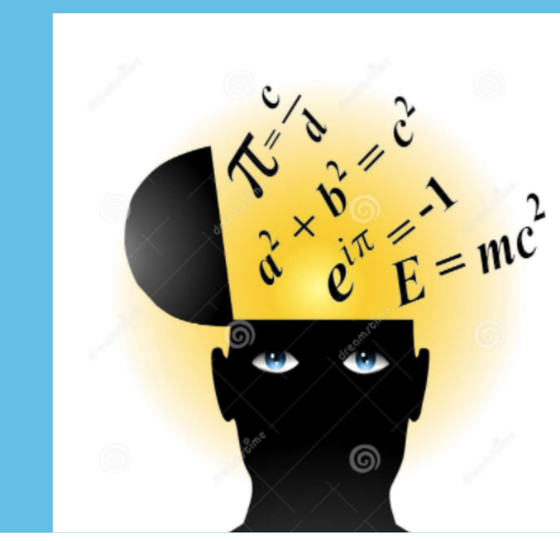
Computational Parametric Mapping for Neurometric Power Law Testing and Analysis for Experimental Design Efficiency



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Introduction

- This experiment will focus on developing simulations for fMRI data that serve as ground truth for Computational Parametric Mapping.
- It will also evaluate the statistical efficiency of different experiment designs for inferring parameters across parameter space.

Background

- fMRI
- Neurometric power law
- Model Based fMRI.
- General Linear Model: Y = Xβ + Ɛ
- CPM: Bayesian statistics:

Stevens Power Law

$$\psi(I) = kI^a,$$

$$p(Y_v|\theta) = \int p(Y_v|\beta, \sigma^2, \theta)\, d(\beta, \sigma^2)\,(P)$$

$$p(\theta|Y_v) = \frac{p(Y_v|\theta)\, p(\theta)}{p(Y_v)}$$

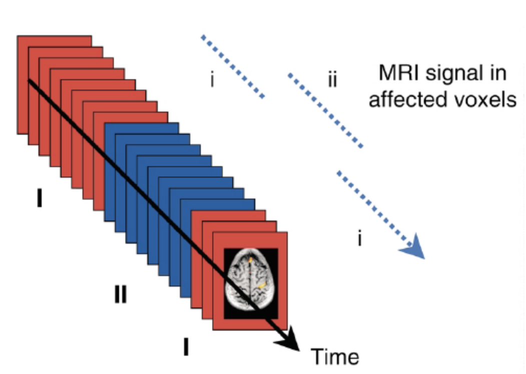
Experiment Design:

- Categorical Design: Cognitive subtraction, Task A - Task B
- Parametric Design: Varying the stimulus-parameter of interest, and relating BOLD to this parameter.

a. Linear

b. Non-linear: Quadratic/ cubic etc.

c. "Data Driven": "Neurometric functions.

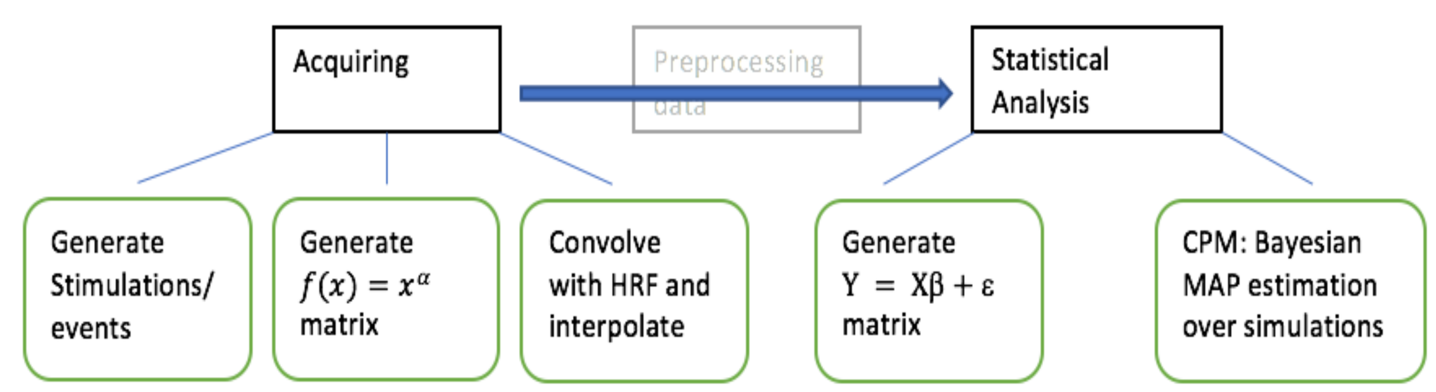


Aim:

1. To simulate how well CPM can infer parameters of neurometric encoding.
2. How to design efficient neuroimaging experiments that probe neurometrics

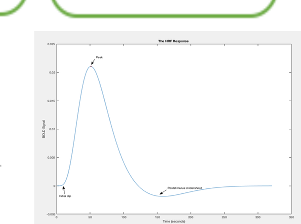
Methods

Length of the fMRI study	Number of Scans	Scan Time Interval	Number of Events	Event Time Interval	Magnitude of Jitter	Number of Simulations
40min (2400 secs)	800 scans	Every 3 seconds	85	Every ≈ 28.235 seconds	(0,10), randomly generated	1000
			Round $\frac{2400}{\text{No. Periods}}$	A list of periods: [1, 2, 3, …, 60]	[0, 0.2 × Period, 0.4 × Period]	

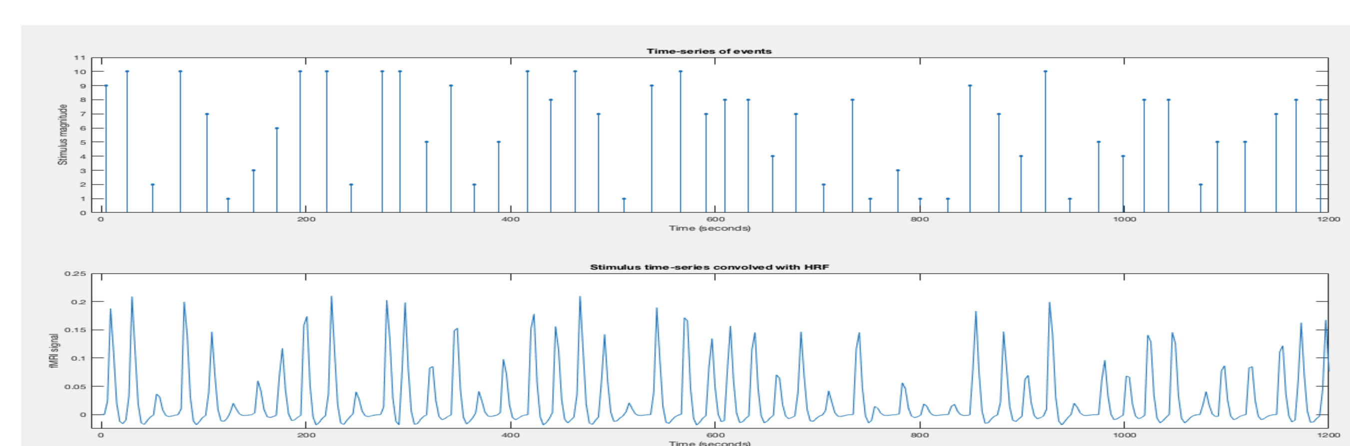


For $f(x) = x^\alpha$, where K = 1

For Y = Xβ + Ɛ, where β = 1



$$\begin{pmatrix} y_v(1) \\ y_v(2) \\ y_v(3) \\ \vdots \\ y_v(800) \end{pmatrix} = \begin{pmatrix} x_1(1) & x_\alpha(1) \\ x_1(2) & x_\alpha(2) \\ x_1(3) & x_\alpha(3) \\ \vdots & \vdots \\ x_1(800) & x_\alpha(800) \end{pmatrix} \begin{pmatrix} 1 \\ \beta_\alpha \end{pmatrix} + \begin{pmatrix} \epsilon(1) \\ \epsilon(2) \\ \epsilon(3) \\ \vdots \\ \epsilon(800) \end{pmatrix}$$



Conclusion

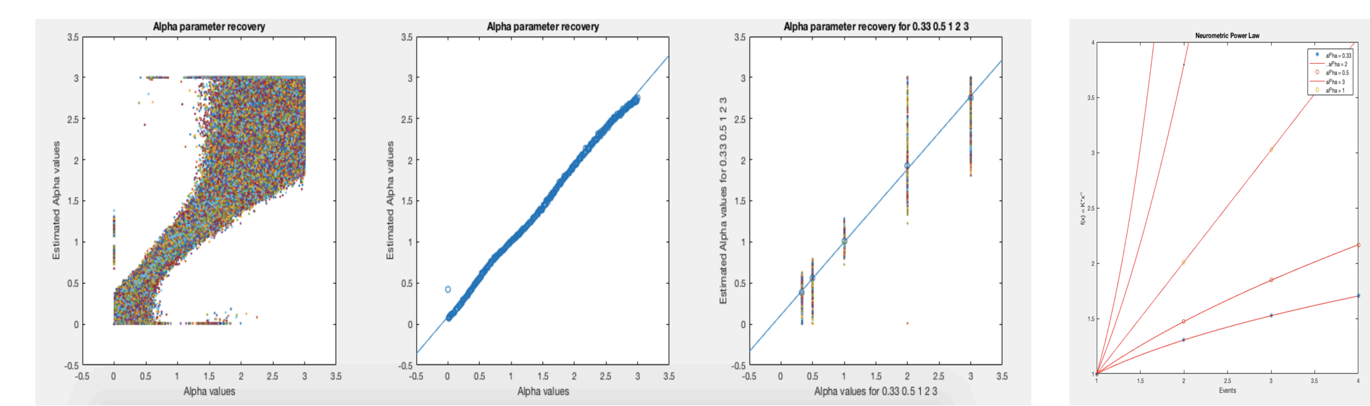
- The predicted neurometric power law line has suppressing, inflating and no effect for alpha values of interest.
- CPM can allow for accurate decoding of computational variables, but greater simulation variation for alpha values after 1.5.
- Experiment design efficiency appears at larger jitter involved with stimulation period shown to be almost invariant.
- Future study could investigate scaling effect β and the multiplicative number K to see their effects on experiment design efficiency.

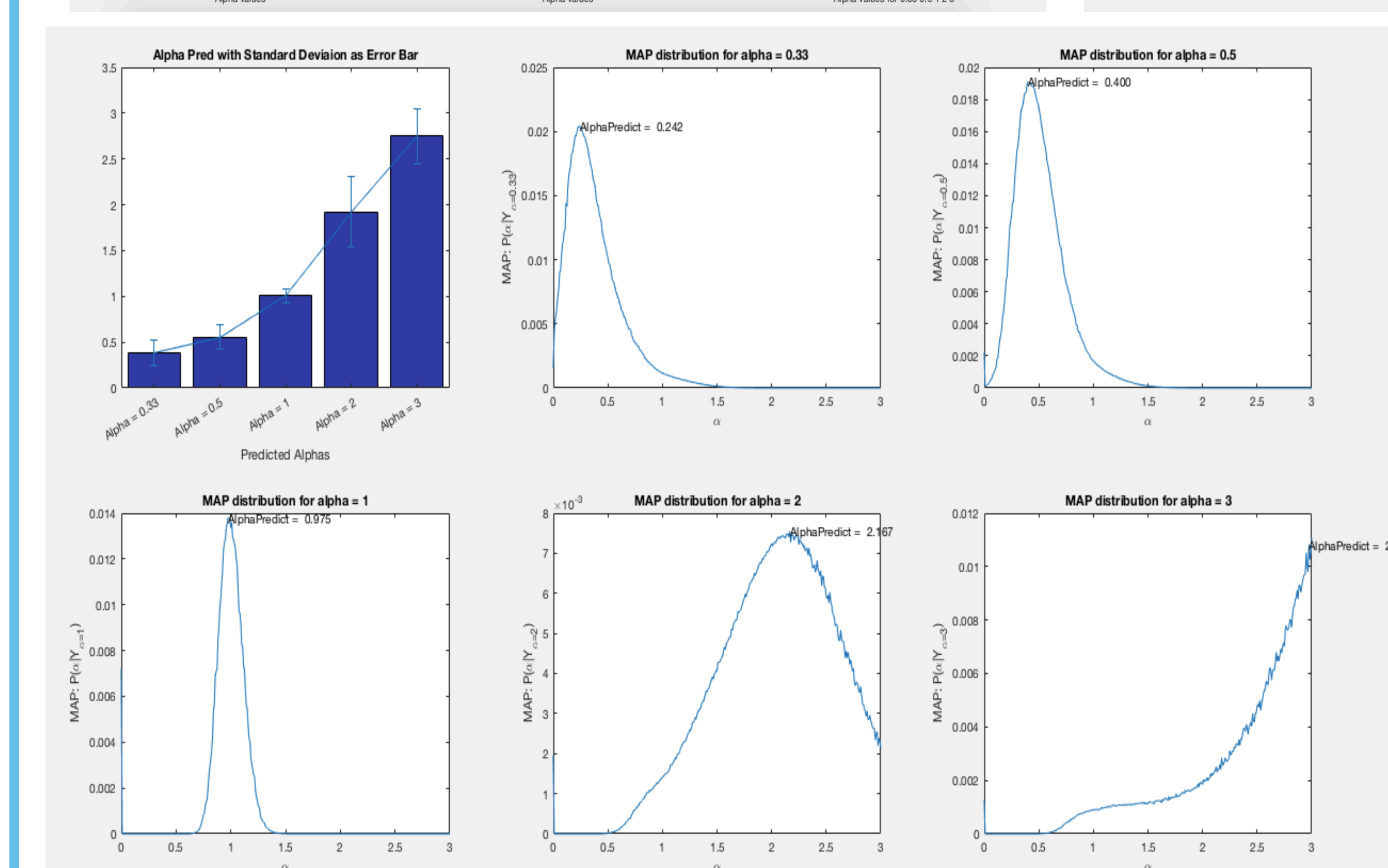
Results

- MAP estimates over alpha space for exemplar values of alpha, showing CPM can decode alpha accurately
- The heat maps showing how to design efficient experiments, with the best recover at alpha = 1.5.

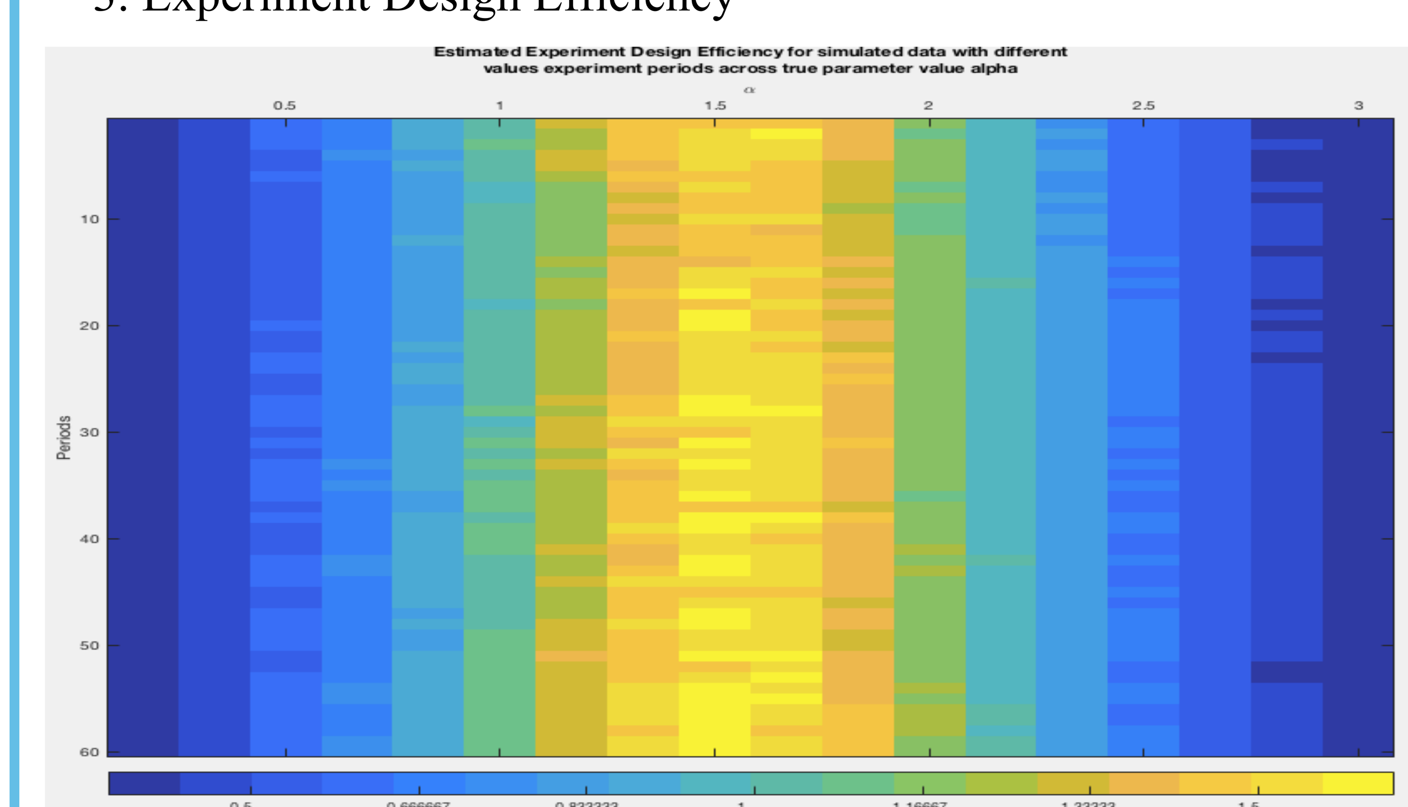
1. Alpha Parameter Recovery

2. Neurometric Power Law





3. Experiment Design Efficiency



References

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