Methods for Dummies
2nd level analysis

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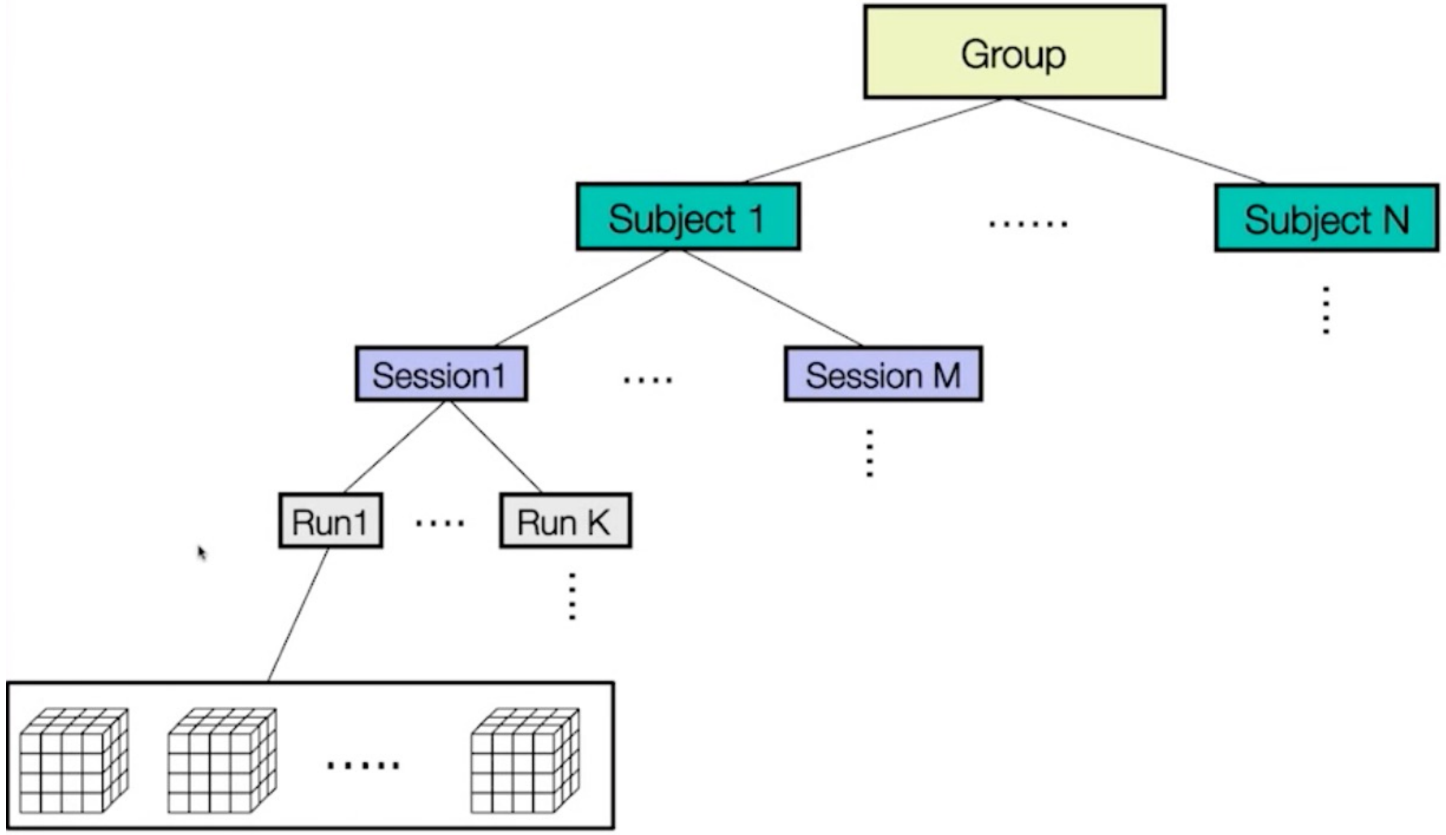
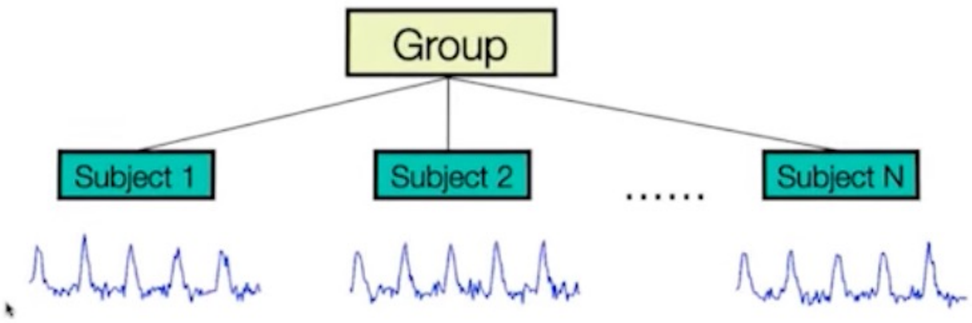
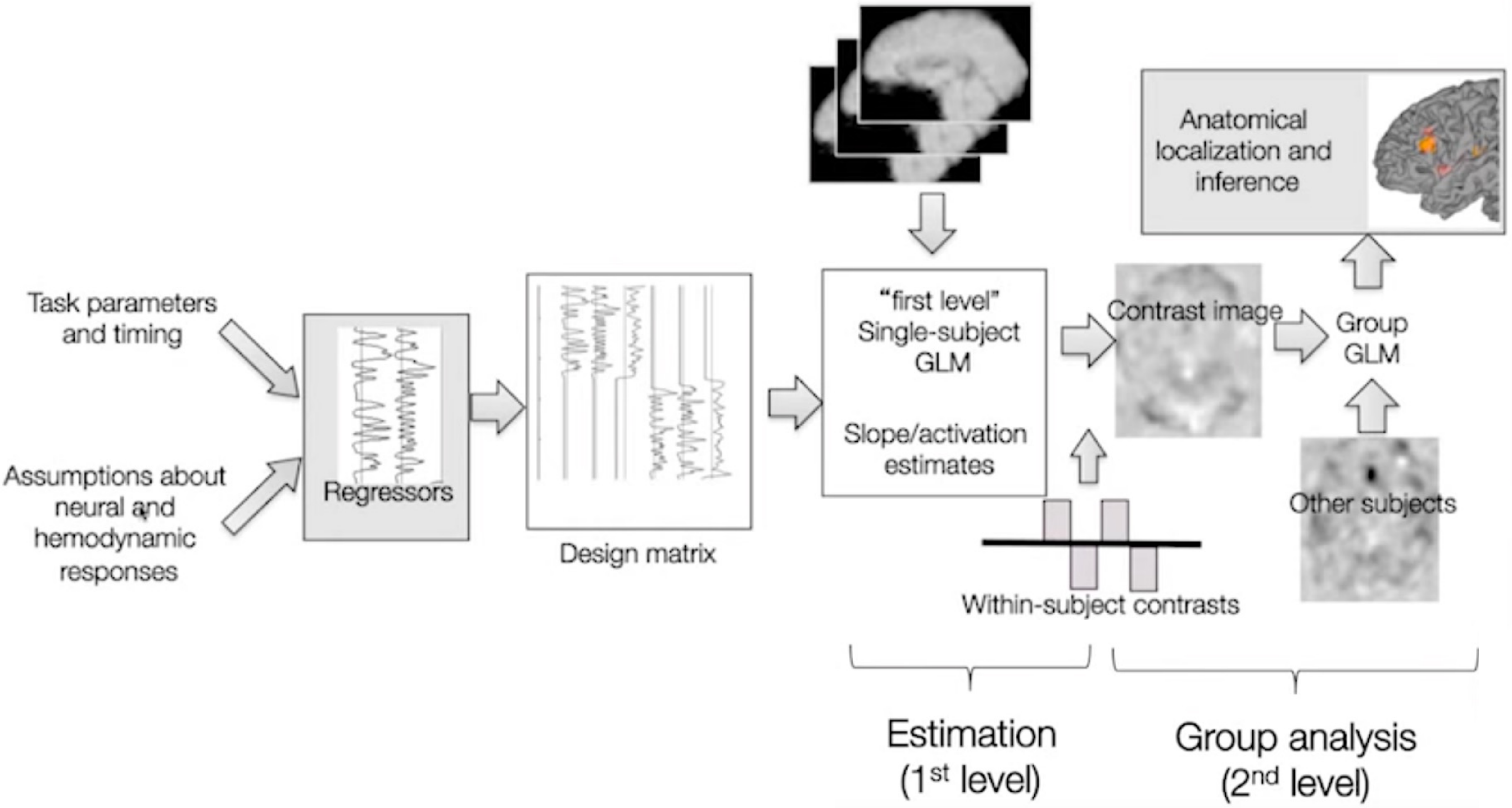
Hierarchical structure of data



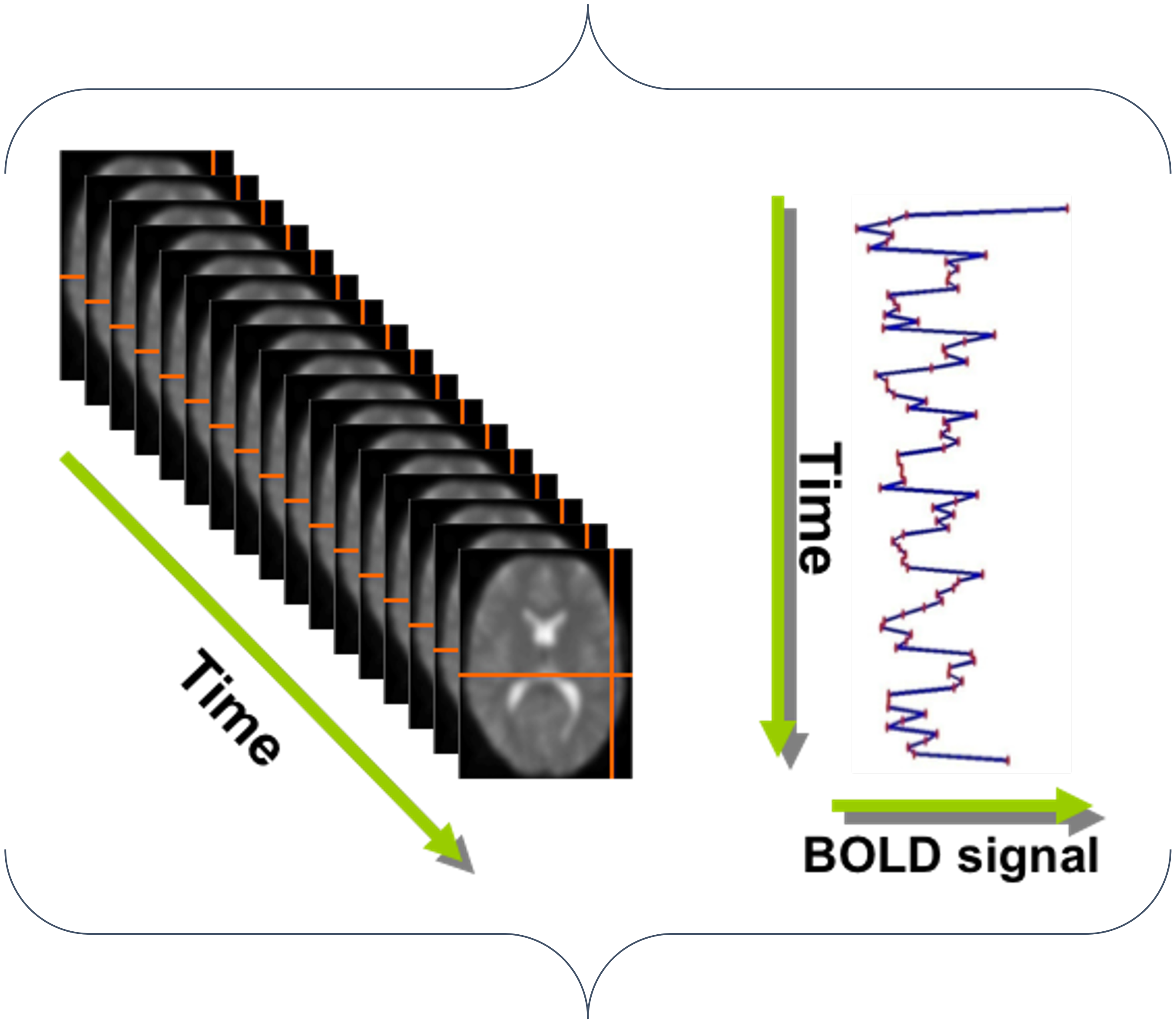
Multi-level Model

- Analysis performed in two levels
  - The first level deals with individual subjects
  - The second level deals with groups of subjects




Task parameters and timing
Assumptions about neural and hemodynamic responses
Regressors
Design matrix
"first level" Single-subject GLM
Slope/activation estimates
Within-subject contrasts
Contrast image
Group GLM
Other subjects
Anatomical localization and inference
Estimation (1st level)
Group analysis (2nd level)

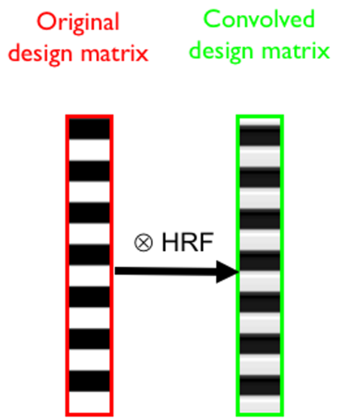
Time-series per voxel, per participant

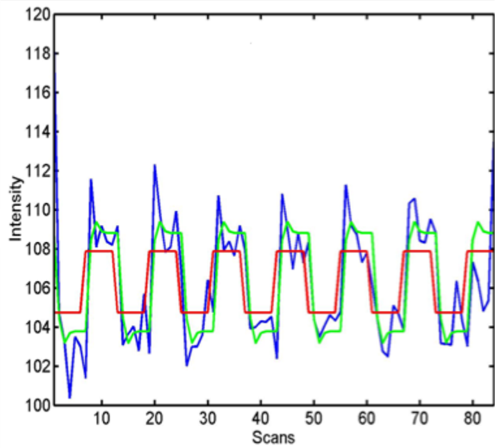


GLM:

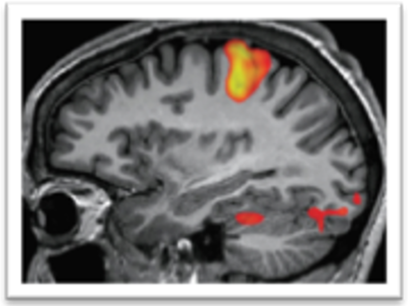
$$Y = \beta_0 + \beta_1 X_1 + \epsilon$$

Convolution:





Contrasts:



Why 2nd level analysis?

- **1st level analysis = looking at single subject effect – contrast map is only applicable to that particular subject**

- **2nd level analysis = looking at across subject effects as opposed to single subject effect**

- Significant differences in activation between different situations are unlikely to be manifest identically in all individuals. Therefore, we might ask:
    - Is this contrast in activation different on average between groups? e.g. males vs. females?
    - Is this contrast in activation seen on average in the population?

What is 2nd level analysis?

- We need to look at which voxels are showing a significant activation difference between levels of X consistently within a group. To do this, we need to consider:
    - The average contrast effect across our sample
    - The variation of this contrast effect
    - T-tests involve mean divided by standard error of mean

Fixed vs. Random effects

Assume the signal strength varies across sessions and subjects.

There are two sources of variation:

(i) Measurement error

(ii) Response magnitude - Each subject/ session has a random magnitude.

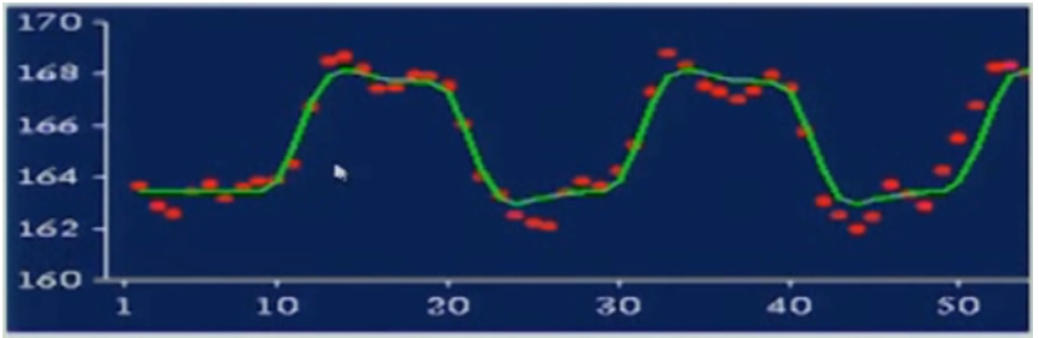
The population mean is fixed.

Fixed vs. Random effects

Never used if the goal is to make inferences on a population

Fixed effects model	**Random effects model**
Comparing effect size to *within subject* variability (i.e. not an inference about the pop.).	Comparing group effect to *between subject* variability (i.e. an inference about the pop.).
Only one source of variation - measurement error (true response magnitude is fixed).	Models multiple sources of variation - measurement error AND true response magnitude (i.e. individual difference, which is random).
Levels not drawn from random sample; always the same e.g. Drug use Y/N.	Levels randomly sampled from population e.g. participant selected at random.
CANNOT generalise to unobserved subjects.	CAN generalise to unobserved subjects.

Fixed effects analysis example



Subject 1
Effect size c = 4 for given voxel
Within subject variability = 0.9

For group of N = 12 subjects x 50 scans = 600

Effect sizes c = [4,3,2,1,1,2,3,3,3,2,4,4]

Within subject variability = [0.9,1.2,1.5,0.5,0.4,0.7,0.8,2.1,1.8,0.8,0.7,1.1]

Mean group effect M = 2.67

Average within subject variability (SD) $\sigma_w^2 = 1.04$

Standard Error Mean (SEM) = $\sigma_w^2 /(\mathrm{sqrt}(N))=0.04$

$t=M/SEM = 62.7$, $p=10^{-51}$

Random effects model
Comparing group effect to *between subject* variability (i.e. an inference about the pop.).
Models multiple sources of variation - measurement error AND true response magnitude (i.e. individual difference, which is random).
Levels randomly sampled from population e.g. participant selected at random.
CAN generalise to unobserved subjects.

How is random effects analysis calculated differently?

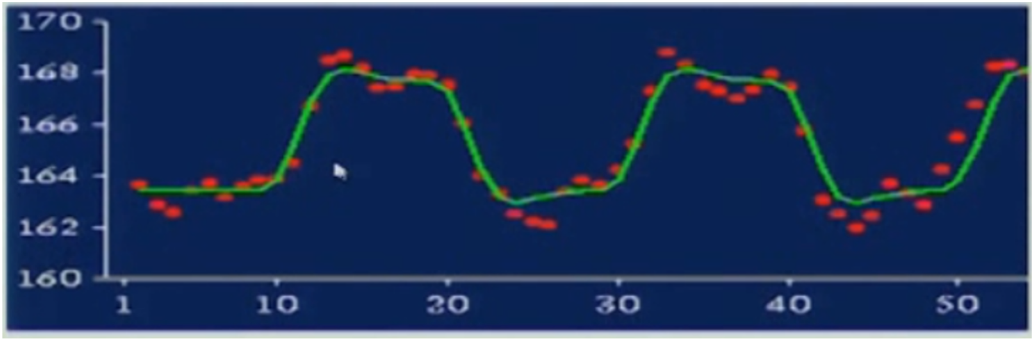
Assume our sample is a set of individuals taken at random from the population of interest.

To do this we need to consider the between subject variance AND within subject variance – and estimate the likely variance of the population from which our sample is derived.

$$y = \mathbf{X}_0\beta_0 + \mathbf{X}^{(1)}\beta^{(1)} + \varepsilon^{(1)}$$

$$\beta^{(1)} = \mathbf{X}^{(2)}\beta^{(2)} + \varepsilon^{(2)}$$

Random effects example



Subject 1
Effect size c = 4 for given voxel

For group of N = 12 subjects

Effect sizes c = [4,3,2,1,1,2,3,3,3,2,4,4]

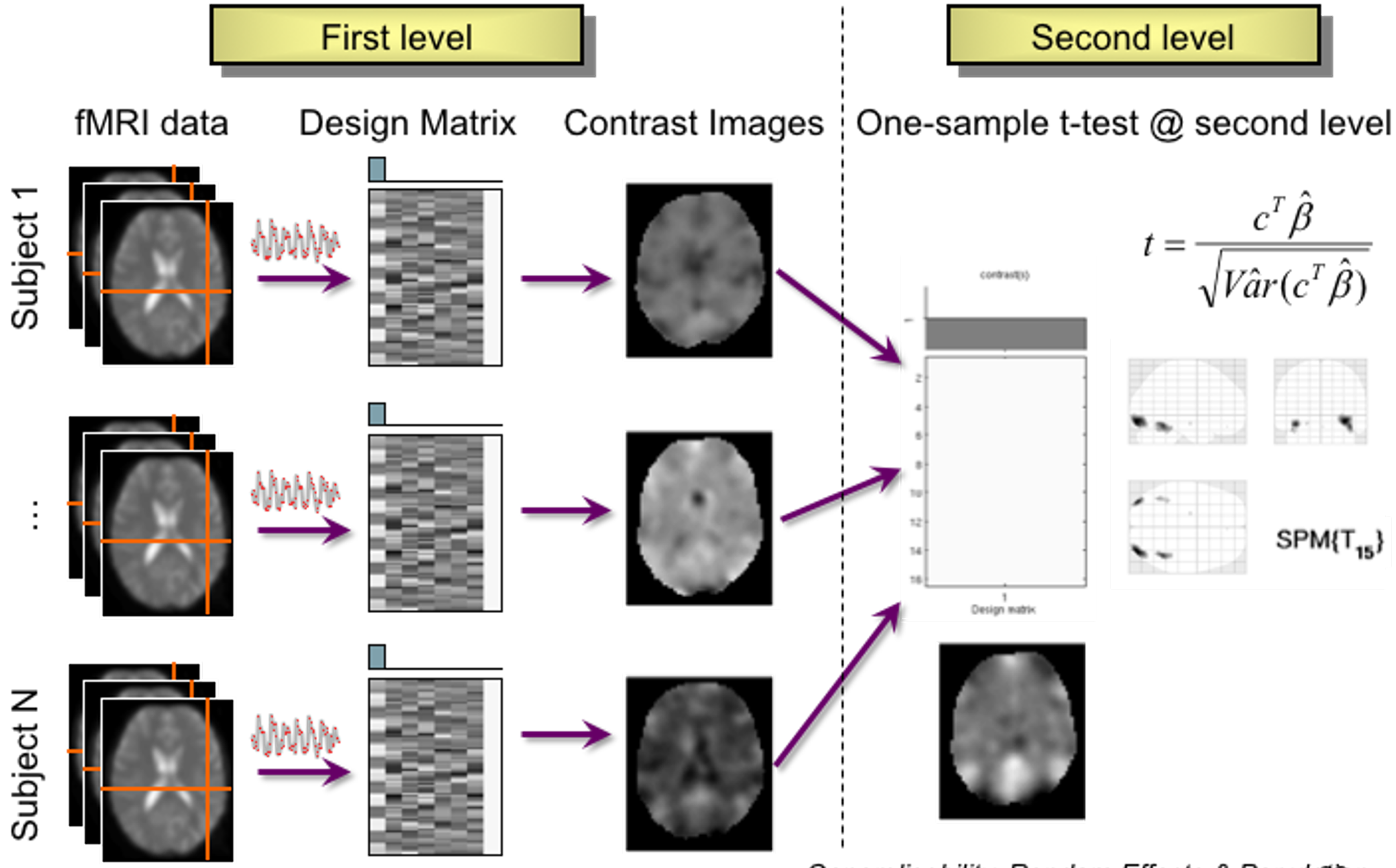
Mean group effect m = 2.67

Between subject variability (SD) $\sigma_b^2 = 1.07$

Standard Error Mean (SEM) = σ_b^2 /(sqrt(N))=0.31

t=M/SEM = 8.61, $p=10^{-6}$

Summary statistics concept recap



Generalisability, Random Effects & Population Inference. Holmes & Friston, NeuroImage,1998.

Overview

- 2nd level analysis = looking at across subjects effects (commonly with the goal of drawing conclusions about a population).
- Between-subject variance is much greater than within-subject variance. We need to consider both variances to make any inferences **about the wider population**, rather than just our sample – this is why random effects analysis is so often preferred
- Fixed effects analysis 'overestimates' the significance of effects – random effects analysis is more conservative, highlighting the greater effects that may be seen across the population.
- Fixed effects analysis is never useful if the goal is to make inferences.

SPM demo by Jolanda

Thank you! Hope you all learned a little something today ☺