Emergence of Spatial Clustered Orientation Map in Mouse Primary Visual Cortex

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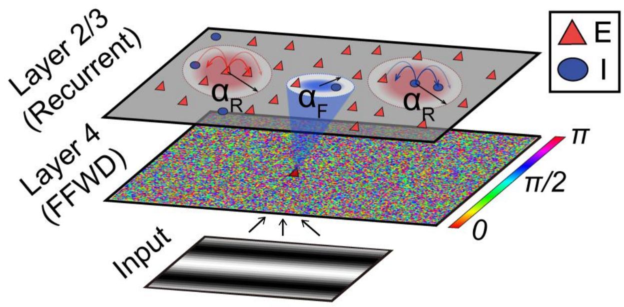
A **spatial balanced E-I network** with **random connectivity** captures **spatially clustered structure** (i.e. non-salt-and-pepper) of orientation tuning in layer 2/3 of mouse V1.

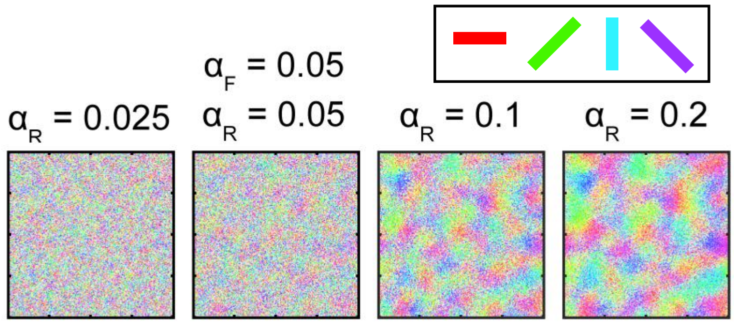


L4 input layer: "Salt-and-pepper" layout.

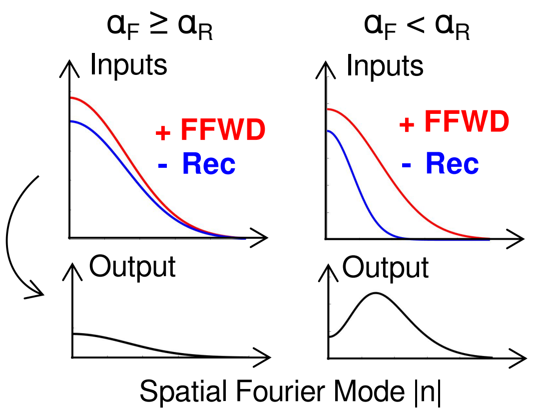
Connectivity: Spatial Gaussian, (α_F, α_R);

No feature based spatial organization.

No long-range inhibition.



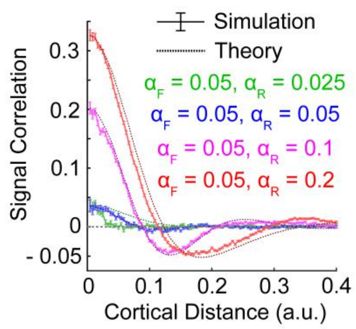
Spatial clustering appears only when **recurrent connections are BROADER than feedforward** ($\alpha_F < \alpha_R$**).**

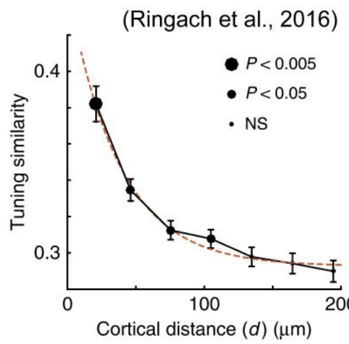


How clustering emerge: (in Fourier domain)

Low-pass F & R input terms;

Band-pass summation when $\alpha_F < \alpha_R$.





Tuning similarity as a function of cortical distance, compared with previous report (D. Ringach et al., 2016)

Supplement: Mathematics of the linear response theory.

Linearized Dynamics, in Spatial Fourier Space:

$$0 = \frac{d\vec{\mathbf{r}}}{dt} = -\vec{\mathbf{r}} + \mathbf{G}(\mathbf{J}\vec{\mathbf{r}} + \vec{\mathbf{h}})$$

$$\vec{\mathbf{r}}(\vec{\mathbf{n}}) = [\mathbf{G}^{-1} - \mathbf{J}(\vec{\mathbf{n}})]^{-1} \cdot \vec{\mathbf{h}}(\vec{\mathbf{n}})$$

Where: $(i, j = E, I, F)$

$$J_{ij}(\mathbf{n}) = \frac{1}{\sqrt{N_{rec}}} N_j \, p_{ij}^0 \, j_{ij}^0 \cdot e^{-2\pi^2 \alpha_{ij}^2 \mathbf{n}^2}$$

$$\mathbf{G} = \begin{bmatrix} G_E & 0 \\ 0 & G_I \end{bmatrix} \qquad h_i(\mathbf{n}) = J_{iF}(\mathbf{n}) \cdot A_0 e^{i\phi}$$

(For 'salt-and-pepper' input from L4)

Solutions of Firing Rates:

$$|\mathrm{r}_E(\mathbf{n})| = \frac{[G_I^{-1} + J_{II}(\mathbf{n})]J_{EF}(\mathbf{n}) - J_{EI}(\mathbf{n})J_{IF}(\mathbf{n})}{[G_I^{-1} + J_{II}(\mathbf{n})][G_E^{-1} - J_{EE}(\mathbf{n})] + J_{IE}(\mathbf{n})J_{EI}(\mathbf{n})} \cdot A_0$$

$$|\mathrm{r}_I(\mathbf{n})| = \frac{[G_E^{-1} - J_{EE}(\mathbf{n})]J_{EF}(\mathbf{n}) - J_{IE}(\mathbf{n})J_{IF}(\mathbf{n})}{[G_I^{-1} + J_{II}(\mathbf{n})][G_E^{-1} - J_{EE}(\mathbf{n})] + J_{IE}(\mathbf{n})J_{EI}(\mathbf{n})} \cdot A_0$$

Synaptic Inputs: $(i, j = E, I, F)$

$$\mathrm{Isyn}_{ij}(\mathbf{n}) = J_{ij}(\mathbf{n}) \cdot \mathrm{r}_j(\mathbf{n})$$

Signal Covariance: $(j = E, I)$ (Wiener-Khinchin Theorem)

$$\langle \mathrm{r}_j, \mathrm{r}_j \rangle(\mathbf{n}) = |\mathrm{r}_j(\mathbf{n})|^2$$