# Bocconi

### 10 JUNE 2025 04:00 PM

On Zoom, Streaming in Room 2-E4-SR03 Via Röntgen 1, Milan, 2° floor

# Maximizing Memory Capacity in Heterogeneous Hopfield Networks

#### Abstract

A fundamental question in neuroscience is which neuronal and connectivity properties determine a network's ability to store information. We generalize classical results on Hopfield network memory capacity to heterogeneous networks with arbitrary neuron activation rates (coding levels) and connectivity structures. Our analytical formula predicts how these heterogeneities impact capacity.

We show that, while heterogeneity in coding levels and in-degrees typically reduces capacity, this loss is mitigated when the two are positively correlated. This prediction holds across biologically relevant scenarios: storing random patterns in classical or dendritic networks, as well as clustered patterns that reflect conceptual structure. In all cases, aligning coding levels with in-degrees preserves maximal capacity.

We also examine bipartite models of the hippocampal CA3–DG circuit. Here, capacity is maximized when DG coding is sparse and connections follow a "quasi-indexing" scheme—where each DG neuron binds features from a few patterns rather than fully indexing a single one. This improves both capacity and robustness to cell loss, offering new insight into hippocampal index theory.

Lastly, I will briefly introduce an experimental project on salience signaling in the basal forebrain (BF), a major modulator of cortical state. We identify BF neurons with phasic bursts to cues predicting reinforcement magnitude, probability, and timing. These neurons also respond to unexpected rewards and to novel or sequence-violating objects, but not to reward omissions, suggesting they signal surprise rather than value prediction error. These finding supports the idea that the BF broadcasts generalized salience signals that prime the brain to process behaviorally relevant information.

#### Speaker

## **Kaining Zhang**

Postdoc Washington University in St. Louis

