Balanced inhibition allows for robust learning of input-output associations in feedforward networks with Hebbian plasticity | Gloria Cecchini

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In neural networks within the brain, the activity of a post-synaptic neuron is determined by the combined influence of many pre-synaptic neurons. This distributed processing enables mechanisms like Hebbian plasticity to associate sensory inputs with specific internal states, as seen in feedforward structures such as the CA1 region of the hippocampus. By modifying synaptic weights through Hebbian rules, sensory inputs can subsequently elicit outputs that reliably correlate with their associated internal states. When input and output patterns are uncorrelated, this approach allows for the encoding of a large number of distinct associations, enabling efficient memory storage.

However, our study demonstrates a critical limitation when output patterns become weakly correlated with input patterns, such as through the intrinsic feedforward connectivity of the network. In these cases, the Hebbian rule preferentially strengthens synaptic weights shared across patterns, leading to a “freezing” of the network’s structure. This results in highly correlated output patterns over time, effectively reducing the network’s capacity to store diverse associations and limiting its flexibility in learning.

To address this challenge, we propose the introduction of balanced inhibition, a mechanism that counteracts the undesired correlations between inputs and outputs. By dynamically regulating inhibitory input, balanced inhibition prevents the over-strengthening of shared weights, restoring the network’s ability to maintain robust and flexible learning.