# Robust Linear Modelling of EEG data: the LIMO EEG plug-in

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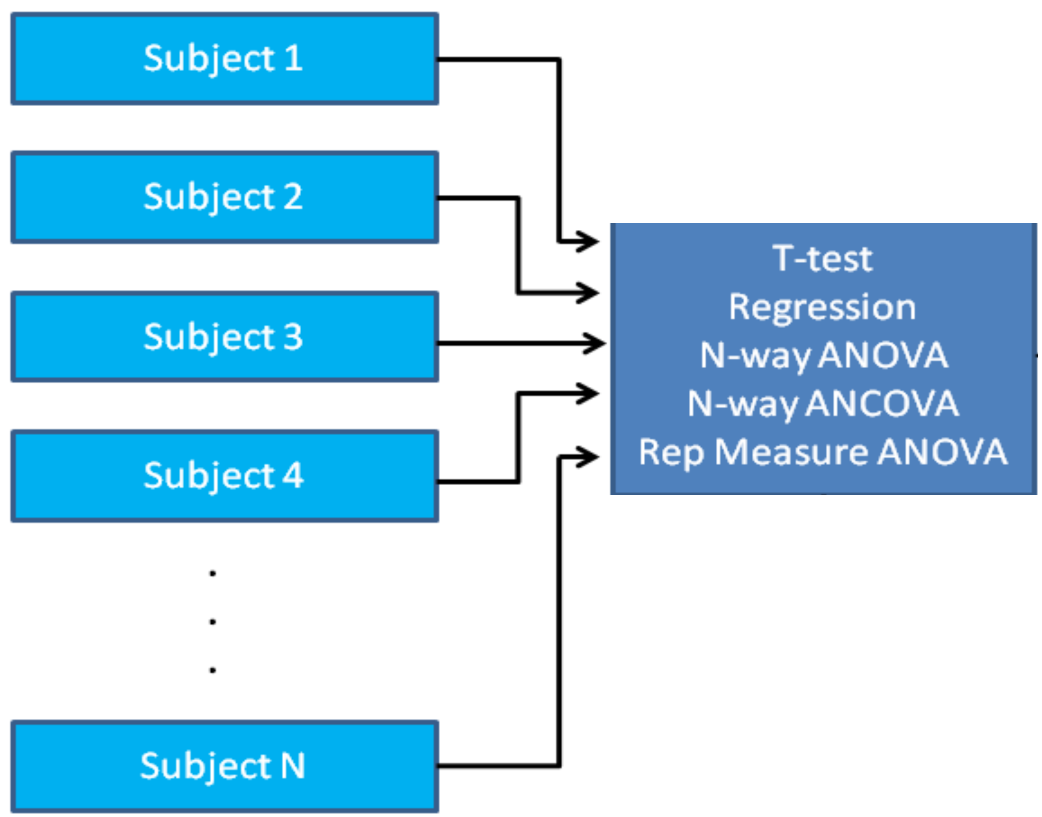
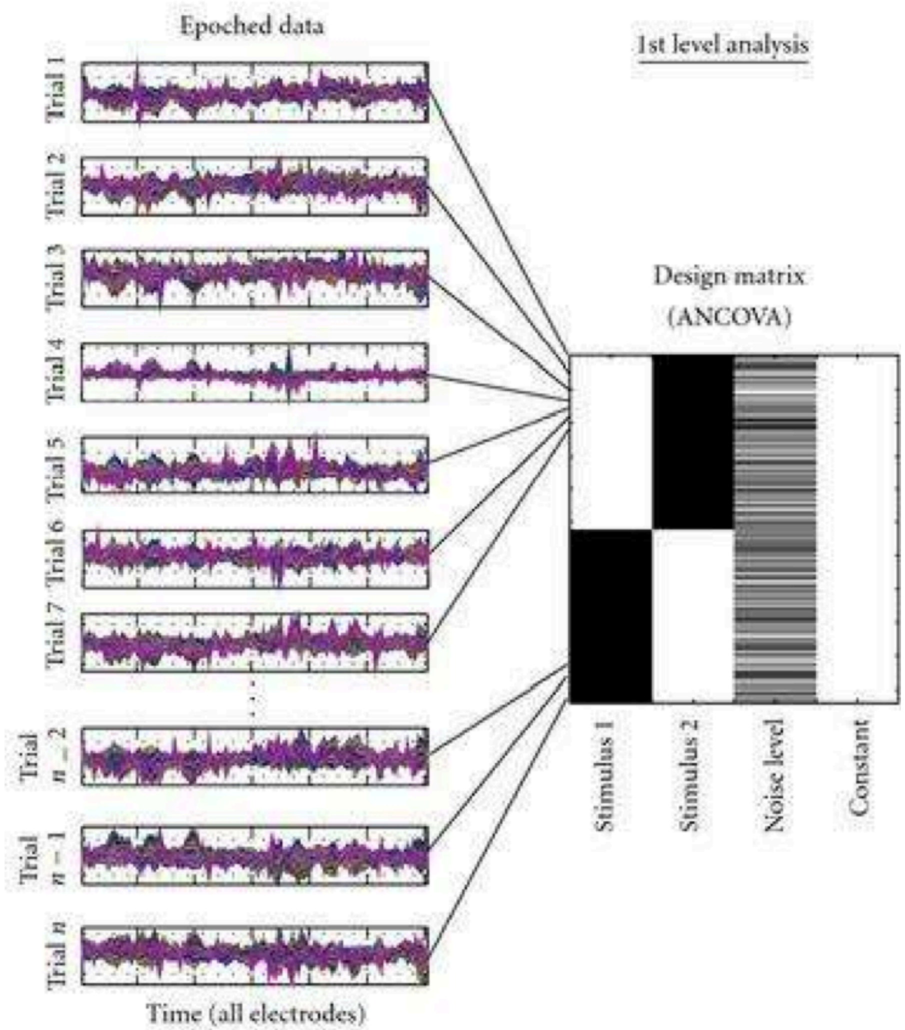
# Hierarchical Linear Model

<u>1st level analysis:</u>
GLM: $Y=X\beta+\varepsilon$
→1 β per column of X
(= within subject effects)

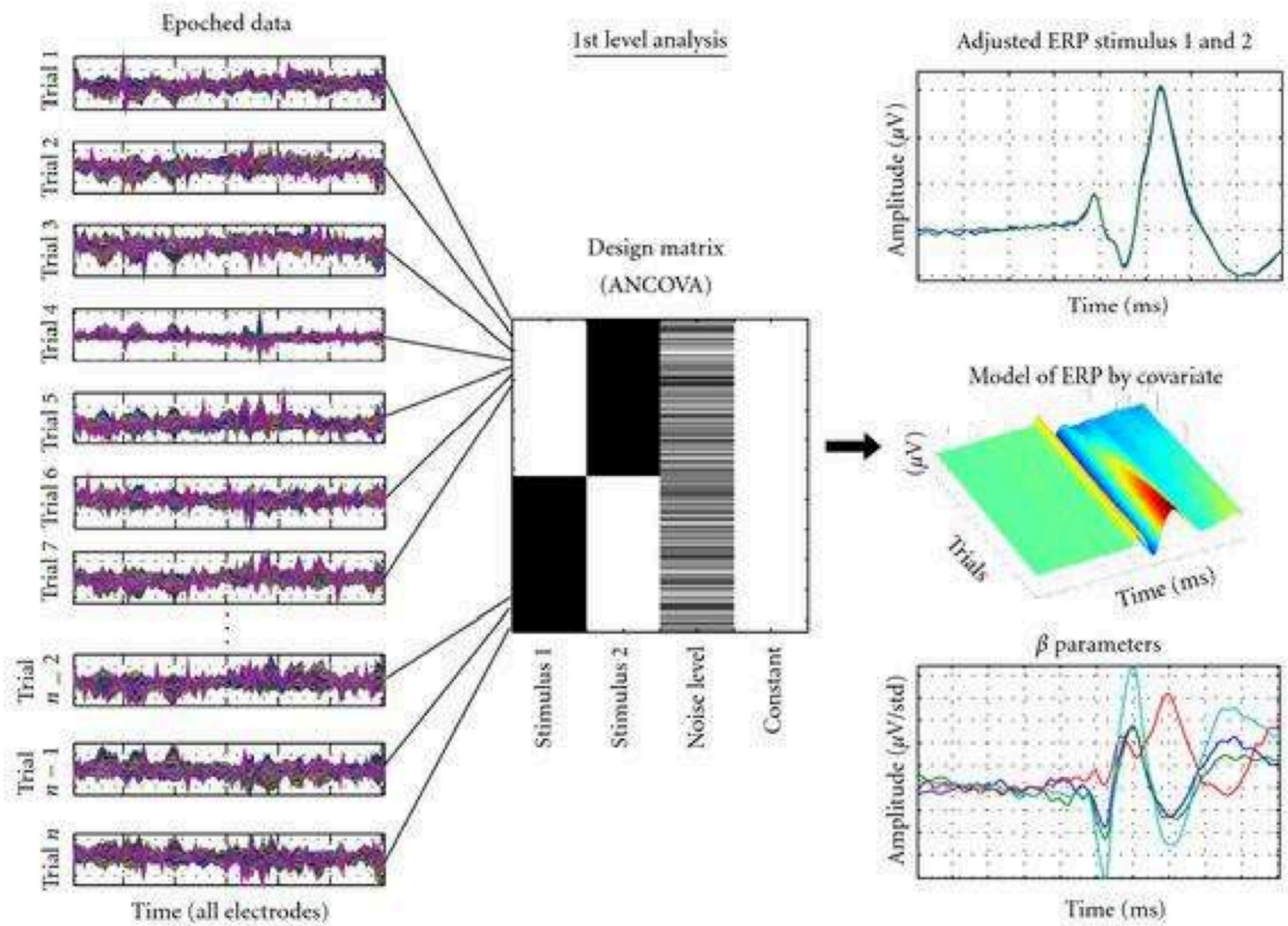
<u>2nd level analysis:</u>
Robust stats (Yuen t-tests, robust GLM, robust Hotelling $T^2$)



# Linear Modeling of EEG data



# Linear Modeling of EEG data

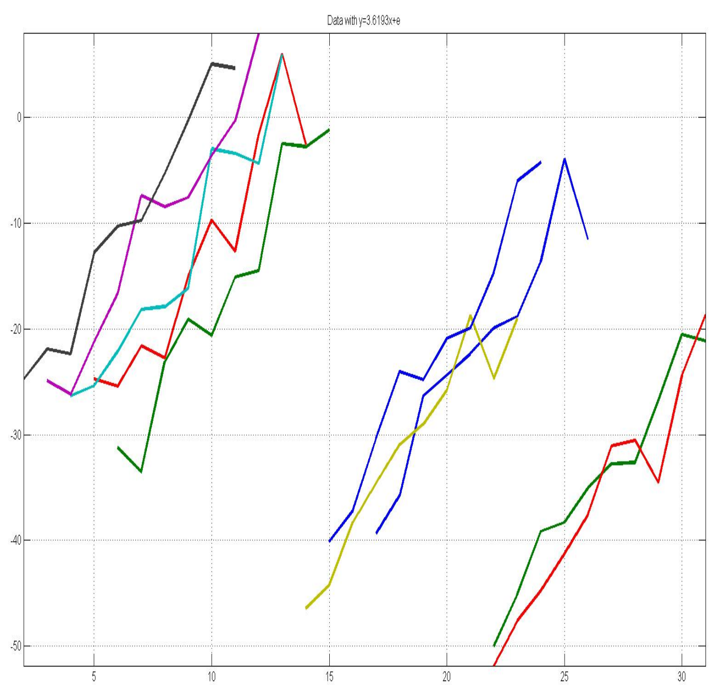


# Random Effect Model

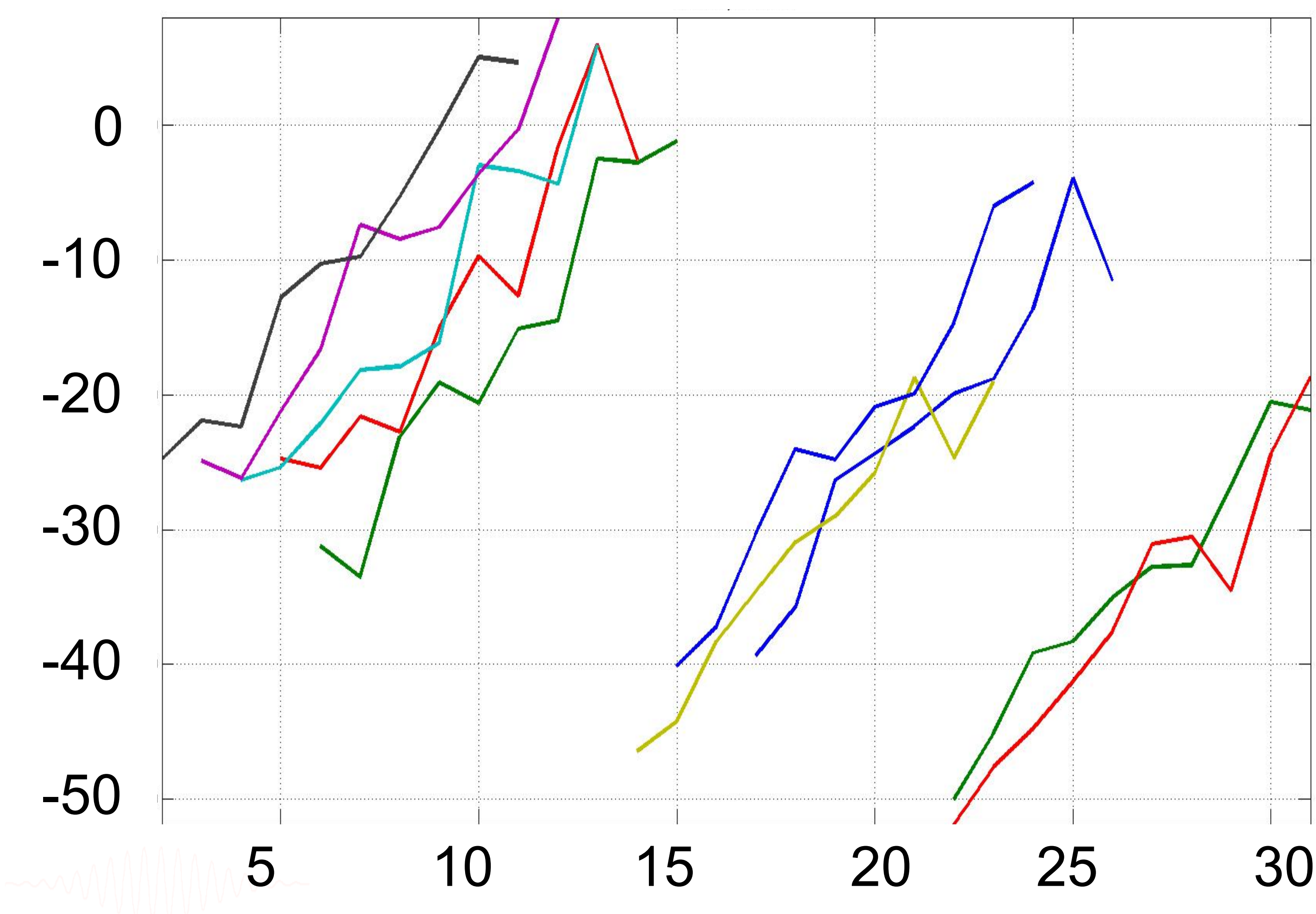
Model the data with fixed effects (the experimental conditions) and a random effect (subjects are allowed to have different overall values – considering subjects as a random variable)

<u>Example</u>: present stimuli from intensity -5 units to +5 units around the subject perceptual threshold and measure RT

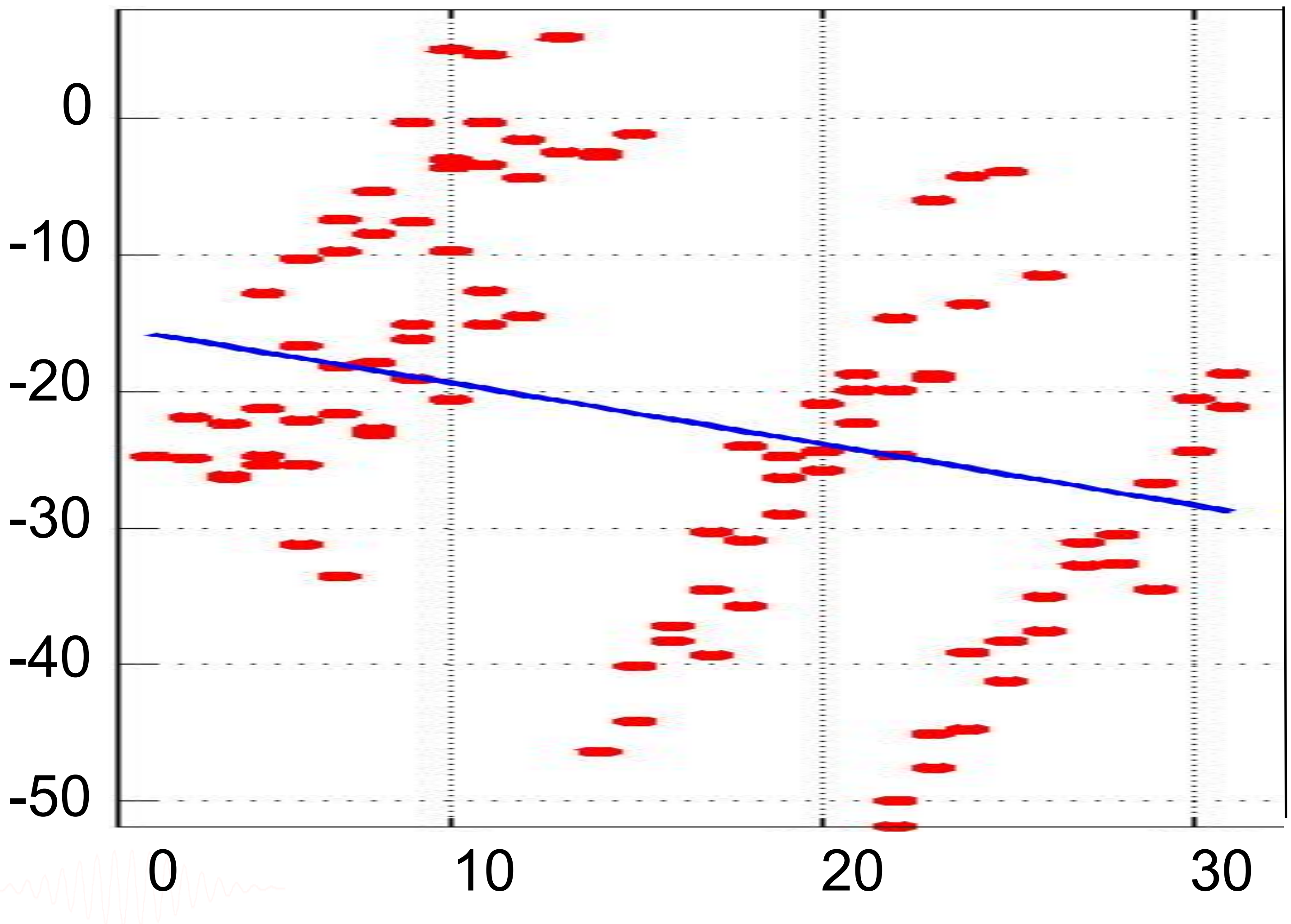
→ Plot the data per intensity



# Fixed Effect



# Fixed effect

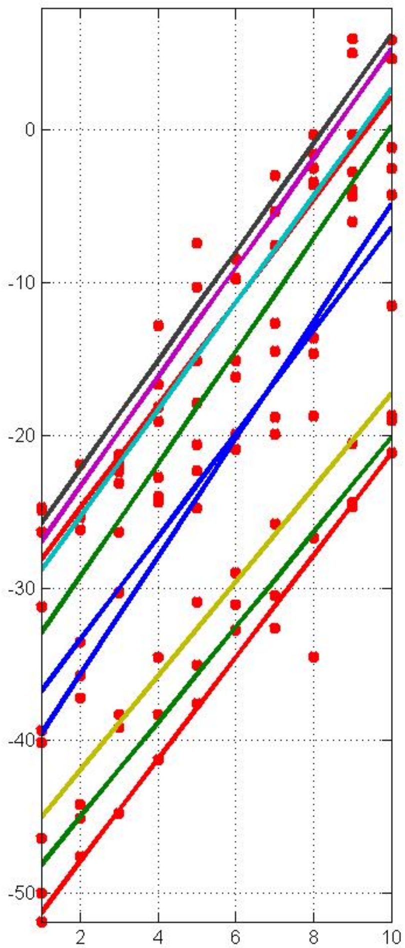



$R^2 = 0.16$
$P<0.03$

Fixed effect = average across subjects → negative correlation?

# Random Effect Model

1st level




2nd level

Slope: [3.43 3.51 3.39 3.41 3.62 3.55 … ]

$p < 10^{-12}$

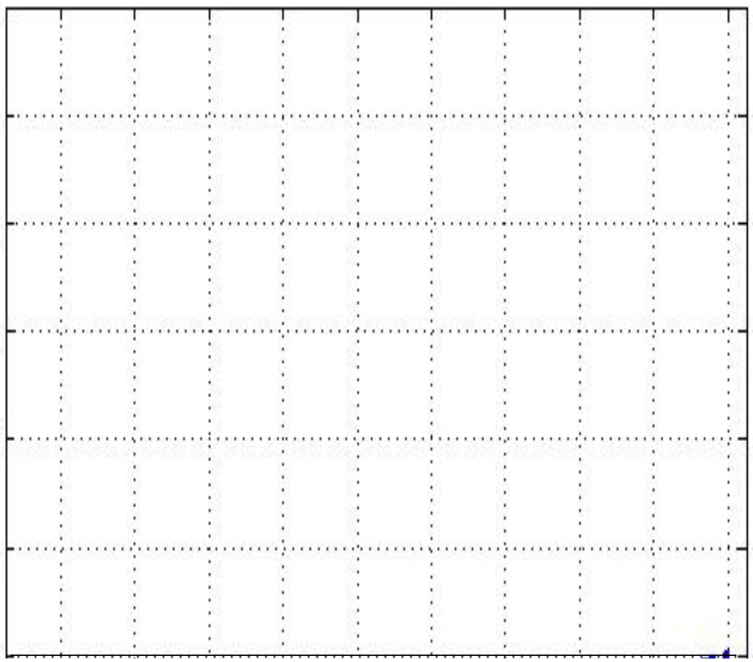
# Linearity

- Means created by lines
- In maths it refers to equations or functions that satisfy 2 properties: additivity (also called superposition) and homogeneity of degree 1 (also called scaling)
- Additivity → $y = x1 + x2$ (output y is the sum of inputs xs)
- Scaling → $y = \beta\, x1$ (output y is proportional to input x)

http://en.wikipedia.org/wiki/Linear

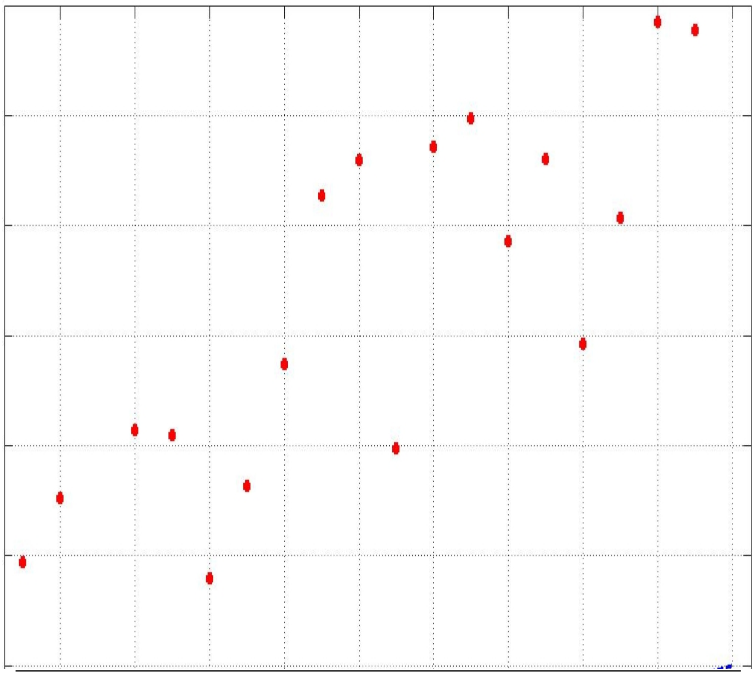
# A regression is a linear model

- We have an experimental measure x (e.g. stimulus intensity from 0 to 20)



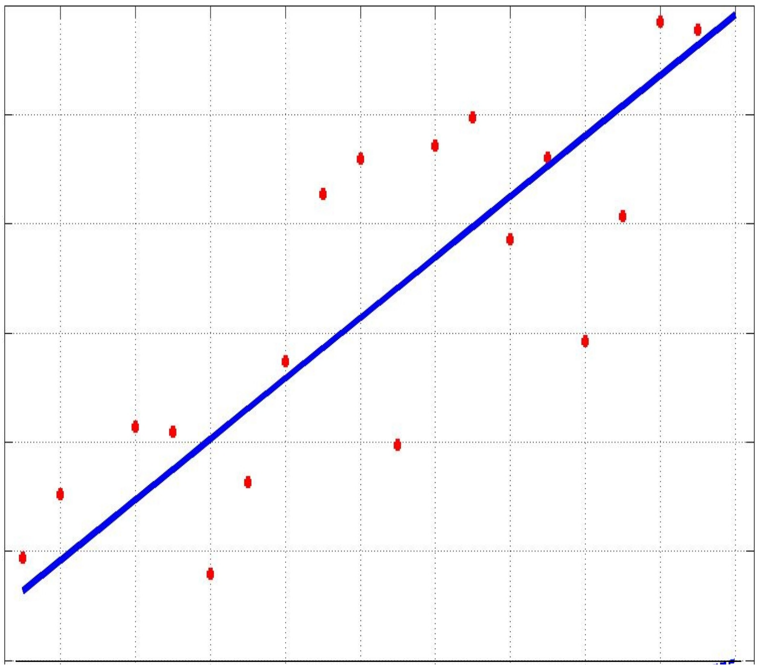
# A regression is a linear model

- We have an experimental measure x (e.g. stimulus intensity from 0 to 20)
- We then do the expe and collect data y (e.g. RTs)



# A regression is a linear model

- We have an experimental measure x (e.g. stimulus intensity from 0 to 20)
- We then do the expe and collect data y (e.g. RTs)
- Model: y = $\beta 1 x + \beta 2$
- Do some maths / run a software to find $\beta 1$ and $\beta 2$
- $\hat{y}$ = 2.7x+23.6



# Linear algebra for ANOVA

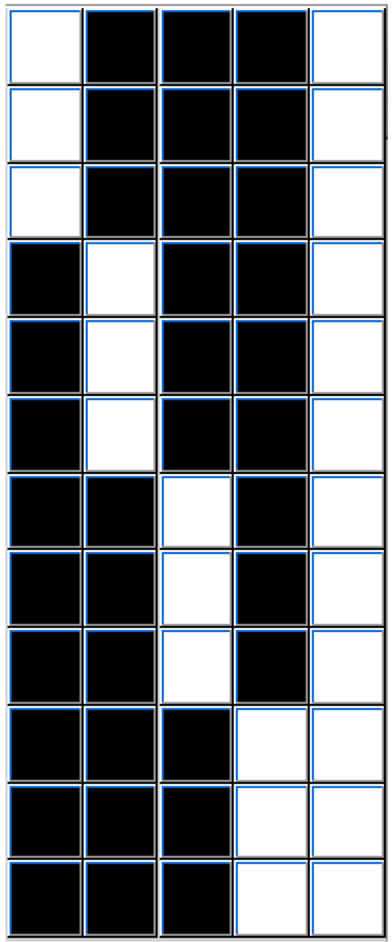
- In text books we have $y = u + xi + \varepsilon$, that is to say the data (e.g. RT) = a constant term (grand mean u) + the effect of a treatment (xi) and the error term ($\varepsilon$)
- In an ANOVA xi is designed to represent groups using 1 and 0

# Linear algebra for ANOVA

| Y | Gp |
|---|---|
| 8 | 1 |
| 9 | 1 |
| 7 | 1 |
| 5 | 2 |
| 7 | 2 |
| 3 | 2 |
| 3 | 3 |
| 4 | 3 |
| 1 | 3 |
| 6 | 4 |
| 4 | 4 |
| 9 | 4 |

Design matrix

$G_1$ $G_2$ $G_3$ $G_4$ C



y(1..3) = 1xβ1+0xβ2+0xβ3+0xβ4+c+error
y(4..6) = 0xβ1+1xβ2+0xβ3+0xβ4+c+error
y(7..9) = 0xβ1+0xβ2+1xβ3+0xβ4+c+error
y(10..12) = 0xβ1+0xβ2+0xβ3+1xβ4+c+error
...

$$\begin{Bmatrix} 8 \\ 9 \\ 7 \\ 5 \\ 7 \\ 3 \\ 3 \\ 4 \\ 1 \\ 6 \\ 4 \\ 9 \end{Bmatrix} = \begin{Bmatrix} 1\,0\,0\,0\,1 \\ 1\,0\,0\,0\,1 \\ 1\,0\,0\,0\,1 \\ 0\,1\,0\,0\,1 \\ 0\,1\,0\,0\,1 \\ 0\,1\,0\,0\,1 \\ 0\,0\,1\,0\,1 \\ 0\,0\,1\,0\,1 \\ 0\,0\,1\,0\,1 \\ 0\,0\,0\,1\,1 \\ 0\,0\,0\,1\,1 \\ 0\,0\,0\,1\,1 \end{Bmatrix} * \begin{Bmatrix} \beta 1 \\ \beta 2 \\ \beta 3 \\ \beta 4 \\ c \end{Bmatrix} + \begin{Bmatrix} e1 \\ \vdots \\ e13 \end{Bmatrix}$$

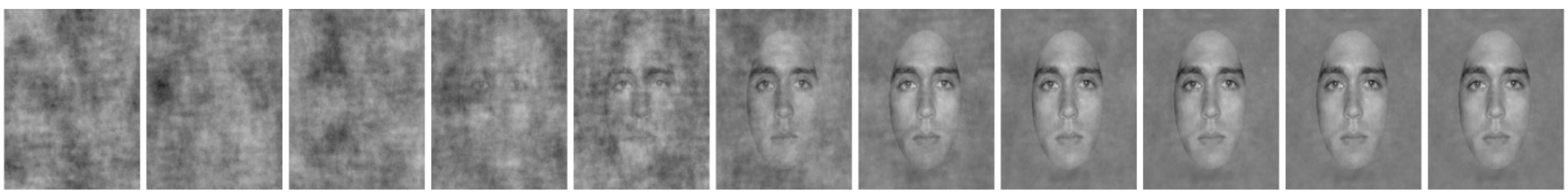
# What is a linear model?

- An equation or a set of equations that models data and which corresponds geometrically to straight lines, planes, hyper-planes and satisfy the properties of additivity and scaling.

- Simple regression: $y = \beta 1x+\beta 2+\varepsilon$
- Multiple regression: $y = \beta 1x1+\beta 2x2+\beta 3+\varepsilon$
- One way ANOVA: $y = u + xi + \varepsilon$
- …

# Design considerations

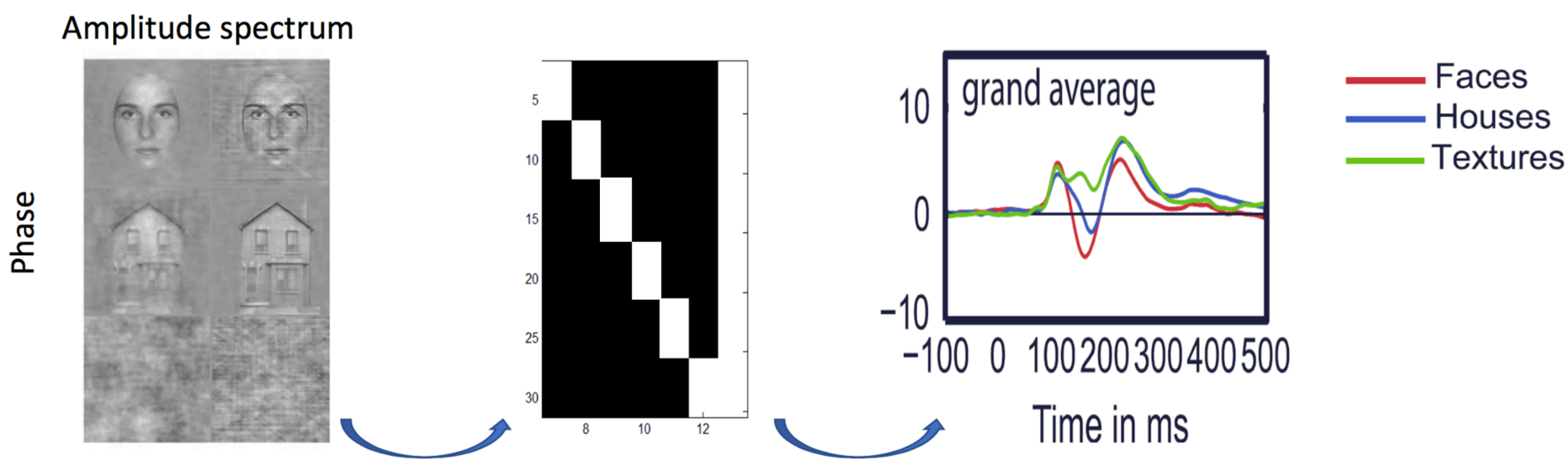
***Illustration with a set of studies looking at the effect of stimulus phase information***



[Rousselet, Pernet, Bennet, Sekuler (2008). Face phase processing. *BMC Neuroscience 9:98*]

# Categorical designs

## Factorial Designs: 3*2

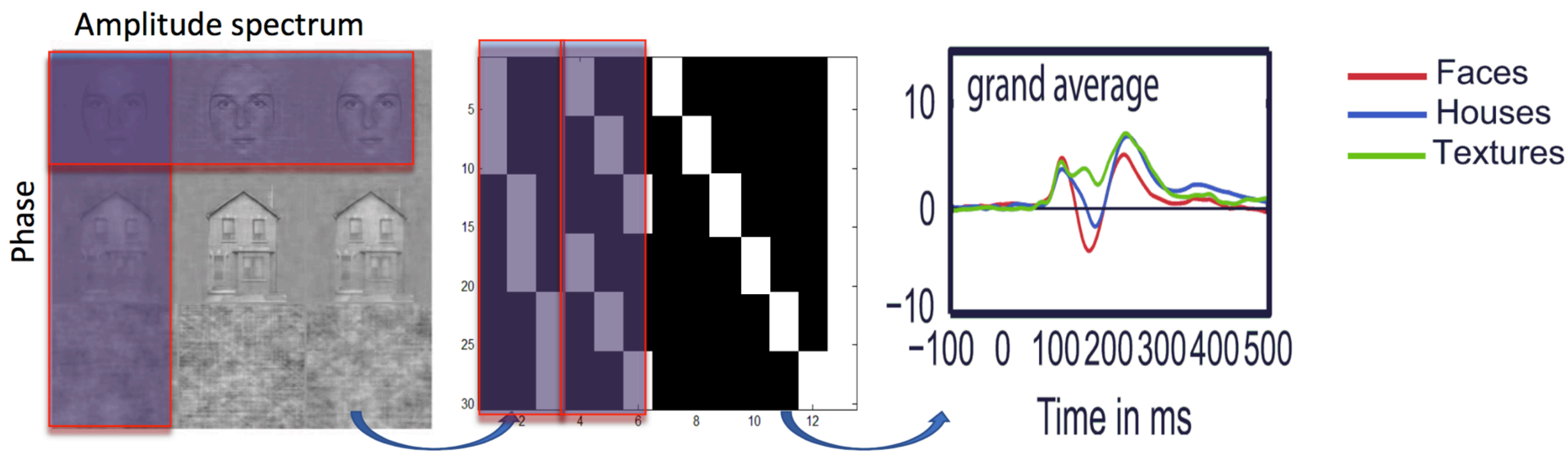



For group analyses, all you need is an estimate for each condition per subject
Level 1: Y = XB1→6, each beta is a mixture of the factors at that stage, but estimate the condition
Level 2: Y = XB1→12, the beta of the 1st level are now split into factors (3*2).

Bienek, et al (2012). Phase vs Amplitude Spectrum. Journal of Vision 12

# Categorical designs

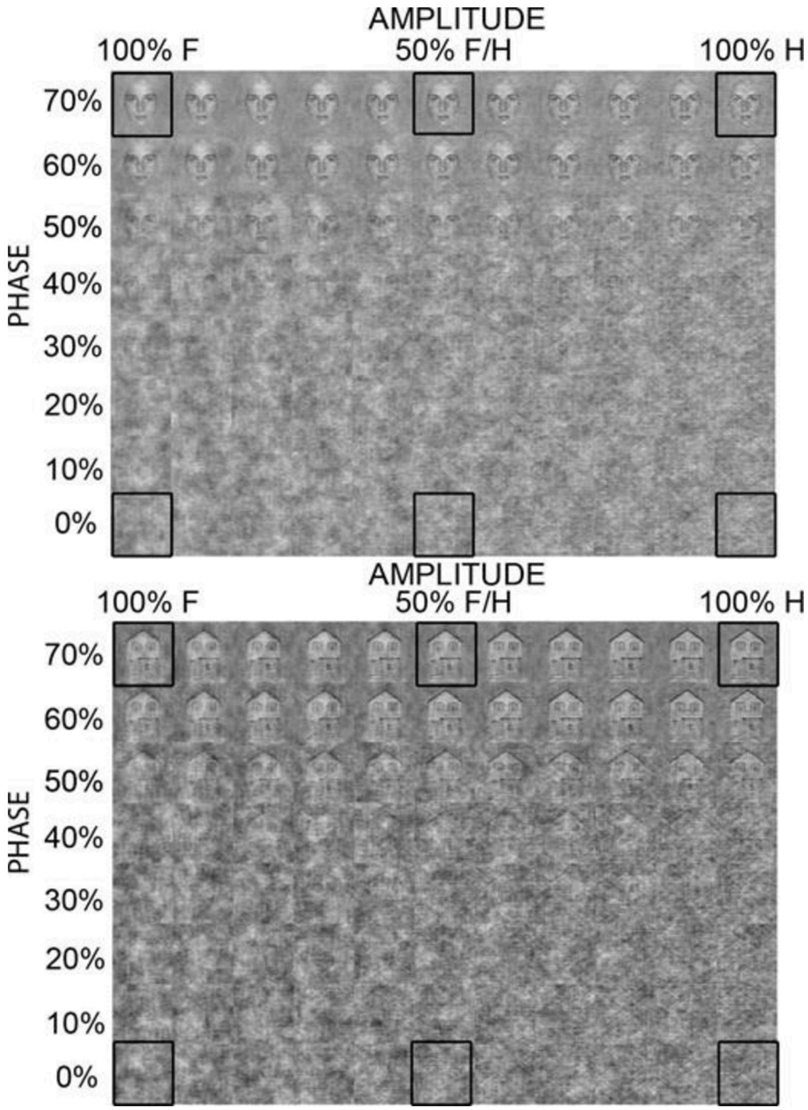
## Factorial Designs: N*N*N*…

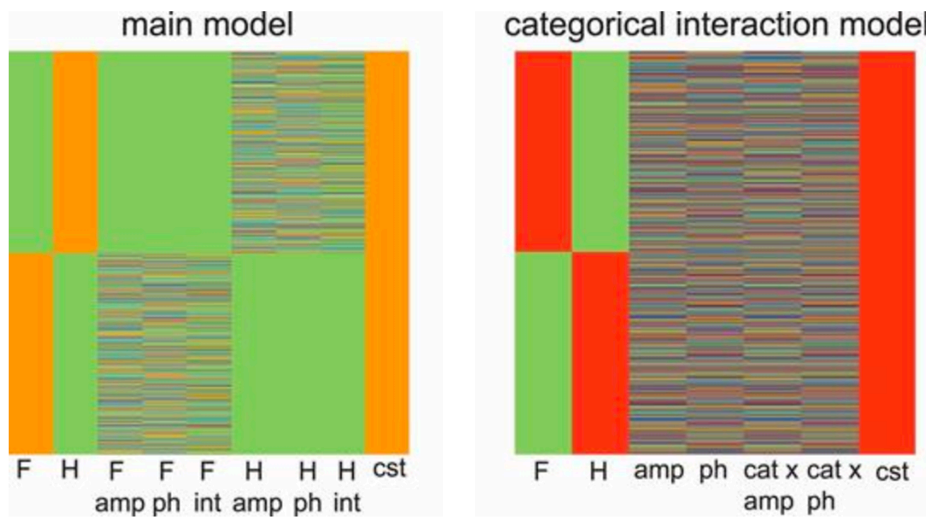



For single subject analyses, you need all effects
Level 1: Y = XB1→12, the data of each subject are split into factors (3*3) and interaction (6)
Level 2: nothing left to explain (stats on attributes)

Bienek, et al (2012). Phase vs Amplitude Spectrum. Journal of Vision 12

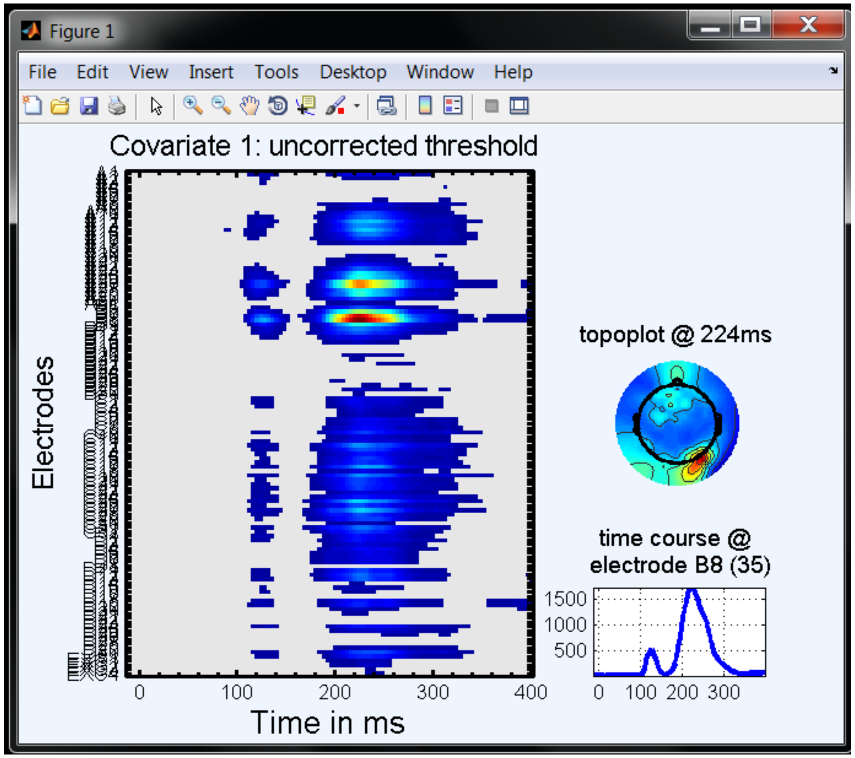
# Continuous designs

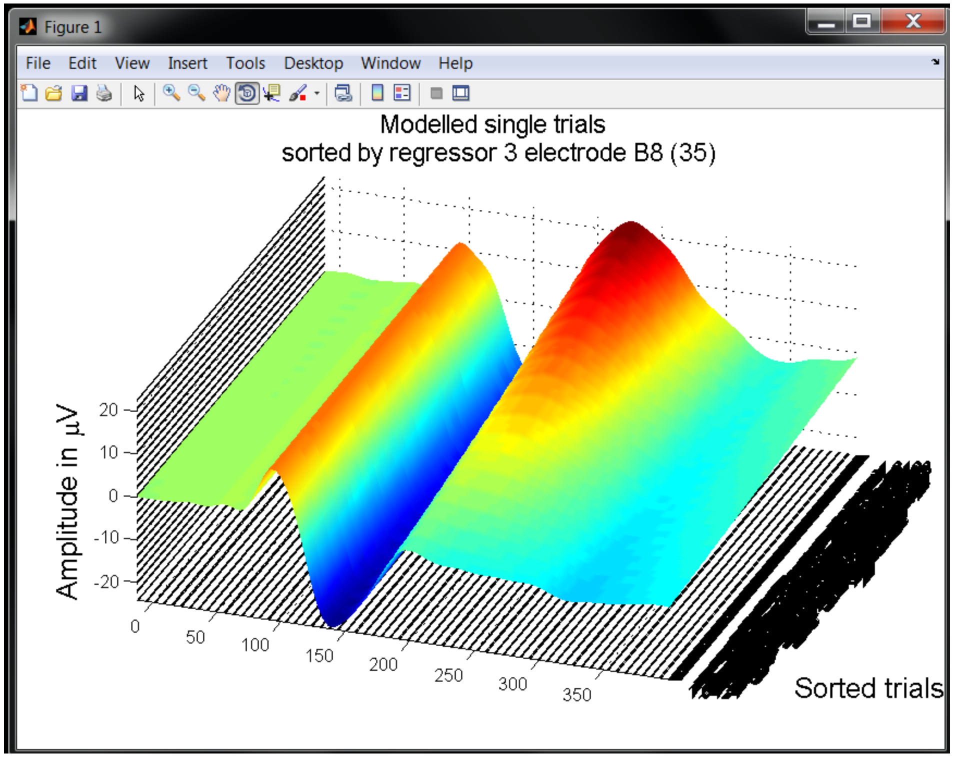


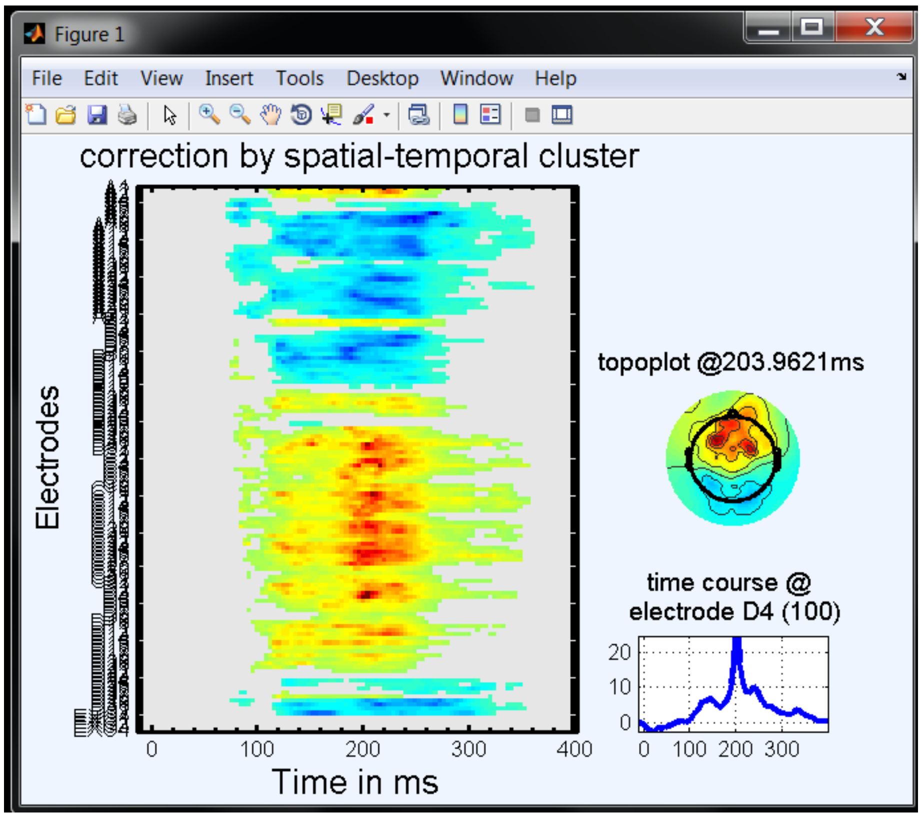
# What have we done: results

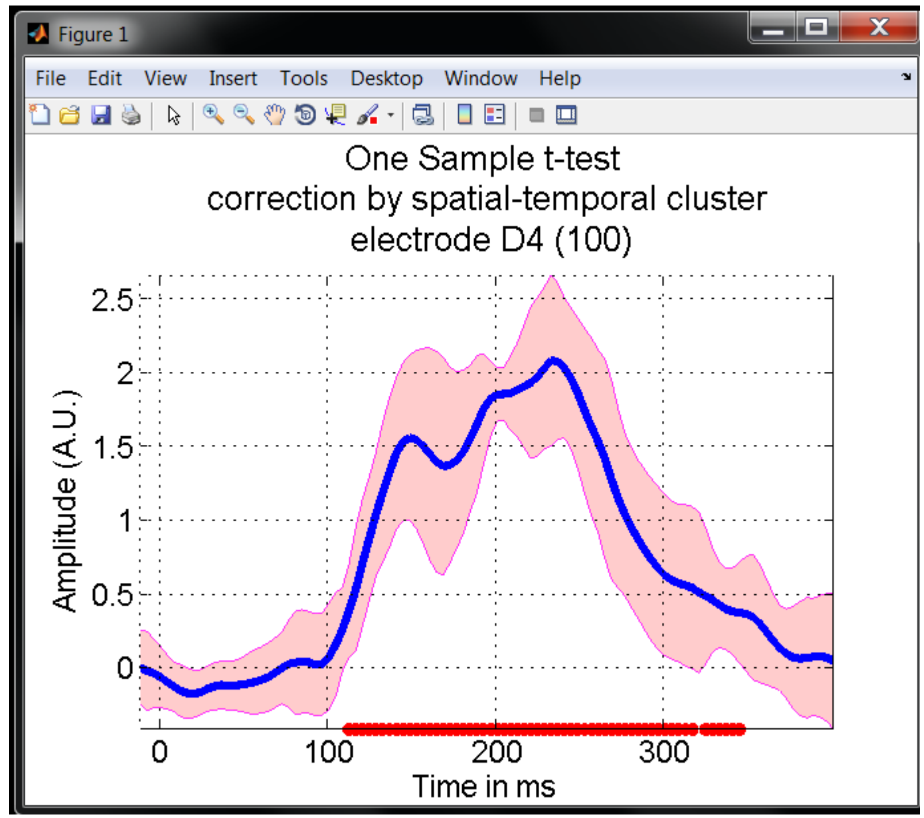
- Image all (R2, condition, covariate)
- Course plots, topoplots



# Review group level results



# Design questions!

- Let's think how to analyse your data!
- Nb of conditions / covariates
- contrasts
- 1st level covariates
- 2nd level covariates