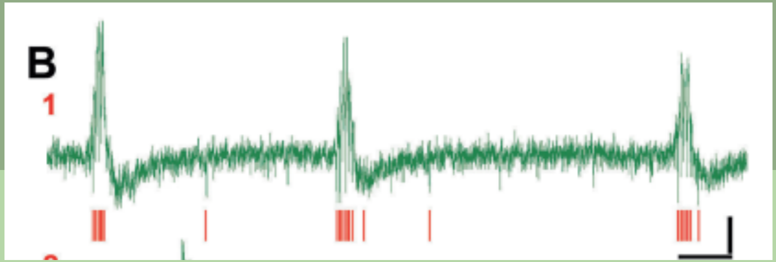
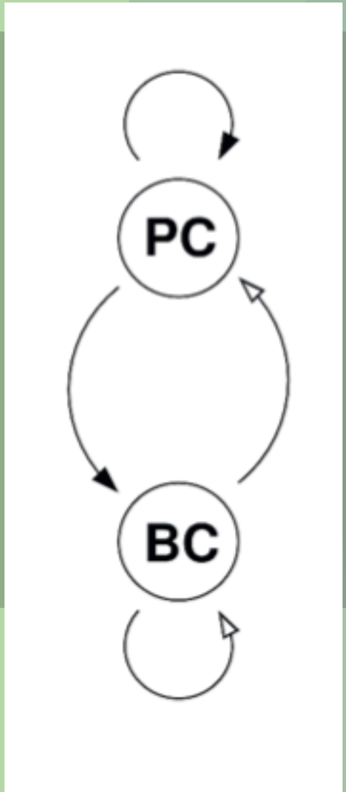
RES 2: Brain Networking

A Very Quick Intro to Brain Networking

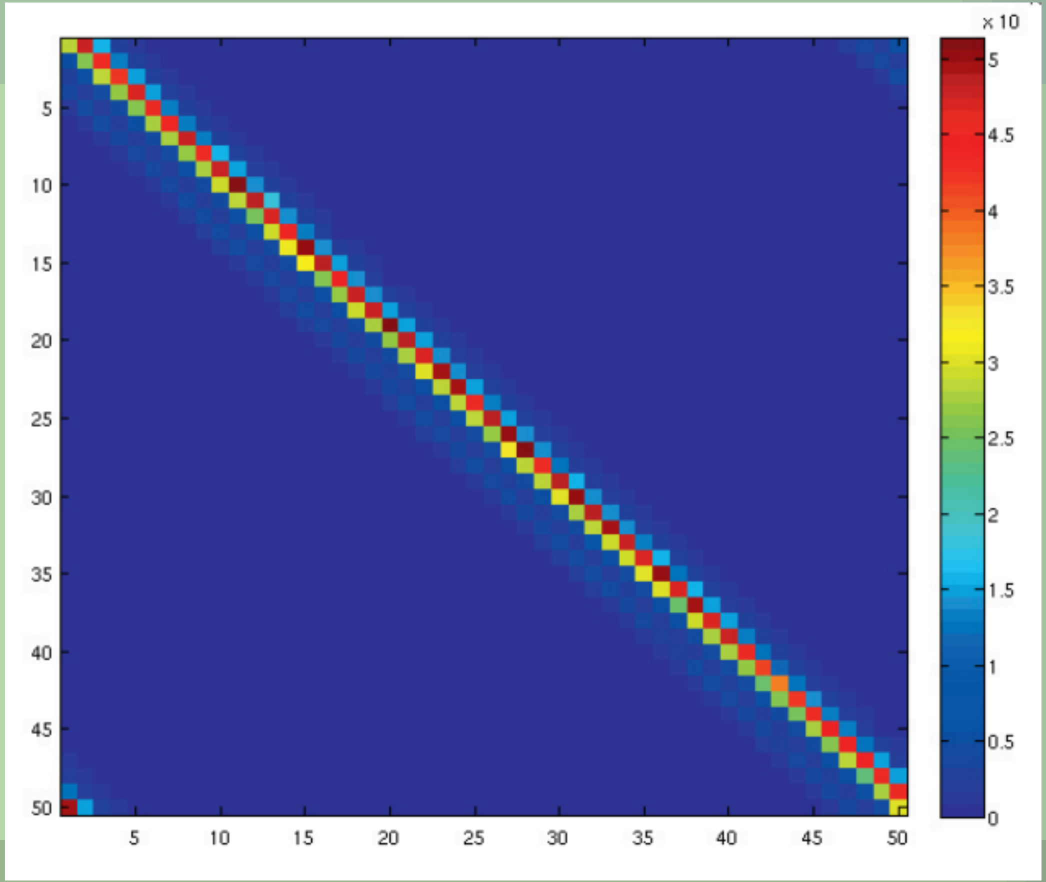
PC(pyramidal cells): activate the neural activity
BC(Fast-spiking basket cell): inhibit the neural activity



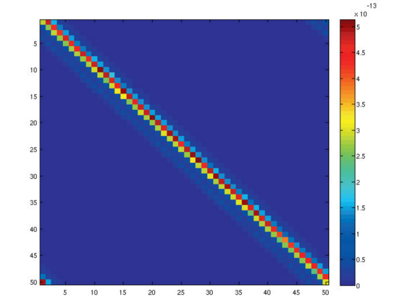
Sharp Wave Ripples (SWR)

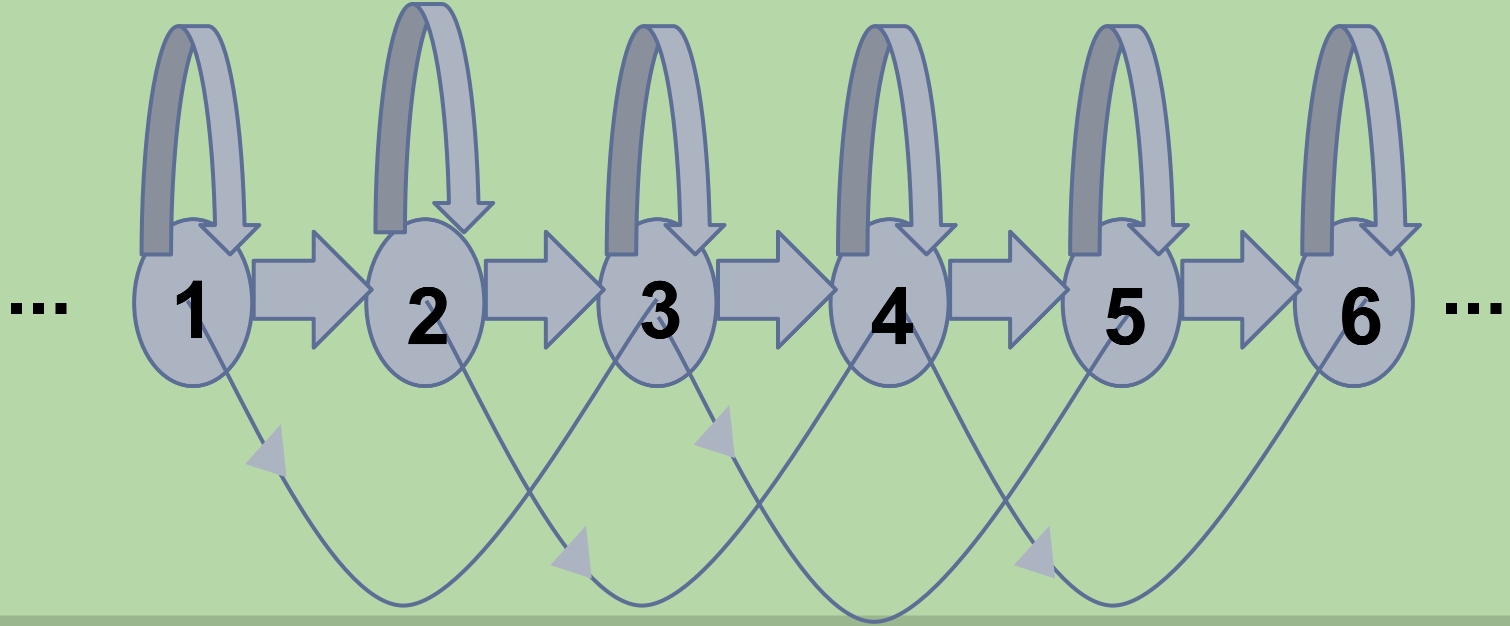


Weighted Pyramidal Cell Adjacency Matrix



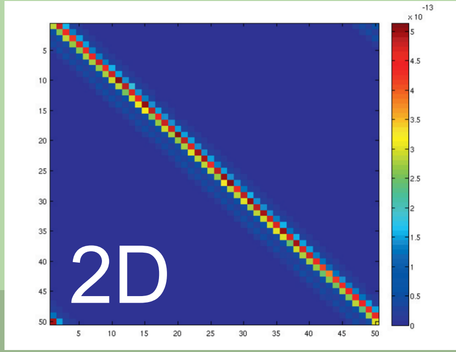
The block structure

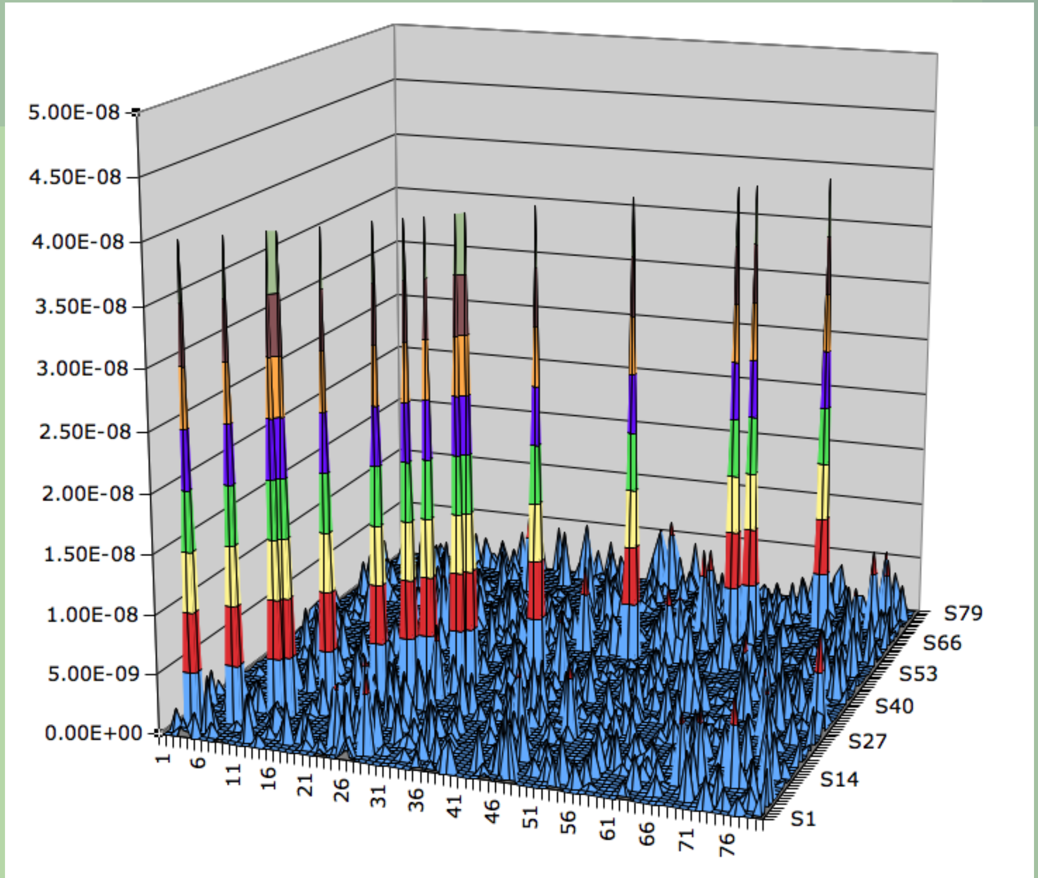




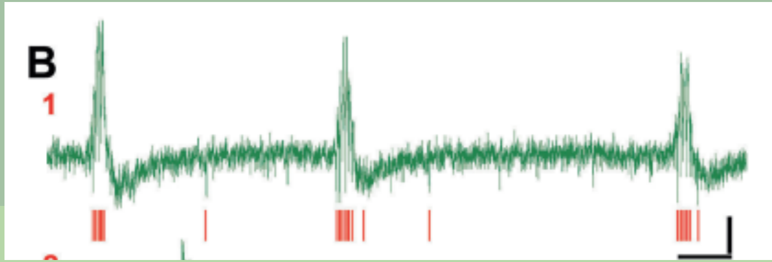
3D, One Block Displayed Visually

Weighted Pyramidal Cell Adjacency Matrix

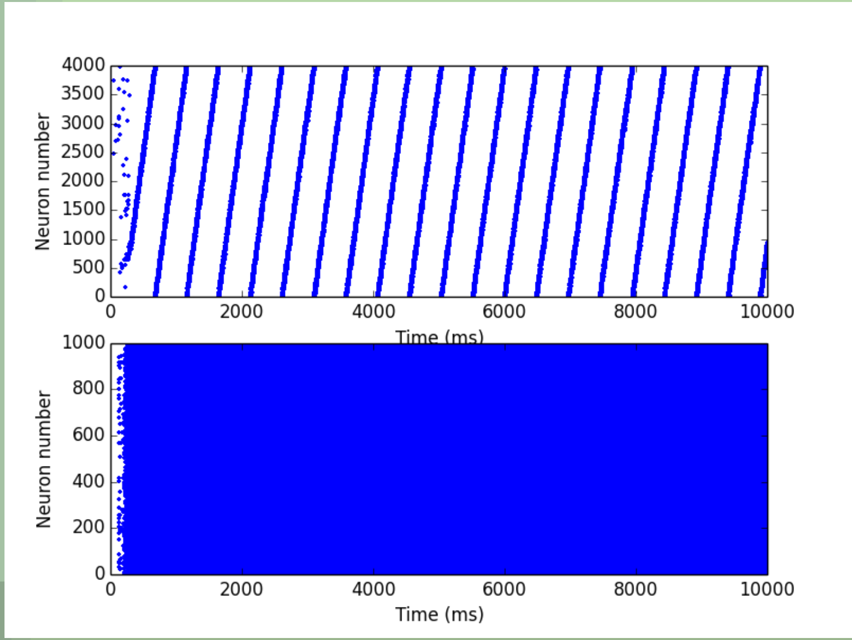


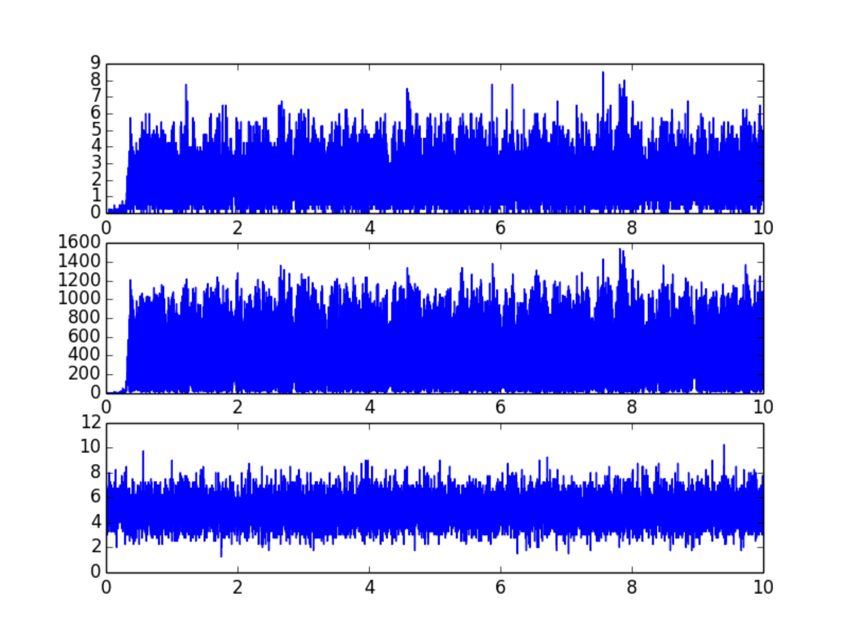


Original Block

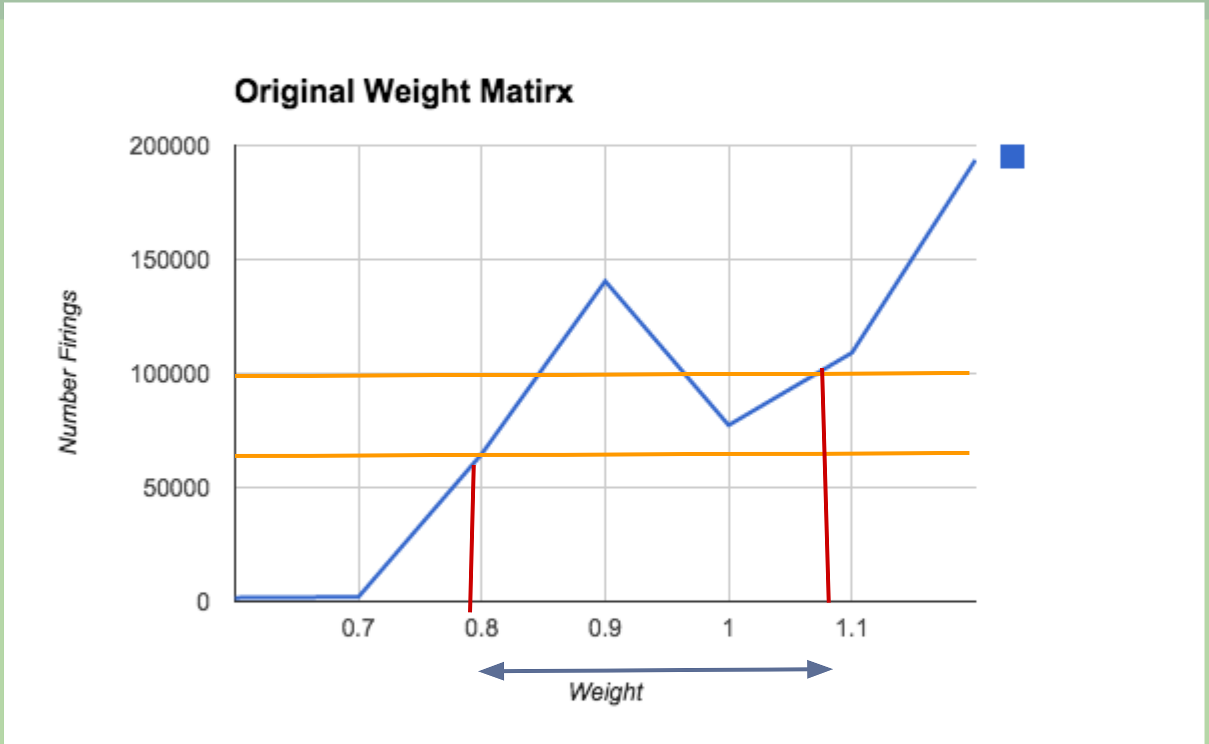


Large- scale model of the wmx produces spontaneous **SWR**s.



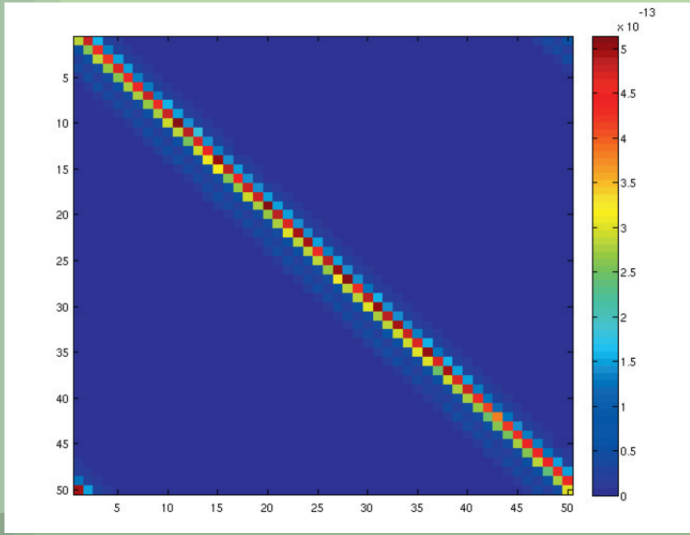


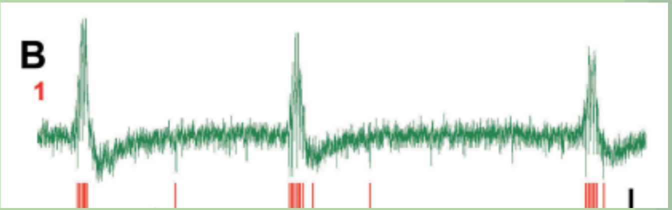
Sensitivity of Original WMX



Primary Question:

What structure of PC neuron connections is necessary to produce SWR patterns?





Outcomes: Outside the Blocks

- Total Randomization
- “Boring”
- As expected, perturbing outside the 80 x 80 blocks results in a nonfunctioning brain (no SWR)

Techniques: Markov Chain Monte Carlo

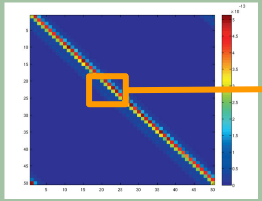
- random walk Monte Carlo method
- approximate uniform distribution or other distributions
- develop a score for the difference between original matrix and expeced matrix.

Techniques: Simulated Annealing

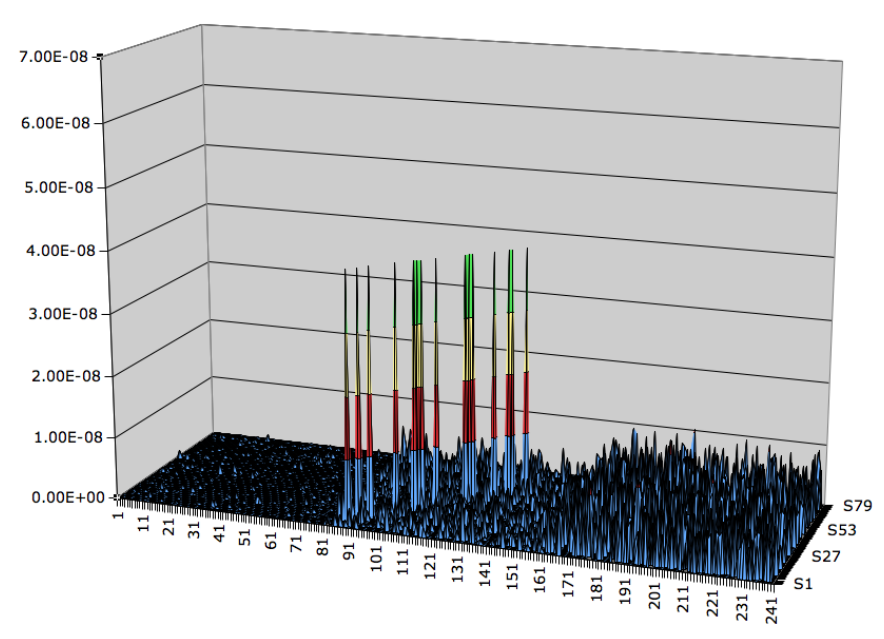
- search for the local **maximal variance** of weights using the stochastic search
- Define the score as Statistical Variance

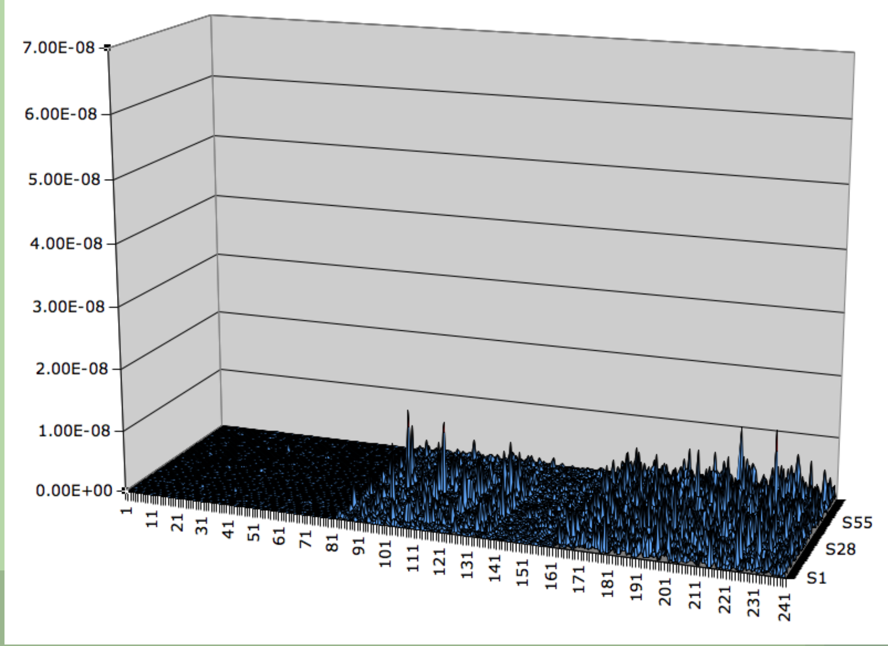
$$\text{Variance} = \frac{1}{n}\sum_{x_i}^{n}(x_i - \bar{x})^2$$

Visual Outcomes



Shuffle Within Blocks:





Randomization Techniques: Swaps

Generalized swap:

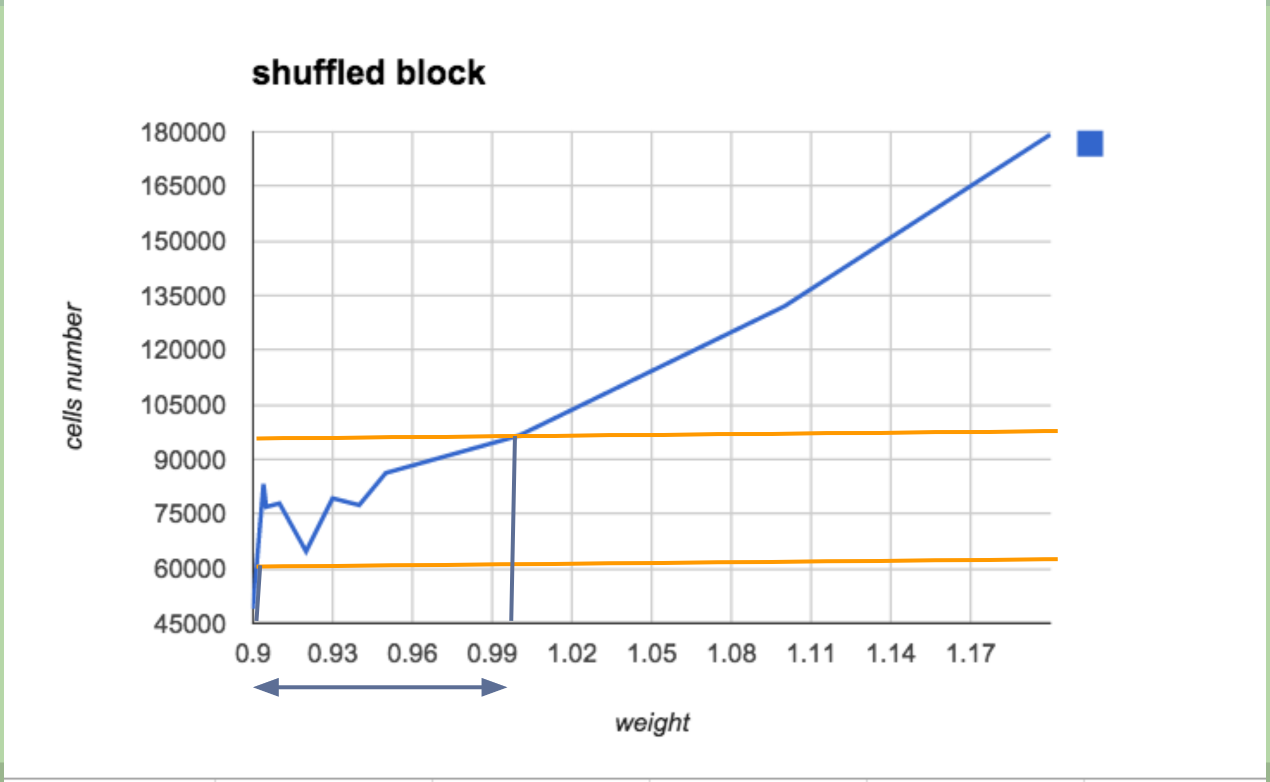
$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \longrightarrow \begin{pmatrix} a - w & b + w \\ c + w & d - w \end{pmatrix}$$

Restricted swap:

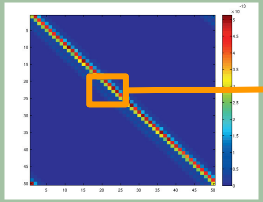
$$\begin{pmatrix} a & b \\ b & a \end{pmatrix} \longrightarrow \begin{pmatrix} b & a \\ a & b \end{pmatrix}$$

- Preserve the sum of the rows and columns.
- Using MCMC, will converge to a uniform distribution.

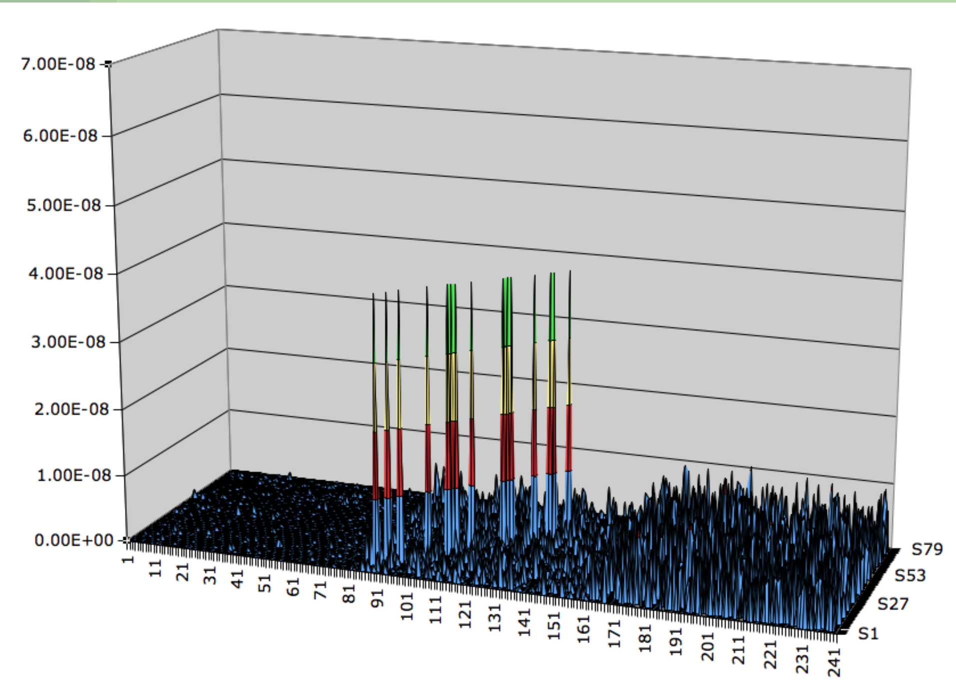
Sensitivity of the shuffled block



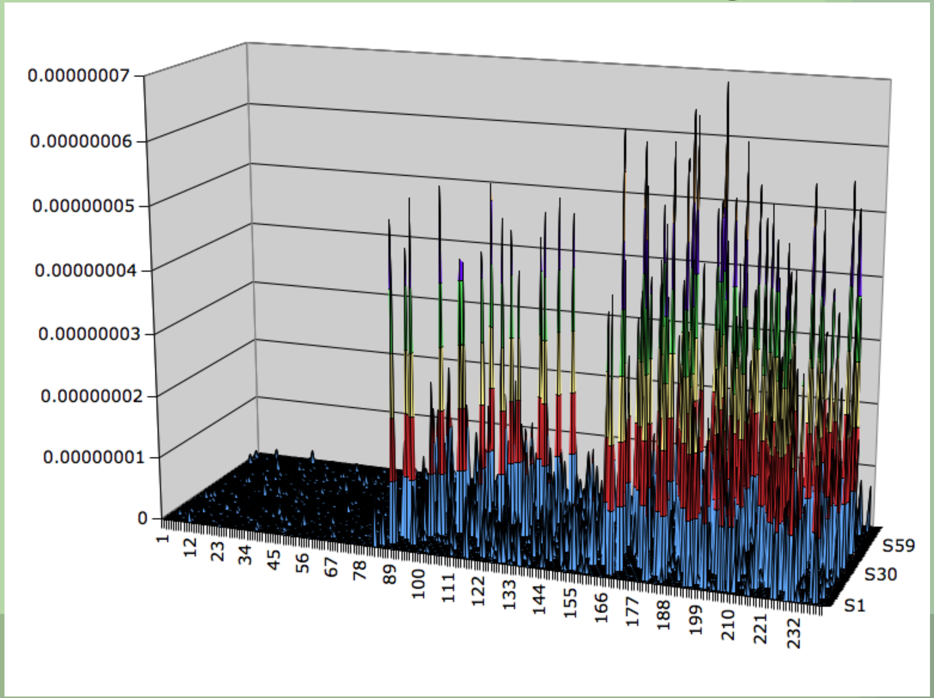
Visual Outcomes



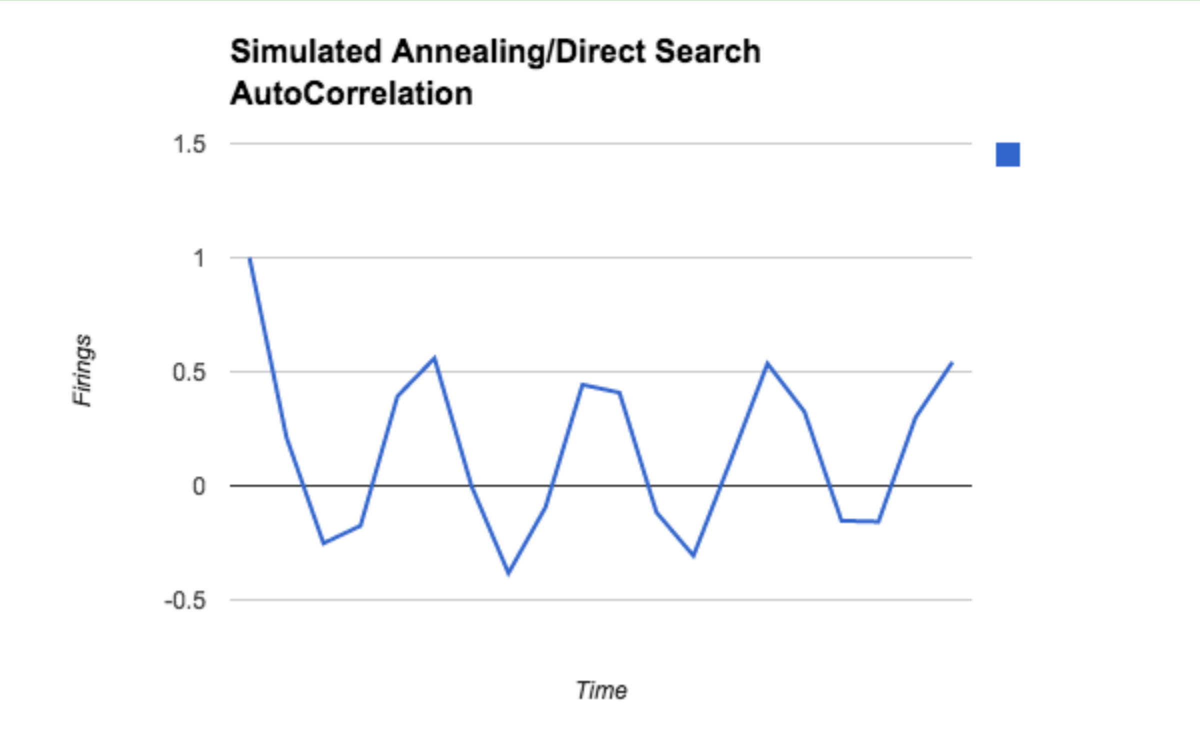
Original:



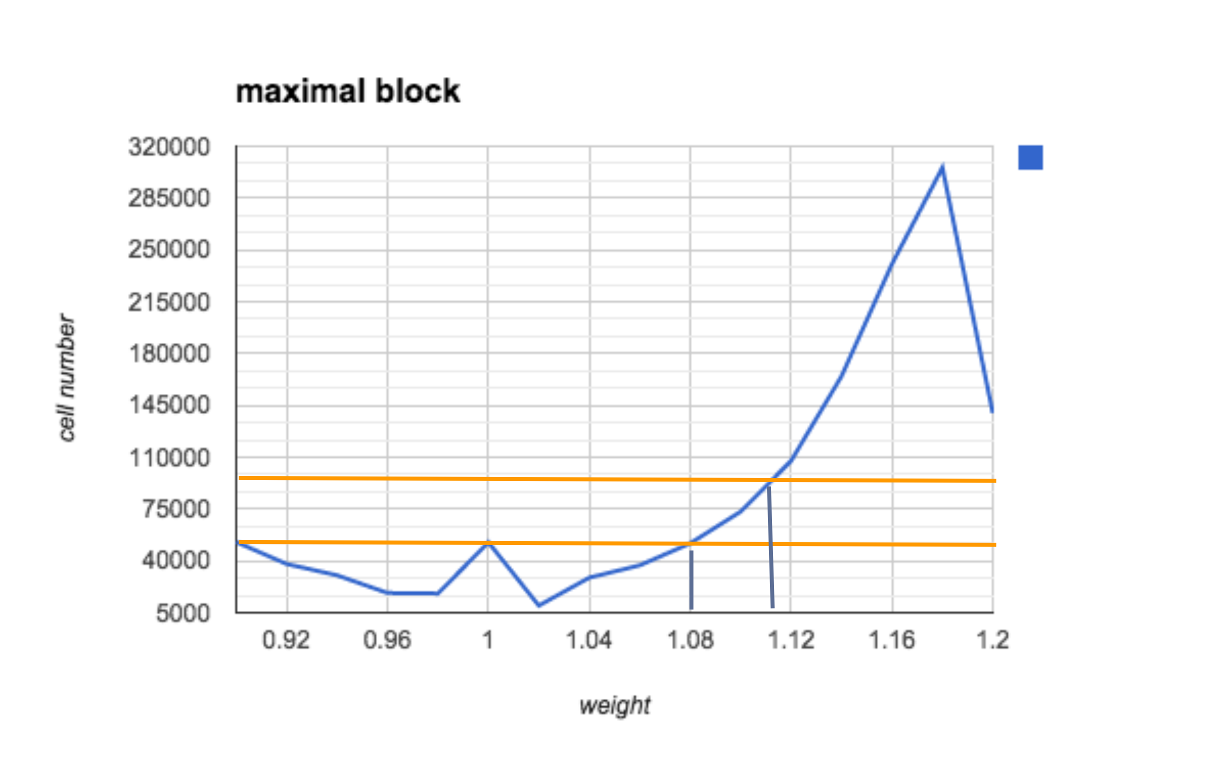
Simulated Annealing:



Outcomes:
High Energy/Simulated Annealing



Sensitivity of the Matrix after Simulated Annealing



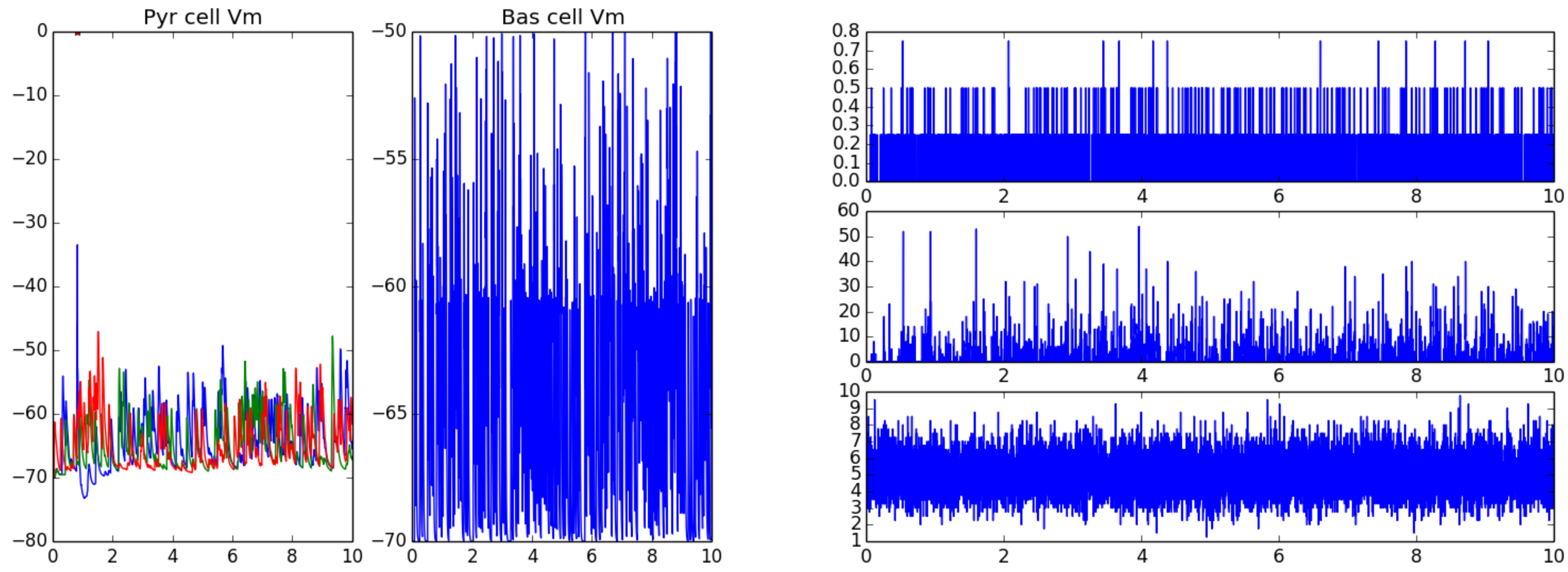
Randomization Techniques: Averaging

1. Averaging within blocks

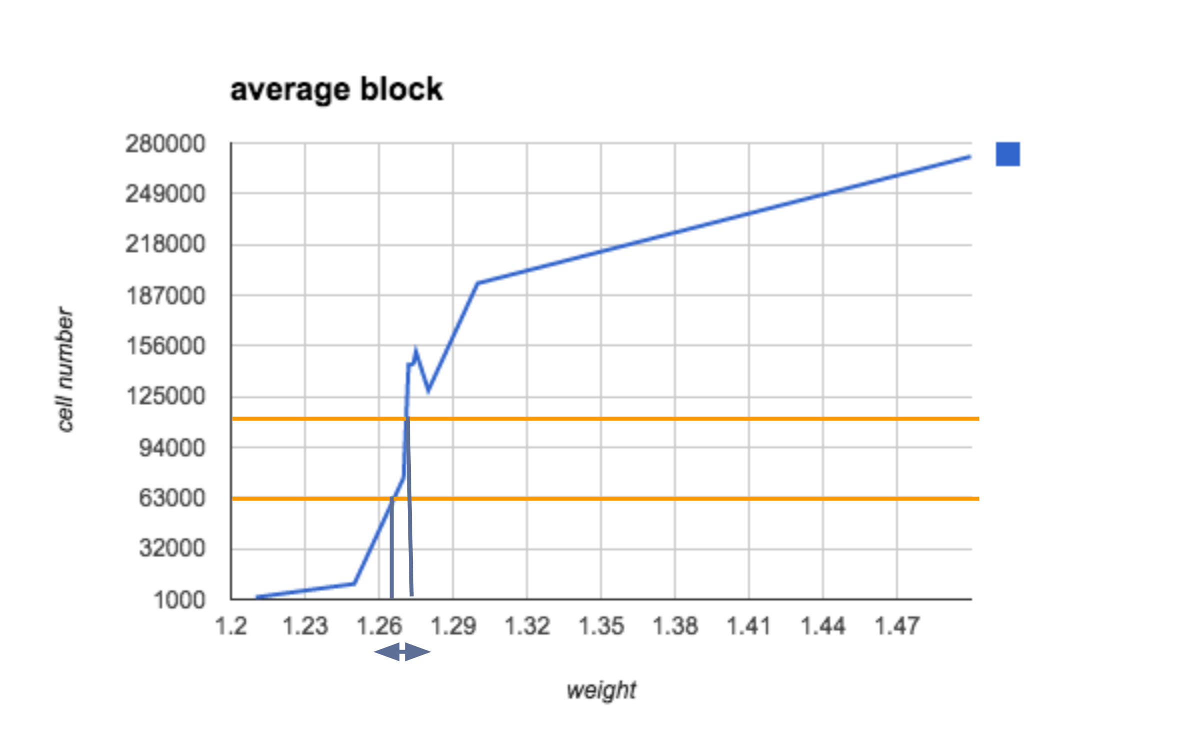
2. Averaging along diagonal:

	1	2	3
a	$\overline{1a}$	$\overline{2a}$	$\overline{3a}$
b	$\overline{1b}$	$\overline{2b}$	$\overline{3b}$
c	$\overline{1c}$	$\overline{2c}$	$\overline{3c}$

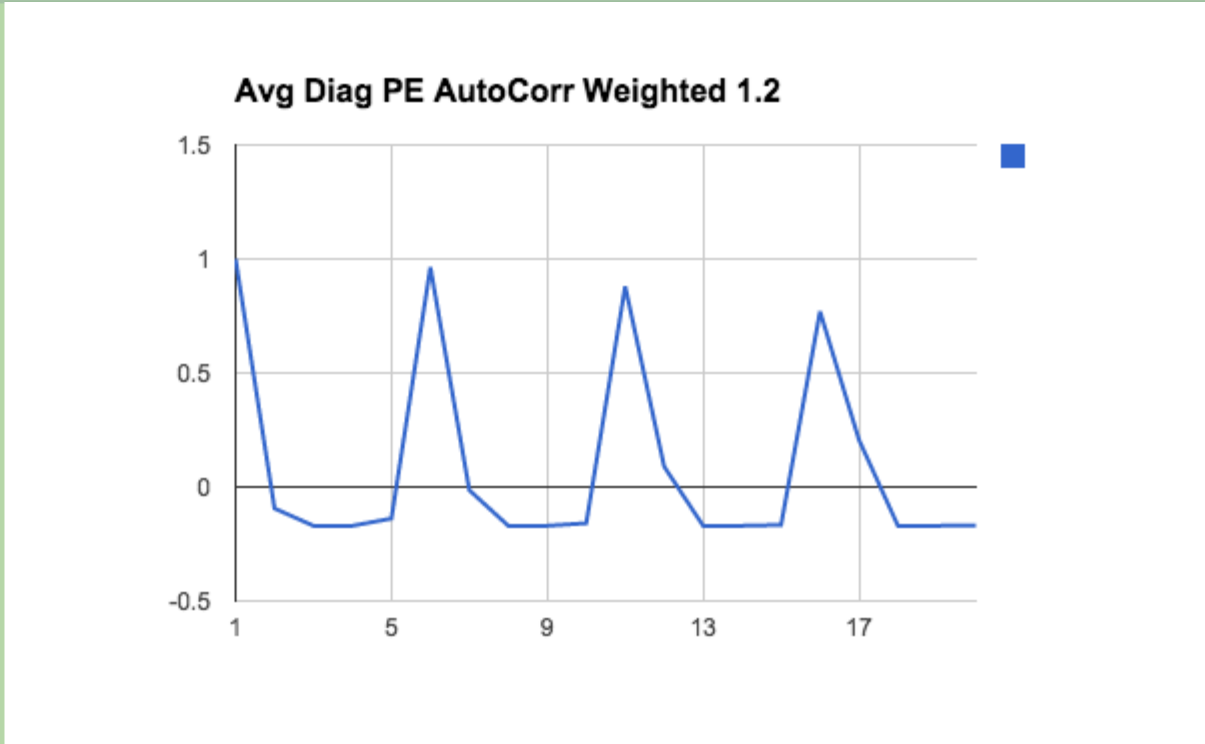
Outcomes: Block Averages



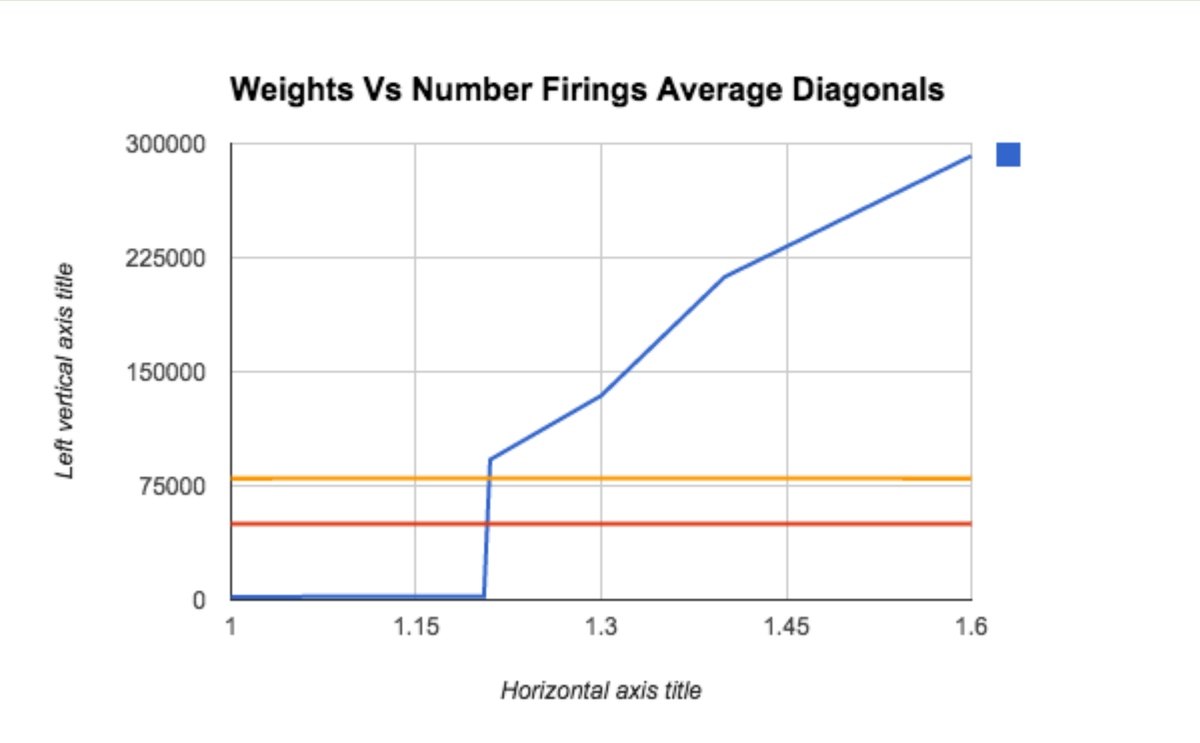
Sensitivity of Block Averages



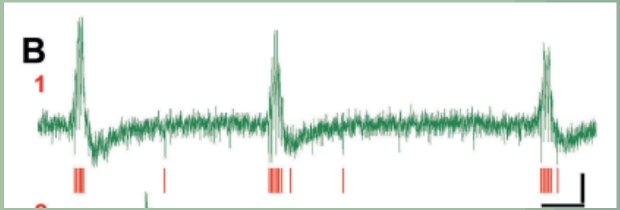
Outcomes: Diagonal Averaging



Sensitivity of Average Diagonals



Summary



- Block Structure = Vital to a functioning brain
- Within blocks, no specific structure needed
- Extremal variances result in high sensitivity

http://www.brainhealth.utdallas.edu/blog_page

Open Mathematical Questions: Perturbating Matrices with Fixed Spectrum

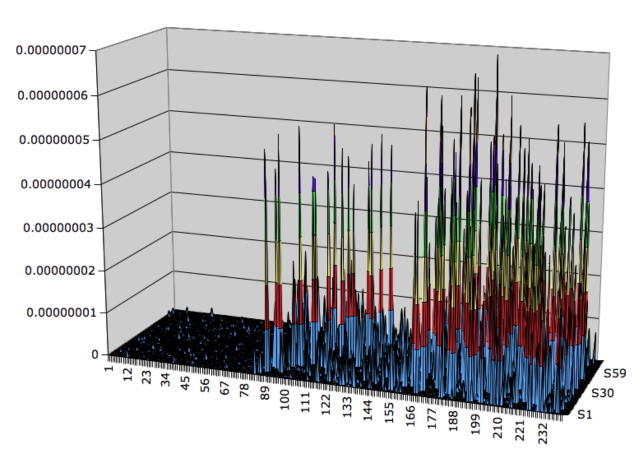
- Is it sufficient to only have **restricted swaps?**
- Conjecture is no
- For future research

Open Mathematical Questions: Finding Maximum $\sum x_{ij}^2$

- Maximizing the **variance** of synaptic weights, keeping row/column sums

- Finding **min** variance is **easy**

Simulated Annealing Result:



Next Semester’s Goals

- Can the system be reduced(a block smaller than 80 by 80)?
- What if we have a more complicated block structure?