What is Random Effects Meta-Analysis?

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Introduction

For group fMRI analyses, random effects inferences are essential for drawing conclusions that generalise to the population of subjects studied. In (non-imaging) meta-analysis, random effects models are also regarded as best practice, as they account for random differences among each study's population or methods. However, outside the context of linear regression, the meaning of what exactly is a 'fixed effects' or 'random effects' is ambiguous (Gelman, 2006).

Existing neuroimaging coordinate based meta-analysis (CBMA) methods, Activation Likelihood Estimation (ALE) in particular, report 'random effects' inferences (Eickhoff et al., 2009, Eickhoff et al., 2012), on the basis of a resampling inference method that distinguishes coordinates within a study from those between studies. We perform a set of simulations to study the sensitivity properties of ALE in the presence of varying number of all-noise studies.

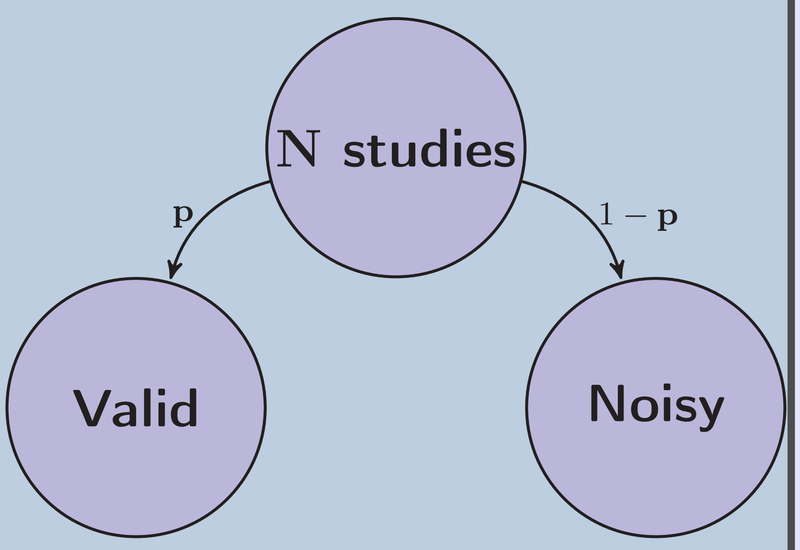
Objectives

Study various aspects of the ALE algorithm:

1. Sensitivity properties
2. Robustness to noise
3. Random effects nature

Simulation study

- Eight true population centers
- Foci normally distributed around population centers
- Each simulated meta-analysis includes:



Parameter Specifications:

- $N = 20, 40, 60, 80, 100$ and 120
- $p = 0, 0.05, 0.1, ..., 0.95, 1$
- $B = 1000$ datasets for each N, p

Power measures considered:

1. Probability at least one center detected
2. Probability all 8 centers detected
3. Mean number of centers detected
4. Mean voxel-wise true positive rate

Noisy studies:

- Foci uniformly drawn from brain mask

Simulation of valid studies

- Each center present in a study with probability 0.8
- Conditional on center being present, the study has:
  - 1 foci with probability 40%
  - 2 foci with probability 35%
  - 3 foci with probability 25%
- Average 14 foci

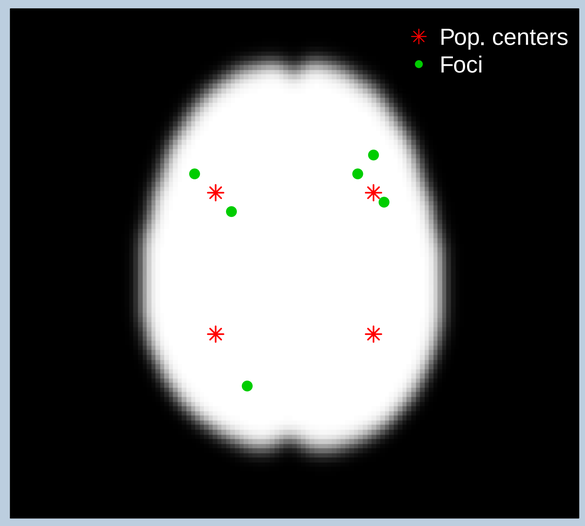


Figure 1: Simulated valid study.

Results

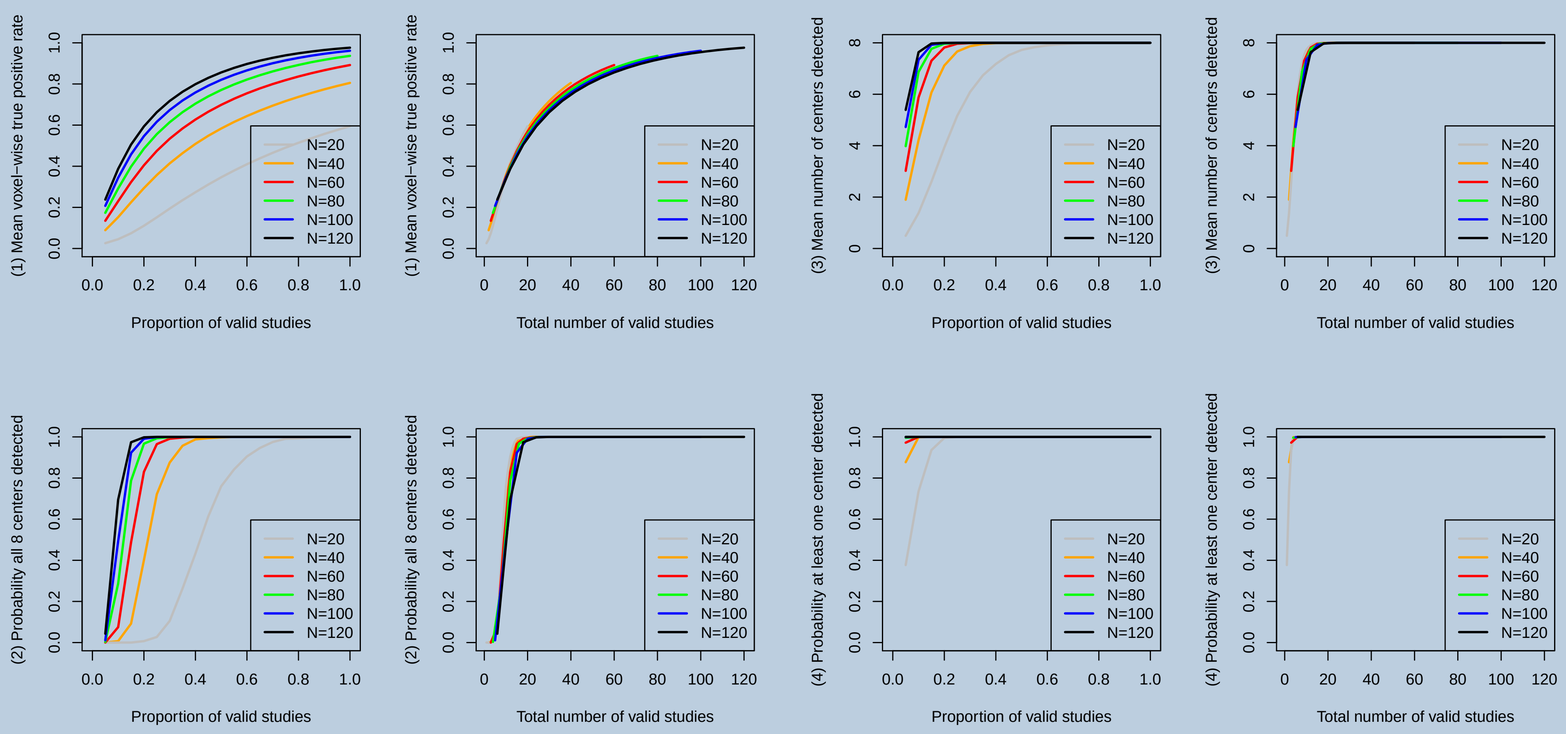


Figure 2: Simulation results.

- All measures of power converge to the maximal values with increasing number of studies
- For given N, power increases with p (columns 1 & 3)
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- For fixed total number of valid studies, pN, lines coincide (columns 2 & 4)

Conclusions

- *Consistency*: sensitivity increases with sample size
- *Robustness to noise*: more noisy studies do not degrade sensitivity
  - Potential drawback: a small proportion of studies can drive inference
  - Fixed effects inference characteristic

Future work

- Randomness in both location & total number of foci can be expressed via spatial Poisson model. At each voxel v (or ROI) total number of foci $K(\mathrm{v}) \sim \mathrm{Pois}\,(\mu(\mathrm{v}))$
- Study random effects α_i can be incorporated:

$$\mathbb{E}K(\mathrm{v}) = \mu(\mathrm{v}) + \alpha_i,\ \alpha_i \sim \mathcal{N}(0, \tau^2)$$

References

- S. Eickhoff et al. (2009). *Human Brain Mapping*, 30(9), 2907-26.
- S. Eickhoff et al. (2012). *NeuroImage*, 59(3), 2349-61.
- A. Gelman (2005). *The Annals of Statistics*, 33(1), 1-53.

Acknowledgements

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