Edinburgh Imaging
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LIMO EEG: what are robust statistics? Application to a categorical design

D2.A1 & D2.A3. – 2.00 to 3.30

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www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

SUBJECT CATEGORIES

» Electroencephalography -EEG

» Brain imaging

A multi-subject, multi-modal human neuroimaging dataset

Daniel G. Wakeman[1,2] & Richard N. Henson[2]

- *Scientific Data* **2**, Article number: 150001 (2015)
- doi:10.1038/sdata.2015.1

The Data

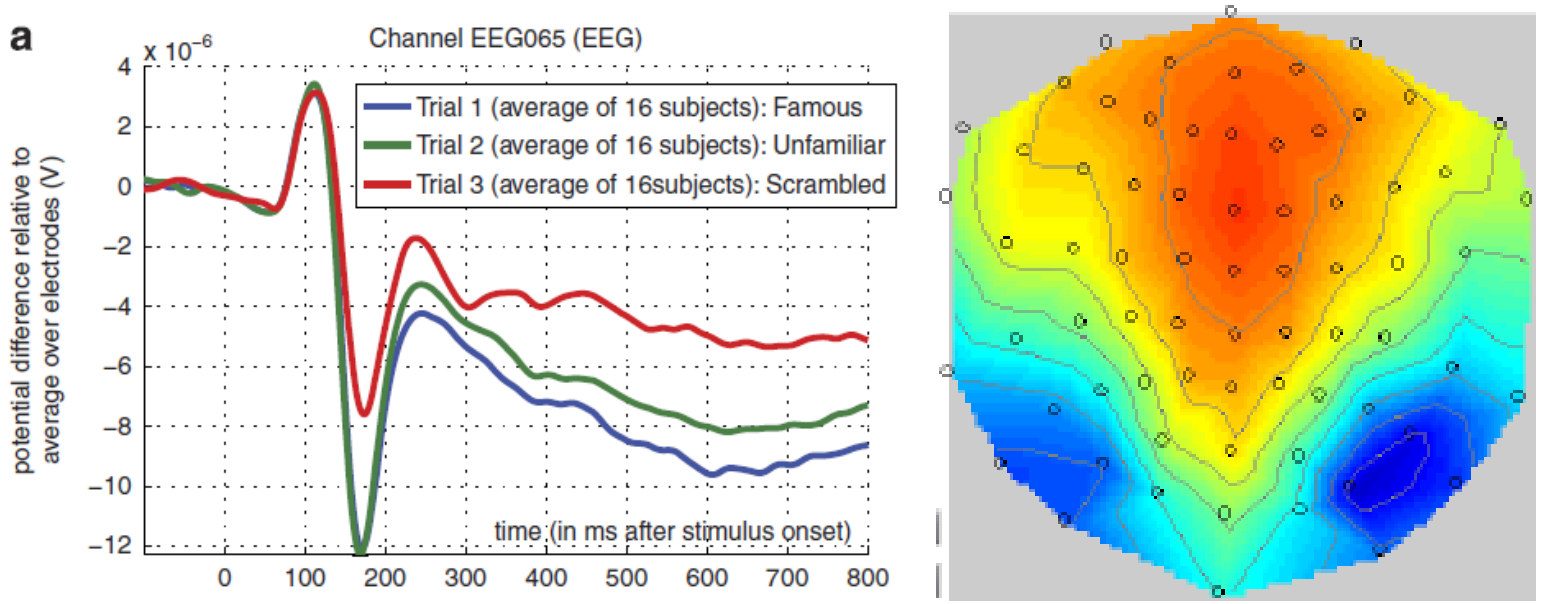
- 3 types of stimuli: Famous faces, Non-famous faces, Scrambled faces
- 3 levels of repetition: 1st time, 2nd time (right after), 3rd time (delayed)

→Priming experiment with a possible interaction with the type of stimuli.

We need the conditions computed per subject (1st level) and then do the repeated measure ANOVA to test main effects and interactions.

What are we going to do?

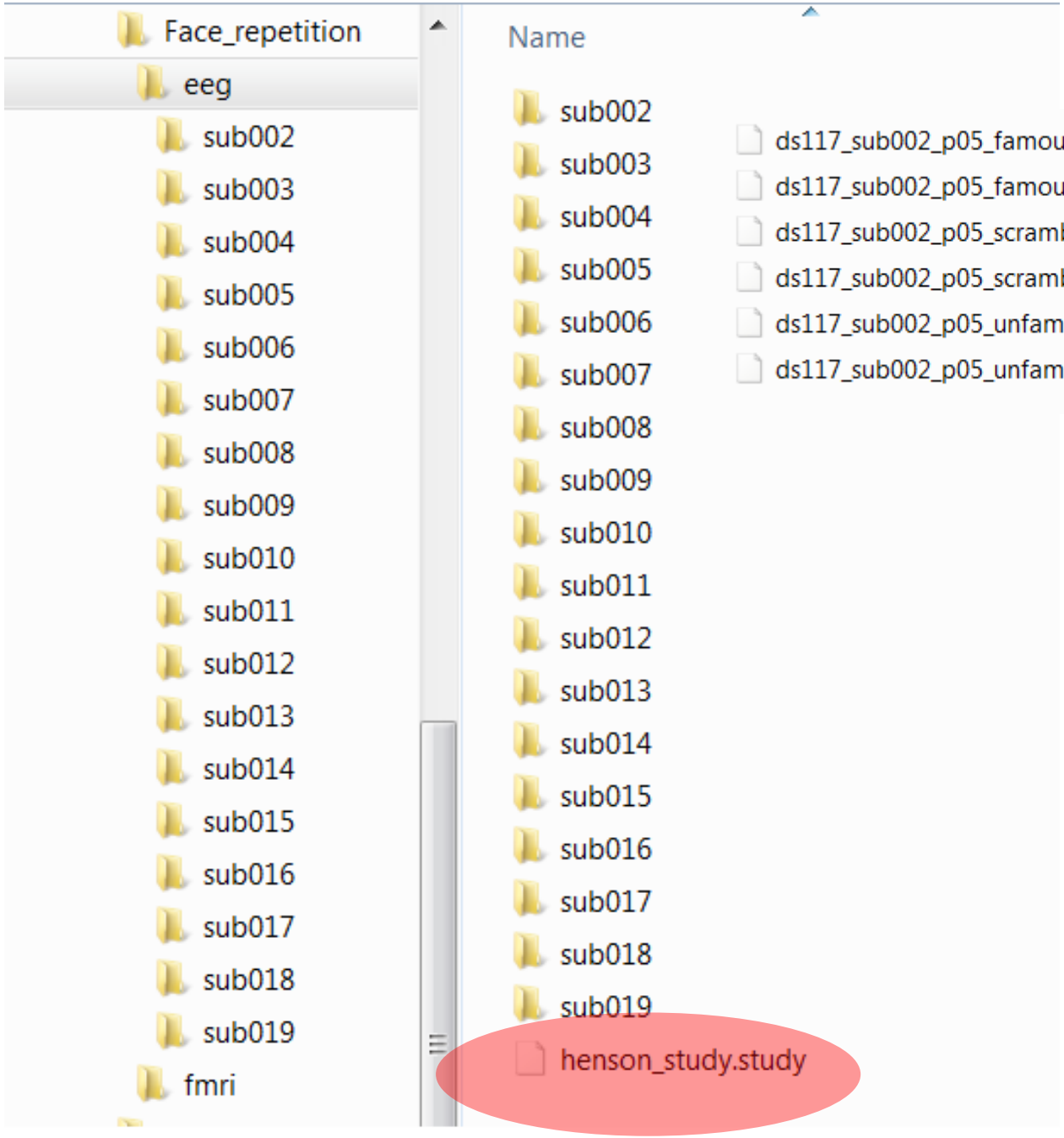
- 1 – Replicate Henson et al. – faces vs. scrambled

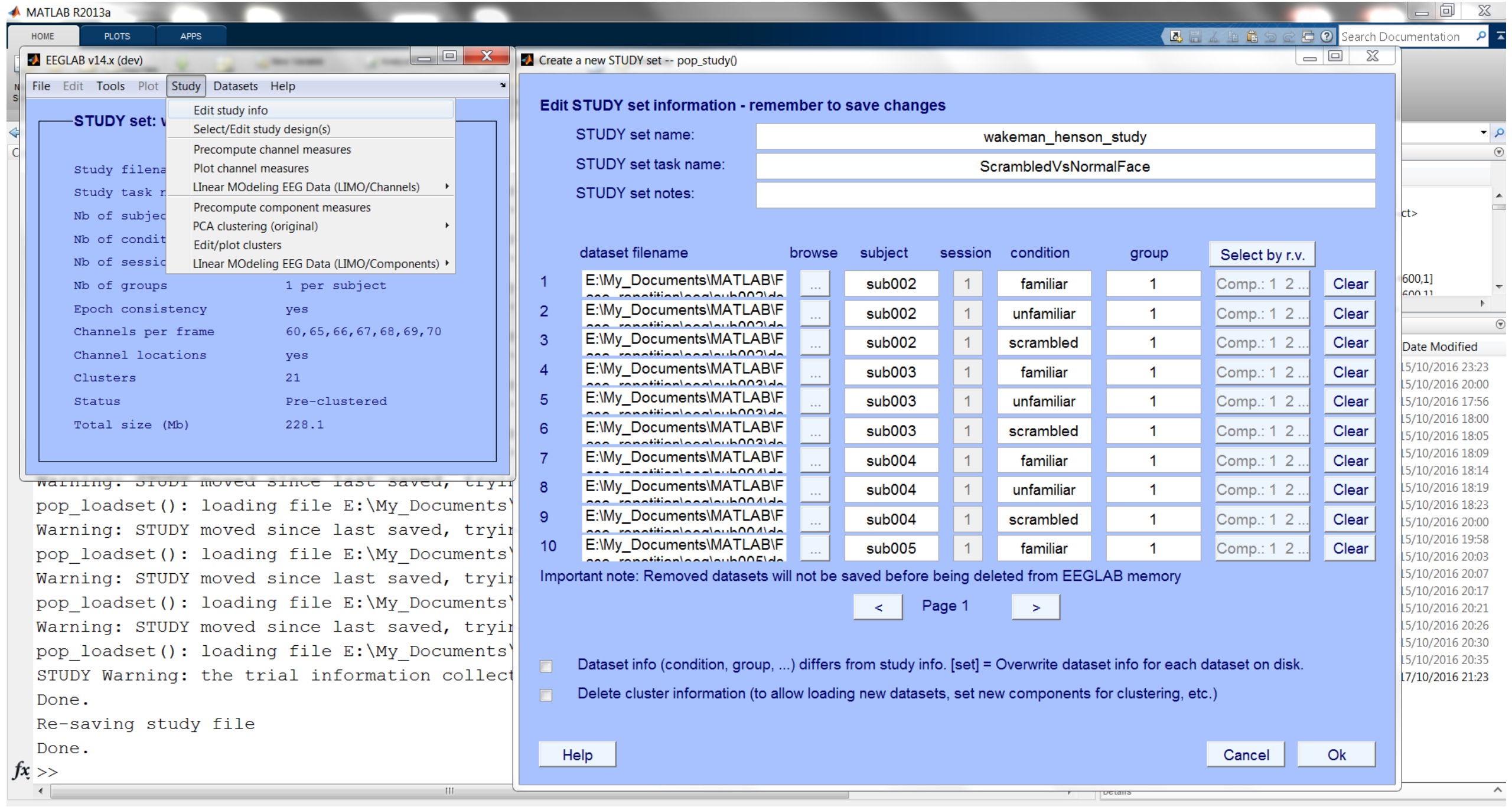


- 2 – learn about robust statistics
- 3 – see how to extend to a 3 (category) by 3 (repetition) design

Let's get started

- Open Matlab
- Move to the data
  - ➢ 18 subjects
- type 'eeglab'
- Load/Make the 'study'
  - ➢ file → load existing study




MATLAB R2013a
HOME
PLOTS
APPS
Search Documentation
EEGLAB v14.x (dev)
File Edit Tools Plot Study Datasets Help
Edit study info
Select/Edit study design(s)
Precompute channel measures
Plot channel measures
LInear MOdeling EEG Data (LIMO/Channels)
Precompute component measures
PCA clustering (original)
Edit/plot clusters
LInear MOdeling EEG Data (LIMO/Components)
STUDY set: w
Study filena
Study task n
Nb of subjec
Nb of condit
Nb of sessio
Nb of groups 1 per subject
Epoch consistency yes
Channels per frame 60,65,66,67,68,69,70
Channel locations yes
Clusters 21
Status Pre-clustered
Total size (Mb) 228.1
pop_loadset(): loading file E:\My_Documents\
Warning: STUDY moved since last saved, tryi
pop_loadset(): loading file E:\My_Documents\
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Warning: STUDY moved since last saved, tryi
pop_loadset(): loading file E:\My_Documents\
STUDY Warning: the trial information collect
Done.
Re-saving study file
Done.
>>
Create a new STUDY set -- pop_study()
Edit STUDY set information - remember to save changes
STUDY set name: wakeman_henson_study
STUDY set task name: ScrambledVsNormalFace
STUDY set notes:
dataset filename browse subject session condition group Select by r.v.
1 E:\My_Documents\MATLAB\F ... sub002 1 familiar 1 Comp.: 1 2 ... Clear
2 E:\My_Documents\MATLAB\F ... sub002 1 unfamiliar 1 Comp.: 1 2 ... Clear
3 E:\My_Documents\MATLAB\F ... sub002 1 scrambled 1 Comp.: 1 2 ... Clear
4 E:\My_Documents\MATLAB\F ... sub003 1 familiar 1 Comp.: 1 2 ... Clear
5 E:\My_Documents\MATLAB\F ... sub003 1 unfamiliar 1 Comp.: 1 2 ... Clear
6 E:\My_Documents\MATLAB\F ... sub003 1 scrambled 1 Comp.: 1 2 ... Clear
7 E:\My_Documents\MATLAB\F ... sub004 1 familiar 1 Comp.: 1 2 ... Clear
8 E:\My_Documents\MATLAB\F ... sub004 1 unfamiliar 1 Comp.: 1 2 ... Clear
9 E:\My_Documents\MATLAB\F ... sub004 1 scrambled 1 Comp.: 1 2 ... Clear
10 E:\My_Documents\MATLAB\F ... sub005 1 familiar 1 Comp.: 1 2 ... Clear
Important note: Removed datasets will not be saved before being deleted from EEGLAB memory
< Page 1 >
Dataset info (condition, group, ...) differs from study info. [set] = Overwrite dataset info for each dataset on disk.
Delete cluster information (to allow loading new datasets, set new components for clustering, etc.)
Help
Cancel
Ok
Date Modified
15/10/2016 23:23
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15/10/2016 18:05
15/10/2016 18:09
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15/10/2016 18:23
15/10/2016 20:00
15/10/2016 19:58
15/10/2016 20:03
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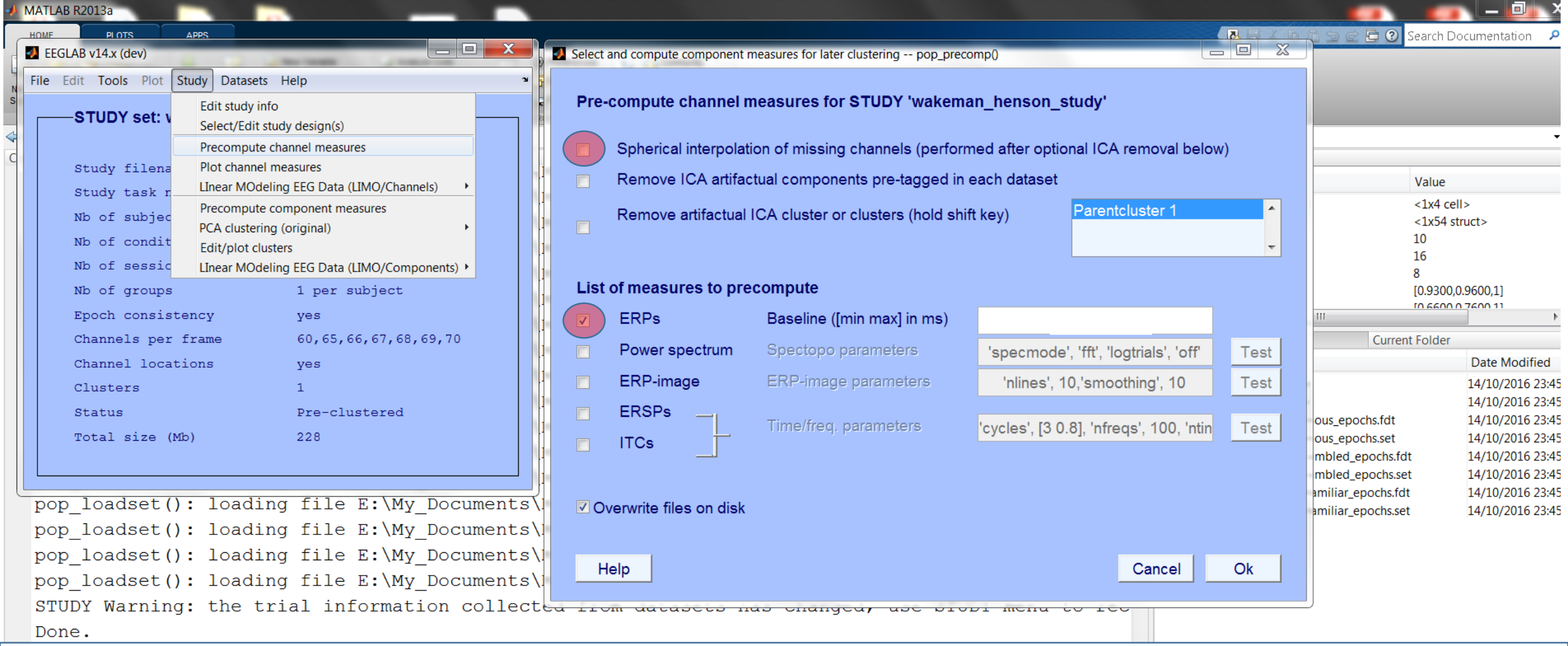
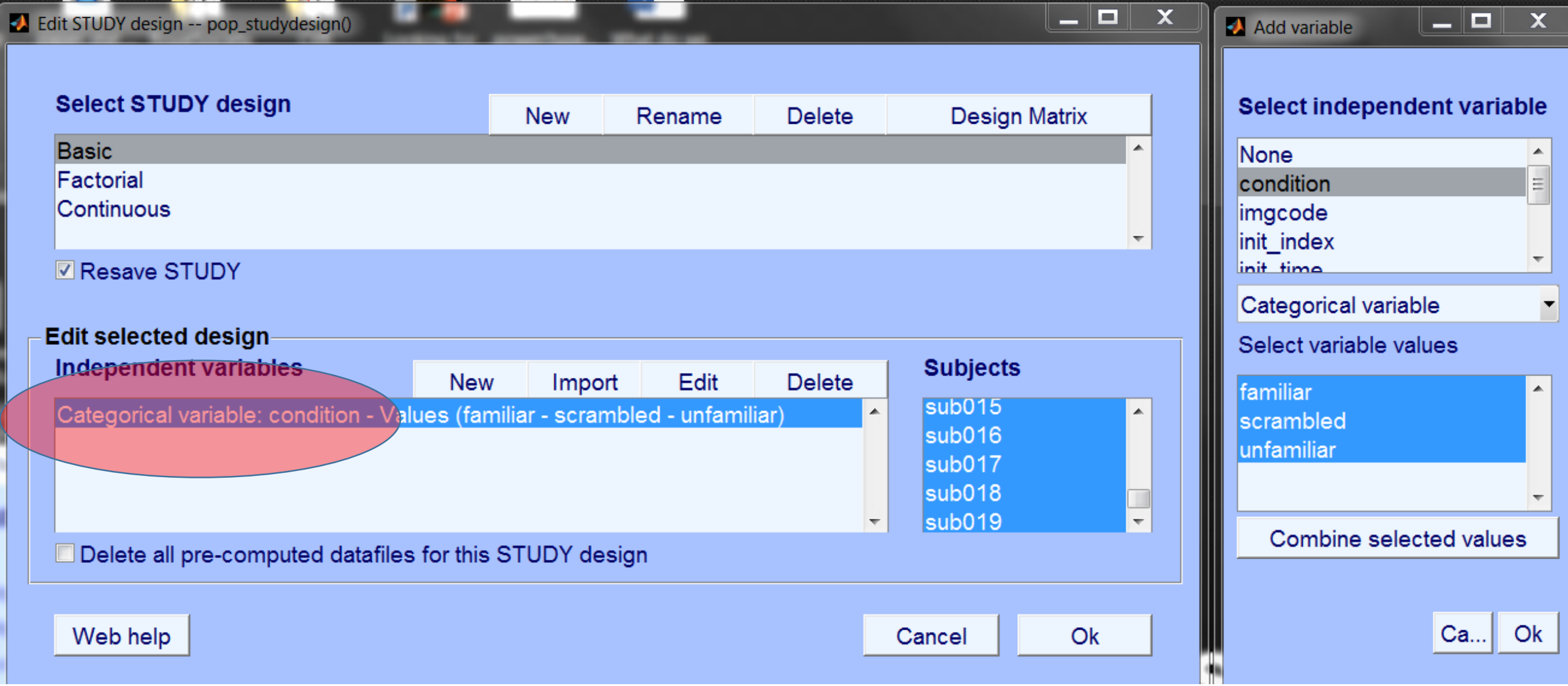
17/10/2016 21:23



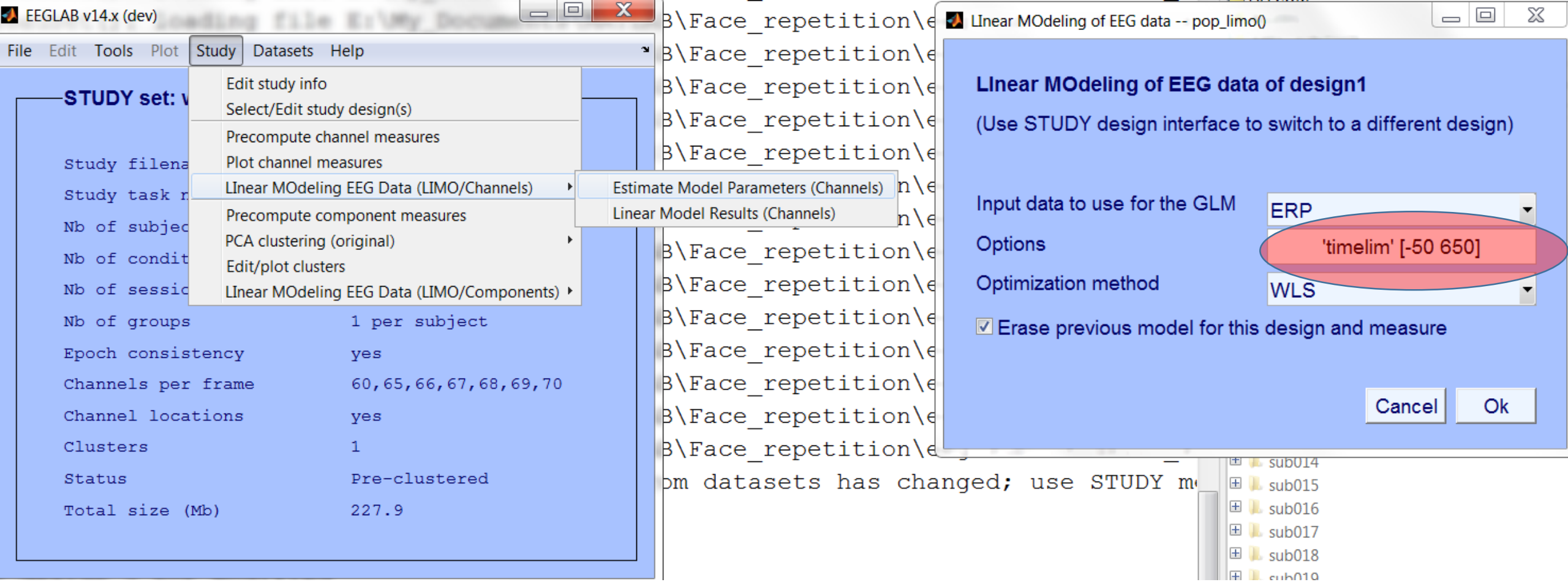
We now extract all the single trials

-- no interpolation of missing channels ; LIMO EEG handles missing data

-- data were processed with epochs -200/800



The new STUDY allows all sorts of designs
By default, you can model each and any condition / covariate
Here, we pick the categorical variable ‘condition’



1 – we have created a study

2 – we have generated single trials for this study

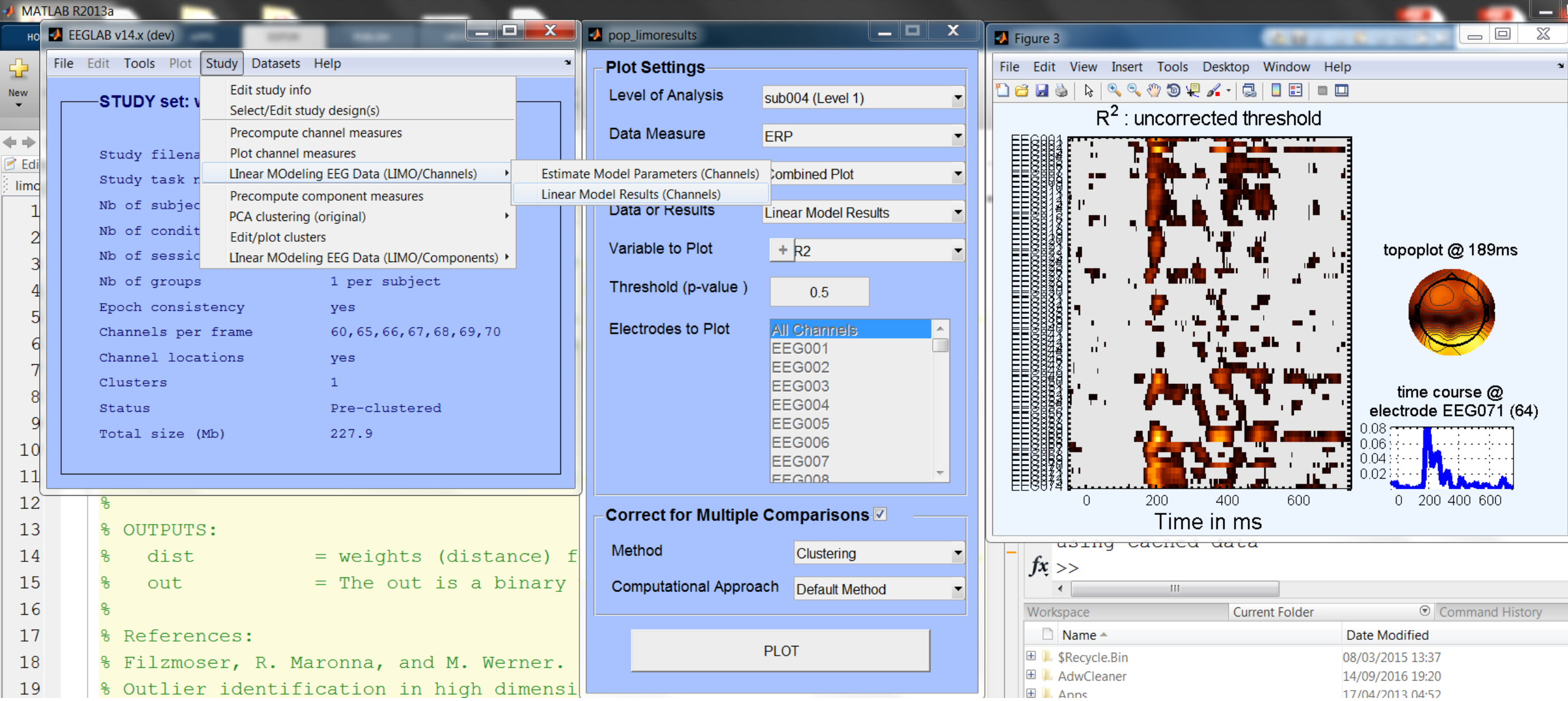
3 – we made a design = statistical model

4 – now we have to do the stats = estimate the model parameters (b)

→ Restrict ‘timelim’ [-50 650] and use Weighted Least Square

Whilst it's computing, let's recap

- For each subject, at each electrode we have a statistical model: Y = XB + e
- The Weighted Least Square solution is B = pinv(WX)*WY for which the matrix W minimizes the influence of outliers in an otherwise (assumed) normally distributed data-set.
- Outliers are defined in a multivariate space, for instance a trial with a time course 'different' from others
- For each subject we have Yr (data), LIMO (model, weights, other info), Betas (parameters), Yhat (LIMO.design.X*Betas = model), Res (residuals), R2 (model fit), Condition_effect1 (=ANOVA F test across all conditions).

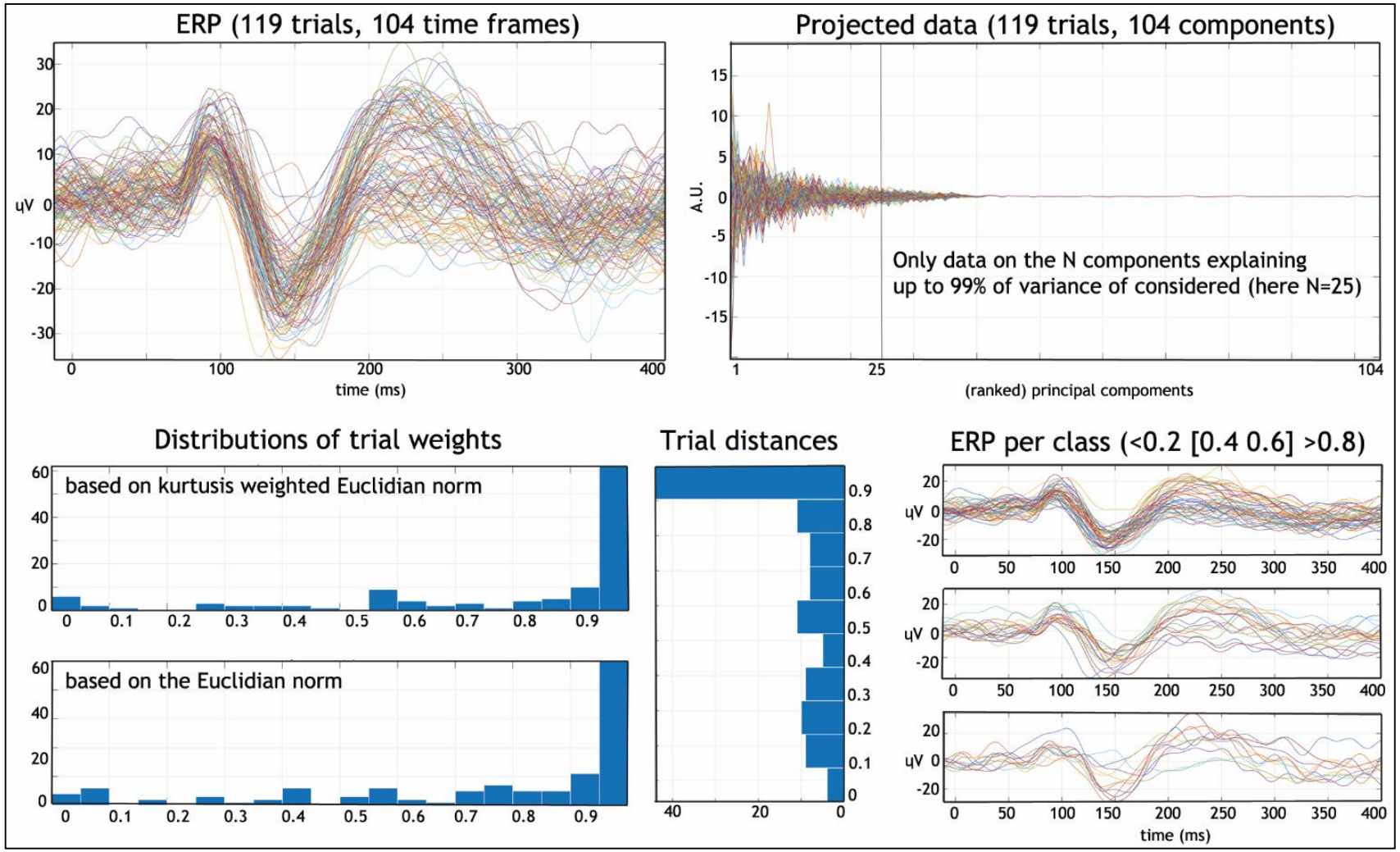


we can mow easily look at each subject

the group level one-sample t-test is also always computed (not always meaningful)

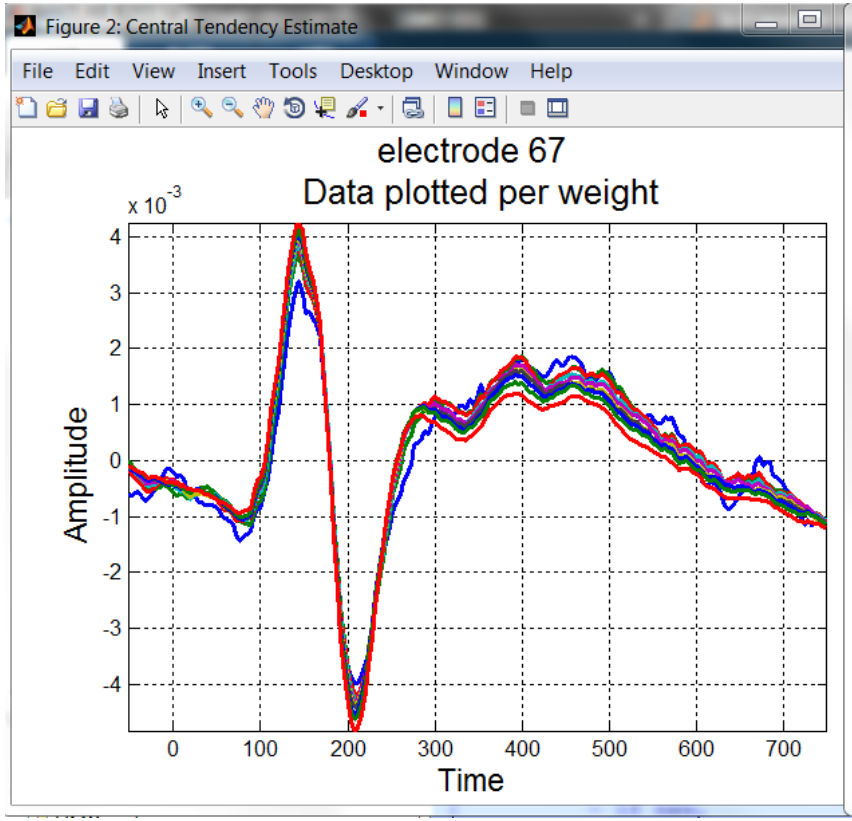
Weighted least squares in LIMO EEG

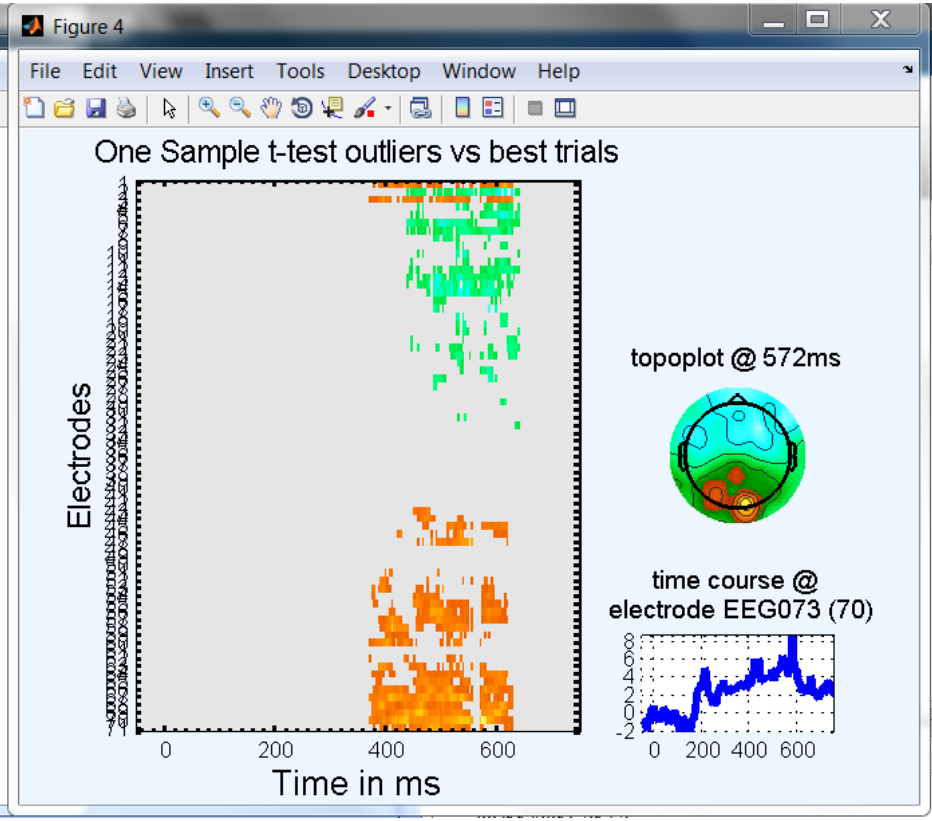
- Principal Component Projection method:
- PCA
- outlier detection on projected data points (Filzmoser et al., 2008)
- 1 weight per trial

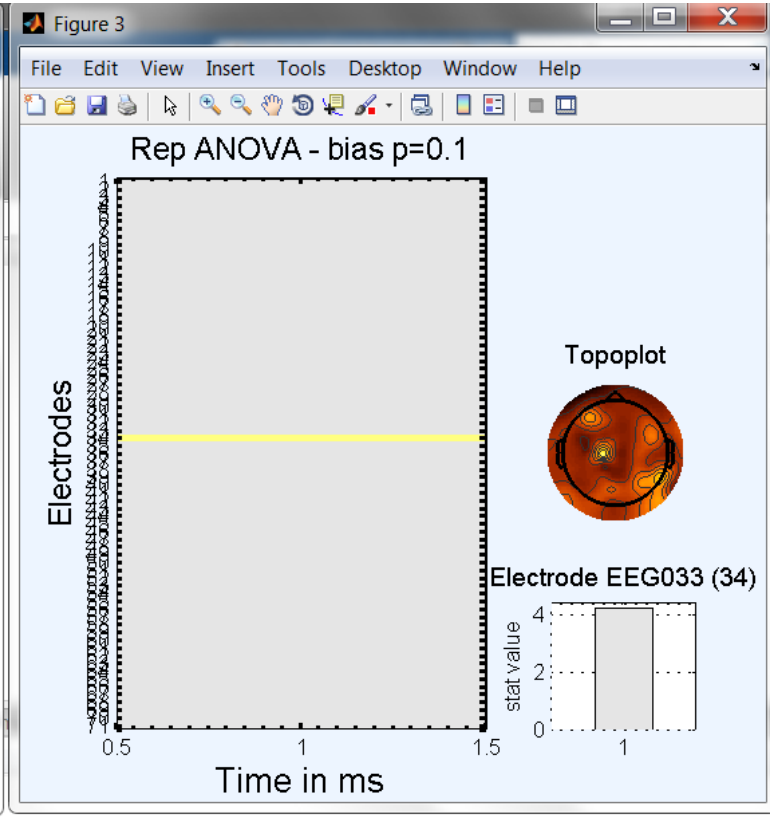


Let's check the weights

- In LIMO Tools, select 'Check weights'







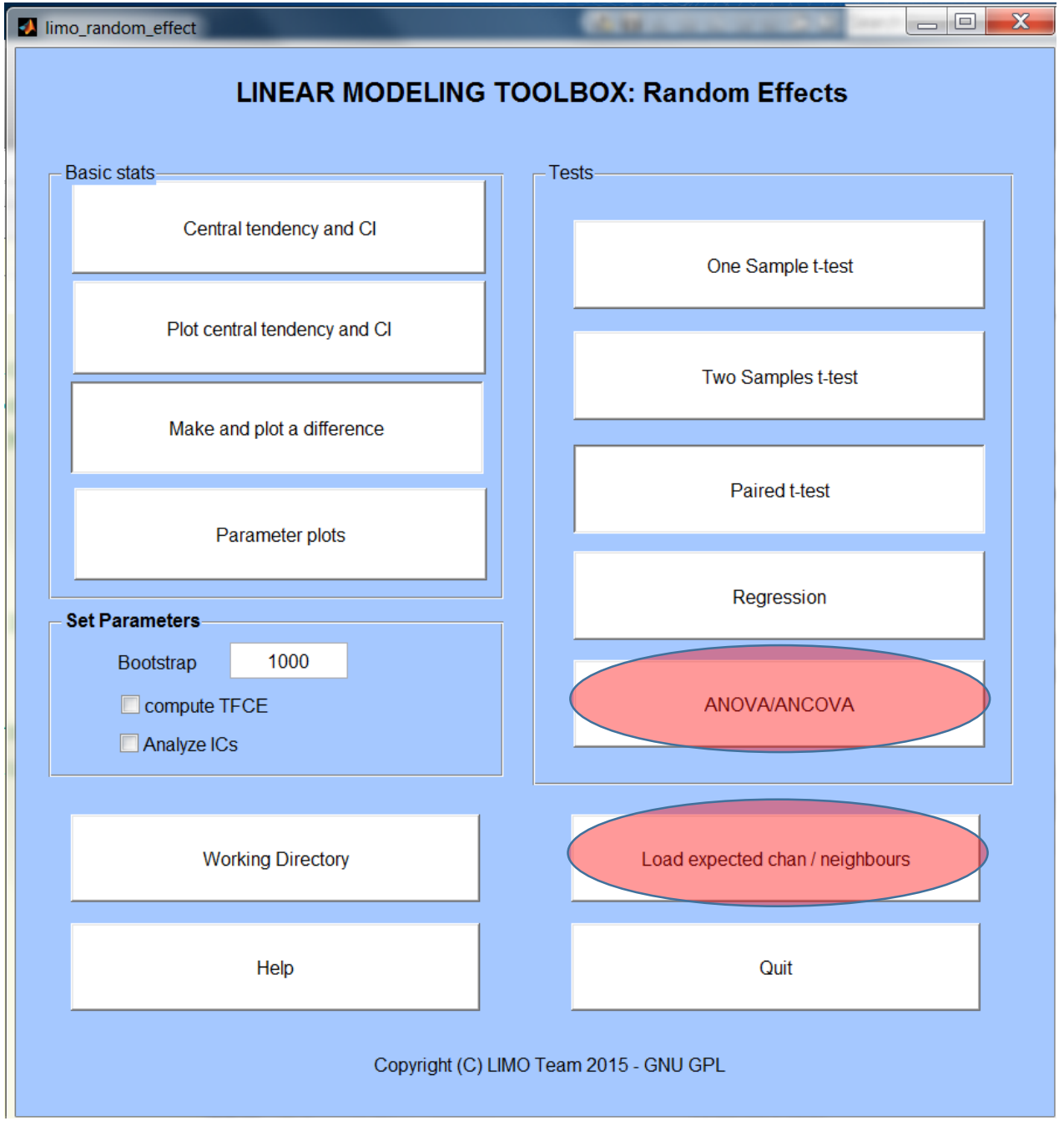
Group level analysis

- Just the same as with ERP but (i) we use betas (ii) LIMO EEG uses robust statistics (essentially 20% trimmed means – except *for now* the repeated measures ANOVA)

- Call the LIMO GUI, and select random effects
- Need a way to group subject with different channels (no interpolation) – the study created such file for you and it should be loaded by default – if not load:

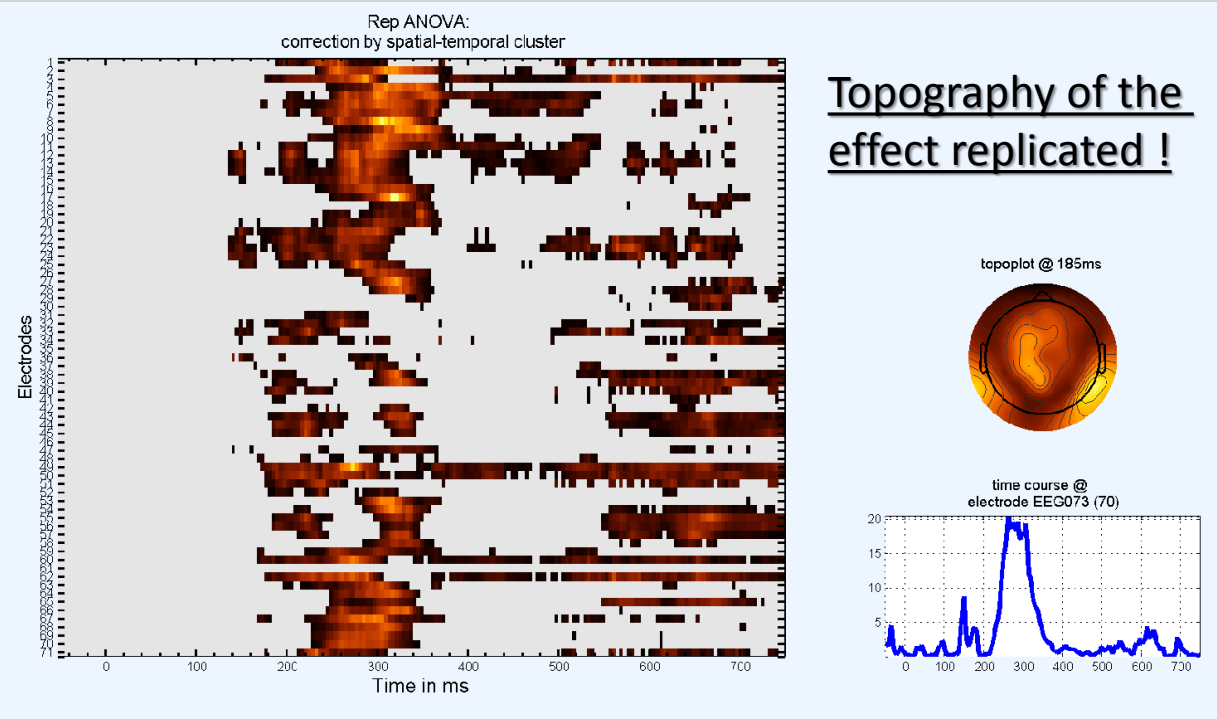
  → *limo_gp_level_chanlocs.mat*

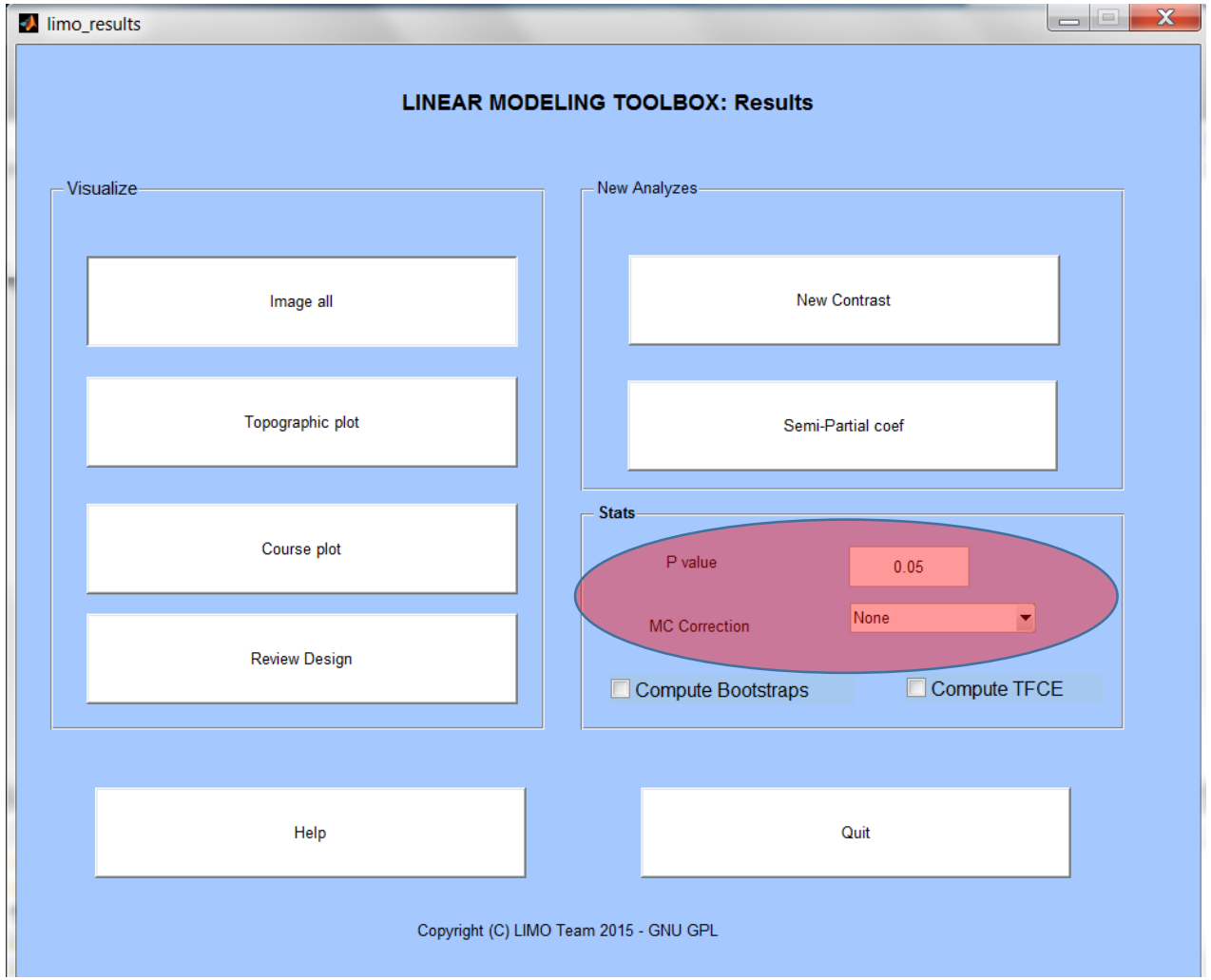
- Create a folder for the results and do a repeated measure ANOVA selecting the beta files [1 2 3]



Group level analysis

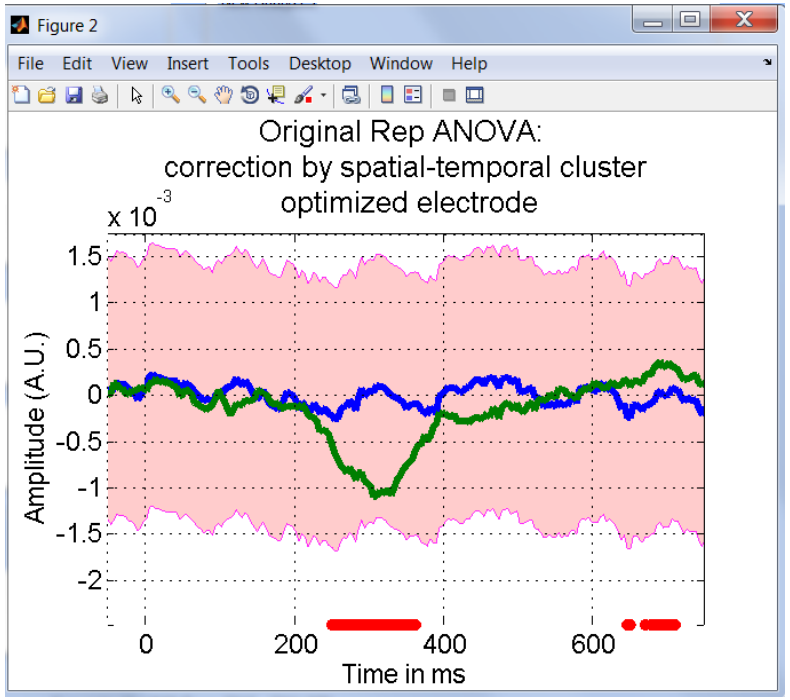
- Call LIMO Results to look at the ANOVA results
- Note the choice between uncorrected and corrected p-values

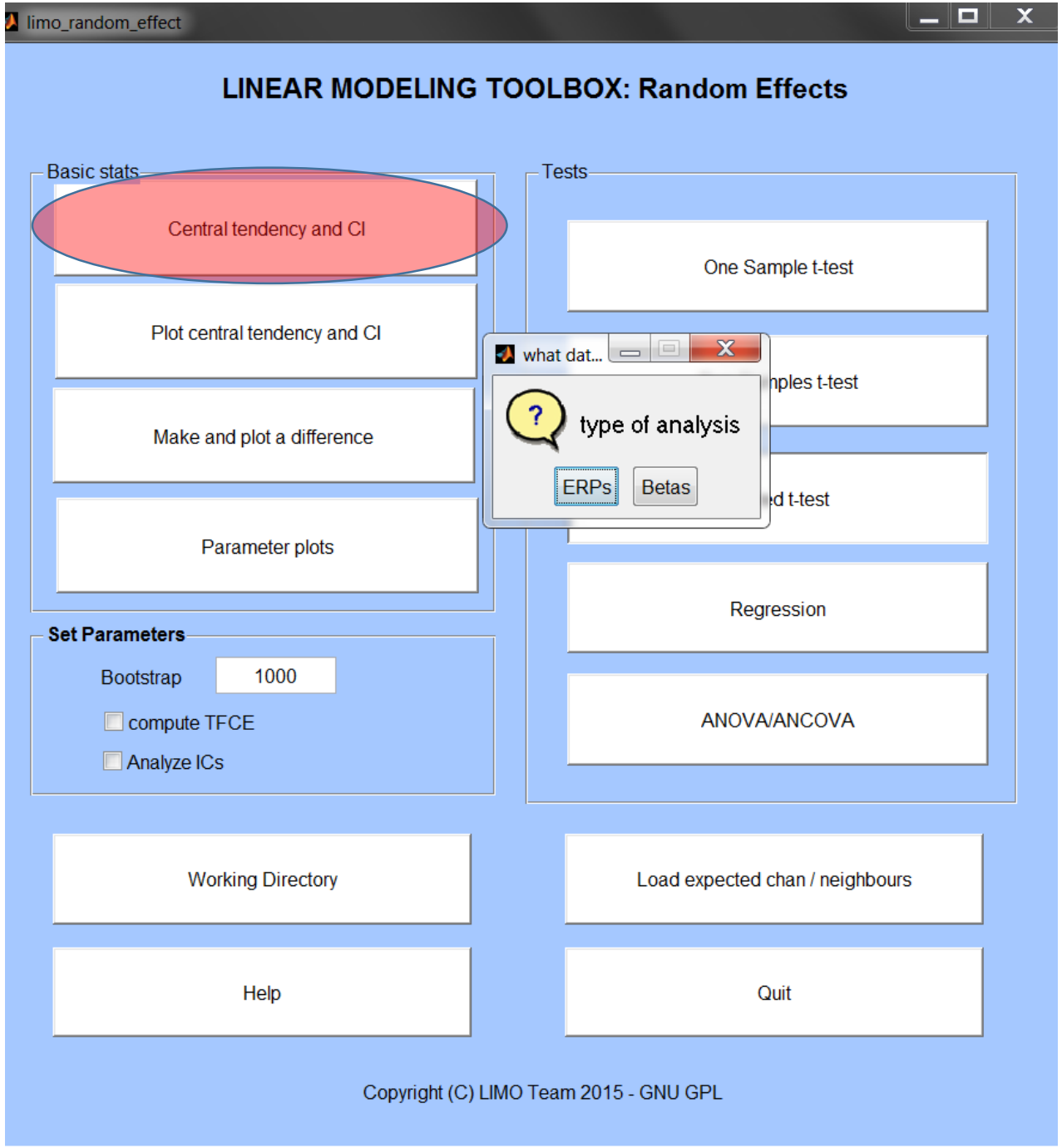




Group level analysis

- If you check the 'course plot' all we have is the contrast used to get the F values
- Best check the 'real' data – plotting the betas and ERP → back to Random Effect





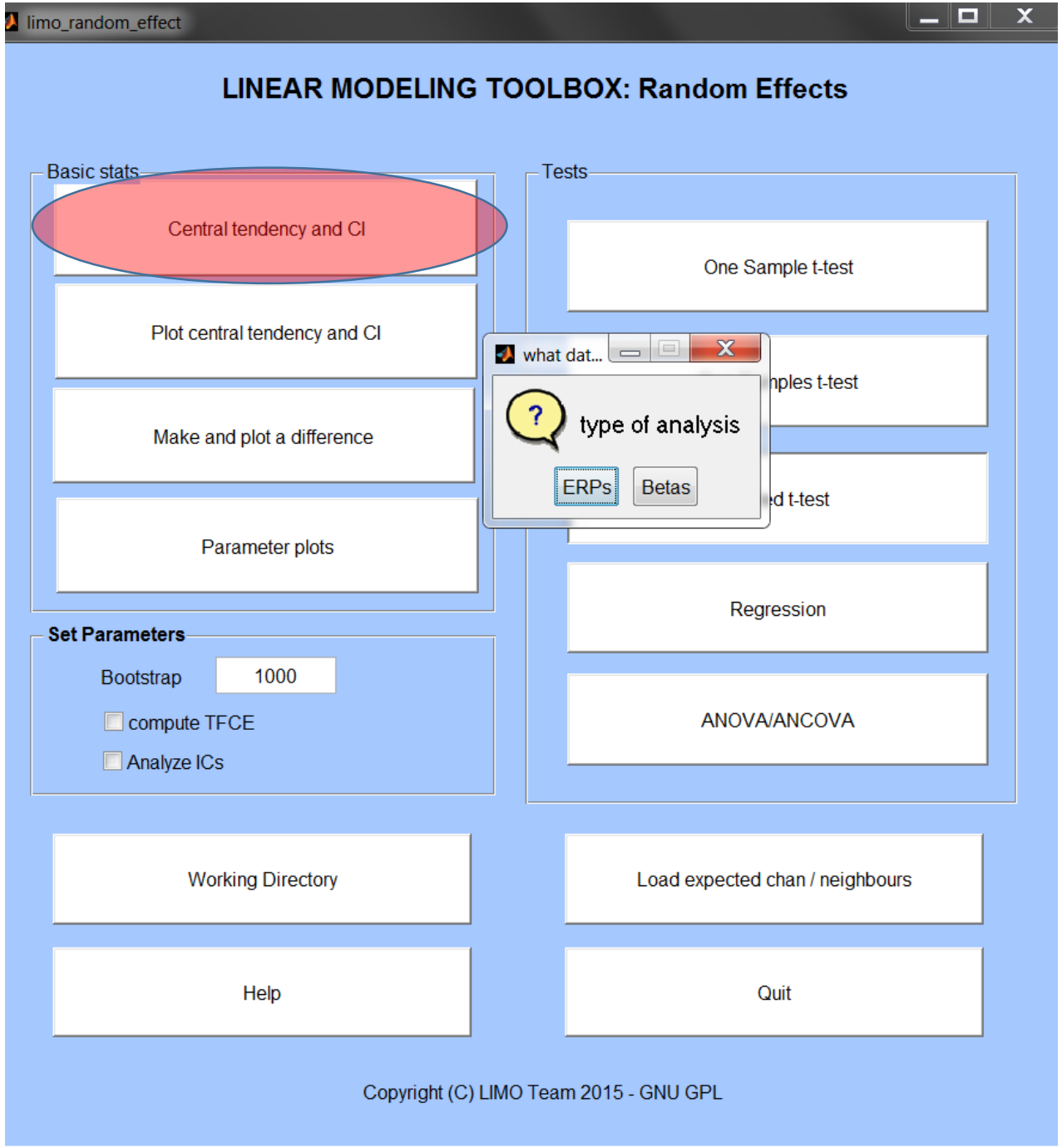
Group level analysis

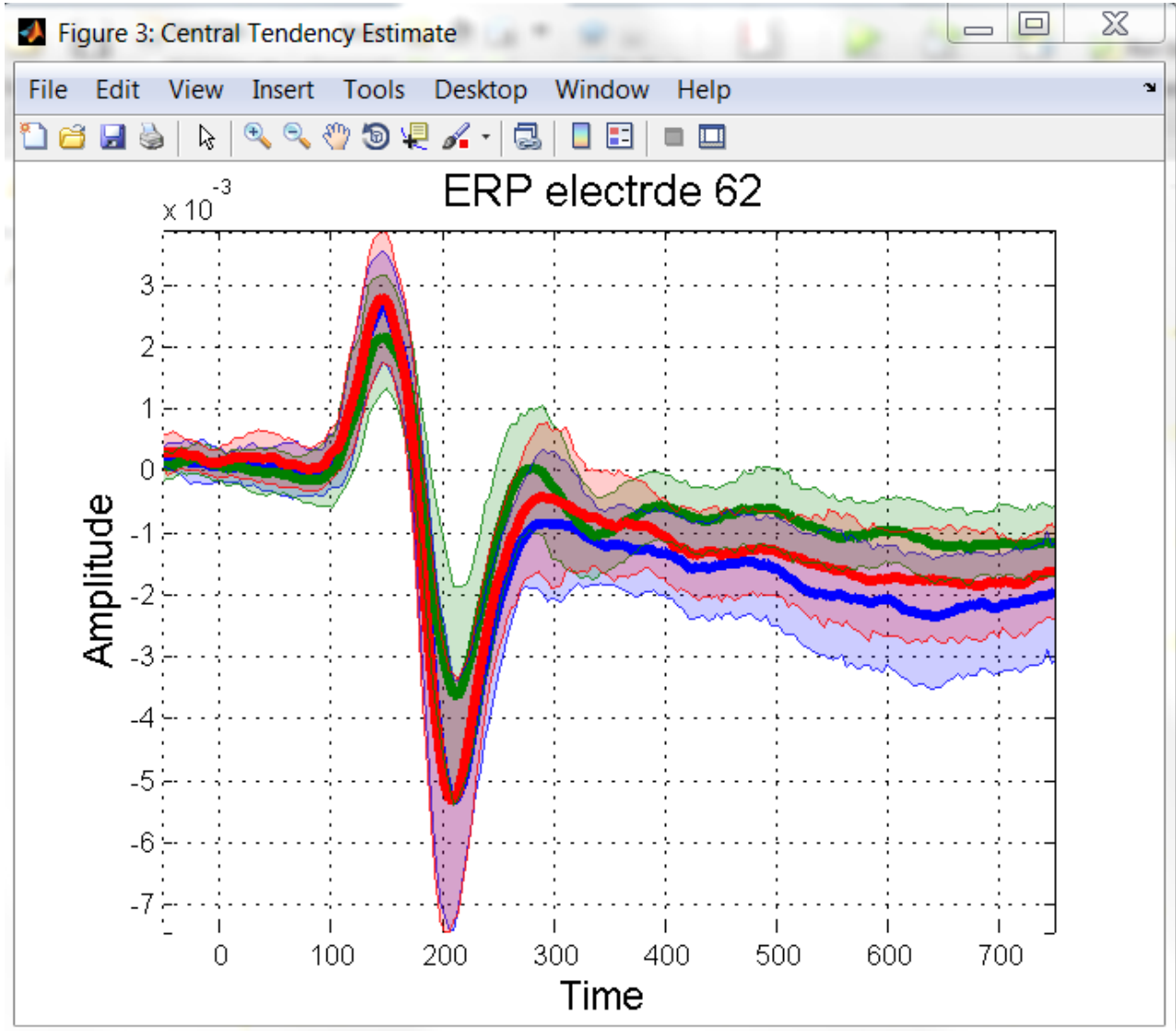
- For Betas – select the txt file listing betas of each subject (you can also load one by one if you like clicking)
- For ERP – select the txt file listing LIMO files of each subject, use weights

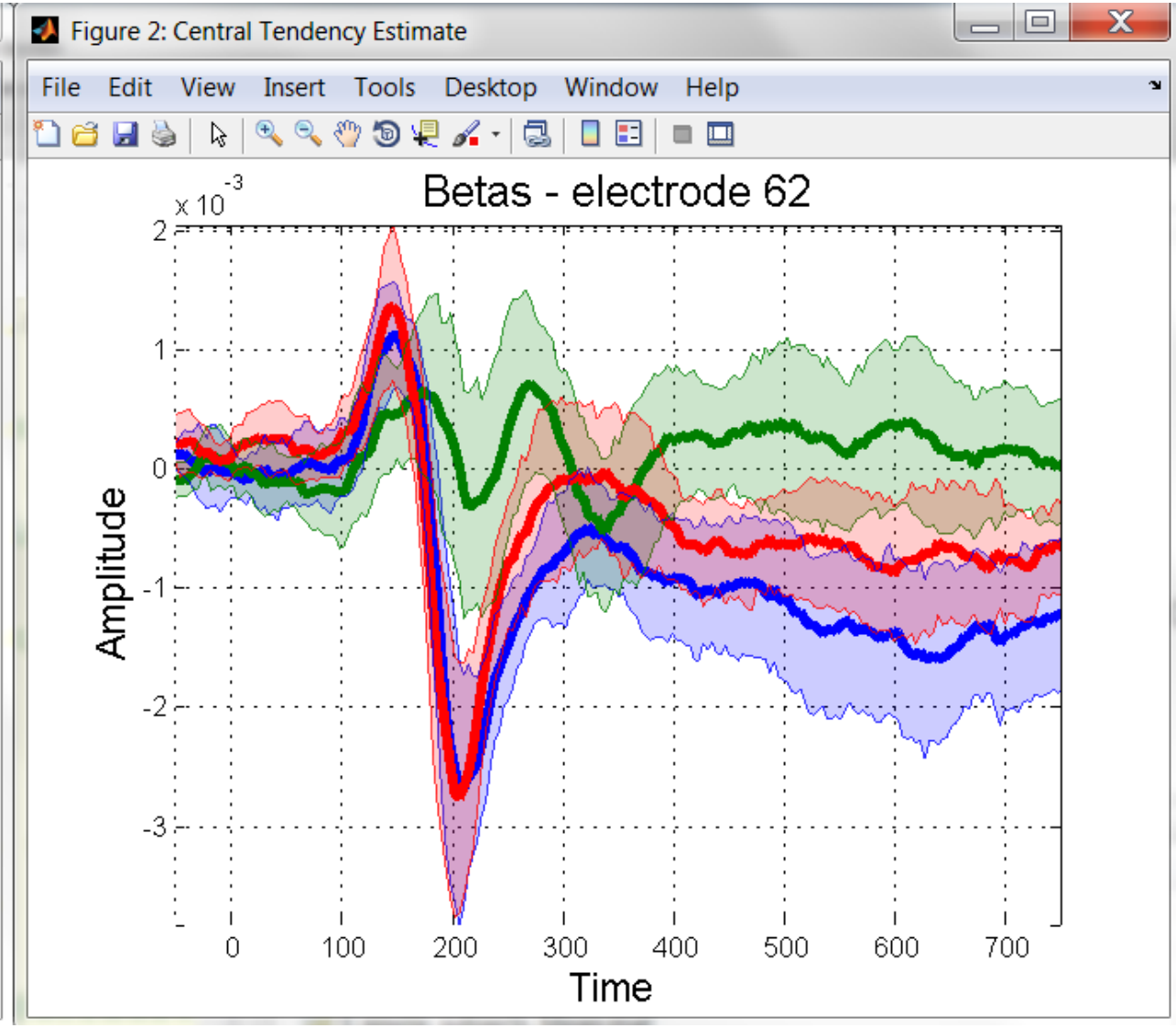
- *Using Plot central tendency and CI, you should be able to:*

1 – see the mean beta 1 / 2 / 3 used in the ANOVA

2 – see the corresponding ERP for Famous faces, scrambled faces and non famous faces



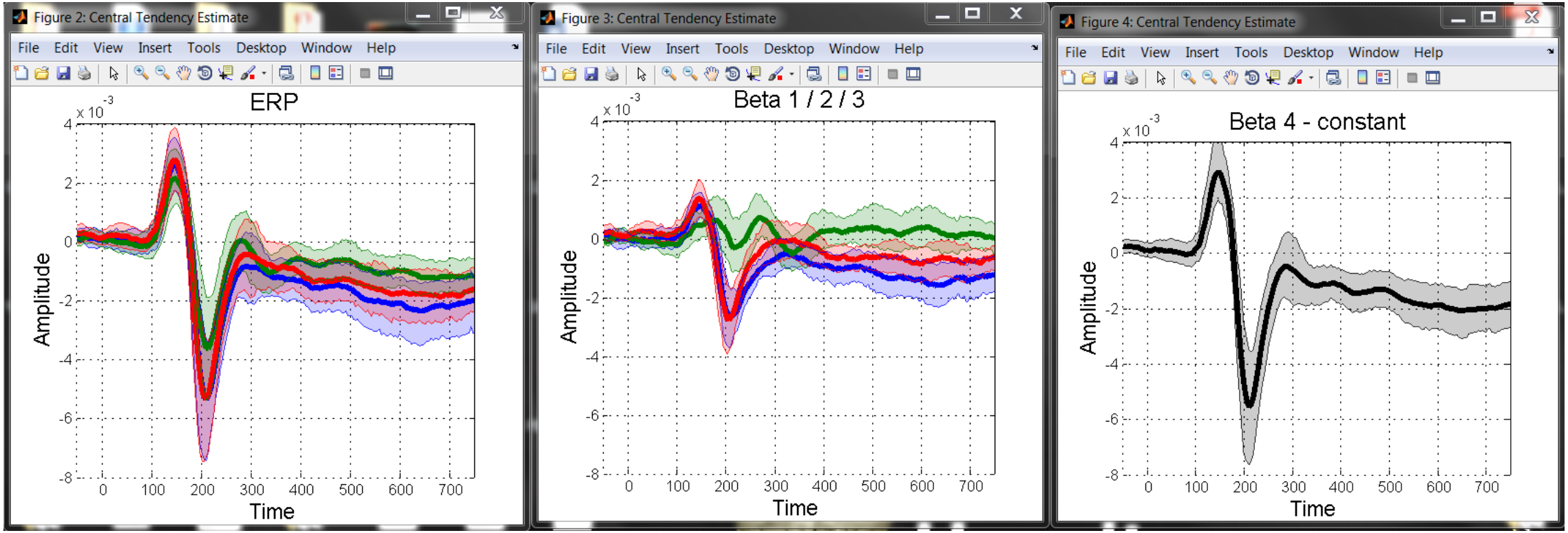




<u>Our ERP looks a lot like the published results – replicated ! (but not so such betas ?)</u>

Bonus: 95% CI are Bayesian = this is the probability of the estimator

Wait a minute ! The model was …



Y (the data) = FF*Beta1 + SF*Beta2 + NFF*Beta 3 + Beta 4 + e

Figure 1

File Edit View Insert Tools Desktop Window Help

Channel locations

71 of 71 electrode locations shown

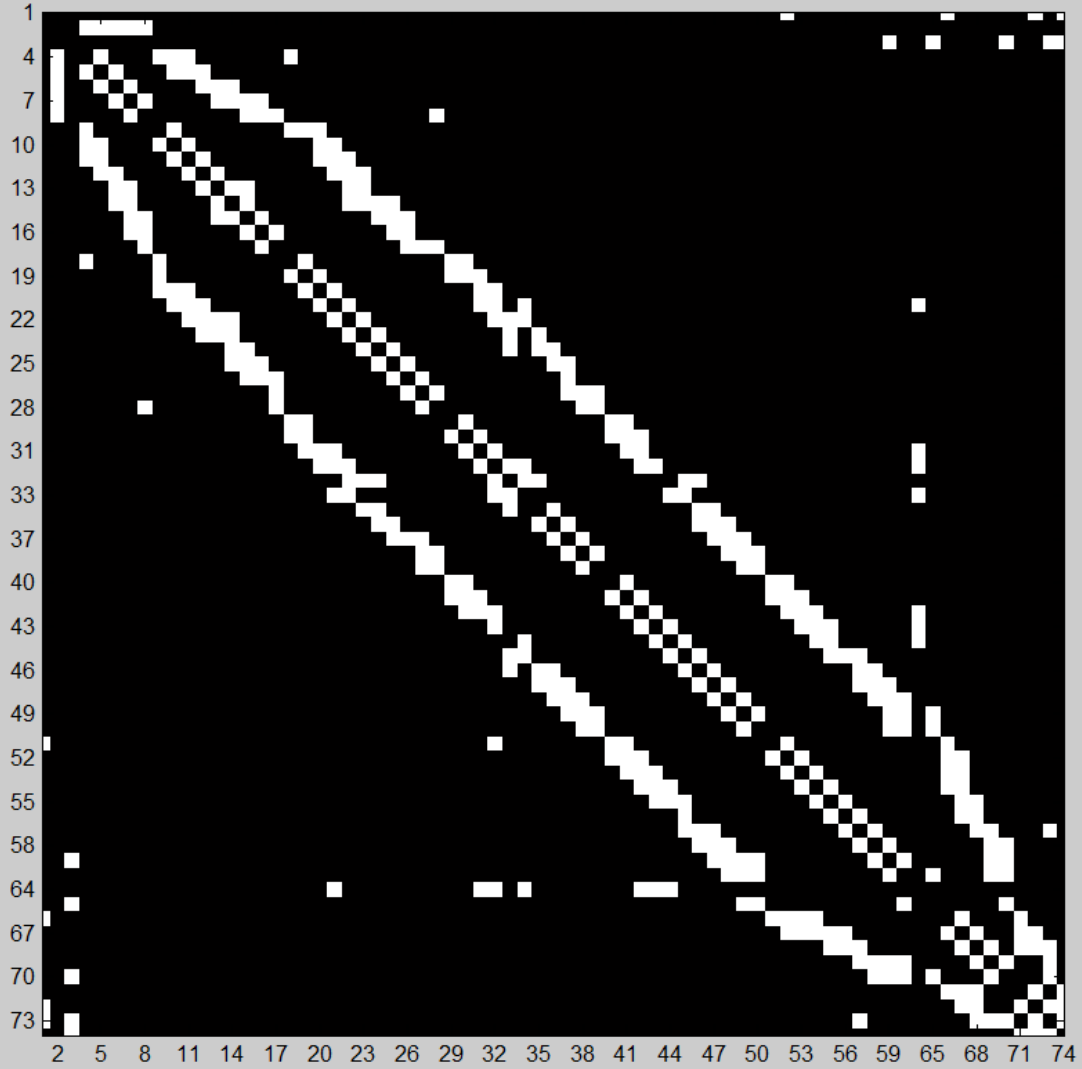
Click on electrodes to toggle name/number

Are your results a little different from mine?
LIMO Tools – I edited my neighbourhood matrix

Figure 3

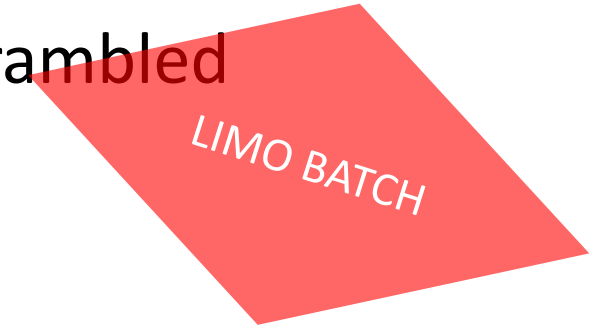
File Edit View Insert Tools Desktop Window Help

Connectivity matrix between channels



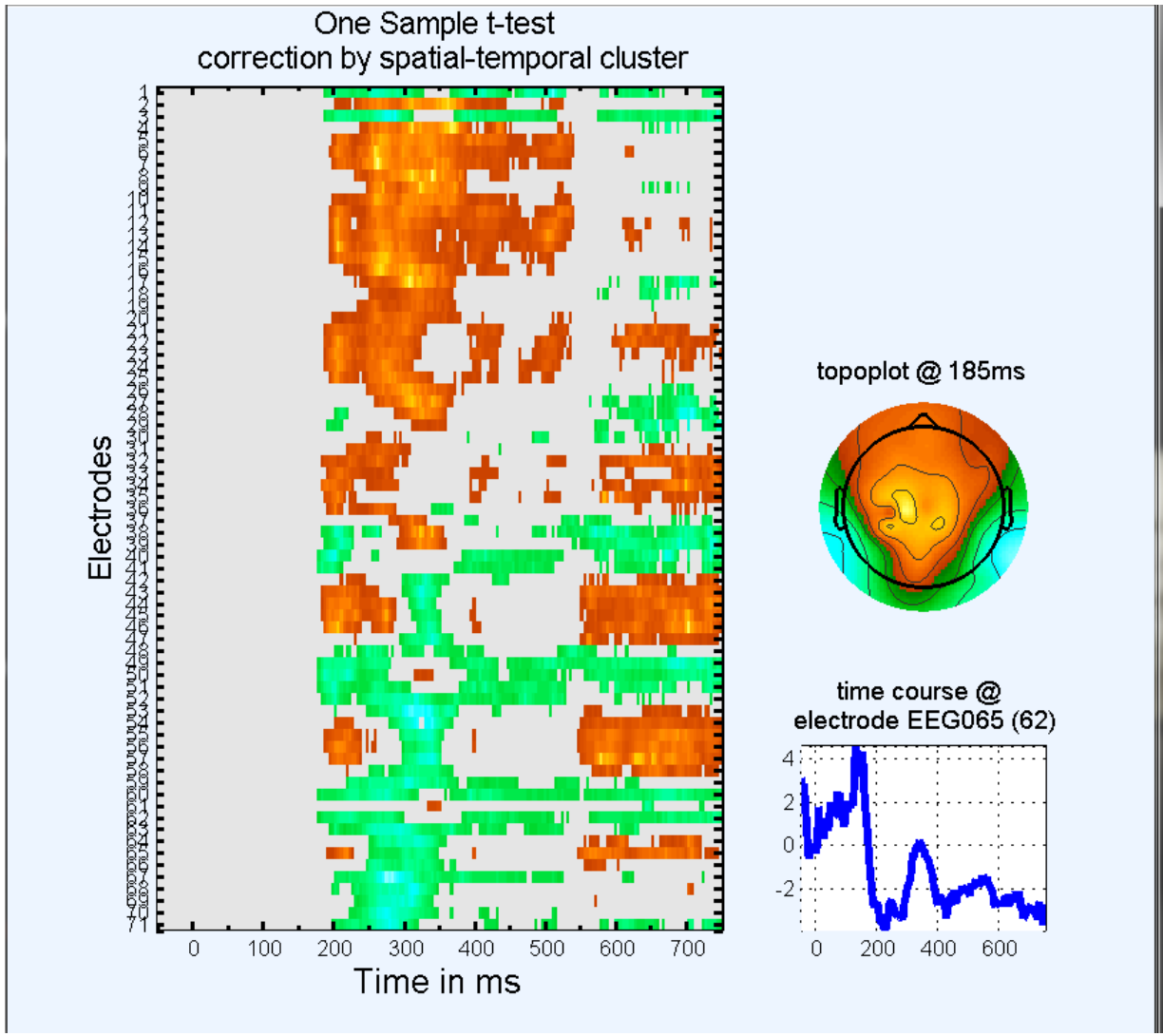
Let’s try faces vs scrambled !

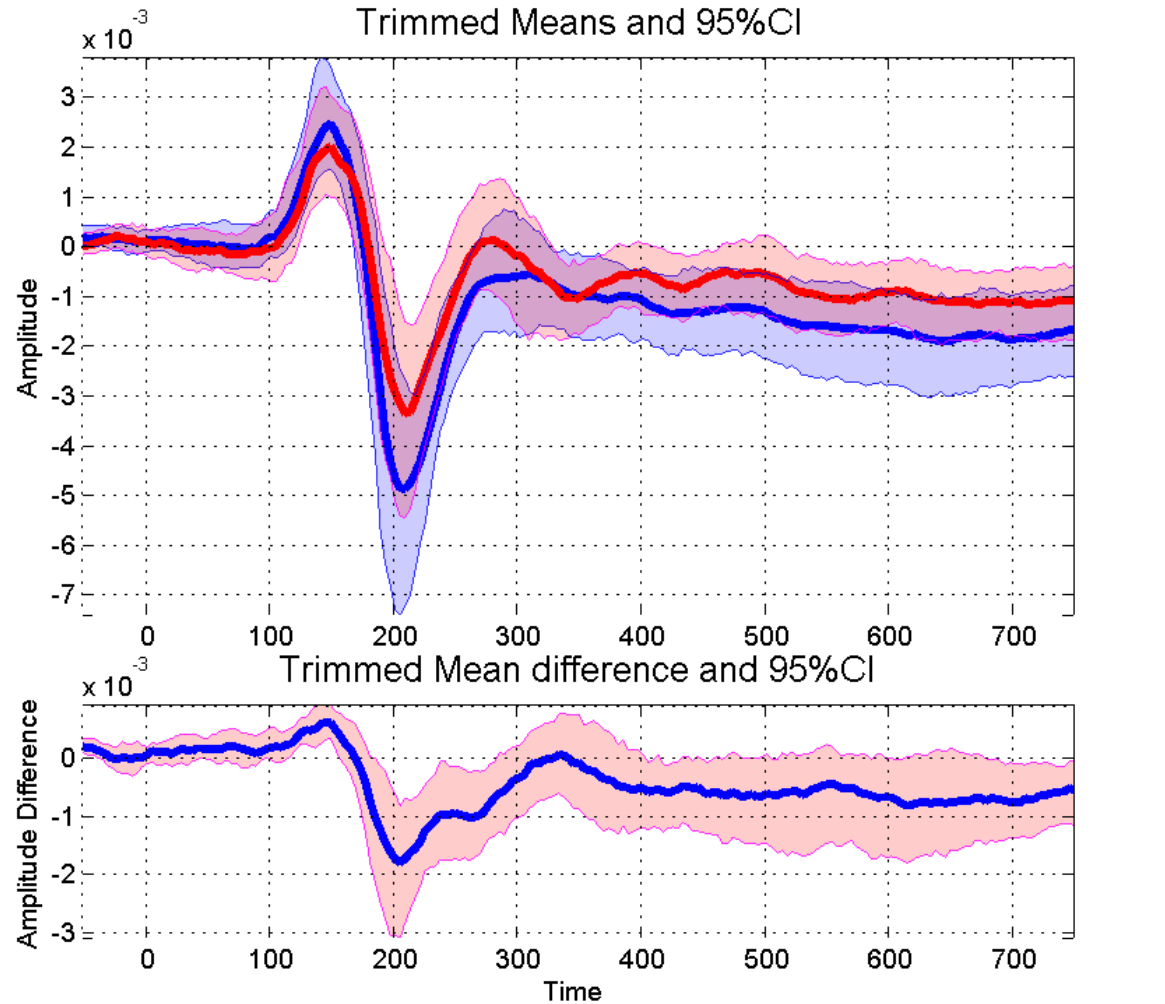
- Per subject compute a contrast famous + non-famous > scrambled
- [1 -2 1] tests [famous – 2*scrambled + non-famous] = 0



- At the group level, do a one-sample t-test
- At the group level, you can build an ERP pooling famous + non-famous

faces vs scrambled





Why is LIMO Robust?

- Standard stats are all instantiations of a GLM using an Ordinary Least Square solution → implies looking at the mean
- the breakdown point of an estimator is the proportion of incorrect observations (e.g. arbitrarily large observations) an estimator can handle before giving an incorrect
- For data x1 to xn – the mean has a bkdp of 0 because we can make the mean large changing any xi – the median has a bkdp of 50%

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

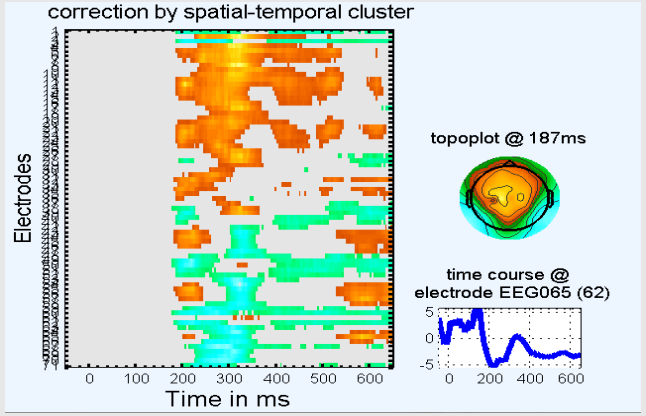
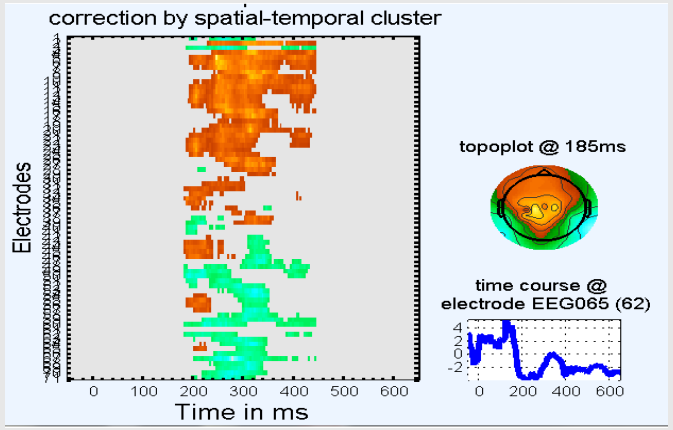
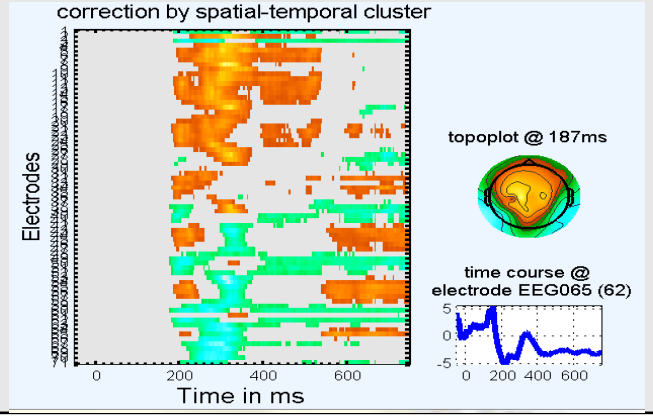
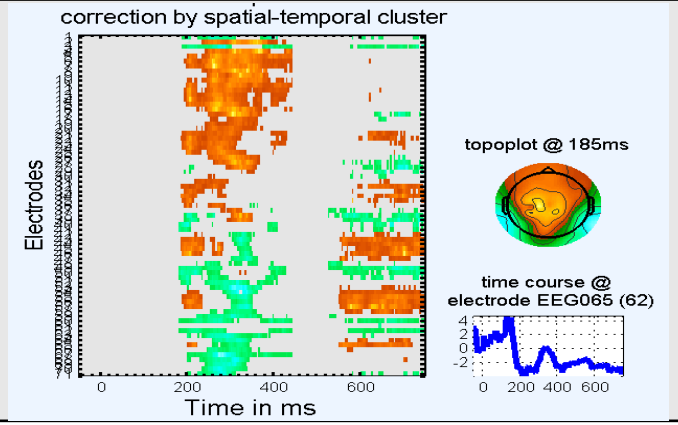
Why is LIMO Robust?

- Are you sure?
- Micceri (1989). The Unicorn, The Normal Curve, and Other Improbable Creatures. Psych Bul. 105, 156-166
- If the data are Gaussian, the median, the trimmed mean is the same as the mean ! So no reason not to use alternative techniques.

- 1st level, uses weighted least square (weights down bad trials – bkdp variable)
- 2nd level involves 20% trimmed mean (weights = 0 for bad subjects): t-tests, 1-way ANOVA, Repeated Measures ANOVA (soon)
- For regressions and N-way ANOVA/ANOVA we use an IRLS (all subjects have weights from 0 to 1 – bkdp variable)

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

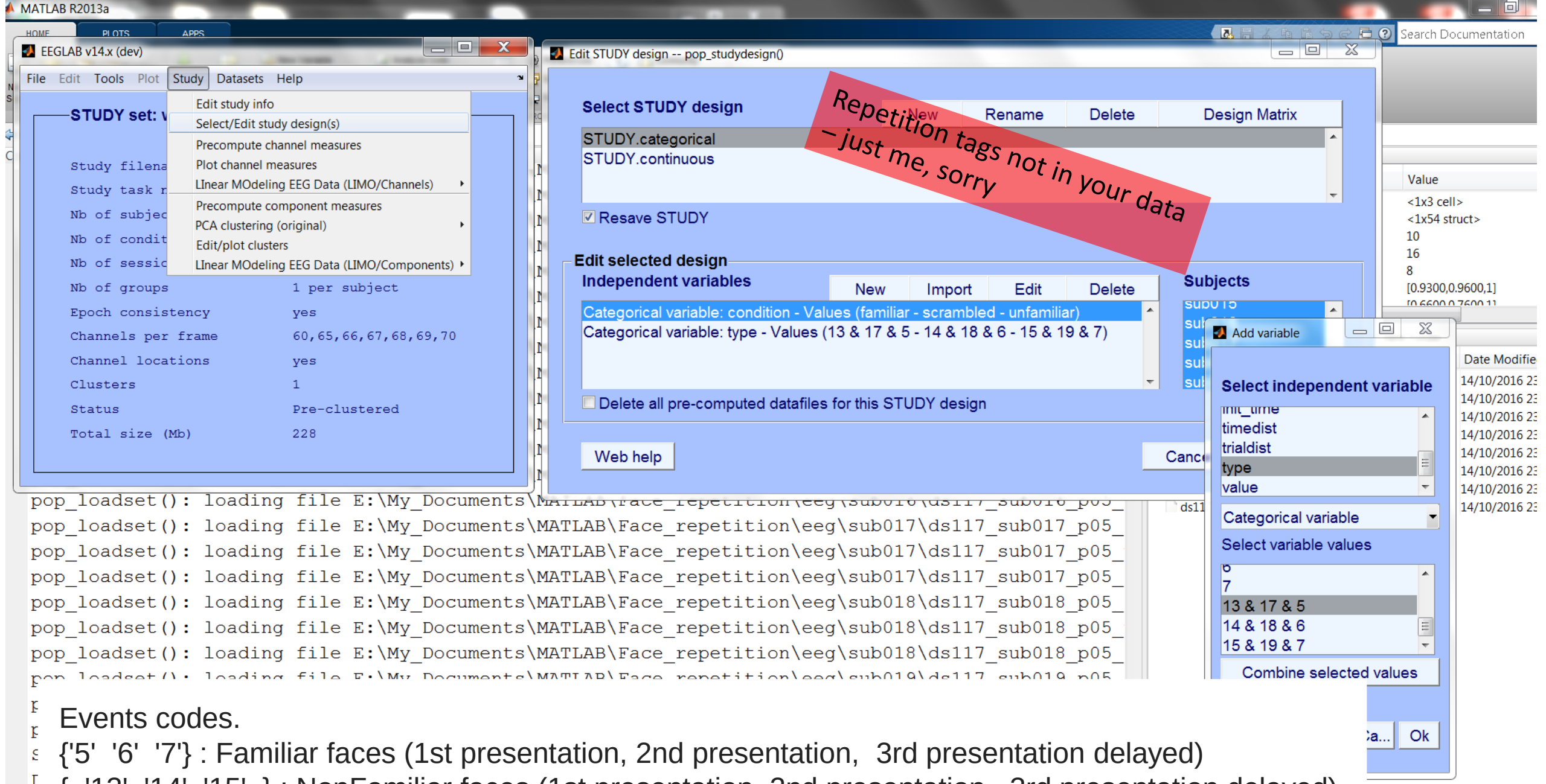
Let’s look again at faces vs scrambled

	T-test on mean	T-test on trimmed mean
OLS		
WLS		

3 x 3 repeated measures ANOVA

- Since we have 3 types of faces and 3 repetition levels – we can do a 3 by 3 ANOVA

- Question: How many 1^{st} level regressors?
- Question: Why not modelling interaction at the subject level?



Events codes.

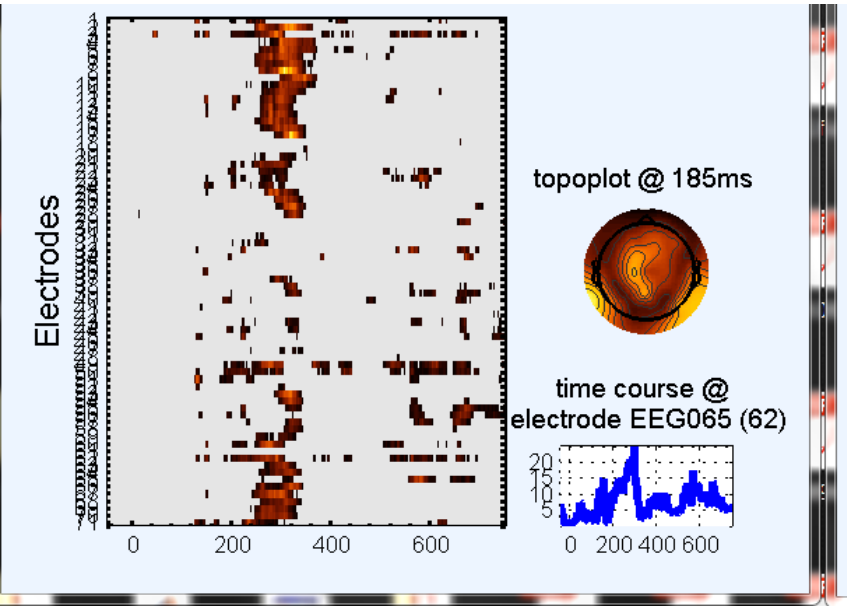
{'5' '6' '7'} : Familiar faces (1st presentation, 2nd presentation, 3rd presentation delayed)

{ '13' '14' '15' } : NonFamiliar faces (1st presentation, 2nd presentation, 3rd presentation delayed)

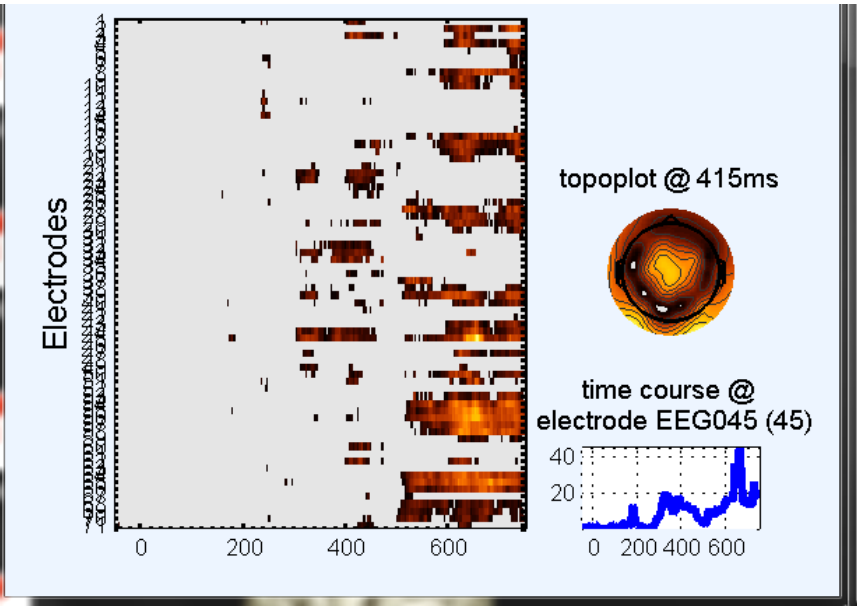
{ '17' '18' '19' }: Scrambled faces (1st presentation, 2nd presentation, 3rd presentation delayed}

3 x 3 repeated measures ANOVA

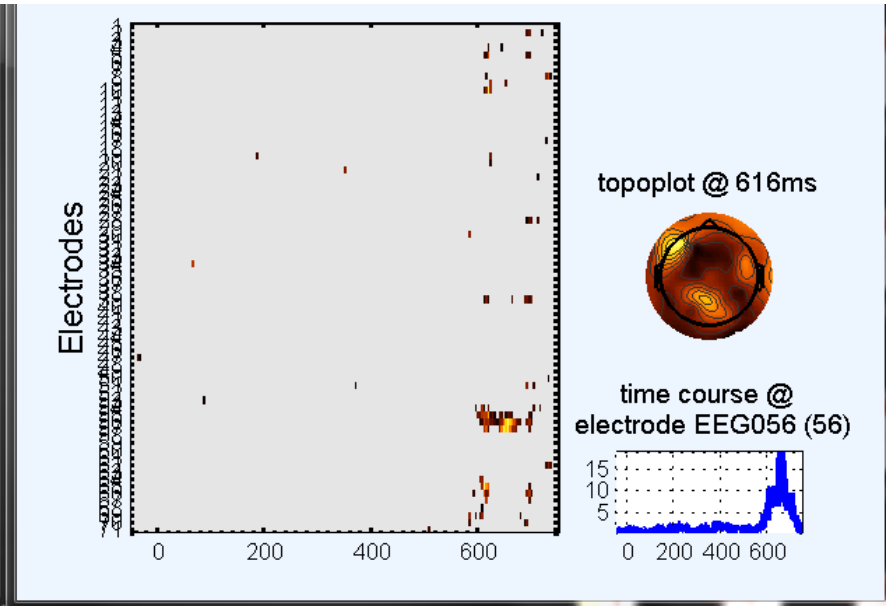
Category effect



Repetition effect

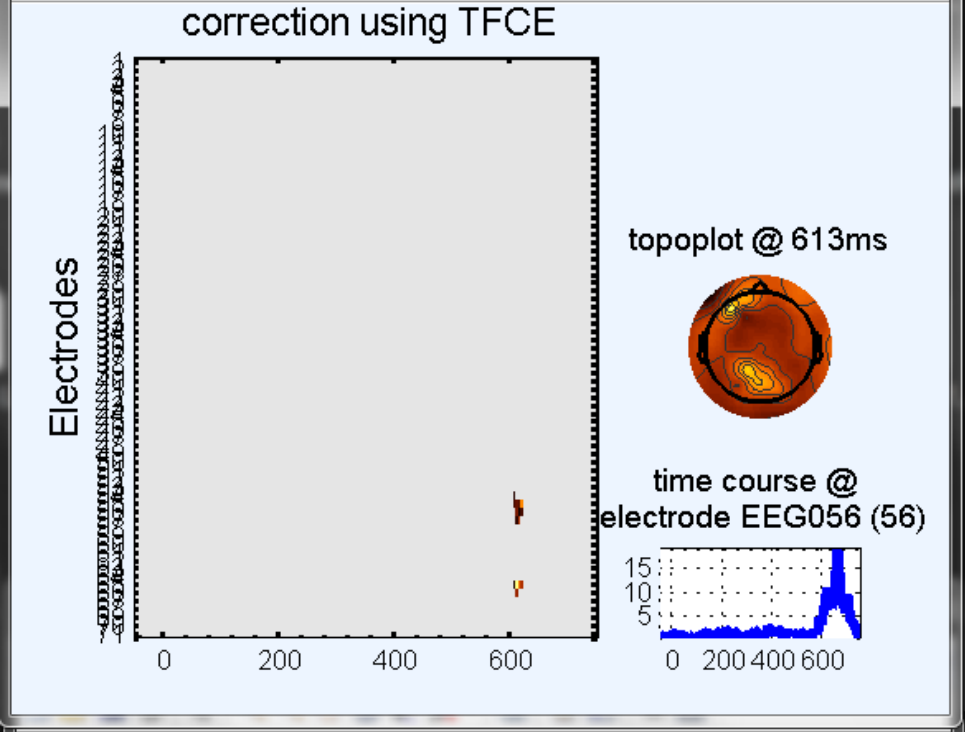


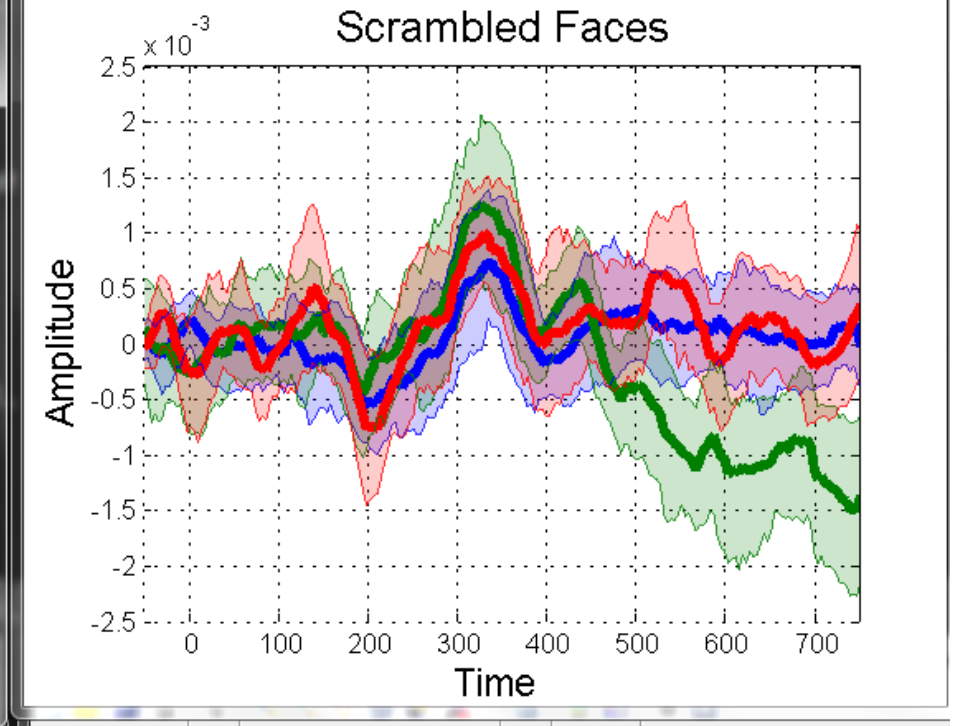
Interaction effect

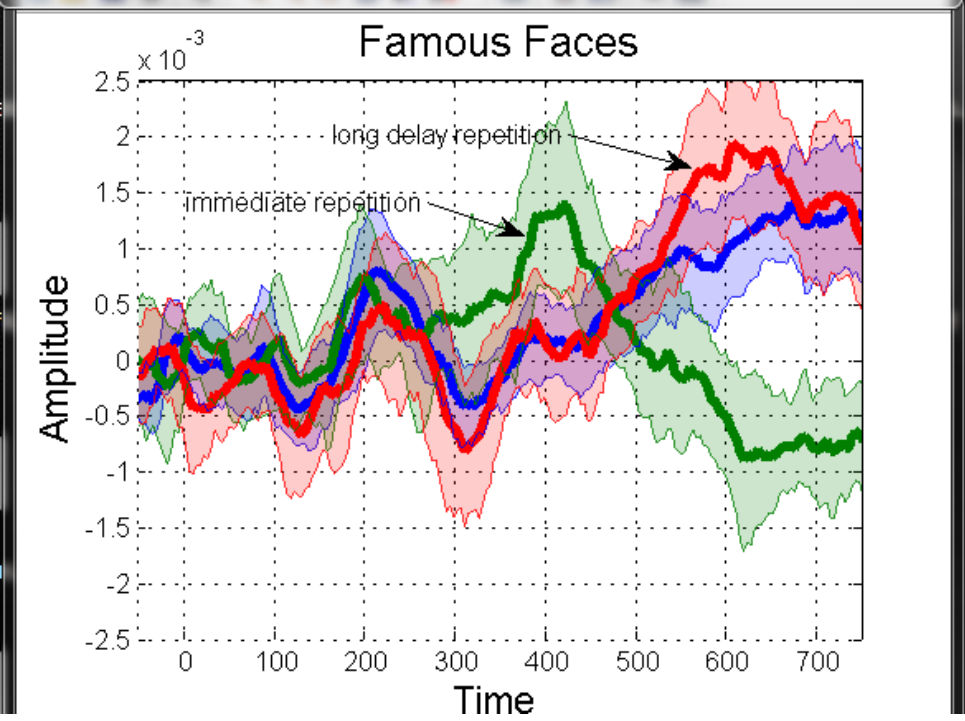


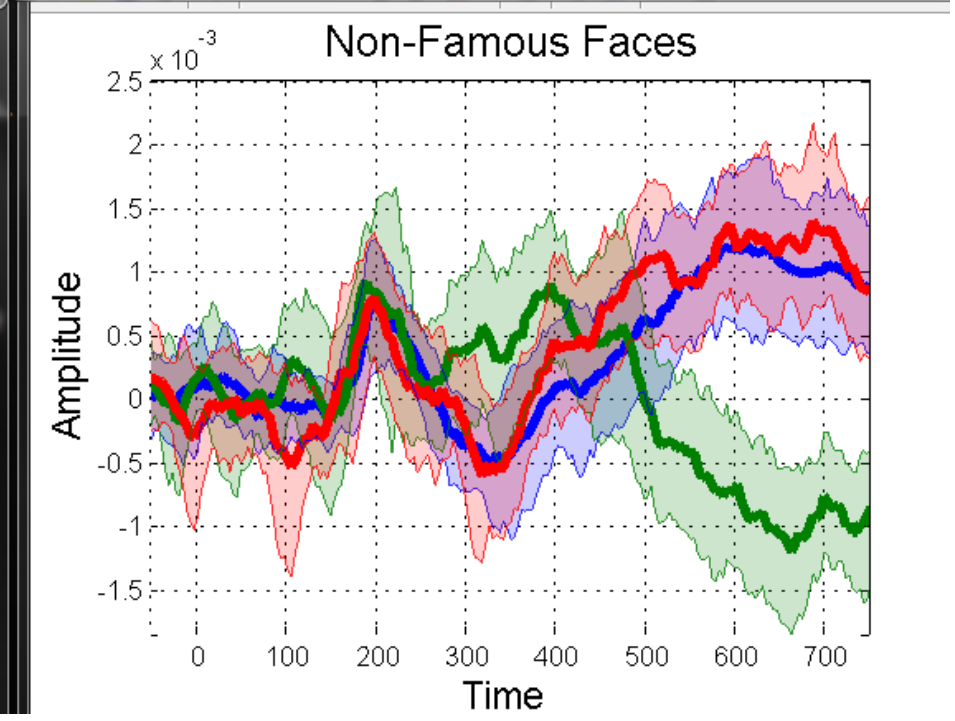
dataviz @ p = 0.005 uncorrected

Inference TFCE show category effect @ 200ms +, repetition effect @ 600ms +, and interaction at 600ms +









We have a main repetition effect driven by the direct repetition starting circa 380ms but sig only at 550ms

We have a small interaction effect with famous faces showing enhanced activity from circa 550ms

The maths behind the GUI

- If you want to go for coffee now, it’s fine
- 4 slides showing how standard and robust are different

One sample t-test

$$t = \frac{Mean}{std/\sqrt{n}}$$

p = 2 ∗ tcdf(abs(t), df)

df = n -1

limo_ttest.m

$$t = \frac{Trimmed\ Mean}{\sqrt{WinVar/(1 - 2 * trimming\ percentage)} * \sqrt{n}}$$

$$p = 2 * (1 - tcdf(abs(t), df)$$

df = n-2*floor((trimming percentage/100)*n)-1

limo_trimci.m

Paired t-test

$$t = \frac{Mean\ (diffeence)}{std\ (difference)/\sqrt{n}}$$

p = 2 ∗ tcdf(abs(t), df) with df = n -1

limo_ttest.m

$$t = \frac{Difference\ of\ trimmed\ means}{\sqrt{\frac{\left(WinVar1 * (n-1)\right) + \left(WinVar2 * (n-1)\right) - (2 * (n-1) * WinCov)}{(n-2) * n\ trim}}}$$

$$p = 2 * (1 - tcdf(abs(t), df)\ with$$ df =$((n-2) * n\ trim)$-1

limo_yuend_ttest.m

Two-samples t-test

$$t = \frac{mean(gp1) - mean(gp2)}{\sqrt{\frac{var(gp1)}{n1} + \frac{var(gp2)}{n2}}}$$

p = 2 ∗ tcdf(abs(t), df)

$$df = \frac{(s1+s2)^2}{\frac{s1}{n1-1} + \frac{s2}{n2-1}}$$

limo_ttest.m

$$t = \frac{Difference\ of\ trimmed\ means}{\sqrt{\frac{(n1-1) * WinVar1}{n1\ trim\ * (n1\ trim\ - 1)} + \frac{(n2-1) * WinVar2}{n2\ trim\ * (n2\ trim\ - 1)}}}$$

$$p = 2 * (1 - tcdf(abs(t), df)$$

$$\mathrm{df} = \frac{(Yuen\ s1 + Yuen\ s2)^2}{\frac{Yuen\ s1}{n1\ trim\ -1} + \frac{Yuen\ s2}{n2\ trim\ -1}}$$

limo_yuen_ttest.m

IRLS

- **Limo_wls.m and limo_irls.m (for trials vs across subjects)**

- Start by OLS to obtain residuals
- Check outliers in standardized residuals (MAD)
- Compute weights (bisquare function)
- Recompute on weighted data
- Check residuals again until E(e) = 0

  → for eeg, iterate until max(abs(oldRes-newRes)) < (0.0001)

$$Wy = WX\,\beta + We\,,\quad E(e) = 0,\quad Cov(e) = \sigma^2 I$$