A MICROCIRCUIT MODEL WITH DIFFERENT INTERNEURON SUBTYPES

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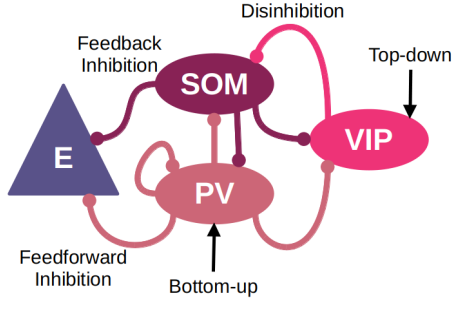
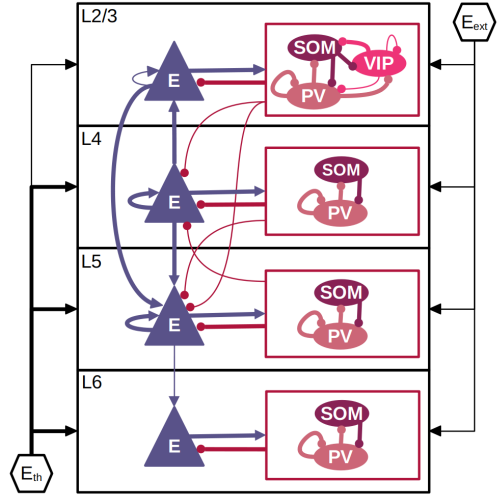
INTRODUCTION

- Parvalbumin (PV), somatostatin (SOM), vasoactive intestinal peptide (VIP) cells are the three major subtypes of interneurons in the cerebral cortex
- We develop a microcircuit model with PV, SOM, VIP cells to study how they contribute to network dynamics and sensory signal processing



MODEL OVERVIEW

- NEST 2.16.0
- Adapted from the microcircuit model of Potjans & Diesmann (2014)
- Leaky-integrate-and-fire neurons with exponential postsynaptic current
- Parameters based on mouse barrel cortex
- External Poisson inputs
  - E_{ext}: constant background input (strengths optimized)
  - E_{th}: transient thalamic input



POPULATIONS

- Neuron numbers
- Cell-type-specific parameters

	Exc	PV	SOM	VIP
L2/3	1691	90	74	85
L4	1656	85	48	-
L5	1095	109	105	-
L6	1288	56	66	-

(Lefort et al., 2009; Lee et al., 2010)

Parameter	L2/3, L4 Exc	L2/3, L4 PV	L2/3, L4 SOM	VIP	L5, L6 Exc	L5, L6 PV	L5, L6 SOM
τ_m(ms)	5.16	2.95	11.22	10.37	5.94	3.8	11.13
C_m (pF)	229.8	93.9	123.3	86.5	269.2	81.0	146.8
V_{rest} (mV)	-67.4	-66.4	-59.9	-65.7	-63.2	-67.1	-63.2
V_{th} (mV)	-41.5	-41.6	-41.8	-43.7	-45.2	-42.3	-48.1

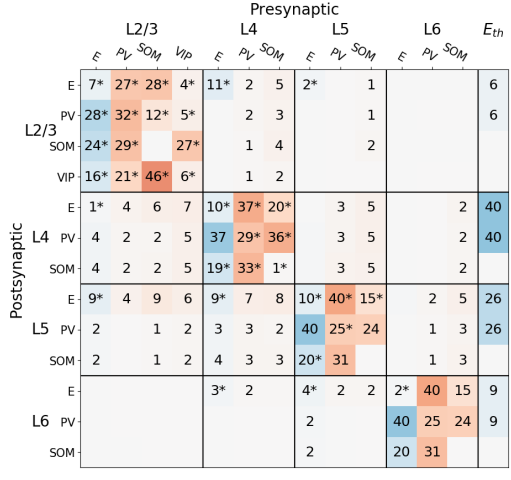
(Neske et al., 2015)

CONNECTIVITY

- Synaptic parameters
- Connection probabilities

Parameter	Value
$EPSP$	0.5±0.5 mV
$IPSP$	–2.0±2.0 mV
$EPSP_{th}$	0.49±0.13 mV
$EPSP_{ext}$	0.5 mV
$\tau_{syn(E)}$	2.0 ms
$\tau_{syn(I)}$	4.0 ms
d_E	1.36±0.51 ms
d_I	1.43±1.09 ms
d_{th}	1.72±0.73 ms

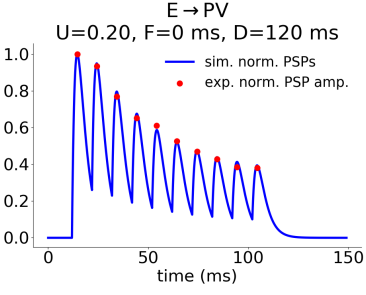
(Bruno & Sakmann, 2006; Jouhanneau et al., 2015, 2018)



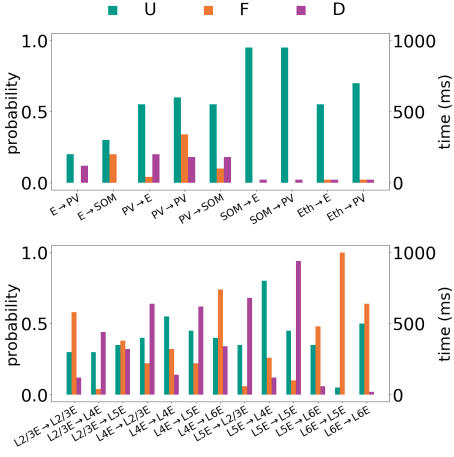
unit: %; numbers <1% are not shown

SYNAPTIC SHORT-TERM PLASTICITY (STP)

- Synaptic STP parameters (Tsodyks et al., 2000) are fitted to experimental data



U: parameter for release probability
F: facilitation time constant
D: depression time constant

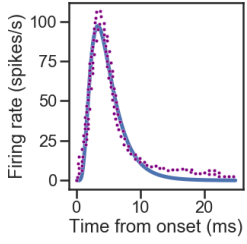


Fitted STP parameters of different connections

THALAMIC INPUT

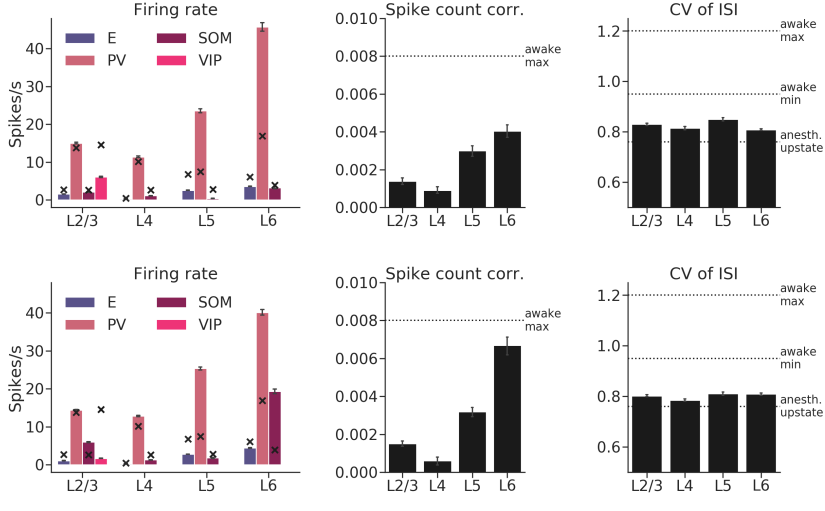
Simulating the thalamocortical responses to a whisker touch

- Two hundred thalamic neurons, firing time course according to *in vivo* data (Yu et al., 2019)
- Weight=0.49$\pm$0.13 mV (Bruno & Sakmann, 2006)
- Connect to E and PV cells, with STP parameters (Hu & Agmon, 2016)
- Layer-specific connection probability:
  L2/3: 0.062 L4: 0.4
  L5: 0.259 L6: 0.09
  (Constantinople & Bruno, 2013)



GROUND STATES

- Population firing rates vs. *in vivo* data (Yu et al., 2019)
- Asynchronous irregular state vs. *in vivo* data (Maksimov et al., 2018)

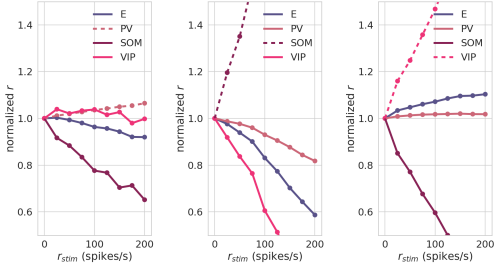


Top row: static-synapse. Bottom row: STP.

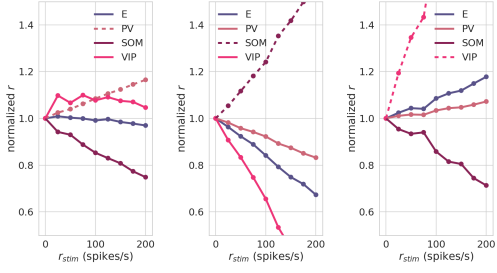
RESPONSES TO INTERNEURON ACTIVATION

- Responses in L2/3 to the activation of different interneurons show their **inhibition** (PV, SOM) and **disinhibition** (VIP) effects

Static-synapse

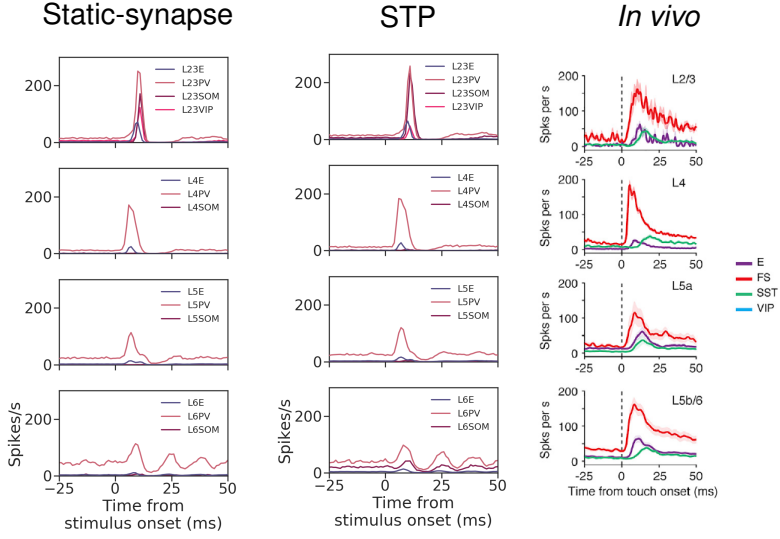


STP



RESPONSES TO THALAMIC INPUT

- Responses to the thalamic input vs. *in vivo* data (Yu et al., 2019)



DISCUSSION

- This model reproduces experimental observations and is suitable for relevant computational studies
- We seek to further analyze the mechanisms behind the results and study the roles of different interneurons
  - Compare with model without specific parameters of interneuron subtypes
  - Mean-field analysis
- Future works:
  - State-dependent neuromodulation (ACh)
  - Neuron-astrocyte interaction
  - Other sensory modalities

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