MRC Cognition and Brain Sciences Unit

UNIVERSITY OF CAMBRIDGE

EEG/MEG 1:

Averaging

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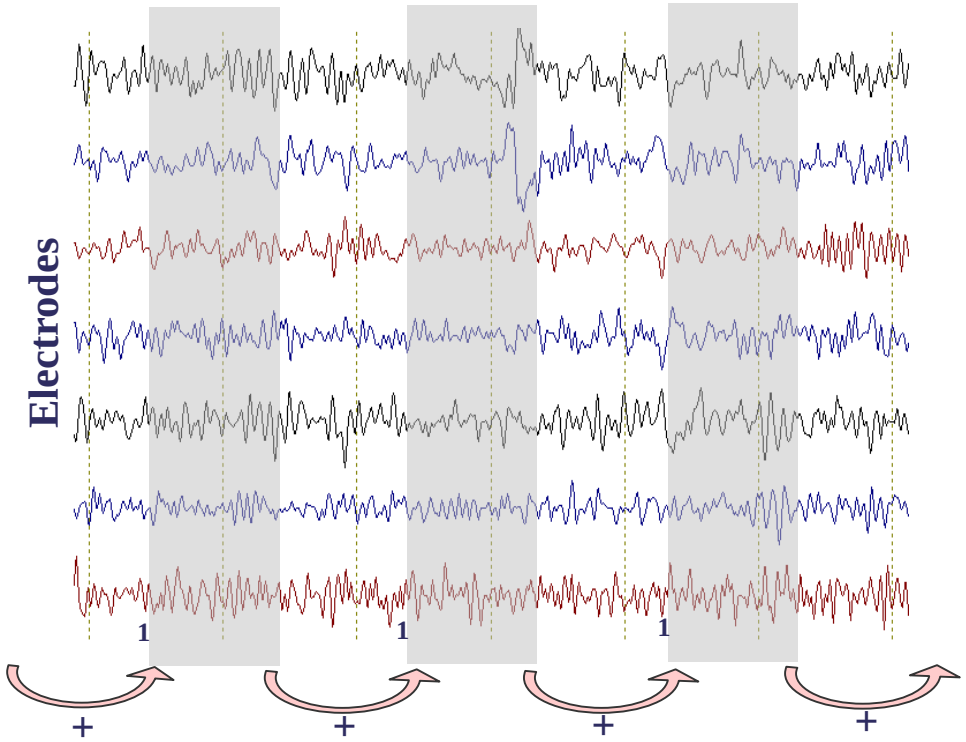
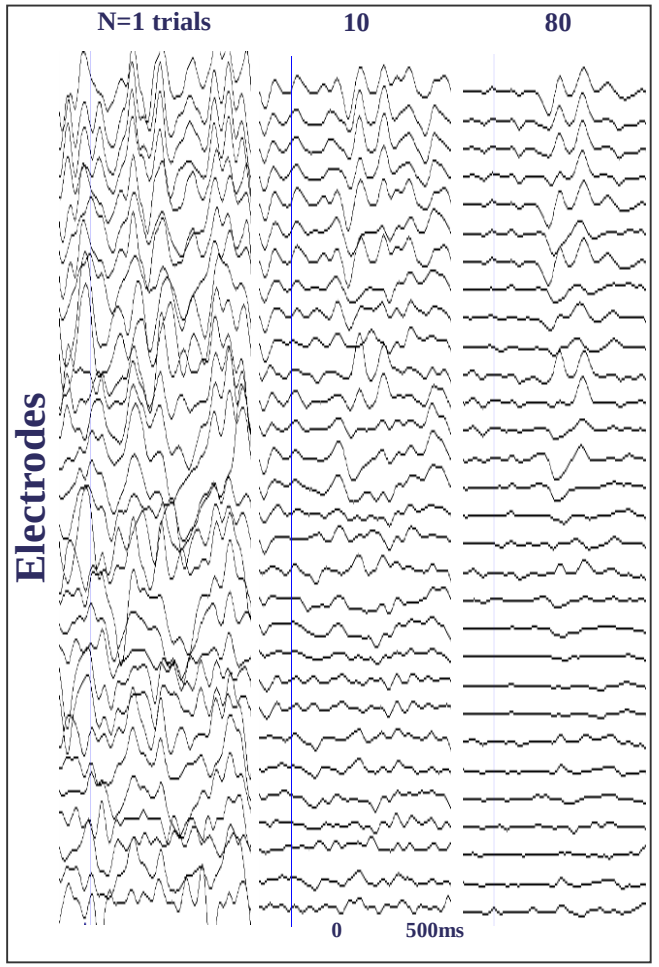
Event-Related Potentials and Fields (ERPs and ERFs)

Data Averaging

Continuous “raw” data:

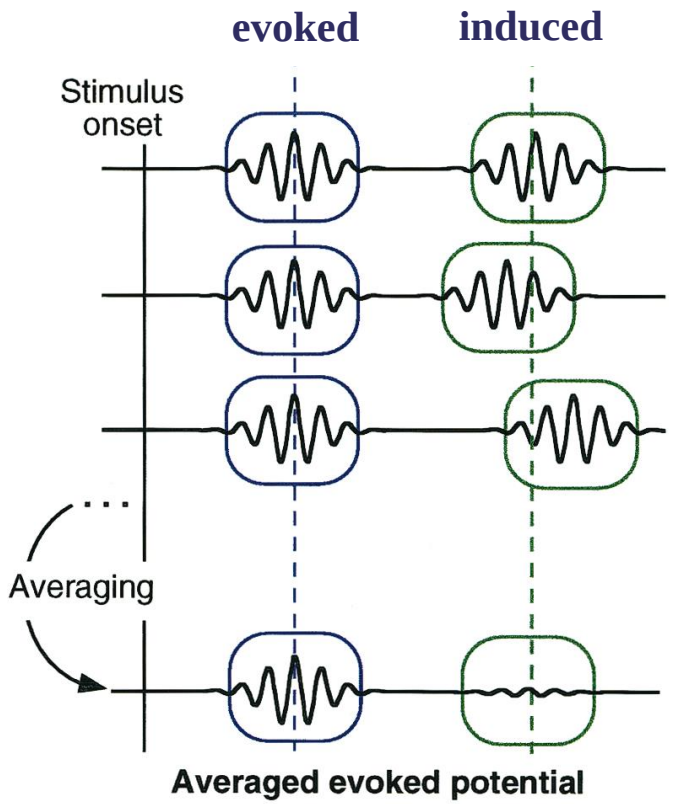


Averaged data:



http://imaging.mrc-cbu.cam.ac.uk/meg/IntroEEGMEG

Evoked and Induced Activity



Tallon-Baudry & Bertrand, TICS 1999

Temporal jitter across trials has a larger effect on higher frequencies, and they are more likely to be attenuated by averaging.

Data Averaging

The necessary number of trials depends on effect size, noise, variability across participants, your stats etc. –
the more the better if feasible.

For random noise, variance goes down with n, and standard deviation with sqrt(n).

For “one-off” artefacts, amplitude in the average goes down with n.

“Robust Averaging” procedures exist (e.g. in SPM) that weigh epochs with an estimate of their reliability (e.g. distance to mean).

The average will be affected by the amplitude as well as jitter of evoked activity. Amplitude differences between conditions may therefore reflect true activation differences or different variability across trials.

Artefact Rejection

Usually, epochs are excluded from averaging when their data exceed some maximum-minimum criterion.

Make sure “chronically bad channels” are excluded from this procedure
(or there won’t be any data left to average).

Prior to any procedure that combines signals across channels, such as average reference, SSP or ICA, bad channels should be removed or interpolated
(or signals from bad channels may be projected into the good ones).

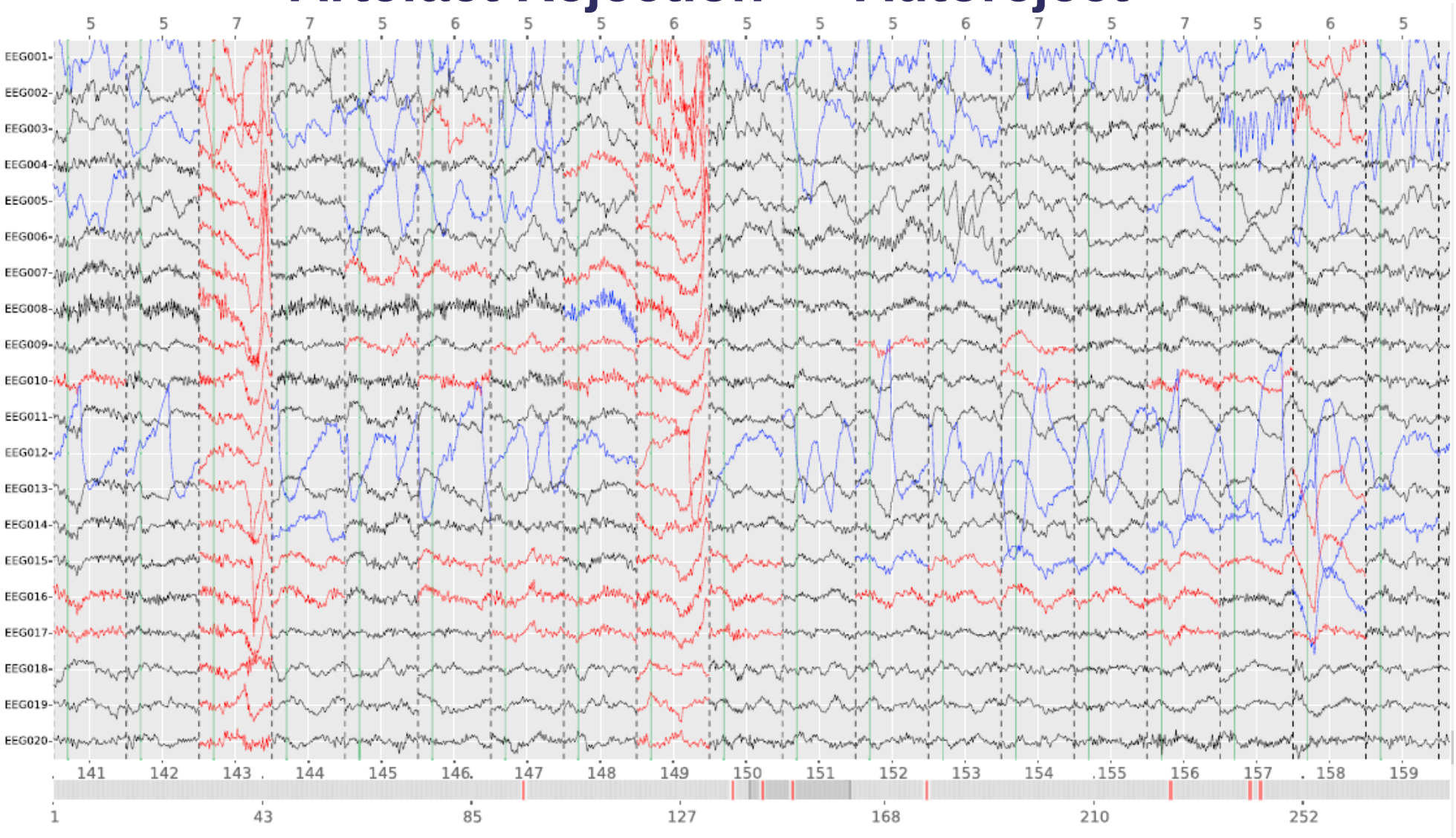
Appropriate filtering and artefact correction (e.g. ICA) should be applied beforehand
(but don’t feel too safe: artefacts may slip through).

The proof of the pudding is in the eating:
Check data quality by visual inspection, compute SNRs, etc.

Artefact Rejection

- While chronically bad channels should be interpolated or excluded, we usually also exclude epochs or data segments that are likely to contain artefacts.
- This can be done by visual inspection – which is time-consuming and subjective.
- It is common to specify “rejection thresholds” and reject epochs that have amplitude fluctuations larger than these thresholds (per channel type).
- It is worth checking whether epochs get rejected because of the same channels (which could be marked as bad) or systematic artefacts (e.g. eye blinks, which could be corrected with ICA).
- It may be wasteful to reject whole epochs because of artefacts in few channels, especially when data are “precious”, e.g. for patient data and small datasets.
- There are algorithms that attempt to deal with this, e.g. “Autoreject” (https://autoreject.github.io/stable/index.html).

Artefact Rejection – “Autoreject”



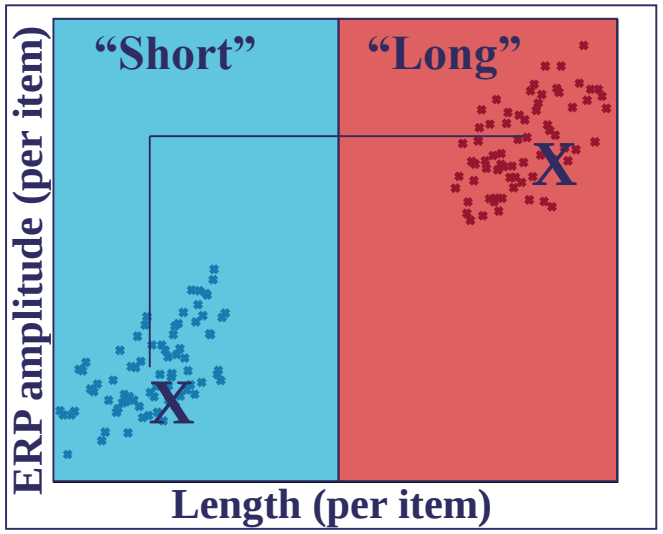
Good Bad and interpolated Bad not interpolated

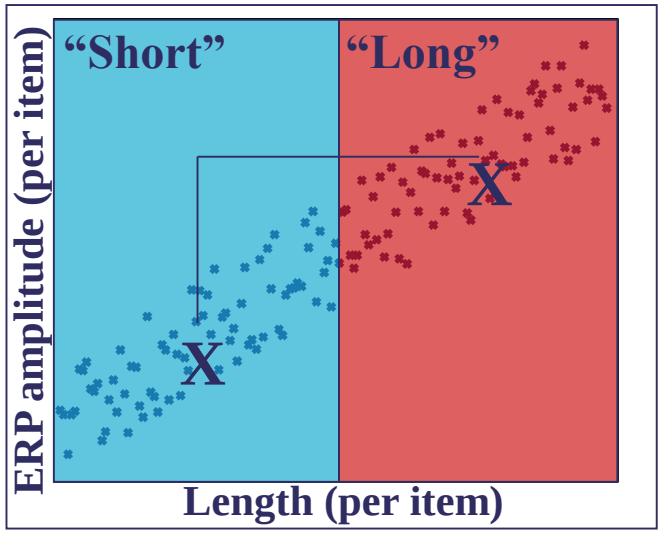
Jas et al., NI 2017, https://autoreject.github.io/stable/index.html

Parametric vs Factorial Designs

Consider parametric analysis/GLM if stimulus variables are continuous.

(still less common in EEG/MEG than in fMRI analysis)





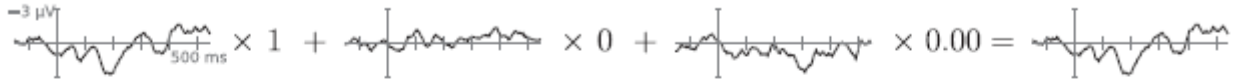
Smith & Kutas, Psychophysiol 2015a

Hauk et al., Neuroimage 2006

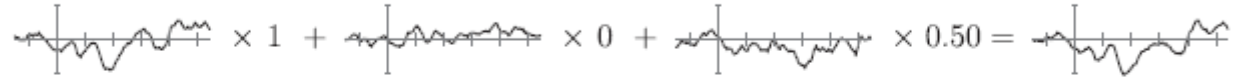
“Single-trial” analysis

β_1	x_{1i}	β_2	x_{2i}	β_3	x_{3i}	Predicted ERP

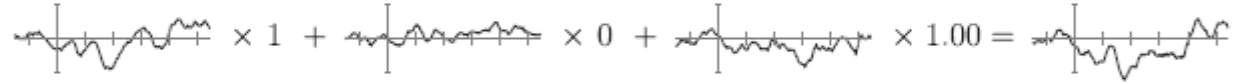
a with 0% expectancy:



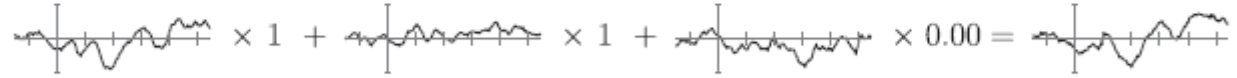
a with 50% expectancy:



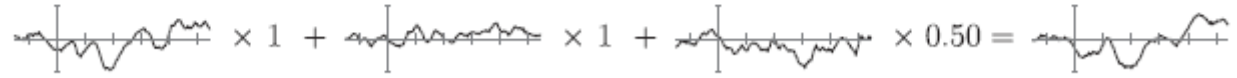
a with 100% expectancy:



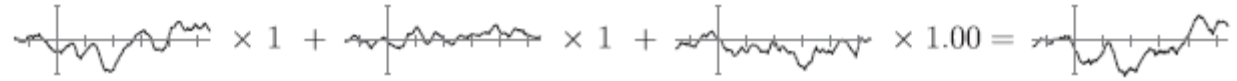
an with 0% expectancy:



an with 50% expectancy:



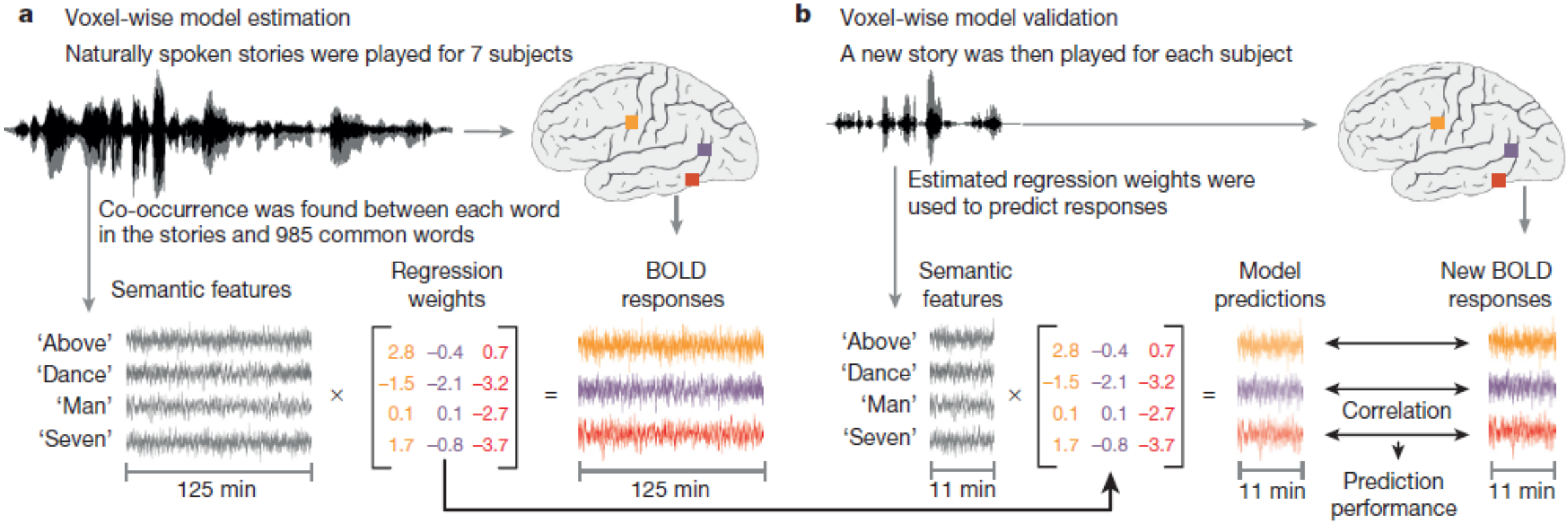
an with 100% expectancy:



Smith & Kutas, Psychophysiol 2015a
Also: Hauk et al., Neuroimage 2006

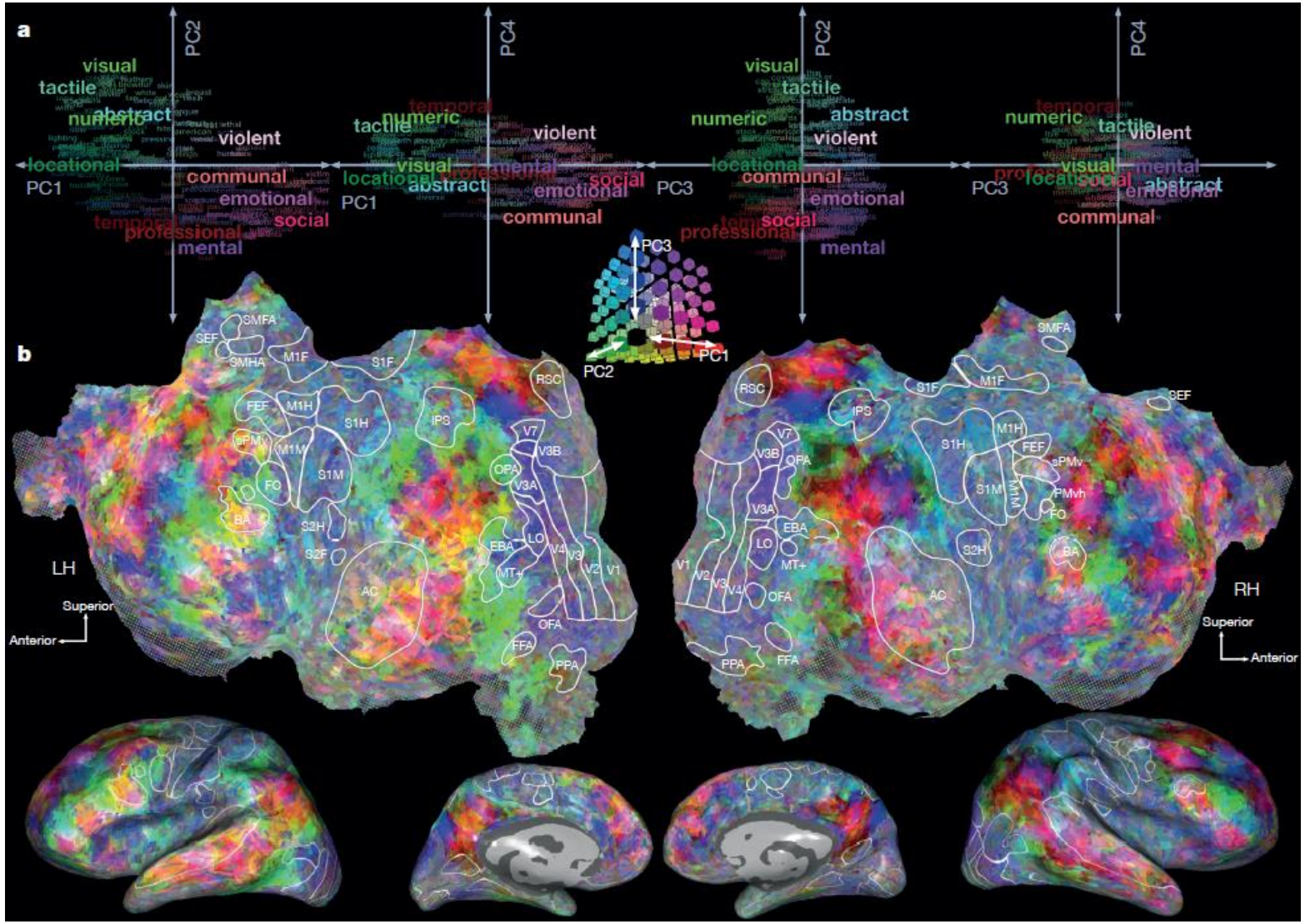
Parametric vs Factorial Designs

Factorial designs may not always be feasible, e.g. in naturalistic paradigms.



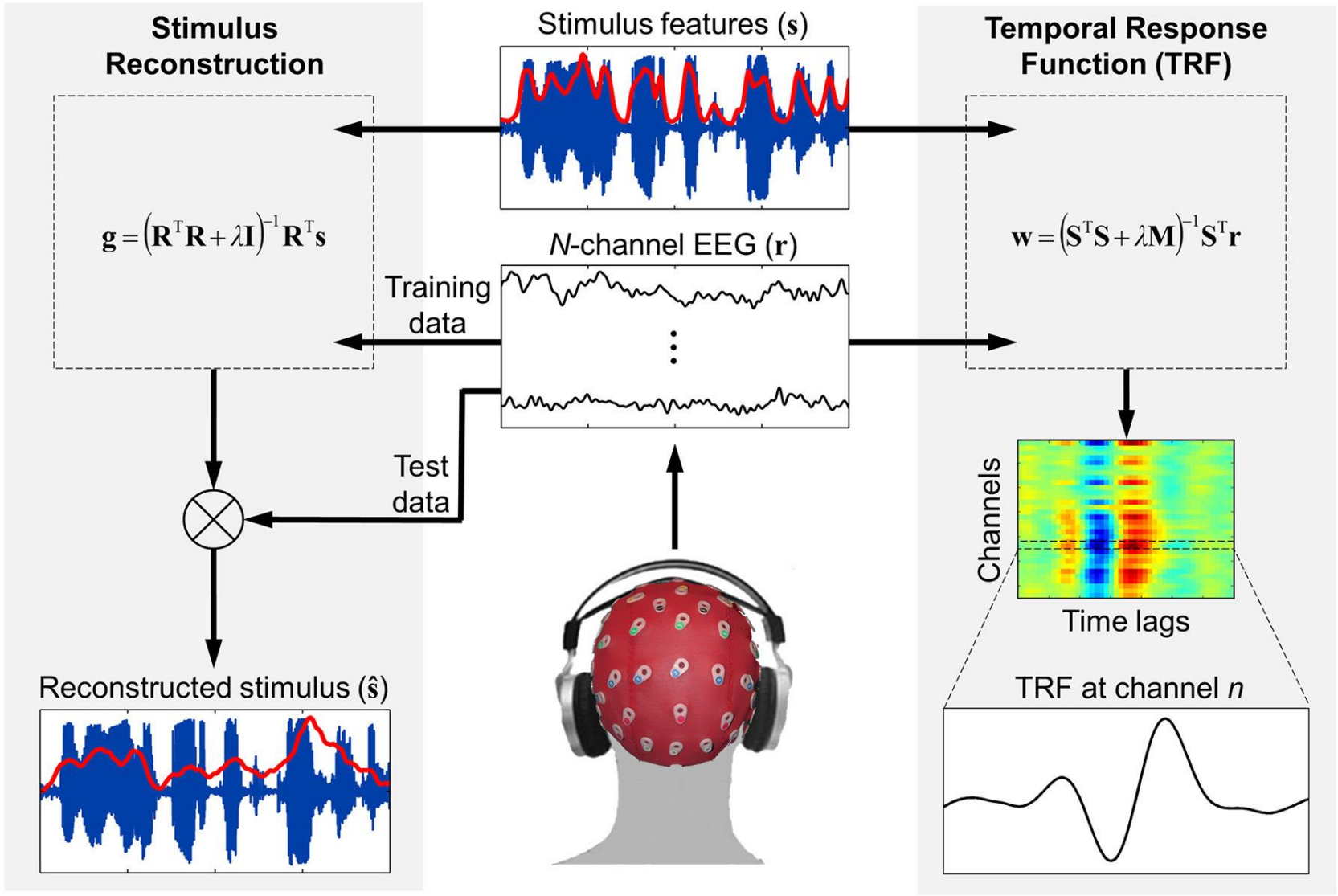
Huth et al., Nature 2016

“Semantic Maps” from natural listening tasks



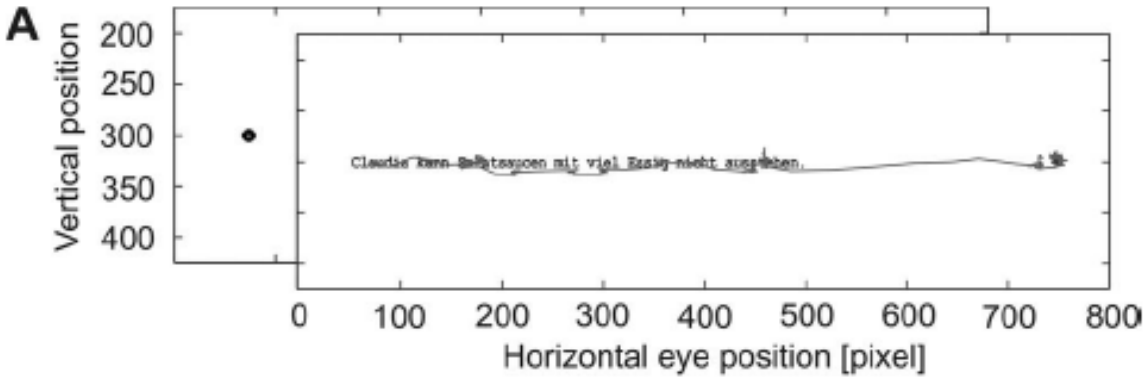
Huth et al., Nature 2016

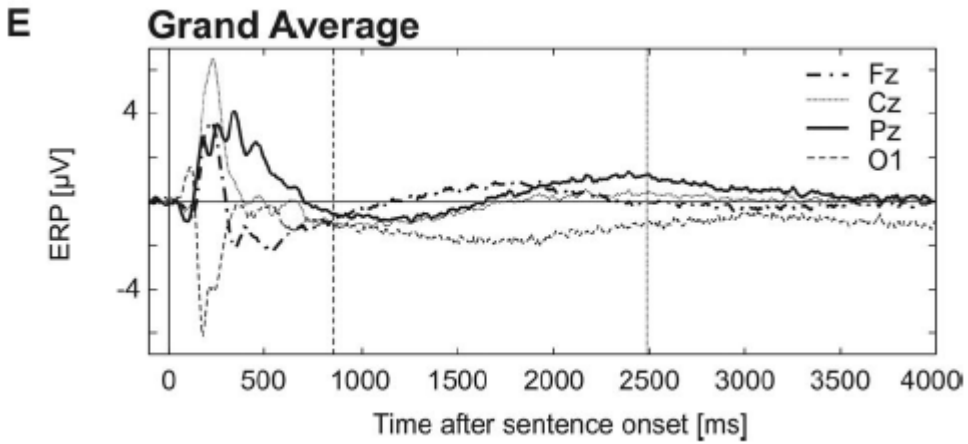
The Multivariate Temporal Response Function (mTRF) Toolbox

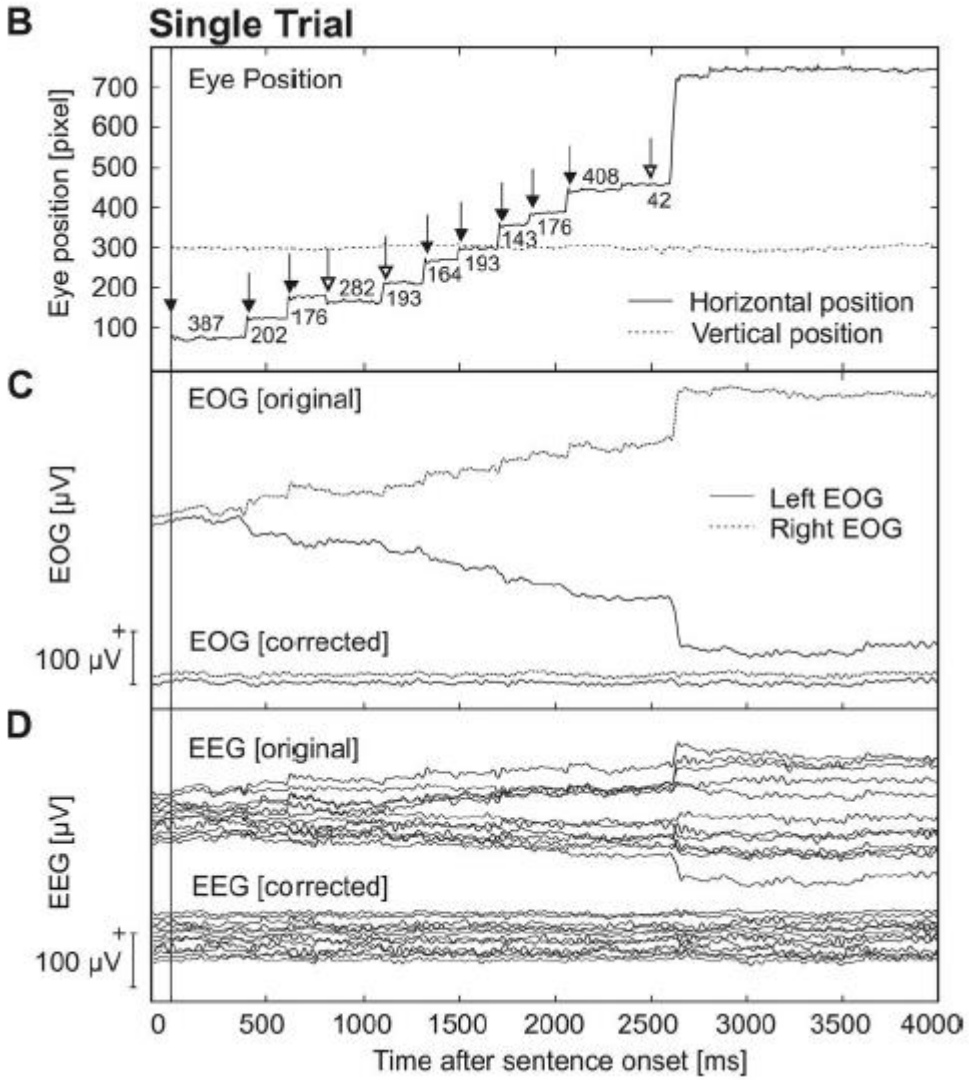


Crosse et al., Front HN16, https://www.frontiersin.org/articles/10.3389/fnhum.2016.00604/full

EEG with eye movements

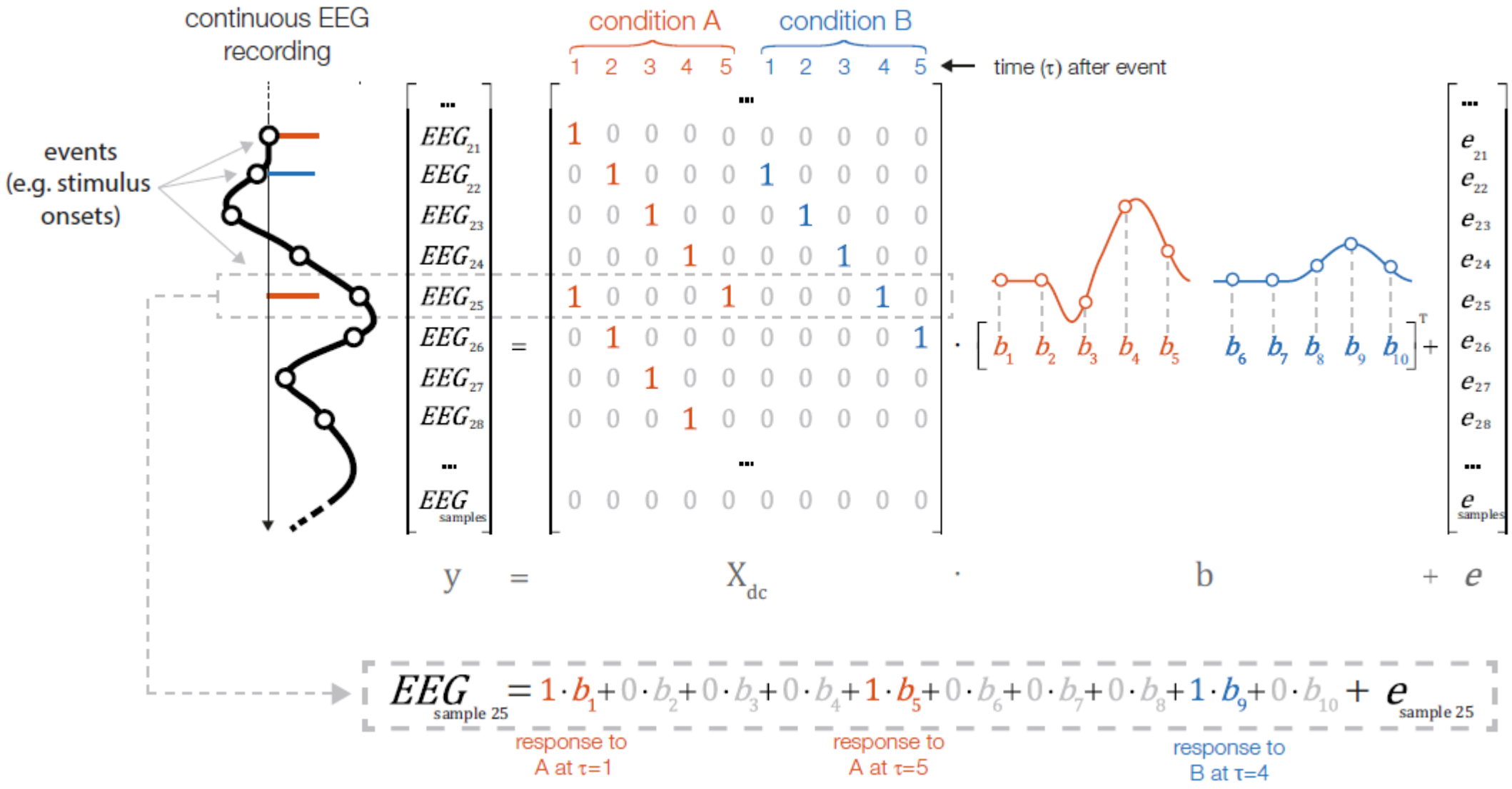






Dimigen, JEP-G 2011, https://pubmed.ncbi.nlm.nih.gov/21744985/

Deconvolution of EEG signals – UNFOLD toolbox



Ehinger & Dimigen, PeerJ 2019, https://www.unfoldtoolbox.org

Unfortunately…

1. Polarity of effects (betas) is harder to infer when applied to signed data (e.g. ERPs). For example, a positive beta value for a negative ERP (e.g. “N1 peak”) reflects smaller amplitude with increasing values.

2. Most higher-level analysis methods such as connectivity and decoding are (currently) designed for factorial designs.

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Thank you