Prospective power estimation for peak inference with the toolbox neuropower.

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Introduction

- There is increasing concern about statistical power in neuroscience research: an underpowered study has poor predictive power (Ioannidis, 2005).
  ⇒ **A power analysis is a critical component of any study**
- Power analyses for fMRI are difficult: need to specify magnitude, spatial extent and location of a hypothesized effect.
- We present a simple way to characterize the spatial signal in a fMRI study, and a direct way to estimate power based on an existing pilot study.
- Based on estimates of the volume of the brain that is activated and the average effect size in these active regions, power can be calculated for a given sample size, search volume and smoothness.

Power estimation procedure

- We start from peaks and their uncorrected p-values in a group level analysis. We estimate π_1, proportion of peak p-values thare are non-null, as described in Durnez, Moerkerke & Nichols (2014).
- Assuming an exponential null distribution for peak values (Friston, 2007) and a truncated normal distribution (truncation at excursion threshold u) for the alternative distribution, the distribution of peak values can be written as a mixture:

$$f(z^u|\pi_0,\mu_1,\sigma_1,u) = (1-\pi_1)\underbrace{u\exp(-u(z^u-u))}_{\text{null distribution}} + \pi_1 \underbrace{\frac{\frac{1}{\sigma_1}\varphi\left(\frac{z^u-\mu_1}{\sigma_1}\right)}{1-\Phi\left(\frac{u-\mu_1}{\sigma_1}\right)}}_{\text{alternative distribution}}$$

- μ_1 and σ_1 are estimated using maximum likelihood, where μ_1 is the expected peak height in activated regions.
- Power can be estimated for a given threshold t as $P(T > t|H_a)$ with T the T-statistic of the peak.

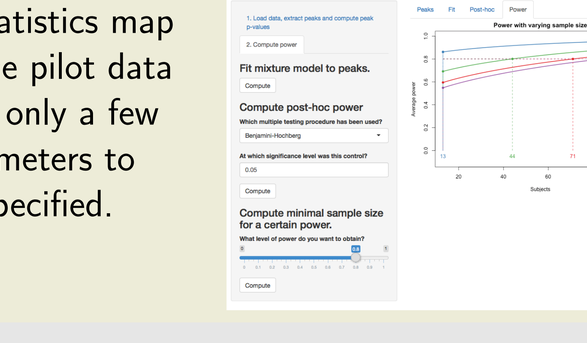
Validation with simulations

500 full-brain datasets with smooth Gaussian noise (3 voxels) superimposed with activation in 4 foci.

Estimation of π_1 and μ_1 in a sample with $n = 10$:

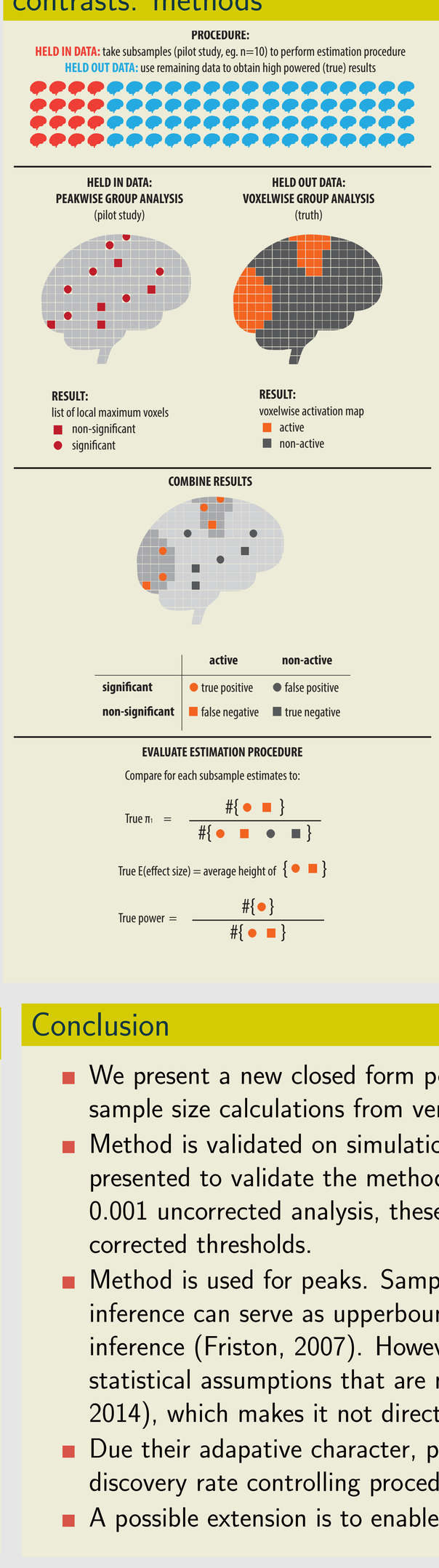
Prevalence of activation (π_1) tends to be underestimated for low effect sizes and over-estimated for large effect sizes, while effect size is generally well estimated except for very small effect sizes.

Power estimation for uncorrected thresholding $p < .001$:



For large effect sizes we accurate estimate power curves.

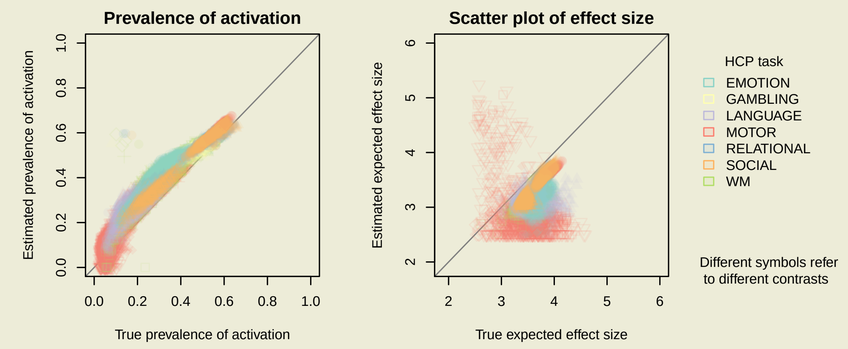
Validation with 47 unique HCP contrasts: methods



Validation with 47 unique HCP contrasts: results

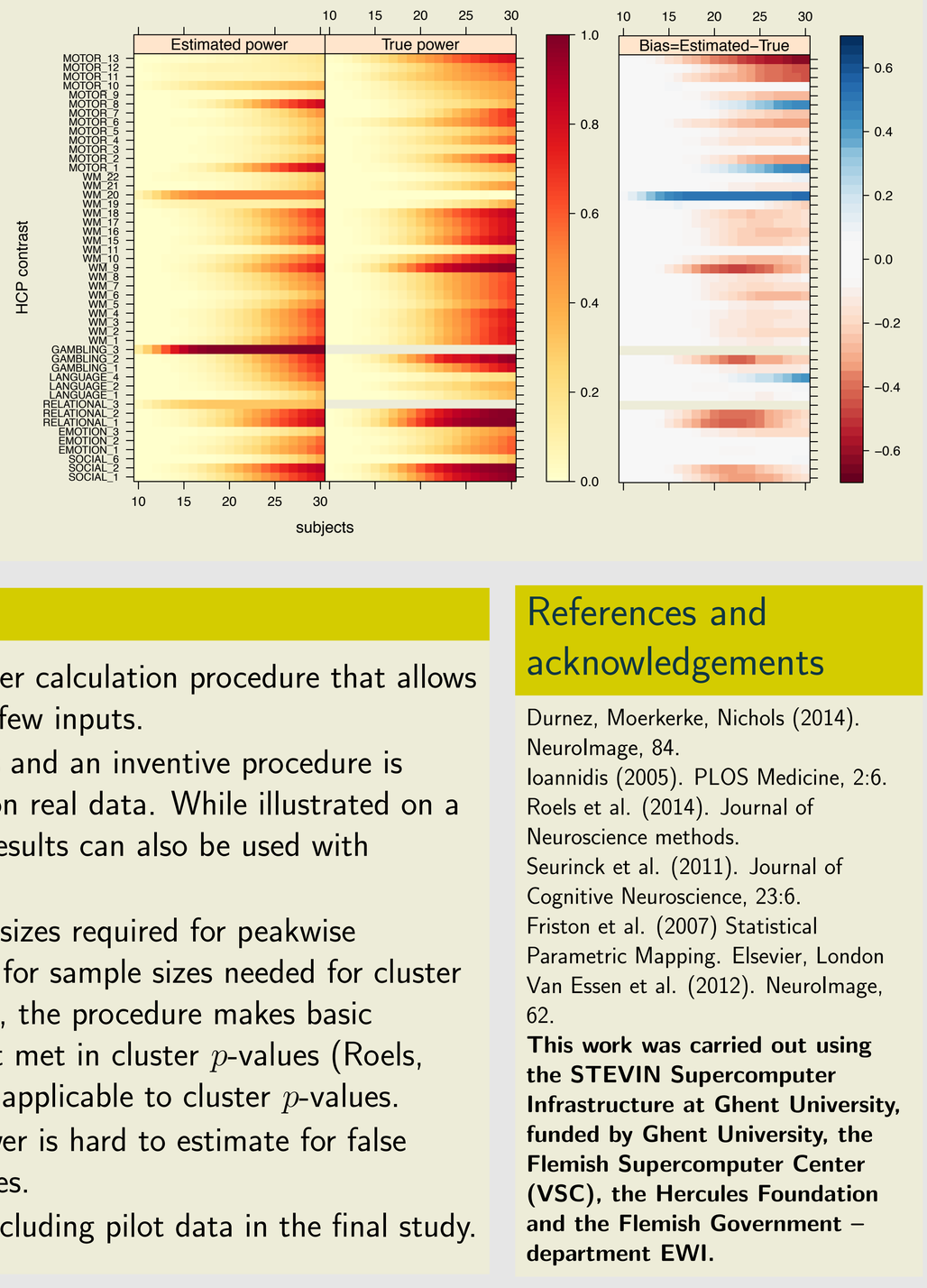
Estimation of π_1 and μ_1 in a sample with $n = 10$:

Estimates are corrected for possible errors in the definition of 'truth'



Estimation of power in a sample with $n = 10$ with uncorrected threshold at $p < .001$:

- Most contrasts range from 0% to 100% power
- For most contrasts, bias ranges from 0% to -10% (underestimation)



https://neuropower.shinyapps.io/neuropower

Online application allows to easily apply this method by uploading the T-statistics map of the pilot data with only a few parameters to be specified.

Conclusion

- We present a new closed form power calculation procedure that allows sample size calculations from very few inputs.
- Method is validated on simulations and an inventive procedure is presented to validate the method on real data. While illustrated on a 0.001 uncorrected analysis, these results can also be used with corrected thresholds.
- Method is used for peaks. Sample sizes required for peakwise inference can serve as upperbound for sample sizes needed for cluster inference (Friston, 2007). However, the procedure makes basic statistical assumptions that are not met in cluster p-values (Roels, 2014), which makes it not directly applicable to cluster p-values.
- Due their adapative character, power is hard to estimate for false discovery rate controlling procedures.
- A possible extension is to enable including pilot data in the final study.

References and acknowledgements

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