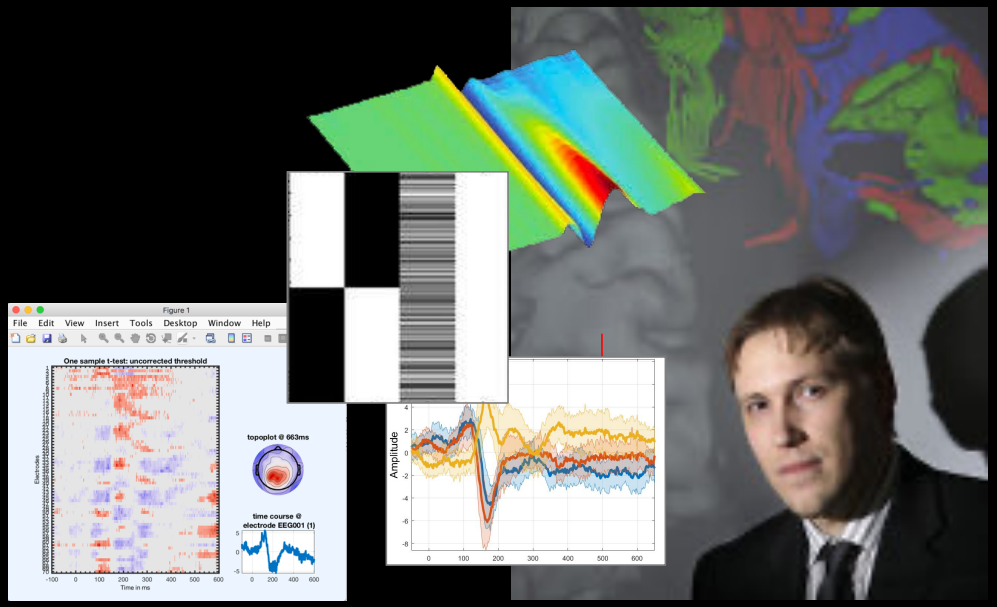
General Linear Modeling in EEGLAB/LIMO

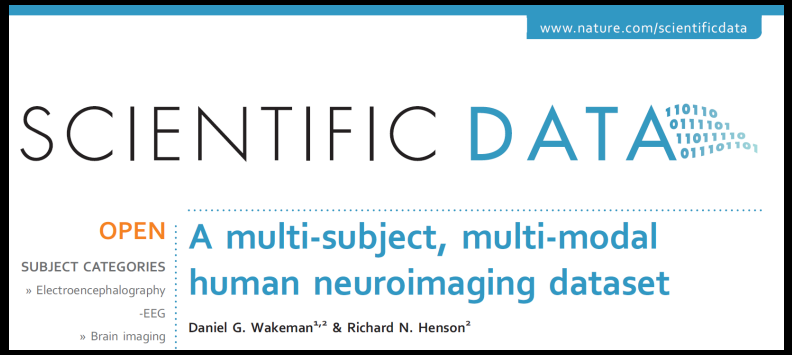
Practice

Arnaud Delorme

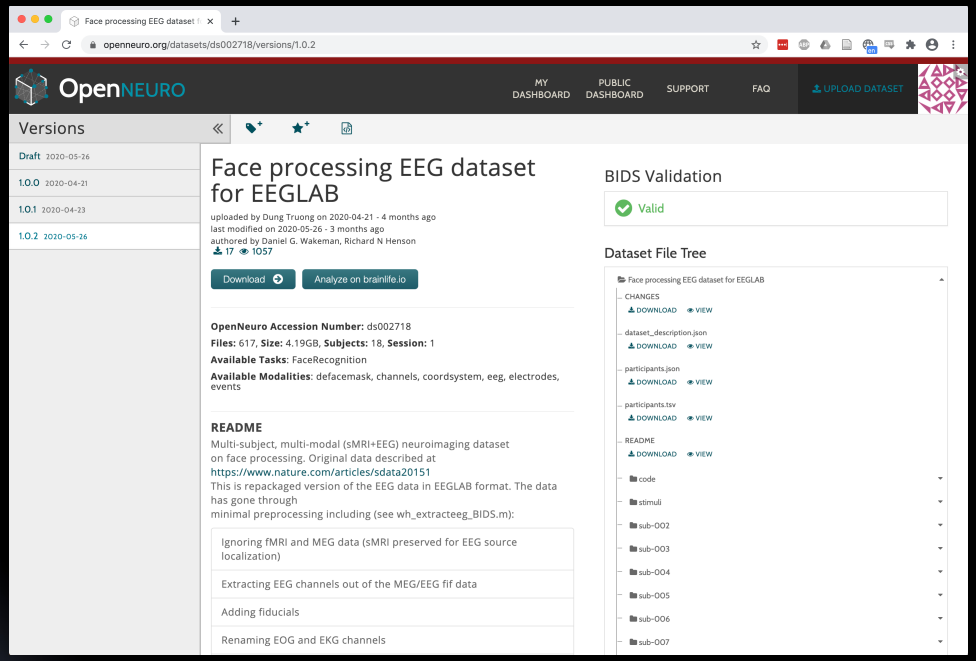


Cyril Pernet

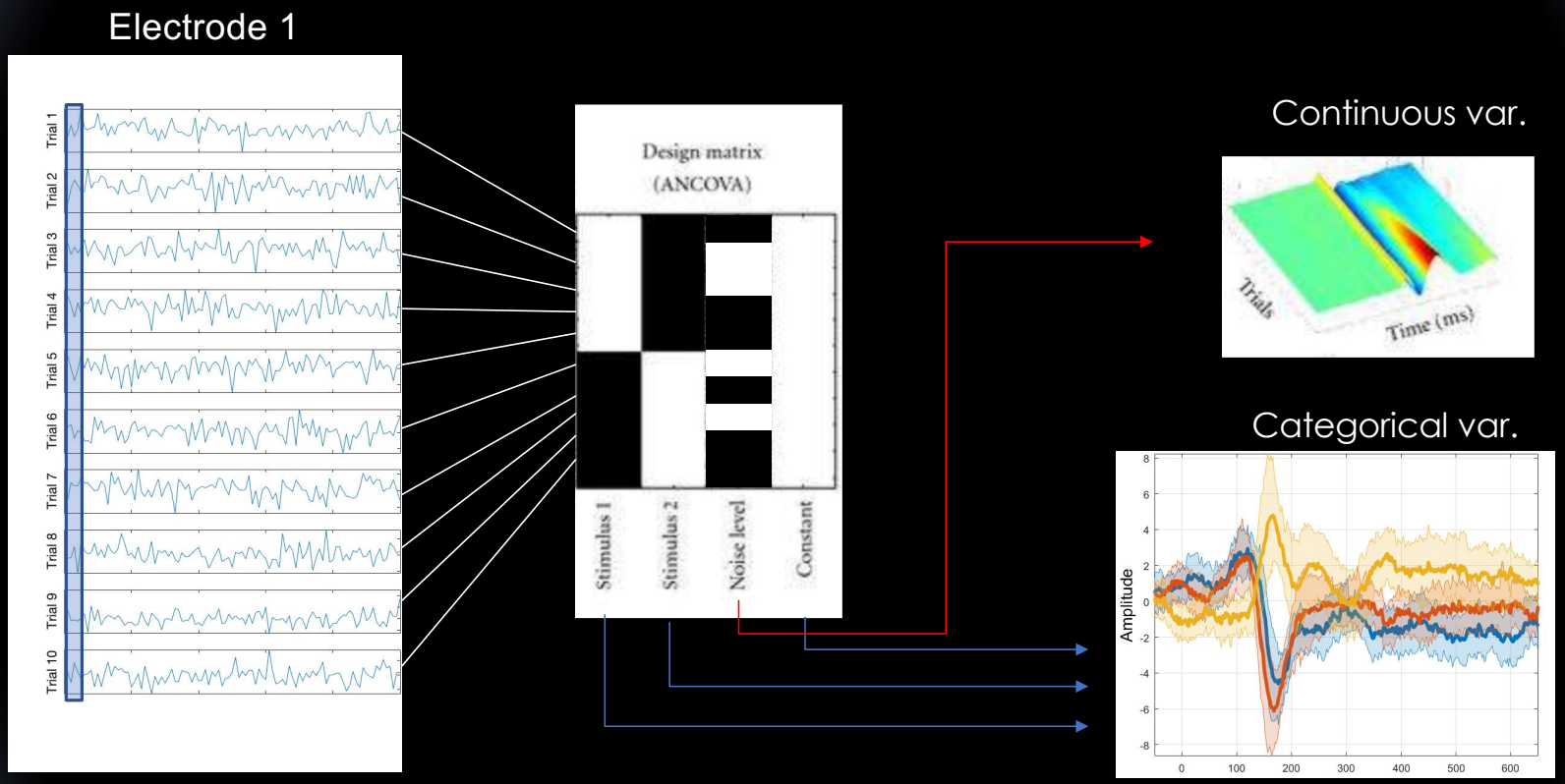
https://www.nature.com/articles/sdata20151



Download the data at https://openneuro.org/datasets/ds002718



Linear Modeling of EEG data: level 1



GLM: ordinary least square (OLS) versus weighted least square (WLS)

Significance: bootstrap trials to get confidence interval of beta parameters

The Data

Famous

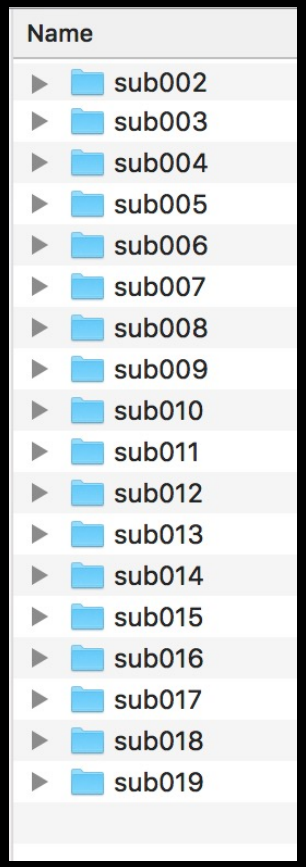
Unfamiliar

Scambled

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

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

Let's get started



- Download the data
https://openneuro.org/datasets/ds002718

- Open Matlab

- Start EEGLAB

```
% start EEGLAB
clear
[ALLEEG, EEG, CURRENTSET, ALLCOM] = eeglab;

% import BIDS
filepath        = 'XXX\WakemanHenson_Faces\eeg';
[STUDY, ALLEEG] = pop_importbids(filepath, 'bidsevent','on','bidschanloc','on', ...
    'studyName','Face_detection');
ALLEEG = pop_select( ALLEEG, 'nochannel',{'EEG061','EEG062','EEG063','EEG064'});
CURRENTSTUDY = 1; EEG = ALLEEG; CURRENTSET = [1:length(EEG)];

% Remove bad channels
EEG = pop_clean_rawdata( EEG,'FlatlineCriterion',5,'ChannelCriterion',0.8,...
    'LineNoiseCriterion',4,'Highpass',[0.25 0.75] ,...
    'BurstCriterion','off','WindowCriterion','off','BurstRejection','off',...
    'Distance','Euclidian','WindowCriterionTolerances','off' );

% Rereference using average reference
EEG = pop_reref( EEG,[],'interpchan',[]);

% Run ICA and flag artifactual components using IClabel
EEG = pop_runica(EEG(s), 'icatype','runica','concatcond','on','options',{'pca',-1});
EEG = pop_iclabel(EEG(s),'default');
EEG = pop_icflag(EEG(s),[NaN NaN;0.8 1;0.8 1;NaN NaN;NaN NaN;NaN NaN;NaN NaN]);
EEG = pop_subcomp(EEG(s), []); % remove bad components

% clear data using ASR - just the bad epochs
EEG = pop_clean_rawdata( EEG,'FlatlineCriterion','off','ChannelCriterion','off',...
    'LineNoiseCriterion','off','Highpass','off','BurstCriterion',20,...
    'WindowCriterion',0.25,'BurstRejection','on','Distance','Euclidian',...
    'WindowCriterionTolerances',[-Inf 7] );

% Extract data epochs (no baseline removed)
EEG    = pop_epoch( EEG,{'famous_new','famous_second_early','famous_second_late',...
    'scrambled_new','scrambled_second_early','scrambled_second_late','unfamiliar_new',...
    'unfamiliar_second_early','unfamiliar_second_late'},[-0.5 1] ,'epochinfo','yes');
EEG    = pop_saveset(EEG, 'savemode', 'resave');
ALLEEG = EEG;

% Create study design
STUDY  = std_checkset(STUDY, ALLEEG);
STUDY  = std_makedesign(STUDY, EEG, 1, 'name','Faces','delfiles','off',...
                        'defaultdesign','off','variable1','type','values1',{});
eeglab redraw
```

Import BIDS dataset/remove unwanted channels

Clean data lightly

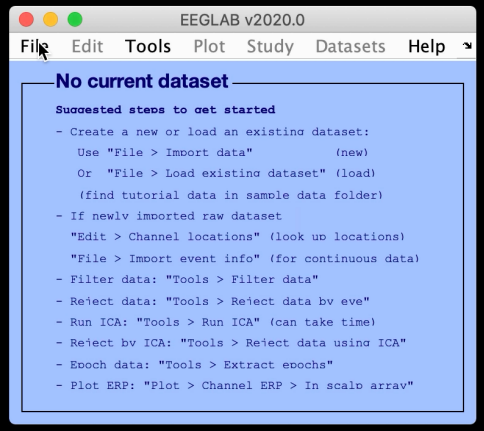
Re-reference

Run/Remove ICA

Clean data aggressively

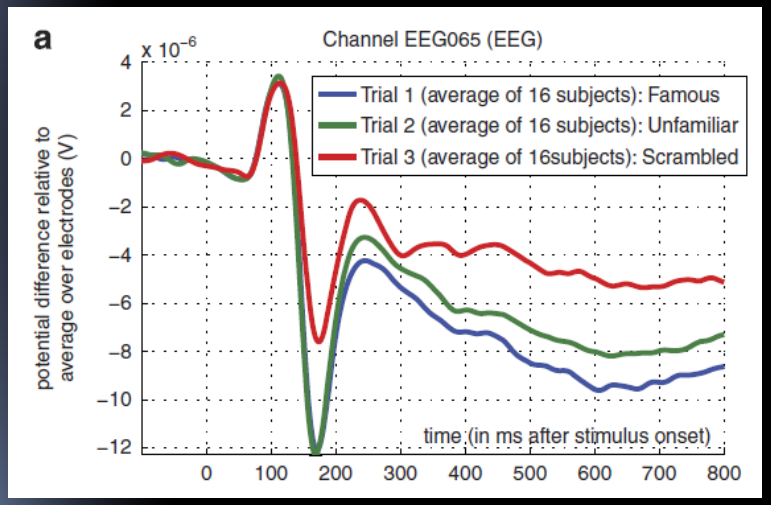
Extract epochs

Create STUDY and STUDY design

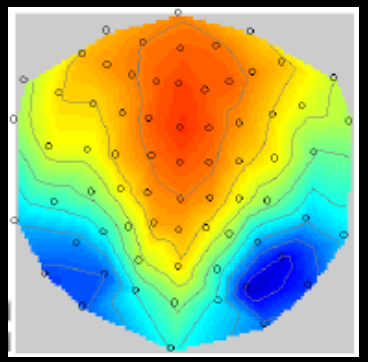

EEGLAB v2020.0
File Edit Tools Plot Study Datasets Help
No current dataset
Suggested steps to get started
- Create a new or load an existing dataset:
Use "File > Import data" (new)
Or "File > Load existing dataset" (load)
(find tutorial data in sample data folder)
- If newly imported raw dataset
"Edit > Channel locations" (look up locations)
"File > Import event info" (for continuous data)
- Filter data: "Tools > Filter data"
- Reject data: "Tools > Reject data by eve"
- Run ICA: "Tools > Run ICA" (can take time)
- Reject by ICA: "Tools > Reject data using ICA"
- Epoch data: "Tools > Extract epochs"
- Plot ERP: "Plot > Channel ERP > In scalp array"

What are we going to do?

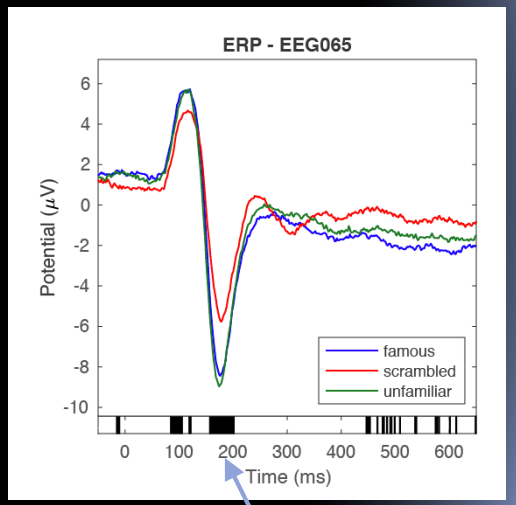
- 1 – Replicate Henson et al. – faces vs. scrambled



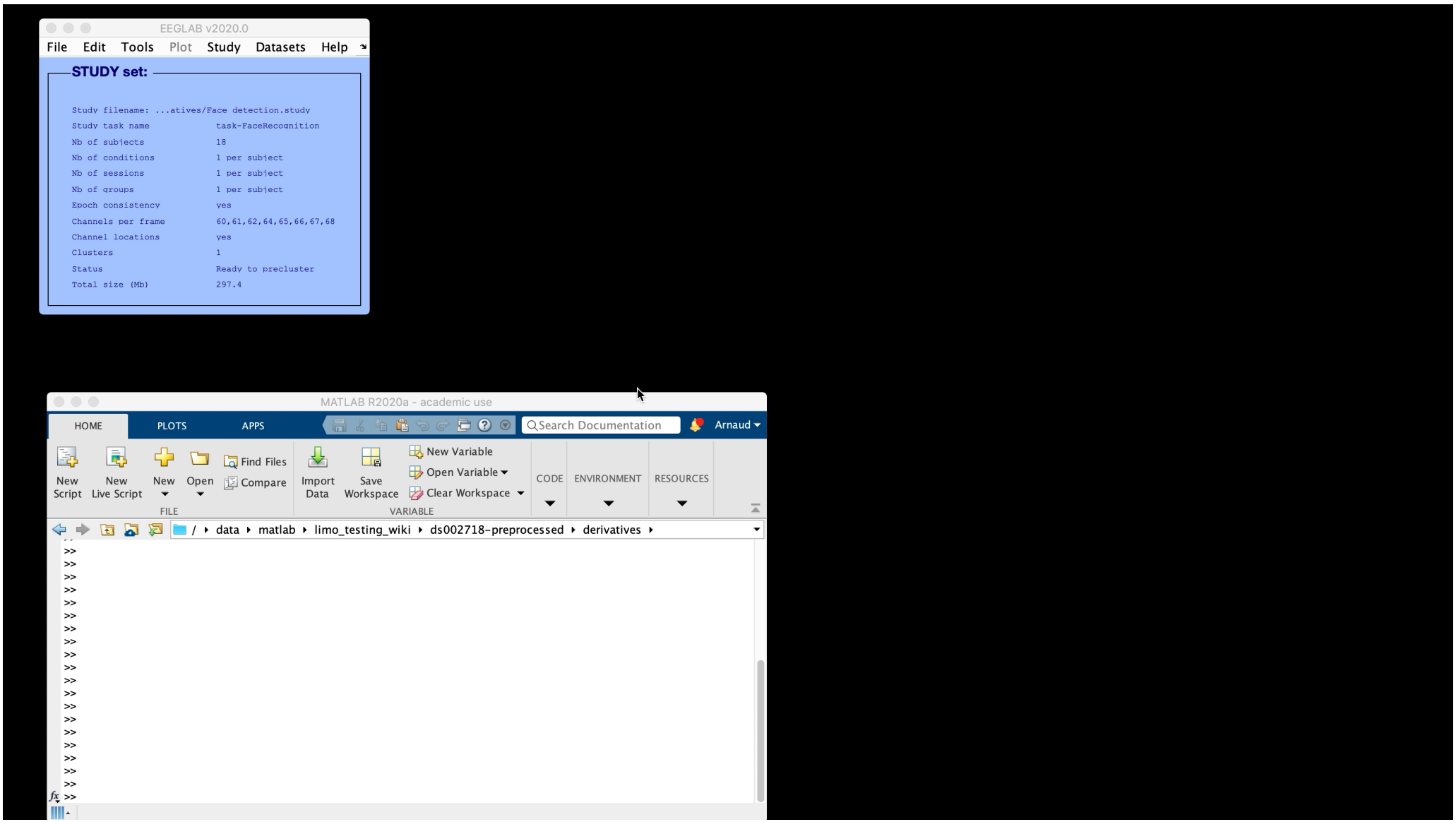
Topography 170 ms



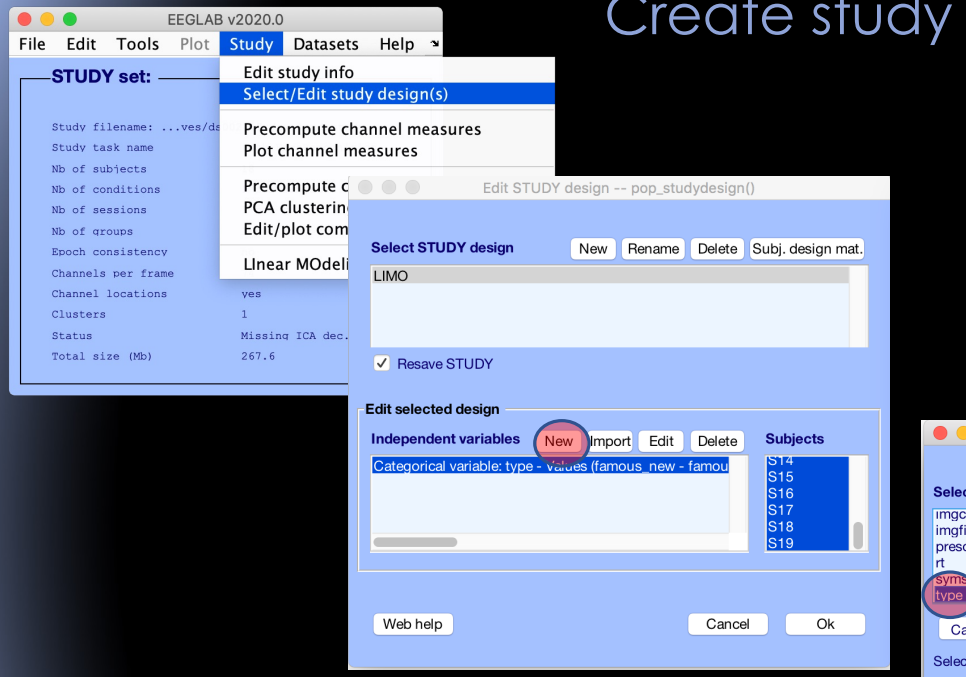
EEGLAB

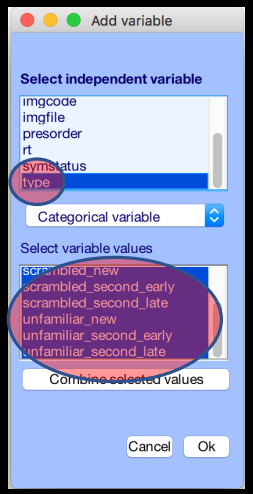


p<0.001


EEGLAB v2020.0
File Edit Tools Plot Study Datasets Help
STUDY set:
Study filename: ...atives/Face detection.study
Study task name task-FaceRecognition
Nb of subjects 18
Nb of conditions 1 per subject
Nb of sessions 1 per subject
Nb of groups 1 per subject
Epoch consistency yes
Channels per frame 60,61,62,64,65,66,67,68
Channel locations yes
Clusters 1
Status Ready to precluster
Total size (Mb) 297.4
MATLAB R2020a - academic use
HOME PLOTS APPS
Search Documentation
Arnaud
New Script
New Live Script
New
Open
Find Files
Compare
FILE
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
VARIABLE
CODE
ENVIRONMENT
RESOURCES
/ data matlab limo_testing_wiki ds002718-preprocessed derivatives
>>

Create study designs

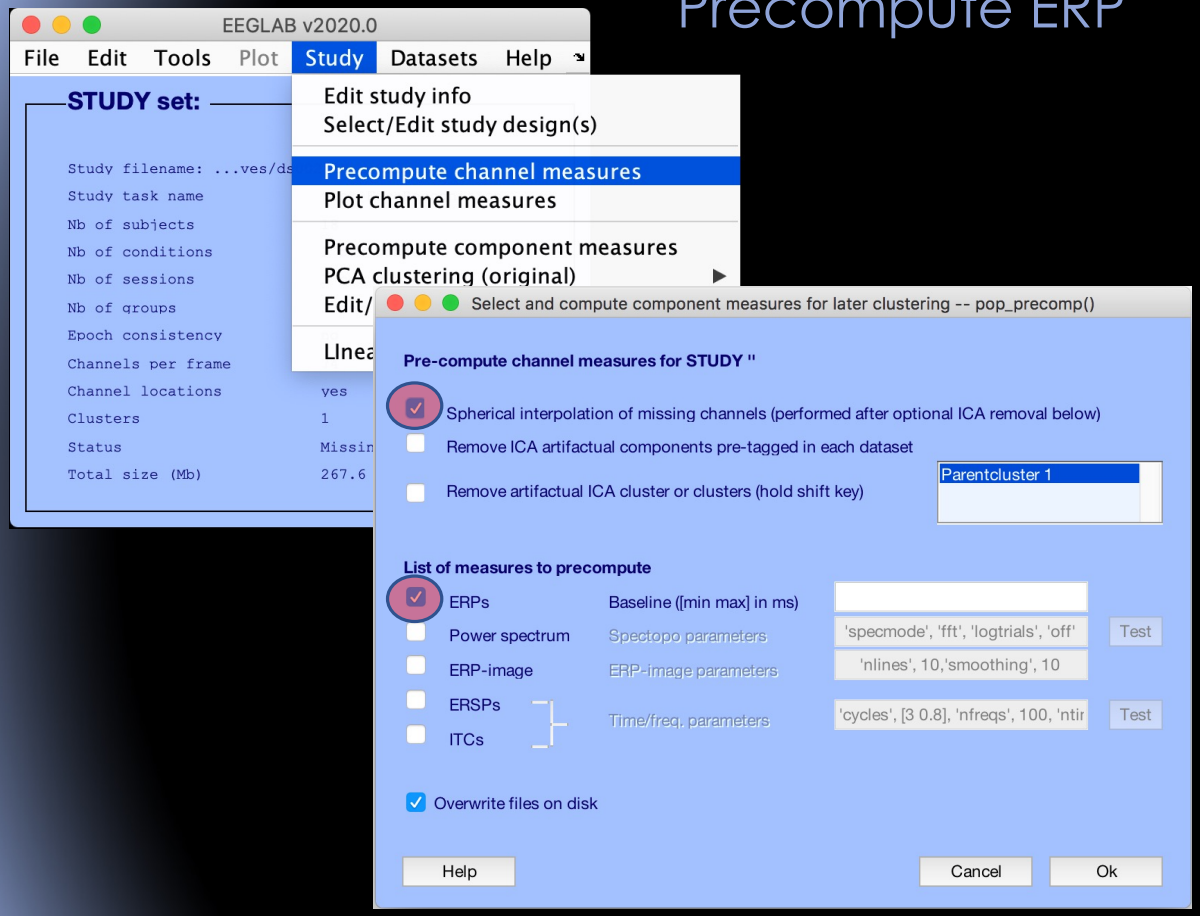




Here, we pick the 'type' and select all 9 conditions

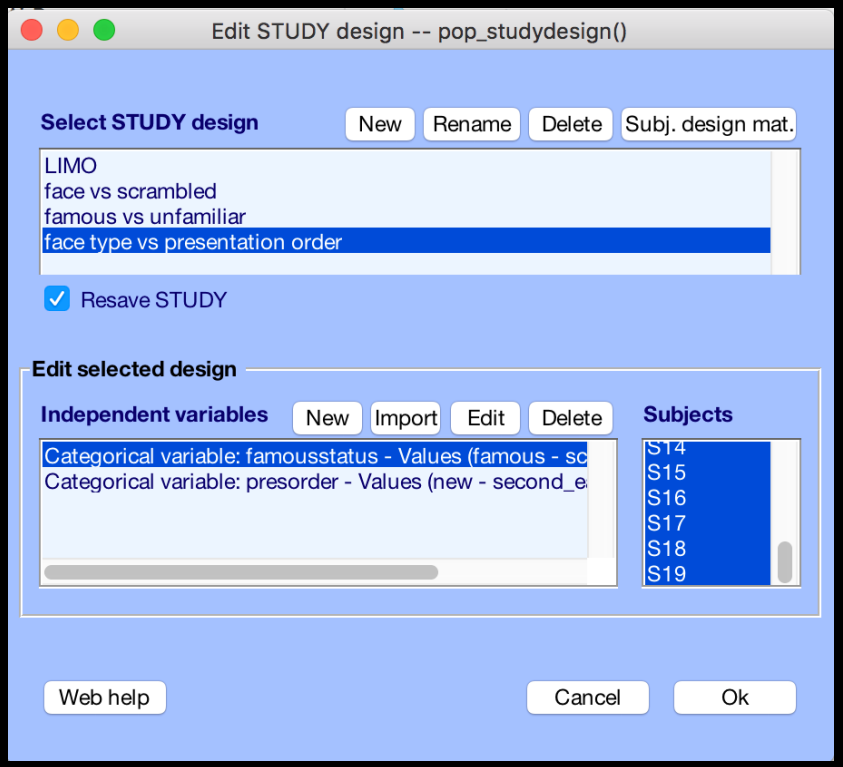
The new STUDY interface allows all sorts of designs. By default, you model each and any condition / covariate (the more complete the model the better)

Precompute ERP



Precompute channel measures (single trials)
with or without interpolation of missing channels

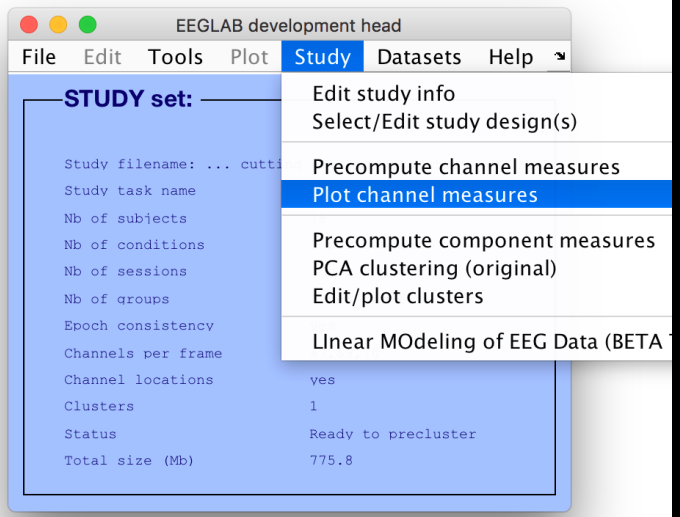
Create other study designs

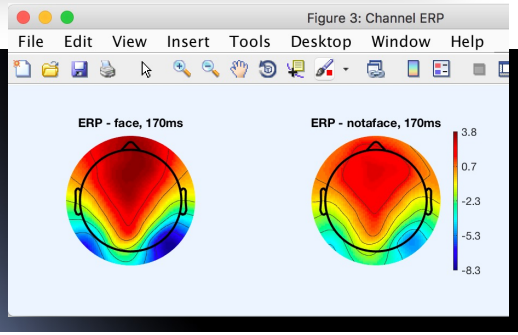


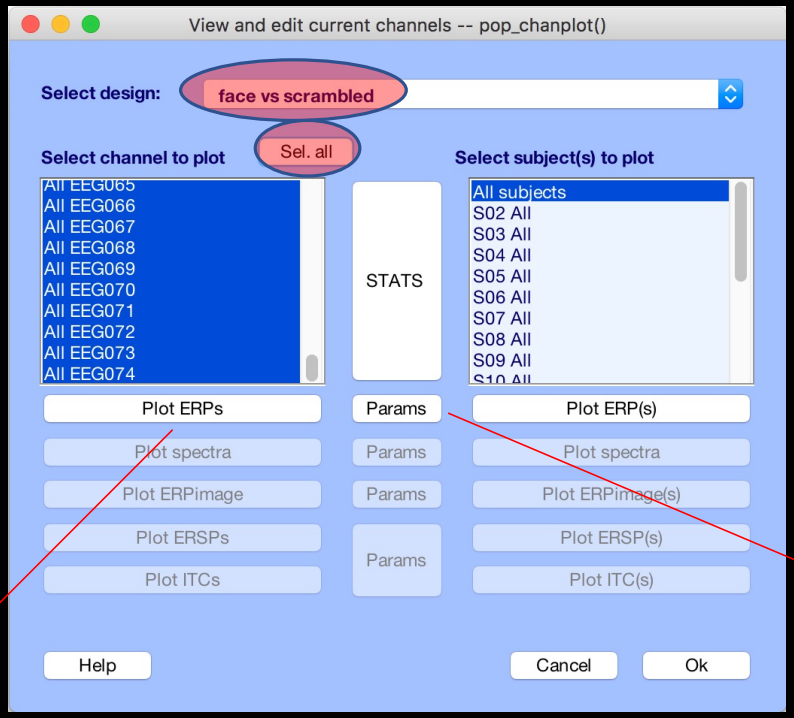
Select/edit study design

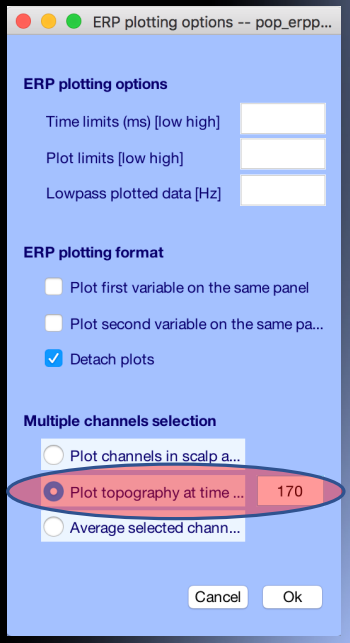
The new STUDY interface allows all sorts of designs. By default, you model each and any condition / covariate (the more complete the model the better)

Standard EEGLAB statistics

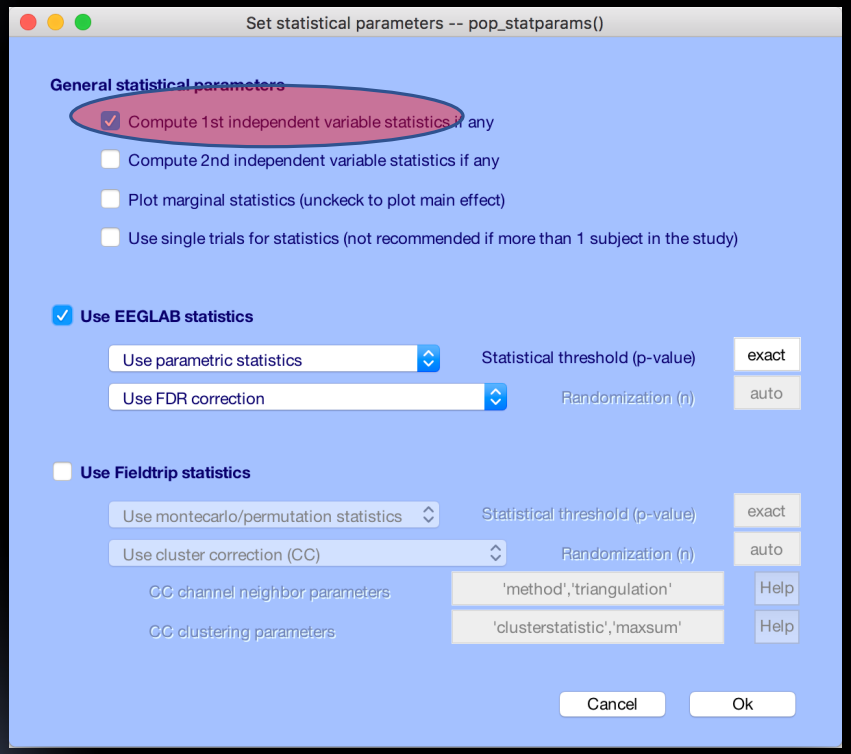




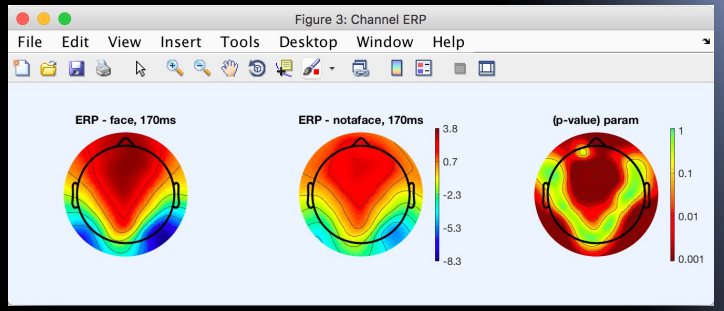




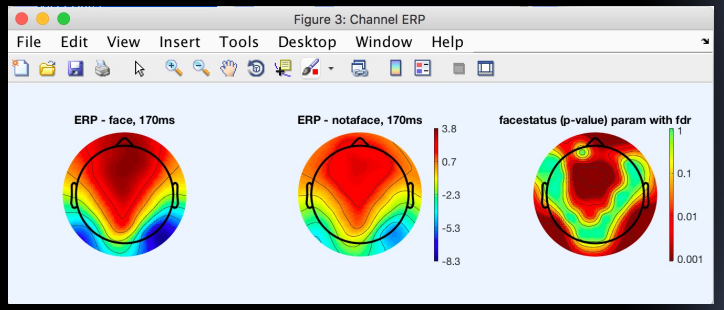
Standard EEGLAB statistics



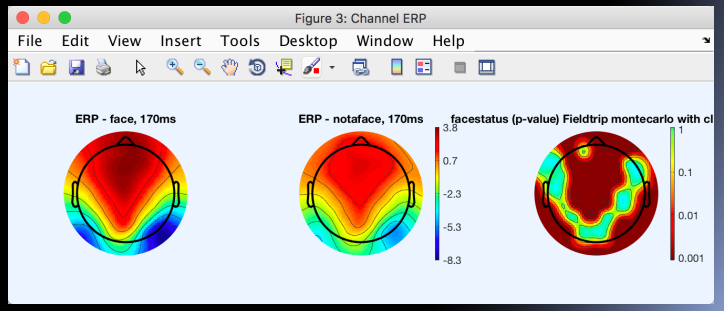
Uncorrected

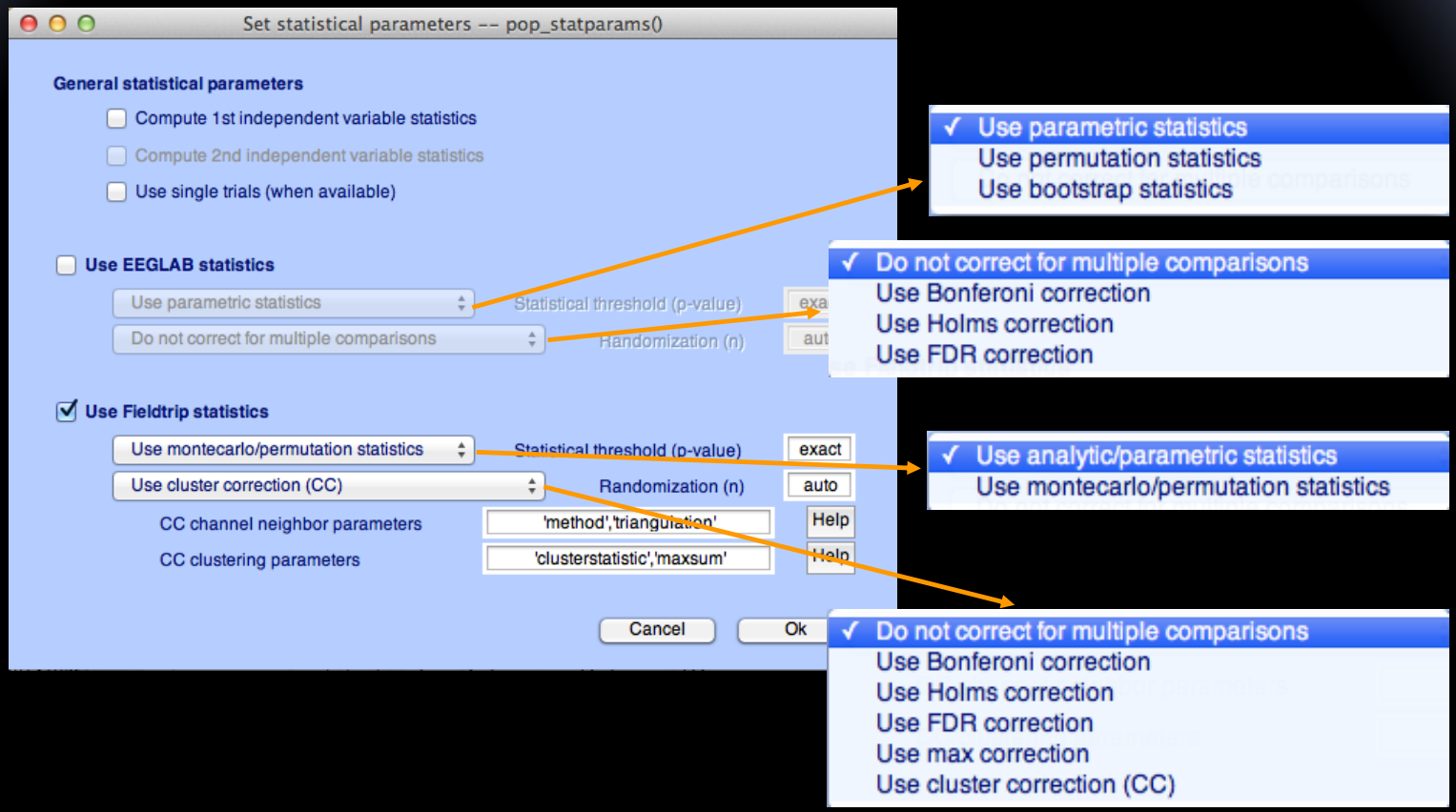


FDR corrected



Cluster corrected



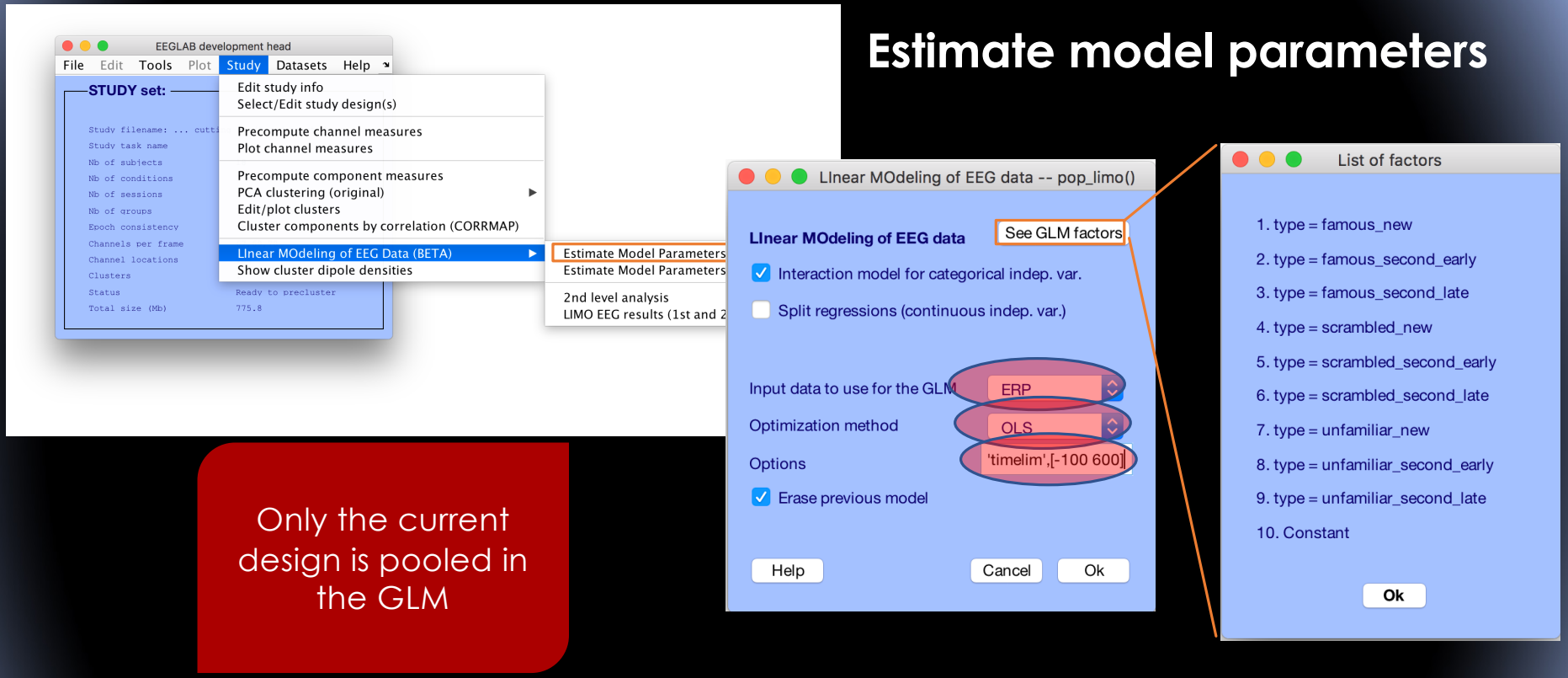


std_stat() function in EEGLAB

Exercise

1. Load "ds002718processed/Face_detection.study" file
2. Edit STUDY design and delete current variable(s) (menu item *STUDY > Select/Edit STUDY design(s)*) – Do not resave STUDY
3. Create a new indep. Variable design to compare Famour vs. Unfamiliar stimuli
4. Recompute spectrum and ERP (remove labeled ICA comp.) (menu item *STUDY > Precompute channel measures*)
5. Plot ERP for Electrode 65 (menu item *STUDY > Plot channel measures*)
6. Plot scalp topography at 170 ms (ERP) for both conditions
7. Compare using no correction, FDR correction and permutation statistics cluster correction (Fieldtrip – statistics)

Estimate model parameters



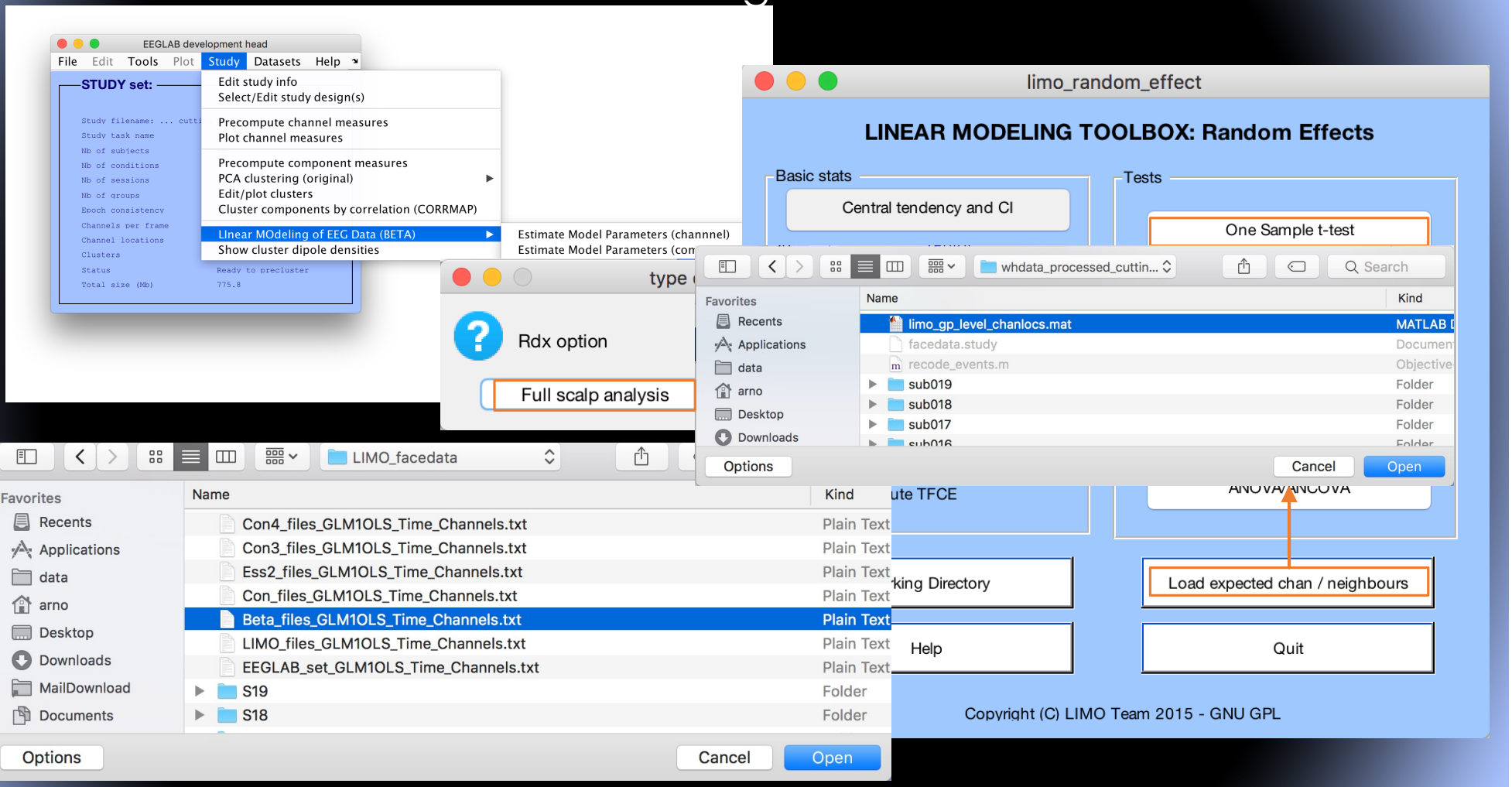
Only the current design is pooled in the GLM

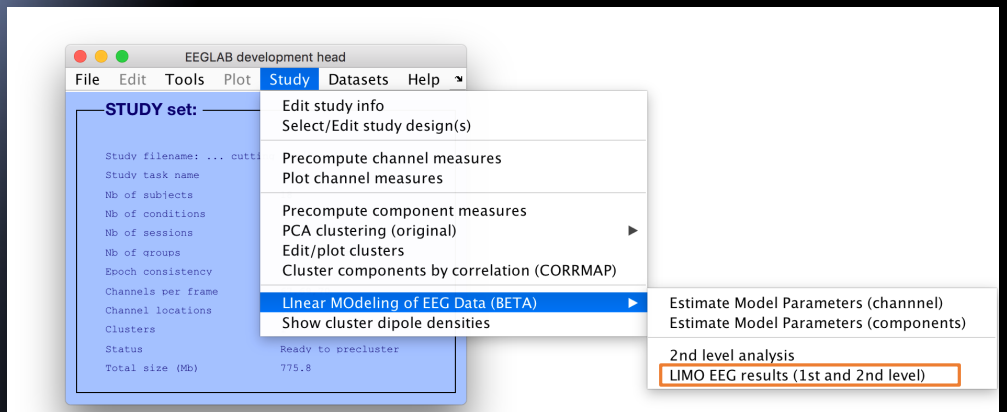
Estimate Model Parameter

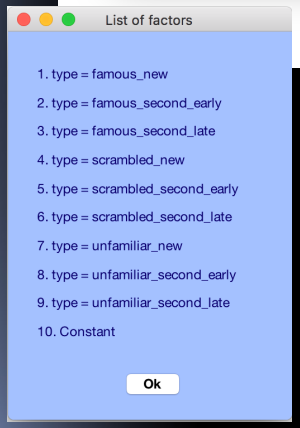
Have generated single trials, specified the model, we now do the stats

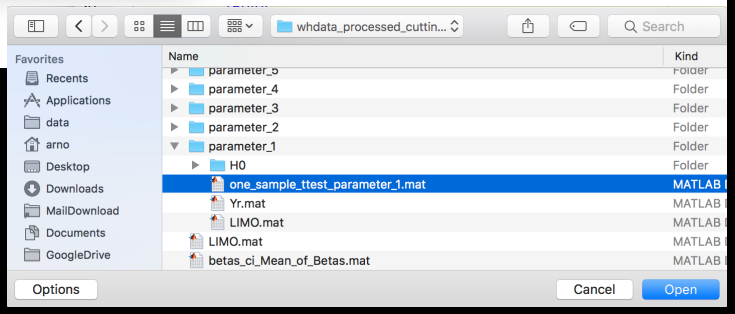
→ Restrict 'timelim' [-50 650]

Are Beta significant?




EEGLAB development head
File Edit Tools Plot Study Datasets Help
STUDY set:
Edit study info
Select/Edit study design(s)
Precompute channel measures
Plot channel measures
Precompute component measures
PCA clustering (original)
Edit/plot clusters
Cluster components by correlation (CORRMAP)
LInear MOdeling of EEG Data (BETA)
Show cluster dipole densities
Estimate Model Parameters (channnel)
Estimate Model Parameters (components)
2nd level analysis
LIMO EEG results (1st and 2nd level)


List of factors
1. type = famous_new
2. type = famous_second_early
3. type = famous_second_late
4. type = scrambled_new
5. type = scrambled_second_early
6. type = scrambled_second_late
7. type = unfamiliar_new
8. type = unfamiliar_second_early
9. type = unfamiliar_second_late
10. Constant
Ok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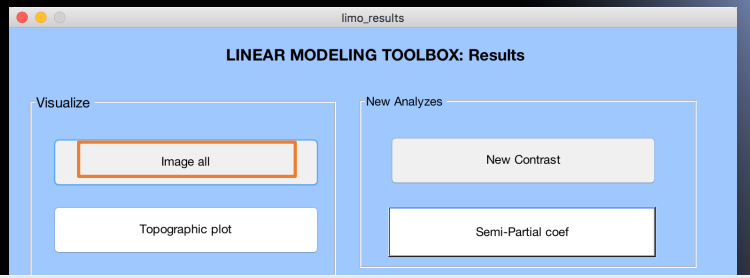

limo_results
LINEAR MODELING TOOLBOX: Results
Visualize
Image all
Topographic plot
New Analyzes
New Contrast
Semi-Partial coef

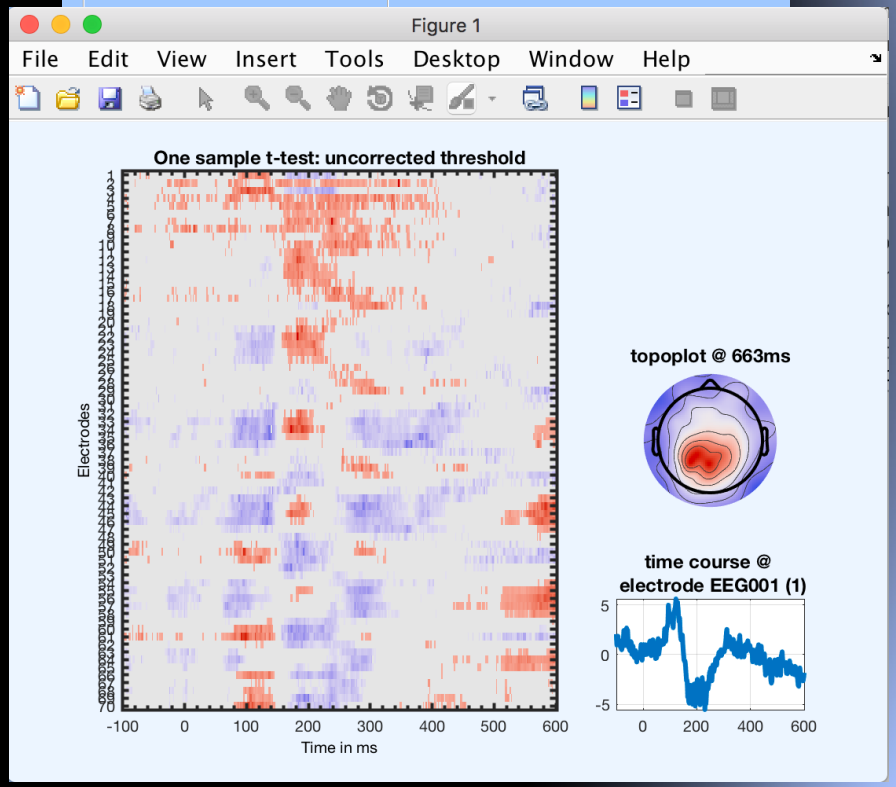
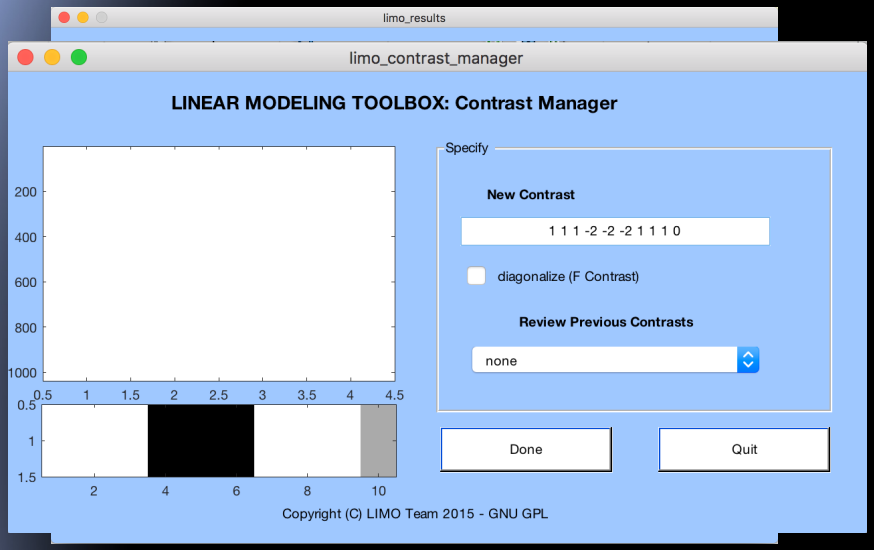
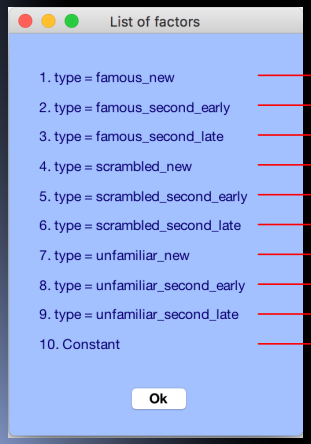


Figure 1
File Edit View Insert Tools Desktop Window Help
One sample t-test: uncorrected threshold
Electrodes
Time in ms
-100 0 100 200 300 400 500 600
topoplot @ 663ms
time course @
electrode EEG001 (1)
5
0
-5
0 200 400 600

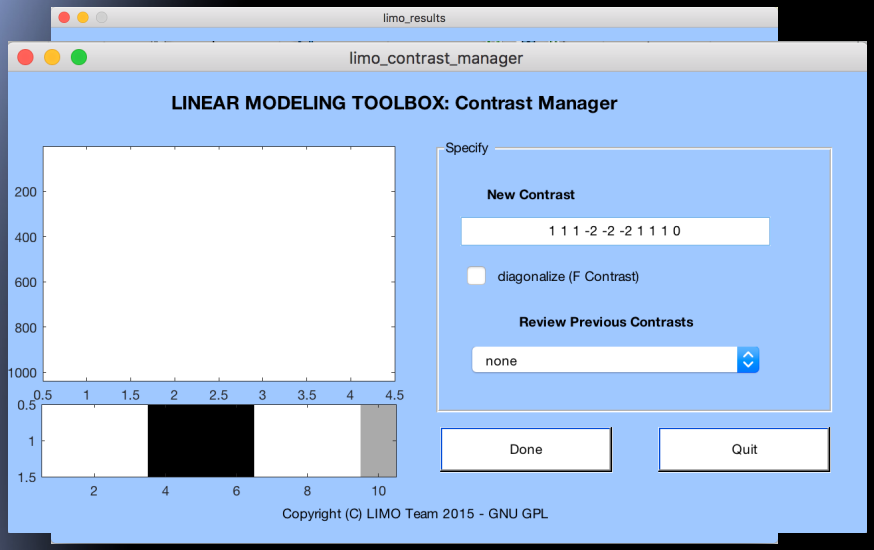
Grouping betas and differences between conditions



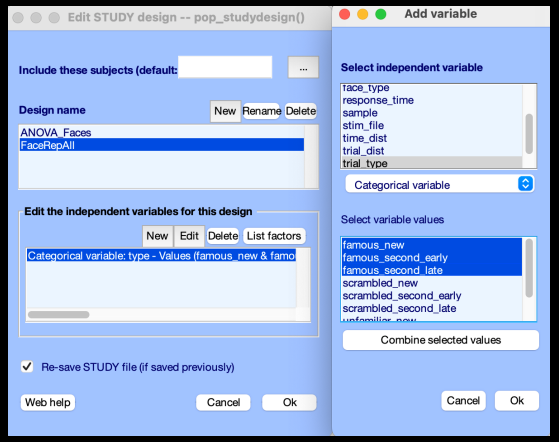


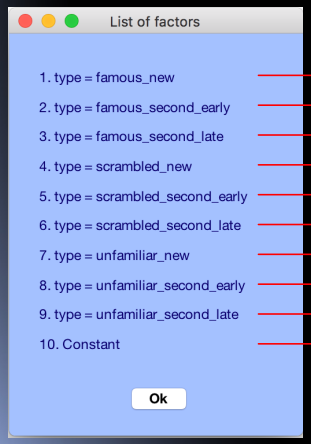
Faces vs non-faces	Famous	Scrambled	Unfamiliar	ANOVA (famous/scambled/unfamiliar)	ANOVA (new/early/late)
1	1	0	0	1 0 0	1 0 0
1	1	0	0	1 0 0	0 1 0
1	1	0	0	1 0 0	0 0 1
-2	0	1	0	0 1 0	1 0 0
-2	0	1	0	0 1 0	0 1 0
-2	0	1	0	0 1 0	0 0 1
1	0	0	1	0 0 1	1 0 0
1	0	0	1	0 0 1	0 1 0
1	0	0	1	0 0 1	0 0 1
0	0	0	0	0 0 0	0 0 0

Grouping betas and differences between conditions



Contrast were automatically created when we combined variables





Faces vs non-faces	Famous	Scrambled	Unfamiliar
1	1	0	0
1	1	0	0
1	1	0	0
-2	0	1	0
-2	0	1	0
-2	0	1	0
1	0	0	1
1	0	0	1
1	0	0	1
0	0	0	0

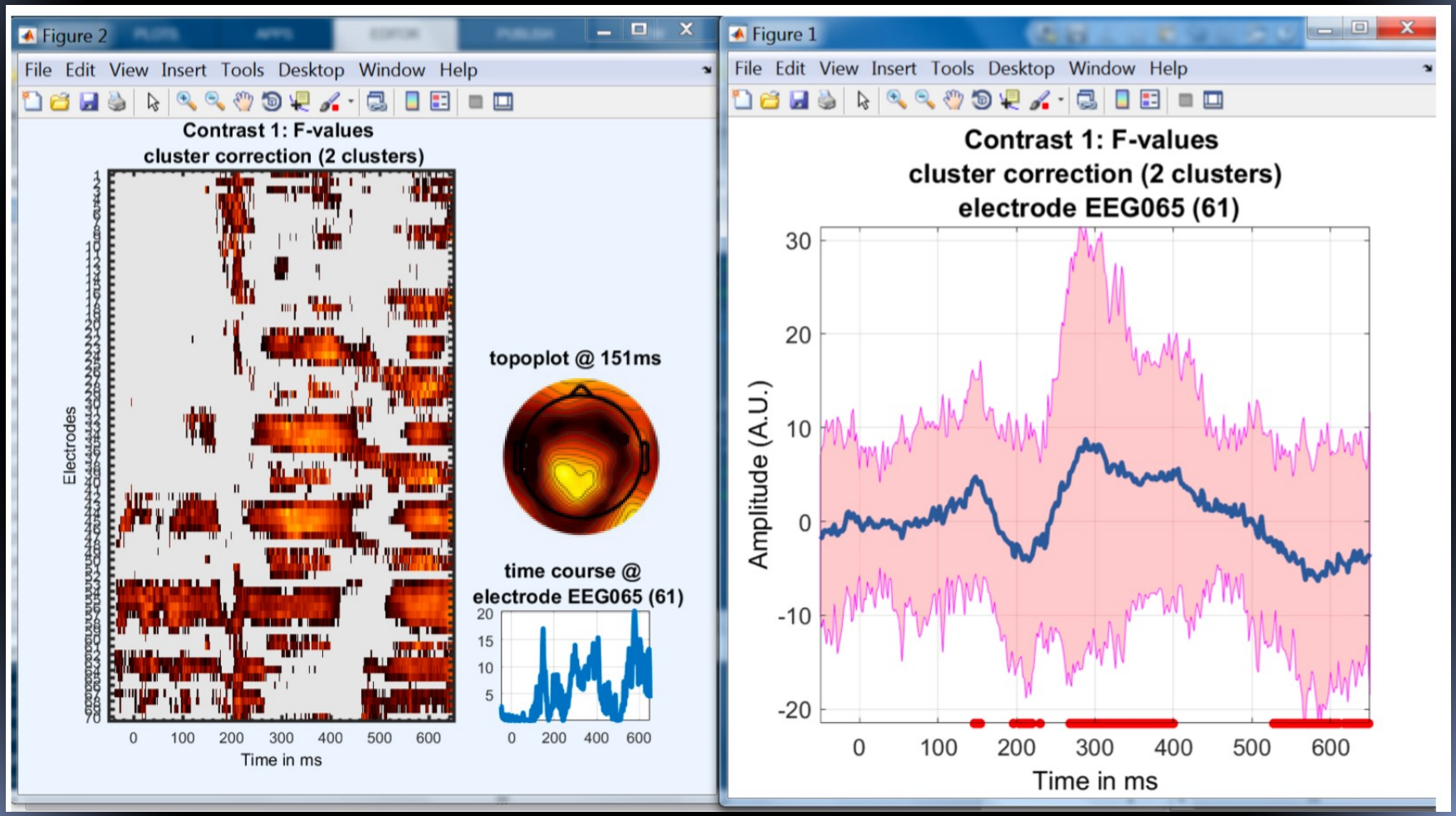
ANOVA (famous/scambled/unfamiliar)

1	0	0
1	0	0
1	0	0
0	1	0
0	1	0
0	1	0
0	0	1
0	0	1
0	0	1
0	0	0

ANOVA (new/early/late)

1	0	0
0	1	0
0	0	1
1	0	0
0	1	0
0	0	1
1	0	0
0	1	0
0	0	1
0	0	0

ANOVA (famous/scambled/unfamiliar)



Exercise

1. Install LIMO plugin
2. Reload "ds002718processed/Face_detection.study" file
3. NOT NEEDED HERE -- Edit STUDY and create design (menu item *STUDY > Select/Edit STUDY design(s)*)
4. NOT NEEDED HERE -- Recompute ERP (remove labeled ICA comp.) (menu item *STUDY > Precompute channel measures*)
5. Compute LIMO for all subjects (Menu *STUDY > Linear Modeling of EEG data > Estimate Model Parameters (channel)*)
6. Compute and plot group level measures (Menu *STUDY > Linear Modeling of EEG data > 2nd Level analysis*)