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

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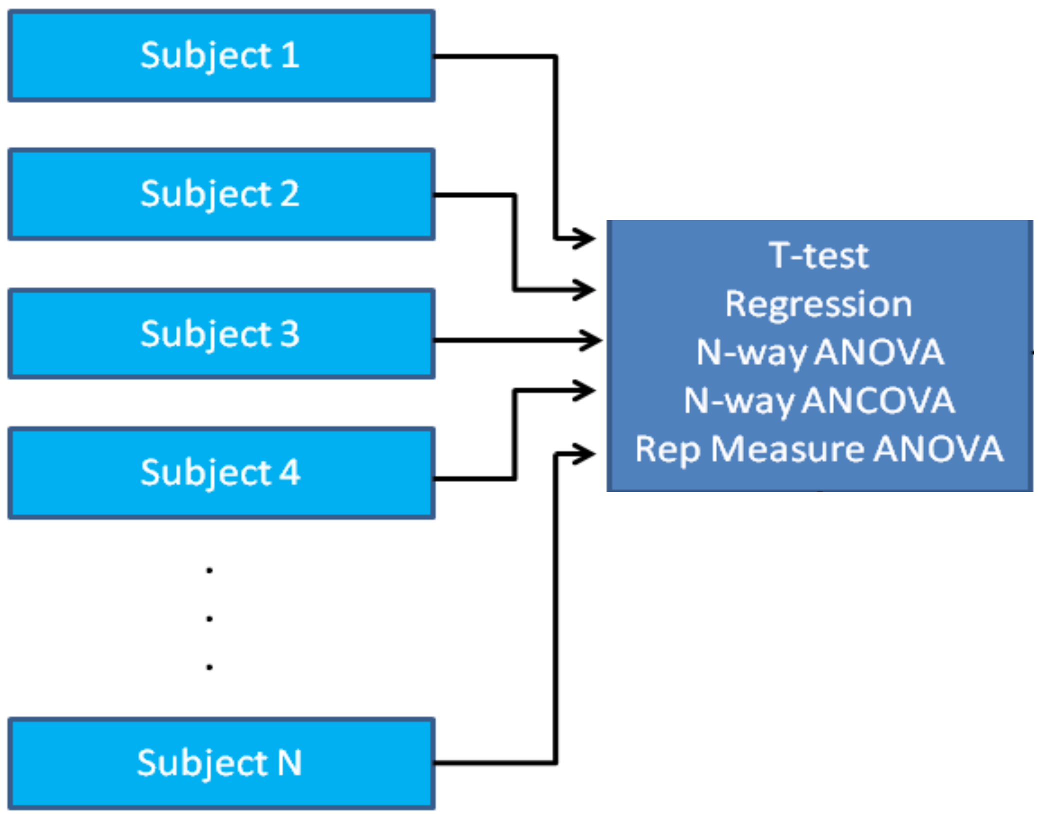
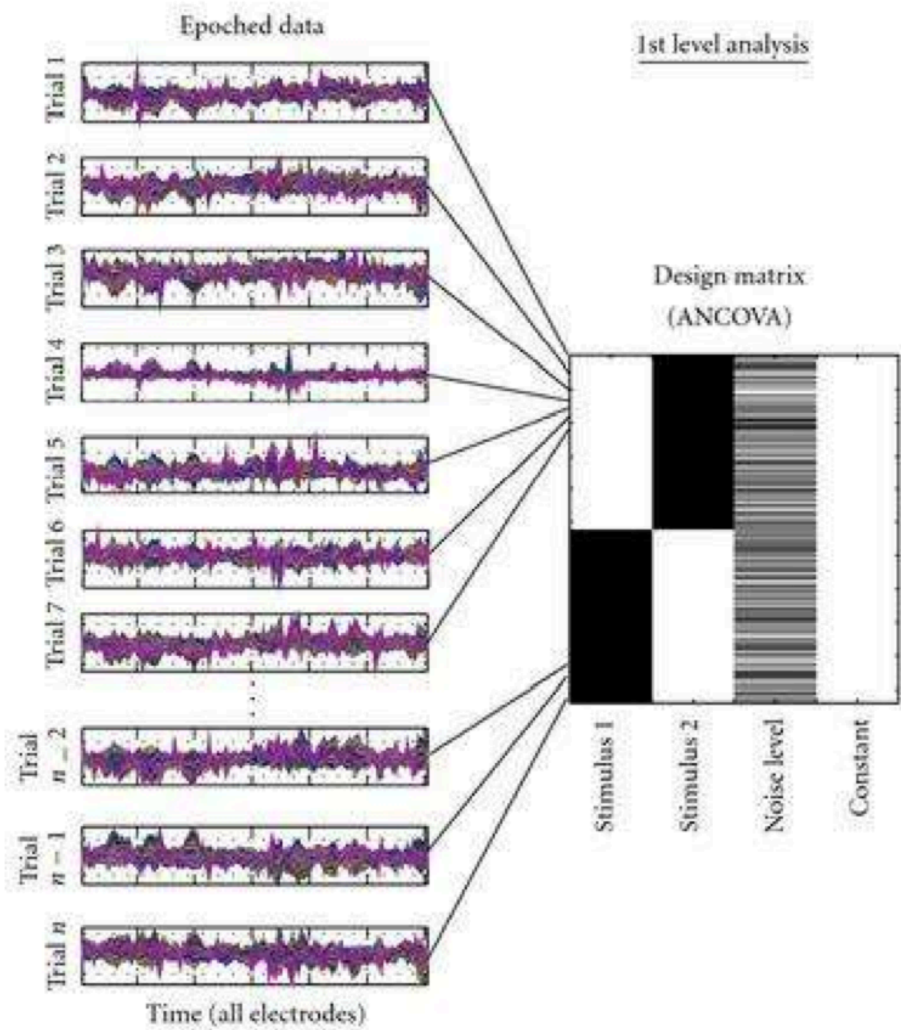
Hierarchical Linear Model

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

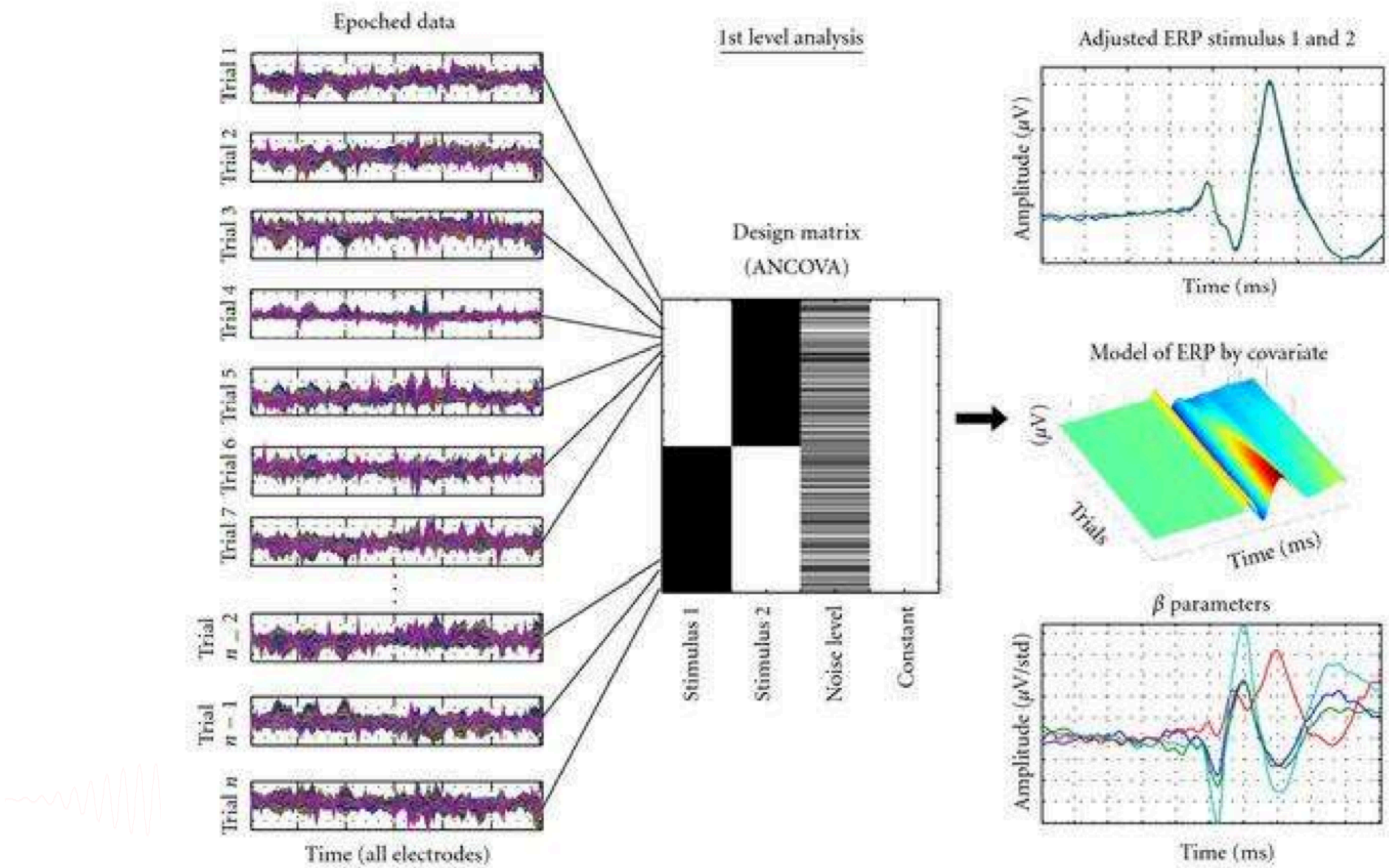
<u>2^{nd} level analysis:</u>
Robust stats (Yuen t-tests, robust GLM, robust Hotelling T^2)



Linear Modeling of EEG data



Linear Modeling of EEG data

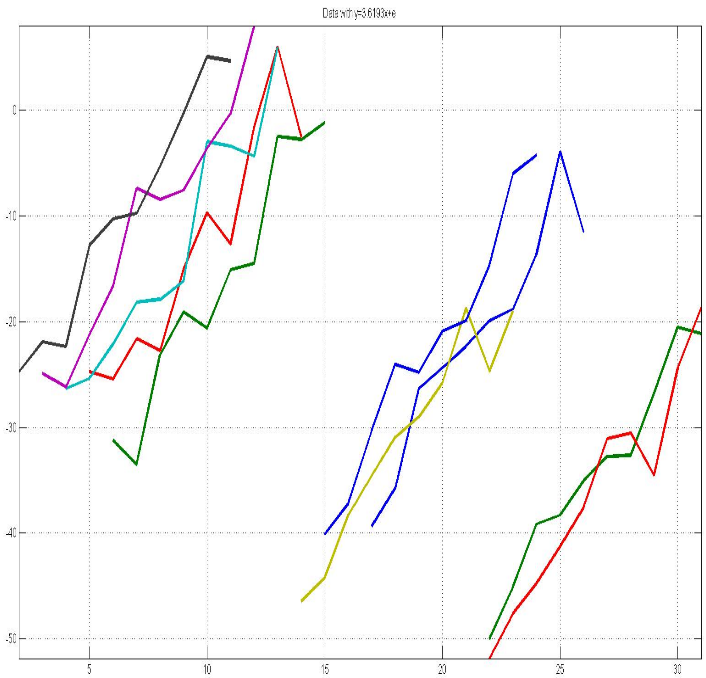


Random Effect Model

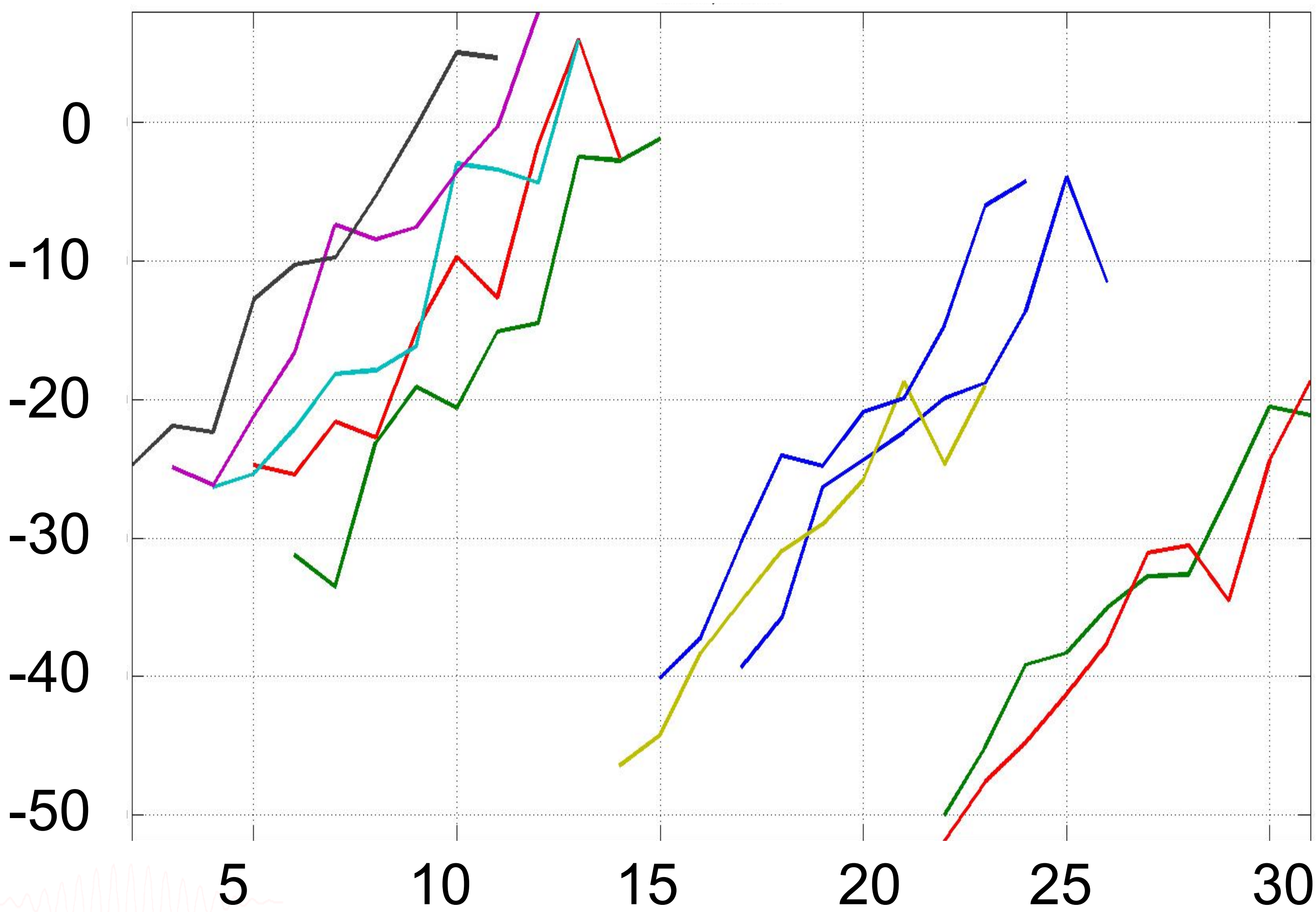
Model the data with fixed effects (the experimental conditions) and a random effect (subjects are allowed to have different overall values – considering subjects as a random variable)

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

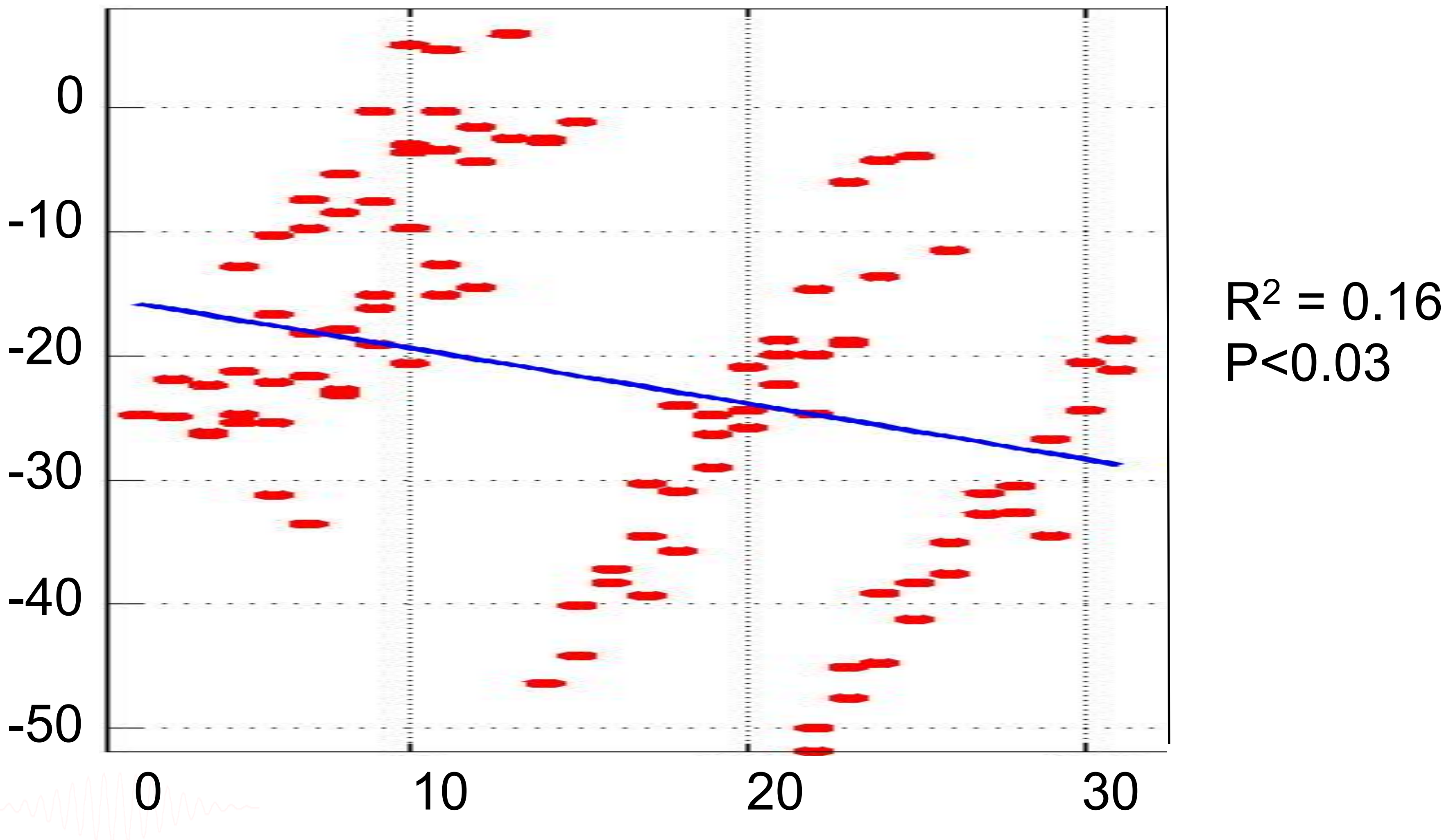
→ Plot the data per intensity



Fixed Effect



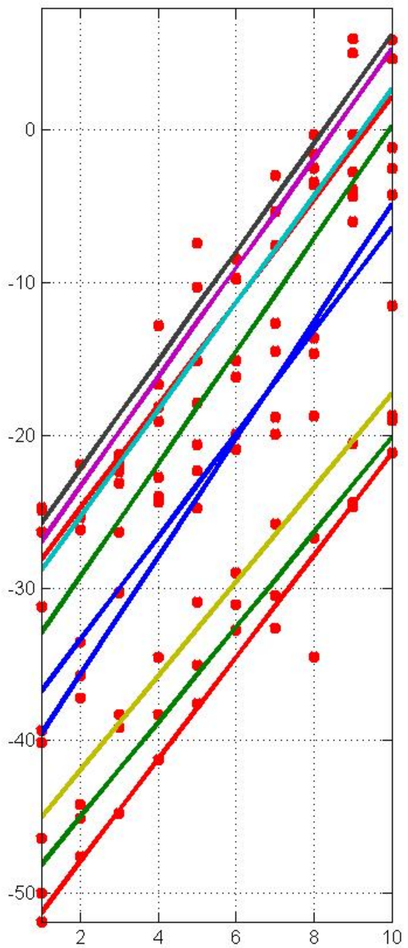
Fixed effect



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 …]

$p < 10^{-12}$

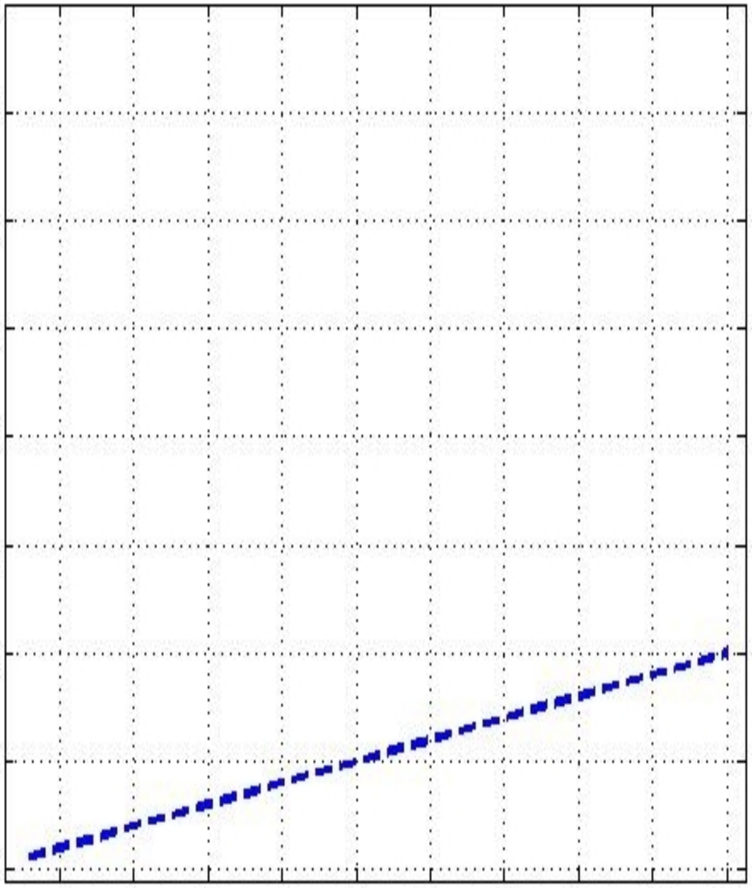
Linearity

- 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

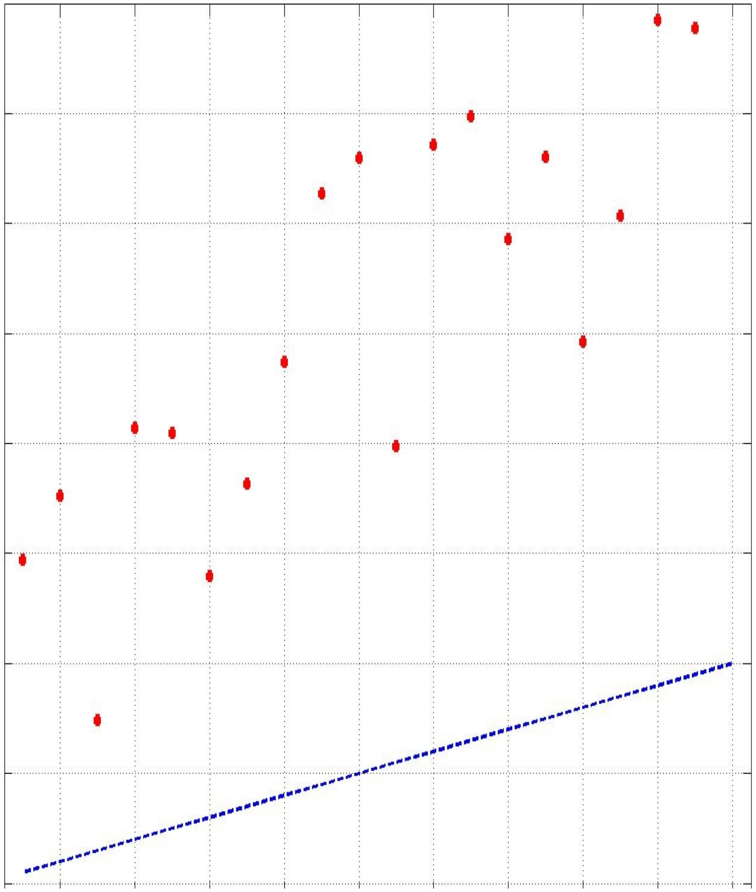
A regression is a linear model

- 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

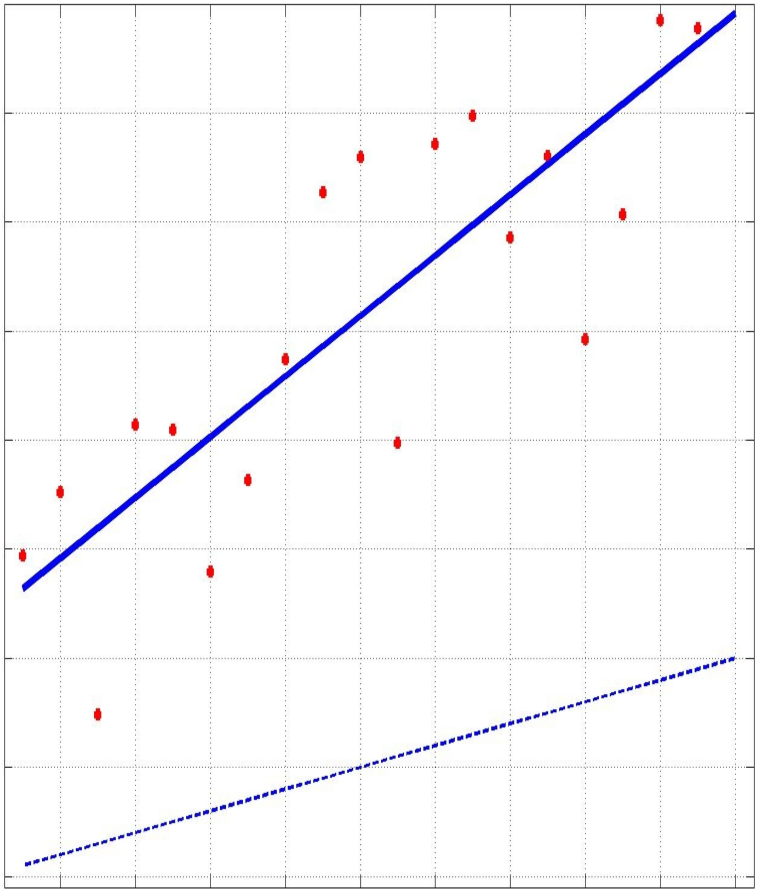
- We have an experimental measure x (e.g. stimulus intensity from 0 to 20)

- 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 $\beta 2$

- $y\text{^} = 2.7x + 23.6$



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 (ε)
- In a regression xi takes several values like e.g. [1:20]
- In an ANOVA xi is designed to represent groups using 1 and 0

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.

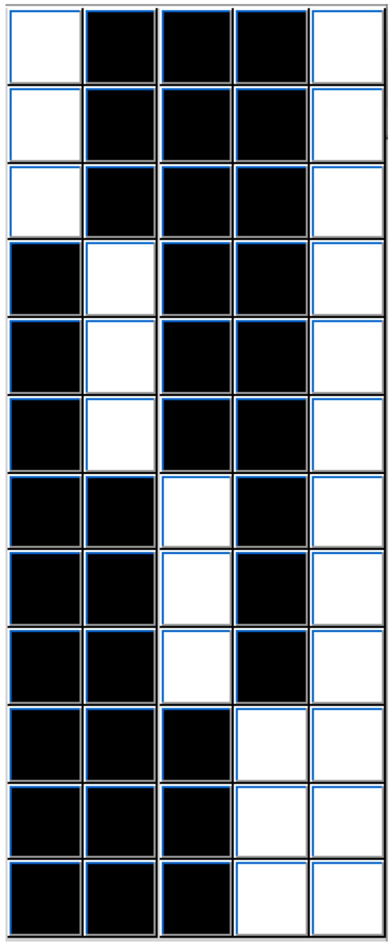
- Simple regression: $y = \beta 1x+\beta 2+\varepsilon$
- Multiple regression: $y = \beta 1x1+\beta 2x2+\beta 3+\varepsilon$
- One way ANOVA: $y = u+\alpha i+\varepsilon$
- Repeated measure ANOVA: $y=u+\alpha i+\varepsilon$
- …

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

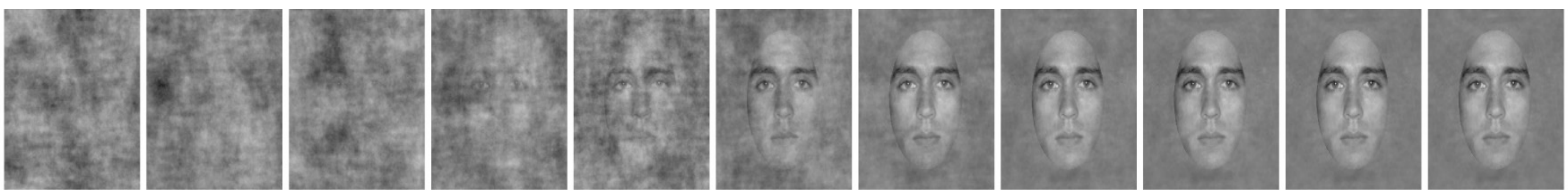


y(1..3)1= 1x1+0x2+0x3+0x4+c+e11
y(1..3)2= 0x1+1x2+0x3+0x4+c+e12
y(1..3)3= 0x1+0x2+1x3+0x4+c+e13
y(1..3)4= 0x1+0x2+0x3+1x4+c+e13

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

Design considerations

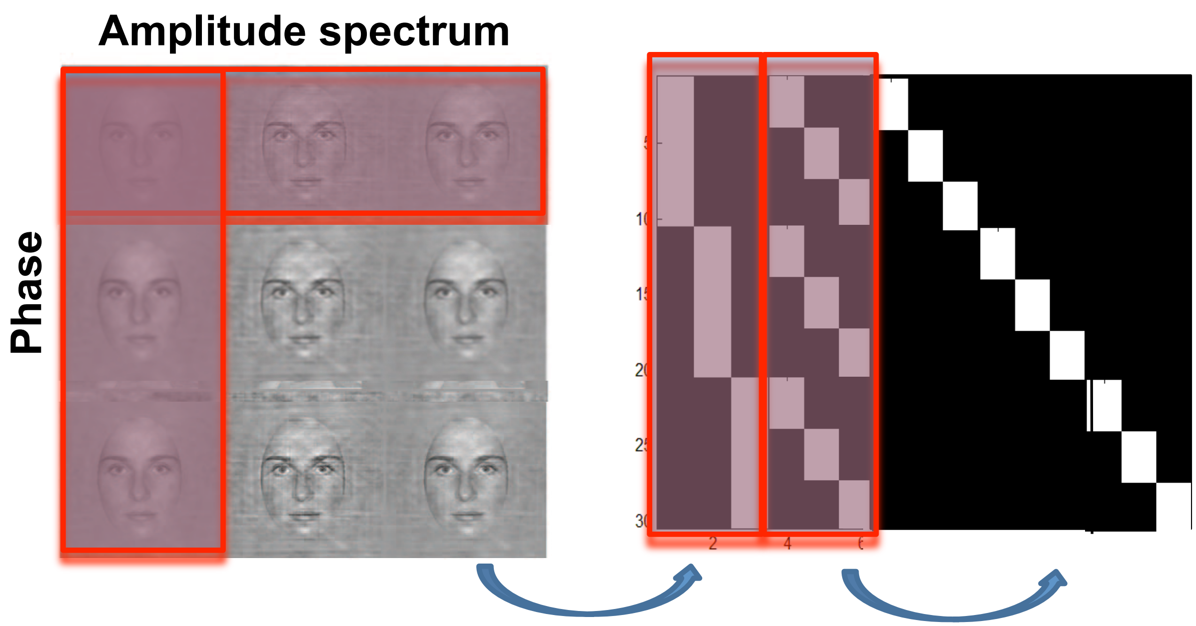
Illustration with a set of studies looking at the effect of stimulus phase information



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

Factorial Designs: N*N*N*…

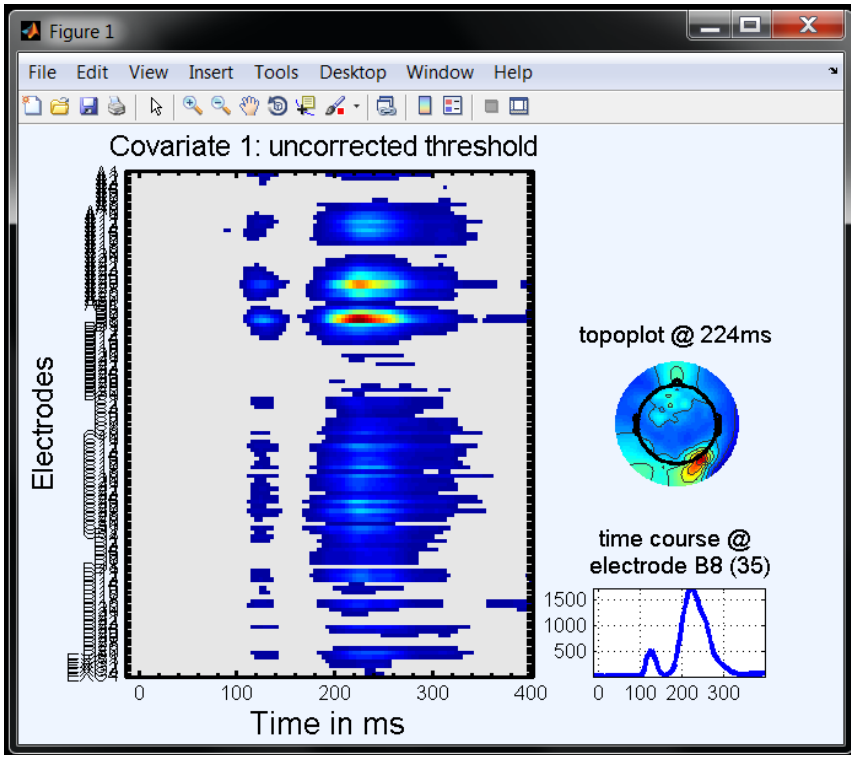
Categorical designs: Group level analyses of course but also Individual analyses with bootstrap

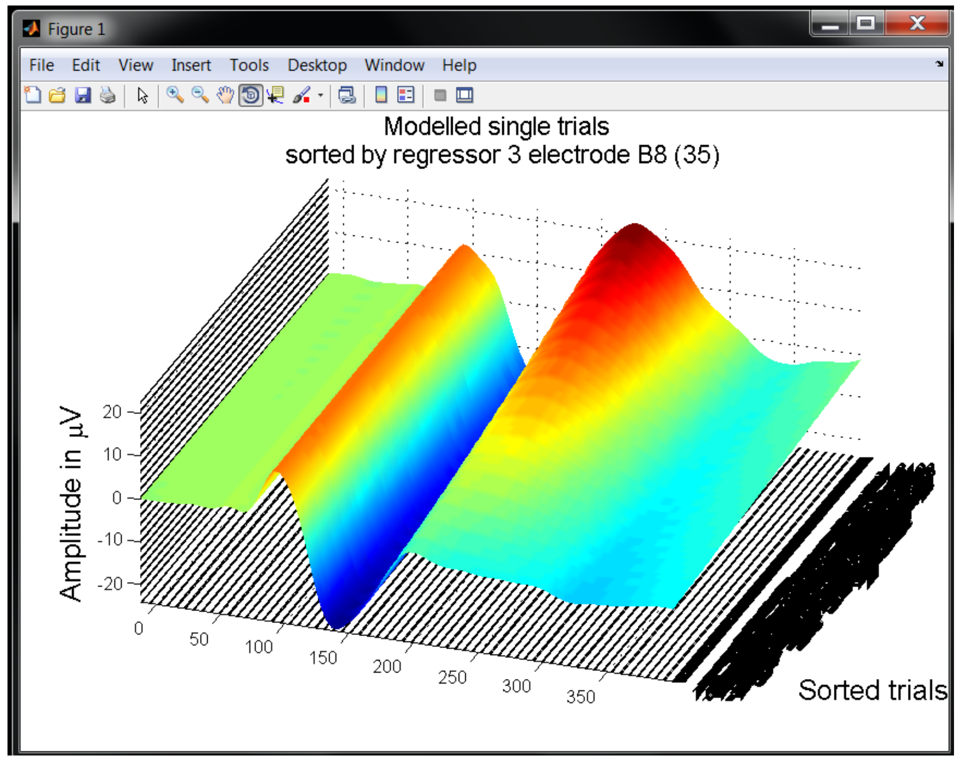


3 betas for phase
3 betas for amplitude

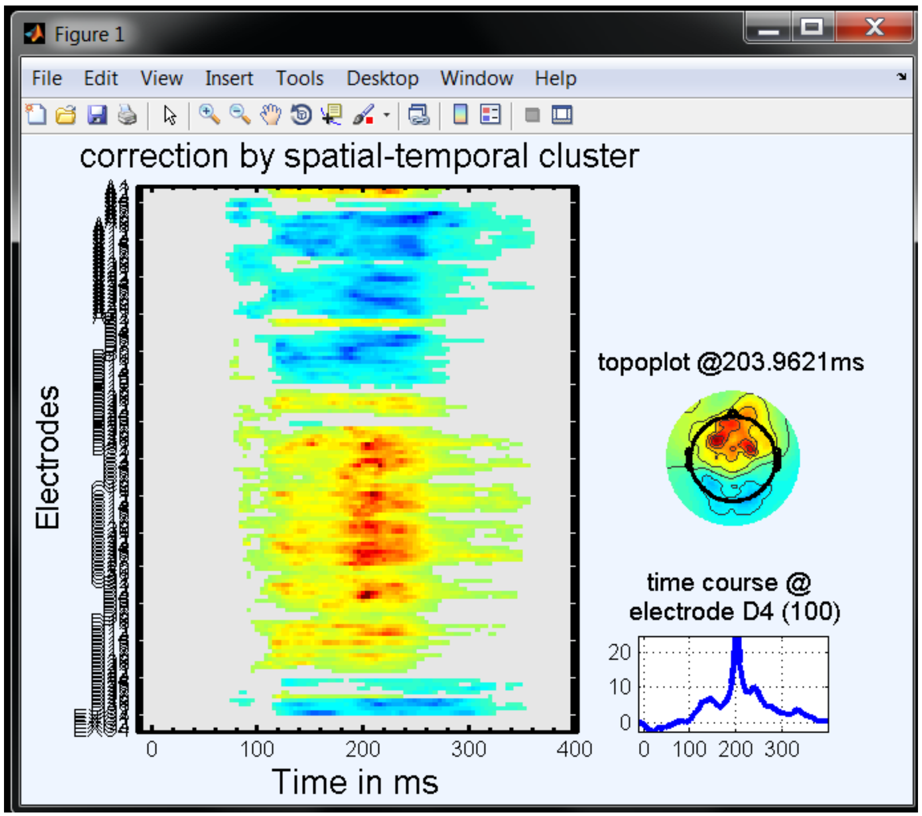
What have we done: results

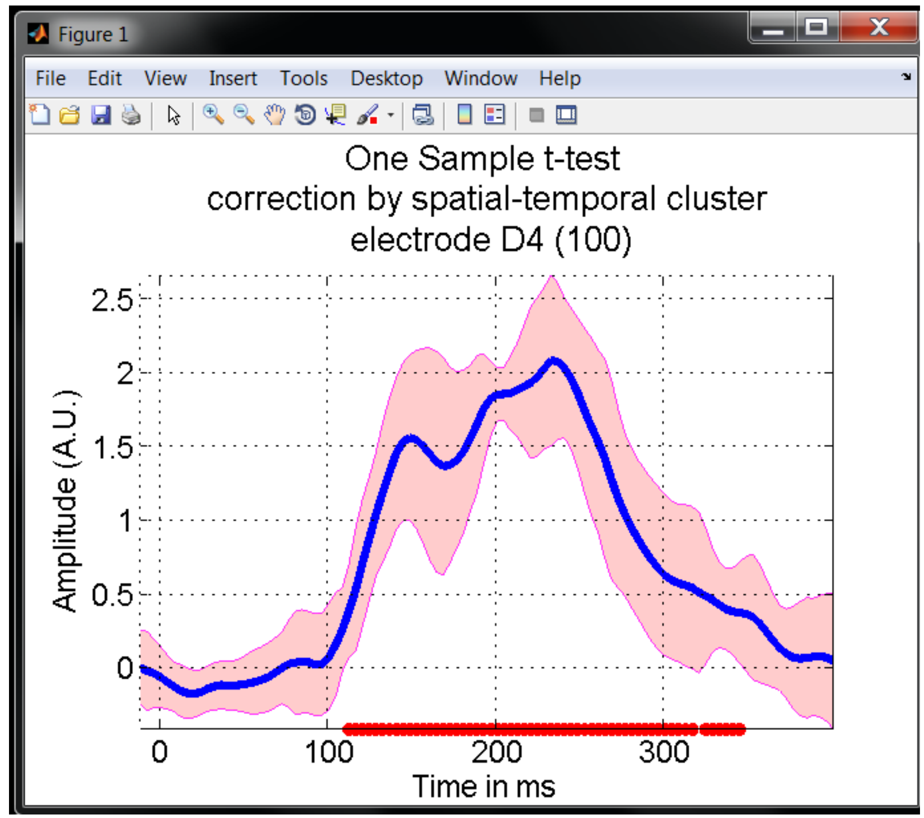
- Image all (R2, condition, covariate)
- Course plots, topoplots





Review gp level results





Design questions!

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