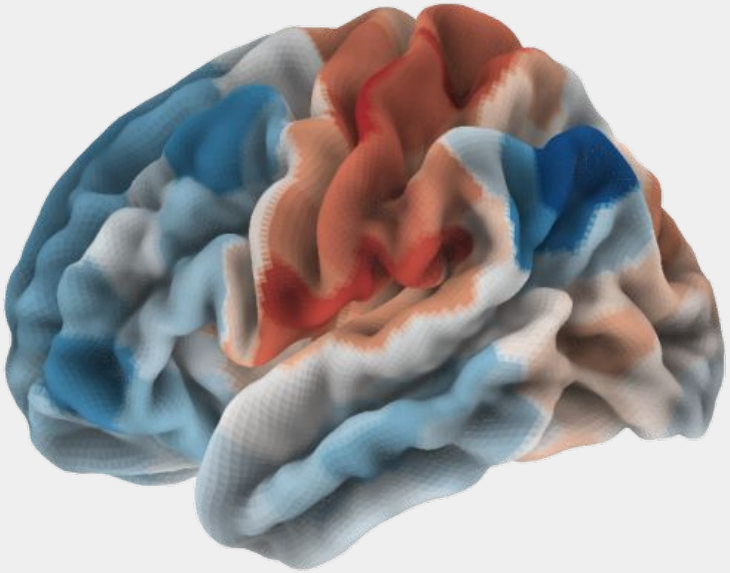
Fundamentals of fMRI data analysis

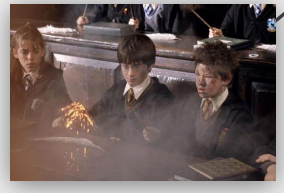


Karolina Finc

Centre for Modern Interdisciplinary Technologies Nicolaus Copernicus University in Toruń

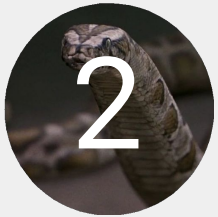
PART #5: General Linear Model 2

Study plan



BEFORE

Open science & neuroimaging



fMRI data manipulation in python

fMRI data preprocessing

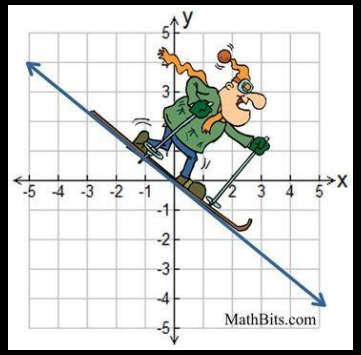
General Linear Model

Functional connectivity

Machine Learning on fMRI data

AFTER

Slope-intercept form of linear function



slope

intercept

$$y = mx + b$$

coefficients

desmos Graphing Calculator

https://www.desmos.com/calculator

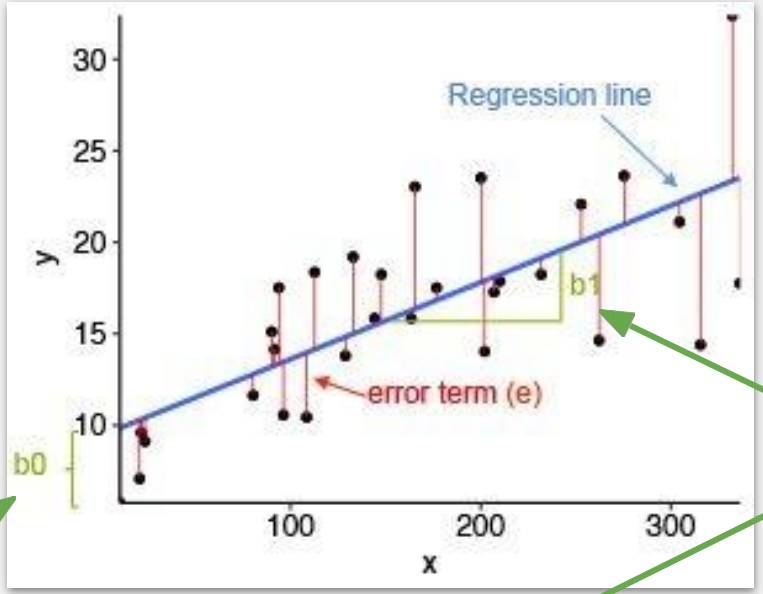
Linear regression

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

Regression problem:
predict real-valued output

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

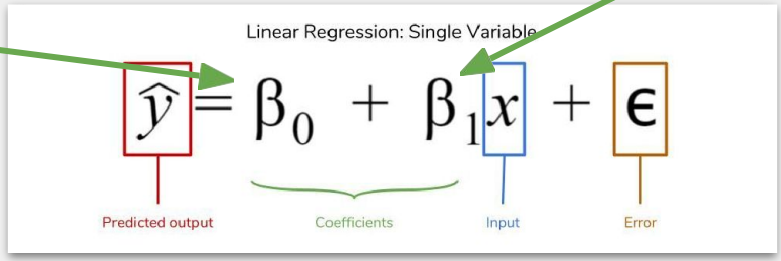
Fitting regression line



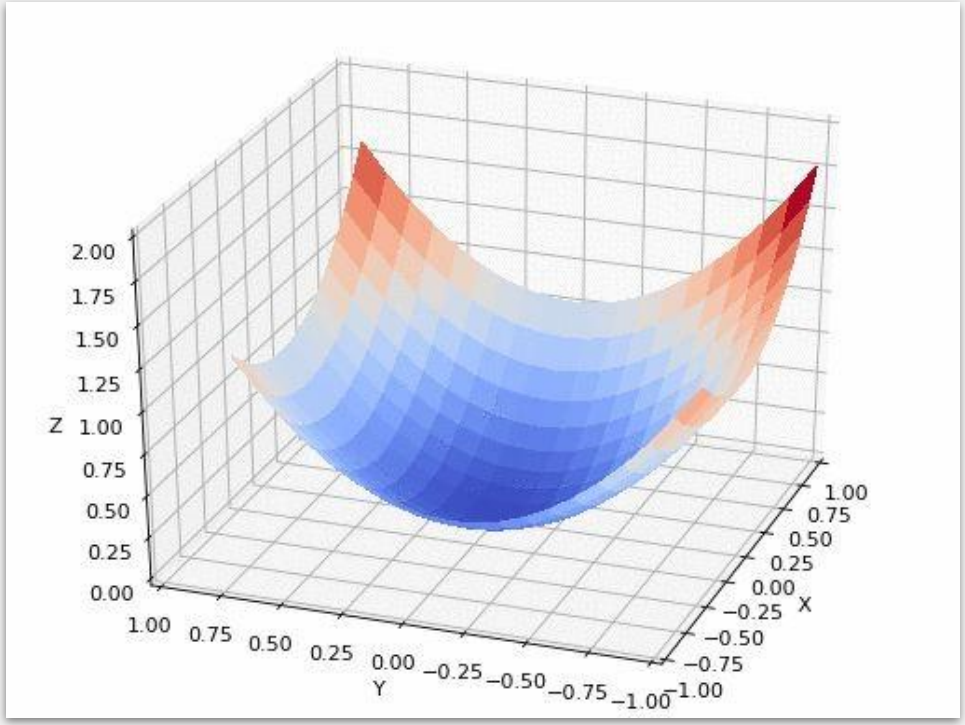
Find such β_0 and β_1 that minimize *cost function*: **sum of squared errors** function

slope

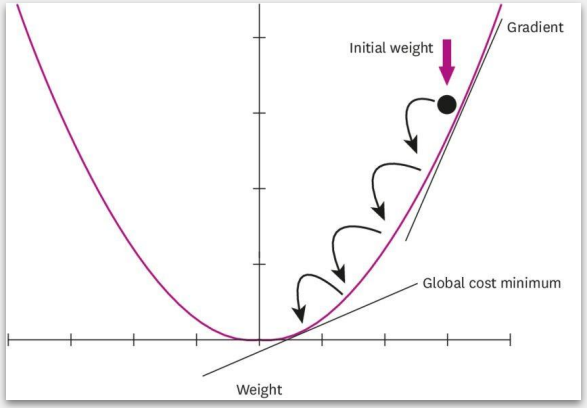
intercept



Gradient descent



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

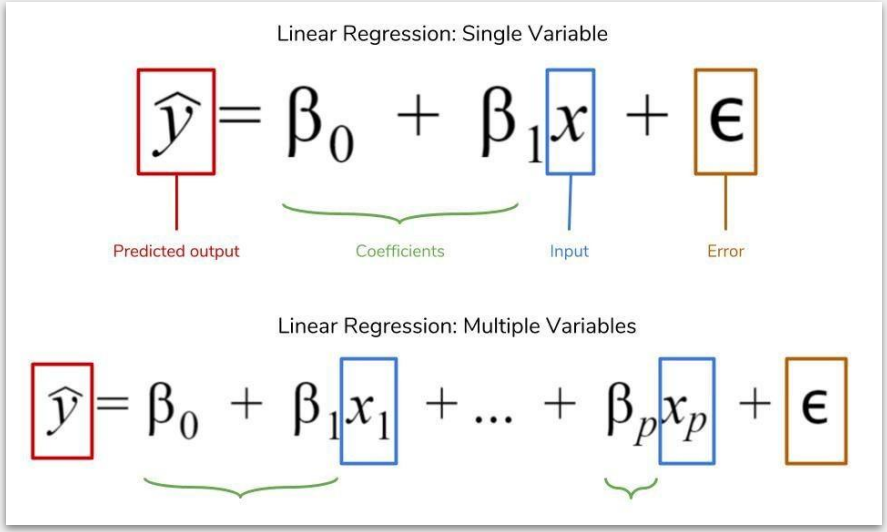


Linear combination

 = a  + b  + ε

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

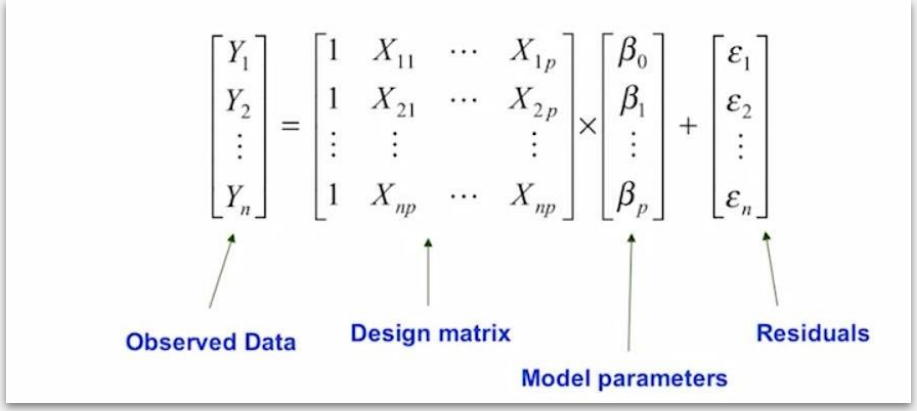
Multiple linear regression



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

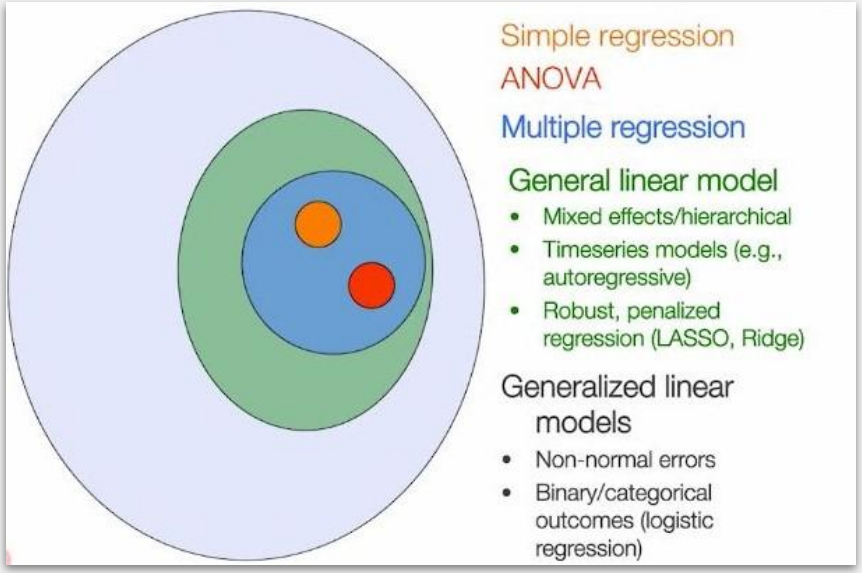
Matrix notation

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



Coursera, *Principles of fMRI*

Generalized Linear Model



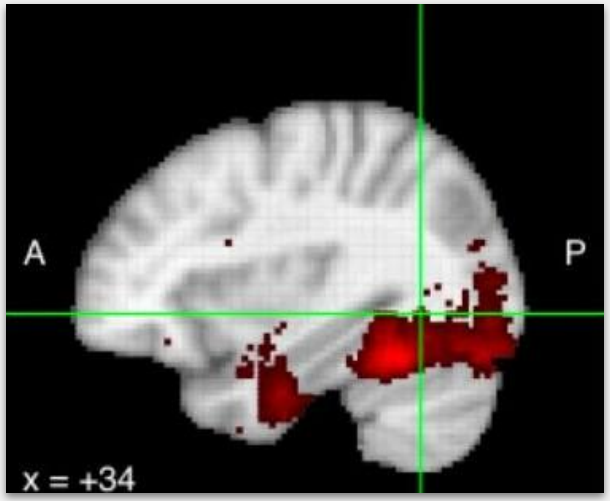
Coursera, *Principles of fMRI*

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

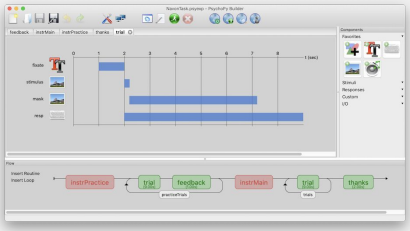
Equipment

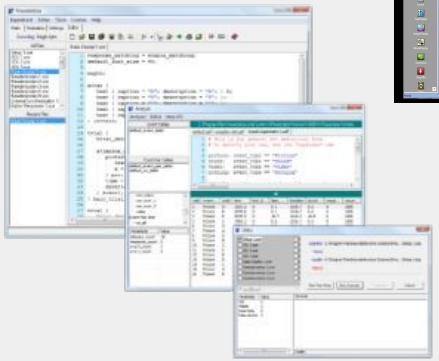
Software

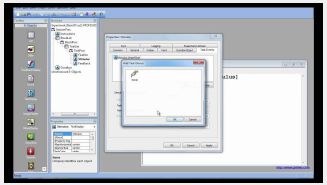
PsychoPy3
Now running studies online

presentation®

E-Prime 3

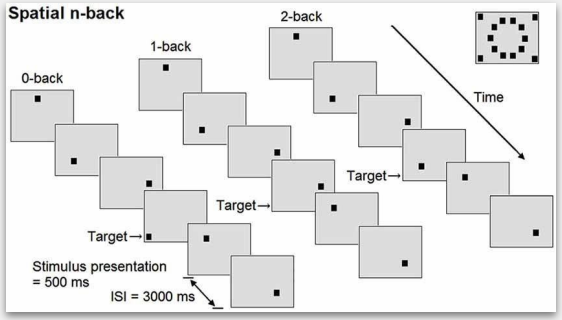






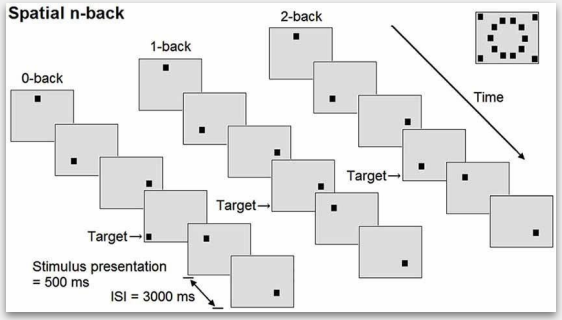
What to present?

Simple stimuli

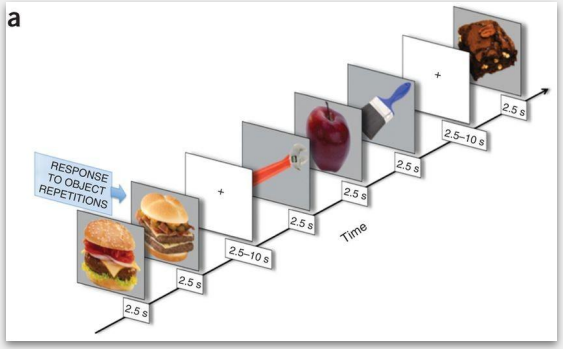


What to present?

Simple stimuli

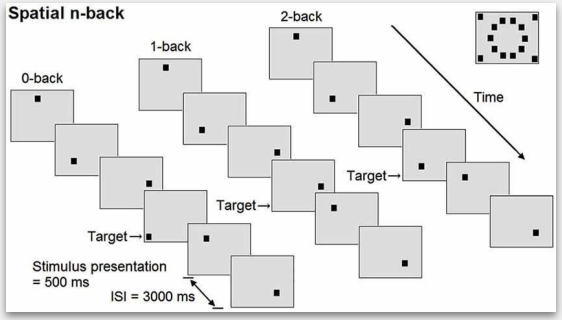


Photos



What to present?

Simple stimuli



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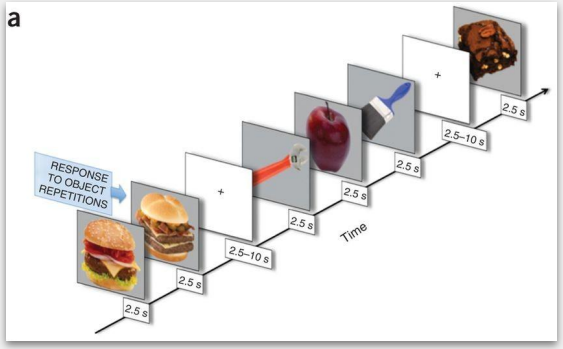
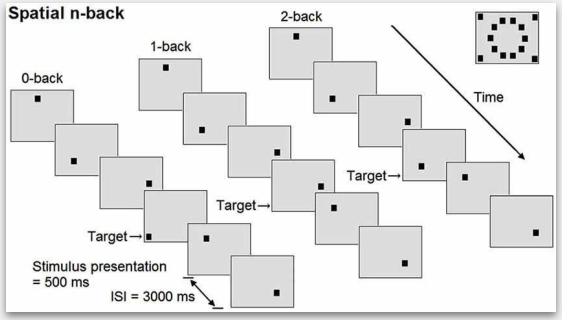


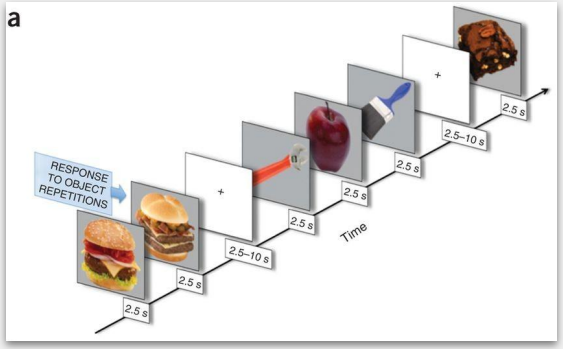
Movie

What to present?

Simple stimuli

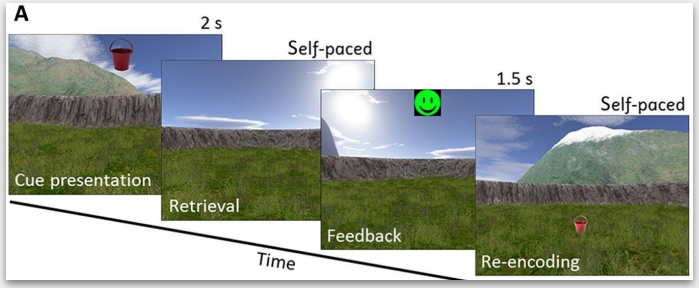


Photos



Movie

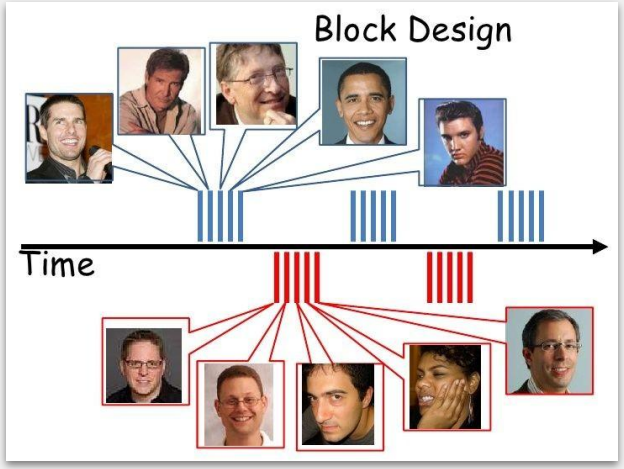
Virtual reality



Task designs

Famous people

Non-famous people



Block design

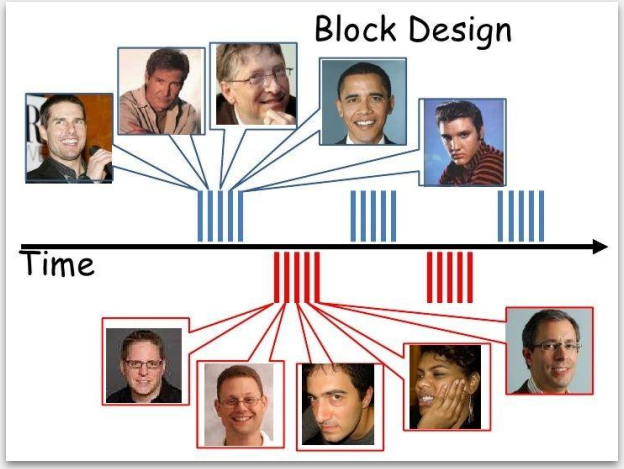
similar events are grouped

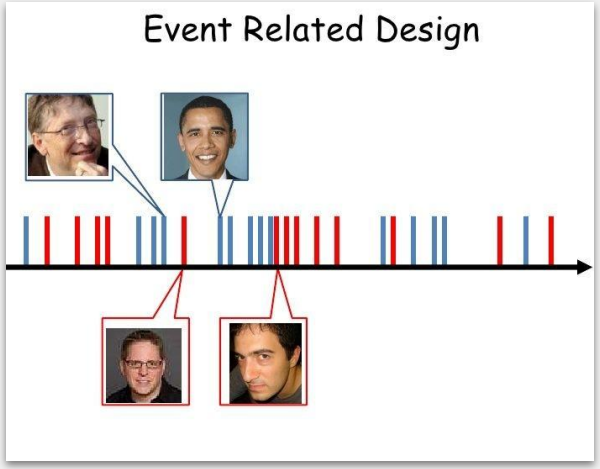
https://www.slideshare.net/rnja8c/fmri-study-design-9138161

Task designs

Famous people

Non-famous people





Block design
similar events are grouped

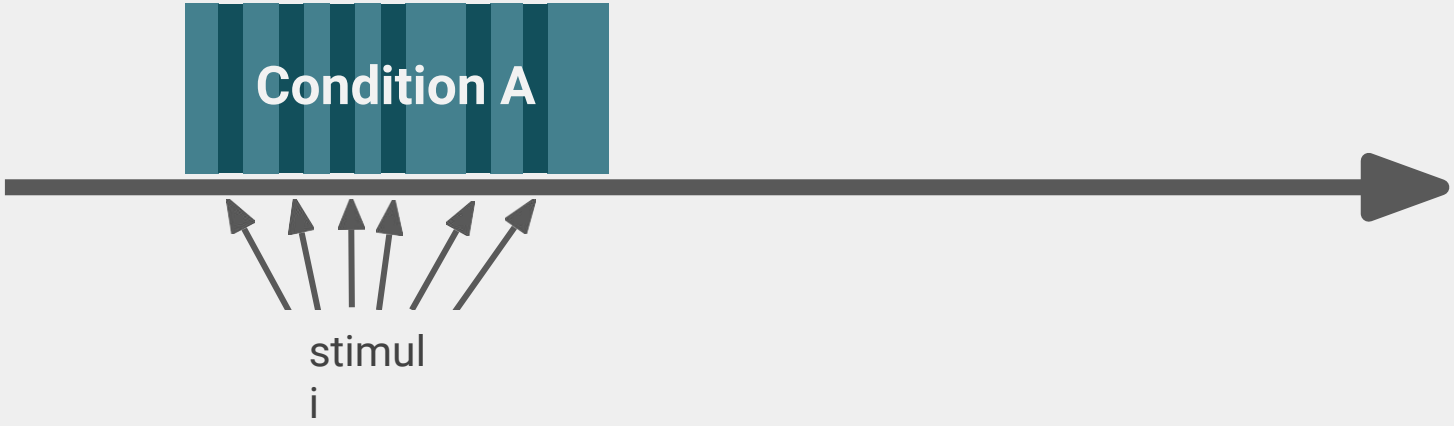
Event-related design
events are mixed

https://www.slideshare.net/rnja8c/fmri-study-design-9138161

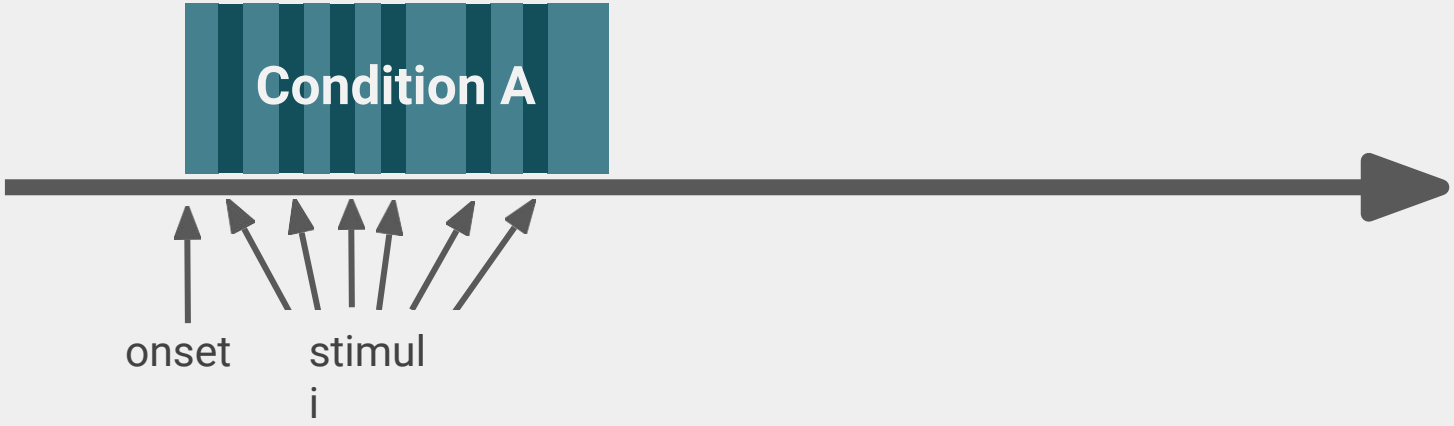
Events parameters

Events parameters

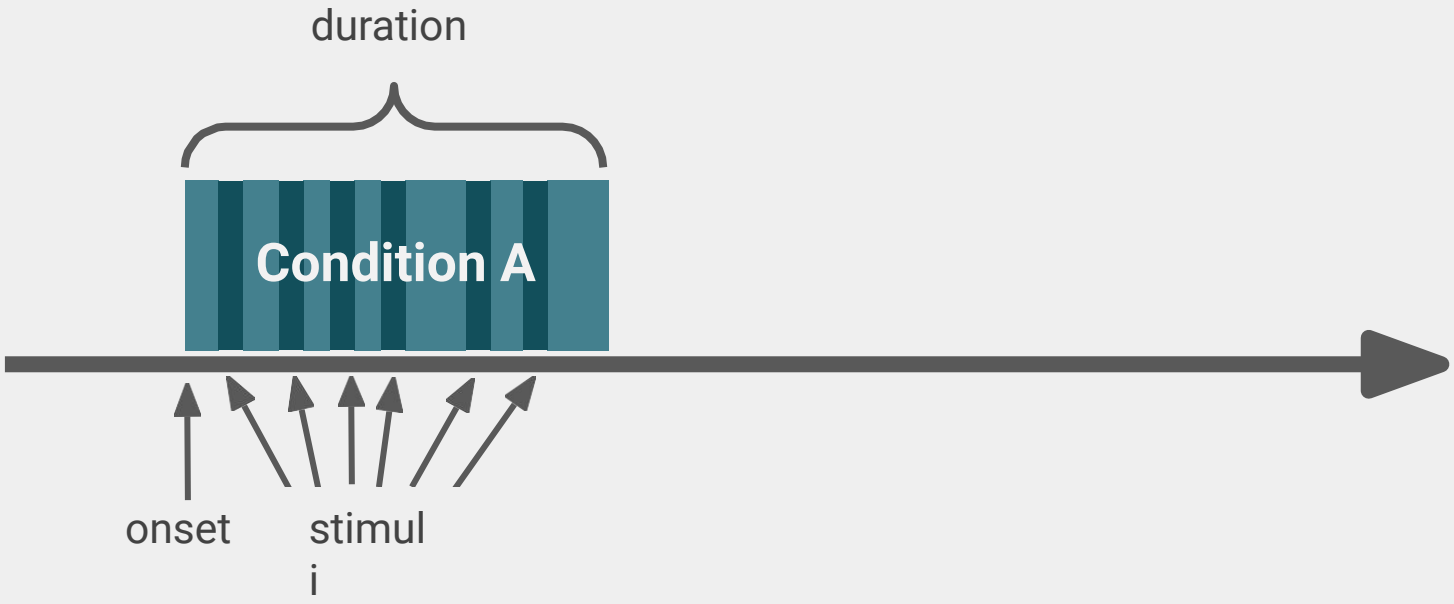
Events parameters



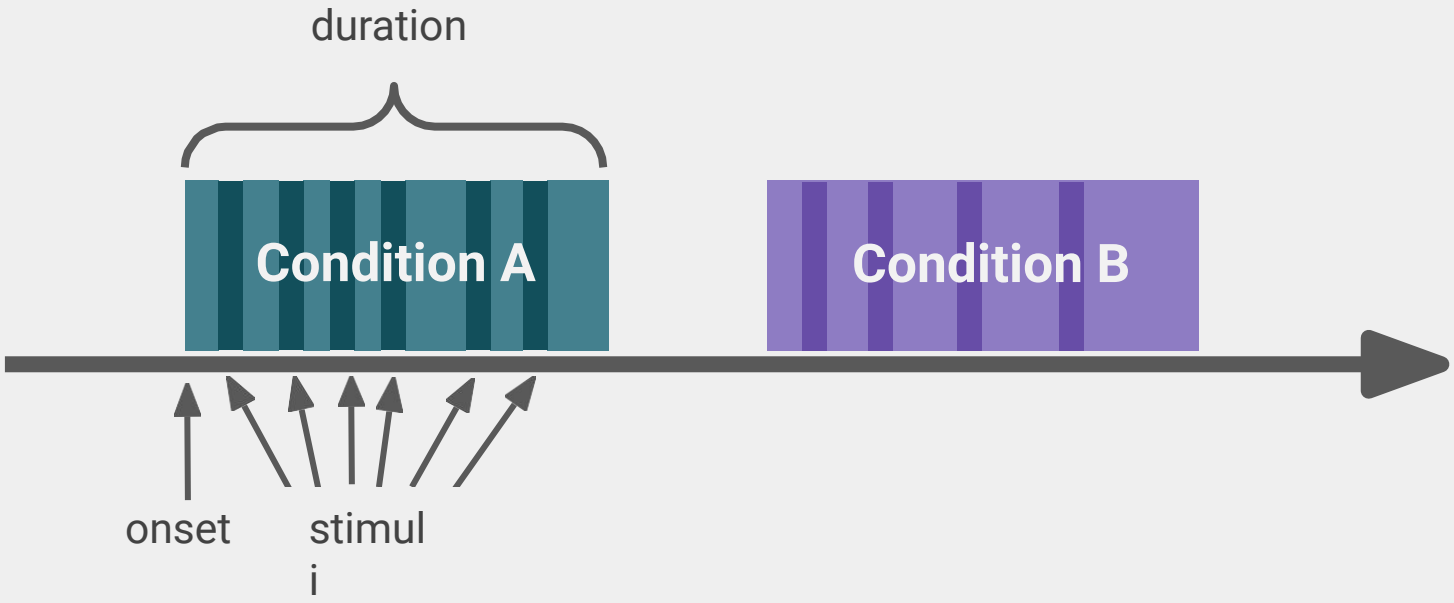
Events parameters



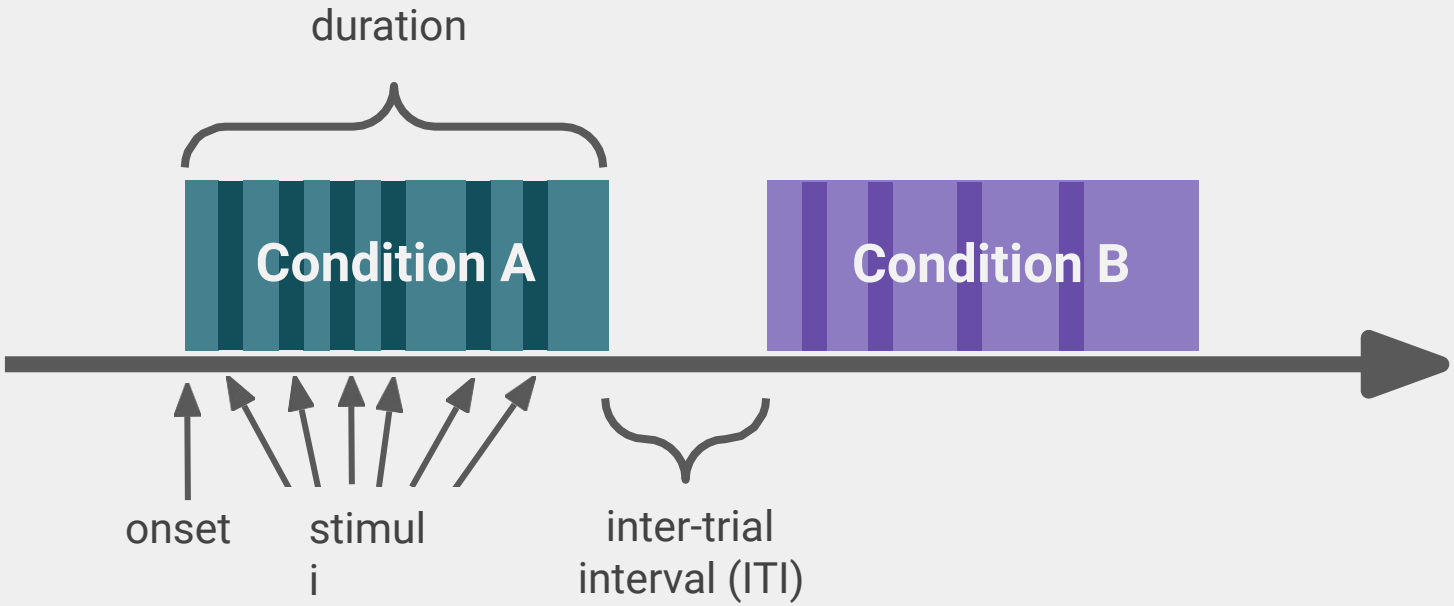
Events parameters



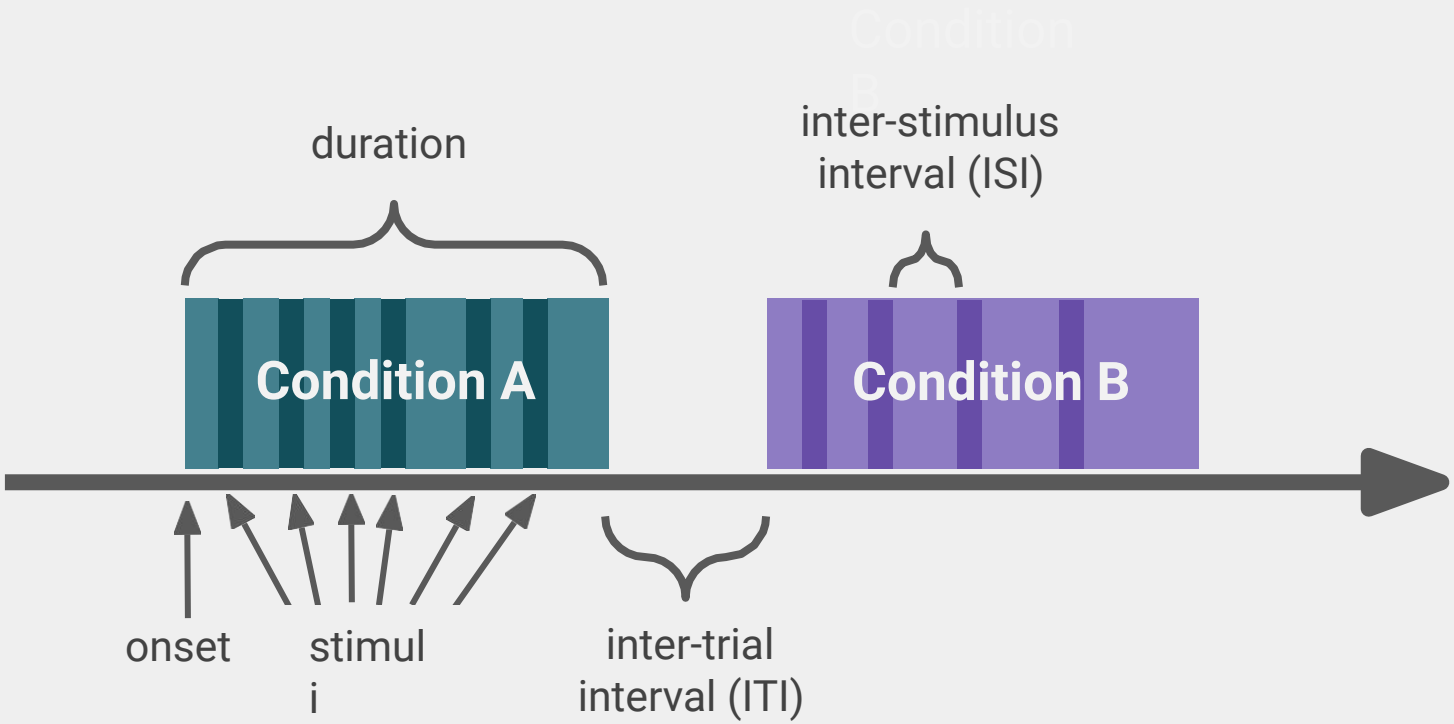
Events parameters



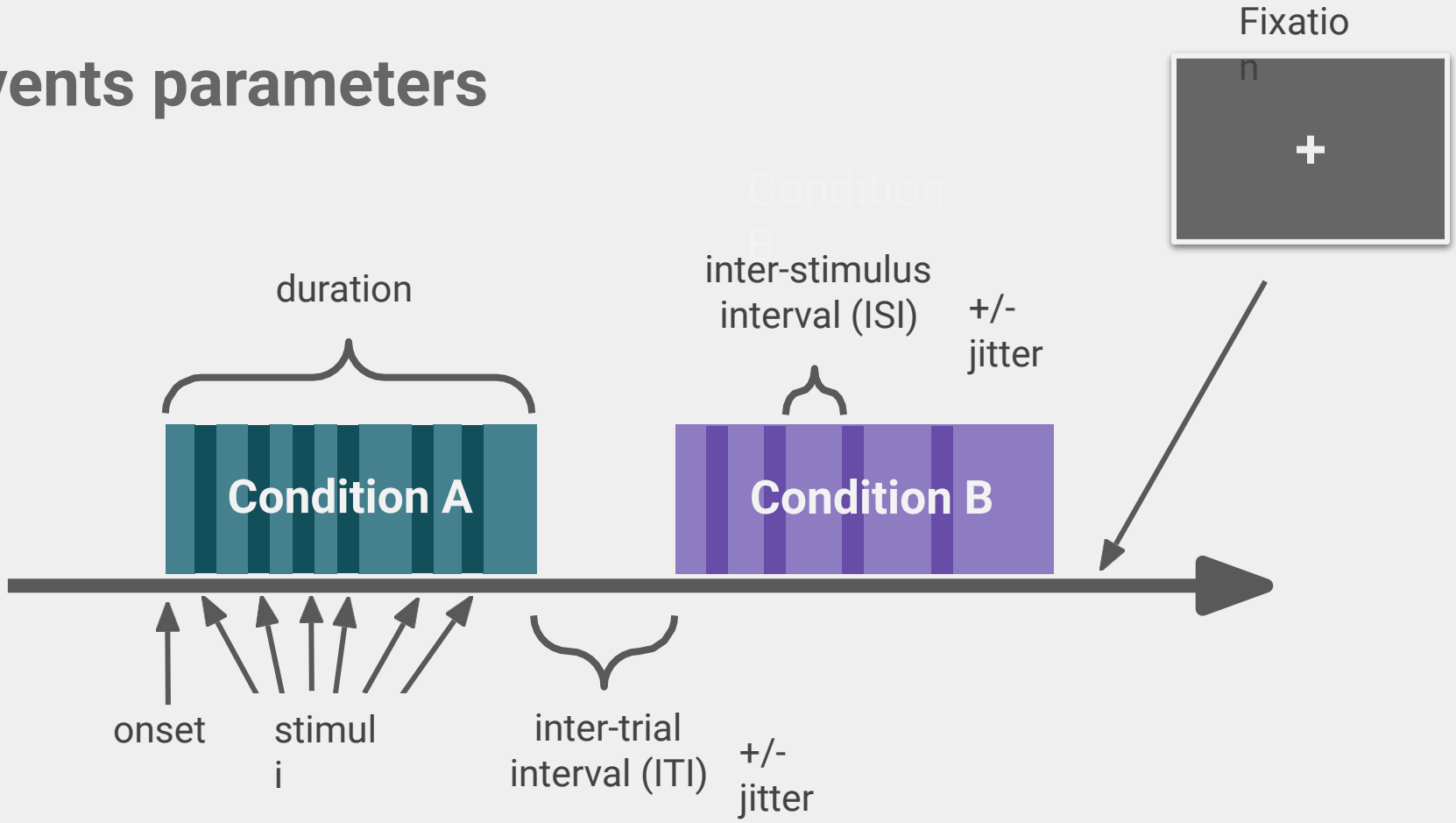
Events parameters



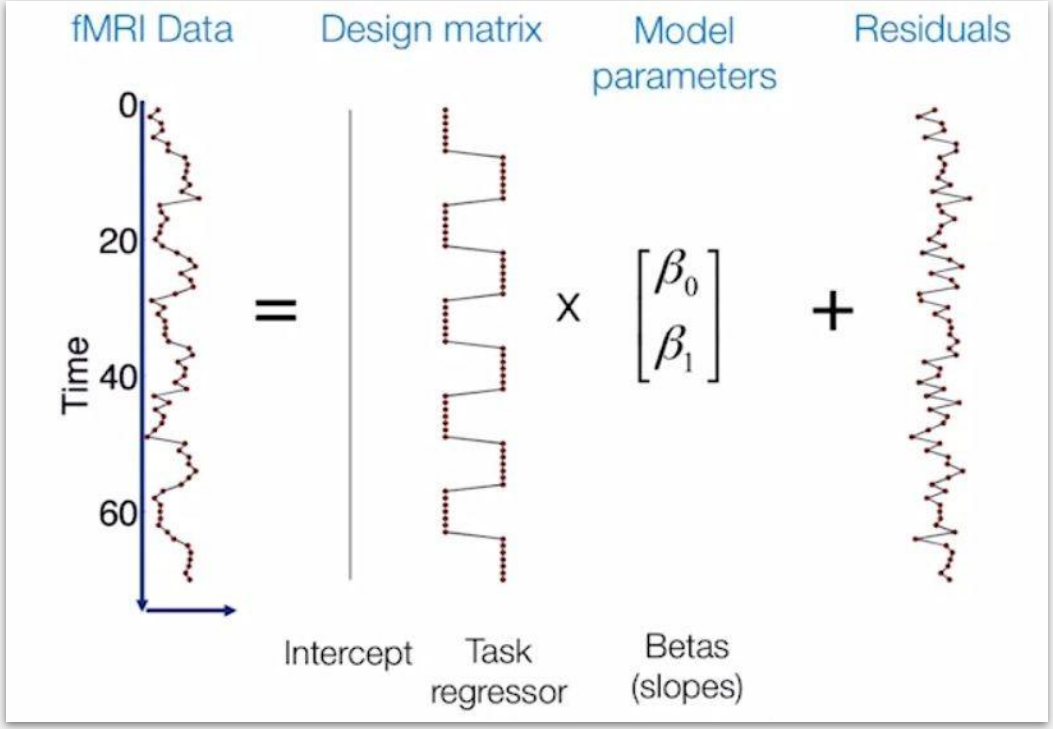
Events parameters



Events parameters

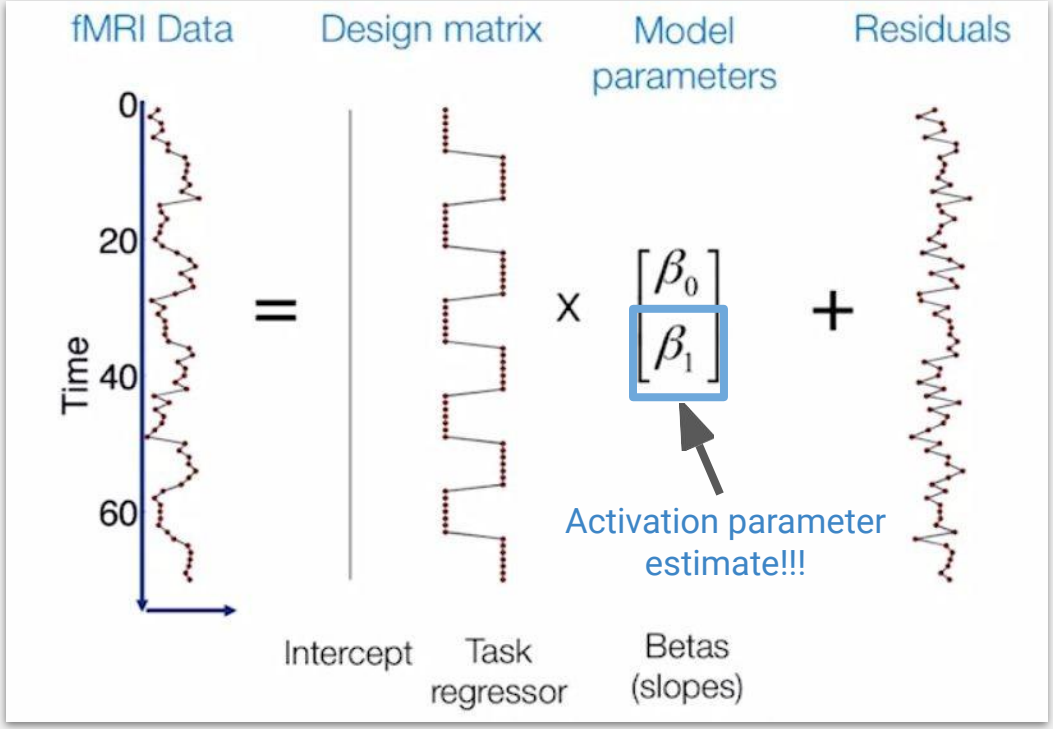


First level GLM



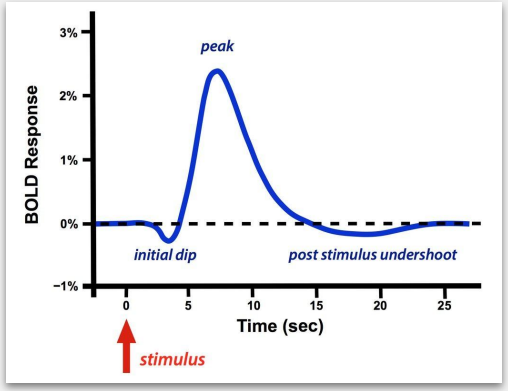
Coursera, *Principles of fMRI*

First level GLM

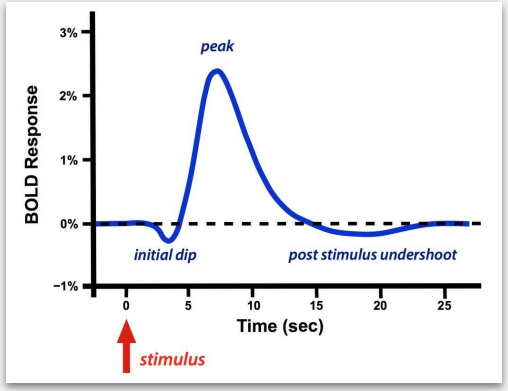


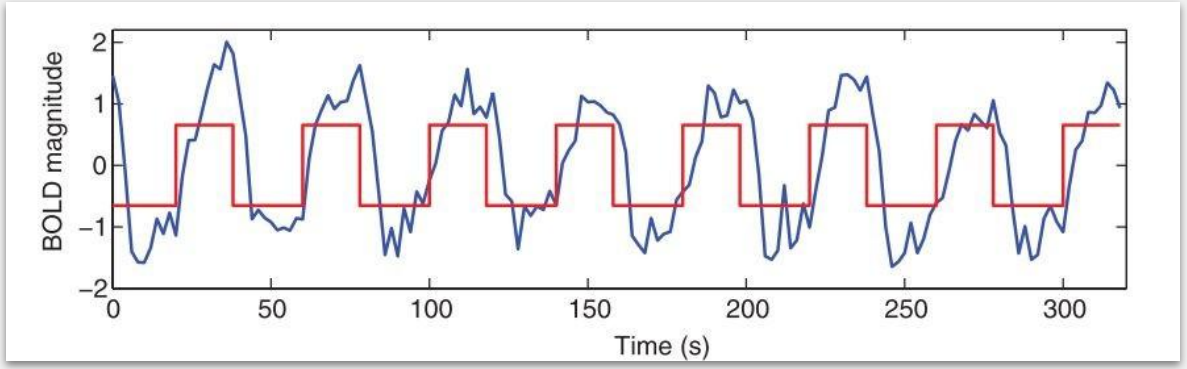
Coursera, *Principles of fMRI*

Haemodynamic delay!

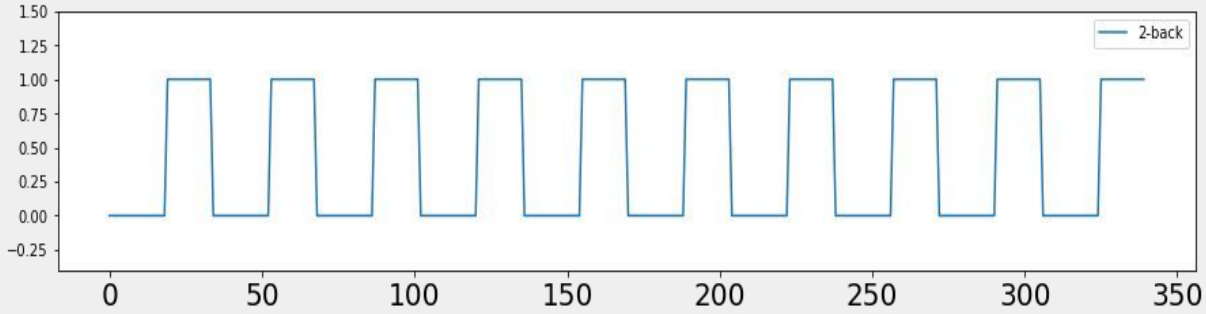


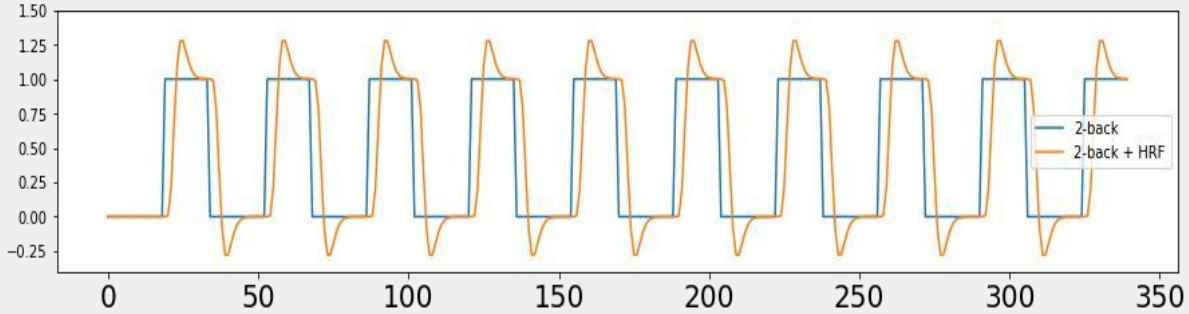
Haemodynamic delay!



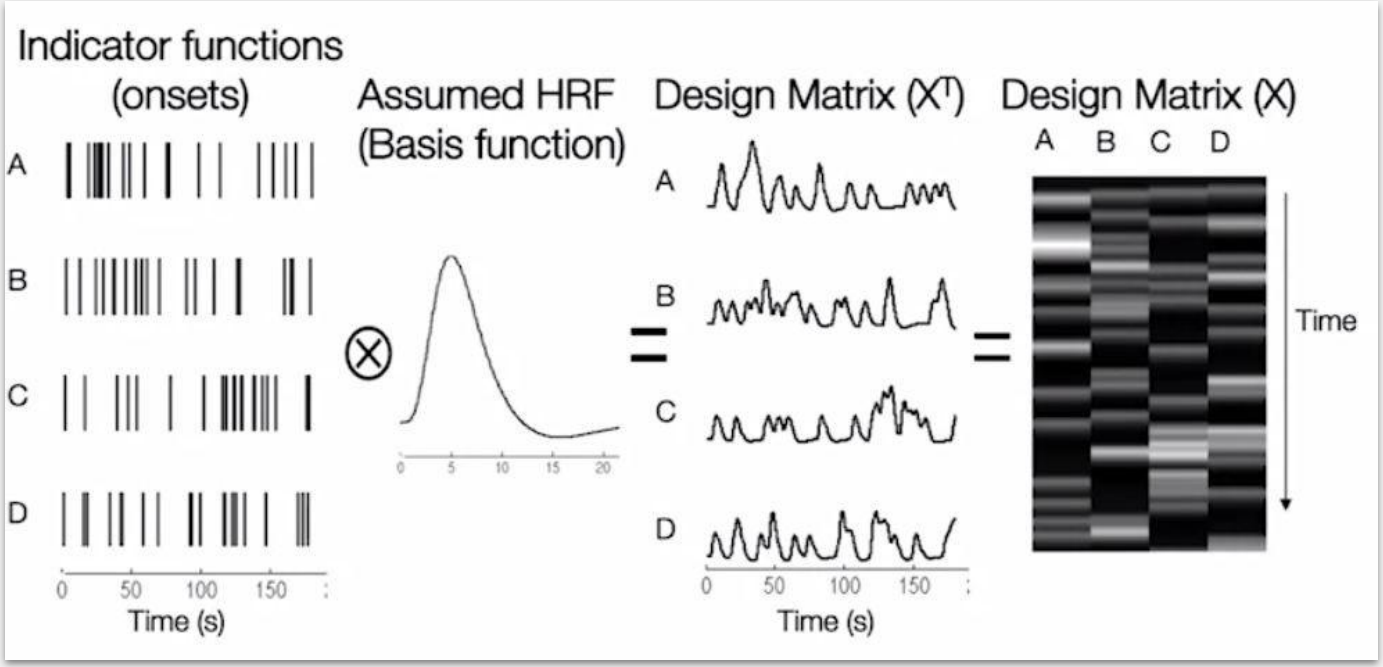


Convolution





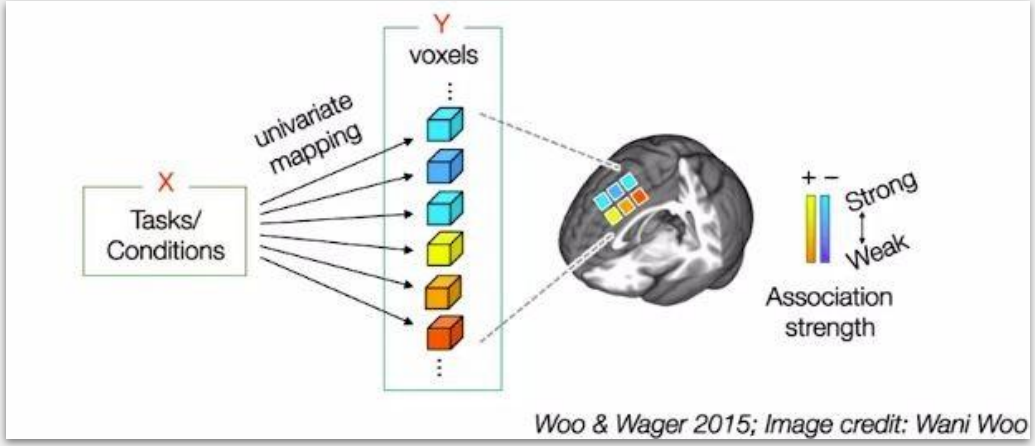
Building design matrix from events data



How to do this on the whole brain?

Mass univariate approach

Assumes voxels are independent, each owns a separate model.

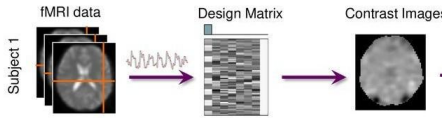


Woo & Wager 2015; Image credit: Wani Woo

Analysis steps

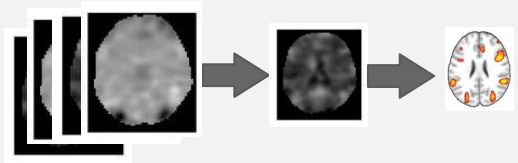
1-level analysis
(within-subject; individual)

How was the brain active in a one particular brain?

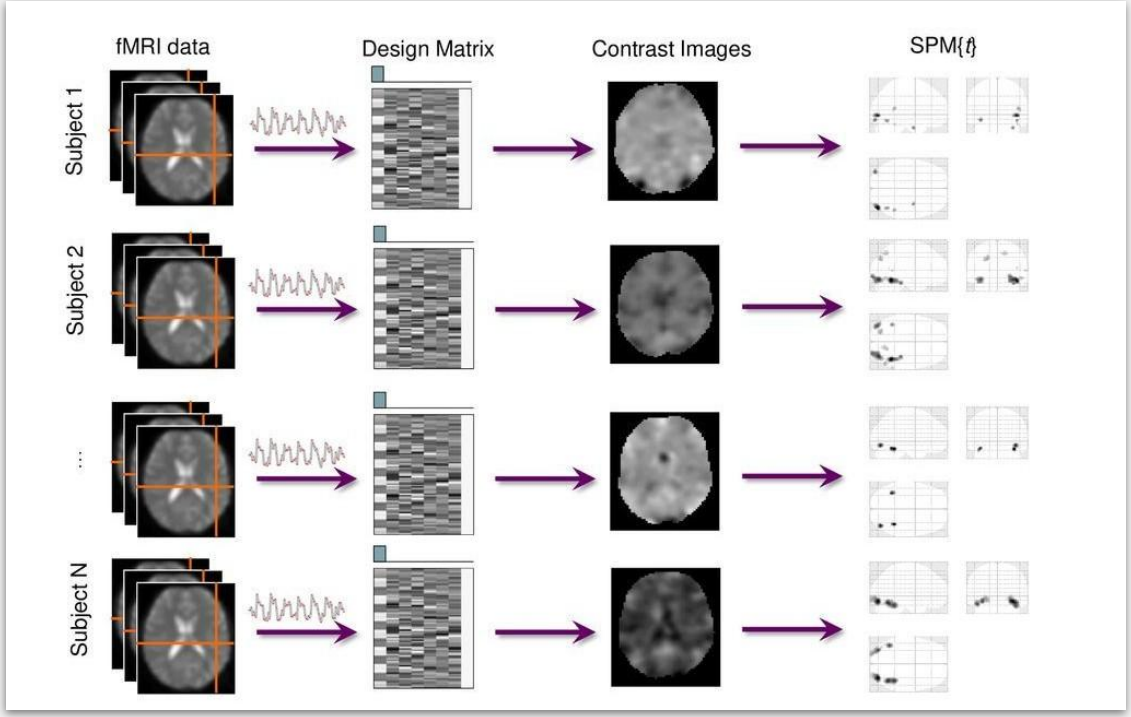


2-level analysis
(across-subject; group)

How brain activations look in general (for the whole group)?
Differences between groups?



1-level analysis

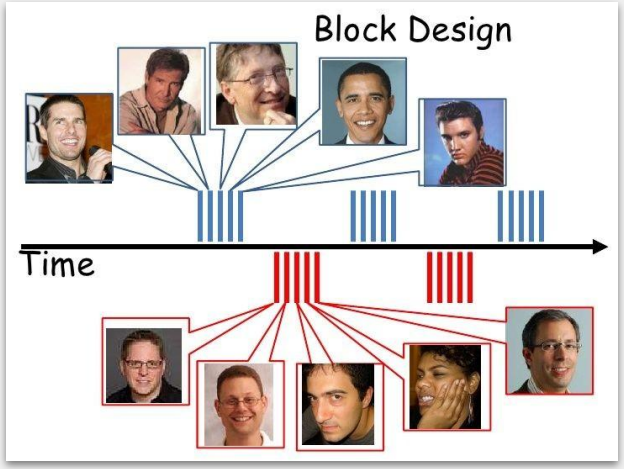


https://slideplayer.com/slide/16403606/

Contrasts

Famous people

Non-famous people



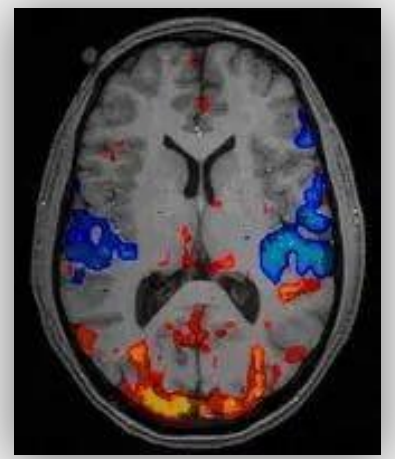
- Difference between conditions
- Each condition separately
- Average of two conditions

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

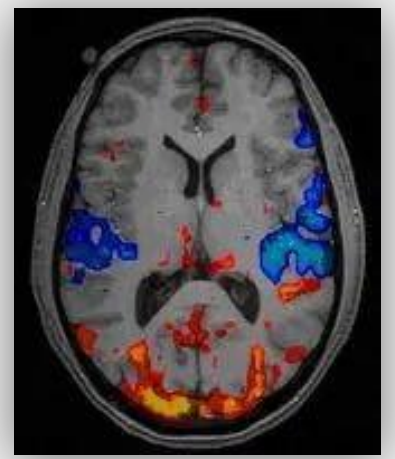
Contrast - a *linear combination* of GLM parameters.

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

Multiple comparison correction

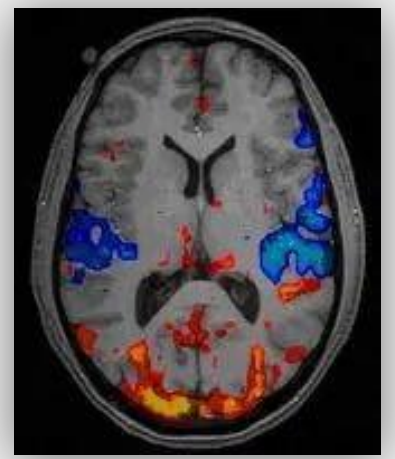


Multiple comparison correction



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

Multiple comparison correction



For 100 000 voxels
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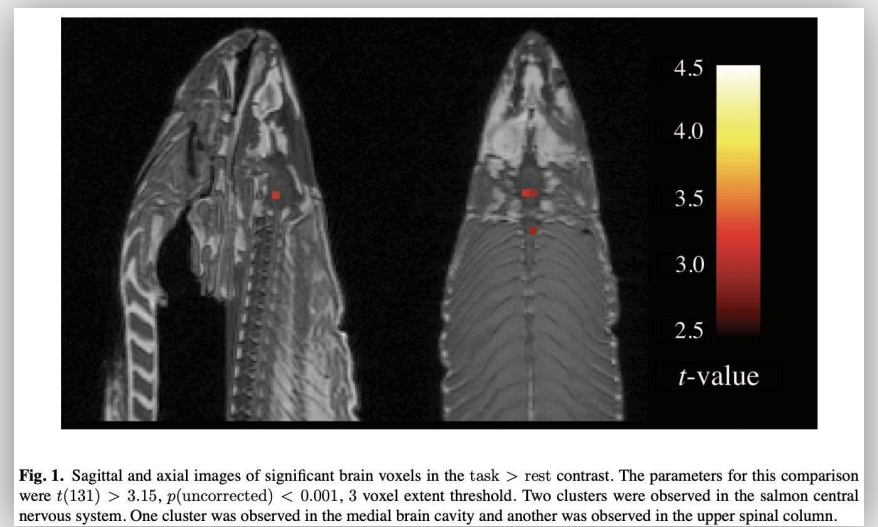
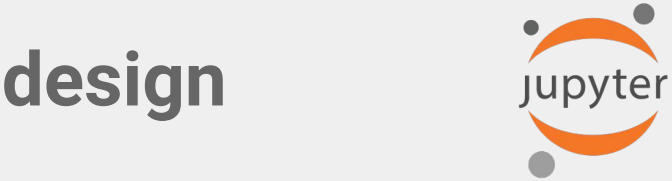
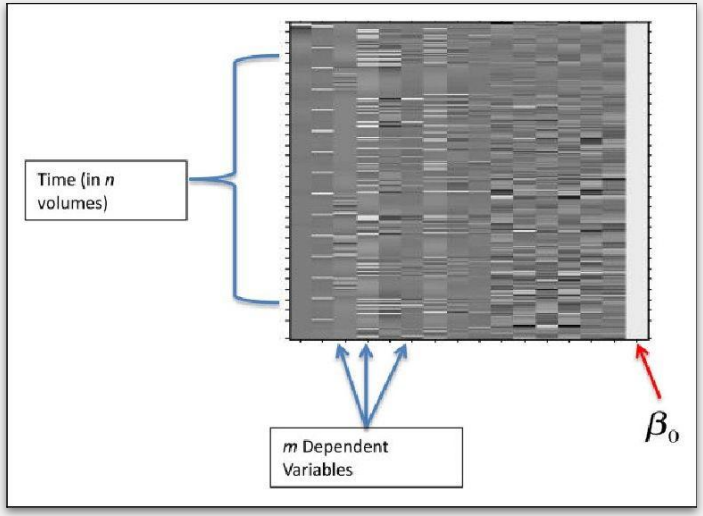


Fig. 1. Sagittal and axial images of significant brain voxels in the task > rest contrast. The parameters for this comparison were $t(131) > 3.15$, $p(\text{uncorrected}) < 0.001$, 3 voxel extent threshold. Two clusters were observed in the salmon central nervous system. One cluster was observed in the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

Important questions about task design



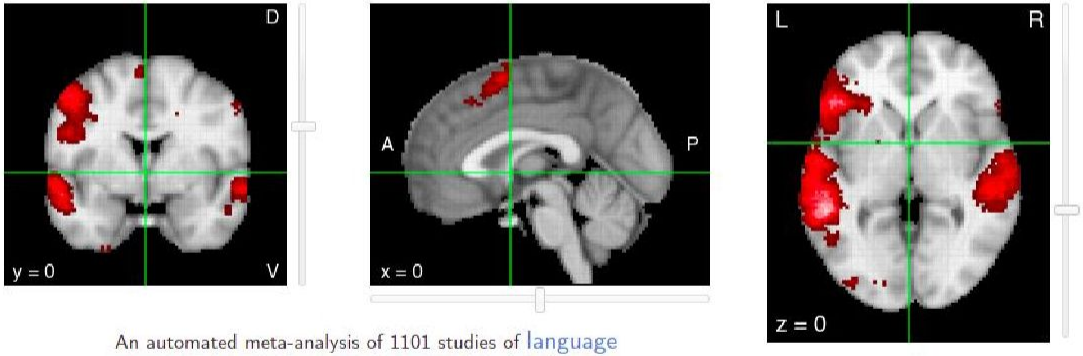
- Block vs. event-related?
- How many conditions?
- How many runs?
- What's repetition time (TR)?
- How stimuli were organized in time (onsets, durations)?



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:



An automated meta-analysis of 1101 studies of language

Database Status

507891 activations reported in 14371 studies

Interactive, downloadable meta-analyses of 1335 terms

Homework

1. **GitHub Classroom**

   GLM analysis & fMRI results plotting

Next

Functional connectivity