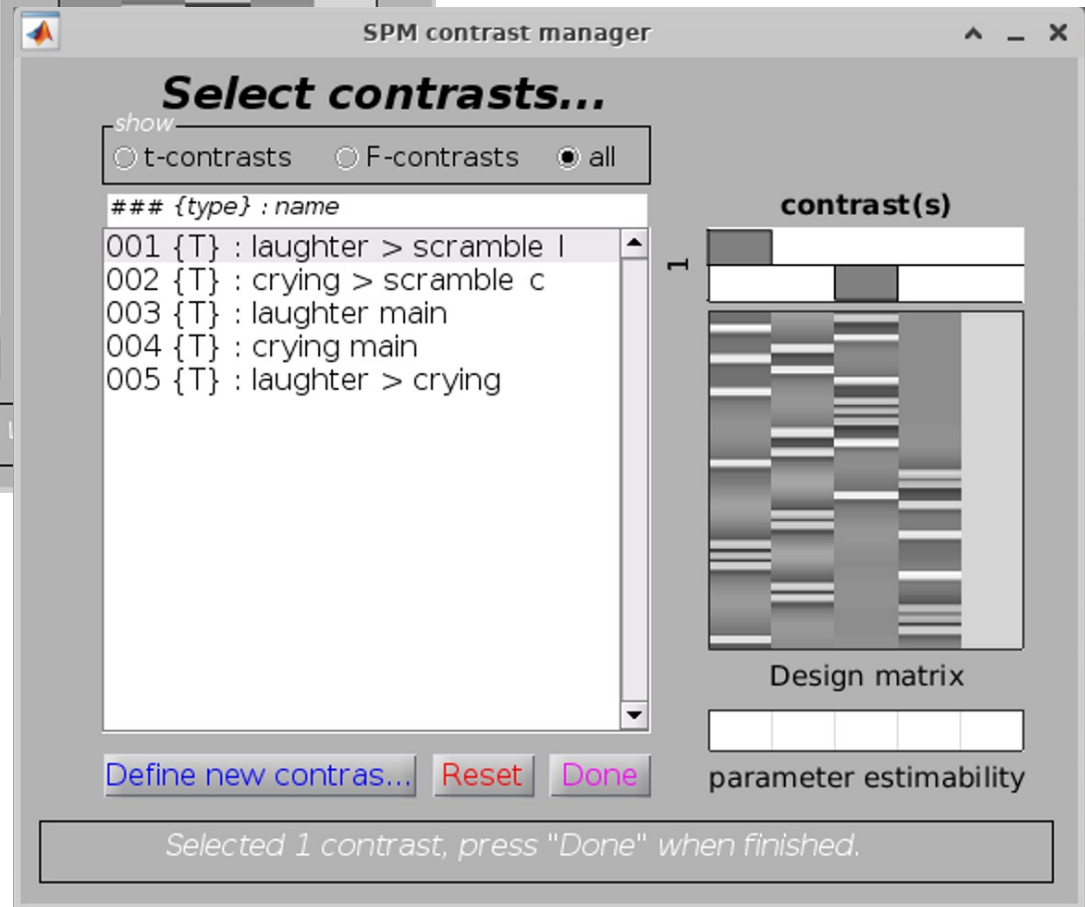
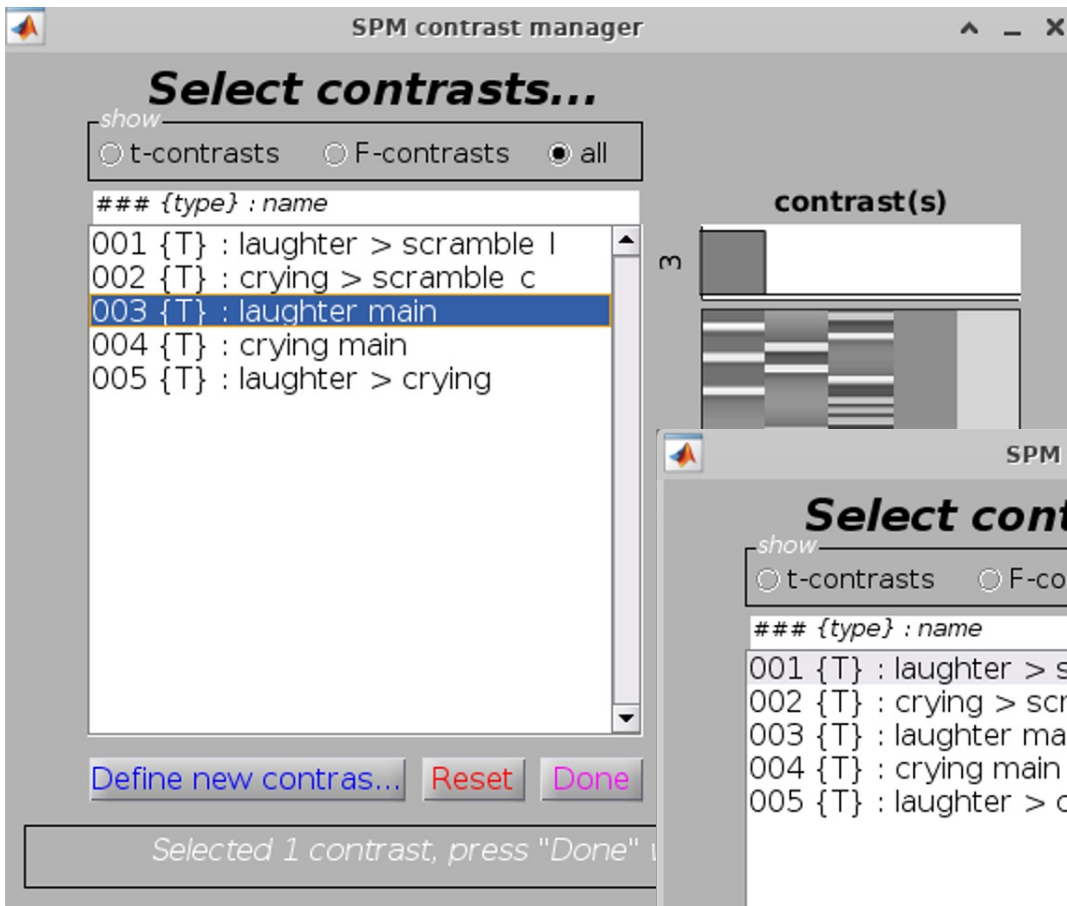
**Module List**

Model estimation	<-X
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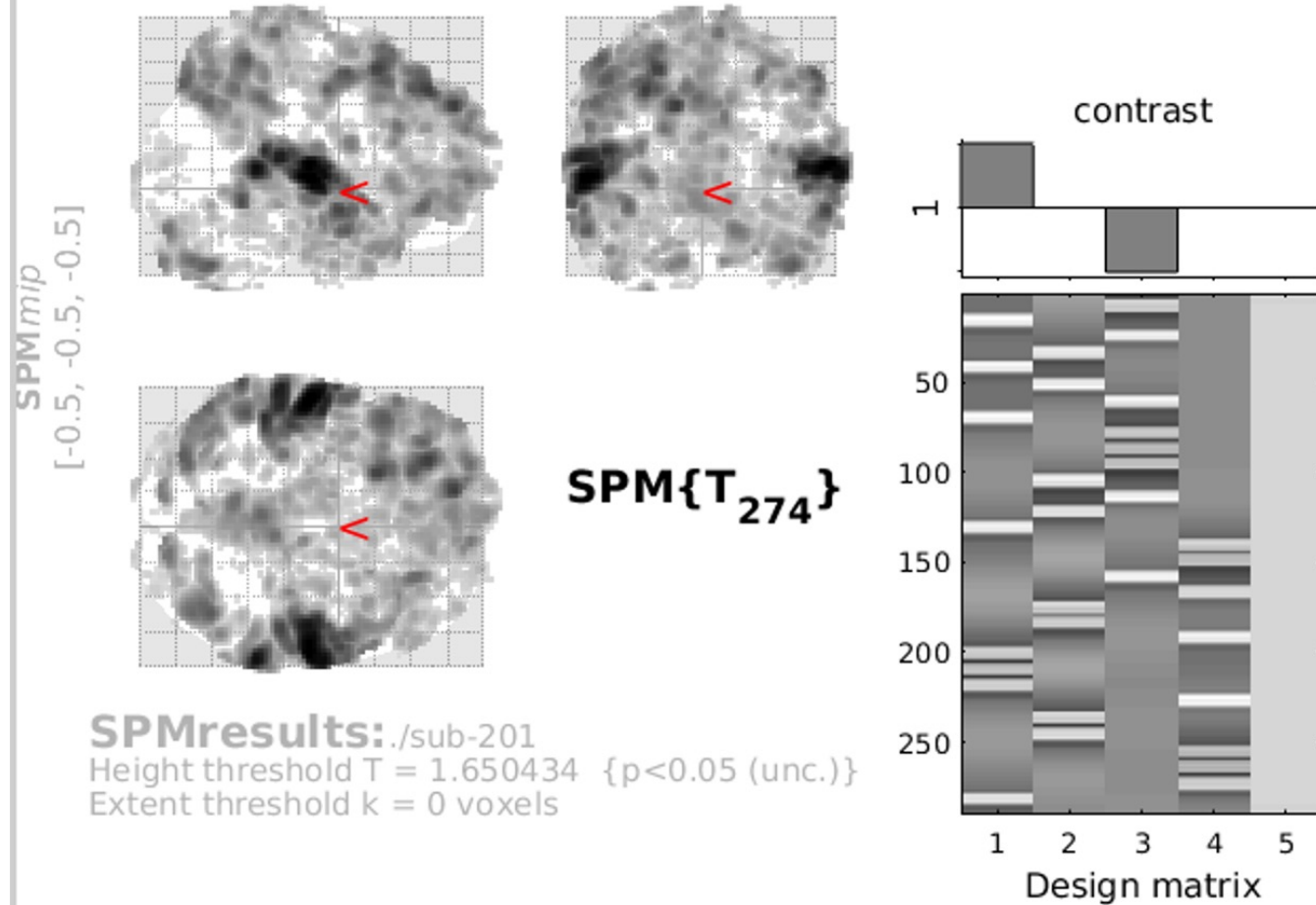
**Current Module: Model estimation**

- Help on: Model estimation
- Select SPM.mat
- Write residuals
- Method
- . Classical

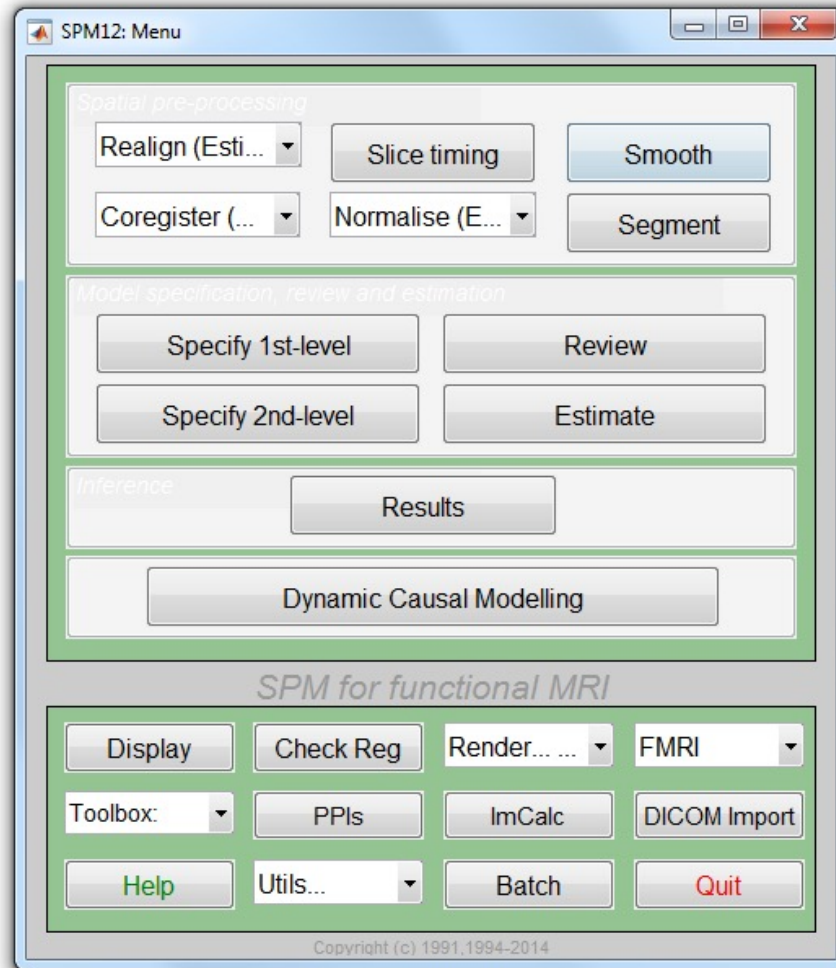
# SPM12: setting contrasts



## laughter > scramble\_I



# Ready for 2nd-level analysis



# Resources

- Principles of fMRI: <https://youtu.be/OyLKMb9FNhg>
- Spm12 manual:  
[https://www.fil.ion.ucl.ac.uk/spm/doc/spm12\\_manual.pdf](https://www.fil.ion.ucl.ac.uk/spm/doc/spm12_manual.pdf)
- Behav Res (2014) 46:596–610