Supporting Text

Detailed Learning Rule and Parameters. The 100 excitatory synapses follow the calcium-dependent plasticity rule,

$$\frac{dw_i}{dt} = \eta([\mathrm{Ca}]_i)[\Omega([\mathrm{Ca}]_i) - \lambda w_i], \quad (1)$$

where w_i is the weight of synapse i, i = 1, 2, …, 100. The learning curve Ω is a difference of sigmoids,

$$\Omega([\mathrm{Ca}]_i) = \sigma([\mathrm{Ca}]_i, \alpha_1, \beta_1) - 0.5 \times \sigma([\mathrm{Ca}]_i, \alpha_2, \beta_2), \quad (2)$$

with $\sigma(x,a,b) = \exp(b(x-a))/[1+\exp(b(x-a))]$ and (α_1, β_1, α_2, β_2) = (0.25, 60, 0.4, 20). The precise shape of Ω does not qualitatively affect the results of our simulations, as long as the U-shaped dependence on calcium is maintained. The learning rate η depends linearly on calcium, $\eta([\mathrm{Ca}]_i) = 2 \times 10^{-5}\,[\mathrm{Ca}]_i$, so potentiation occurs faster than depression. For the sake of simulation times, we set $\eta([\mathrm{Ca}]_i) = 2 \times 10^{-3}\,[\mathrm{Ca}]_i$ in the simulations showing input selectivity. We have verified that the fixed point is not altered as long as the rate of homeostasis is multiplied by the same factor. Finally, λ = 0.005 is the synaptic decay.

The local NMDAR-mediated calcium concentration follows a first-order linear differential equation,

$$\frac{d[\mathrm{Ca}]_i}{dt} = I - \frac{[\mathrm{Ca}]_i}{\tau}, \quad (3)$$

where I is the *N*-methyl-D-aspartate (NMDAR) calcium current and τ = 20 ms is the calcium passive decay time constant. I depends on the association between presynaptic spike times and postsynaptic depolarization level as $I_i = g f_i(t) H(V)$, where f describes the dynamics of the glutamate-receptor interaction, H describes the voltage-dependent

magnesium-block of the NMDAR, and g is the NMDAR conductance. Upon a prespike, f reaches its peak value of one. 70% of this value decays with a fast time constant τ_f^N = 50ms and the remainder decays with a slower time constant τ_s^N = 200 ms. H is given by

$$H(V) = \frac{V - V_{rev}}{1 + e^{-0.062V} / 3.57}, \tag{4}$$

with reversal potential for calcium V_{rev} = 130 mV. The contribution of the local depolarization to the H-function is negligible compared to the back-propagating action potentials (BPAP), so here we use $V = V_{\text{rest}}$ + BPAP(t).

Integrate-and-Fire Model. An integrate-and-fire model simulates the dynamics of the somatic membrane potential

$$\frac{dV_m(t)}{dt} = \frac{1}{\tau_m}\{V_{rest} - V_m(t) + G_{ex}(t)[V_{ex} - V_m(t)] + G_{in}(t)[V_{in} - V_m(t)]\}, \tag{5}$$

where τ_m = 20 ms is the membrane time constant, V_{ex} = 0, V_{in} = 65 mV and V_{rest} is the resting membrane potential. To simulate spike-frequency adaptation, V_{rest} is decreased by 2 mV upon a postsynaptic spike and decays back to the baseline value of -65 mV, with a time constant of 100 ms. If a presynaptic spike arrives at the excitatory [inhibitory] synapse i, $G_{ex[in]}(t) = G_{ex[in]}(t)(t\text{-}1) + s_i g_{ex[in]}^{\max}$, otherwise, G_{ex} and G_{in} decay exponentially with a time constant τ_g = 5 ms. For excitatory synapses, $(s_i, g_{ex}^{\max}) = (w_i, 0.03)$, while for inhibitory synapses, $(s_i, g_{in}^{\max}) = (1, 0.1)$. If V_m reaches the firing threshold of –55 mV, a postsynaptic spike is generated and BPAP(t) is updated to its peak value of 42 mV. 75% of this value decays rapidly (τ_f^B = 3ms) and the remainder decays slowly (τ_s^B = 35 ms).

Implementation of Stabilization. The biophysical model of stabilization can be implemented through a kinetic model for insertion and removal of NMDARs:

$$g \underset{k_+}{\overset{k_-(V-V_{rest})^2}{\rightleftarrows}} g_u, \qquad (6)$$

where g is the amount of NMDARs at the synapses, g_u is the amount of unused NMDARs from the internal pool, $k_-(V-V_{\text{rest}})^{\alpha}$ and k_+ are the kinetic constants of removal and insertion, respectively. As before, $V = V_{\text{rest}} + \text{BPAP}(t)$. If the number of receptors is proportional to their effective conductance, we can write the dynamic equation for the NMDAR conductance,

$$\frac{dg}{dt} = -\left[k_-(V - V_{rest})^2 + k_+\right]g + k_+ g_t, \qquad (7)$$

with the normalization factor $g_t = g + g_u$, $g_t = 4.5 \times 10^{-3}$ μM/(μV.ms), $k_- = 8 \times 10^{-9}$ ms^{-1} and $k_+ = 8 \times 10^{-7}$ ms^{-1}, except for the input selectivity simulations for which $k_- = 8 \times 10^{-7}$ ms^{-1}, $k_+ = 8 \times 10^{-5}$ ms^{-1} (see above). The results are not sensitive to the detailed functional form of the voltage-dependent transition rate.

1. Jahr, C. E. & Stevens, C. F. (1990) *J. Neurosci.* **10,** 3178-3182.