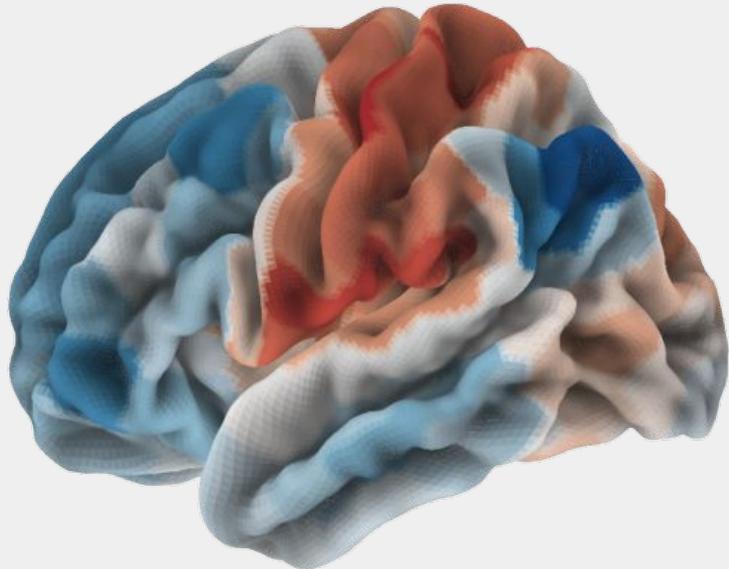


Fundamentals of fMRI data analysis

Karolina Finc

Centre for Modern Interdisciplinary
Technologies Nicolaus Copernicus University
in Toruń



COURSE #5: General Linear Model 2 | 11th January 2021

Study plan

Open science & neuroimaging



BEFORE

fMRI data manipulation
in python



fMRI data
preprocessing



3

Functional
connectivity



5



4

General
Linear Model



AFTER

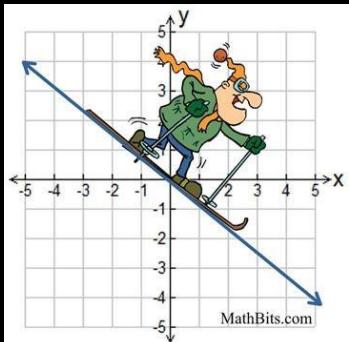


Machine Learning
on fMRI data

Machine Learning
on fMRI data



Slope-intercept form of linear function

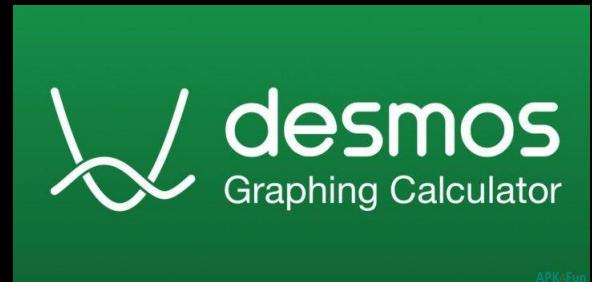


slope

$$y = \textcolor{green}{m}x + \textcolor{blue}{b}$$

coefficient
s

intercept



<https://www.desmos.com/calculator>

Linear regression

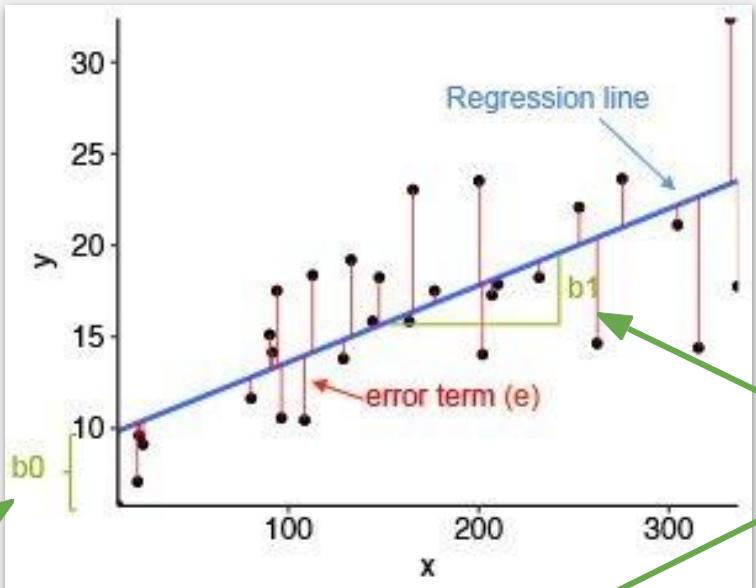


Regression line provides a **model** of the data

Regression problem:
predict real-valued output

Regression is an example of
supervised learning
(answers are given)

Fitting regression line



Find such β_0 and β_1 that minimize cost function: sum of squared errors function

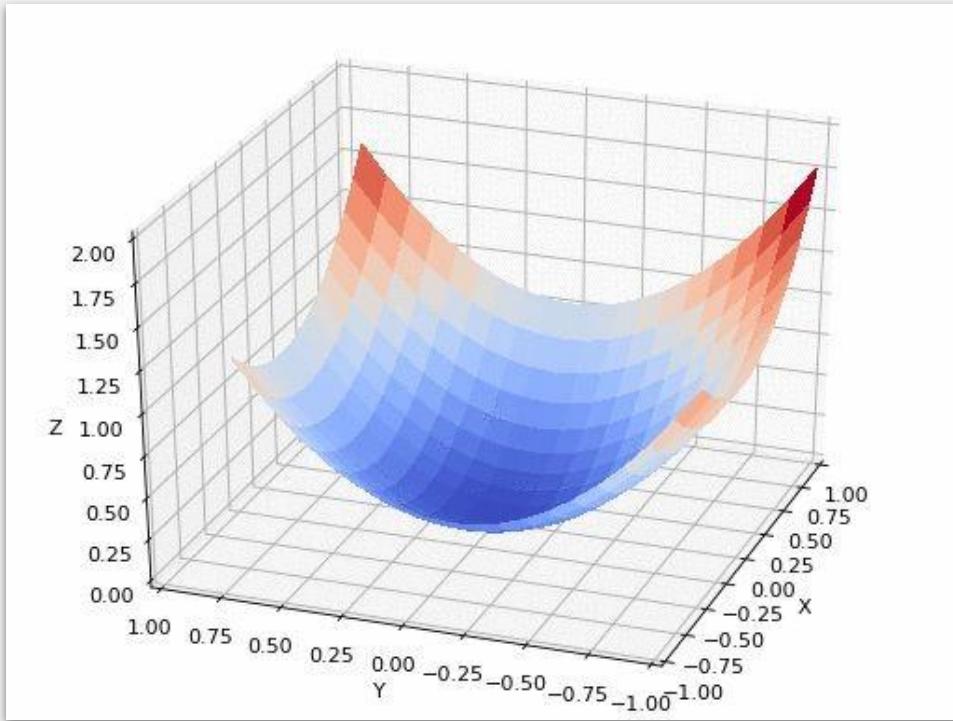
intercept

Linear Regression: Single Variable

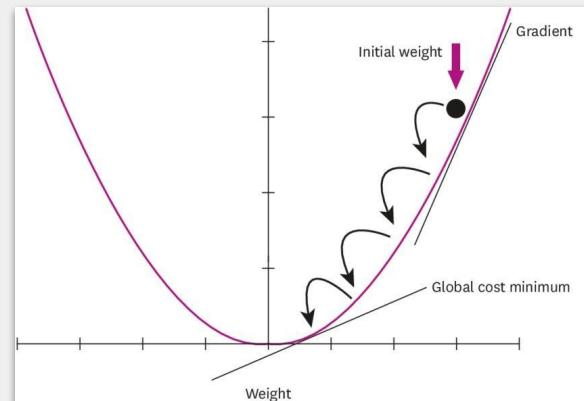
$$\hat{y} = \beta_0 + \beta_1 x + \epsilon$$

Predicted output Coefficients Input Error

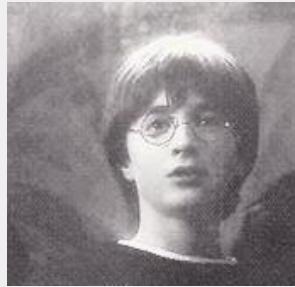
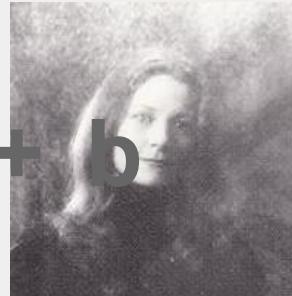
Gradient descent



- Algorithm for minimizing cost function
- Is used not only in linear regression



Linear combination

 $= a + b$  $+ \epsilon$

What **combination** of Lily & James gives a better **prediction** of harry?

Multiple linear regression

Linear Regression: Single Variable

$$\hat{y} = \beta_0 + \beta_1 x + \epsilon$$

Predicted output Coefficients Input Error

Linear Regression: Multiple Variables

$$\hat{y} = \beta_0 + \underbrace{\beta_1 x_1}_{\text{Coefficients}} + \dots + \underbrace{\beta_p x_p}_{\text{Coefficients}} + \epsilon$$

Each parameter β_i is interpreted as the effect of x_i controlling for all other variables in the model.

Matrix notation

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

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

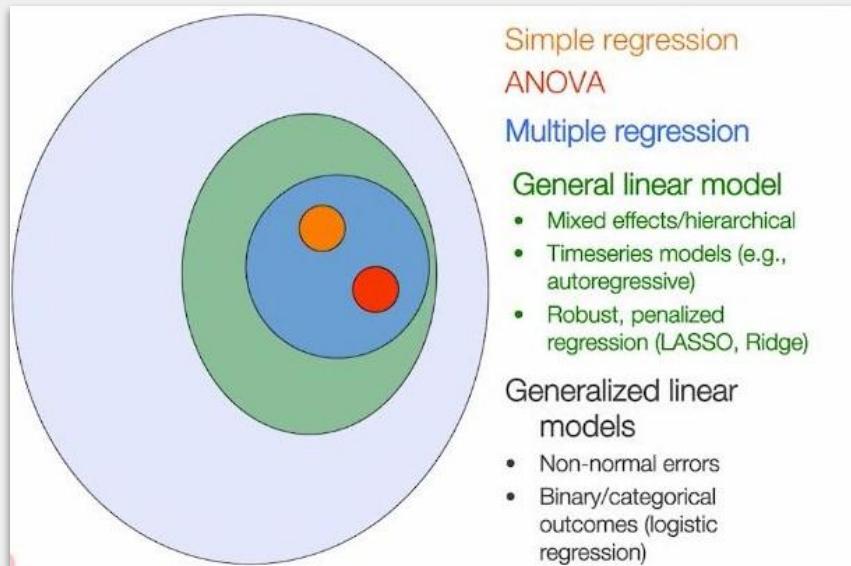
Observed Data

Design matrix

Model parameters

Residuals

Generalized Linear Model



The general linear model (GLM) approach treats the fMRI data as a linear combination of model functions, predictors, plus noise, or error.

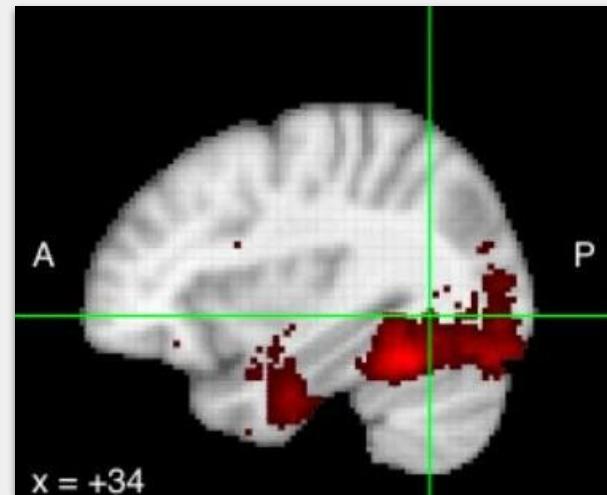


What we want to achieve when asking participant to perform a task in the fMRI scanner?



Goals of task-based fMRI

1. Induce in a study participant to do actions or experience cognitive states you're interested in.
2. You want to detect brain signals that are related to this cognitive states or actions.



Presentation method

Equipment



Presentation method

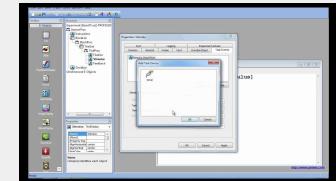
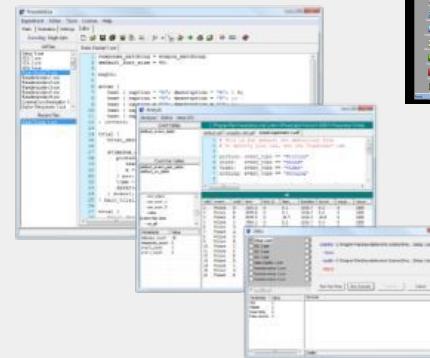
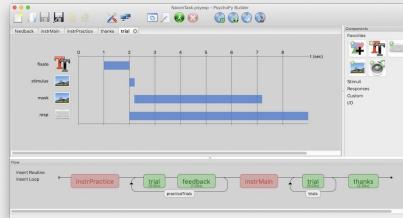
Equipment



Software

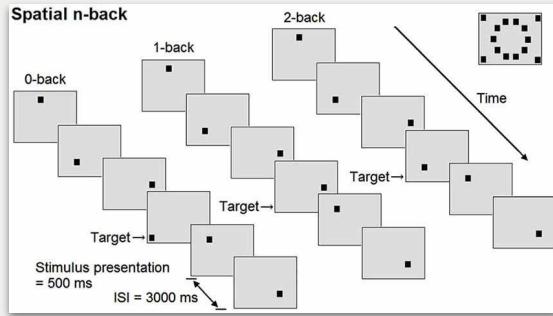


*PsychoPy*³
Now running studies online



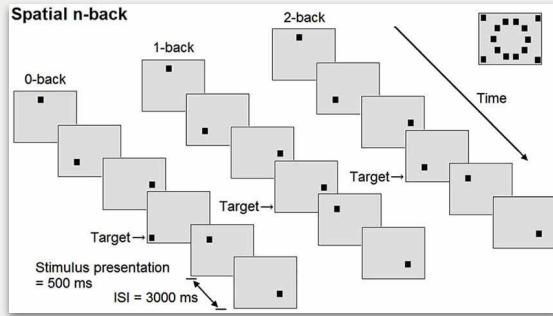
What to present?

Simple stimuli

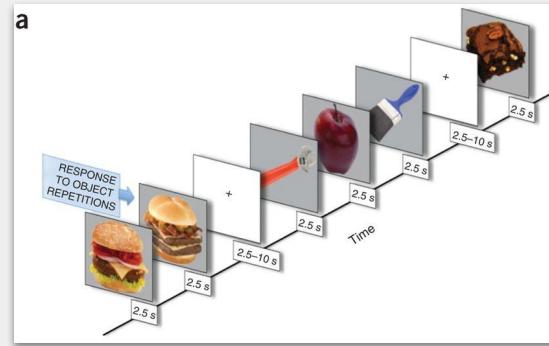


What to present?

Simple stimuli

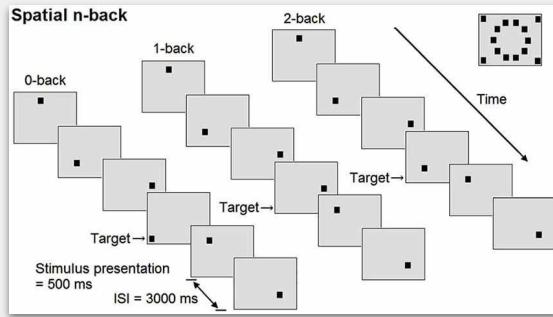


Photos

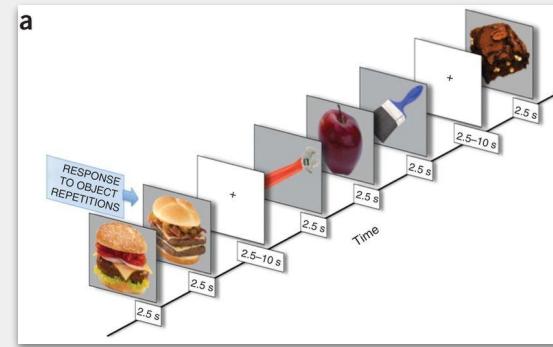


What to present?

Simple stimuli



Photos

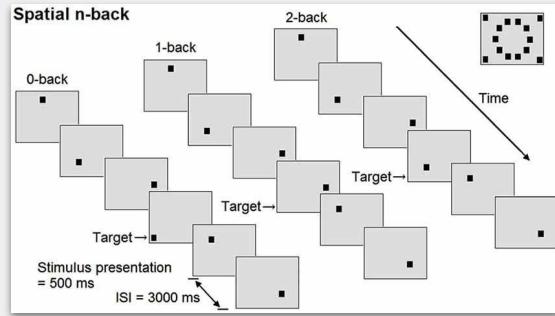


Movie

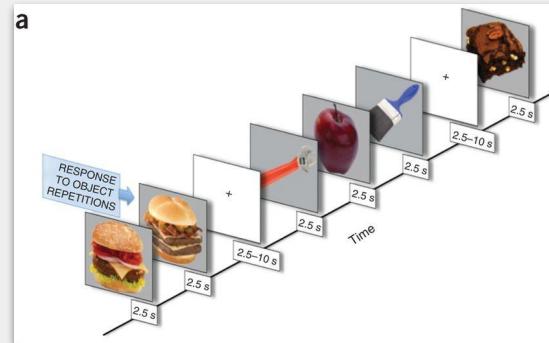


What to present?

Simple stimuli



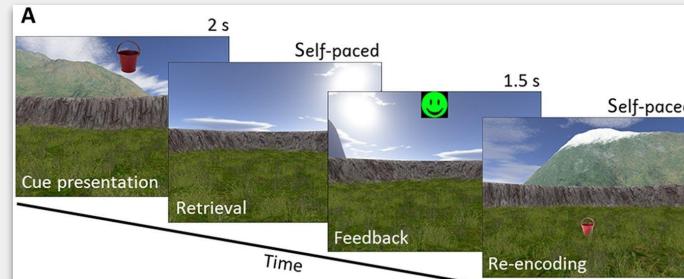
Photos



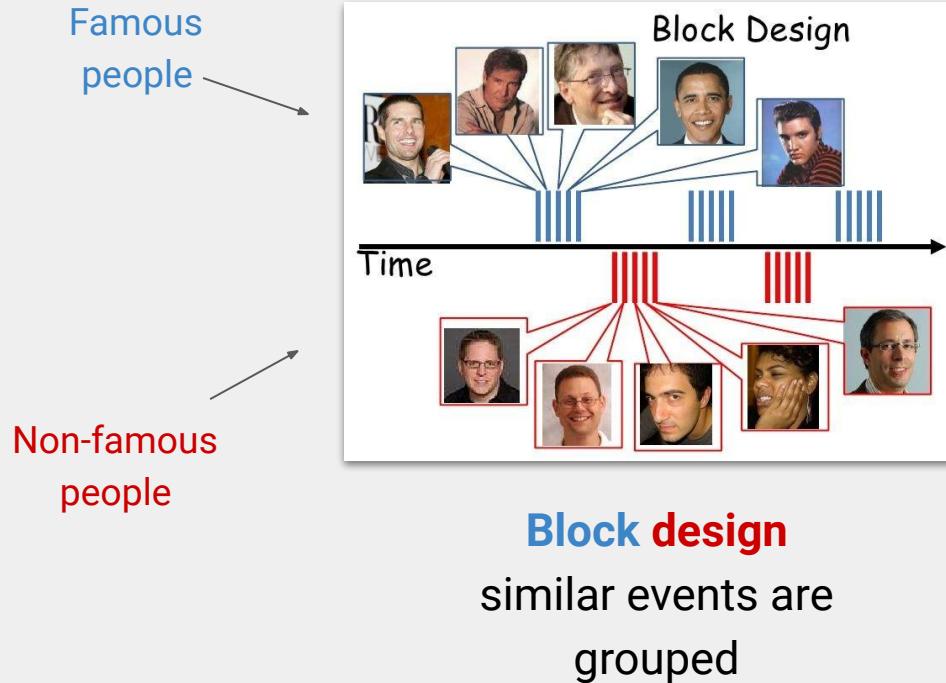
Movie



Virtual reality

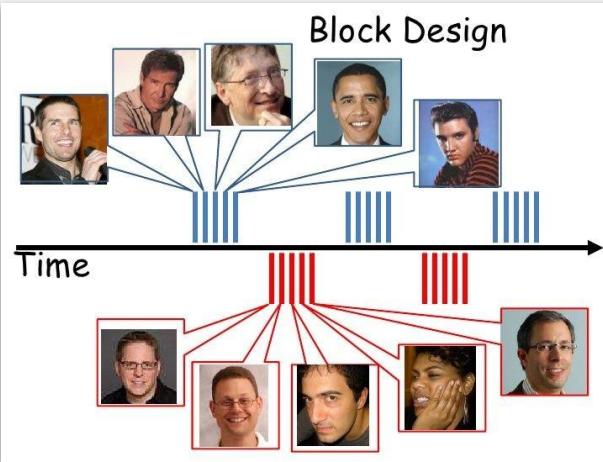
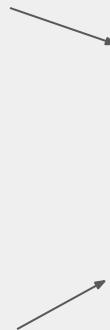


Task designs

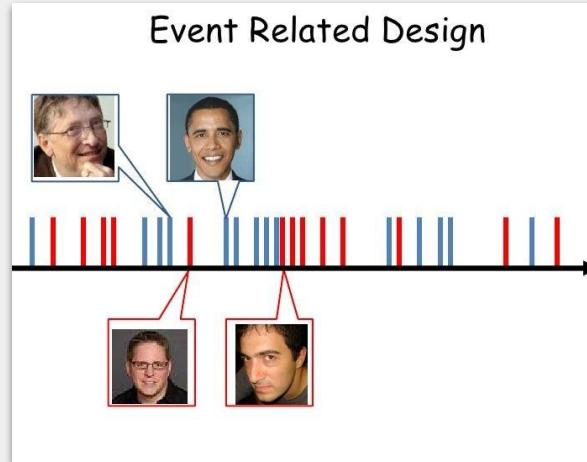


Task designs

Famous people



Block design
similar events are
grouped



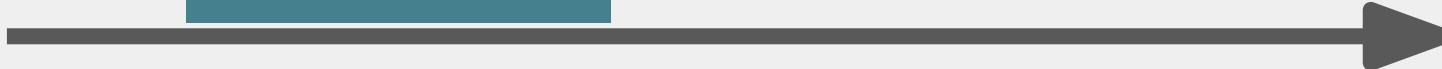
Event-related design
events are mixed

Events parameters

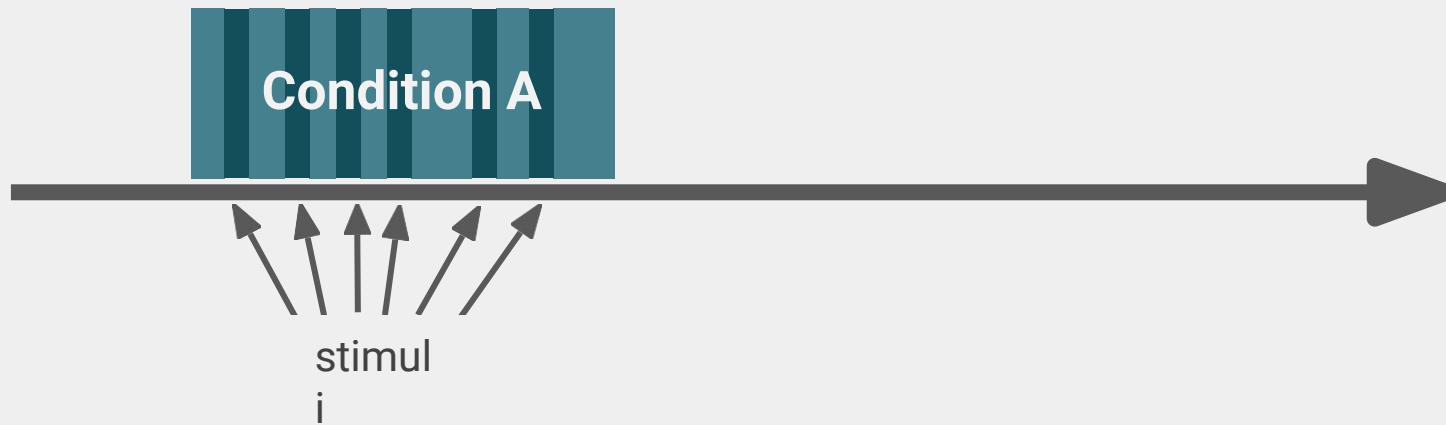


Events parameters

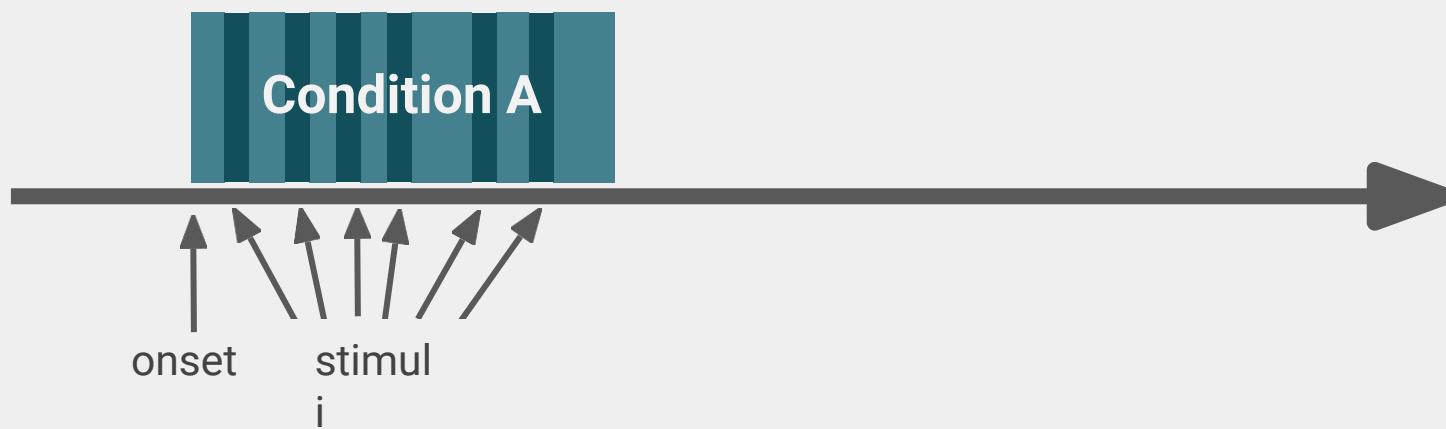
Condition A



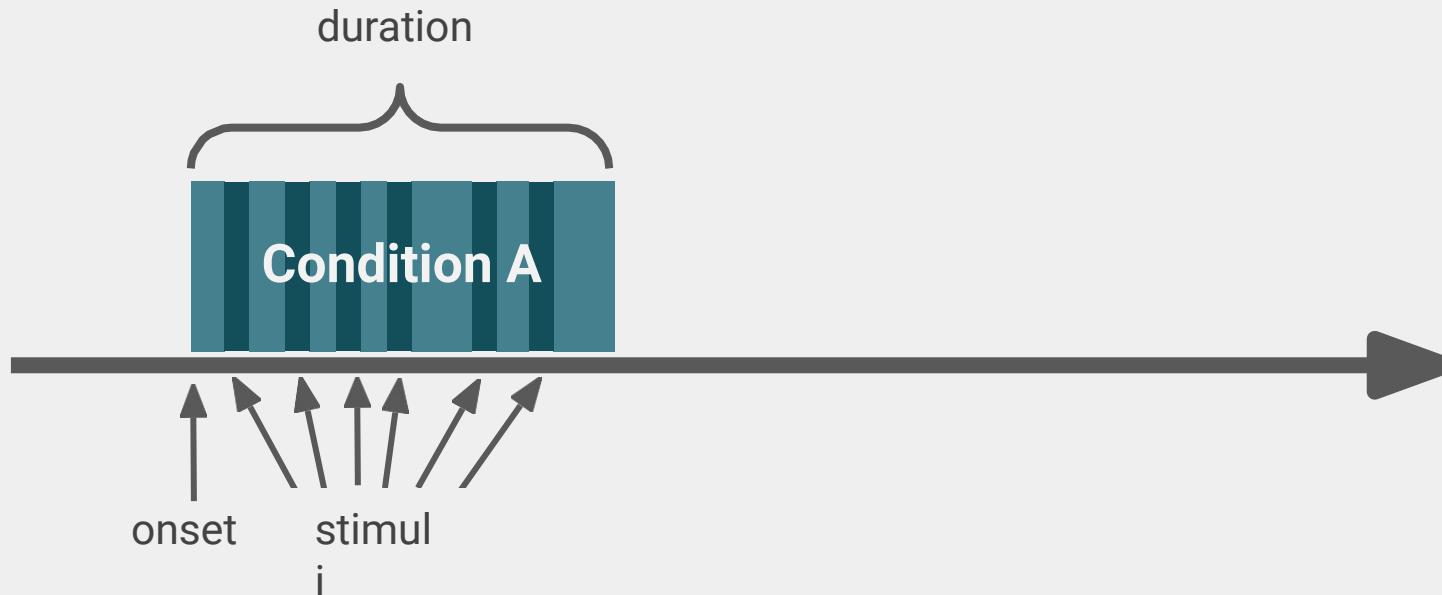
Events parameters



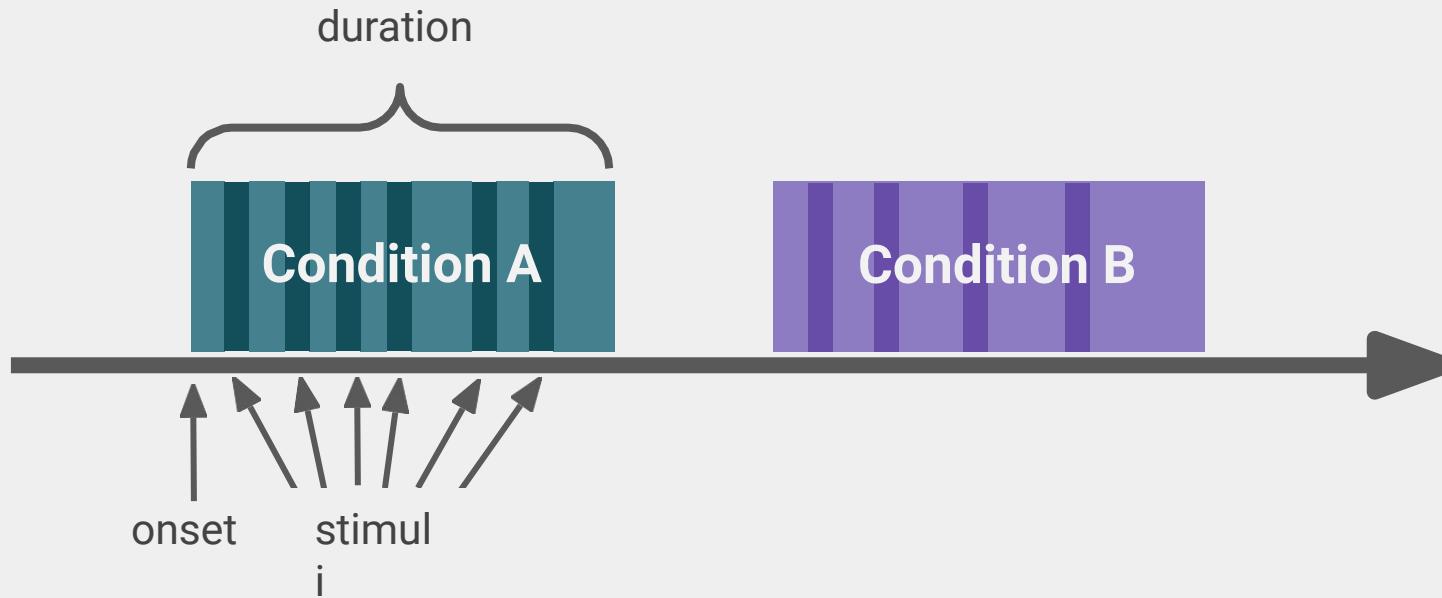
Events parameters



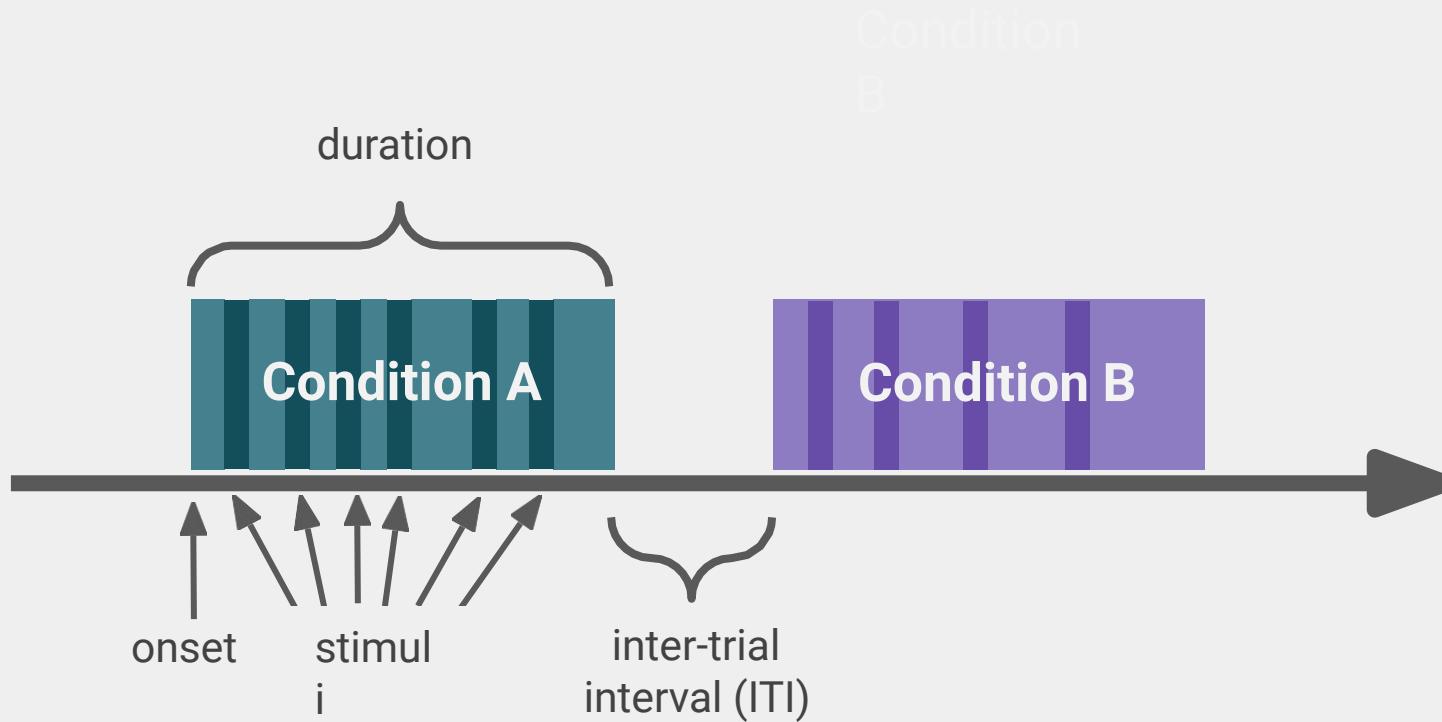
Events parameters



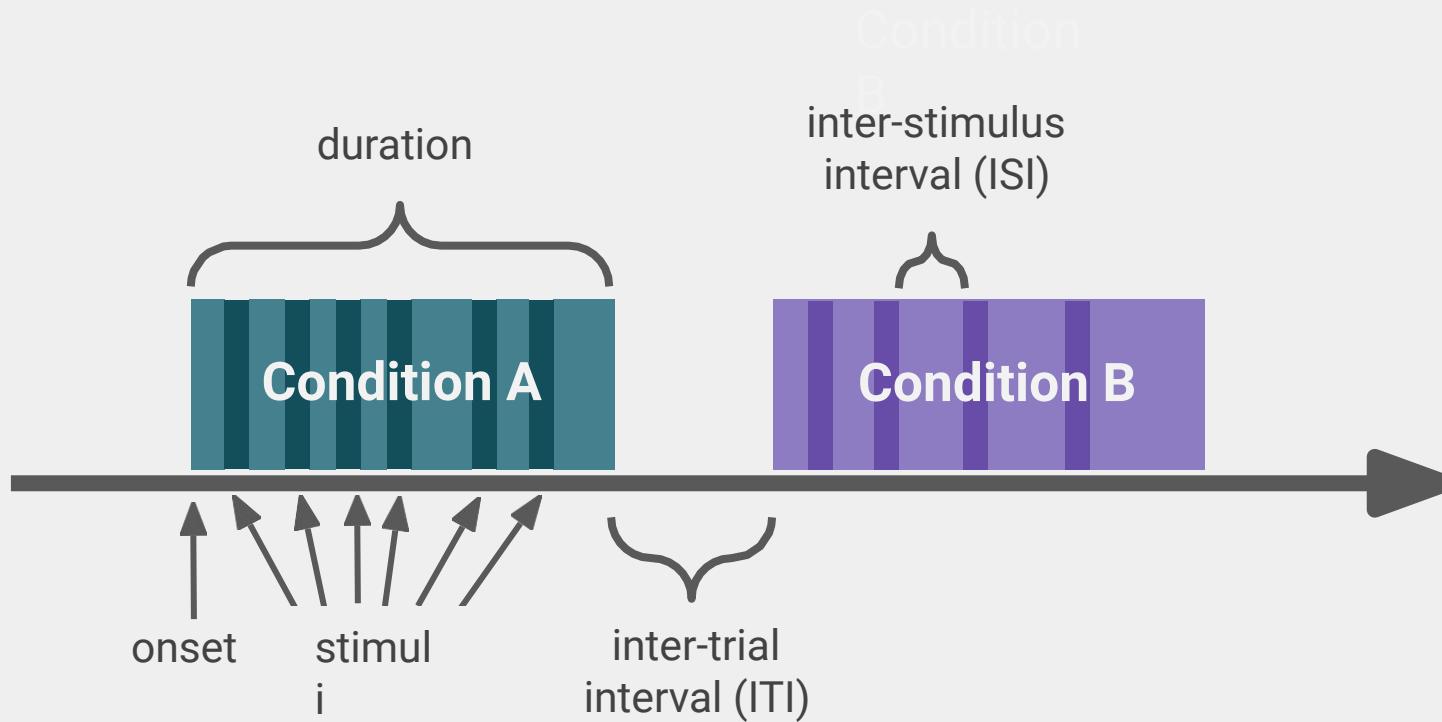
Events parameters



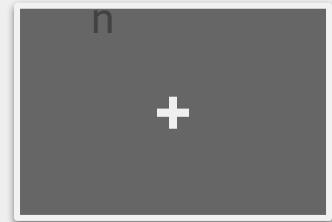
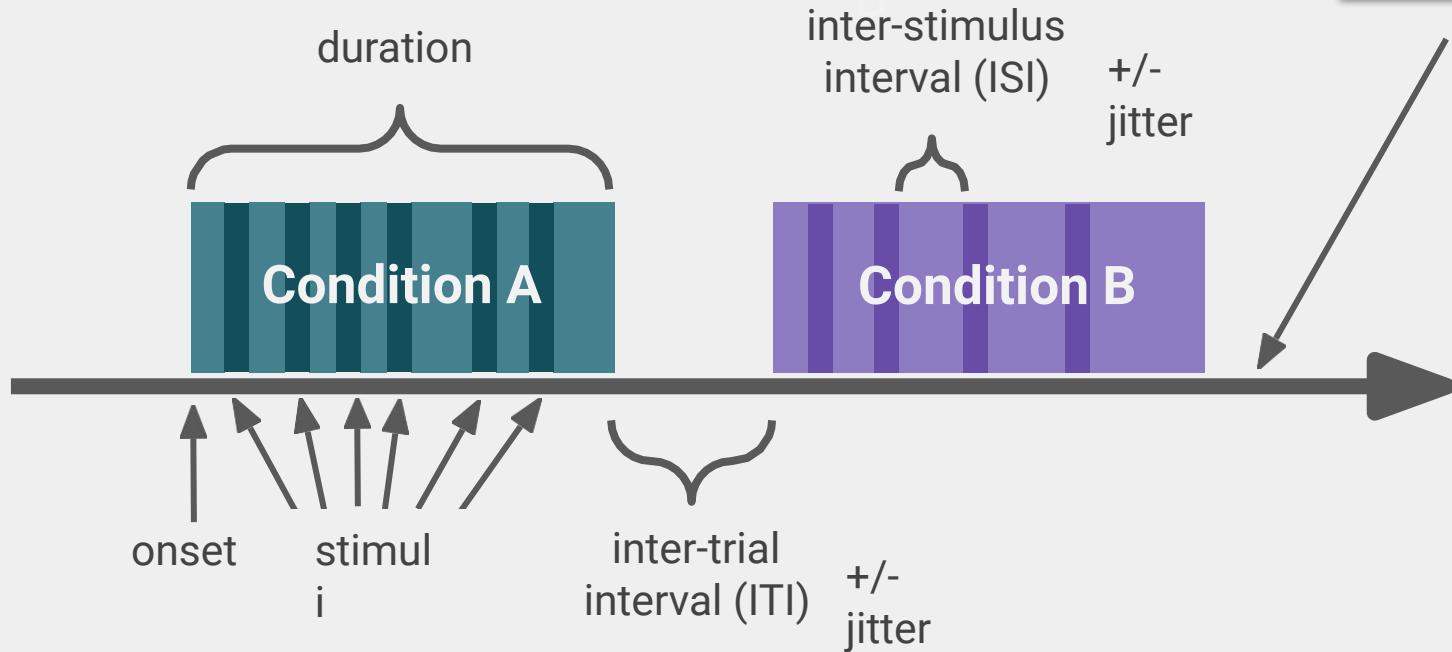
Events parameters



Events parameters



Events parameters



Condition

P

inter-stimulus
interval (ISI)

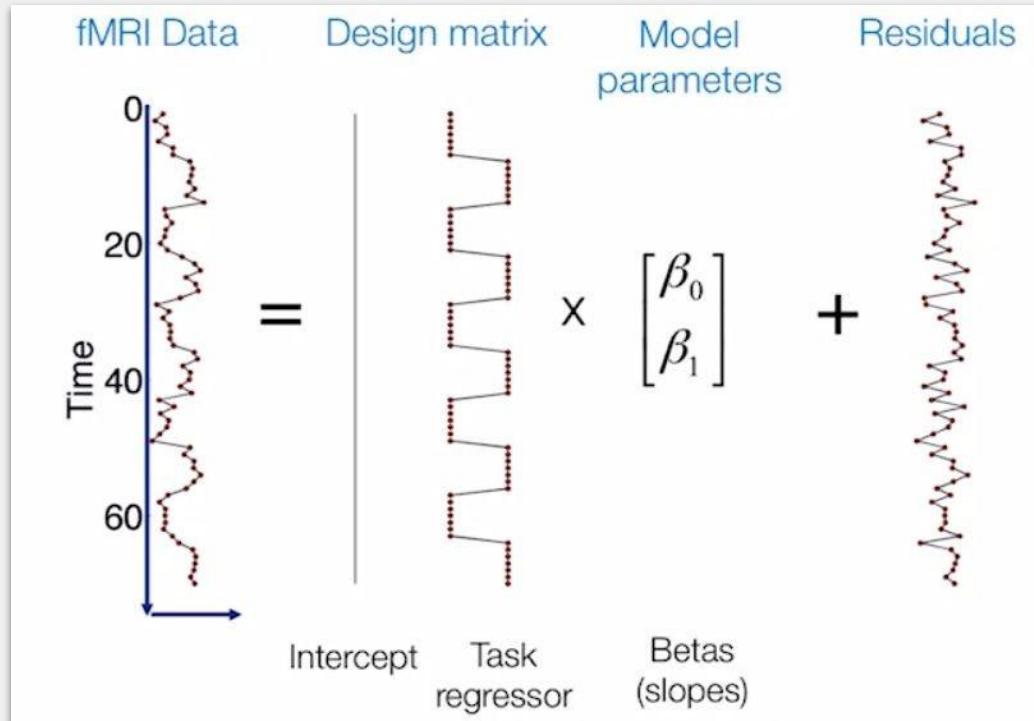
+/-
jitter

Fixatio

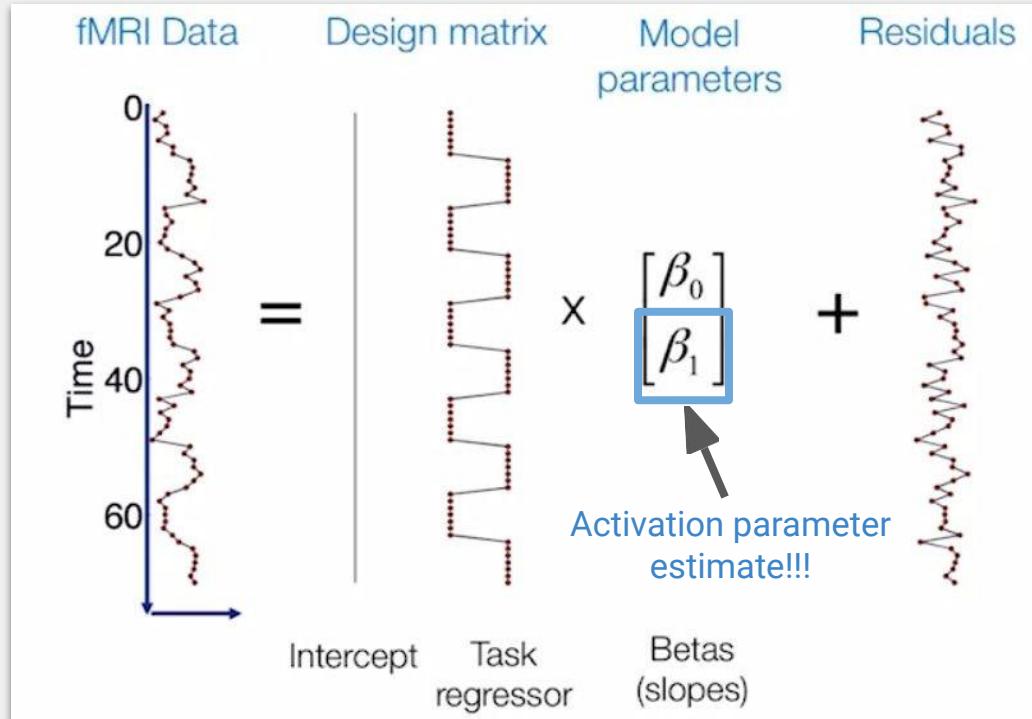
n

+

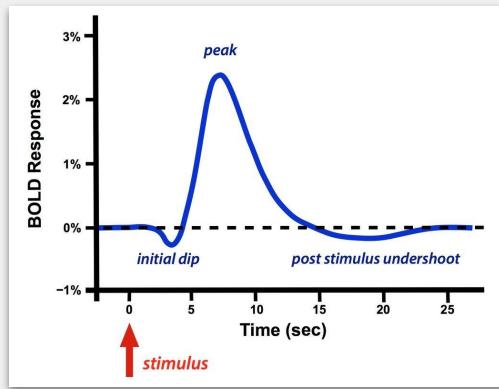
First level GLM



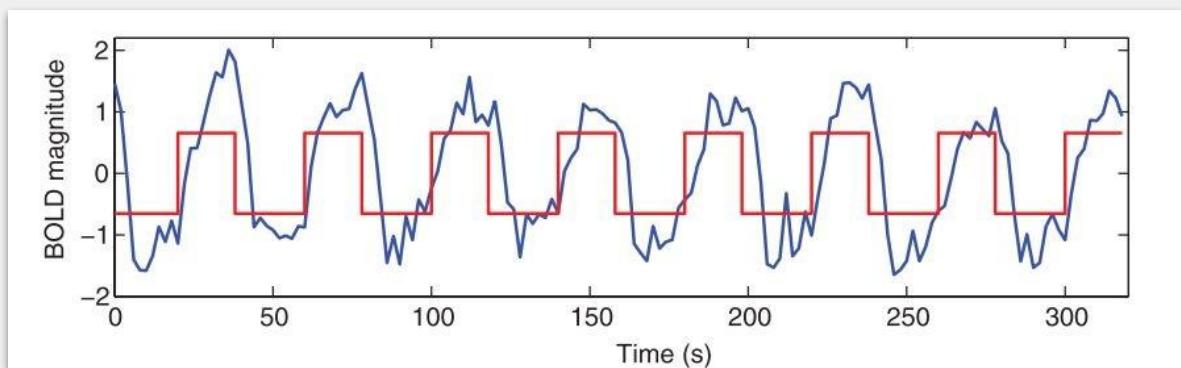
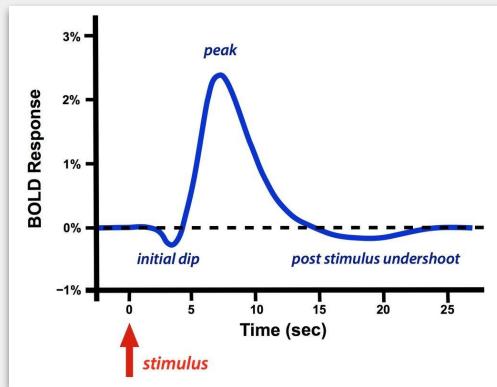
First level GLM



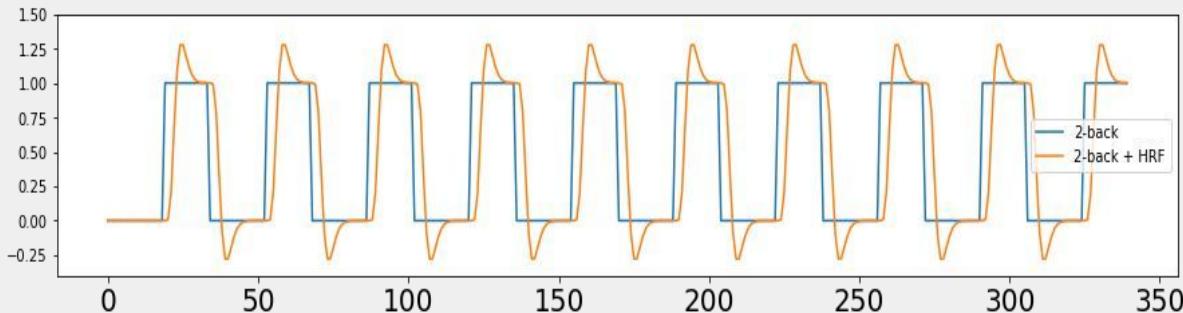
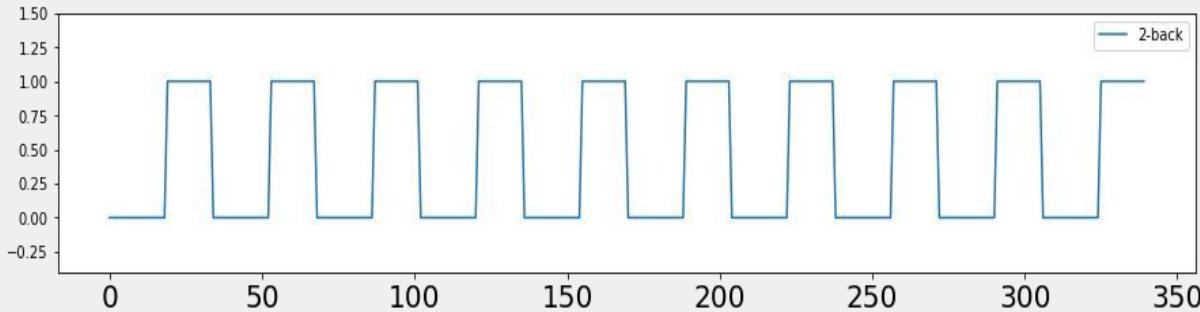
Haemodynamic delay!



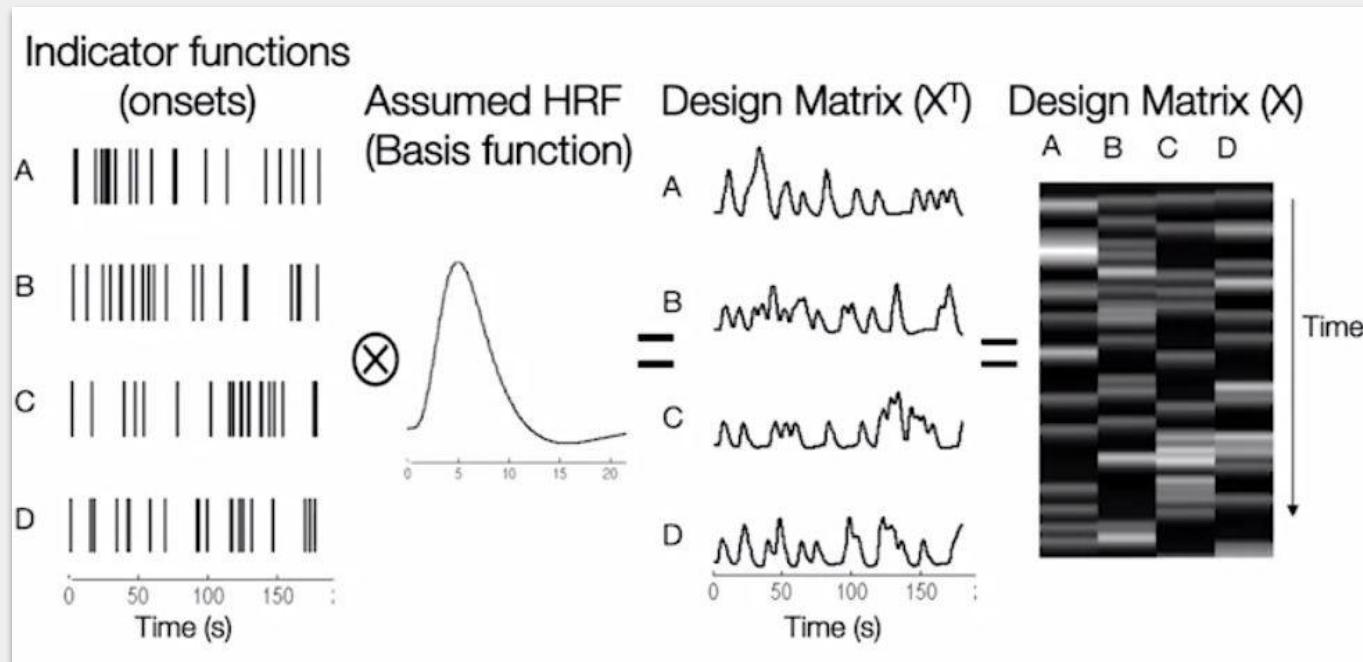
Haemodynamic delay!



Convolution



Building design matrix from events data

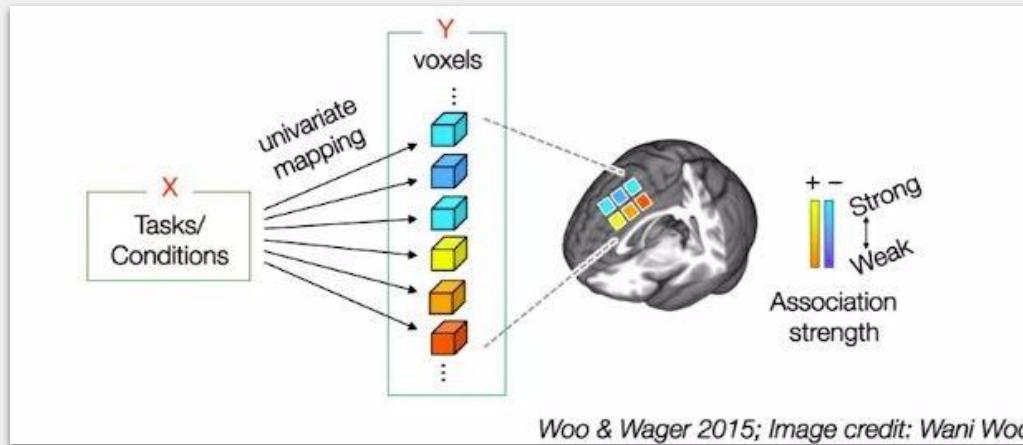


How to do this on the whole brain?



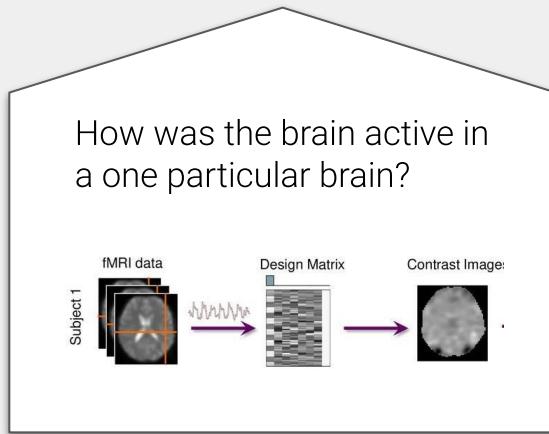
Mass univariate approach

Assumes voxels are independent, each owns a separate model.

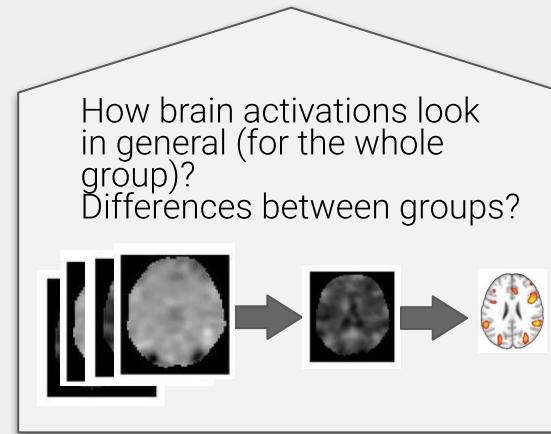


Analysis steps

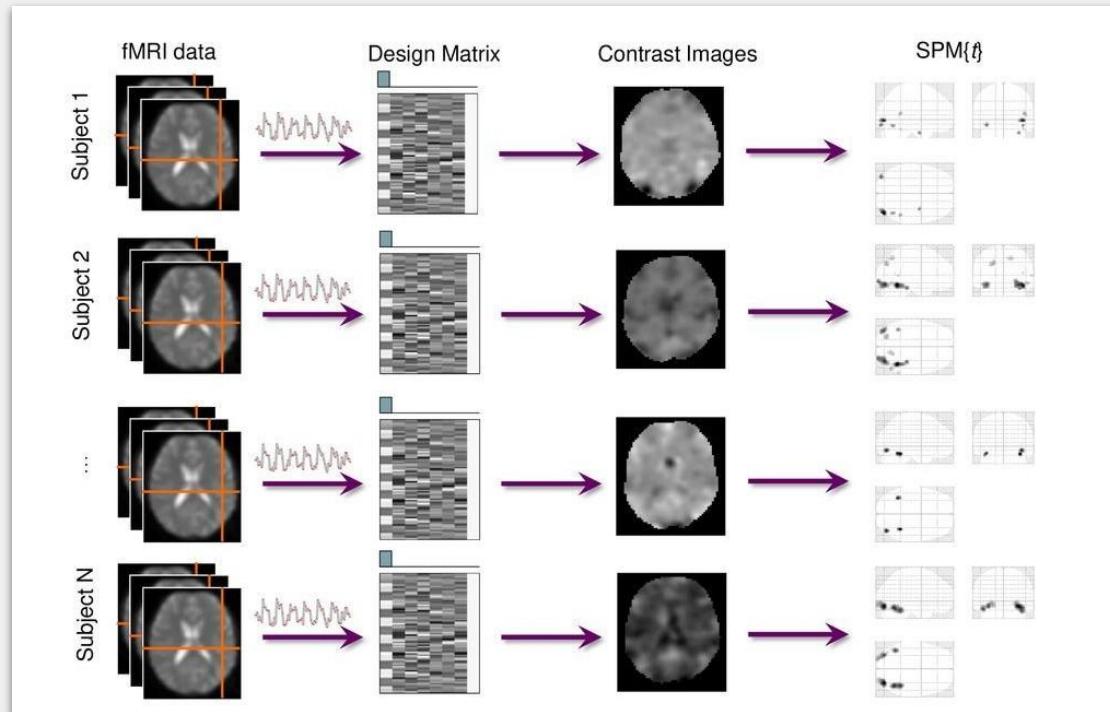
1-level analysis
(within-subject; individual)



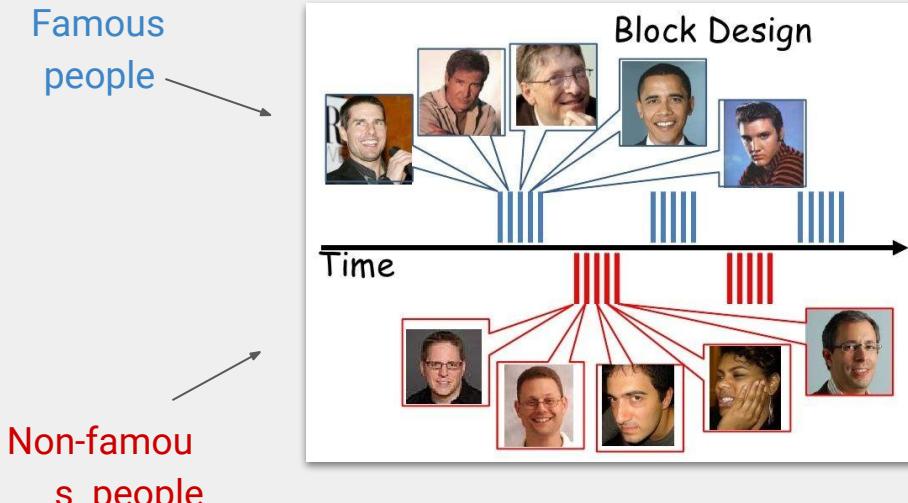
2-level analysis
(across-subject; group)



1-level analysis



Contrasts



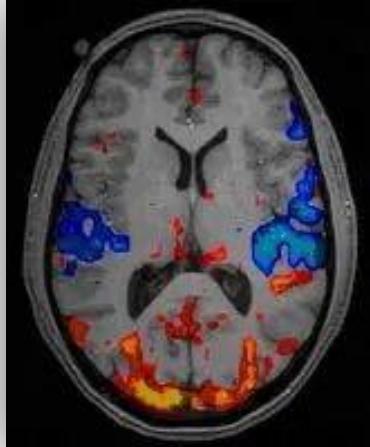
- Difference between conditions
- Each condition separately
- Average of two conditions

This function can be assessed with different linear **contrasts**.

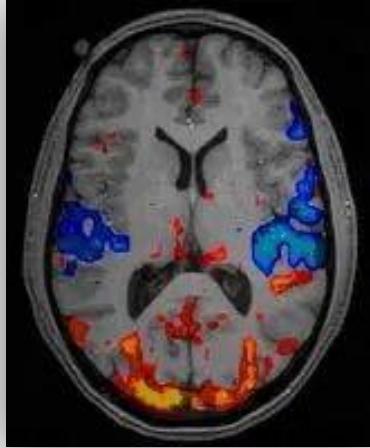
Contrast - a *linear combination* of GLM parameters.

Is this combination **significantly** different from zero (T, F statistical testing)?

Multiple comparison correction

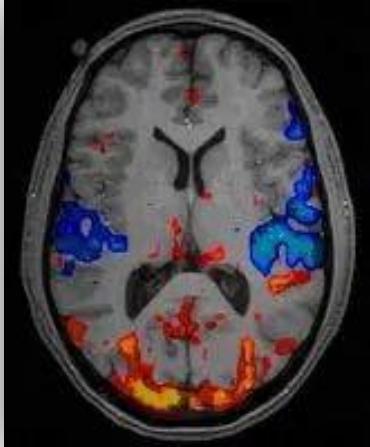


Multiple comparison correction



For 100 000 voxels
~ 5 000 false
positives!!!

Multiple comparison correction



For 100 000 voxels
~ 5 000 false
positives!!!

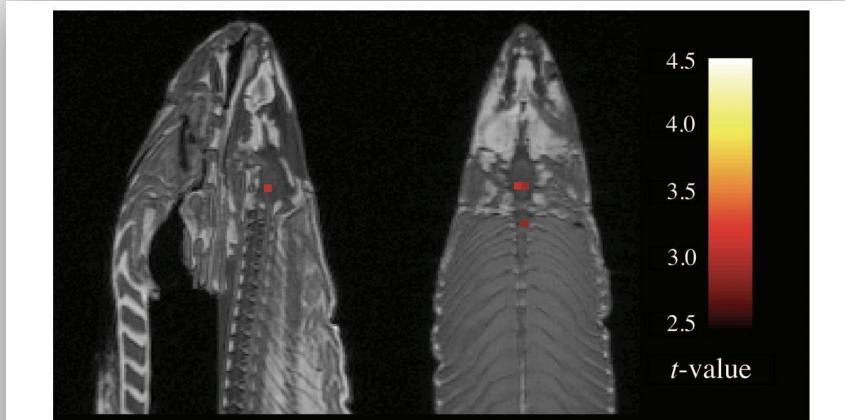


Fig. 1. Sagittal and axial images of significant brain voxels in the task > rest contrast. The parameters for this comparison were $t(131) > 3.15$, $p(\text{uncorrected}) < 0.001$, 3 voxel extent threshold. Two clusters were observed in the salmon central nervous system. One cluster was observed in the medial brain cavity and another was observed in the upper spinal column.



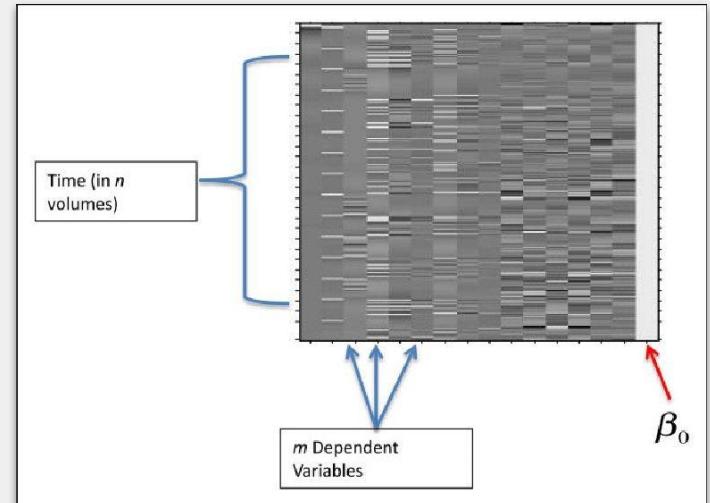
Important questions about task design

- Block vs. event-related?
- How many conditions?
- How many runs?
- What's repetition time (TR)?
- How stimuli were organized in time (onsets, durations)?

ALPHA VERSION
Looking for contributors and alpha testers.
Non backward compatible changes can still take place in the source code.

Nistats:
Functional MRI Neuro-Imaging in Python

 niLearn
Machine learning for Neuro-Imaging in Python

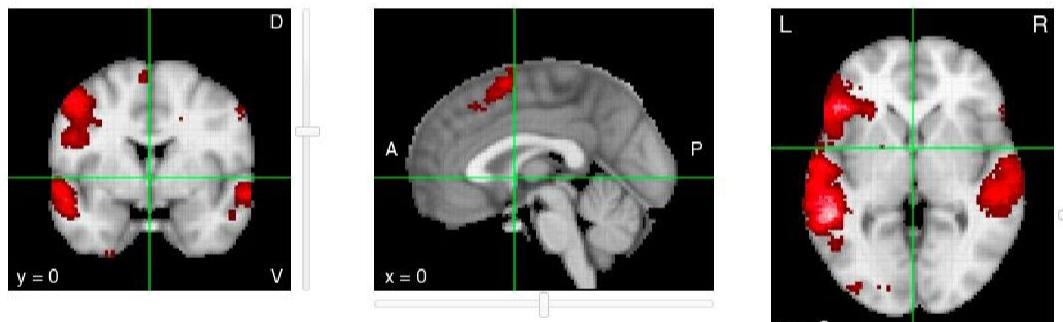




neurosynth.org

Neurosynth is a platform for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data.

It takes thousands of published articles reporting the results of fMRI studies, chews on them for a bit, and then spits out images that look like this:



Database Status

507891 activations reported in **14371** studies

Interactive, downloadable meta-analyses of **1335** terms

Homework

1. GitHub Classroom

GLM analysis & fMRI results
plotting Deadline: **25-01-2020**



Next



Functional connectivity