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Supplemental Information

All-Optical Electrophysiology Reveals the Role of Lateral Inhibition in Sensory Processing in Cortical Layer 1

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Item	**Part number**	**Comments**
2P Laser	Coherent DeepSee	
Scanning galvos	Cambridge Technologies 6215H	
PMT	Hamamatsu, H11706P-40	
25x objective	Olympus XLPLN25XWMP2	
L1	400 mm, Edmund, 88-598-INK	
L2	Effective focal length, 150 mm, two 300 mm lenses, Thorlabs, AC508-300-A-ML	Two lenses back to back in Plössl configuration to reduce aberration
L3	75 mm, Thorlabs, AC254-075-A-ML	Relay lens to allow more space
L4	75 mm, Thorlabs, AC254-075-A-ML	Relay lens to allow more space
L5	60 mm, Thorlabs, AC254-060-A-ML	
L6	First generation: Sigma macro 18-200 mm Second generation: 75 mm, Thorlabs, AC508-075-A-ML	First generation: Zoom lens for varying NA of red illumination and size of red targeted region; Second generation: 75 mm lens to reduce aberration
L7	200 mm, Thorlabs, AC508-200-A-ML	
L8	45 mm, Olympus XLFLUOR 4X/340	Objective used as a tube lens for reducing aberration and achieving large field of view
L9	Thorlabs, SL50-CLS2	Optimized scan lens
L10	Thorlabs, TL200-CLS2	Optimized tube lens
L11	16 mm, Thorlabs, AC080-016-A-ML	
L12	75 mm singlet, Thorlabs, LA1608-A-ML	
488 nm laser	Cobolt, 06-01 series, λ = 488 nm, 60 mW	
AOTF	Gooch and Housego TF525-250-6-3-GH18A	
DMD	Vialux, V-7001 VIS	
639 nm laser	CNI Inc., MRL-FN-639, λ = 639 nm, 700 mW single transverse mode	
SLM	Meadowlark 1920SLM VIS	
0-order block	home-made anti-pinhole comprised of a dot of solder on a glass slide	
sCMOS camera	Hamamatsu ORCA-Flash 4.0	
Sample stage	Sutter instrument, FG-MPC78, Moving stage plat W/MPC-200 for XY stage; SA-MP285-1X-M for Z axis	
DAQ system	NI PCIe-6363	

Table S1. Related to Figure 1. Components required to build an optical system for holographic structured illumination voltage imaging combined with patterned optogenetic stimulation.

Parameter	**eNGC neuron**	**SBC-like neuron**	**Meaning and comments**
g_{Na}	35 mS/cm^2	35 mS/cm^2	Voltage gated Na$^+$ channel
g_K	9 mS/cm^2	9 mS/cm^2	Voltage gated K$^+$ channel
g_L	0.23 mS/cm^2	0.23 mS/cm^2	leak conductance
g_A	10 mS/cm^2	0	A-type inactivating potassium current
g_{SK2}	0	10 mS/cm^2	Slow outward potassium current
E_{Na}	55 mV	55 mV	Na$^+$ reversal potential
E_K	-90 mV	-90 mV	K$^+$ reversal potential
E_{leak}	-66.4 mV	-66.8 mV	Resting membrane potential; set at -55 mV for high spontaneous activity to mimic awake state
E_A	-75 mV		Reversal potential for g_A
E_{SK2}		-70 mV	Reversal potential for g_{SK2}
τ	4.3 ms	4.3 ms	Membrane time constant
C_m	1 μF/cm^2	1 μF/cm^2	Membrane capacitance
E_{ChR}, E_{AMPAR}, E_{nAchR}	0 mV	0 mV	Reversal potential of excitatory conductances
E_{GABAR}	-70 mV	-70 mV	Reversal potential of inhibitory (GABA$_A$R-mediated) conductances

Parameter	**Source Data**	**Model**
eNGC firing pattern	Chu et al. J. Neurosci. 23 (2003): 96-102. Fig. 1	Modified from Wang, Xiao-Jing, and György Buzsáki. *Journal of neuroscience* 16.20 (1996): 6402-6413. Added A-type inactivating potassium current from (Ermentrout, G. Bard, and David H. Terman. *Mathematical foundations of neuroscience*. Vol. 35. Springer Science & Business Media, 2010.)
SBC firing	Chu et al. J. Neurosci. 23 (2003):	Modified from Wang, Xiao-Jing, and György

pattern	96-102. Fig. 1	Buzsáki. *Journal of neuroscience* 16.20 (1996): 6402-6413. Added a slow potassium current from (Ermentrout, G. Bard, and David H. Terman. *Mathematical foundations of neuroscience*. Vol. 35. Springer Science & Business Media, 2010.)
IPSP waveform: eNGC → eNGC	Chu et al. J. Neurosci. 23 (2003): 96-102. Fig. 5	$g_{inh}(t) = g_{inh}^{0}\left(\frac{t}{\tau_1}e^{1-\frac{t}{\tau_1}} + 0.6\frac{t}{\tau_2}e^{1-\frac{t}{\tau_2}}\right)$ g_{inh}^{0} = 0.035 – 0.04 mS/cm^2, τ_1 = 5 ms, τ_2 = 30 ms
IPSP amplitude eNGC → eNGC	Jiang et al. Science 350 (2015): aac9462. Table S6	-1.6 mV
IPSP waveform eNGC → SBC	Chu et al. J. Neurosci. 23 (2003): 96-102. Fig. 4 Jiang et al. Science 350 (2015): aac9462. Fig. 3a	$g_{inh}(t) = g_{inh}^{0}\left(\frac{t}{\tau_1}e^{1-\frac{t}{\tau_1}} + 0.6\frac{t}{\tau_2}e^{1-\frac{t}{\tau_2}}\right)$ g_{inh}^{0} = 0.035 – 0.04 mS/cm^2, τ_1 = 5 ms, τ_2 = 30 ms
IPSP amplitude eNGC → SBC	Jiang et al. Science 350 (2015): aac9462. Table S6	-1.8 mV
Length scale of eNGC → eNGC coupling	Jiang et al. Science 350 (2015): aac9462. Figs. S2, S3	σ = 200 μm (sum of axonal and dendritic length scales)
Length scale of eNGC → SBC coupling	Jiang et al. Science 350 (2015): aac9462. Figs. S2, S3	σ = 225 μm (sum of eNGC axonal and SBC dendritic length scales)
L1 neuron density	Abdelfattah et al., BioRxiv: /10.1101/436840. Fig. S23 Meyer et al., PNAS 110 (2013) 19113-19118. Table S3	3000-7,000 mm^{-3}, 15 – 67 neurons/barrel (in rat)
Ratio of eNGC to SBC cells	Schuman et al. J. Neurosci. 39 (2019): 125-139. Fig. 2,4	~2:1
Thalamocortical EPSP waveform in eNGC	Zhu and Zhu, J. Neurosci. 24 (2004): 1272-1279. Fig. 2	$g_{exc}(t) = g_{exc}^{0}\frac{t}{\tau}e^{1-\frac{t}{\tau}}$ g_{exc}^{0} = 0.05 mS/cm^2, τ = 3 ms
Thalamocortical EPSP amplitude in eNGC	Zhu and Zhu, J. Neurosci. 24 (2004): 1272-1279. Fig. 2 Lee et al., J. Neurosci. 30 (2010): 16796-16808. Fig. 7	3 - 7 mV
Thalamocortical EPSP waveform	Zhu and Zhu, J. Neurosci. 24 (2004): 1272-1279. Fig. 2	$g_{exc}(t) = g_{exc}^{0}\frac{t}{\tau}e^{1-\frac{t}{\tau}}$

in SBC		g_{exc}^{0} = 0.04 mS/cm^2, τ = 3 ms
Thalamocortical EPSP amplitude in SBC	Zhu and Zhu, J. Neurosci. 24 (2004): 1272-1279. Fig. 2 Lee et al., J. Neurosci. 30 (2010): 16796-16808. Fig. 7 (But see also Cruikshank et al. J. Neurosci. 32 (2012): 127813-17823. Fig. 4d)	3 - 7 mV
Strength of neuromodulatory input to eNGC	Unknown	Assumed to be same for eNGC and SBC
Strength of neuromodulatory input to SBC	Unknown	Assumed to be same for eNGC and SBC

Table S2. Related to Figure 7. Parameters of conductance-based models of L1 interneuron network. At the top of the table are the intrinsic electrophysiological properties of the individual eNGC and SBC-like neurons. At the bottom of the table are parameters related to the network. Some parameters were from data in rats or from different brain regions. We verified that where there was uncertainty in parameter values, the simulation results did not qualitatively depend on precise parameter values.