## Dreaming and clipping in the Hopfield model

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The Hopfield model provides a paradigmatic framework for associative memory, where information is stored as stable attractors of the network dynamics. In its classical formulation based on the Hebbian learning rule, however, the model suffers from a fundamental limitation: when the number of stored patterns exceeds a critical threshold, the system undergoes catastrophic forgetting, abruptly losing the ability to retrieve any memory. While this transition has been extensively studied, it remains both biologically implausible and functionally undesirable, as real neural systems typically exhibit gradual rather than abrupt memory degradation.

A natural and biologically motivated modification of the model consists in imposing bounds on synaptic strengths through a clipping mechanism [1]. Clipping prevents unbounded synaptic growth and replaces catastrophic forgetting with a progressive form of interference, in which newer memories overwrite older ones. Although this mechanism eliminates the abrupt loss of information, it significantly reduces the overall storage capacity of the network, raising the question of whether additional biologically plausible processes can compensate for this limitation.

In parallel, early work by Hopfield and collaborators [2] introduced the idea of "unlearning," whereby the network undergoes a dreaming phase in which internally generated activity selectively weakens spurious attractors. This mechanism has been shown to improve storage capacity and stability in unconstrained networks. More recently, mixed learning–dreaming protocols have been revisited and shown to display remarkable effectiveness [3].

In this work [4], we investigate the interplay between synaptic clipping and dreaming in a Hopfield-type associative memory. We consider a learning protocol in which phases of standard Hebbian acquisition are interleaved with dreaming phases. Our results show that clipping robustly eliminates catastrophic forgetting, leading to a realistic regime of gradual memory degradation. More importantly, we find that the introduction of dreaming substantially enhances the effective storage capacity of the clipped model, partially compensating for the loss induced by bounded synapses.

A key finding of our analysis is that, in the presence of clipping, the memorization capacity exhibits a broad and smooth maximum as a function of the relative duration of learning and dreaming phases. This contrasts sharply with the unclipped case, where optimal performance typically requires fine-tuned parameter choices and is therefore difficult to achieve in practice. The emergence of a wide optimum suggests that alternating learning–dreaming cycles can provide a robust and adaptive mechanism for memory optimization, potentially accessible through evolutionary processes.

References:

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