A Cautionary Note on Testing for Interaction Effects in Whole-Brain ANOVA

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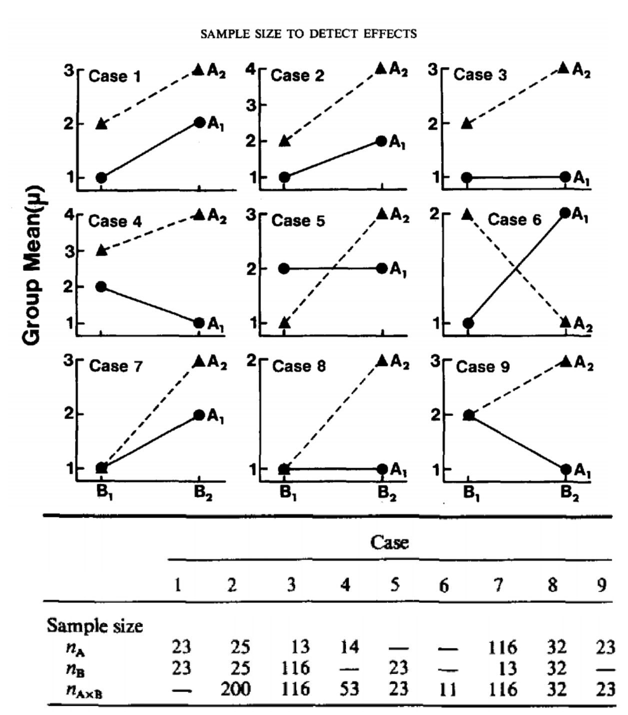
INTRODUCTION

Whole-brain analysis of variance (ANOVA) is a common analytic approach, and researchers are often interested in testing interaction effects.

Of the many patterns than an interaction between two factors can take, disordinal (i.e. crossover) interactions generally require the least amount of power to detect (Wahlsten, 1991).

This fact when combined with mass univariate testing may bias whole-brain ANOVAs towards the detection of crossover interactions, even in cases when the true interaction effect is not disordinal.

Here we present a series of simulations aimed at highlighting this issue.



(Wahlsten,1991)

METHODS

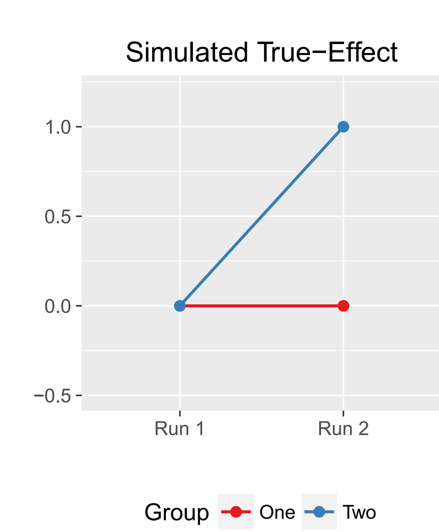
Simulation Set 1

Pure Noise

- 10,000 ANOVAs (2×2) simulated using data randomly sampled from a uniform distribution.
- Both mixed-effects and within-subject ANOVAs were tested.

True-Effect Present

- Simulations were repeated after inserting a known true effect.
- The shape of simulated true-effect is plotted on the right.
- True effect emulates a 2×2 mixed-effects ANOVA comparing two groups at two time points.
- 1000 simulations at each of four levels of SNR and five sample sizes.



Simulation Set 2 - Realistic fMRI Noise & Analysis

FMRI data was simulated using the neuRosim package in R (Welvaert et al., 2011), following the same mixed-effects ANOVA design as the non-fMRI simulations in an event-related design.

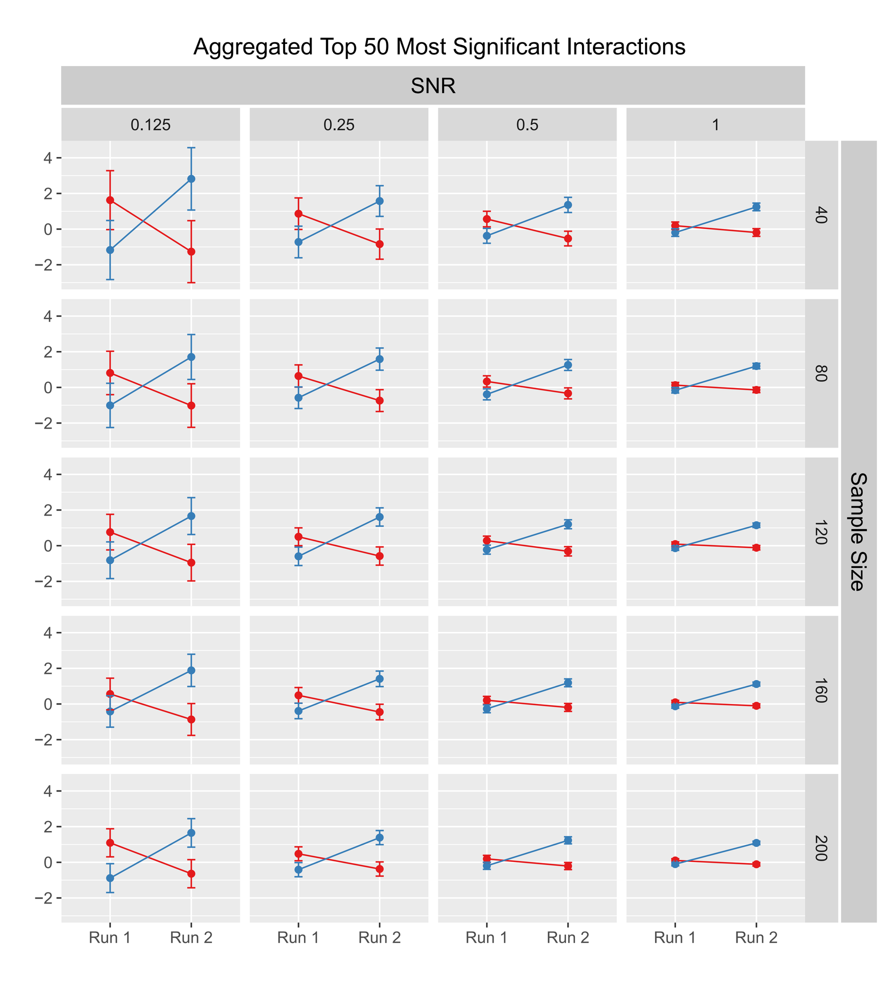
- Contrasting 2 task conditions within each of 2 runs between 2 groups.
- Total N = 200 (n = 100 per group).
- Mixed-source noise SNR = 0.25.
- True-effects planted in 5 ROIs (3mm radius).
- Standard preprocessing and first-level analyses conducted using FSL.
- Group-level analyses conducted in R.

RESULTS

Do crossover interactions disproportionately appear in pure noise?

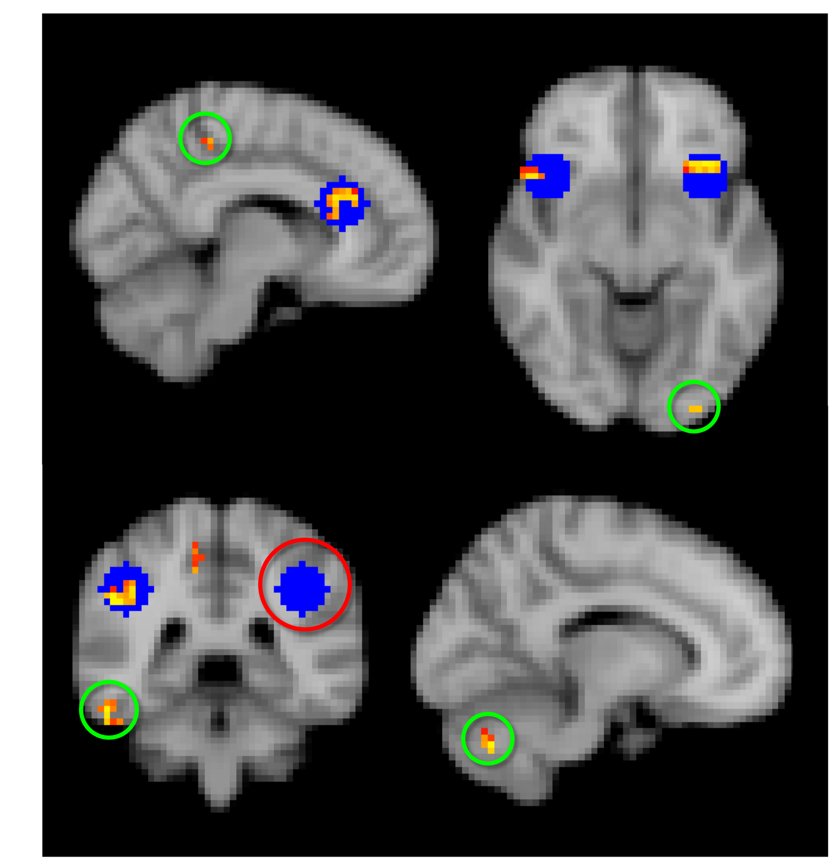
- Crossover interactions dominate results in simulations (n = 10,000) using pure noise data.

Does this bias distort true effects?



- When true effects are present, interactions are more likely to be distorted towards a "crossover-like" pattern at low levels of SNR.
- Larger sample sizes do little to mitigate this bias.

Is this issue present in fMRI data?



- Group-level results are shown at a cluster forming threshold of p = .005 with 10 voxel extent.
- True-effects were recovered in 4 of 5 ROIs, leaving one false negative region.
- False positives were found in 4 clusters outside of the implanted ROIs.
- Crossover effects are prominent within the false positive clusters.
- Although true-effect clusters appear less like crossovers, spurious between-group differences at Run 1 are shown, potentially leading to misinterpretations.

CONCLUSIONS

Results indicate that whole-brain ANOVAs are biased towards the detection of crossover interactions, even in large samples (n = 200).

Spurious crossover interactions occurred more frequently at low SNR.

These results suggest that certain types of interaction effects routinely seen in the behavioral literature may be impractically difficult to detect in whole-brain ANOVAs.

Researchers interested in interaction effects should take extra steps to maximize the design efficiency of their experiments (e.g., favoring block designs over event-related designs).

Constraining the search space with independent regions of interest may reduce both false positives and the distortion of true positives when the true effect is not disordinal.

References

Wahlsten, D. (1991). Sample size to detect a planned contrast and a one degree-of-freedom interaction effect. *Psychological Bulletin*, *110*(3), 587.

Welvaert, M., Durnez, J., Moerkerke, B., Verdoolaege, G., & Rosseel, Y. (2011). neuRosim: An R package for generating fMRI data. *Journal of Statistical Software*, 44(10), 1-18.

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