Helmstaedter et al., 2008, “The Relation between Dendritic Geometry, Electrical Excitability, and Axonal Projections of L2/3 Interneurons in Rat Barrel Cortex”. CerebCortex, doi:10.1093/cercor/bhn138

Numerical Simulations of L2/3 interneuron firing patterns: Model details.

We found experimentally that the number of primary dendrites was correlated with the ratio of action potential frequency adaptation in L2/3 interneurons from barrel cortex (Helmstaedter et al., 2008, Fig. 6). We investigated to what degree the morphology of the soma and dendrites alone can account for this correlation. Numerical simulations of 54 L2/3 interneurons and 4 L2/3 pyramidal neurons were made using identical sets of conductance densities in all simulations (for findings, cf. Helmstaedter et al., 2008, Fig 7,8, Suppl. Figure 9).

Morphologies

Manual reconstructions of the soma and dendrites of 54 L2/3 interneurons and 4 L2/3 pyramidal neurons were converted to the .hoc format. These models are available online:
http://www.mpimf-heidelberg.mpg.de/~mhelmsta/interneurons/.
A stereotypic axon was attached to all models using the routine from Mainen et al., 1995 and Mainen & Seijnowski 1996 (see `proc create_axon()` in `axonCreator.hoc` in the attached procedures). Spines were not inserted.

Passive and active membrane properties

Two sets of conductance densities were tested (s. Table 1 in this document). Conductance set 1 was based on the conductance distributions and mod-files used in Mainen and Seijnowski, 1996 with minor modifications. Conductance set 2 had less extreme values for C_m, R_i, E_{Ca} (s. Table 1). Also, we modified the active conductance densities in conductance set 2 to obtain more realistic passive voltage responses in the interneuron models. Note that with this conductance set 2, pyramidal neurons typically did not fire more than 1 AP in a train.

Current stimuli and output format

900ms long rectangular current pulses of varying amplitudes were applied (s. `automaticPars_v00.par` for numbers and `electrodeHandling.hoc` for implementation). The somatic membrane voltage is written in text format to a [40000x16]-matrix [$n_{timepoints}$ x n_{stim}] which can be read in by most analysis software. AP frequency adaptation was quantified in the trace with the initial AP frequency closest to 80Hz. In that trace, the following AP intervals were converted to frequencies and normalized to the initial frequency. AP frequency adaptation ratio was defined as the median of the normalized “80Hz”-AP frequency trace. (For conductance set 1, the minimum of the normalized AP frequency traces was used because of the high incidence of burst firing).

Comment

The goal of this study was to quantify the possible contribution of morphology to firing patterns, not to model realistic firing patterns in the first place. An identical set of conductances is highly unlikely to provide realistic firing patterns in a large variety of interneuronal morphologies as used here (cf. Suppl. Figs. 3-6 in Helmstaedter et al., 2008).

Running the models:

The models were run under Windows, NEURON version 5.9 (http://www.neuron.yale.edu):

Conductance set 1:

```
neuron.exe –dll mod-Files\nrnmech.dll conductanceSet1.par firingPatterns_automatic.hoc
```

Conductance set 2:

```
neuron.exe –dll mod-Files\nrnmech.dll conductanceSet2.par firingPatterns_automatic.hoc
```

An output folder “VOutput” is expected to exist in the home directory.

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	Mainen & Seijnowski, 1996, Nature 382: 363-366						Helmstaedter, Sakmann, Feldmeyer 2008, CerebCortex doi:10.1093/cercor/bhn138											
							conductance set 1						conductance set 2					
R_m [Ωcm^2]						30000						30000						40000
C_m [µF/cm^2]						0.75						0.75						0.9
R_i [Ωcm]						150						150						100
myelin_cm [µF/cm^2]						0.04						0.04						0.04
ranvier_rm [Ωcm^2]						50						50						50
E_{pas} [mV]						-70						-70						-70
E_K [mV]						-90						-90						-80
E_{Na} [mV]						60						60						60
E_{Ca} [mV]						140						140						0
	soma	dend	hill	iseg	node	myelin	soma	dend	hill	iseg	node	myelin	soma	dend	hill	iseg	node	myelin
gbarNa [pS/µm^2]*	20	20	30000	30000	30000	20	25	25	40000	40000	40000	25	6.25	6.25	10000	5000	5000	6.25
gbarKv [pS/µm^2]	200	0	2000	2000	2000	0	0	0	4000	4000	4000	0	200	0	1000	1000	1000	0
gbarKm [pS/µm^2]	0.1	0.1	0	0	0	0	0.1	0.1	0	0	0	0	0.025	0.075	0	0	0	0
gbarKca [pS/µm^2]	3	3	0	0	0	0	6	6	0	0	0	0	60	60	0	0	0	0
gbarCa [pS/µm^2]	0.3	0.3	0	0	0	0	0.5	0.5	0	0	0	0	0.5	0.5	0	0	0	0
temperature [°C]						37						33						36

* shift of activation and inactivation by -5mV as in Mainen & Seijnowski, 1996

Table 1