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Interaction of short- and long-term plasticity forms anisotropic connectivity

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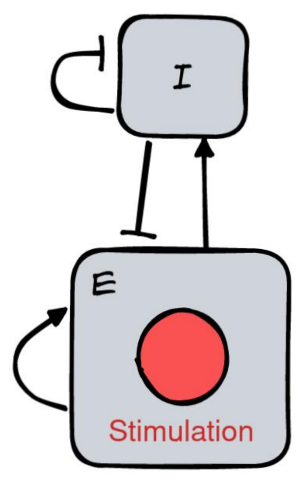
INTRODUCTION

Before an agent can perform a specific movement, it must form an internal representation of it as a sequence of neuronal activity that spans the behavioral timescale, which is tremendously longer than that of individual neurons. To bridge the timescale gap between the sequence and individual neurons, Spreizer et al. proposed by that spatial asymmetries in the synaptic connectivity profile of a neuronal circuit are utilzied. However, the biological mechanism that generates such asymmetry, is unknown. As a possible explanation for the emergence of asymmetry, we studied the interaction of short- and long-term plasticity in neuronal populations under constant stimulation. Our aim is to investigate the influence of different plasticity processes on the network's asymmetry.

METHOD

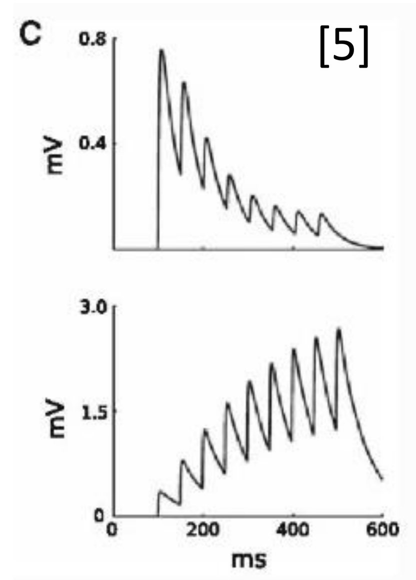
Network Specification

- *Populations*: Excitatory (E) and global inhibitory (I)
- *Connectivity*: Local isotropic Gaussian profile
- *Boundary conditions*: Periodic
- *Neuron type*: LIF
- *Synaptic delays*: proportional to the distance



Stimulus

constant current on circular patch (1 min.)



Plasticity Rules

- Short-term: Tsodysk-Markram [2]

$$\frac{du}{dt} = \frac{U-u}{\tau_f} + \sum_k U(1-u)\delta(t-t_k)$$

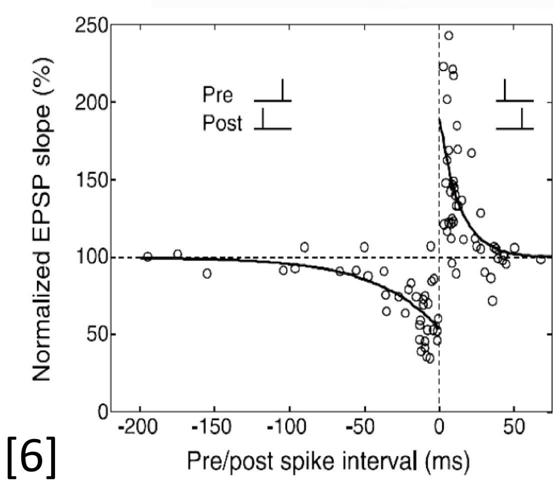
$$\frac{dx}{dt} = \frac{1-x}{\tau_d} - \sum_k xu\delta(t-t_k)$$

- Long-term plasticity: STDP [3,4]

$$\frac{dA_{pre}}{dt} = -\frac{A_{pre}}{\tau_{pre}} - \sum_k wa_{post}\delta(t-t_k)$$

$$\frac{dA_{post}}{dt} = -\frac{A_{post}}{\tau_{post}} + \sum_k (1-w)a_{post}\delta(t-t_k)$$

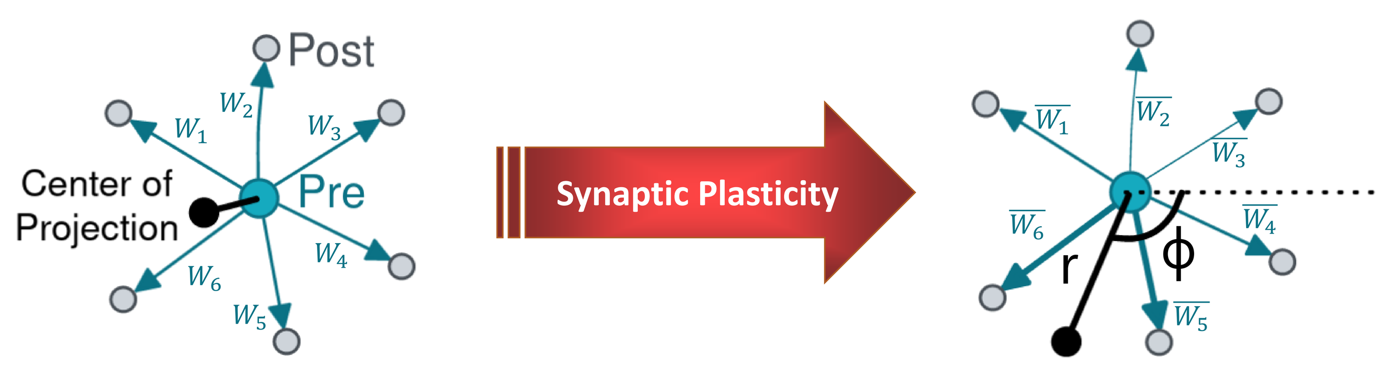
$$\frac{dw}{dt} = \sum_k A_{pre}\delta(t-t_k^{(post)}) - \sum_k A_{post}\delta(t-t_k^{(pre)})$$



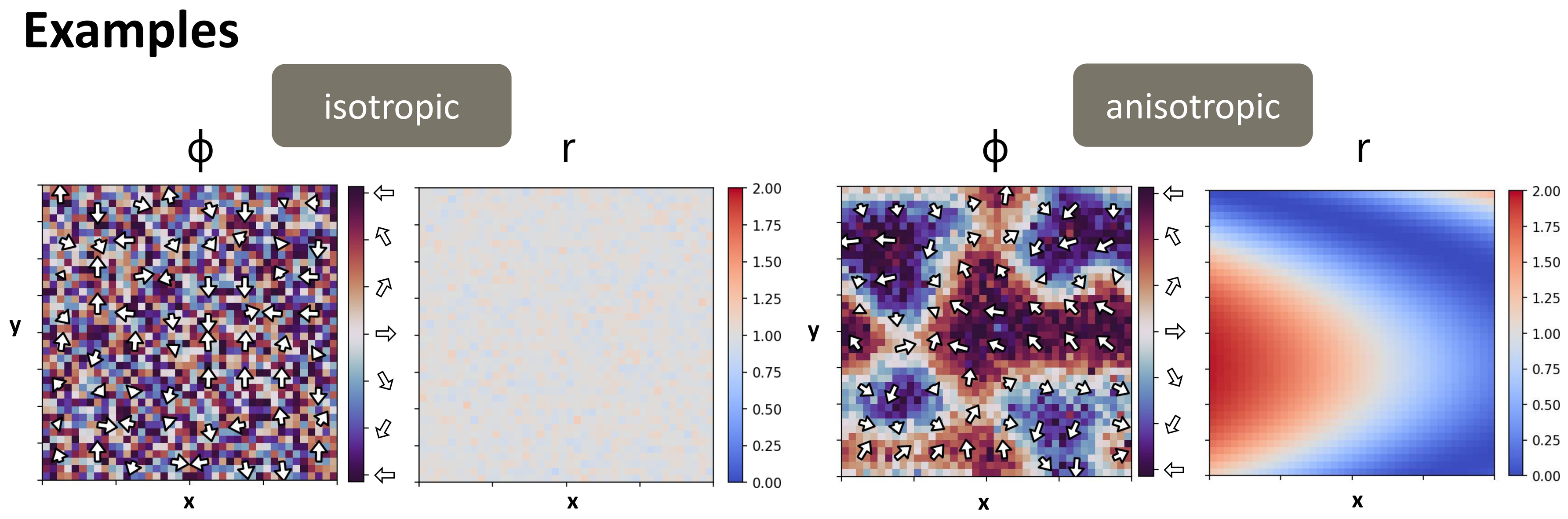
[6]

Asymmetry Measure: Anisotropy

direction(**φ**) and strength(**r**) of the synpatic projection center.

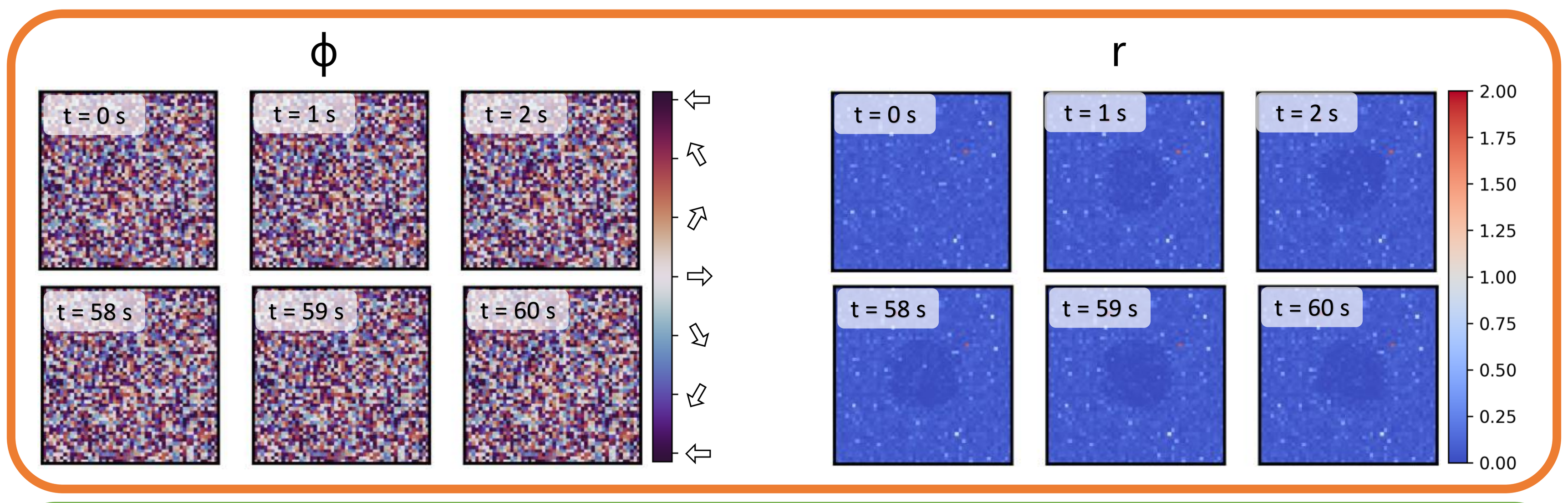


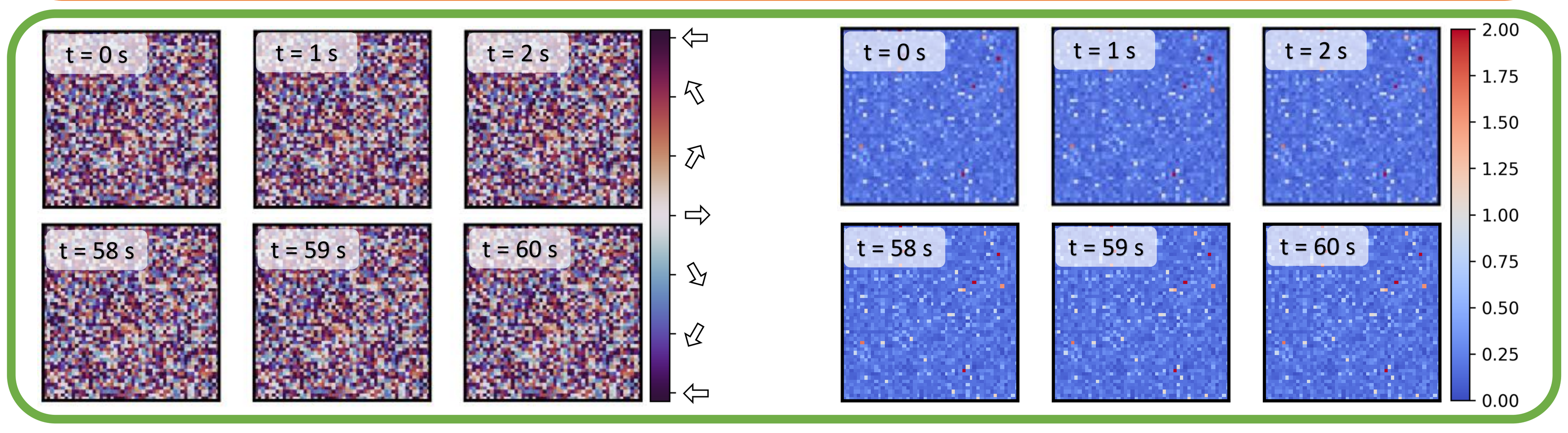
Examples

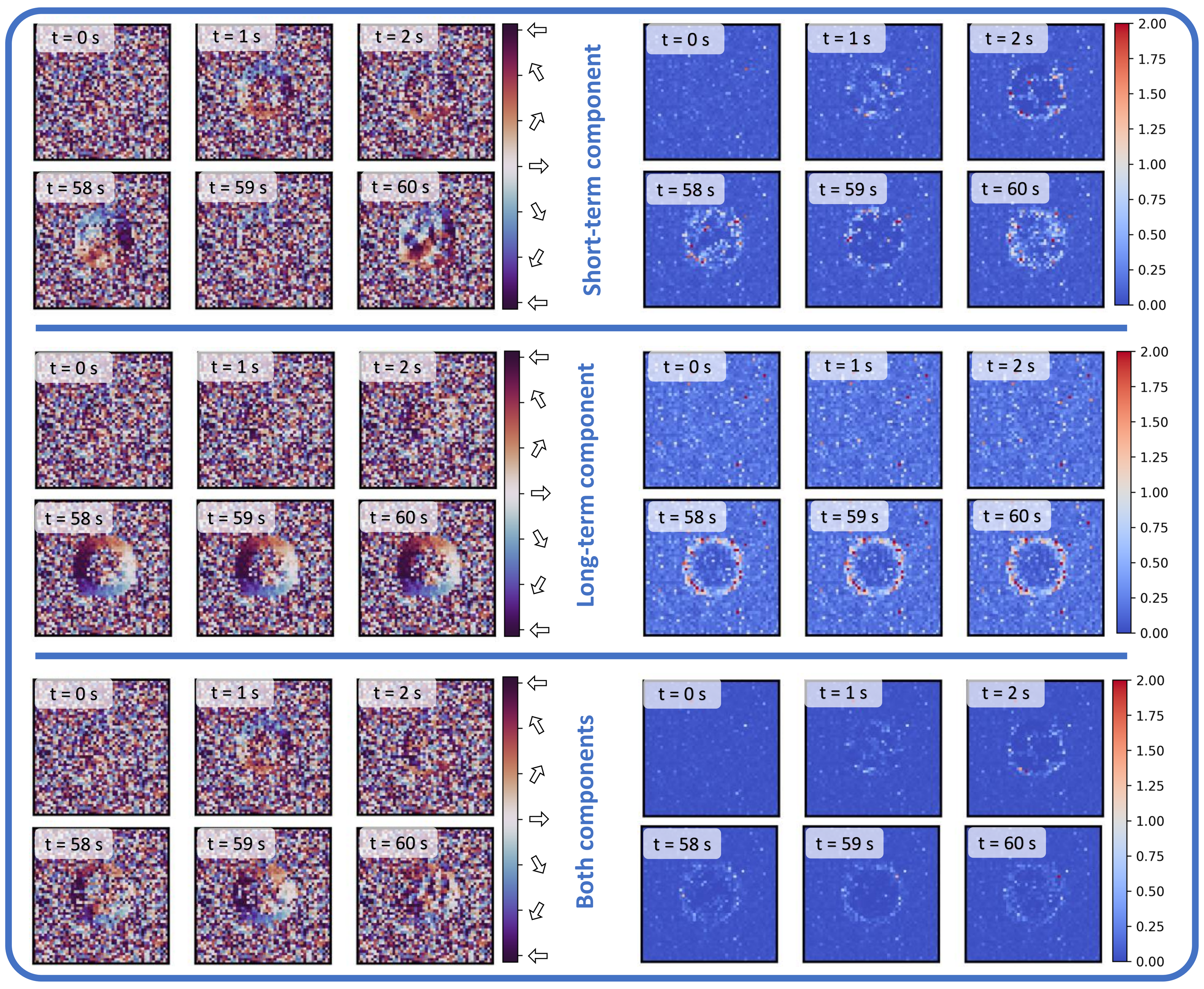


RESULTS

1. **Only** short-term plasticity: W(t) = u(t) x(t)
2. **Only** long-term plasticity: W(t) = w(t)
3. Long- **and** short-term plasticity: W(t) = u(t) x(t) w(t)







CONCLUSION

1. Short- or long-term plasticity alone cannot induce anisotropic connectivity.
2. Behavioral sequences of neuronal activity likely require both forms of synaptic plasticity.

OUTLOOK

Our study provides the first indications of anisotropy emergence at the network-level. Our next step is to explore the correlation between spatially correlated stimuli projection and the observed anisotropic pattern in conjunction with plasticity interaction. Furthermore, we will investigate the biological mechanisms that mediate such correlated input projection.

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