Entorhinal cortex grid cell to CA1 place cell transformation

Model Summary	
Populations	Grid cells: 10000 excitatory. Place cells: 2000 excitatory.
Connectivity	Grid cells to place cells: sparse-random.
Neuron model	Grid cells: hexagonal sum of 2D cosine gratings. Place cells: rectified linear with percent-of-maximum-excitation competition.
Plasticity	Grid cells to place cells: correlative Hebbian plasticity of strengths, random structural plasticity, homeostasis by divisive normalization.
Input	Positional information.

Populations		
Name	**Elements**	**Size**
Grid cells	Sum-of-cosine-gratings Neuron	10000
Place cells	Linear with percent-of-maximum-excitation competition Neuron	2000

Connectivity			
Name	**Source**	**Target**	**Pattern**
GrPl	Grid cells	Place cells	Random, 2000 grid cells per place cell; plastic, initial weight sampled from empirical distribution

Neuron Models	
Grid cell	**Hexagonal sum of 2D cosine gratings**
Firing rate (Eq. 1)	$\boldsymbol{G(r,\lambda,\theta,c) = g\left(\sum_{k=1}^{3}\cos\left(\frac{4\pi}{\sqrt{3}\lambda}u(\theta_k+\theta)\cdot(r-c)\right)\right)}$
Place cell	**Linear with percent-of-maximum-excitation competition**
Synaptic input (Eq. 2)	$\boldsymbol{I_{grid}^{i}(r) = \vec{G}(r)\cdot\vec{w}_i}$
Firing rate (Eq. 3)	Model one: $\boldsymbol{F_{i=1}(r) = I_{grid}^{i=1}(r)}$ Model two: $\boldsymbol{F_i(r) = I_{grid}^{i}(r)\cdot H\left(I_{grid}^{i}(r)-(1-k)\cdot I_{grid}^{max}(r)\right)}$

Plasticity		
Type	**Mechanism**	**Connections**
Hebbian (Eq. 4)	$\boldsymbol{\Delta w_{ij} = \eta\sum_{r} G_i(r)F_j(r)}$	GrPl, all synapses, every trial
Structural	Random elimination at 10% of occupied sites, random formation at 10% of unoccupied sites	GrPl, all synapses, every trial
Homeostatic	For each place cell *j*, the strength of the synapse from grid cell *i* is adjusted as $\Delta w_i = -w_i + E\frac{w_i}{\sum_i w_i}$, where E is the expected sum of 1200 random draws from the distribution of synaptic strengths	GrPl, all synapses, every trial

Input	
Positional information	Grid cell activities are determined by positional information from a simulated animal on a linear running track. Positions range from one to 100 centimeters in one-centimeter increments

Table S1. Summary of network models one and two.

LGN center-surround to V1 simple cell transformation

Model Summary			
Populations	LGN cells: 20000 excitatory. V1 cells: 1000 excitatory.		
Connectivity	LGN cells to V1 cells: three bars of LGN cells, two “on” flanking one “off” per V1 cell.		
Neuron model	LGN cells: on- and off-center surround. V1 cells: rectified linear with percent-of-maximum-excitation competition.		
Plasticity	LGN cells to V1 cells: correlative Hebbian plasticity of strengths, random structural plasticity, homeostasis by divisive normalization.		
Input	Static gratings.		
Populations			
Name	**Elements**	**Size**	
LGN cells	Rectified sum of 2D Gaussians	20000	
Place cells	Linear with percent-of-maximum-excitation competition Neuron	1000	
Connectivity			
Name	**Source**	**Target**	**Pattern**
LgnV1	LGN cells	V1 cells	Three parallel bars across the visual field per V1 cell: bars 1 and 3) 33 on-center LGN cells, bar 2) 64 off-center LGN cells; plastic, initial weight sampled from empirical distribution
Neuron Models			
LGN center-surround	**Rectified sum of 2D Gaussians**		
Synaptic input (Eq. 9)	$I^i_{LGN}(a_i, x, y, c^i_x, c^i_y, \theta, \phi) = -aI(x, y, \theta, \phi)D(x, y, c^i_x, c^i_y)$		
Firing rate (Eq. 10)	$F^i_{LGN}(a_i, c_{xi}, c_{yi}, \theta, \phi) = \max\left(\sum_{x,y}[I^i_{LGN}(a_i, x, y, c^i_x, c^i_y, \theta, \phi)], 0\right)$		
V1 simple cell	**Linear with percent-of-maximum-excitation competition**		
Synaptic input (Eq. 11)	$I^j_{V1}(\theta, \phi) = \sum_i F^i_{LGN}(a_i, c^i_x, c^i_y, \theta, \phi) w_{i,j}$		
Firing rate (Eq. 12)	$F^j_{V1}(\theta, \phi) = I^j_{V1}(\theta, \phi) \cdot H\left(I^j_{V1}(\theta, \phi) - (1 - k) \cdot I^{max}_{V1}(\theta, \phi)\right)$		
Plasticity			
Type	**Mechanism**	**Connections**	
Hebbian	$\Delta w_{i,j} = \eta \sum_{\theta,\phi} F^i_{LGN}(a_i, c_{xi}, c_{yi}, \theta, \phi) F^j_{V1}(\theta, \phi)$	LgnV1, all synapses, every trial	
Structural	Random elimination at an average of 10% of occupied sites, random formation at 10% of unoccupied sites. The probability of synapse formation decreases with the distance between cells.	LgnV1, all synapses, every trial	
Homeostatic	For each V1 cell *j*, the strength of the synapse from LGN cell *i* is adjusted as $\Delta w_i = -w_i + E\frac{w_i}{\sum_i w_i}$, where E is the expected sum of 1200 random draws from the distribution of synaptic strengths	LgnV1, all synapses, every trial	
Input			
2D grating	LGN cell activities are determined by visual information from 2D gratings with variable orientation and phase but constant spatial period.		

Table S2. Summary of network model three.