Supporting Information

Takahata et al. 10.1073/pnas.1401951111

SI Discussion

Possibly, a lateral inhibition circuit exists between the two eyes involving border strips (BSs). BSs were shown after brief monocular inactivation (MI) as intense immediate-early gene expression in the vicinity of ocular dominance column (ODC) borders in macaques and owl monkeys. To give a simple explanation of the emergence of BSs, let us consider a linear dynamics of the layer 4 (4C) circuit with afferent inputs and local inhibition (Fig. S3*A*). We assume the following linear dynamics of neuronal activities:

$$\frac{d}{dt}\eta_\mu^{ex} = -\eta_\mu^{ex} + \eta_\mu^{LGN} - \gamma\eta_\mu^{inh}$$

$$\frac{d}{dt}\eta_\mu^{inh} = -\eta_\mu^{inh} + w_{\mu,L}\eta_L^{LGN} + w_{\mu,R}\eta_R^{LGN},$$

where η_μ^{ex}, η_μ^{inh}, and η_μ^{LGN} indicate activities of excitatory and inhibitory neurons in layer 4 (4C) and lateral geniculate nuclei (LGN) cells, which are specifically responsive to stimuli presented at the same location in the visual field. γ is the synaptic weight from inhibitory neurons to adjacent excitatory neurons, and $w_{\mu,L}$ and $w_{\mu,R}$ are synaptic weights of excitatory afferent inputs from the LGN in the left-eye and right-eye pathways to inhibitory neurons located in the ocular dominance (OD) domains for ocularity μ. Then we obtain the following expressions of steady-state activities of layer 4 (4C) excitatory neurons in terms of LGN cell activities:

$$\eta_L^{ex} = (1-\gamma w_{L,L})\eta_L^{LGN} - \gamma w_{L,R}\eta_R^{LGN}$$
$$\eta_R^{ex} = -\gamma w_{R,L}\eta_L^{LGN} + (1-\gamma w_{R,R})\eta_R^{LGN}.$$

In the middle of OD bands, we can neglect $w_{L,R}$ and $w_{R,L}$ because of the locality of inhibitory neurons' connections. The inhibitory neurons receive inputs from only one pathway, and the weight is assumed to be constant $w_{L,L} = w_{R,R} = w$. Then we get

$$\eta_L^{ex} = (1-\gamma w)\eta_L^{LGN}$$
$$\eta_R^{ex} = (1-\gamma w)\eta_R^{LGN}.$$

In the vicinity of ODC borders, inhibitory neurons receive inputs from LGN cells of both pathways half-and-half. So the weights are given by $w_{\mu,L} = w_{\mu,R} = w/2$. This leads to

$$\eta_L^{ex} = \left(1-\frac{1}{2}\gamma w\right)\eta_L^{LGN} - \frac{1}{2}\gamma w\eta_R^{LGN}$$
$$\eta_R^{ex} = -\frac{1}{2}\gamma w\eta_L^{LGN} + \left(1-\frac{1}{2}\gamma w\right)\eta_R^{LGN}.$$

In intact animals, activities of afferent inputs are balanced in the two eyes: $\eta_L^{LGN} = \eta_R^{LGN} = \eta^{LGN}$. This indicates that activities of layer-4 (4C) excitatory neurons are uniform irrespective of the cortical location: $\eta_L^{ex} = \eta_R^{ex} = (1-\gamma w)\eta^{LGN}$.

For brief MI at the right-eye pathway ($\eta_L^{LGN} = \eta^{LGN}$ and $\eta_R^{LGN} = 0$), the activities of excitatory neurons in the middle of ODCs and in the vicinity of ODC borders are, respectively, given by

$$\eta_L^{ex} = (1-\gamma w)\eta^{LGN}$$
$$\eta_R^{ex} = 0 \quad \text{in the middle of ODCs,}$$

$$\eta_L^{ex} = \left(1-\frac{1}{2}\gamma w\right)\eta^{LGN}$$
$$\eta_R^{ex} = -\frac{1}{2}\gamma w\eta^{LGN} \quad \text{in the vicinity of ODC borders.}$$

Note that activity η_L^{ex} in the vicinity of ODC borders is larger than that in the middle of the left-eye dominance domains by $\frac{1}{2}\gamma w\eta^{LGN}$. This indicates that the MI induces the enhancement of immediate-early gene (IEG) expression along the ODC borders inside the intact-eye dominance domains. The width of the response enhancement is determined by the local extent of inhibitory connections. However, MI results in the negative responses along the ODC borders inside the inactivated-eye dominance domains, which is simply a theoretical artifact owing to the linearity of the circuit dynamics. BSs were observed only for brief MI. The disappearance of BSs for longer-term MI may be accounted for by homeostatic plasticity of layer 4 (4C) neurons. It is necessary to build a more detailed mathematical model in the future. The arguments above are summarized in Fig. S3*B*.

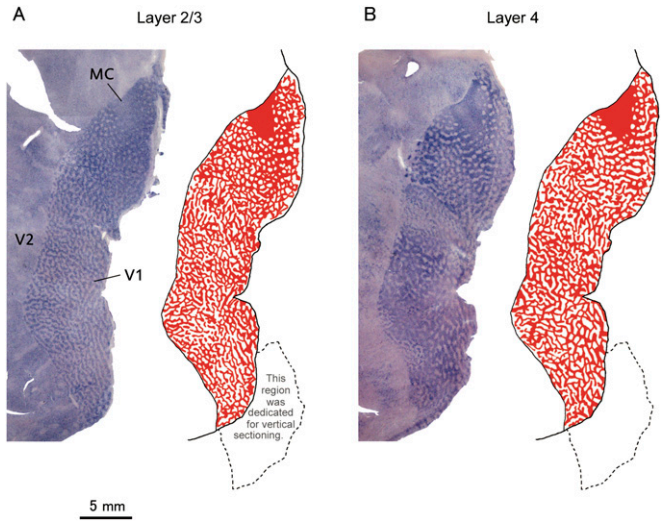

Fig. S1. The left visual cortex of the owl monkey case ID 11-04. As in the right visual cortex shown in Fig. 1, an ODC-like pattern was revealed by IEG expression throughout V1. However, the presumptive monocular segment exhibited uniformly strong IEG signals on this side, whereas that in the right cortex was uniformly pale (compare with Fig. 1 *A* and *B*). A tangential section reacted for *c-Fos* mRNA (*A*) 320 μm from the pial surface, mostly in layer 3 and (*B*) 880 μm from the pial surface, mostly in layer 4 (4C). ODC-like patterns in layer 2/3 (*A*) and layer 4 (4C) (*B*) were illustrated by red on the right side of the sections. (Scale bar, 5 mm.)

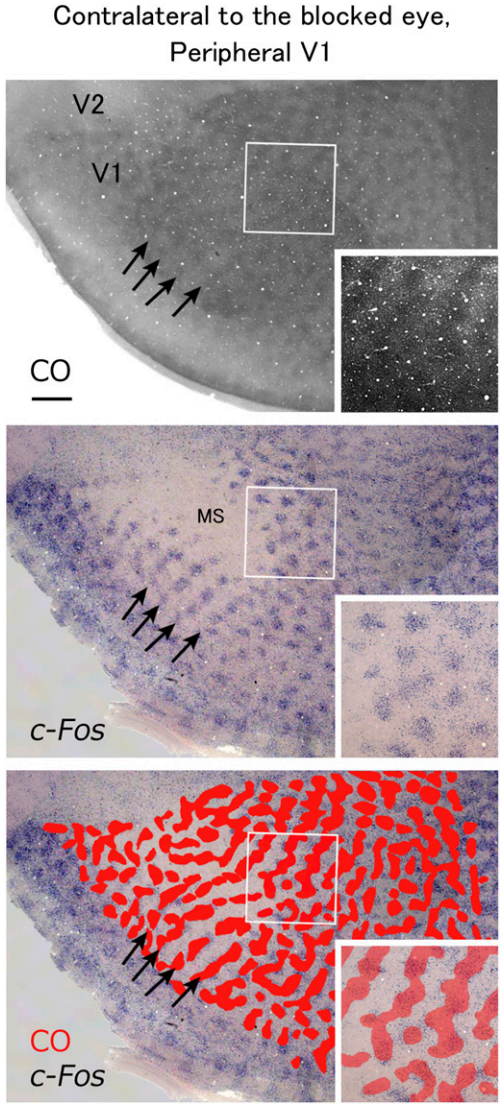

Fig. S2. Examination of spatial relationship between cytochrome oxidase (CO) blobs and OD domains in the tangential contralateral V1 sections to the blocked eye in owl monkey 11-04. Images for CO staining (*Top*) and ISH for *c-Fos* (*Middle*) are aligned exactly the same way guided by radial blood vessels. (*Bottom*) CO blobs are drawn by red over the image for *c-Fos*. (*Insets*) Magnification of the window in the same panel. In peripheral V1, both CO blobs and ipsilateral OD domains line up in the corresponding way (arrows), as in ipsilateral V1 (Fig. 4*A*). (Scale bar, 1 mm.)

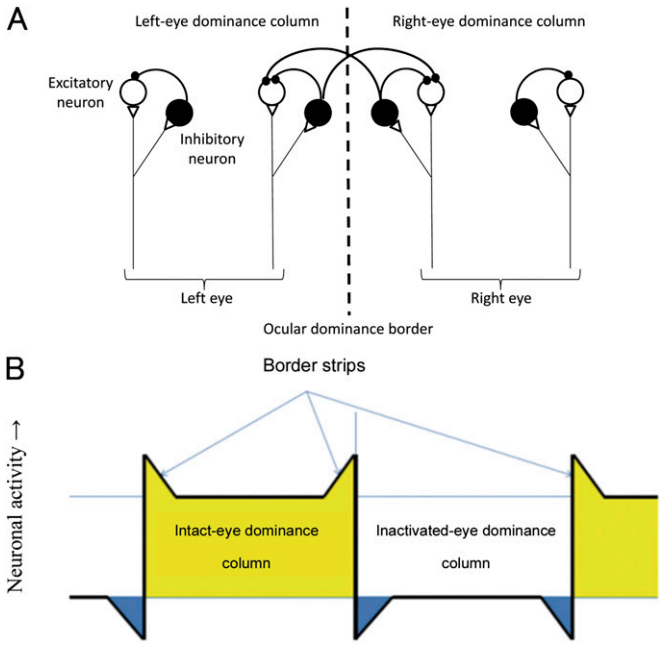

Fig. S3. Activity for brief MI in model layer 4 (4C) of V1. (*A*) Local lateral inhibition circuit is assumed around OD borders. (*B*) Shortly after TTX is injected into one eye, the local lateral inhibition from the inactivated-eye dominance columns to the border regions of intact-eye dominance columns is released, and the activity of neurons in these regions is enhanced above the normal activity level. The BSs are regarded as IEG expression reflecting such a neuronal activity enhancement. Although the border regions of inactivated-eye dominance columns show more reduced neural activity than the spontaneous level in the core zone owing to inhibition from the intact-eye dominance columns, this negative response is a simple artifact of the assumption of linear circuit dynamics.