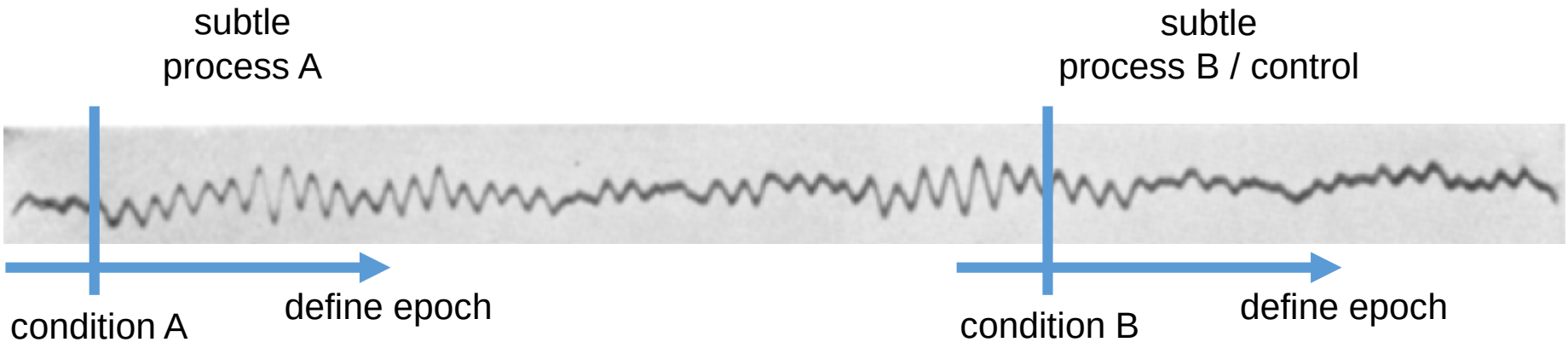
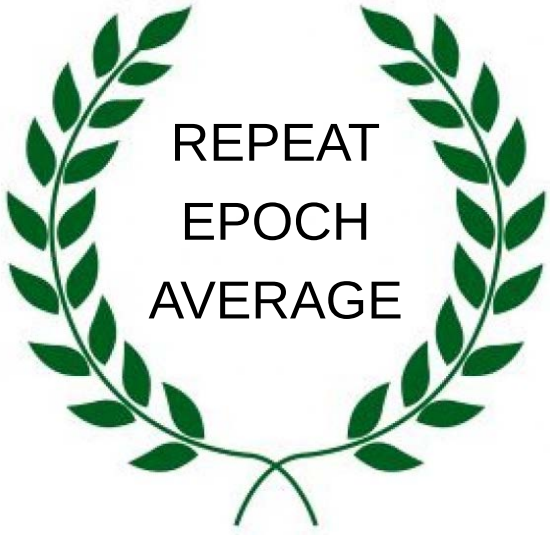
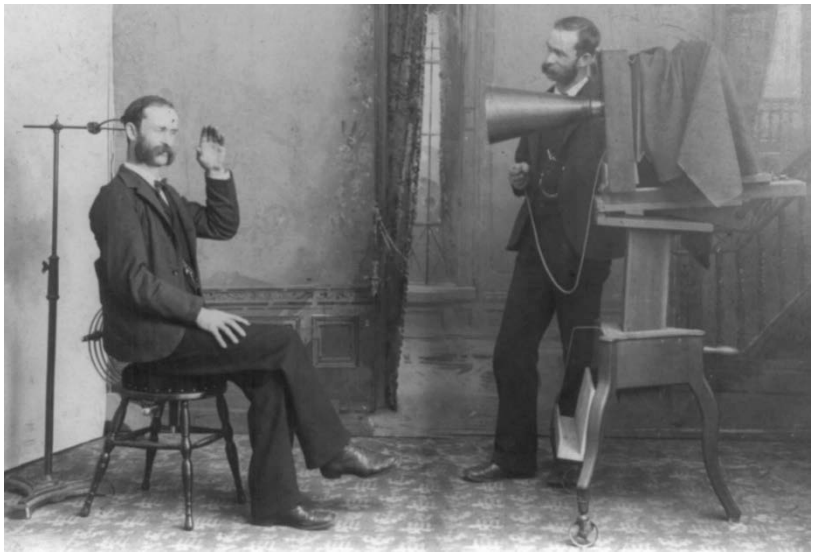
Convolution models for M/EEG

Bernhard Spitzer

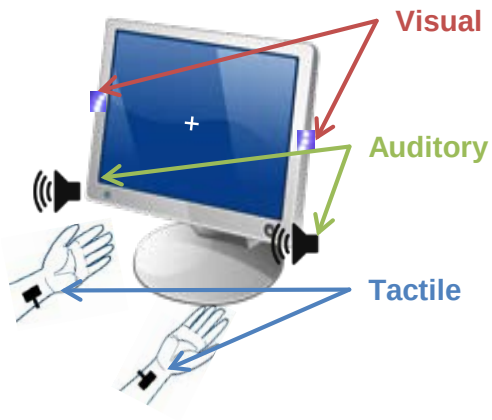
Event-related EEG / MEG / LFP

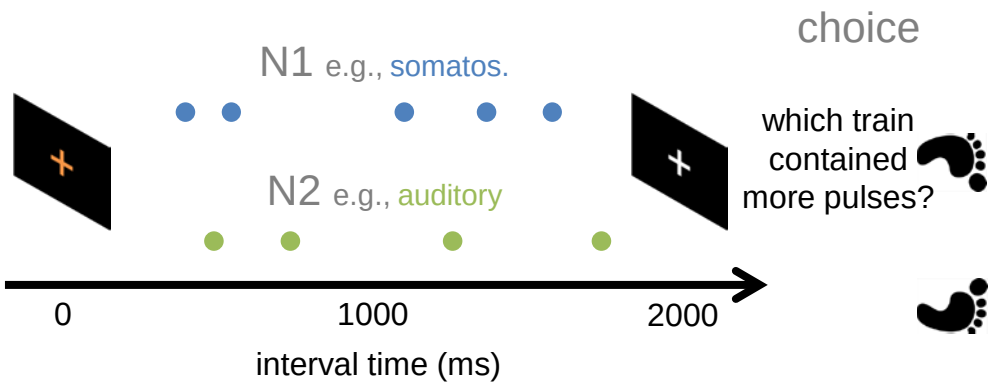


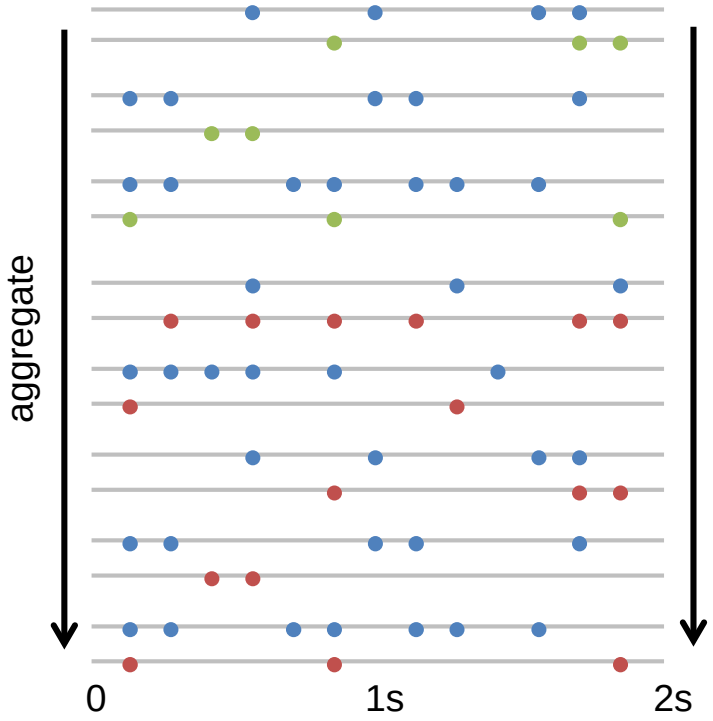




Photographic Studio, Wheeler (1893)

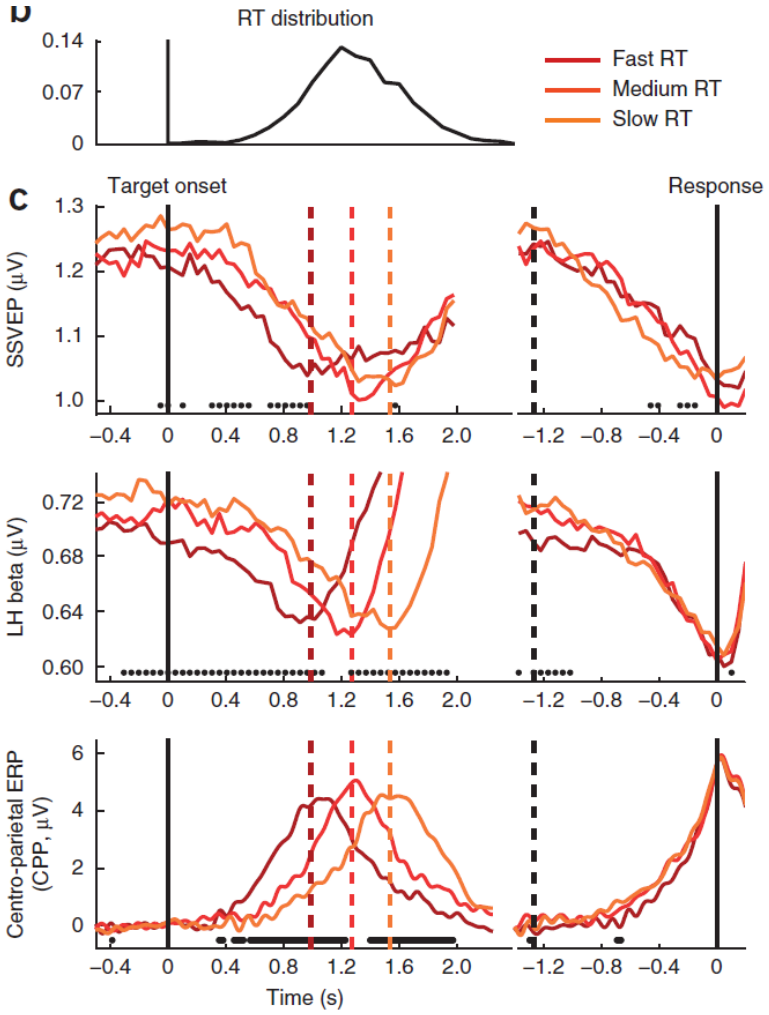

Visual
Auditory
Tactile

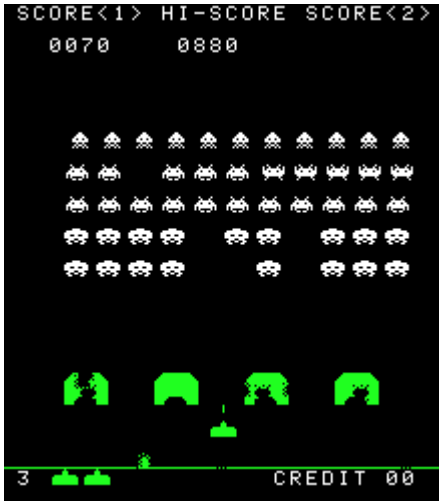

N1 e.g., somatos.
N2 e.g., auditory
choice
which train contained more pulses?
0
1000
2000
interval time (ms)


aggregate
0
1s
2s

subject behavior

dynamic environments

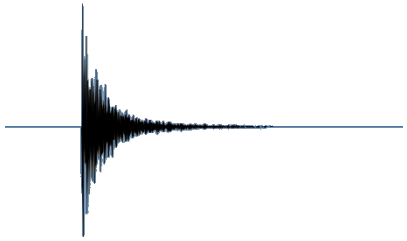


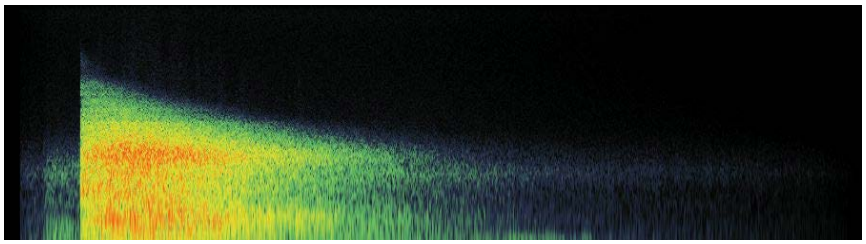


example from O'Connell et al., 2012

convolution models for M/EEG

Impulse response modeling

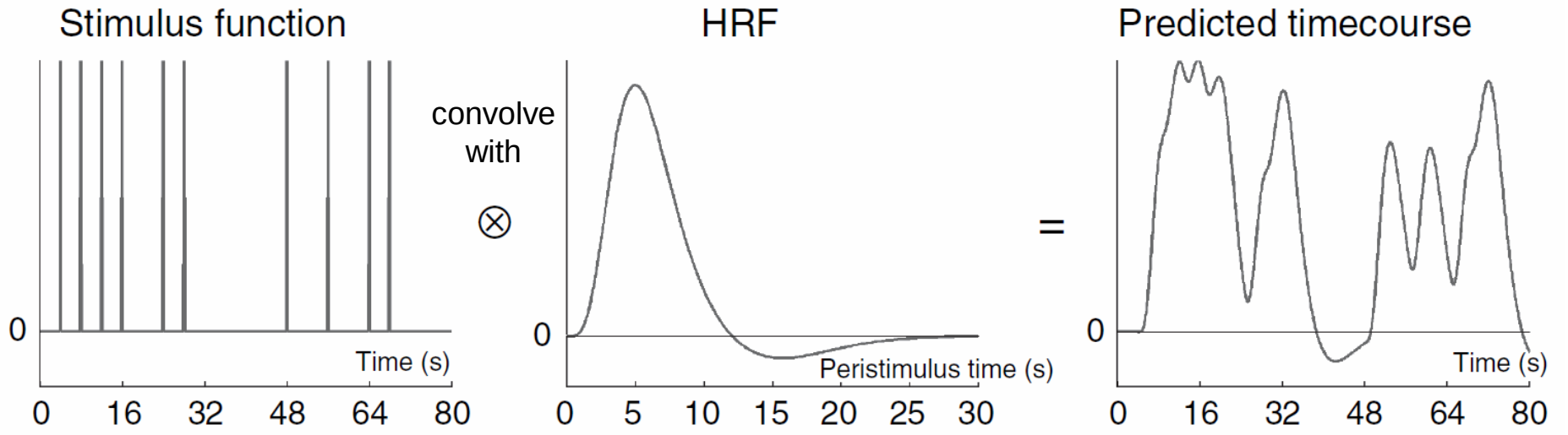




Impulse response modeling of event-related fMRI

convolve with

=

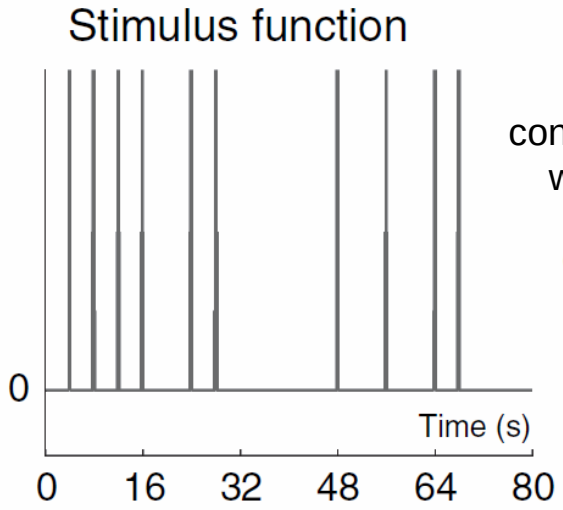


Henson & Friston, 2007

Impulse response modeling of M/EEG

convolve with

=

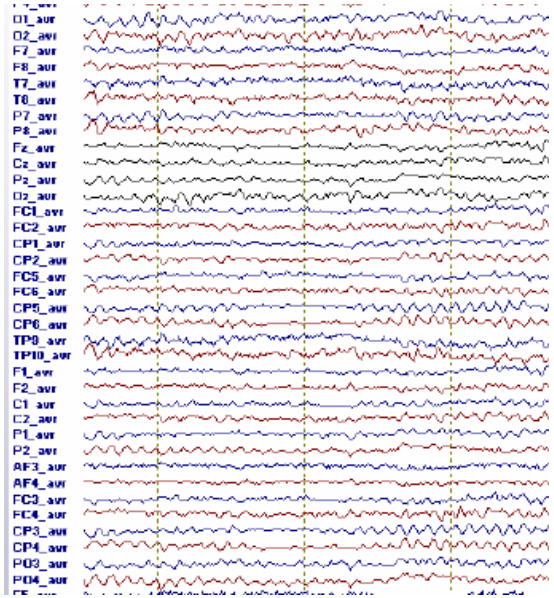


convolve with

⊗

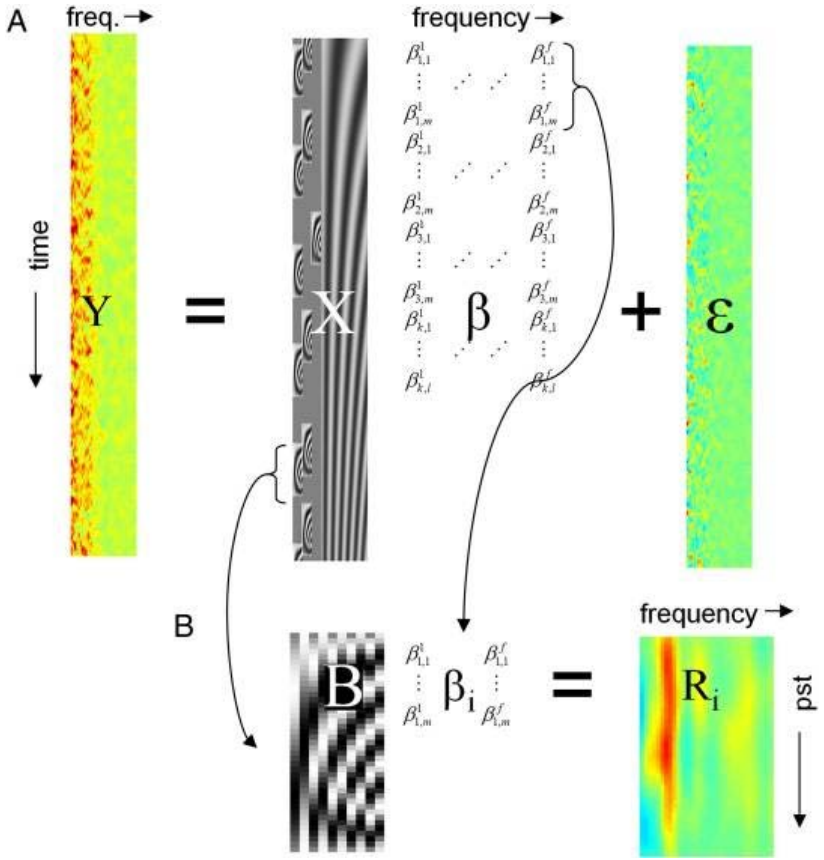
X

=



[hands-on: el convolutor]

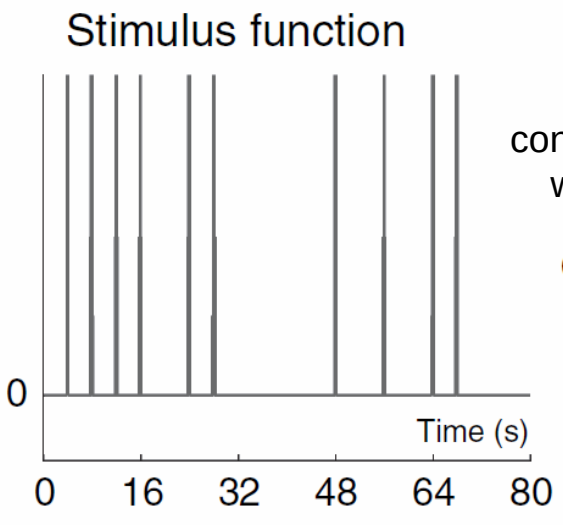
A solution to the X



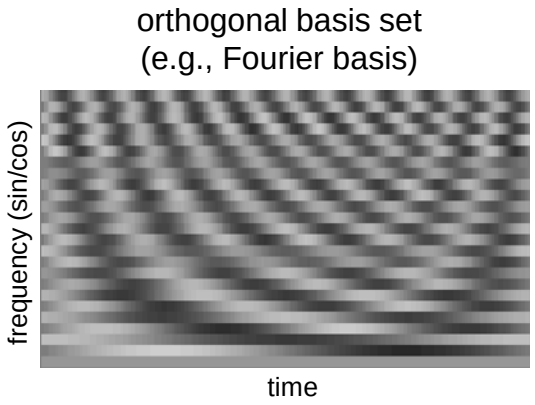
recommended reading
(original method paper)

Litvak et al., 2013, *NeuroImage*

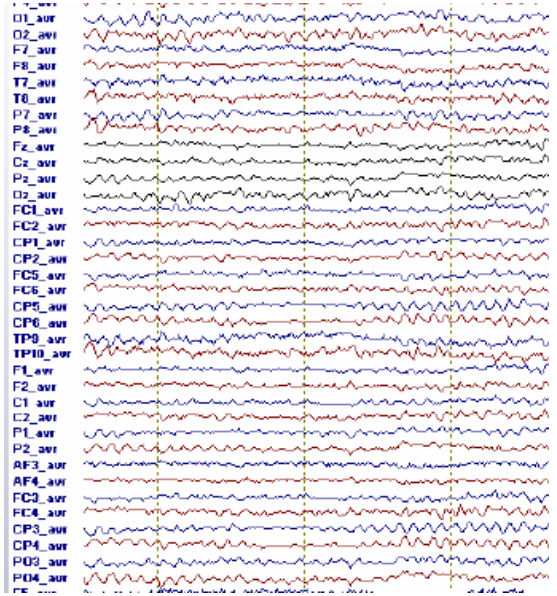
A solution to the X

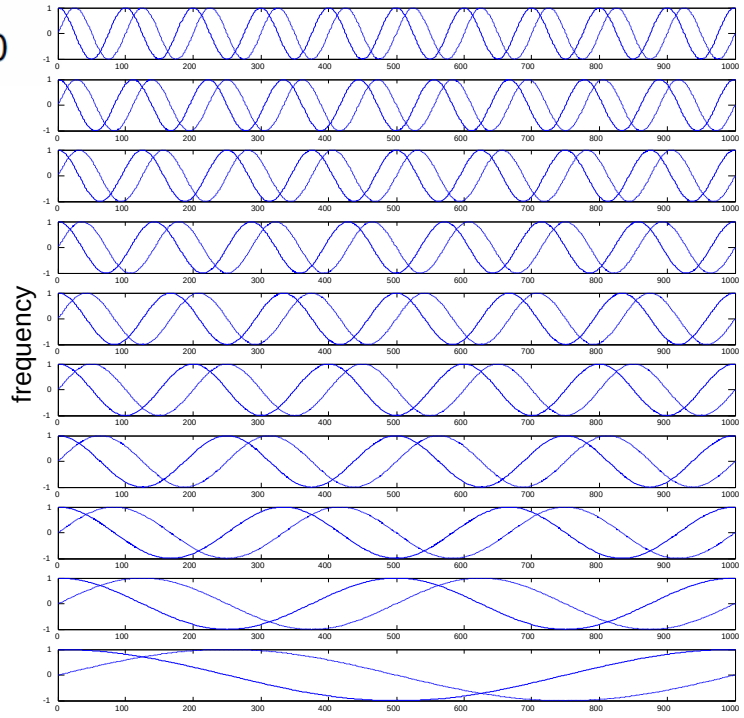


convolve with ⊗

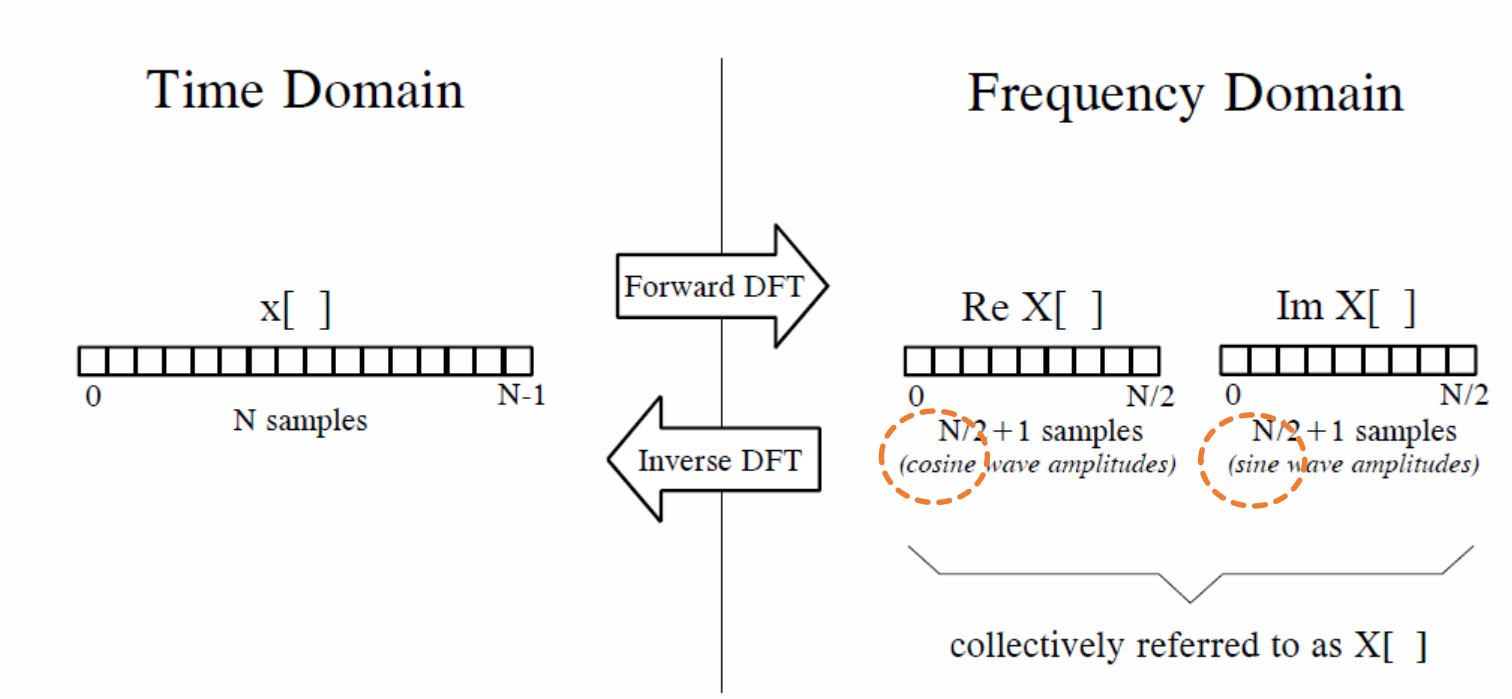


=

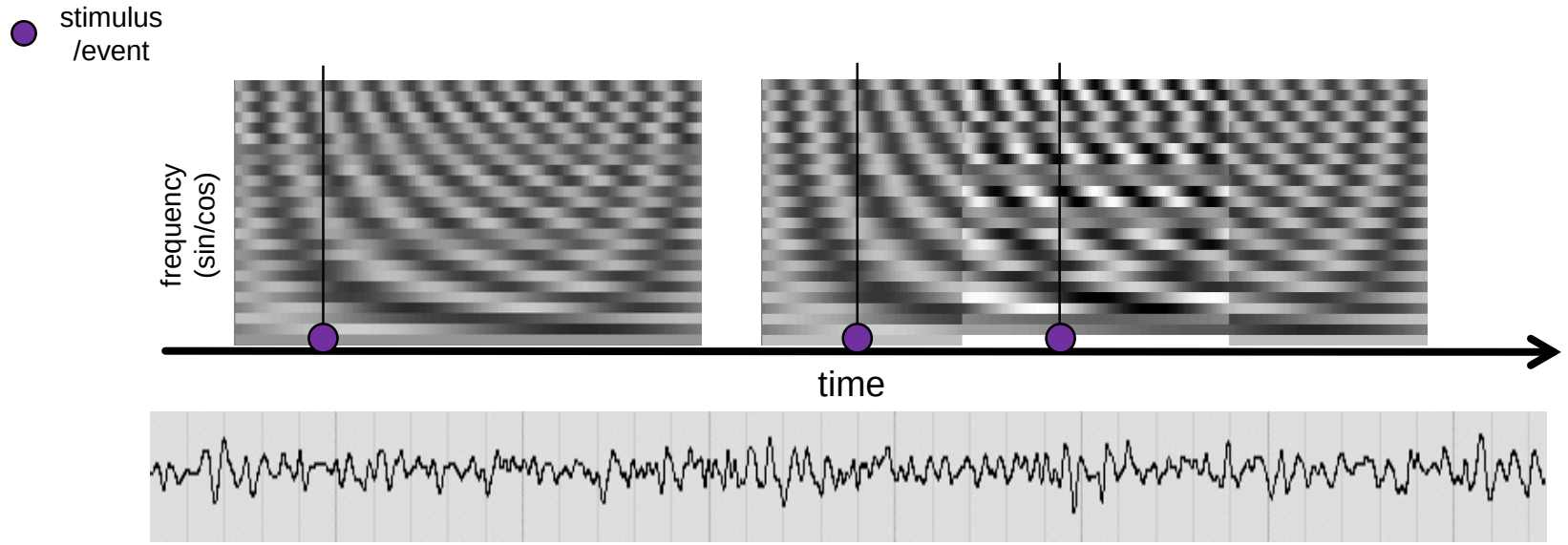




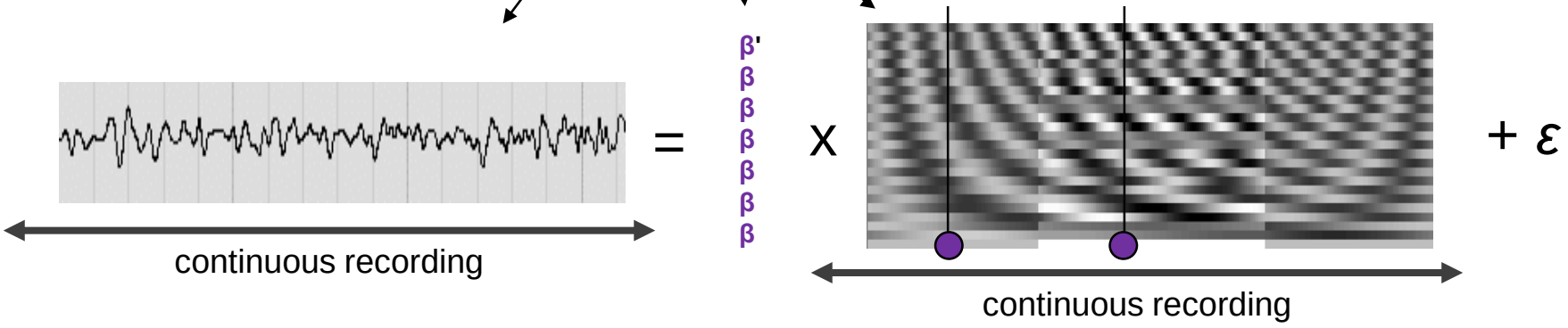
Discrete Fourier Transform (DFT)



IR modeling (time-domain data)

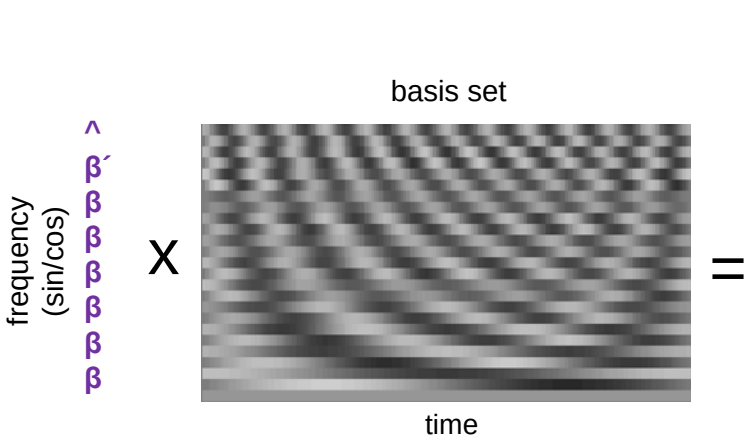


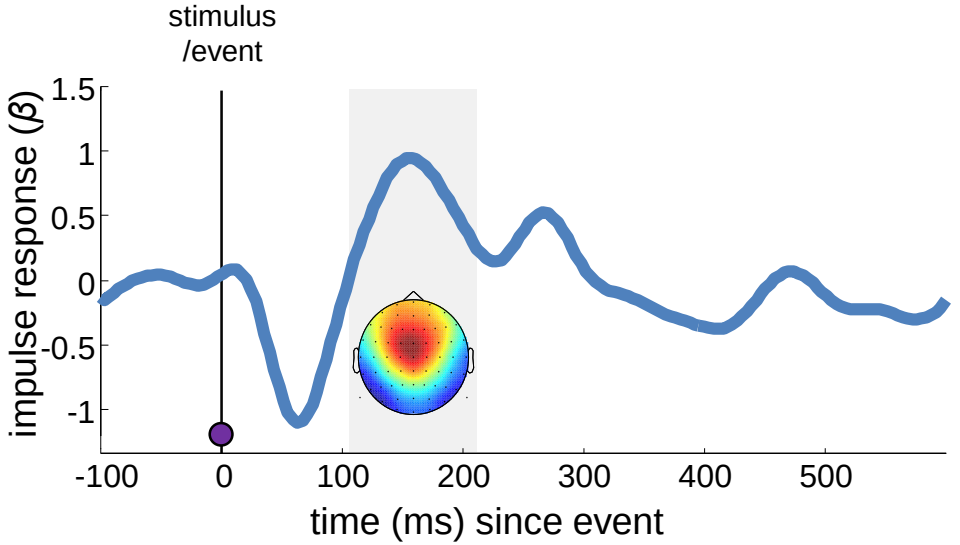
estimate using GLM: $Y = \beta X + \varepsilon$



adapted from Spitzer, Blankenburg, Summerfield (2016)

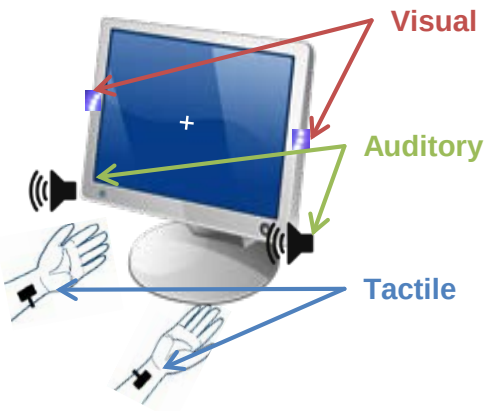
IR modeling: backprojection

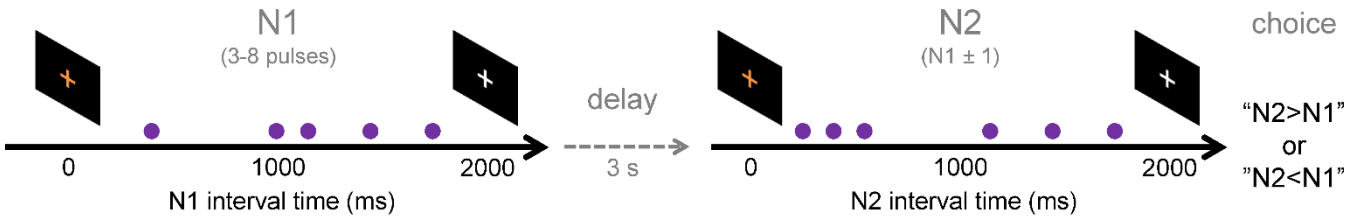


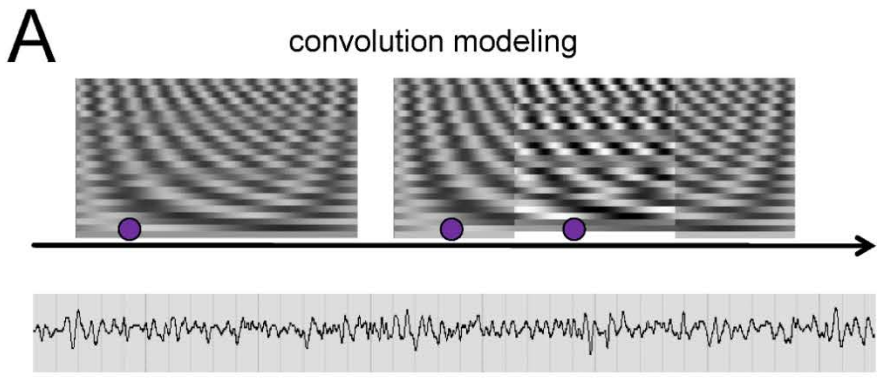


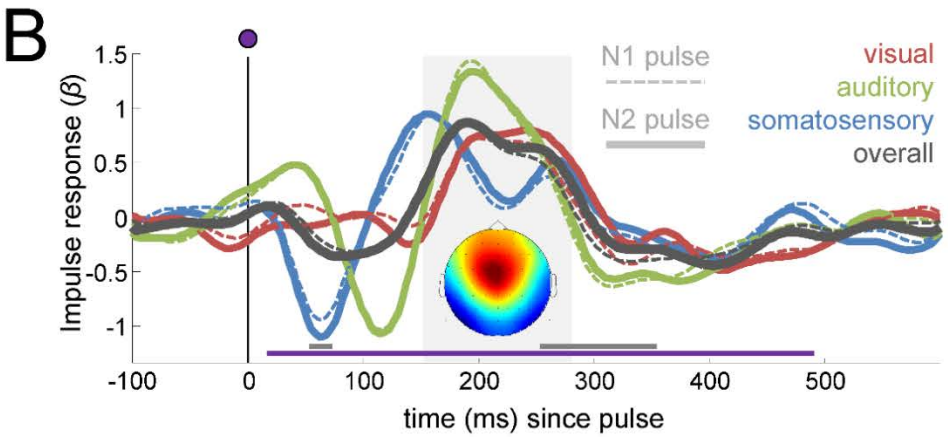
~‚as if' each event had occurred in isolation

example:
stimulus-evoked IRs during sequential processing



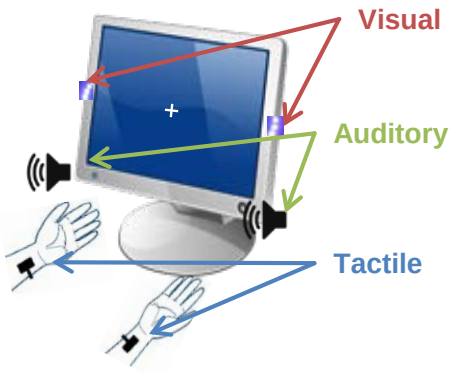




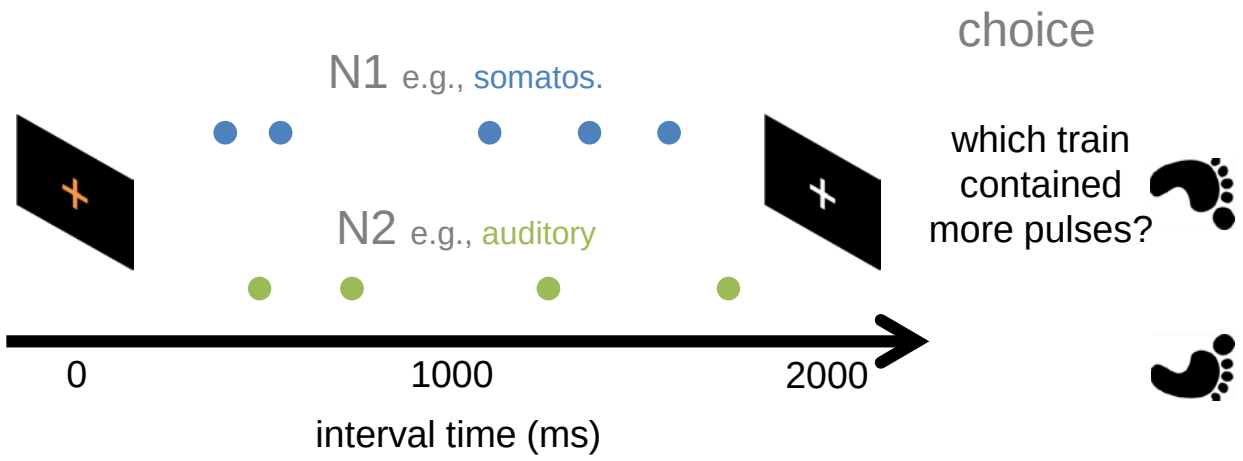


Spitzer, Blankenburg, Summerfield (2016)

Tutorial data:
intermodal numerosity comparison



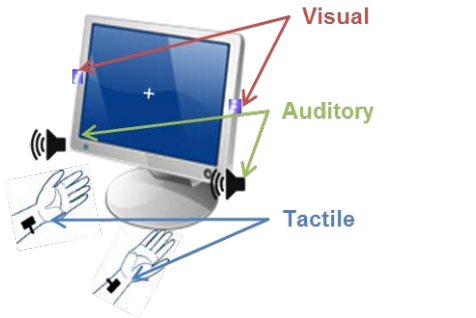
- 3 pairwise combinations of modalities (blocks of 20 trials each, 540 trials in total)
- N pulses varied between 2-7 (random & independent)
- **random & irregular pulse timing**

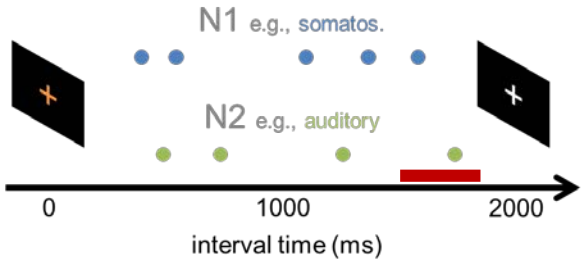


- EEG recording: 64-channel Biosemi Active II + EOG channels

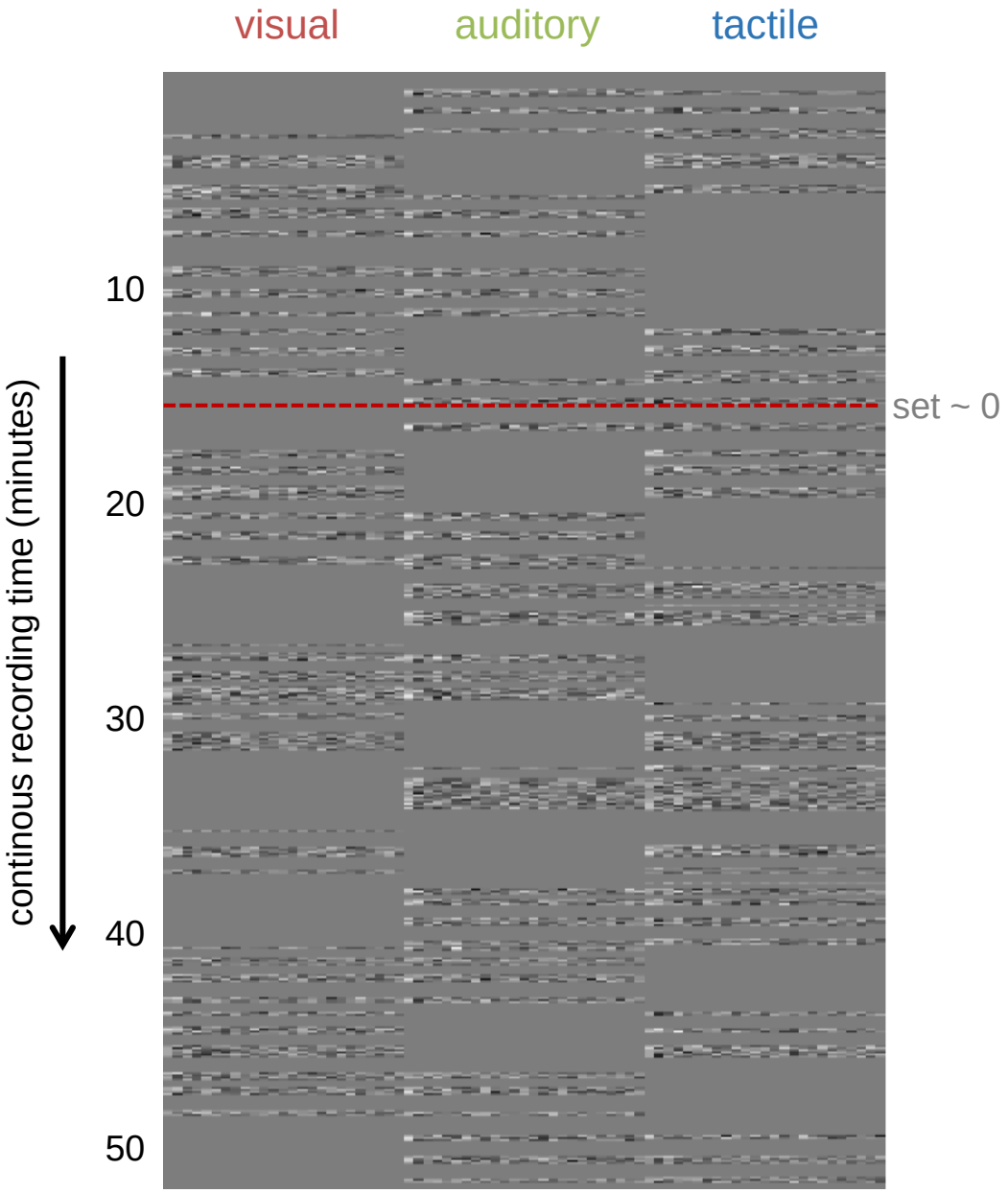
Sebastian Fleck (MSc)

hands-on: deconvolution of pulse-evoked IRs (~ERPs)

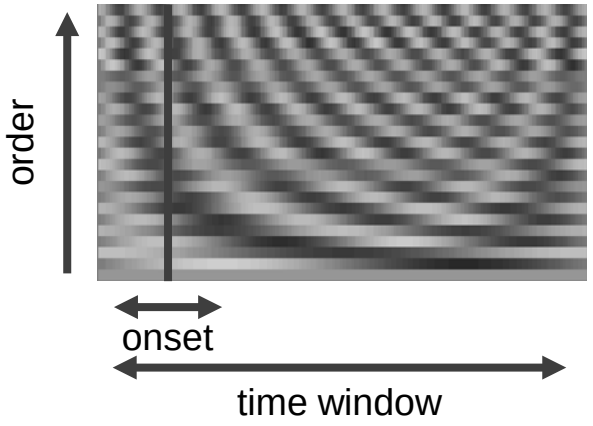




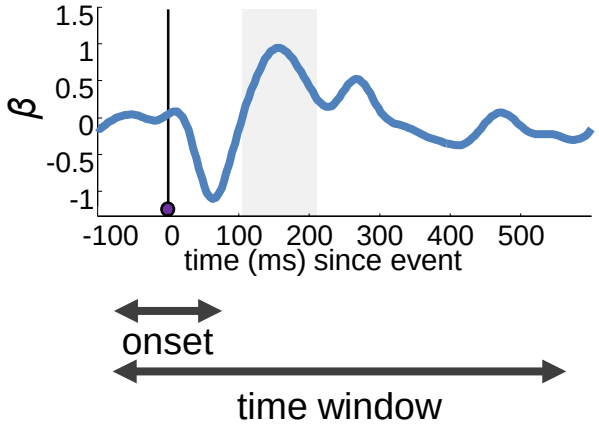
goodie: artefact suppression



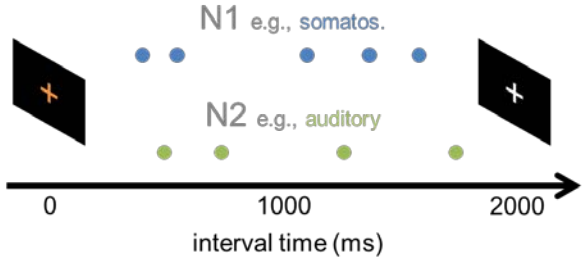
basis functions

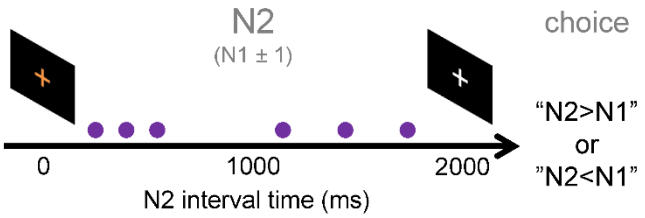


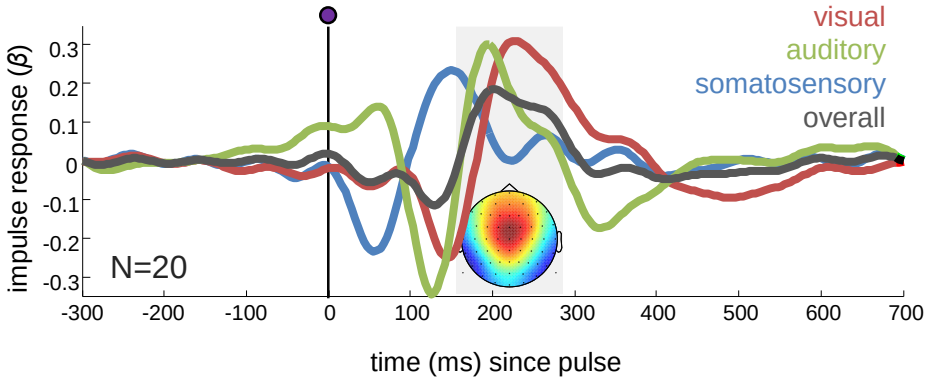
IR



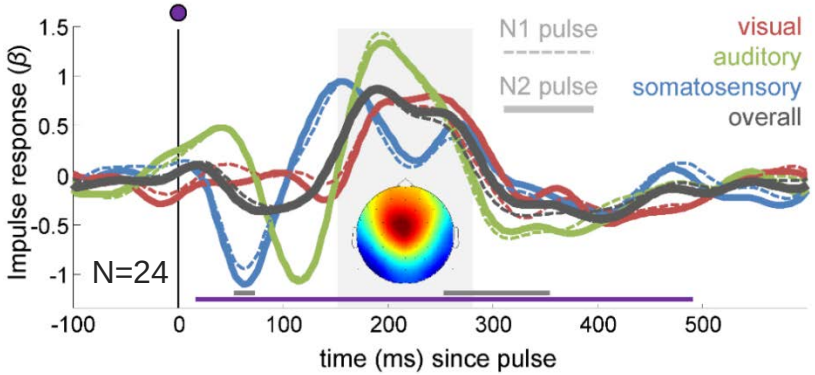
Deconvolution of pulse-evoked IRs (~ERPs)







tutorial data set
(preliminary group-level results)



Spitzer, Blankenburg, Summerfield (2016)

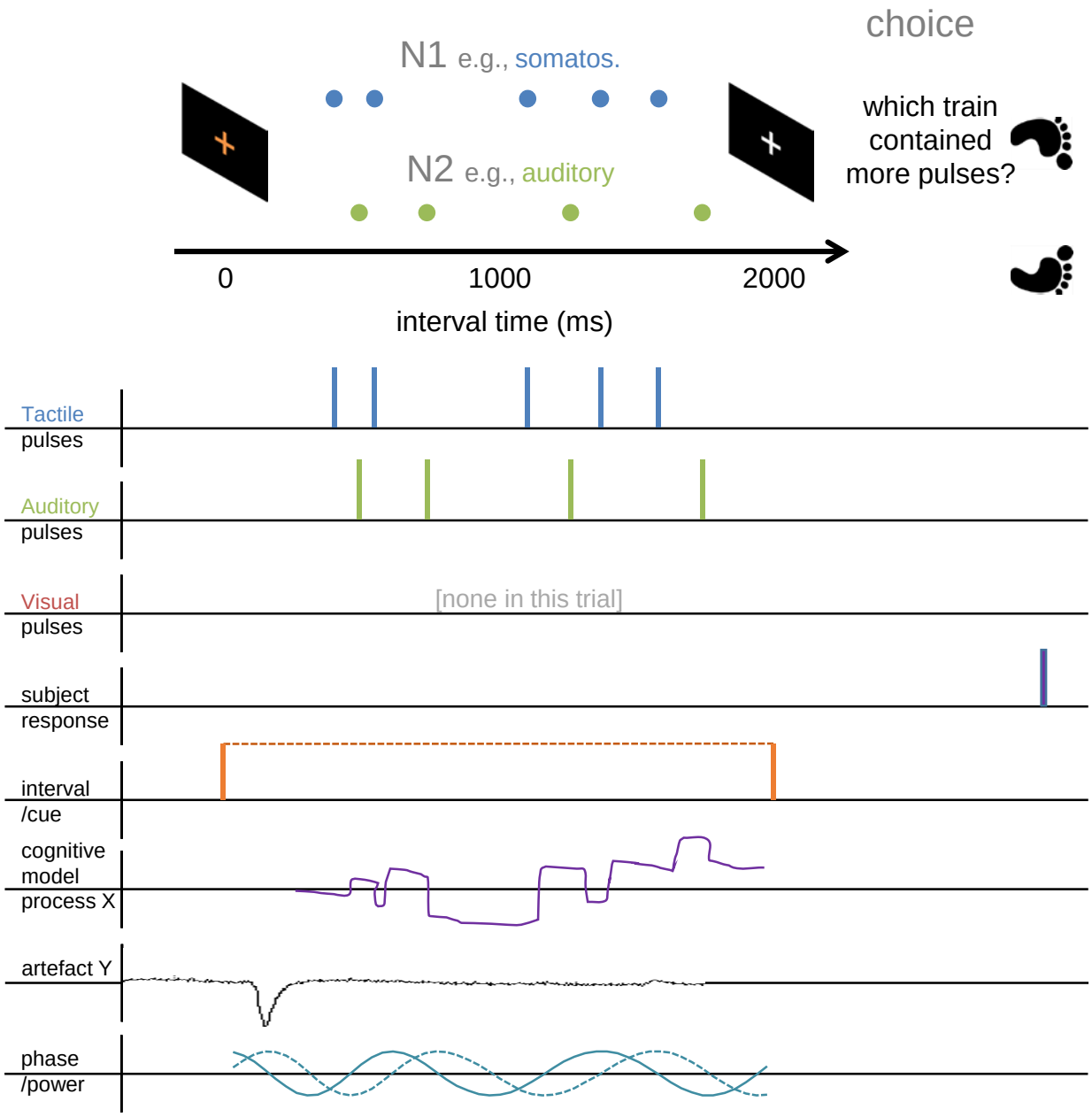
Convolution analysis in SPM12

- preprocess *continuous* data
- specify „1st level“ (GUI/batch/script)

  [low-level function: spm_eeg_firstlevel.m]
- run - creates SPM.m and EEG results file (β-coefficients)
- contrasts

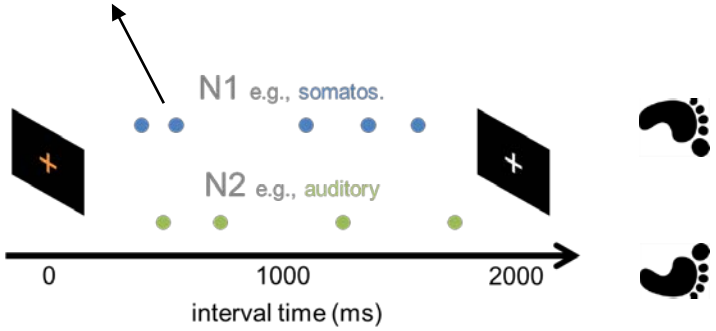
general recommendation: lots of RAM, **64-bit system**

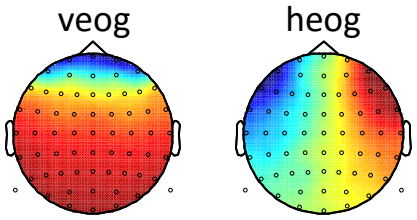
multiple regressors



continuous GLM regressors

EEG signal in peri-pulse time
predictive of later choice?





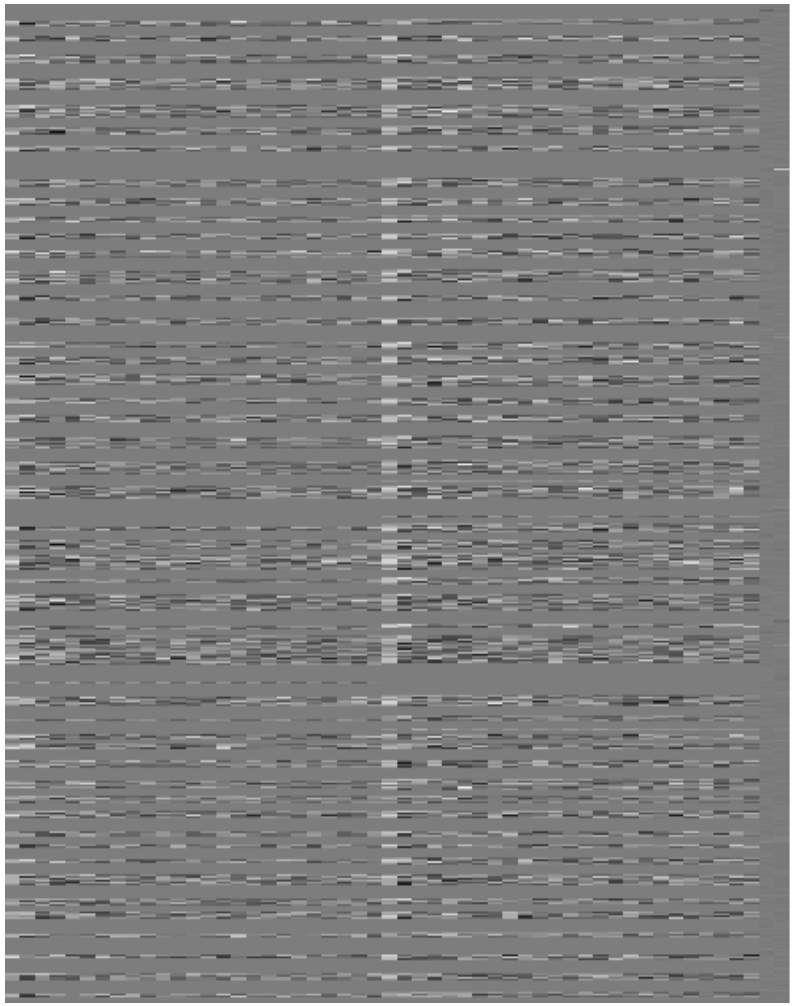
+ *continuous*
regressors

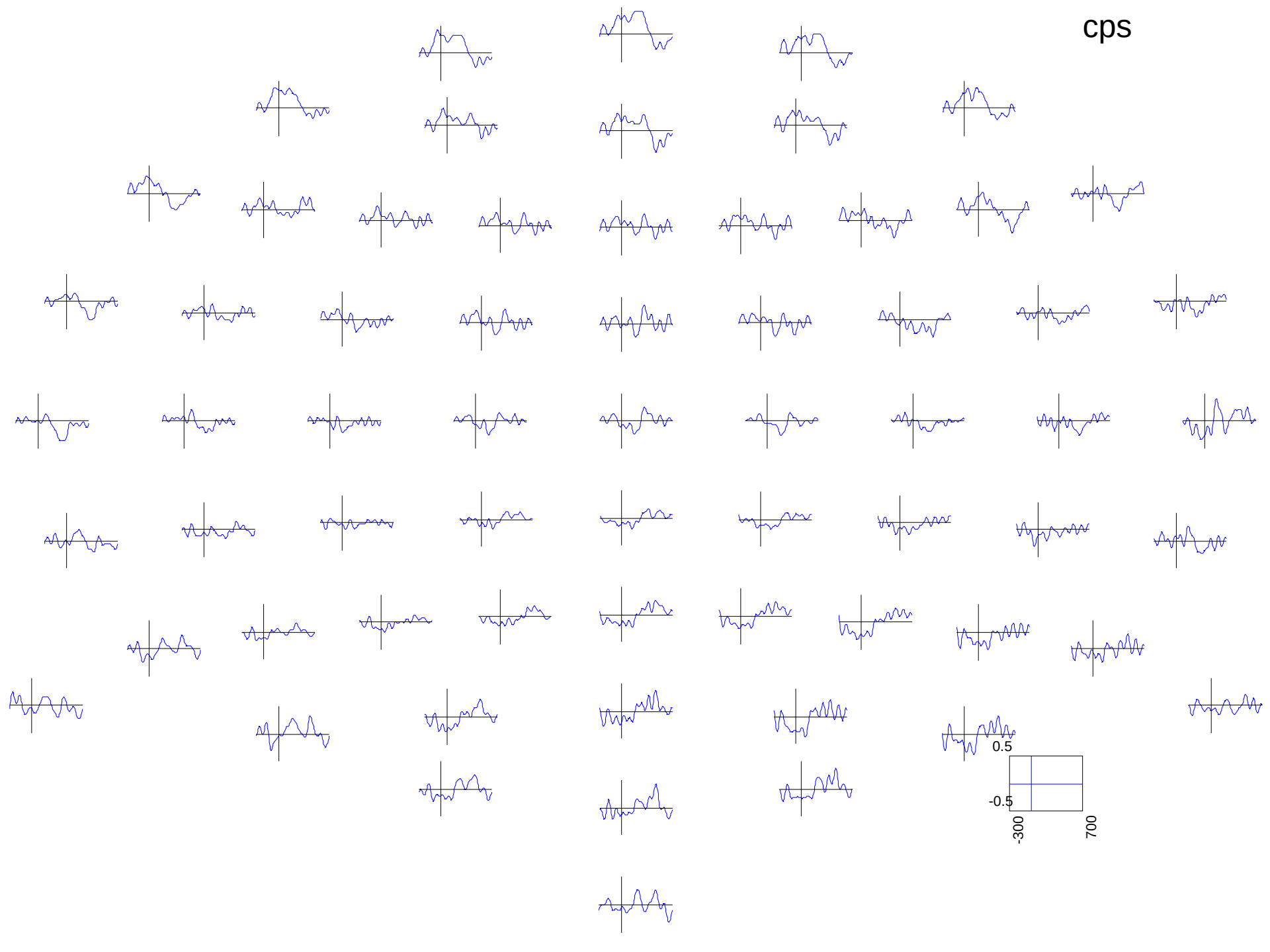
subsequent choice
(collapsed over modalities)

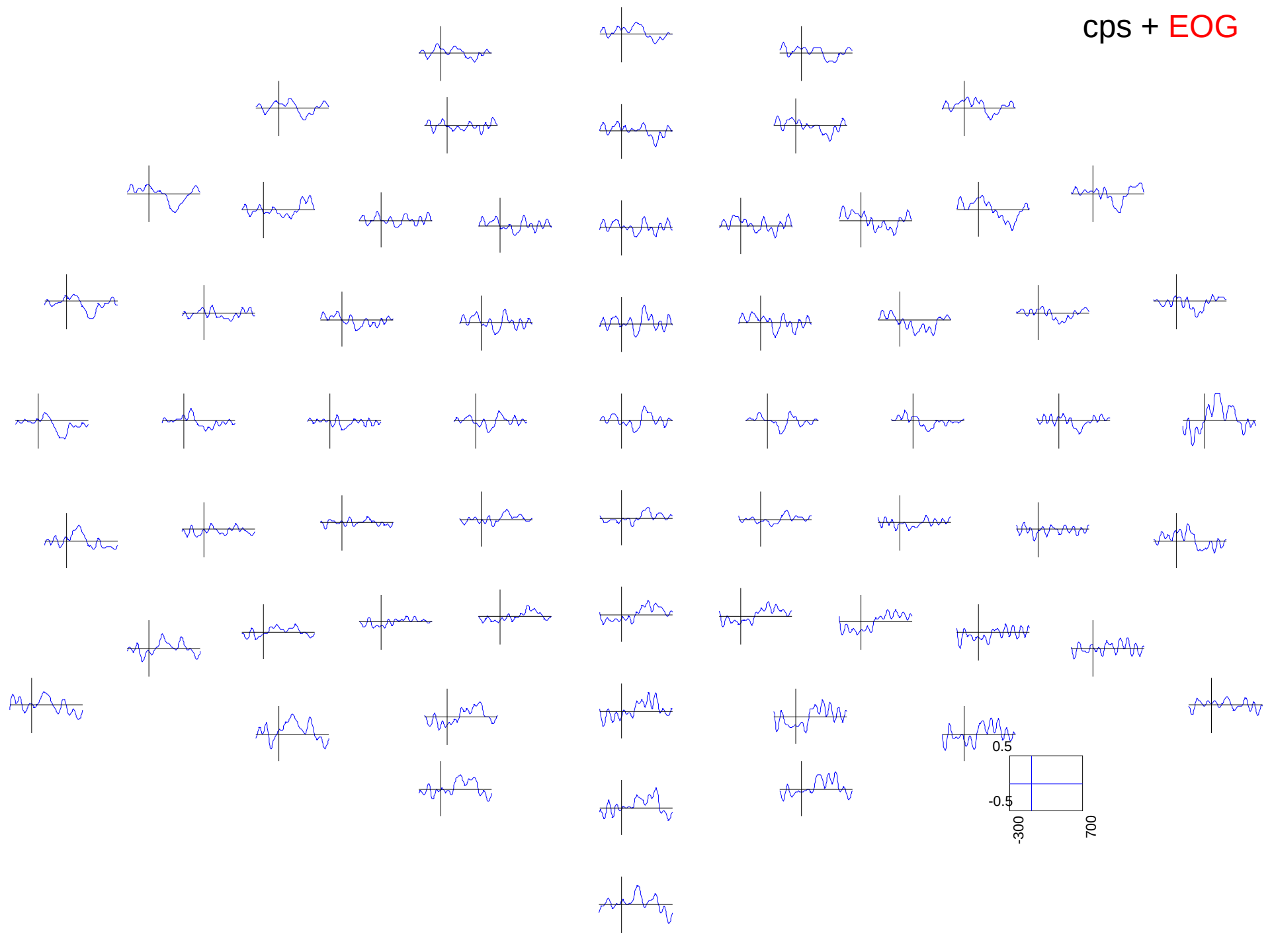
„fewer“ „more“

veog
heog

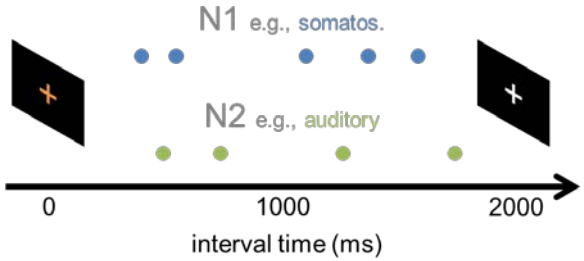
continous recording time

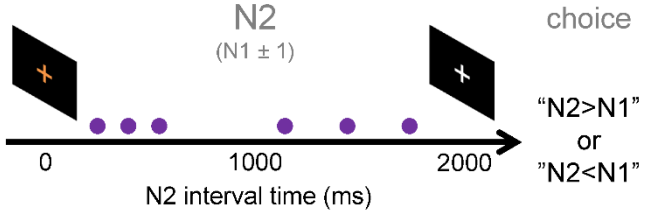


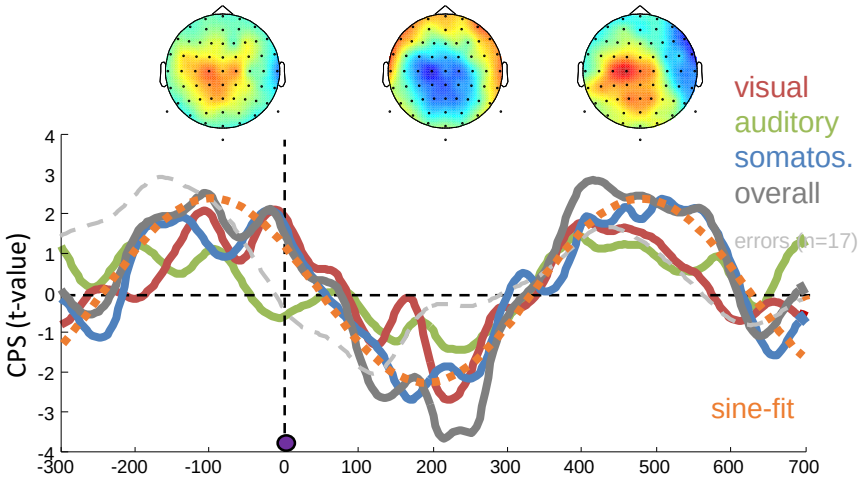

cps
0.5
-0.5
-300
700


cps + EOG
0.5
-0.5
-300
700

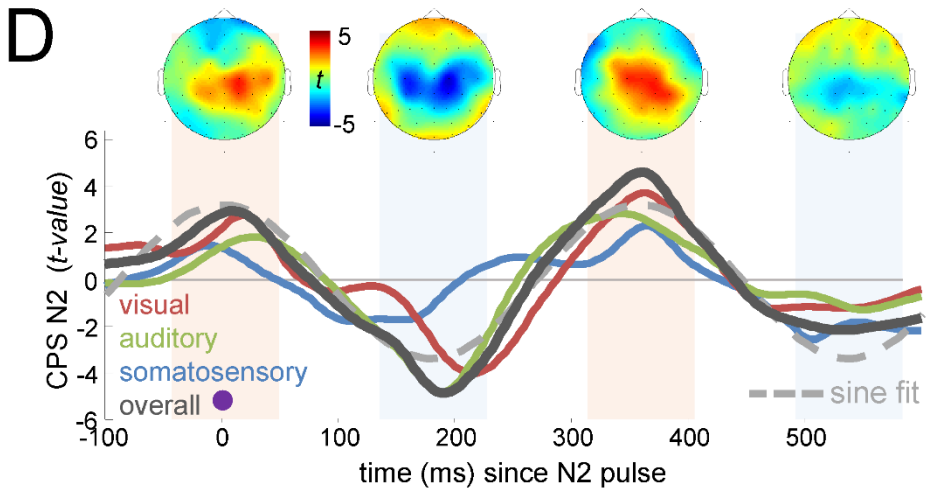
choice-predictive δ-band signals





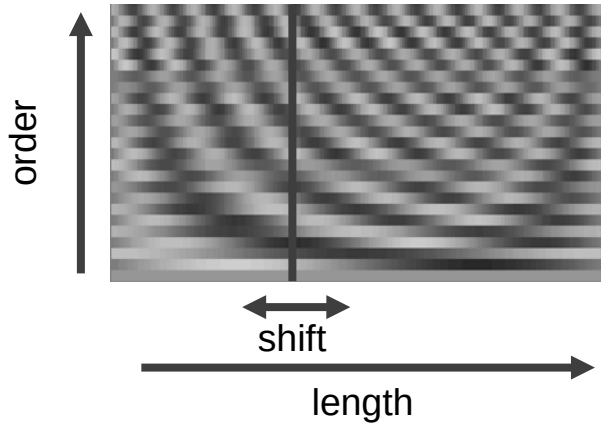


tutorial data-set
(preliminary group-level results)



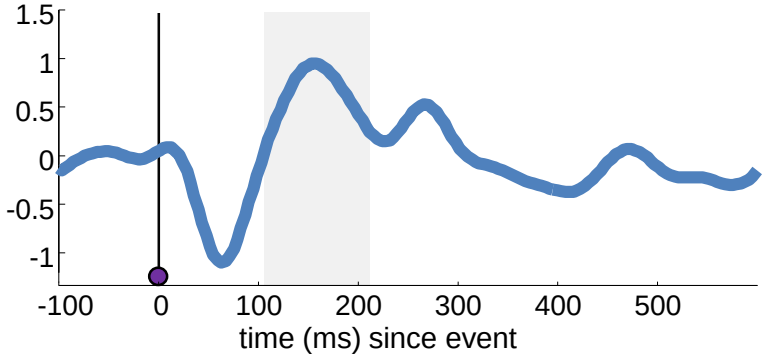
Spitzer, Blankenburg, Summerfield (2016)

Optimizing basis functions

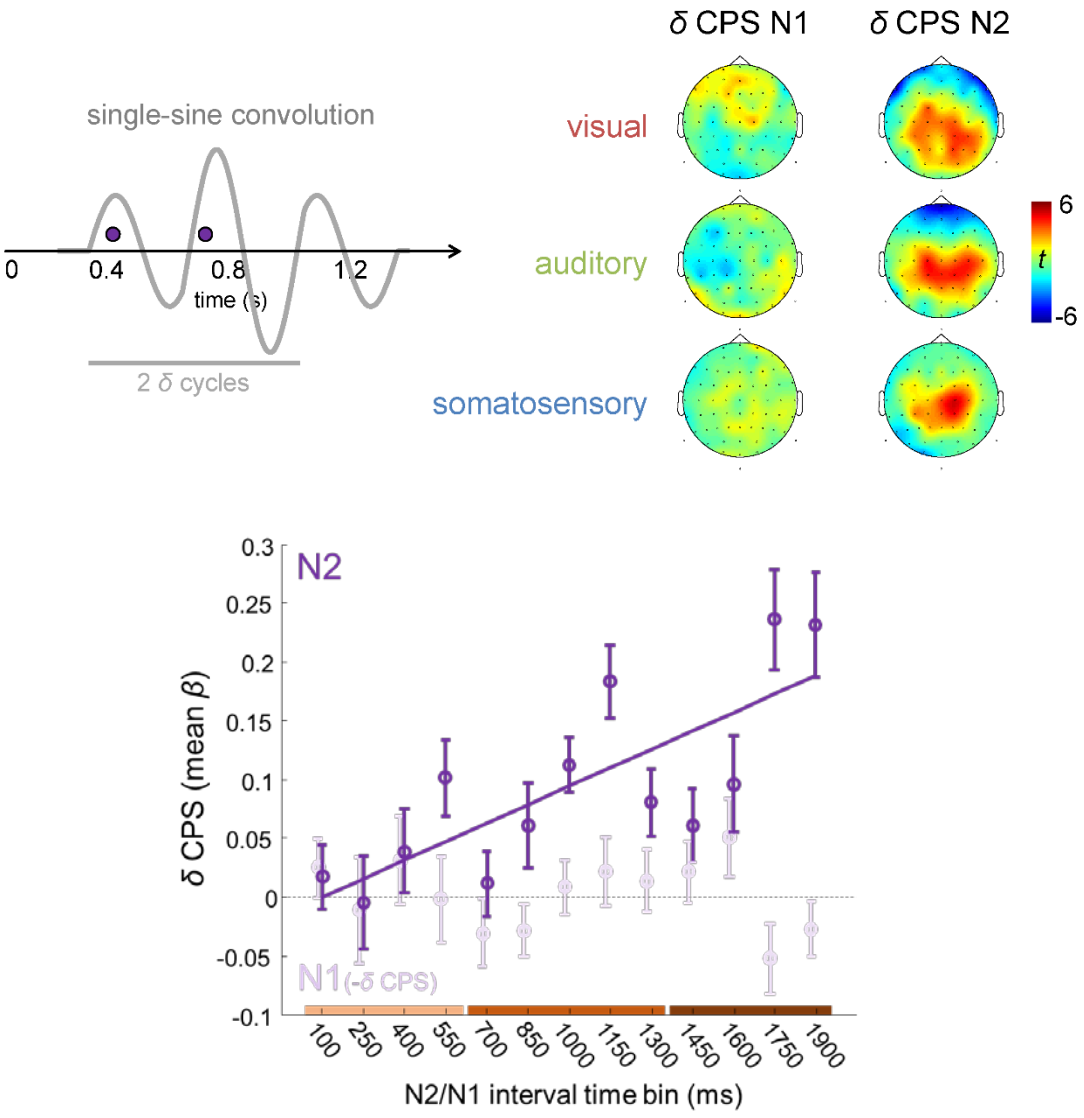


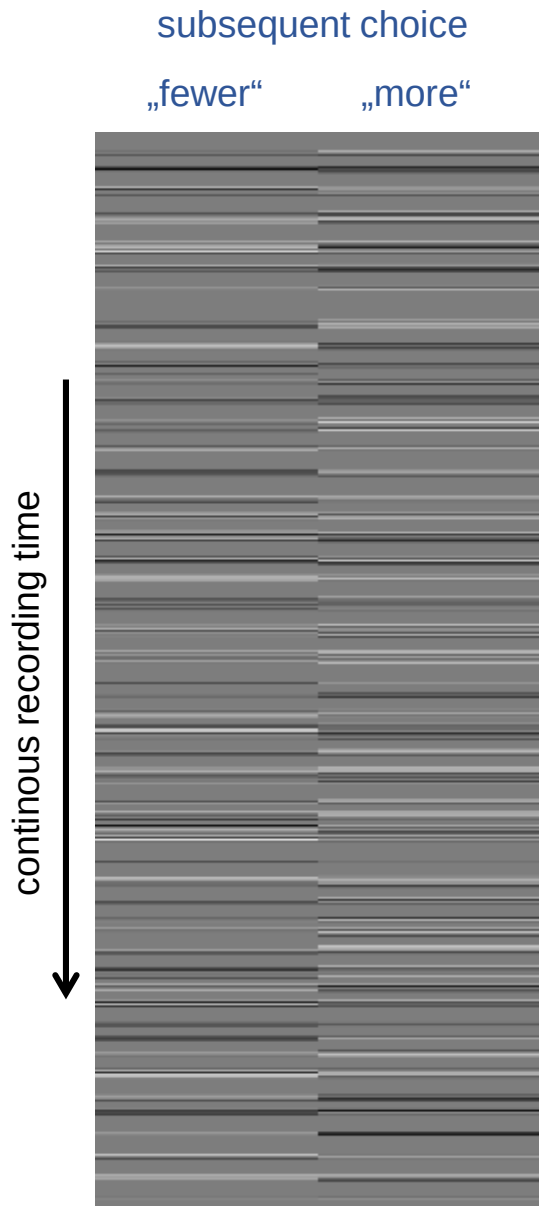
further reading

Litvak et al., 2013, *NeuroImage*



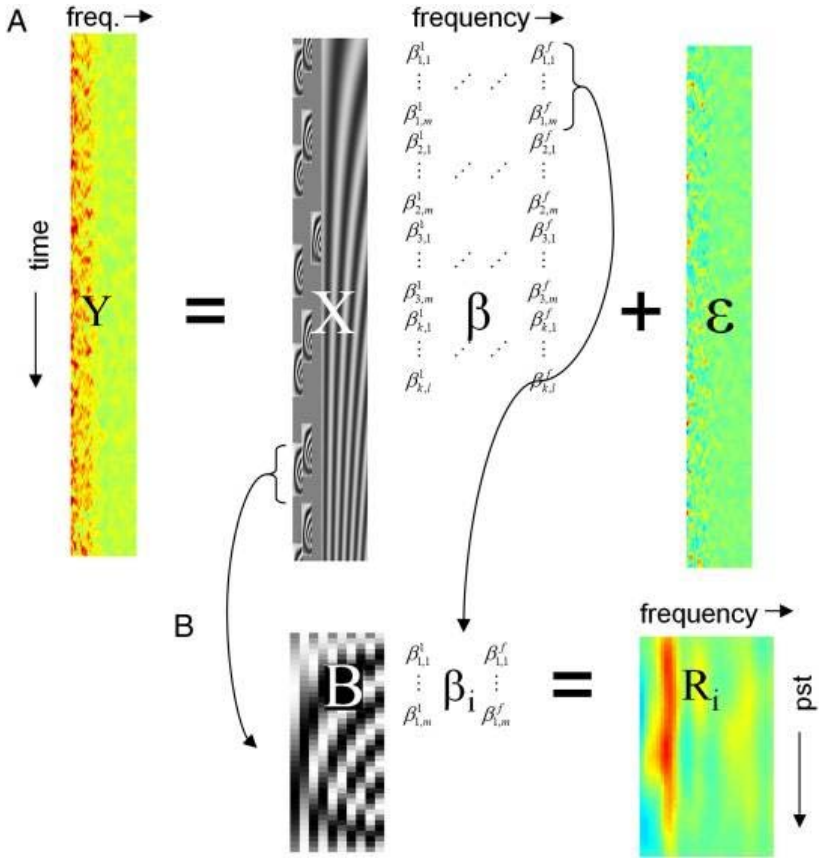
custom basis functions





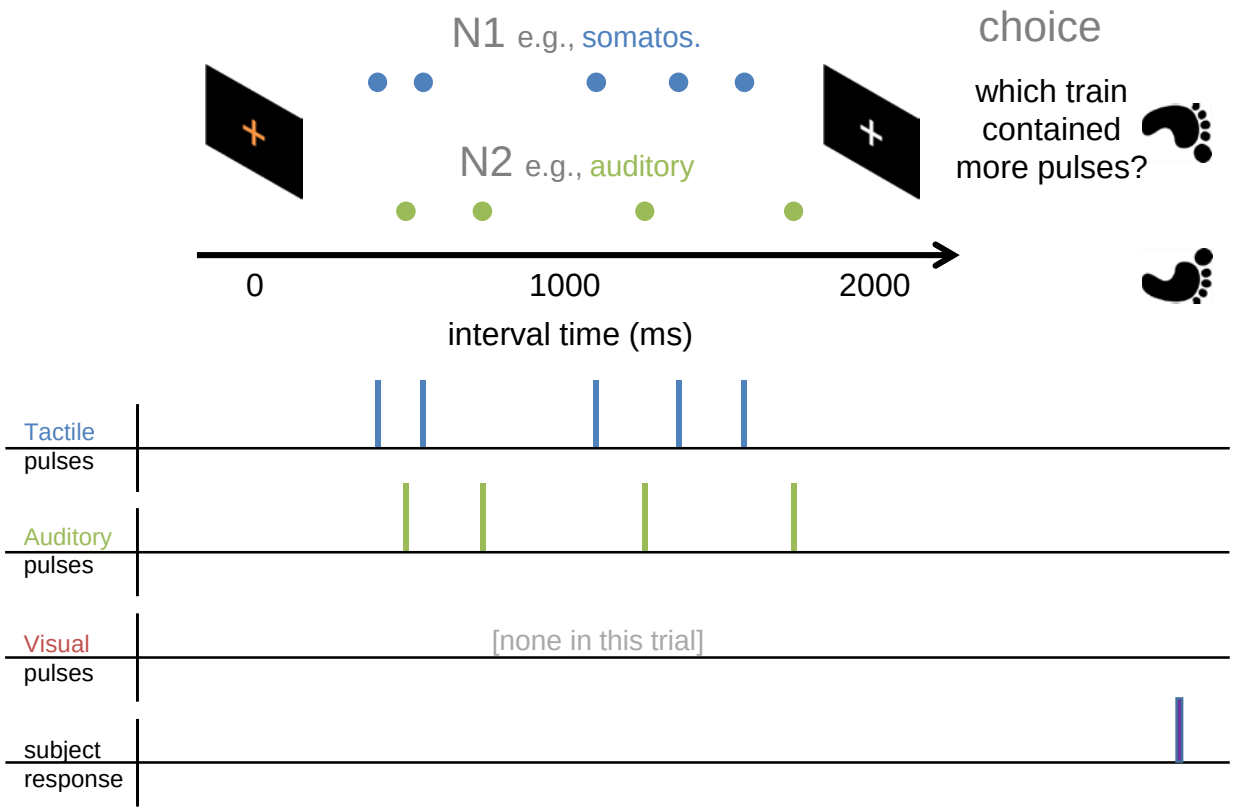
Spitzer, Blankenburg, Summerfield (2016)

Convolution models for induced (TF) responses



Litvak et al., 2013, *NeuroImage*

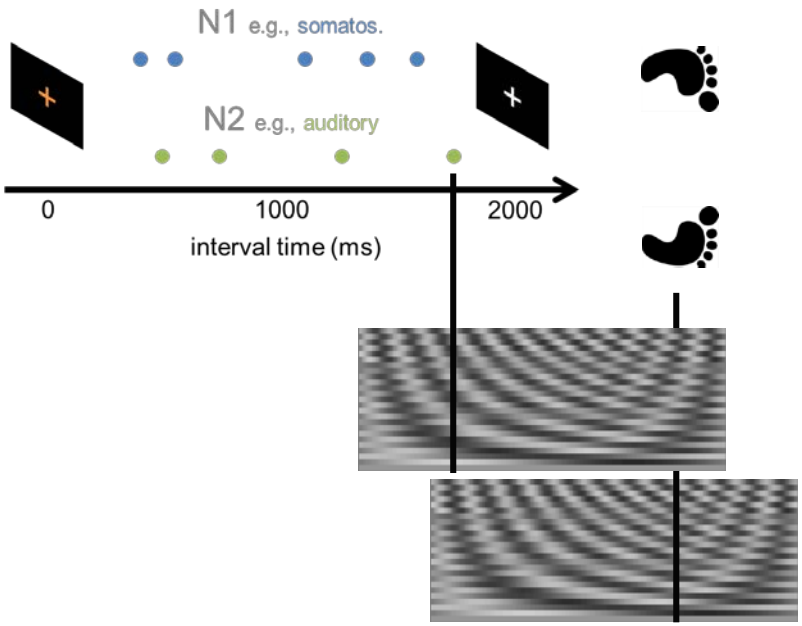
hands-on:
convolution models for TF-responses

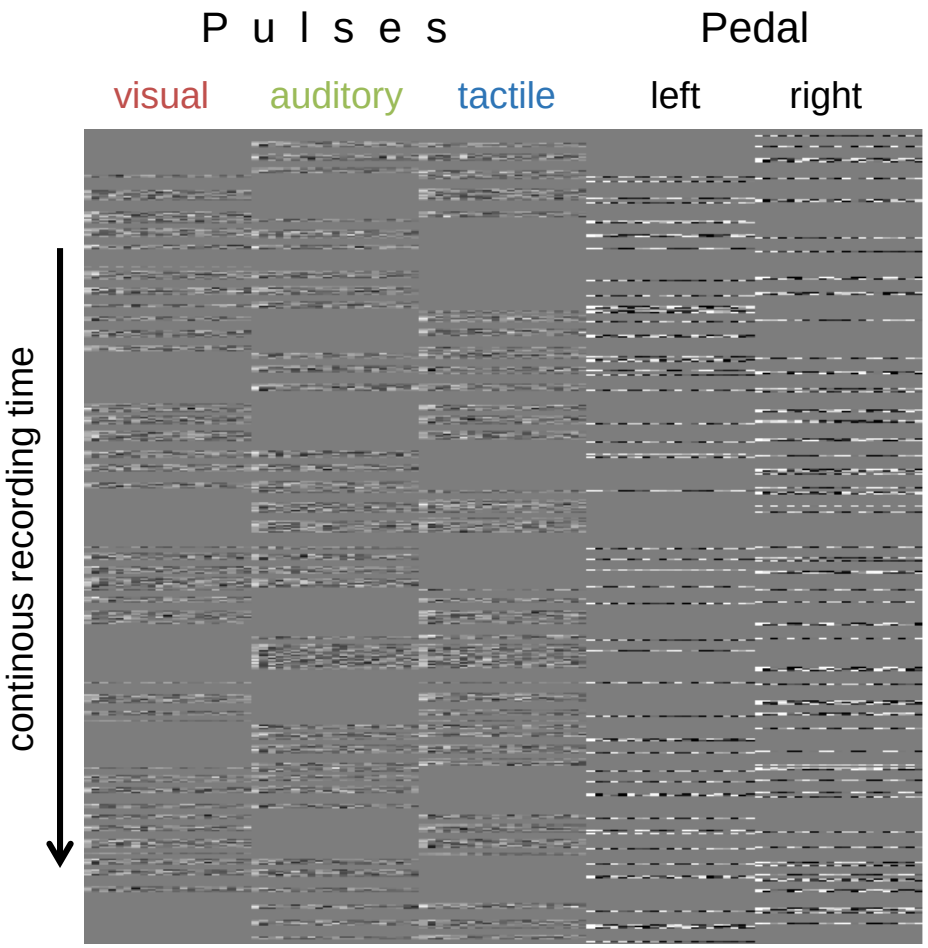


applied to time-frequency-transformation of *continuous* recording

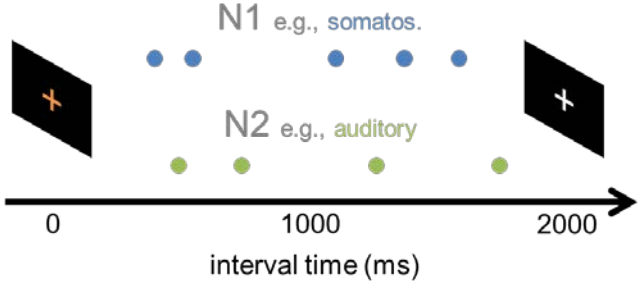
hands-on:
convolution models for TF-responses

applied to TF-transform
of *continuous* recording

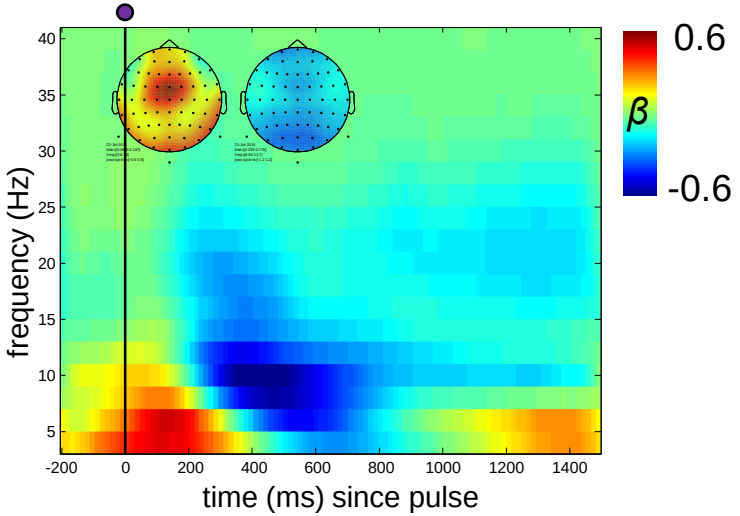




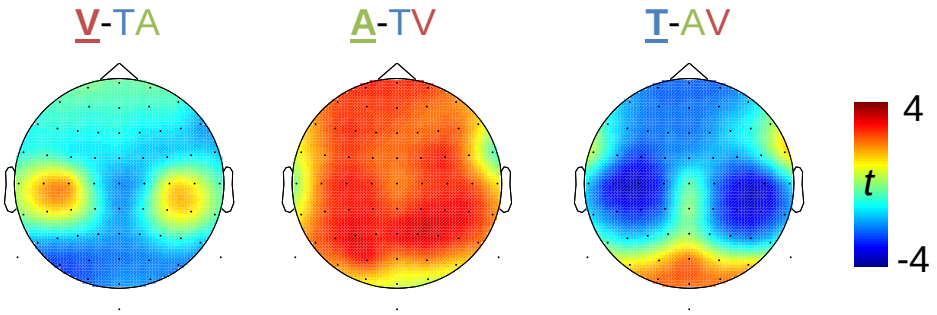
preliminary group-level results



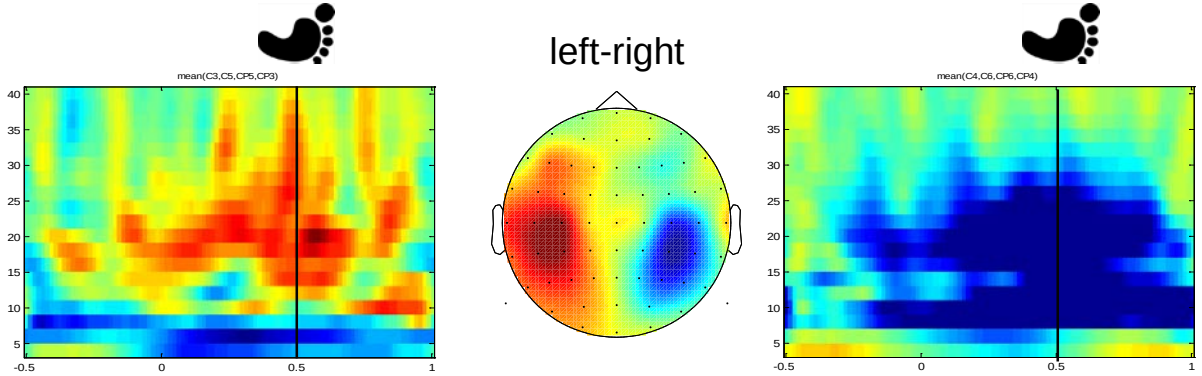
overall IR



modality-specific alpha/beta topographies

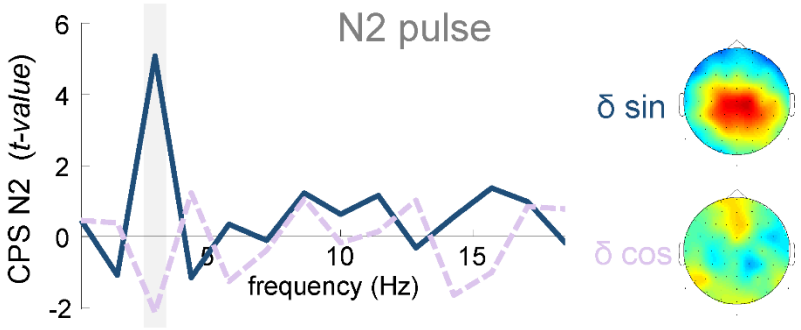


Pedal-press related beta/alpha lateralization



Extensions

Analysis in Fourier-space



Spitzer, Blankenburg, Summerfield (2016)

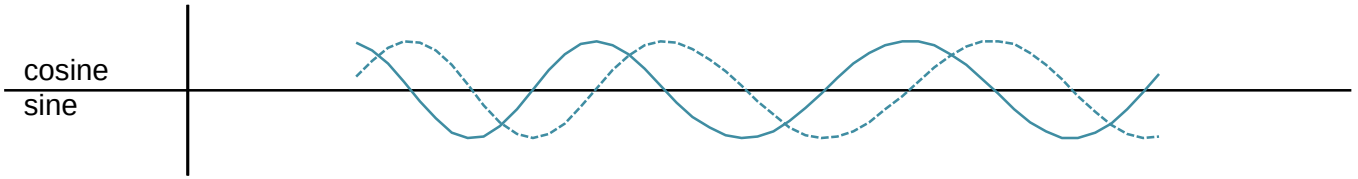
Model residuals

Model I $Y = \beta X + \varepsilon$

use residuals as 'new' data

Model II $Y = \beta X + \varepsilon$

Phase-amplitude / amplitude- amplitude coupling



$$\sqrt{\beta_{cos}^2+\beta_{sin}^2}$$

cf. Penny et al., 2008
van Wijk et al., 2015

Convolution models: Summary

- overlapping and temporally variable responses
- artefacts
- slow drifts
- continuous modulators
- phase-amplitude and amplitude-amplitude relationships (within and between sites/areas/signals)

gain of flexibility in experimental design & analysis

Thank you

London

Vladimir Litvak & Guillaume Flandin

Berlin

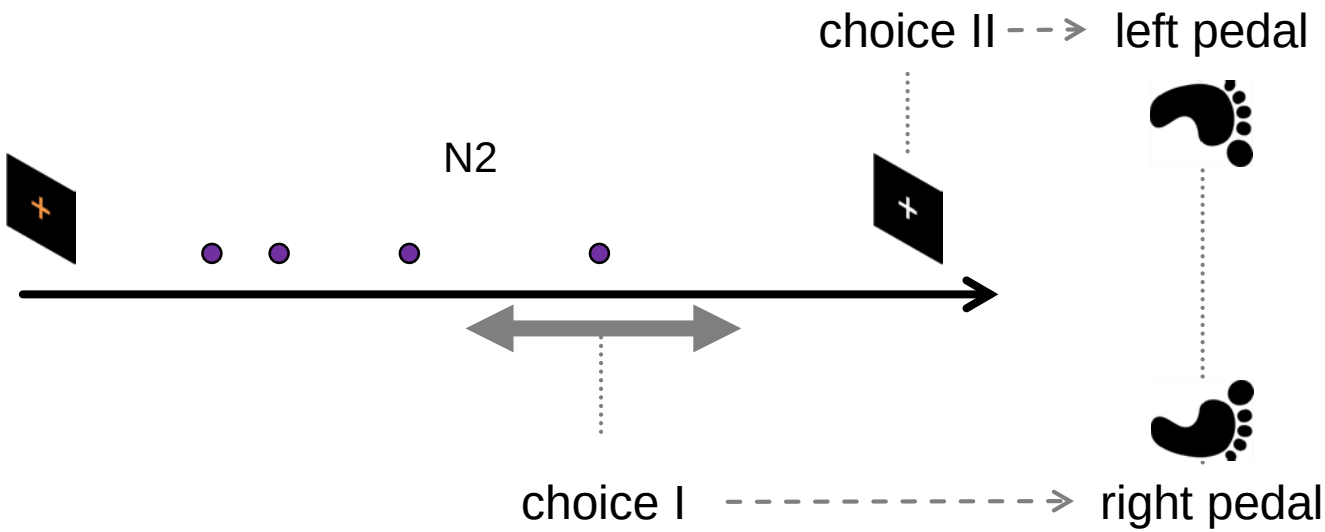
Felix Blankenburg & NNU Berlin

Sebastian Fleck, Jan Herding, Simon Ludwig

Oxford

Chris Summerfield, Ryszard Auksztulewicz

disentangling overlapping induced responses

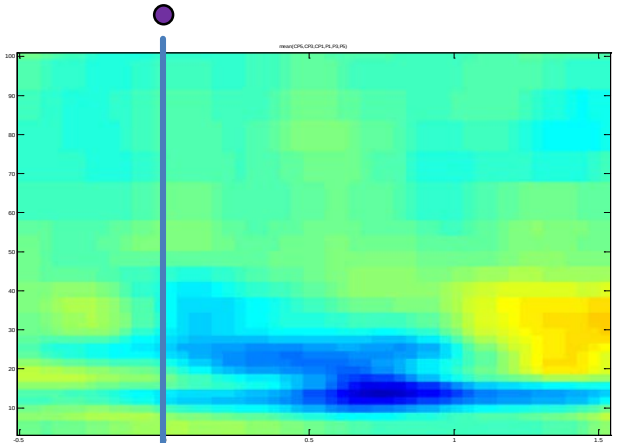


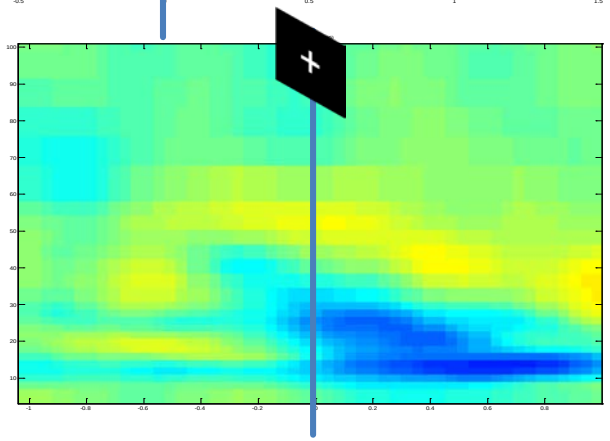
conventional analyses (fixed epochs)

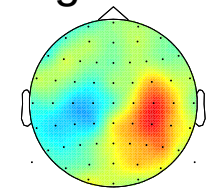
locked to last pulse

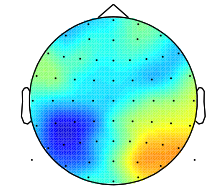
locked to end of interval

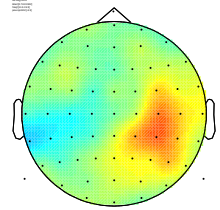
choice right-left

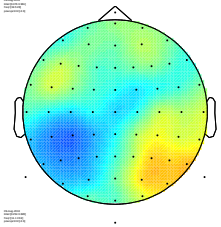


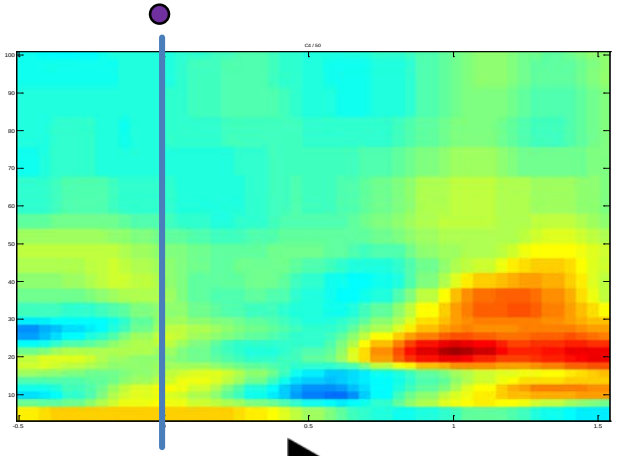


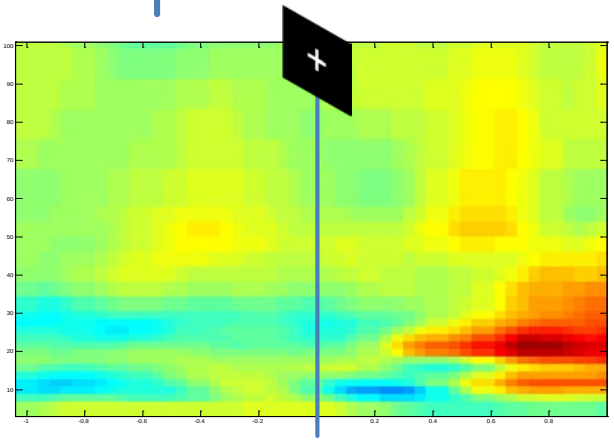






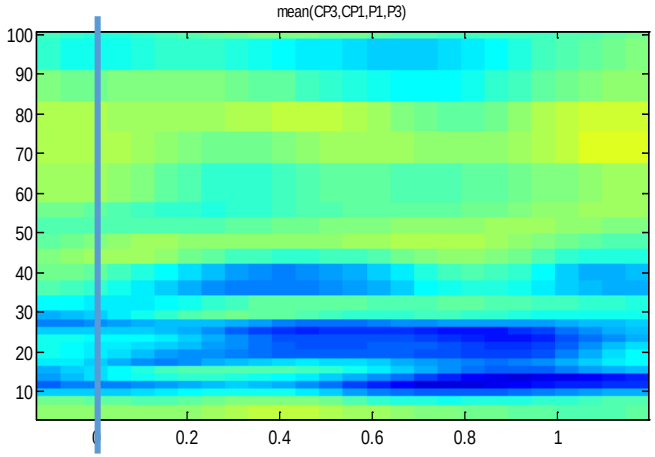




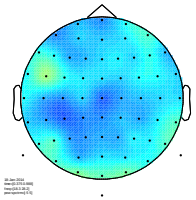


convolution analysis

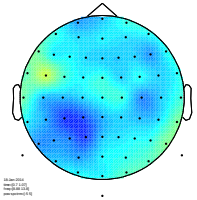
last pulse



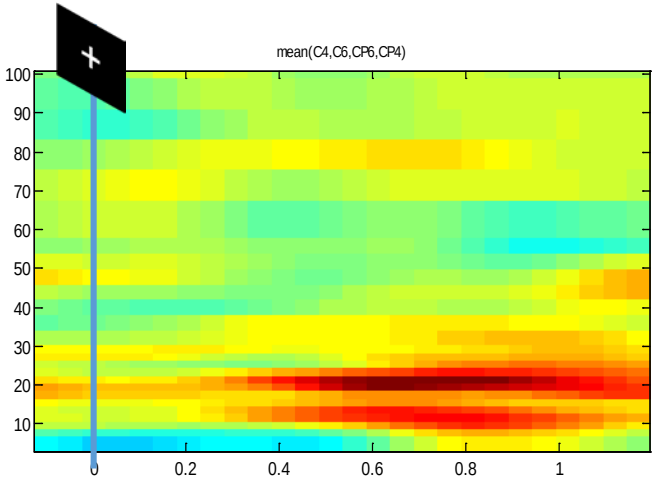
beta



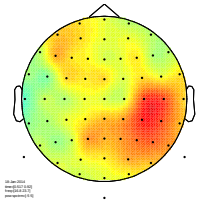
alpha



end of interval



beta



alpha