Model of Patel-Rangan-Cai on J Comput Neurosci 09

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1 Membrane potentials

The membrane potential for each PN is governed by the following equation:

$$C_m \frac{dV_{PN}}{dt} = -g_L(V_{PN} - E_L) - I_{Na} - I_K - I_A - I_{GABA} - I_{nACH} - I_{stim} - I_{slow},$$

where $C_m = 1.0\mu F, g_L = 0.3\mu S, E_L = -64mV$.

The membrane potential for each LN is governed by the following equation:

$$C_m \frac{dV_{LN}}{dt} = -g_L(V_{LN} - E_L) - I_{Ca} - I_K - I_B - I_{GABA} - I_{nACH} - I_{stim},$$

where $C_m = 1.0\mu F, g_L = 0.3\mu S, E_L = -50mV$.

2 Intrinsic currents

The intrinsic currents consisted of fast sodium and potassium currents I_{Na} and I_K, a transient calcium current I_{Ca}, a calcium-dependent potassium current I_B, and a transient potassium current I_A. All such currents obeyed equations of the following form:

$$I_j = g_j m^M h^N (V - E_j),$$

where j is K, Na, Ca, A or B.

The maximal conductances were $g_{Na} = 120\mu S, g_K = 3.6\mu S, g_A = 1.43\mu S$ for PNs; and $g_{Ca} = 5.0\mu S, g_B = 0.045\mu S, g_K = 36\mu S$ for LNs.

For PNs, the reversal potentials were $E_{Na} = 40mV, E_K = E_A = -87mV$; and for LNs, they were $E_{Ca} = 140mV, E_K = E_B = -95mV$.

The gating variables m and h take values between 0 and 1 and obey the following equations:

$$\frac{dm}{dt} = \frac{m_\infty(V) - m}{\tau_m(V)},$$

and

$$\frac{dh}{dt} = \frac{h_\infty(V) - h}{\tau_h(V)}.$$

Detailed parameters can be found from Table [1] and [2], where the dynamics of intracellular calcium concentration $[Ca]$ were governed by the following equation:

$$\frac{d[Ca]}{dt} = -AI_{Ca} - \frac{[Ca] - [Ca]_\infty}{\tau},$$

where $[Ca]_\infty = 0.00024mM, A = 0.0002(mM \cdot cm^2)/(ms \cdot \mu A), \tau = 150ms.$

Table 1: m parameters for gating variables

Gating	M	m_∞	τ_m
I_{Na}	3	$\frac{0.1v-2.5}{0.1v-2.5+4(1-e^{0.1V-2.5})e^{\frac{V}{18}}}$	$\frac{e^{0.1v-2.5}}{0.1v-2.5+4(1-e^{0.1V-2.5})e^{\frac{V}{18}}}$
I_K	4	$\frac{0.01(V-10)}{0.01(V-10)+0.125e^{\frac{v}{80}}}$	$\frac{e^{\frac{v-10}{10}}-1}{0.01(V-10)+0.125e^{\frac{v}{80}}}$
I_{Ca}	2	$\frac{1}{1+e^{-\frac{V+20}{6.5}}}$	$1 + 0.014(V + 30)$
I_A	4	$\frac{1}{1+e^{-\frac{V+60}{8.5}}}$	$0.1+\frac{0.27}{e^{\frac{V+35.8}{19.7}}+e^{-\frac{V+79.7}{12.7}}}$
I_B	1	$\frac{[Ca]}{[Ca]+2}$	$\frac{100}{[Ca]+2}$

Table 2: h parameters for gating variables

Gating	N	h_∞	τ_h
I_{Na}	1	$\frac{0.07e^{0.05V}(e^{0.1V-3}+1)}{1+0.07e^{0.05V}(e^{0.1V-3}+1)}$	$\frac{e^{0.1V-3}+1}{1+0.07e^{0.05V}(e^{0.1V-3}+1)}$
I_K	0	-	-
I_{Ca}	1	$\frac{1}{1+e^{\frac{V+25}{12}}}$	$0.3e^{\frac{V-40}{13}} + 0.002e^{-\frac{V-60}{29}}$
I_A	1	$\frac{1}{1+e^{\frac{V+78}{6}}}$	$5.1\ (V > -63mV)$
			$\frac{0.27}{e^{\frac{V+46}{5}}} + e^{-\frac{V+238}{37.5}}$ (else)
I_B	0	-	-

3 Synaptic currents

The GABA and nicotinic acetylcholine currents were governed by equations of the following form:

$$I_j = g_j[O](V - E_j),$$

where j is $nACH$ or $GABA$.

The reversal potentials were $E_{nACH} = 0mV$ and $E_{GABA} = -70mV$ for both PNs and LNs. For PNs, the maximal synaptic conductances were $g_{GABA} = 0.36\mu S$ (from LNs to this PN), $g_{nACH} = 0.009\mu S$ (from other PNs to this PN); and for LNs, they were $g_{GABA} = 0.3\mu S$ (from other LNs to this LN), $g_{nACH} = 0.045\mu S$ (from PNs to this LN).

The fraction of open channels [O] obeyed the equation

$$\frac{d[O]}{dt} = \alpha(1 - [O])[T] - \beta[O].$$

For GABAergic synapses the rate constants were $\alpha = 10ms^{-1}, \beta = 0.16ms^{-1}$, while for nicotinic acetylcholine synapses the rate constants were $\alpha = 10ms^{-1}, \beta = 0.2ms^{-1}$.

For GABAergic synapses $[T]$ was governed by the equation $[T] = \frac{1}{1+e^{\frac{-(V(t)-V_0)}{\sigma}}}$, where $V_0 = -20mV, \sigma = 1.5$.

For nicotinic acetylcholine synapses $[T]$ was governed by the equation

$$[T] = A\theta(t_0 + t_{max} - t)\theta(t - t_0),$$

where $\theta(x)$ is the Heaviside step function, t_0 is the time of receptor activation, $A = 0.5$, and $t_{max} = 0.3ms$.

The slow inhibitory current from LNs to PNs was governed by the following scheme:

$$I_{slow} = g_{slow}(V - E_K)\frac{[G]^4}{[G]^4 + K},$$

where

$$\frac{d[G]}{dt} = r_3[R] - r_4[G] \text{ ; and in turn } \frac{d[R]}{dt} = r_1(1 - [R])[T] - r_2[R],$$

$g_{slow} = 0.36\mu S$ from LNs to PNs only, the reversal potential was $E_K = -95mV$ and $K = 100\mu M^4$; rate constants were $r_3 = 0.1ms^{-1}$, $r_4 = 0.033ms^{-1}$, $r_1 = 0.5mM^{-1}ms^{-1}$, and $r_2 = 0.0013ms^{-1}$