Supporting Text:

Detailed Description of Single Neuron Models

Pyramidal Cells

We used Hodgkin-Huxley-type conductance-based models for single pyramidal cells and interneurons, which were calibrated by *in vitro* physiological measurements. Pyramidal neurons have three compartments, representing a soma/initial axonal segment (s) and proximal (d1) and distal (d2) dendrites [1]. The neuronal input output relation and the shape of the somatic and dendritic action potential have been calibrated by cortical slice measurements. Several ion conductances that have been identified in prefrontal pyramidal neurons are included in the model [see Tegnér et al.[2] and refs. therein] [3, 4, 5]. The somatic compartment contains spike-generating currents (I_{Na} and I_K), a high-threshold calcium current I_{Ca}, and a slow calcium-dependent cationic current I_{Can}. The proximate dendritic compartment has a persistent sodium current I_{NaP} and a slowly inactivating potassium current I_{KS}. The distal dendritic compartment has an I_{Ca} and a transient A-type potassium current I_A.

The somatic voltage V_s, proximal dendritic voltage V_{d1}, and distal dendritic voltage V_{d2} obey the membrane equations:

$$C_m \frac{dV_s}{dt} = -I_{Na} - I_K - I_{Ca} - I_L - I_{Can} - gc_1(V_s - V_{d1})/p_1 - I_{syn}, \quad (1)$$

$$C_m \frac{dV_{d1}}{dt} = -I_{NaP} - I_{KS} - I_L - gc_1(V_{d1} - V_s)/p_2 - gc_2(V_{d1} - V_{d2})/p_2 - I_{syn}, \quad (2)$$

$$C_m \frac{dV_{d2}}{dt} = -I_A - I_{Ca} - I_L - gc_2(V_{d2} - V_{d1})/(1 - p_1 - p_2) - I_{syn}. \quad (3)$$

The capacitance $C_m = 1 \; \mu F/cm^2$, $I_L = g_L(V - V_L)$ with $g_L = 0.05 \; mS/cm^2$ and $V_L = -70$ mV. We denote the membrane areas for the three compartments as A_s, A_{d1}, A_{d2}, and $A_{tot} = A_s + A_{d1} + A_{d2}$. Then $p_1 = A_s/A_{tot}$, $p_2 = A_{d1}/A_{tot}$, and $1 - p_1 - p_2 = A_{d2}/A_{tot}$. If the axial resistance is R_1 between V_s and V_{d1} and R_2 between V_{d1} and V_{d2}, then $gc_1 = 1/(R_1 A_{tot})$ and $gc_2 = 1/(R_2 A_{tot})$. The electrotonic parameter values are: $p_1 = 0.5$, $p_2 = 0.3$, $gc_1 = 0.75$, $gc_2 = 0.25$.

The voltage-dependent currents are described by the Hodgkin-Huxley formalism. Thus, a gating variable x satisfies a first-order kinetics,

$$\frac{dx}{dt} = \phi_x(\alpha_x(V)(1-x) - \beta_x(V) \; x) = \phi_x(x_\infty(V) - x)/\tau_x(V),$$

where $\phi_x = 1$ unless specified otherwise.

The sodium current $I_{Na} = g_{Na}m^3_\infty(V)h(V - V_{Na})$, where the fast activation variable is replaced by its steady-state, $m_\infty = \alpha_m/(\alpha_m + \beta_m)$, $\alpha_m = -0.1(V + 31)/(\exp(-0.1(V + 31)) - 1)$, $\beta_m = 4\exp(-(V + 56)/18)$; $\alpha_h = 0.07\exp(-(V + 47)/20)$, and $\beta_h = 1/(\exp(-0.1(V+17))+1)$. The delayed rectifier $I_K = g_K n^4(V - V_K)$, where $\alpha_n = -0.01(V+34)/(\exp(-0.1(V+34))-1)$, and $\beta_n = 0.125\exp(-(V+$

44)/80). The temperature factor $\phi_h = \phi_n = 4$. Other parameters are: $g_{Na} = 55$, $g_K = 15$ (in mS/cm^2); and $V_{Na} = +55$, $V_K = -80$ (in mV).

The high-threshold calcium current[6] $I_{Ca} = g_{Ca}m_\infty^2(V)(V - E_{Ca})$, $m_\infty(V) = 1/(1 + \exp(-(V + 20)/9))$, $E_{Ca}=+120$ mV. The calcium dynamics in the soma (s) and the distal dendrite (d2) follows: $d[Ca^{2+}]/dt = -\alpha_{Ca}I_{Ca} - Ca^{2+}/\tau_{Ca}$. Somatic and distal dendritic parameters are: $\alpha_{Ca,s}=0.000667$, $\alpha_{Ca,d2}=0.002$ [in $\mu M(ms\,\mu A)^{-1}cm^2$], $\tau_{Ca,s}=240$, $\tau_{Ca,d2}=80$ (in ms), $g_{Ca,s}=1.5$ $g_{Ca,d2}=0.25$ (in mS/cm^2).

The slow calcium-dependent cationic current [7] $I_{Can} = g_{Can}m^2(V - E_{Can})$, $dm/dt = (m_\infty(Ca) - m)/\tau_{Can}(Ca)$, $m_\infty(Ca) = \alpha Ca^2/(\alpha Ca^2 + \beta)$, $\beta = 0.002$ $(ms)^{-1}$, $\alpha = 0.0056$ $(ms\,(mM)^2)^{-1}$, $\tau_{Can}(Ca) = 1/(\alpha Ca^2 + \beta)(ms)$. $E_{Can} = -20$ mV, $g_{Can}=0.025$ (mS/cm^2).

The persistent sodium current $I_{NaP} = g_{NaP}m_\infty^3 h(V - E_{Na})$ includes a very slow inactivation [4]. The steady-state activation $m_\infty(V) = 1/(1 + \exp(-(V + 55.7)/7.7))$. The kinetic parameters for the inactivation variable h are $\alpha(V) = 0.001\exp((-85 - V)/30)$, $\beta(V) = 0.0034/(\exp((-17 - V)/10) + 1)$, the maximum conductance $g_{NaP}=0.15$ mS/cm^2. The slowly inactivating potassium current $I_{KS} = g_{KS}qr(V - E_{KS})$, with $q_\infty(V) = 1/(1 + \exp(-(V + 34)/6.5))$ and $\tau_q(V) = 8/(\exp(-((V + 55)/30)) + \exp((V + 55)/30))$; $r_\infty(V) = 1/(1 + \exp((V + 65)/6.6))$ and $\tau_r(V) = 100/(1+\exp(-((V+65)/6.8)))+100$, and the maximum conductance $g_{KS}=2$ mS/cm^2.

The A current $I_A = g_A a^4 b(V - E_K)$, with $a_\infty(V) = 1/(1+\exp(-(V+60)/8.5))$ and $\tau_a(V) = 0.37 + 1/(\exp((V + 35.8)/19.7) + \exp(-(V + 79.7)/12.7))$; $b_\infty(V) = 1/(1+\exp((V+78)/6))$ and $\tau_b(V) = 19+1/(\exp((V+46)/5)+\exp((V+238)/(-37.5)))$,

and the maximum conductance g_A=1.0 (in mS/cm^2).

Inhibitory Interneurons

Perisoma-targeting (PV, parvalbumin) interneurons are modeled as $C_m dV/dt = -I_{Na} - I_K - I_L - I_{syn} + I$, hence they include only spike-generating sodium and potassium currents and show tonic fast-spiking behavior[8]. The sodium current $I_{Na} = g_{Na} m_\infty^3 h(V - E_{Na})$. The activation variable m is substituted by its steady-state $m_\infty = \alpha_m/(\alpha_m + \beta_m)$; $\alpha_m(V) = -0.1(V + 35)/(\exp(-0.1(V + 35)) - 1)$, $\beta_m(V) = 4\exp(-(V + 60)/18)$. The kinetic parameters for the inactivation variable h are $\alpha_h(V) = 0.07\exp(-(V + 58)/20)$, and $\beta_h(V) = 1/(\exp(-0.1(V + 28)) + 1)$. $g_{Na} = 35$ mS/cm^2, $E_{Na} = 55$ mV, $\phi = 5$. The delayed rectifier $I_K = g_K n^4(V - E_K)$, with $\alpha_n(V) = -0.01(V + 34)/(\exp(-0.1(V + 34)) - 1)$, and $\beta_n(V) = 0.125\exp(-(V + 44)/80)$; $g_K = 9$ mS/cm^2, $E_K = -90$ mV. Other parameter values: $C_m = 1$ μF/cm^2, $g_L = 0.1$ mS/cm^2, so that the passive membrane time constant is $C_m/g_L = 10$ ms, and $E_L = -65$ mV.

Dendritic targeting calbindin (CB) interneurons show spike-frequency adaptation due to a calcium-activated potassium current and postinhibitory rebound due to a hyperpolarization-activated cationic current [9, 10]. They are modeled as $C_m dV/dt = -I_{Na} - I_K - I_h - I_{Ca} - I_{KCa} - I_L - I_{syn} + I$, where the spike-generating I_{Na} and I_K are the same as for the PV cells. The high-threshold calcium current I_{Ca} follows similar equations as the pyramidal cell model. For the calcium dynamics, $\alpha_{Ca} = 0.002$ $\mu M(ms$ $\mu A)^{-1}cm^2$, and $\tau_{Ca} = 80$ ms. The voltage-independent, calcium-activated potassium current $I_{KCa} = g_{KCa}([Ca^{2+}]/([Ca^{2+}] +$

$K_D))(V - E_K)$, with $K_D = 30\mu$M. The hyperpolarization-activated current follows $I_h = g_h H(V - E_h)$, with $H_\infty(V) = 1/(1 + \exp((V + 80)/10))$, and $\tau_H(V) = 200/(\exp((V + 70)/20) + \exp(-(V + 70)/20)) + 5$, $E_h = -40$ mV. Other parameter values are: g_L=0.1, g_{Na}=35, g_K=9, g_h=0.15, g_{Ca}=1, g_{KCa}=10 (in mS/cm^2); $E_L = -65$, $E_{Na} = 55$ and $E_K = -85$ (in mV).

Calretinin (CR) interneurons show irregular firing patterns [11] due to an interplay between several voltage-activated ion currents. They follow $C_m dV/dt = -I_{Na} - I_K - I_{Ca} - I_{KCa} - I_{Ca,T} - I_{NaP} - I_L - I_{syn}$, where I_{Na} and I_K are the same as for the PV neuron; I_{NaP} is modeled as for the pyramidal neuron; and I_{Ca} and I_{KCa} are modeled as for the CB neuron. The low-threshold calcium current $I_{Ca,T}(V) = g_{Ca,T} m_\infty^2(V) h(V - E_{Ca})$, with $m_\infty(V) = 1/(1 + \exp(-(V + 59)/6.2))$, $h_\infty(V) = 1/(1+\exp((V+81)/4.4))$, and $\tau_h(V) = 7.14+52.4/(1+\exp((V+74)/3))$. The maximum conductances are: g_L=0.1, g_{NaP}=0.0525, g_{Ca}=1.25 (high-threshold calcium conductance), g_{KCa}=1.0, $g_{Ca,T}$=1.475 (T-type calcium conductance) (in mS/cm^2). The reversal potentials $E_L = -75$, $E_{Na} = 55$ and $E_K = -85$ (in mV).

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