

Equations and parameters

The model neuron is described by two differential equations, the membrane potential (V) and the fraction of activated delayed rectifier K^+ channels (n):

$$C \frac{dV_j}{dt} = - \left[I_{Na_j} + I_{K_j} + I_{l_j} + I_{syn,e_j} + I_{syn,i_j} - I_{app} \right] \quad (1)$$

$$\frac{dn_j}{dt} = \alpha_n(V_j)(1 - n_j) - \beta_n(V_j)n_j \quad (2)$$

$$\alpha_n(V) = 0.01(10.0 - V)/(e^{0.1(10.0-V)} - 1.0) \quad (3)$$

$$\beta_n(V) = 0.125e^{-V/80} \quad (4)$$

The neuron diversity activity is established in the population by randomly choosing the applied current parameter, I_{app} , from a uniform distribution over the range -10 to $5\mu A/cm^2$

The Na^+ current is simplified and assumes instantaneous activation as in Rinzel (1985):

$$I_{Na} = g_{Na} m_{\infty}^3(V_j)(0.8 - n_j)(V_j - V_{Na}) \quad (5)$$

The K^+ and leakage currents are, respectively:

$$I_{K_j} = g_K n_j^4 (V_j - V_K) \quad (6)$$

$$I_{l_j} = g_l (V_j - V_l) \quad (7)$$

A subgroup of the N neurons in the population are inhibitory (N_i neurons), while the remainder are excitatory (N_e neurons). The synaptic currents have the form

$$I_{syn,e_j} = g_{syn,e_j}(V_j - V_{exc}) \quad (8)$$

$$I_{syn,i_j} = g_{syn,i_j}(V_j - V_{inh}) \quad (9)$$

where the excitatory and inhibitory synaptic conductances are:

$$g_{syn,e_k} = \frac{\bar{g}_{syn}}{N} \sum_{j=1}^{N_e} a_j s_j - a_k s_k \quad (10)$$

$$g_{syn,i_k} = \frac{\bar{g}_{syn}}{N} \sum_{j=N_e+1}^N a_j s_j - a_k s_k \quad (11)$$

The maximum strength of any one synapse is \bar{g}_{syn} . The sums are over all neurons except for the postsynaptic neuron itself (shown by the subtraction term $a_k s_k$). Both synaptic conductances terms drive the voltage of the actual neuron (Equation 1).

For each of N neurons, the neuron activity a_j and efficacy s_j are described by:

$$\frac{da_j}{dt} = \Pi(V_j) \alpha_a (1 - a_j) - \beta_a a_j \quad (12)$$

$$\frac{ds_j}{dt} = \alpha_s (1 - s_j) - \Pi(V_j) \beta_s s_j \quad (13)$$

The function $\Pi(V_j) = 1/(1 + e^{(v_{th}-V_j)/kv_j})$ reflects synaptic release when the presynaptic voltage V_j depolarizes above V_{th} during an action potential. The average network activity and synaptic efficacy are $\langle a \rangle = \frac{1}{N} \sum_{j=1}^N a_j$ and $\langle s \rangle = \frac{1}{N} \sum_{j=1}^N s_j$, respectively.

Network model parameters are shown in Table 1.

Table 1 Parameters of the network model using Hodgkin-Huxley-type neurons

Parameter	Description	Value
g_l	Leak conductance	0.1 S/cm ²
V_l	Leak reversal potential	-10.6 mV
g_{Na}	Sodium conductance	36 mS/cm ²
V_{Na}	Sodium reversal potential	115 mV
g_k	Potassium conductance	12 mS/cm ²

V_k	Potassium reversal potential	-12 mV
\bar{g}_{syn}	Max. synaptic conductance	3.6 mS/cm ²
V_{exc}	Excitatory reversal potential	70 mV
V_{inh}	Inhibitory reversal potential	70 to -12 mV
I_{app}	Input or applied current	-10 to 5 μ A/cm ²
α_a	Synaptic activation rate	1 ms ⁻¹
β_a	Synaptic decay rate	0.1 ms ⁻¹
α_s	Synaptic recovery rate	0.0015 ms ⁻¹
β_s	Synaptic depression rate	0.12 ms ⁻¹
V_{th}	Threshold for activation/depression	40 mV
