Preliminary results

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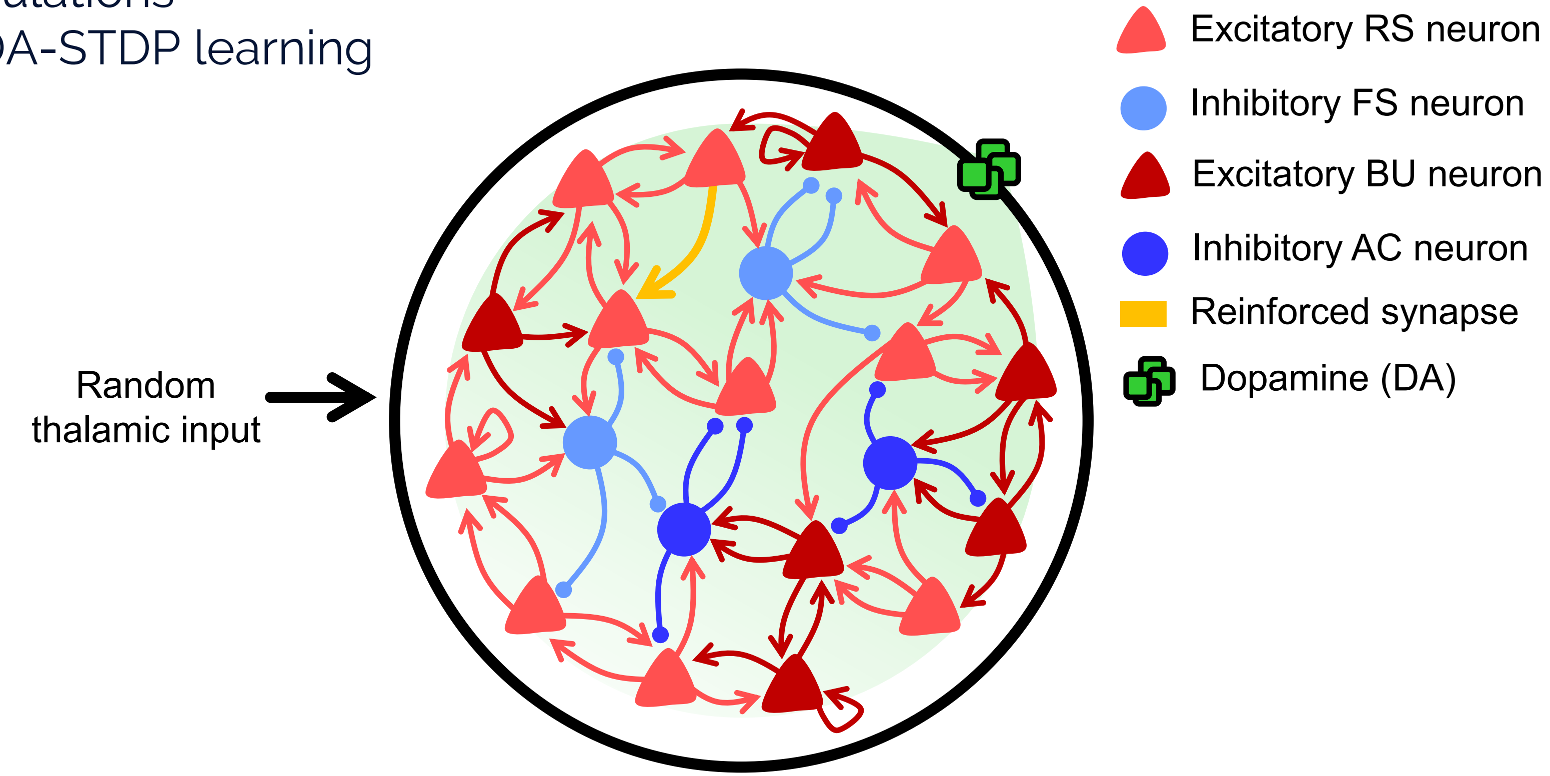
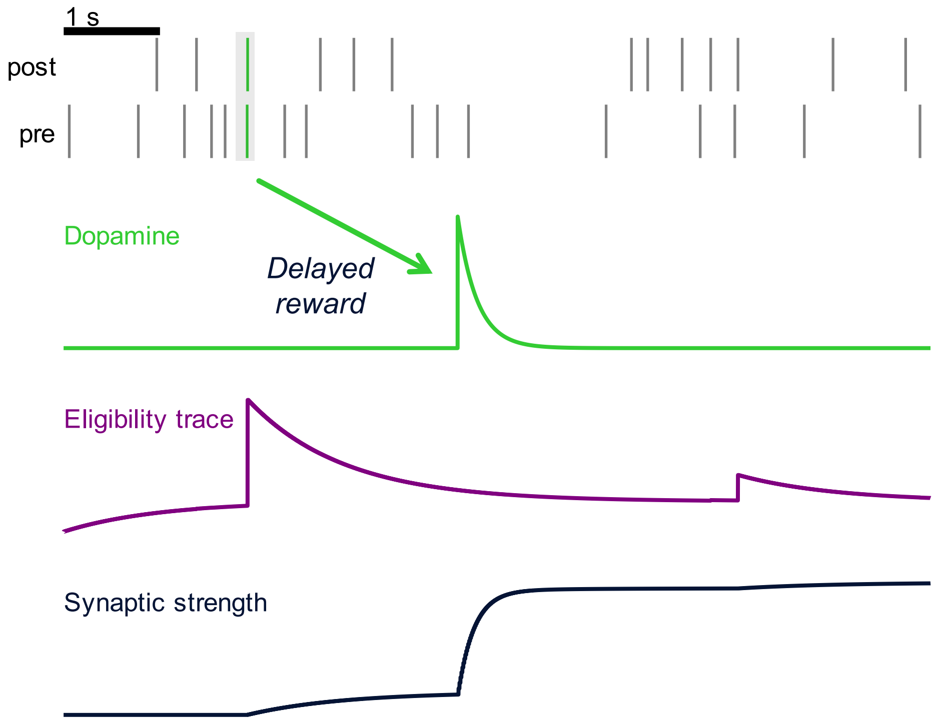
Model

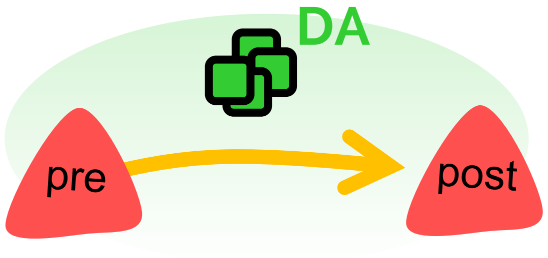
- **Task:** Reinforce firing of 2 neurons via delayed reward (Izhikevich, 2007)
- **Network architecture:** RNN (1000 neurons with 100 connections/neuron), 4:1 EI ratio, different spiking populations
- **Learning:** DA-STDP learning



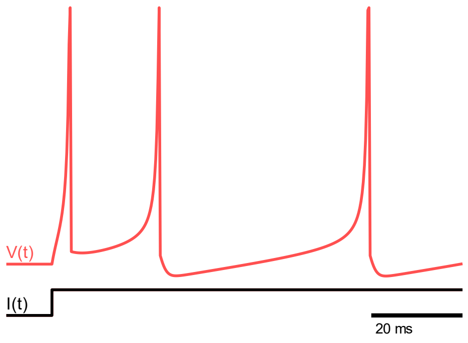
Learning



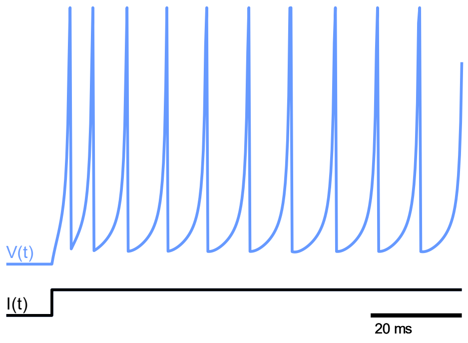
- A reward is delivered with a delay of 1 to 3 seconds whenever pre- and post-synaptic spikes coincide within a 20 ms window.
- The reward triggers dopamine release, enhances the synaptic strength of the connection through DA-STDP learning



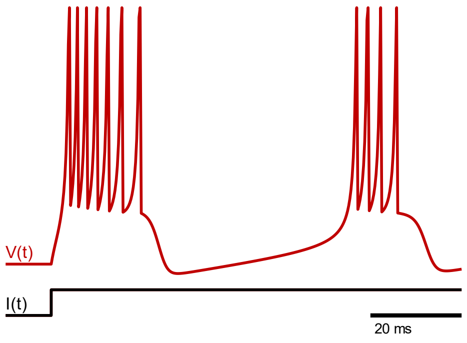
Spiking types



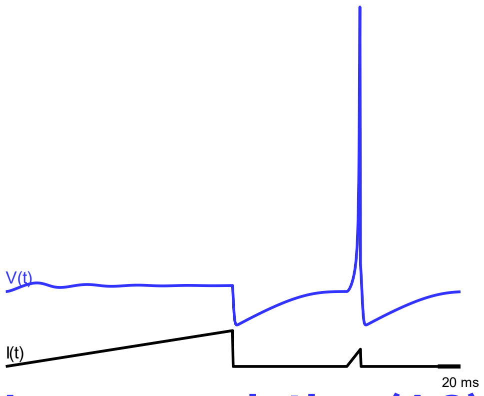
Regular spiking (RS)



Fast spiking (FS)

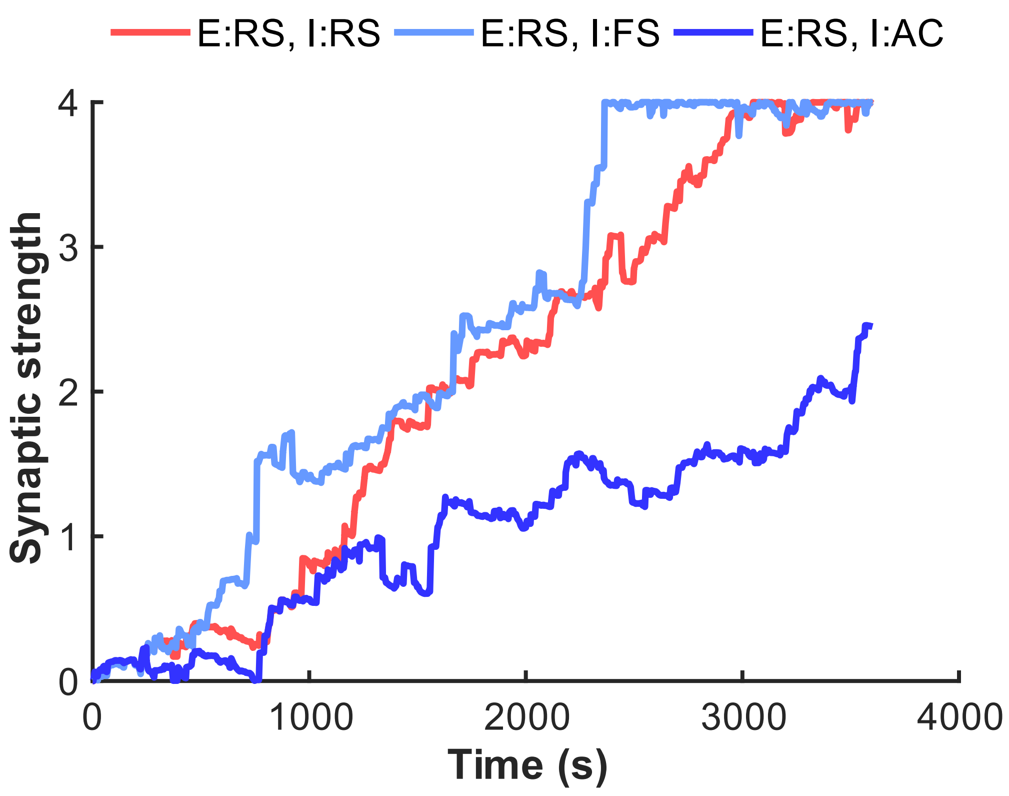


Bursting (BU)



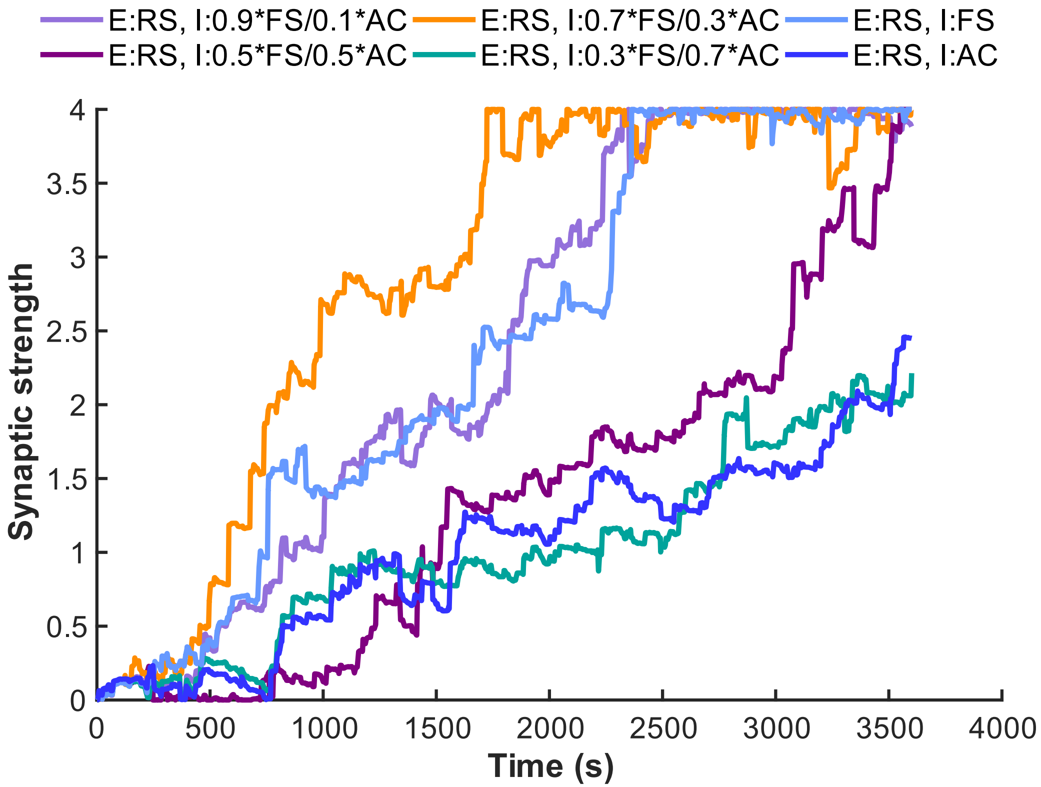
Accommodation (AC)

Impact of inhibitory spiking types



- Considering FS inhibitory neurons enhances learning of the reinforced synapse
- Considering AC inhibitory neurons impairs learning more of the reinforced synapse

Impact of inhibitory spiking heterogeneity

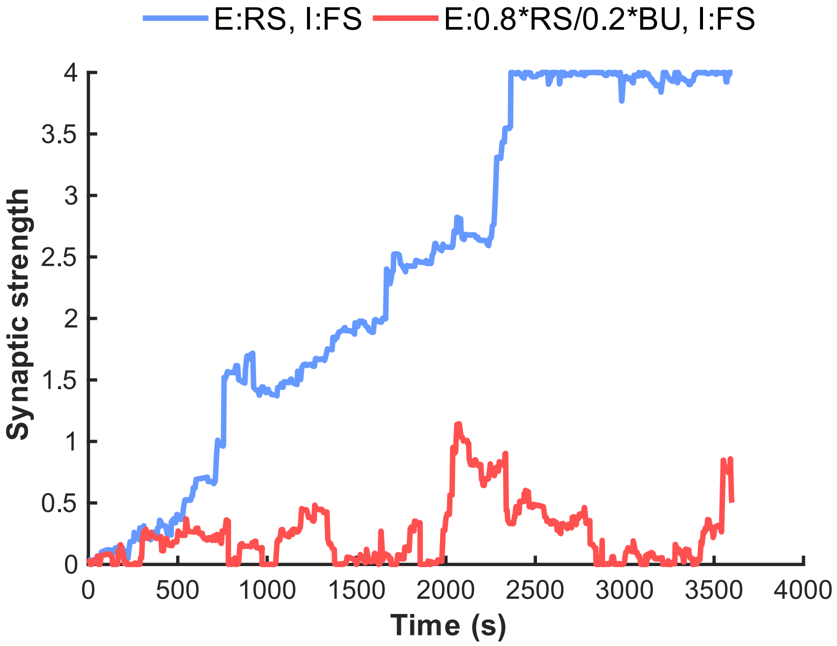


- Including different proportions of spiking heterogeneity has an impact on learning at the synaptic level
- A combination of 70% of FS and 30% of AC inhibitory neurons exhibited the best learning enhancement

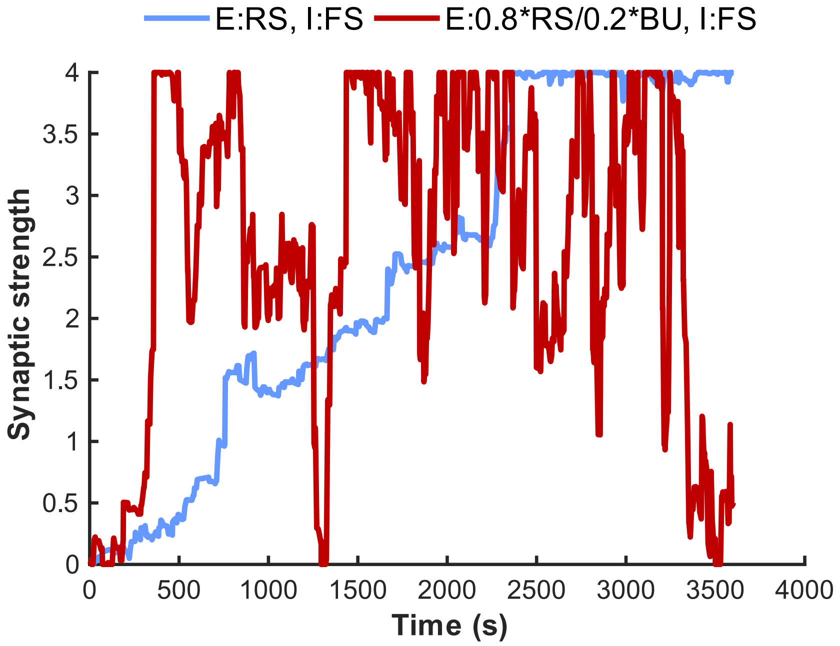
Incorporating spiking heterogeneity provides an additional layer for fine-tuning learning in neural systems

Impact of excitatory spiking heterogeneity

- We studied the effects of bursting activity in the network: 80% RS and 20% BU excitatory neurons
  - Bursting activity increases network instability when pre- and post- neurons are RS
  - Bursting activity prompts unstable learning when pre- and post- neurons are BU



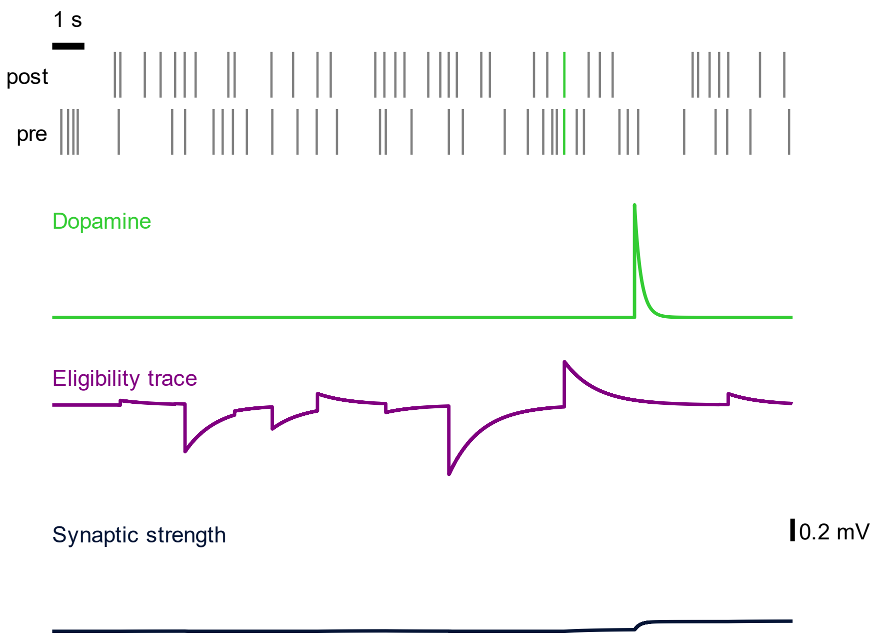
pre- and post- RS neurons



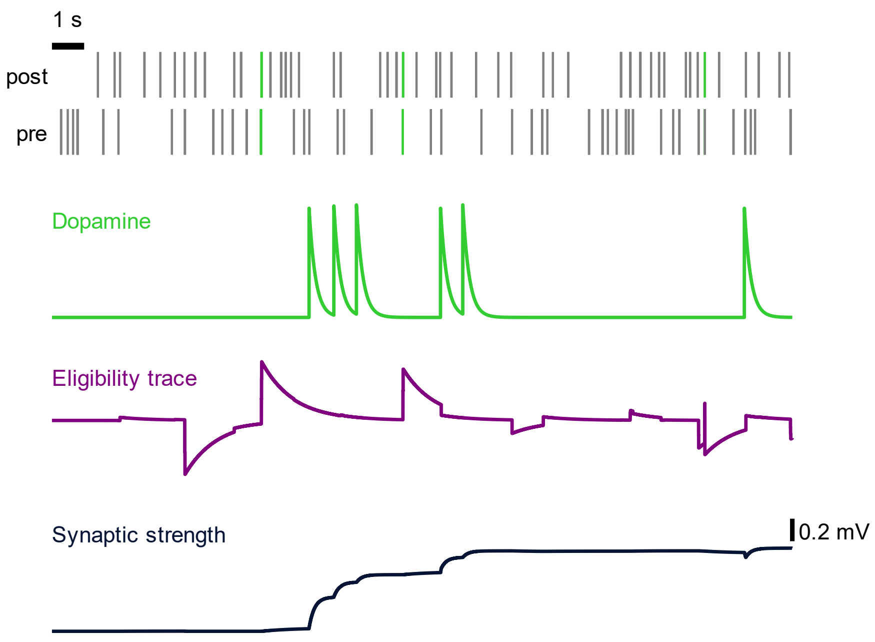
pre- and post- BU neurons

Bursting effect at the synaptic level

- Bursting activity increases post-, pre- correlated spikes (within the 20 ms window) → More DA is released → The synapse is enhanced more rapidly

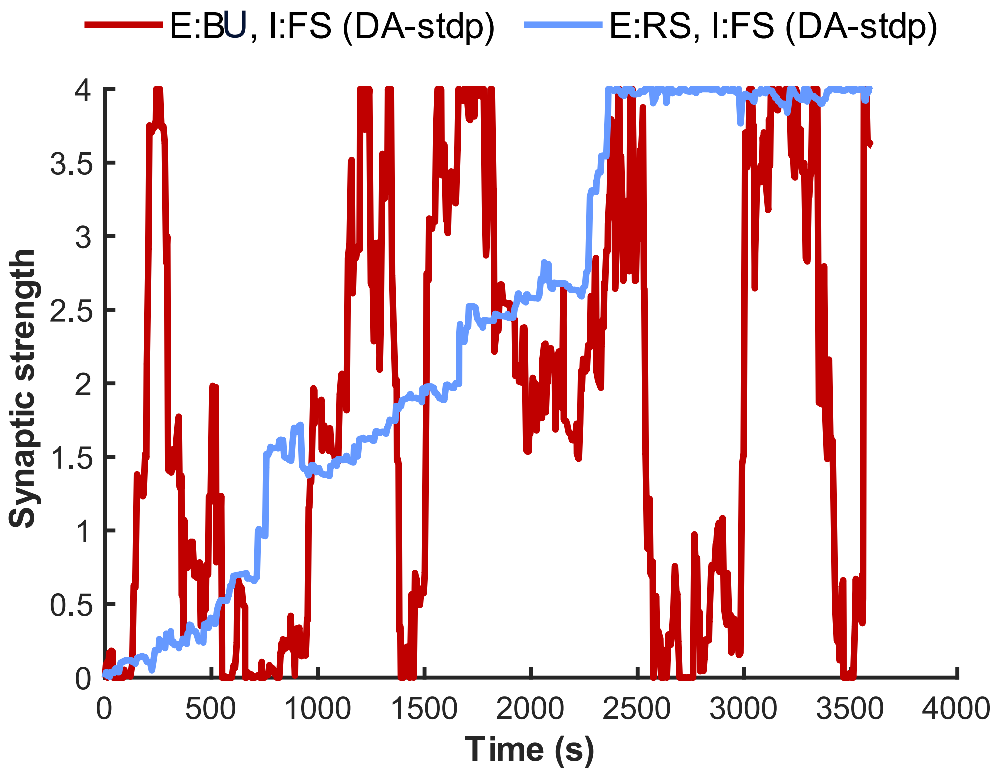


RS neurons



BU neurons

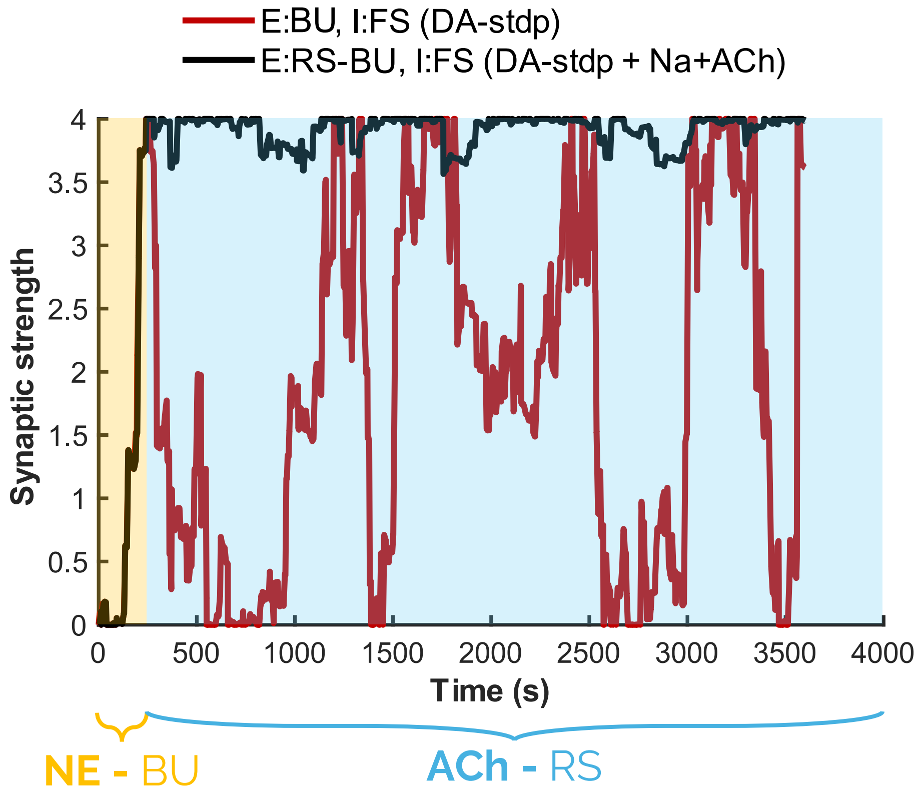
Impact of bursting

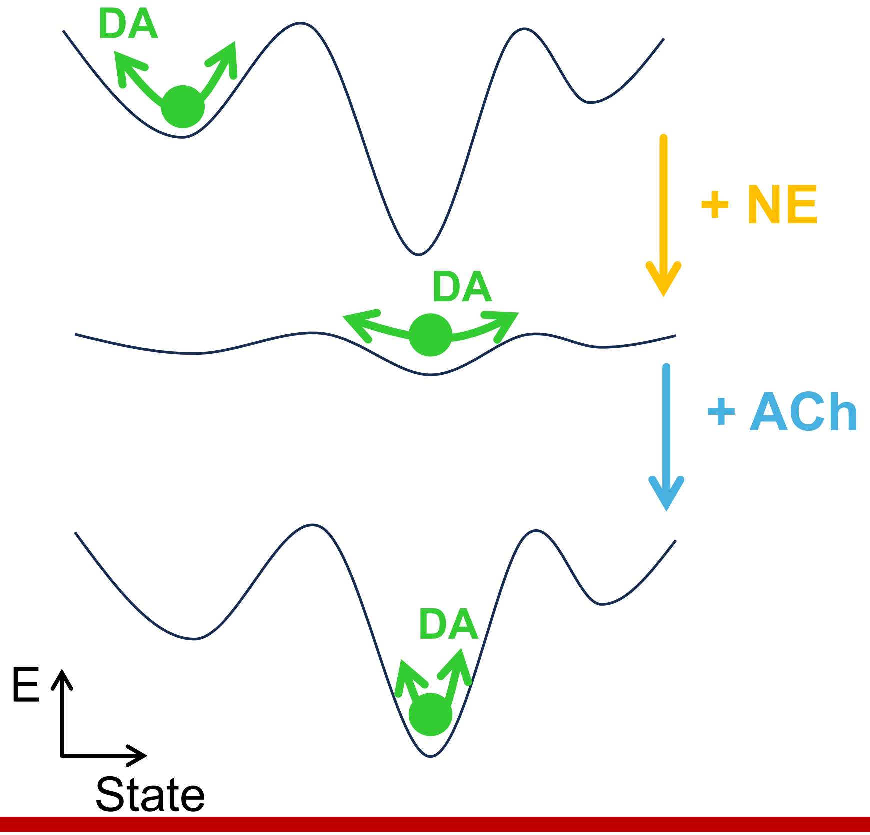


- We now consider all excitatory neurons as BU.
- Bursting activity seem to promote learning by enhancing flexibility.
- However, compared with the RS excitatory neurons it is unstable.

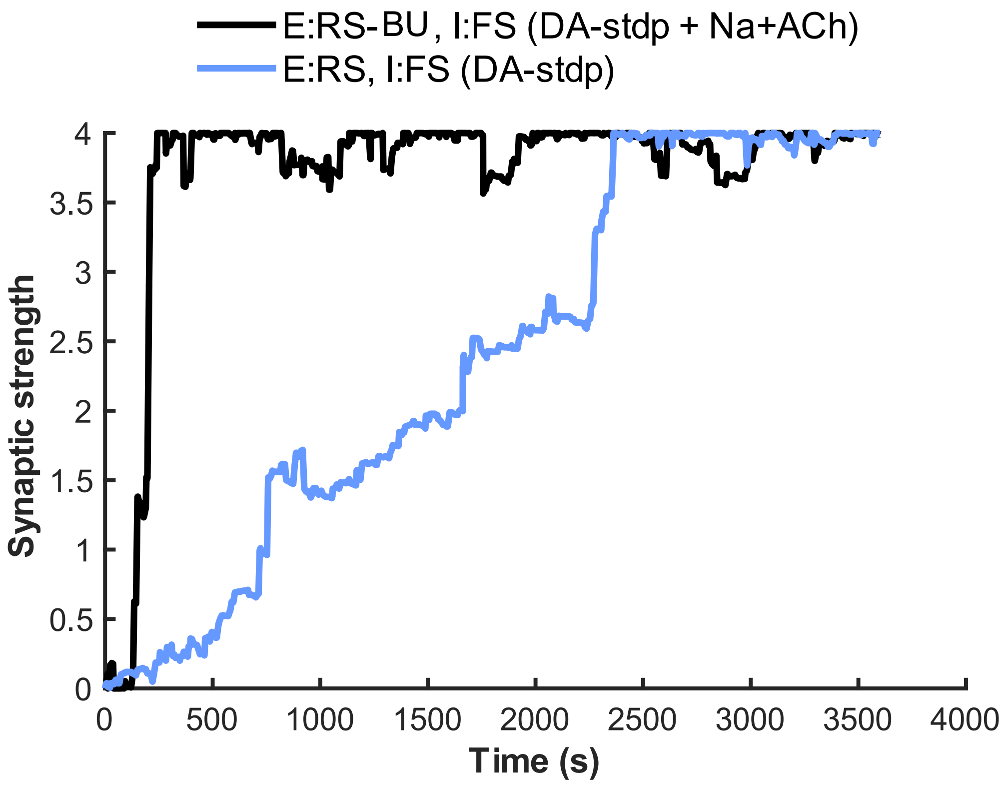
Neuromodulated spiking

- Neuromodulators may act as switches on spiking activity, helping to balance fast learning and stability
- **DA** drives learning, **NE** enhances fast learning through BU spiking, **ACh** enhances stability though RS spiking





Neuromodulated spiking



- Modulating BU activity to RS activity could help control this instability, preserving the network state after learning and enabling both fast learning and long-term stability

Neuromodulators can help to enhance fast learning and stability by controlling the spiking activity at the synaptic level

Key takeaways

1. Incorporating spiking heterogeneity provides an additional layer for fine-tuning learning in neural systems

2. Neuromodulators can help to enhance fast learning and stability by controlling the spiking activity at the synaptic level