Having your cake and eating it too: Flexibility and power with mass univariate statistics for ERP data

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Introduction

- ERP studies generate large amounts of data across time and space. Statistical analyses in the ERP literature often do not sufficiently address the multiple comparisons problem that this creates.[1]
- ERP researchers face a catch-22: pre-specifying spatial and temporal ROIs requires knowing where effects will appear, but choosing analysis parameters based on the observed data inflates Type I error rate.

Mass Univariate Statistics

- Conduct univariate analysis at all or many electrodes/time points; apply multiple comparisons correction.[2]
- Some barriers to widespread use in ERP research:
  - Not implemented for factorial designs
  - Perceived to sacrifice power

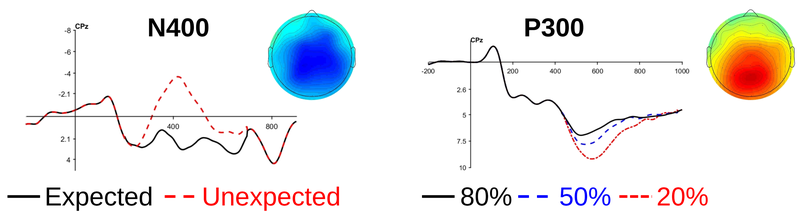
Factorial Mass Univariate Toolbox (FMUT)

MATLAB GitHub Scan me

- Free and open source MATLAB toolbox.
- Extends the Mass Univariate Toolbox[2] to a wide range of factorial ANOVA designs.
- Implements cluster mass, F_{max},, and false discovery rate (FDR) based corrections.
- https://github.com/ericcfields/FMUT/releases

Power Simulation Methods

- Real EEG noise obtained by subtracting condition average from each trial in a group of 48 subjects completing AX-CPT task.
- Real ERP effects from lab studies.



- Simulation procedure
  - Randomly select 24 subjects
  - Randomly select 20 noise trials for each experimental condition
  - Average noise trials and add ERP effect
  - Conduct mass univariate analysis across time window & spatial ROI of interest
  - Repeat 2,500 times
- Power: proportion of simulated studies showing a significant effect at any time point/electrode.

Discussion

- With strong a priori assumptions, mass univariate approaches had better power than traditional mean amplitude analyses.
- As spatial and temporal assumptions are relaxed, mass univariate approaches show modest reduction in power.
- Cluster mass test performs best for broadly distributed effects (e.g., N400 & P300); F_{max} performs best for focal effects (e.g., P1).
- **For many or most research questions, mass univariate statistics will provide the best balance of flexibility, Type I error control, and power.**

References

1. Luck, S. J., & Gaspelin, N. (2017). How to get statistically significant effects in any ERP experiment (and why you shouldn't). *Psychophys*, *54*.
2. Groppe, D. M., Urbach, T. P., & Kutas, M. (2011). Mass univariate analysis of event-related brain potentials/fields I: A critical tutorial review. *Psychophys, 48*.

Results

SIMULATION PARAMETERS			POWER			
Effect	Time Window	Electrodes	mean amplitude	cluster mass	F_{max}	FDR
N400	300 - 500	centroparietal ROI	0.76	0.82	0.77	0.68
N400	200 - 600	full 32	0.47	0.81	0.68	0.63
N400	0 - 1000	full 32	0.16	0.69	0.57	0.49
P300	500 - 750	centroparietal ROI	0.34	0.39	0.34	0.24
P300	400 - 900	full 32	0.10	0.25	0.22	0.14
P300	0 - 1000	full 32	0.07	0.22	0.17	0.10
simulated P1	100 - 150	centroparietal ROI	0.30	0.64	0.99	0.94
simulated P1	0 - 300	full 32	0.05	0.07	0.81	0.70
simulated P1	0 - 1000	full 32	0.05	0.05	0.72	0.54

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