Supplemental Information

Mnemonic functions for nonlinear dendritic integration in hippocampal pyramidal circuits

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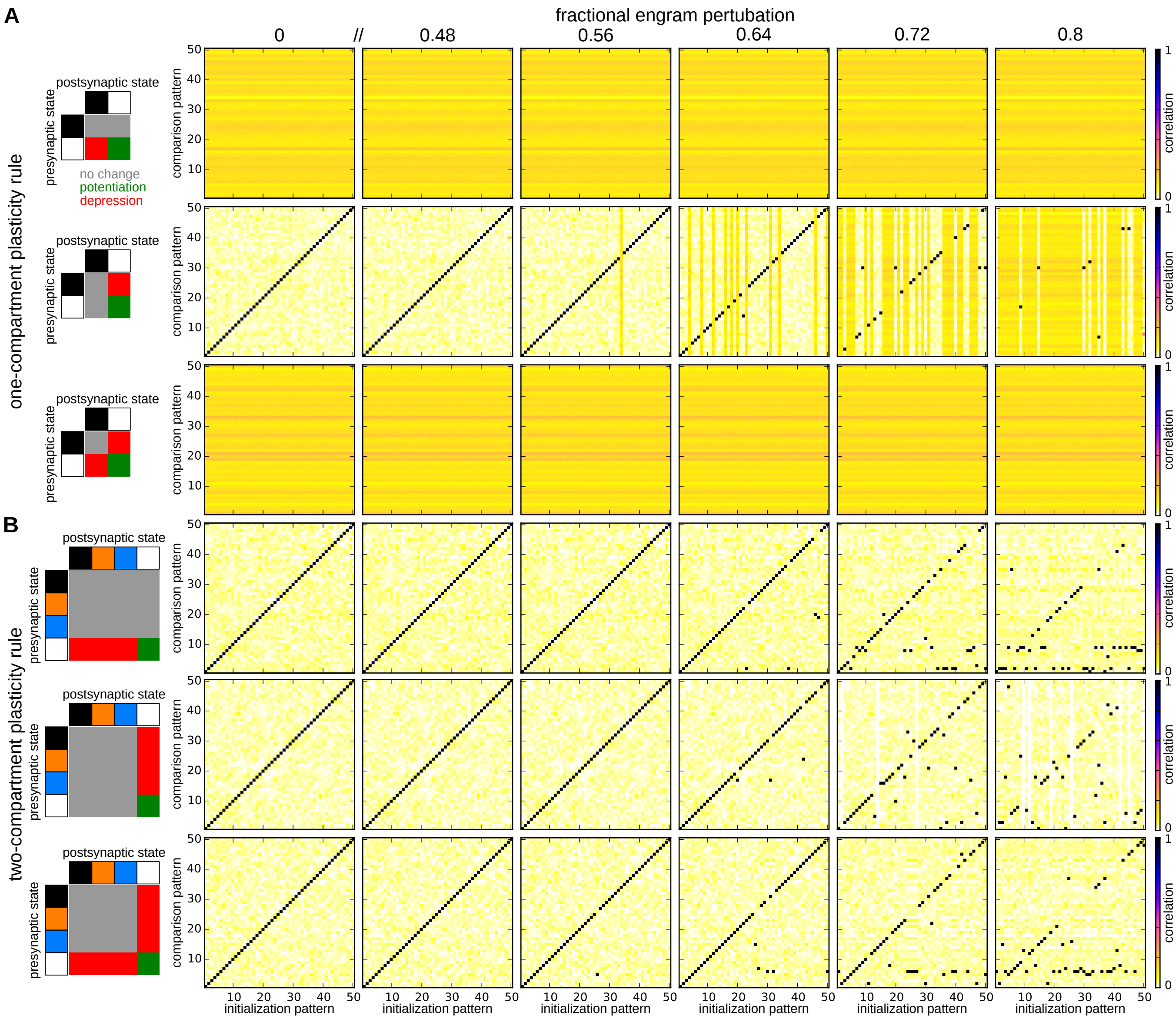
Inventory of supplemental information

A brief overview of how the Supplemental Figures relate to the main text is provided below.

Supplementary Figure 1, related to Figure 5: Recurrent dynamics initialized from perturbed engrams.

Supplementary Figure 2, related to Figure 5: Equilibrium synaptic weights expectations for symmetric and asymmetric plasticity rules.

Supplementary Figures

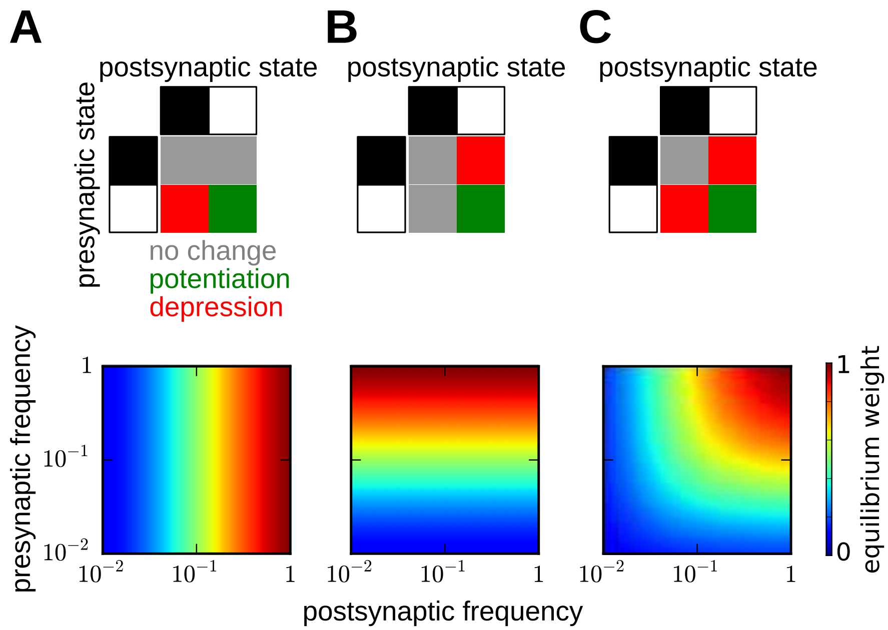


Supplementary Figure 1, related to Figure 5. Recurrent dynamics initialized from perturbed engrams.

Evaluation of engram attractor integrity and basins of attraction following the sequential storage of 200 similar (i.e. same distal inputs) patterns in a network of 10000 neurons, as in Figure 5D. Each correlation plot (right), corresponding to a different plasticity rule (left) and fractional perturbation, shows the correlation between the 50 most recently stored engrams (comparison patterns, ordered with most recent first) and the activity state to which the recall dynamics converged when the network was initialized with a perturbed version of each of these same engrams (initialization patterns). Each perturbed initialization pattern was determined by inactivating a randomly selecting a fraction of the active neurons in the stored pattern, and activating an equal number of randomly selected inactive neurons. All networks were matched with regard to sparsity and the pairwise correlation between similar engrams. Parameters were the same as in Figure 5D, except that in the case of asymmetric plasticity rules, the depression probability was doubled to compensate for the halving of the number of candidate synapses for depression.

(A) All one-compartment plasticity rules involving linear integration result in the formation of a ”composite” attractor. For reasons explored in Supplementary Figure 2, one asymmetric plasticity rule (second row) maintains individual engram attractors despite the presence of this ”composite” attractor.

(B) All two-compartment plasticity rules involving nonlinear integration avoid the formation of a ”composite” attractor and result in engrams with substantial basins of attraction. When perturbed patterns fall outside of the original pattern’s basin of attraction, the networks with nonlinear integration converge either to another similar stored engram (off-diagonal dark dots) or to a low-activity state (white vertical lines) rather than into a composite attractor.



Supplementary Figure 2, related to Figure 5. Equilibrium synaptic weight expectations for symmetric and asymmetric plasticity rules.

We consider the case of sequentially storing independent identically distributed random patterns in which the activity of each neuron is an independently Bernoulli (0 or 1) random variable. For each plasticity rule (top), the equilibrium expectation value of the synaptic weight is plotted (bottom) as a function of the frequencies with with the presynaptic and postsynaptic neurons are active in stored patterns.

(A) With synaptic depression at synapses from active presynaptic neurons to inactive postsynaptic neurons, the equilibrium expected weight is $[1 + (1 - f_{\text{post}})p_{-}/f_{\text{post}}p_{+}]^{-1}$, where p_{+} and p_{-} are the potentiation and depression probabilities and f_{pre} and f_{post} are the fraction of patterns in which the presynaptic and postsynaptic patterns are active.

(B) With synaptic depression at synapses from inactive presynaptic neurons to active postsynaptic neurons, the equilibrium expected weight is $[1 + (1 - f_{\text{pre}})p_{-}/f_{\text{pre}}p_{+}]^{-1}$. The low expected weight at synapses from infrequently active neurons onto frequently active neurons provides an explanation for why the network with this plasticity rule in Supplementary Figure 1A avoids transitions from the individual stored patterns to the composite attractor consisting of the most frequently active neurons.

(C) With synaptic depression at synapses from active presynaptic neurons to inactive postsynaptic neurons and from inactive presynaptic neurons to active postsynaptic neurons, the equilibrium expected weight is $[1 + \frac{1}{2}(f_{\mathrm{pre}}(1 - f_{\mathrm{post}}) + (1 - f_{\mathrm{pre}})f_{\mathrm{post}})p_{-}/f_{\mathrm{pre}}f_{\mathrm{post}}p_{+}]^{-1}$.