Equations

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

$$C\frac{dV_j}{dt} = -\left[I_{Na_j} + I_{K_j} + I_{l_j} + I_{syn,e_j} + I_{syn,i_j} - I_{app}\right] \tag{4}$$

$$\frac{dn_j}{dt} = \alpha_n(V_j)(1-n_j) - \beta_n(V_j)n_j \tag{5}$$

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):

$$I_{Na} = g_{Na}m_\infty^3(V_j)(0.8-n_j)(V_j - V_{Na}) \tag{6}$$

The K^+ and leakage currents are, respectively:

$$I_{K_j} = g_K n_j^4(V_j - V_K) \tag{7}$$

$$I_{l_j} = g_l(V_j - V_l) \tag{8}$$

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

$$I_{syn,e_j} = g_{syn,e_j}(V_j - V_{exc}) \tag{9}$$

$$I_{syn,i_j} = g_{syn,i_j}(V_j - V_{inh}) \tag{10}$$

where the excitatory and inhibitory synaptic conductances are:

$$g_{syn,e_k} = \frac{\bar{g}_{syn}}{N}\sum_j^{N_e} a_j s_j - a_k\, s_k \tag{11}$$

$$g_{syn,i_k} = \frac{\bar{g}_{syn}}{N} \sum_{j}^{N_i} a_j s_j - a_k\, s_k \tag{12}$$

The maximum strength of any one synapse is $\bar{g}_{syn}$. The sums are over all neurons except for the postsynaptic neuron itself. For each of N neurons, the neuron activity a_j and efficacy s_j are described by:

$$\frac{da_j}{dt} = \Pi(V_j)\alpha_a(1 - a_j) - \beta_a a_j \tag{13}$$

$$\frac{ds_j}{dt} = \alpha_s(1 - s_j) - \Pi(V_j)\beta_s s_j \tag{14}$$

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 μA/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