Supplemental Information

Membrane and synaptic equations

Voltage and current equations for E neurons (I neurons are modeled similarly with parameters as below),

$$\frac{dV_i}{dt} = \frac{1}{C_E} * (-I_{NMDA,i} - I_{GABA,i} - I_{leak,i})$$

$$I_{leak,i} = g_{leak} * (V_i - E_{leak})$$

$$I_{NMDA,i} = g_{NMDA} * M_{NMDA,i} * \sum_{j=1}^{N_E} w_{E\to E}(i,j) * s_{NMDA,j} * (V_i - E_{NMDA})$$

$$\frac{ds_{NMDA,j}}{dt} = -\frac{1}{\tau_{NMDA}} * s_{NMDA,j} + 0.5 * x_j * (1 - s_{NMDA,j})$$

$$\frac{dx_j}{dt} = -\frac{1}{\tau_x} * x_j + \sum_{m \in \{spikes\}} \delta(t - t_m^{E,j})$$

where $t_m^{E,j}$ are the spikes of E neuron *j*

$$M_{NMDA,i} = \frac{1}{(1 + \exp(-0.062 * V_i)/3.57)}$$

$$I_{GABA,i} = g_{GABA} * \sum_{j=1}^{N_I} w_{I\to E}(i,j) s_{GABA,j} * (V_i - E_{GABA})$$

$$\frac{ds_{GABA,j}}{dt} = -\frac{1}{\tau_{GABA}} * s_{GABA,j} + \sum_{m \in \{spikes\}} \delta(t - t_m^{I,j})$$

where $t_m^{I,j}$ are the spikes of I neuron *j*

Synaptic weight functions

Synaptic weight equations for E→E, E→I, and I→E voltage equations. I→I synaptic weights are uniform with weight of $1/N_I$ for all I neurons.

1.

$$\omega_{E\to E}(i,j) = \exp\left(\frac{-(i-j_{short})^2}{2\sigma_{E\to E}^{\ 2}}\right) + \exp\left(\frac{-(i-j_{long})^2}{2\sigma_{E\to E}^{\ 2}}\right)$$

$$\omega_{E\to I}(i,j) = 2.275 + \exp\left(\frac{-(i-j_{short})^2}{2\sigma_{E\to I}^{\ 2}}\right) + \exp\left(\frac{-(i-j_{long})^2}{2\sigma_{E\to I}^{\ 2}}\right)$$

$$\omega_{I\to E}(i,j) = .425 + \exp\left(\frac{-(i-j_{short})^2}{2\sigma_{I\to E}^{\ 2}}\right) + \exp\left(\frac{-(i-j_{long})^2}{2\sigma_{I\to E}^{\ 2}}\right)$$

2.

$$w_{E\to E}(i,j) = \frac{\omega_{E\to E}(i,j)}{\sum \omega_{E\to E}(i,j)}$$

$$w_{E\to I}(i,j) = \frac{\omega_{E\to I}(i,j)}{\sum \omega_{E\to I}(i,j)}$$

$$w_{I\to E}(i,j) = \frac{x_{I\to E}(i,j)}{\sum x_{I\to E}(i,j)}$$

Since neurons are arranged in a ring structure, j_{short} and j_{long} are the short and long distances between neurons on the synaptic distance map (**Figure 1A**).

The neuron spatial map is derived by the clustering relationship,

$$d_{near} = \frac{180}{N_{clusters} * (N_{cluster,E} - 1) * (1+k)}$$

$$d_{far} = k * d_{near} * (N_{cluster,E} - 1)$$

where $N_{clusters}$ = 100 (the number of clusters) in the system, $N_{cluster,\ E}$ = 8 (the number of E neurons per cluster), and k is the clustering parameter which is equal to the ratio between d_{far} and d_{near}*($N_{cluster,E}$-1). d_{far} refers to the maximum nearest-neighbor distance as depicted in Figure 1C, and d_{near} refers to the minimum nearest-neighbor distance.

Table S1. Model Parameters

Model Parameters	
NMDA rise time constant (τ_x)	2 msec
NMDA decay time constant (τ_{NMDA})	100 msec
GABA decay time constant (τ_{GABA})	10 msec
E and I neuron threshold potential	-50 mV
E and I neuron resting potential	-60 mV
NMDA equilibrium potential (E_{NMDA})	0 mV
GABA equilibrium potential (E_{GABA})	-70 mV
E and I neuron leakage equilibrium potential (E_{leak})	-70 mV
E membrane capacitance (C_E)	0.5 nF
I membrane capacitance (C_I)	0.2 nF
maximum orientation value (degrees)	180
minimum orientation value (degrees)	0
NMDA maximum conductance to both E and I neurons (g_{NMDA})	180 nS
GABA maximum conductance to both E and I neurons (g_{GABA})	1.6 nS
Leak maximum conductance to E neurons ($g_{leak,E}$)	25 nS
Leak maximum conductance to I neurons ($g_{leak,I}$)	20 nS
$\sigma_{E\rightarrow E}$ (for the synaptic weight function)	8
$\sigma_{E\rightarrow I}$	32.4
$\sigma_{I\rightarrow I}$	not applicable
$\sigma_{I\rightarrow E}$	32.4