Analysis of Network Simulation Figures (N = 50 to 5000)

This section provides an academic and reviewer-ready analysis of eight network simulation figures generated for recurrent neural networks of sizes ranging from $N = 50$ to $N = 5000$. For each figure, we describe (i) what the figure represents, (ii) how the behavior changes as the network size increases, and (iii) whether the observed behavior is consistent with the RCNNG theoretical framework.

Neural Activity (first 5 neurons)

Description. This figure shows the temporal activity of the first five neurons under sinusoidal stimulation.

Changes with network size. For $N = 50$, activity traces are smooth and partially synchronized. For $N = 200$–500, the dynamics become more complex. For $N = 1000$–2000, activity becomes irregular. For $N = 5000$, activity is highly chaotic with transient motifs.

Consistency with RCNNG. The progression from smooth to chaotic trajectories matches RCNNG predictions that larger networks support more resonant closed geometries.

Input Signal

Description. A sinusoidal external input applied uniformly to all neurons.

Changes with network size. The input signal is fixed and does not vary with N.

Consistency with RCNNG. RCNNG assumes that external periodic stimulation seeds the fundamental frequency of resonant geometries.

Network Connectivity Graph

Description. A visualization of the recurrent connectivity matrix.

Changes with network size. For $N = 50$, local clusters are visible. For $N = 200$–500, the graph becomes dense. For $N = 1000$–2000, structural motifs are hard to detect visually. For $N = 5000$, the graph is fully saturated and requires topological tools.

Consistency with RCNNG. RCNNG requires a richly connected recurrent substrate capable of supporting multiple closed resonant geometries.

Hilbert Phase (Neuron 1)

Description. The instantaneous phase of neuron 1 computed via the Hilbert transform.

Changes with network size. For $N = 50$, phase increases smoothly. For $N = 200$–500, small phase slips appear. For $N = 1000$–2000, irregularities emerge. For $N = 5000$, phase stability is significantly reduced.

Consistency with RCNNG. RCNNG predicts reduced global phase stability in larger networks due to interference among resonant geometries.

Mean Activity (all neurons)

Description. The average activity across all neurons.

Changes with network size. For $N = 50$, mean activity is smooth and periodic. For $N = 200$–500, oscillations become more complex. For $N = 1000$–2000, the mean signal becomes noisy. For $N = 5000$, multi-frequency fluctuations dominate.

Consistency with RCNNG. RCNNG predicts multi-frequency interactions in larger networks.

FFT Spectrum (Neuron 1)

Description. The frequency spectrum of neuron 1.

Changes with network size. For $N = 50$, a single dominant peak appears. For $N = 200$–500, additional harmonics emerge. For $N = 1000$–2000, the spectrum broadens. For $N = 5000$, the spectrum becomes wide and noisy.

Consistency with RCNNG. RCNNG predicts richer frequency content in larger networks due to multiple resonant geometries.

Correlation Matrix of Neurons

Description. Pairwise correlations between all neurons.

Changes with network size. For $N = 50$, clear correlation blocks appear. For $N = 200$–500, patterns fragment. For $N = 1000$–2000, the matrix becomes noisy. For $N = 5000$, only small localized patches remain.

Consistency with RCNNG. RCNNG predicts localized synchrony as network size grows.

Closed Cycles in the Network Graph

Description. Detected closed loops (cycle basis) in the connectivity graph.

Changes with network size. For $N = 50$, few short cycles appear. For $N = 200$–500, more cycles emerge. For $N = 1000$–2000, multi-layered structures form. For $N = 5000$, a large number of cycles dominate the topology.

Consistency with RCNNG. This figure provides direct structural evidence for RCNNG: larger networks contain more closed geometries capable of supporting resonant dynamics.

Overall Conclusion

Increasing the network size from $N = 50$ to $N = 5000$ produces a systematic transition from low-dimensional, partially synchronized dynamics to high-dimensional, multi-frequency, and structurally complex behavior. These transitions are fully consistent with the core predictions of the RCNNG framework.