STOCHASTIC THERMODYNAMICS OF LEARNING

Spatial Features of Synaptic Adaptation Affecting Learning Performance

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Spatial features of synaptic adaptation affecting learning performance

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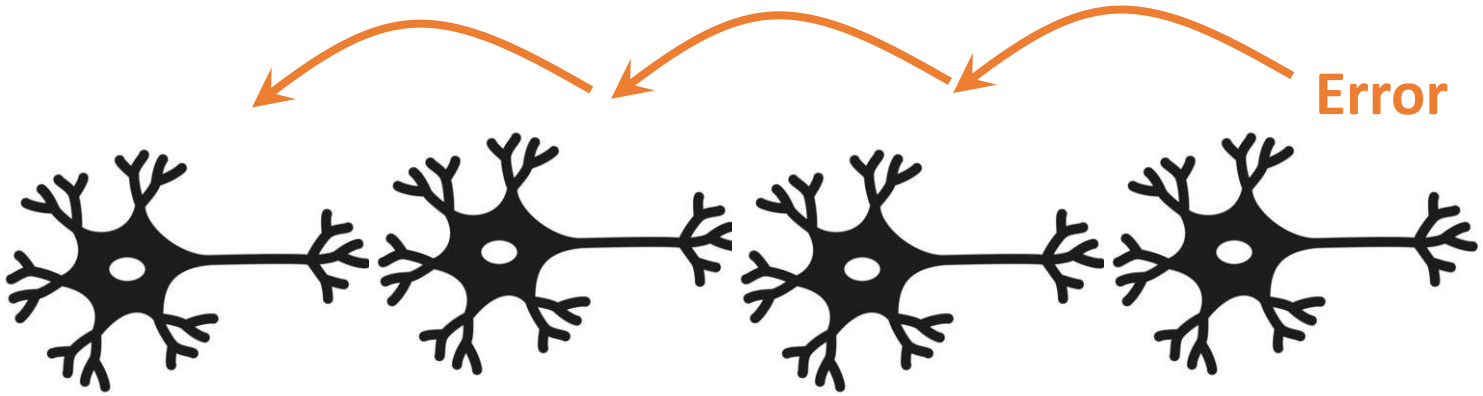
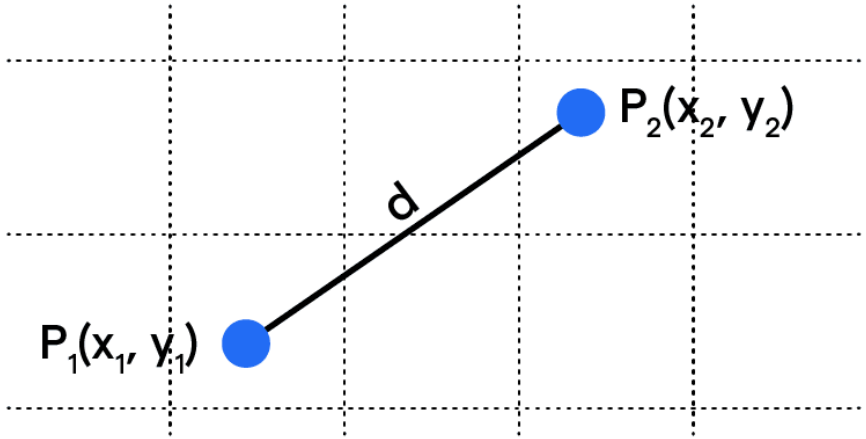


Error back propagation is unlikely to exist in the brain.

Negative feedback signals, which change synapses only if mistakes occurred, are more biologically plausible

Main Idea

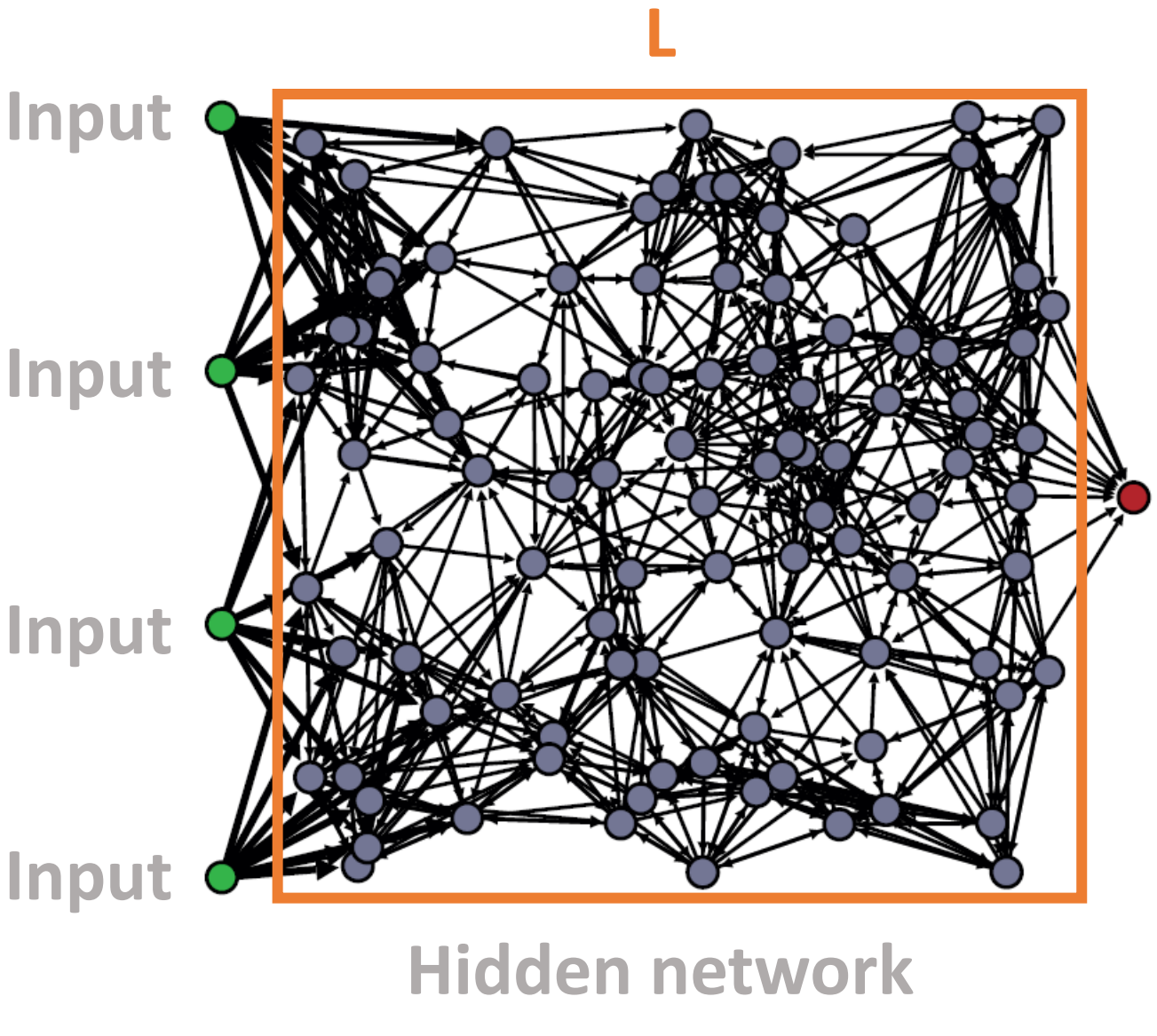
A model, where the strength of the feedback signal does not depend on a network distance, but on the **Euclidean distance**.



$$\text{Euclidean Distance (d)} = \sqrt{(x_2 - y_1)^2 + (y_2 - y_1)^2}$$

Localized learning

This is like spreading of **dopamine** whose effect covers a finite range of tens to thousands of synapses



Each connection is established by choosing a distance d from an exponential distribution

$$p(d) = \frac{1}{d_0} e^{-d/d_0}$$

The Firing Dynamics

1 During each time step all neurons with potential exceeding a certain threshold $v_i \geq v_{max} = 1$ fire.

2 After firing the potential of the neuron i is set back to zero and the voltage of all connected neurons j becomes

$$v_j(t+1) = v_j(t) \pm \omega_{ij}\eta_i$$

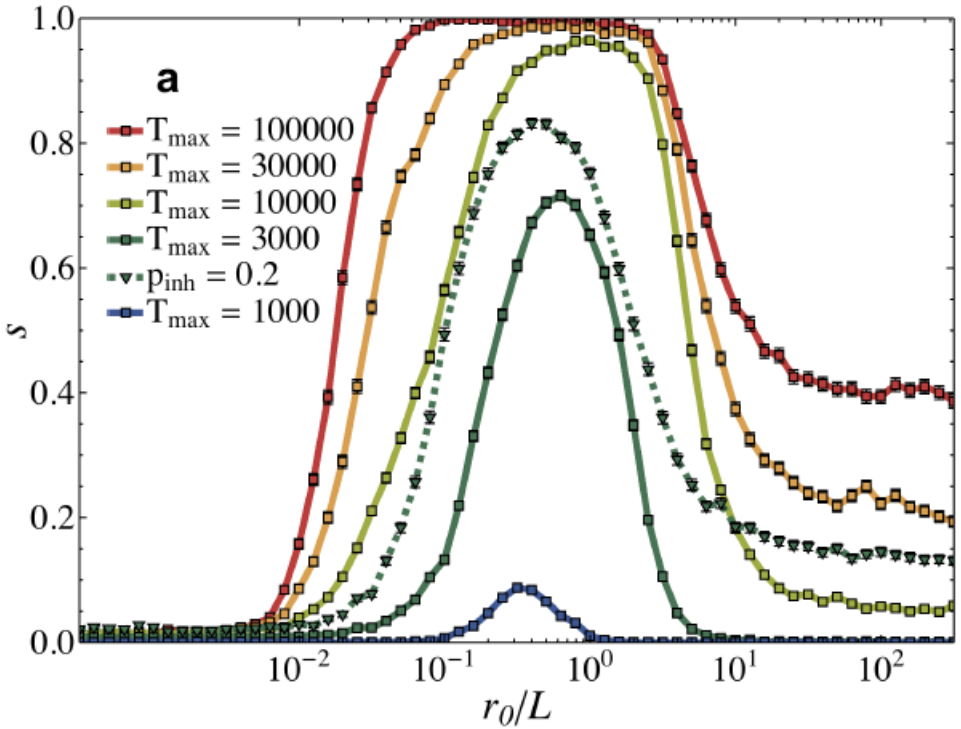
The Learning Process

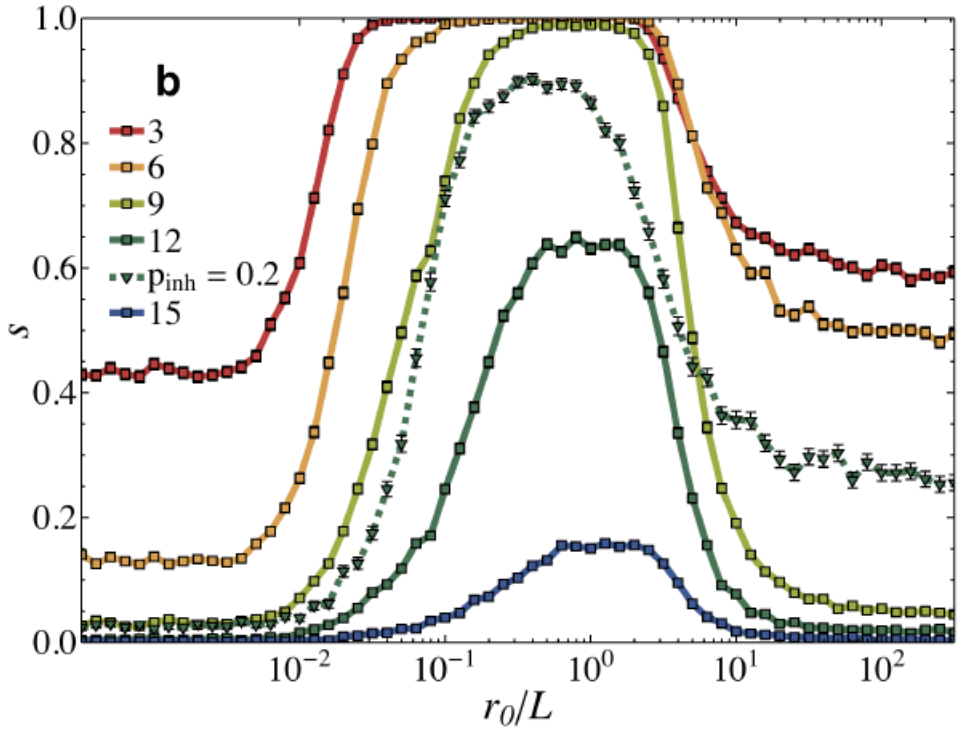
1. Whenever the result is wrong the synaptic strengths are adapted.

2. Only those synapses activated during the activity propagation are modified.

$$\Delta\omega_{ij} = \pm\alpha\omega_{ij}n_{act}e^{-r/r_0}$$

Results





Success rate $\boldsymbol{S}$ is defined by the ratio of networks which are able to learn all patterns within $\boldsymbol{T_{max}}$

Thank you!