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The Effect of Local Learning Rules on Memory

By: The Unsupervised Minds

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01

Introduction & Literature Review

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Why Study Working Memory?

- Enables intelligent behaviors, like planning, reasoning, and sequencing, without explicit instruction.
- Temporarily holds and manipulates information.
- Integrates sensory, spatial, and temporal signals.

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Literature Grounding

- **Hebbian Learning**
  - "Neurons that fire together, wire together" — original local plasticity rule
- **Recurrent Neural Networks (RNNs)**
  - Capture sequential information
  - Well-suited for modeling brain-like behavior
- **Hopfield Networks**
  - Introduced attractor dynamics in RNNs
  - Laid foundation for memory stability
- **Empirical Evidence**
  - Primacy = long-term, Recency = short-term
  - How local rules shape functionally relevant attractors

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02

Question & Hypothesis

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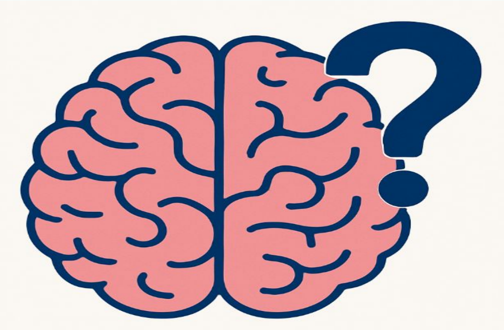
Research Question

★ Core Problem

- How does the brain learn to produce complex, organized behaviors (e.g., playing a tune, recalling an event sequence) without an external teacher?

★ Biological Basis



- Brain = vast network of interconnected neurons
- Learning ⟶ changes in synaptic strength

★ Computational Model

- Use Recurrent Neural Networks (RNNs) to simulate neural self-organization
- RNNs can autonomously generate sequences of activity

★ Focus of This Study

How do different local learning rules (Hebbian, anti-Hebbian) shape a network's

- **Synaptic organization**
- **Attractor landscape**

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Hypotheses

01

Converging Rules

Different learning rules tend to follow a general trajectory, ultimately producing similar solutions for a given task.

02

Diverging Rules

Each learning rule follows a distinct path, resulting in different yet plausible network configurations and solutions.

03

Initial Condition Sensitive

The effectiveness and outcome of a learning rule depend strongly on the initial state of the network.

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03

Method & Results

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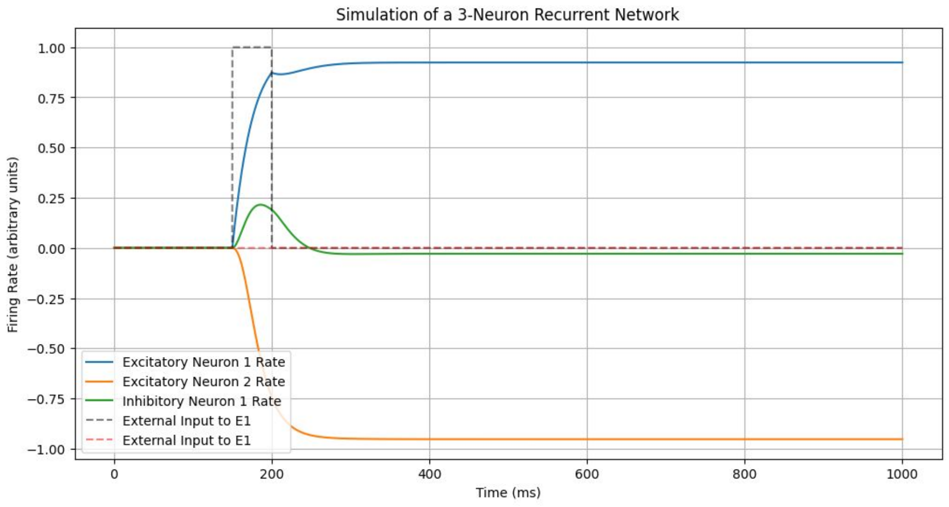

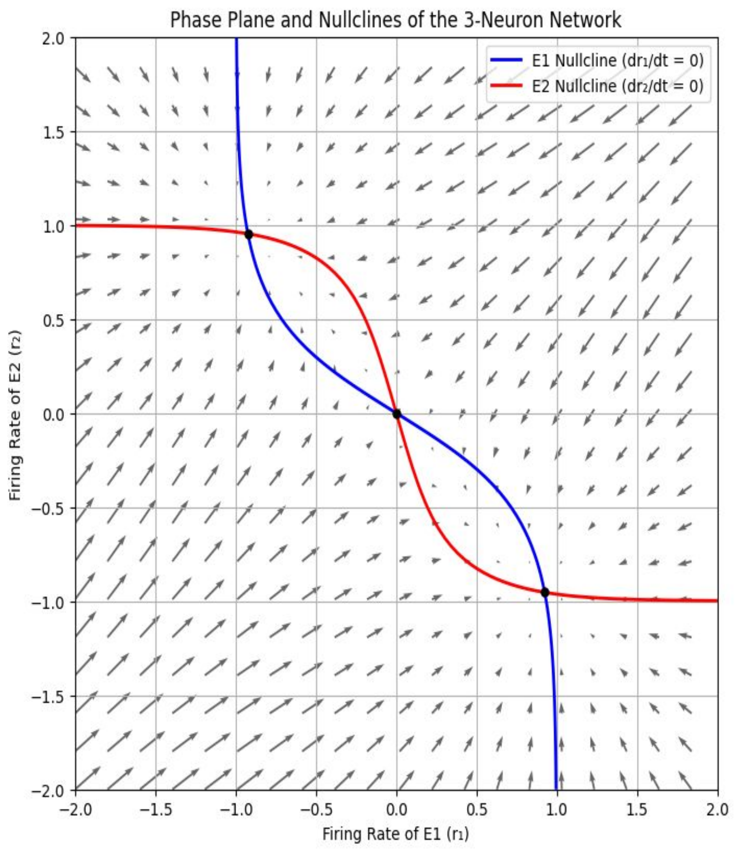

$$\tau \frac{dr}{dt} = -r + F(w \cdot r + I_{\text{ext}})$$

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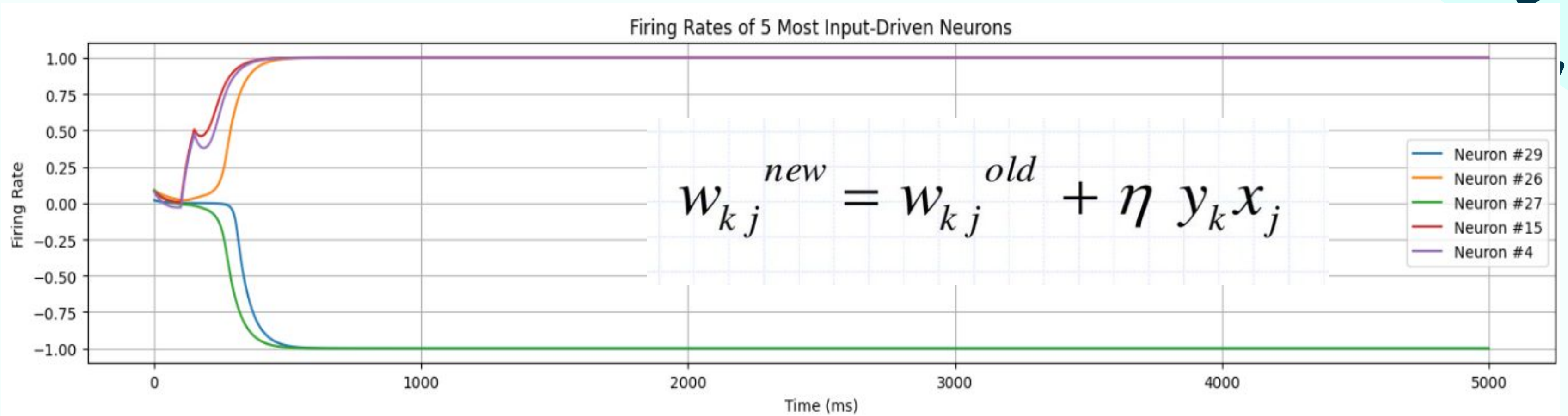
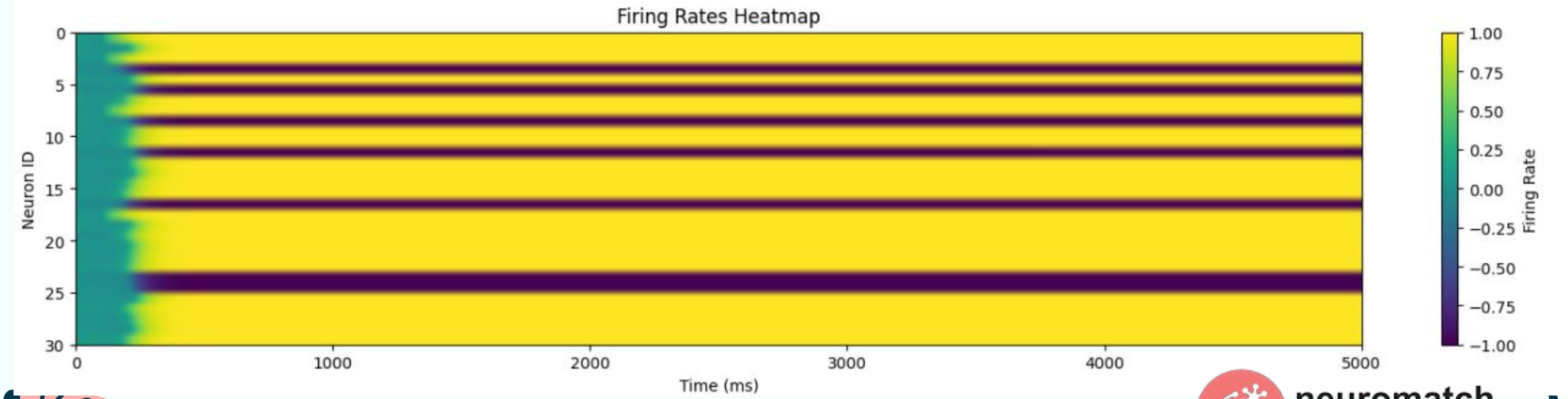


$$w_{kj}^{new} = w_{kj}^{old} + \eta \; y_k x_j$$



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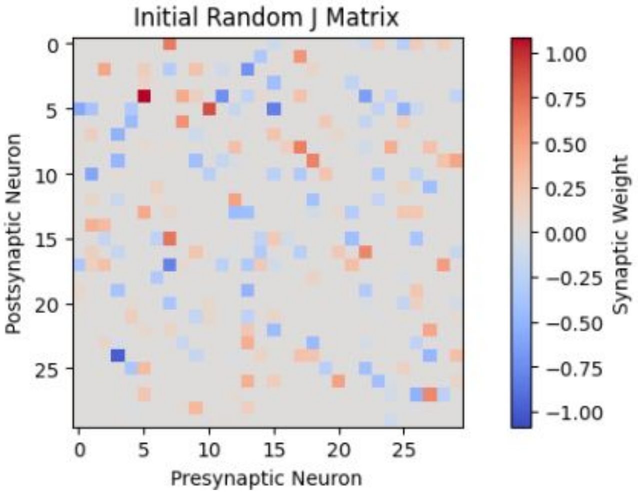

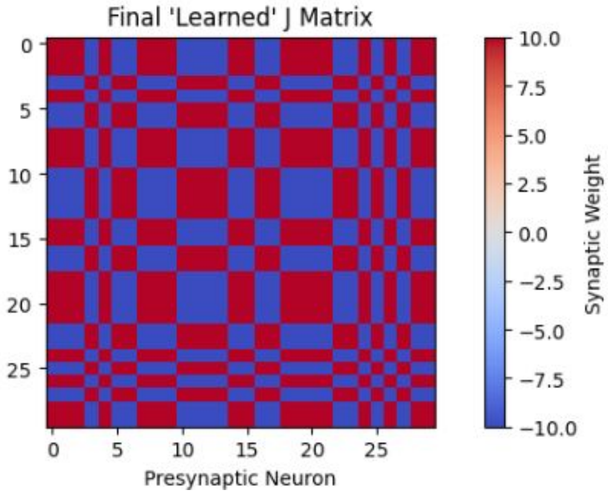

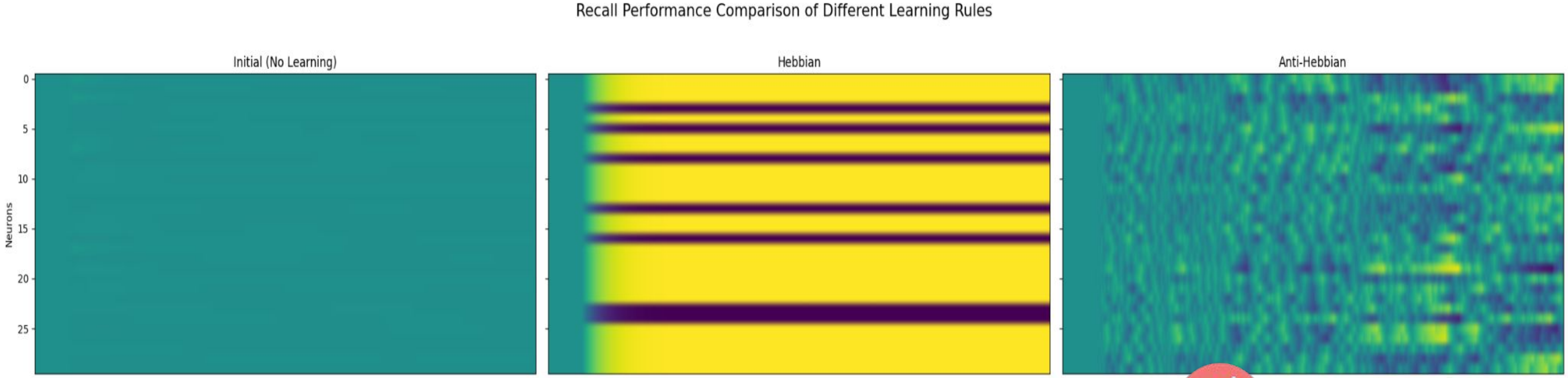

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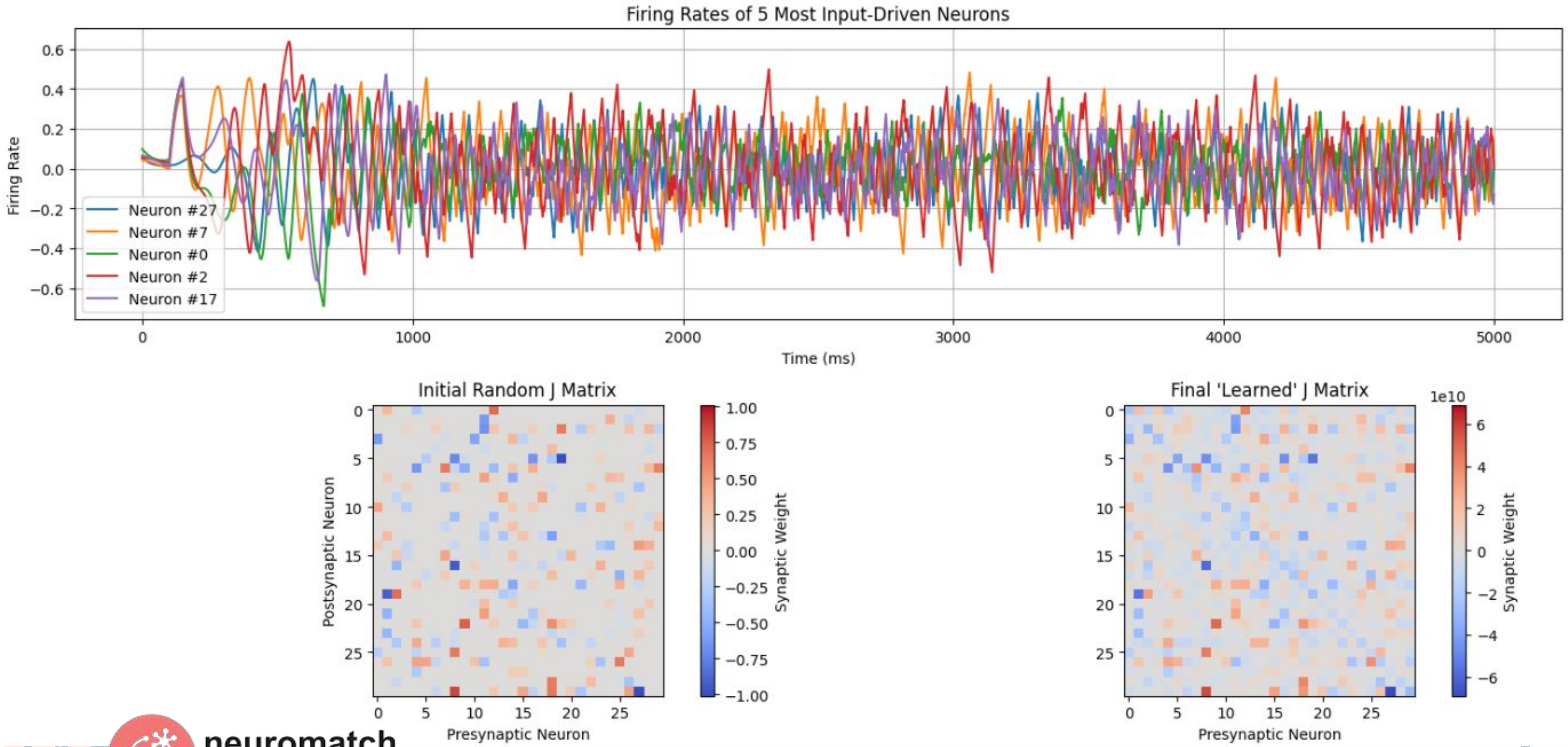

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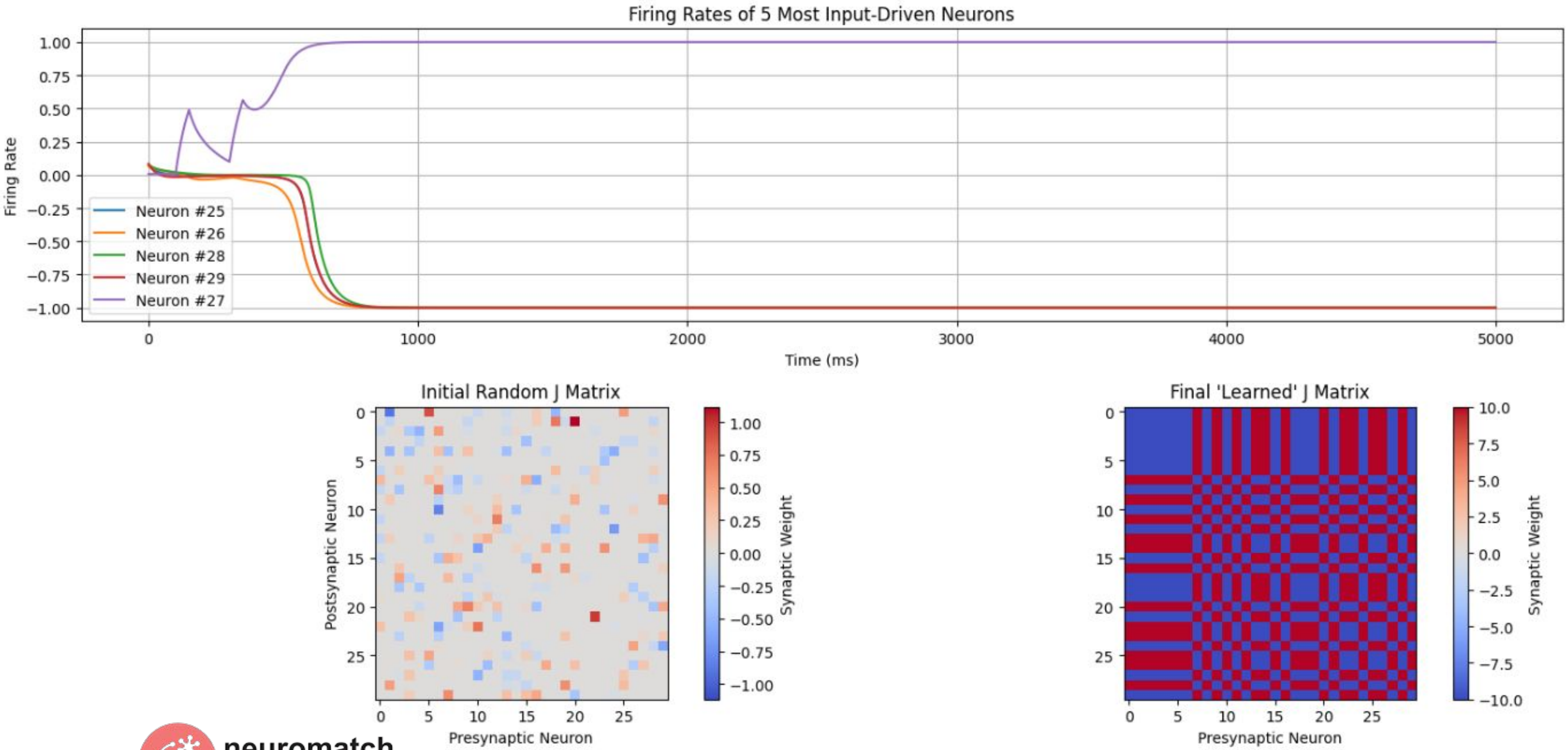

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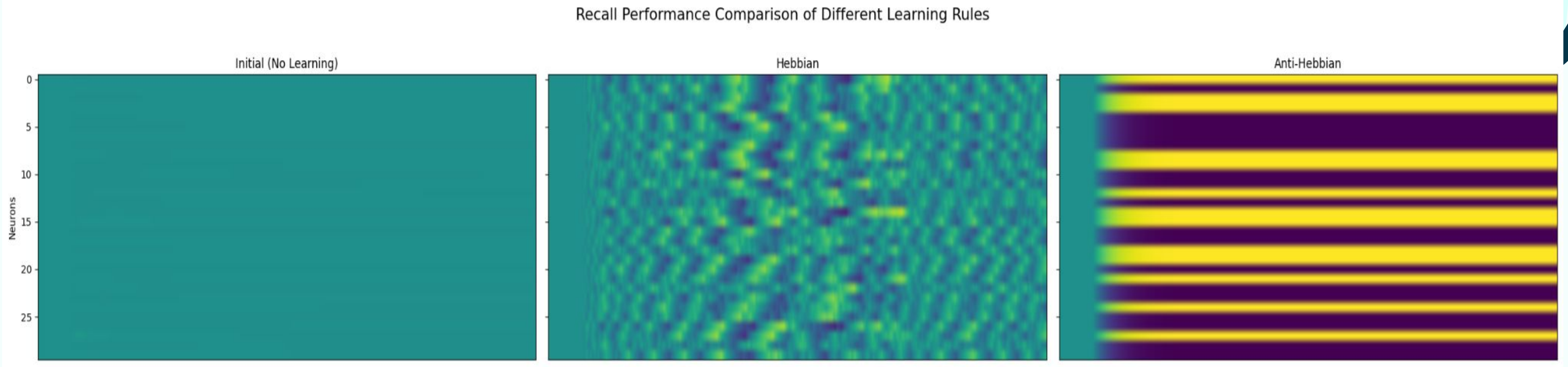

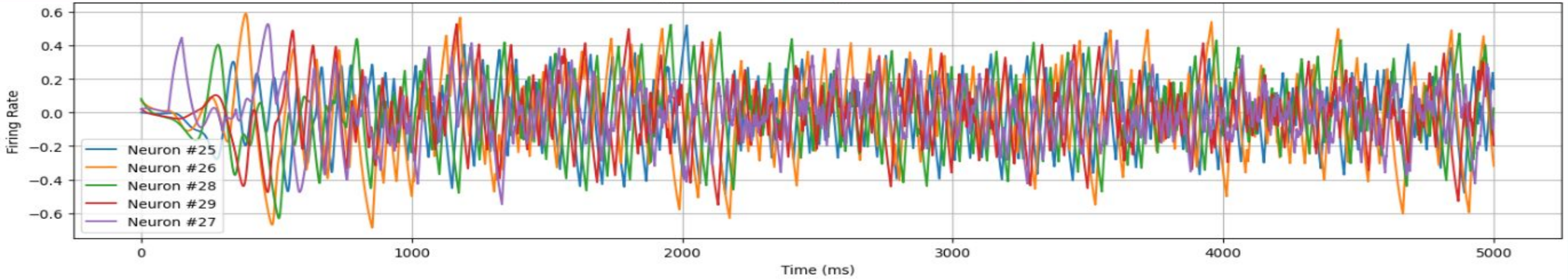

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04

Conclusion

What We Learned from Local Learning Rules

A

Local learning rules **shape neural connectivity** in distinct ways

B

How Hebbian and anti-Hebbian rules lead to different:

- Firing rate dynamics
- Final synaptic structures

Working Memory

C

Supports **Hypothesis 2**:

- Different rules lead to different outcomes in simple memory tasks

D

Supports **Hypothesis 3**:

- The initial state of the network strongly affects memory formation
- Mirrors the primacy effect in cognitive psychology

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Implications & Future Work

01

Biological Relevance

- Self-organizing learning can replicate **working memory effects**
- Different rules may underlie **different memory systems**

02

Computational Insight

- Design of adaptive, autonomous memory systems
- **Biologically-plausible AI**
- Pathways toward **Artificial General Intelligence (AGI)**

03

Future Directions

- Extend capacity to multi-pattern learning
- Explore more biologically grounded rules:
  - BCM — stability and selectivity
  - STDP — precise timing & sequence learning

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Thank you!

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