Applying UnfoldSim.jl, a new simulation toolbox for event-related time series, to show power advantages of the linear mixed model

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Event-related designs are the most common study design in neuroscience, as they allow relating neural activity to experimentally controlled stimulation. The resulting data is typically a multivariate time-series, which is segmented by the temporally synchronized events and finally averaged to remove "noise" activity that is uncorrelated to the stimulus onset.

Surprisingly, only few simulation tools exist for such data, most notably for EEG data, the SEREEGA [1] MatLab toolbox. While providing many features, it lacks certain aspects we are strongly interested in: between-subject variability, simulating continuous and not segmented data and using arbitrary signals, modulated by e.g. linear and non-linear covariates.

To complement the current ecosystem, we present UnfoldSim.jl [2]. It enables researchers to simulate continuous-time model-based event-related data, with arbitrary event-responses. The toolbox is very modular and allows the users to easily replace any of the pre-specified modules with their own. Instead of simulating multi-trial EEG signals with pink noise, one could simulate multi-*subject* pupil responses with autocorrelated noise. We provide documentations and tutorials, example and interactive demos, that allow the users to immediately recognize the impact of their experiment design parameters. For an example visit the interactive UnfoldSim demo.

For this project, to provide a more complex demonstration of the toolbox, we systematically simulated data and analyzed them with the traditional two-stage approach of averaging effects for each subject, then calculating a t-test

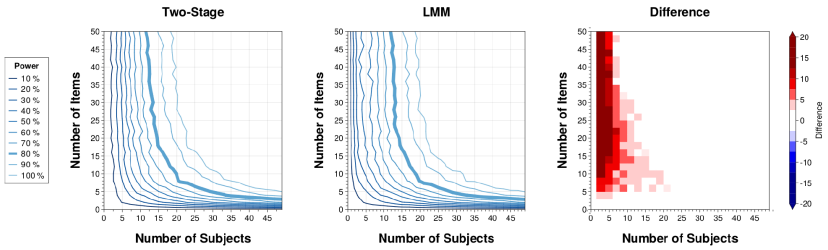

Figure 1: Subject-Trial Power contours of two-stage and linear mixed model simulations. Last row depicts the difference, red shows an advantage of the linear mixed model

across subjects, but also by directly calculating linear mixed models on the full dataset. The promise is, that linear mixed models outperform the two-stage approach, especially when data is scarce, imbalanced, or when so-called item effects occur.

Preliminary results show that for models without item effects and in balanced data, we demonstrate indeed, that the mixed model outperforms the two-stage model, but only in a very limited parameter regime, when the number of subjects or the number of repetitions are small, (Figure 1).

References

[1] Krol, Laurens R., et al. "SEREEGA: Simulating event-related EEG activity." (2018) *Journal of neuroscience methods 309*

[2] Ehinger Benedikt, Lips Luis, Schepers Judith "UnfoldSim.jl v.0.1.1" (2023) `https://github.com/unfoldtoolbox/UnfoldSim.jl`