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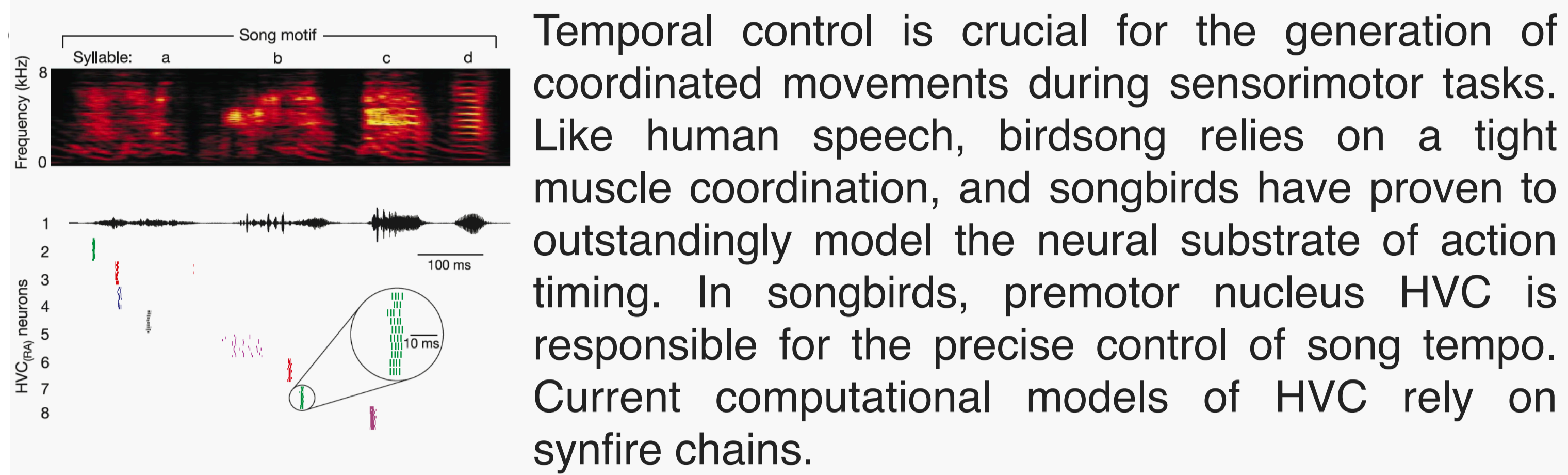
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Temporal Dynamics in an Attractor Model of the Songbird's Premotor Nucleus

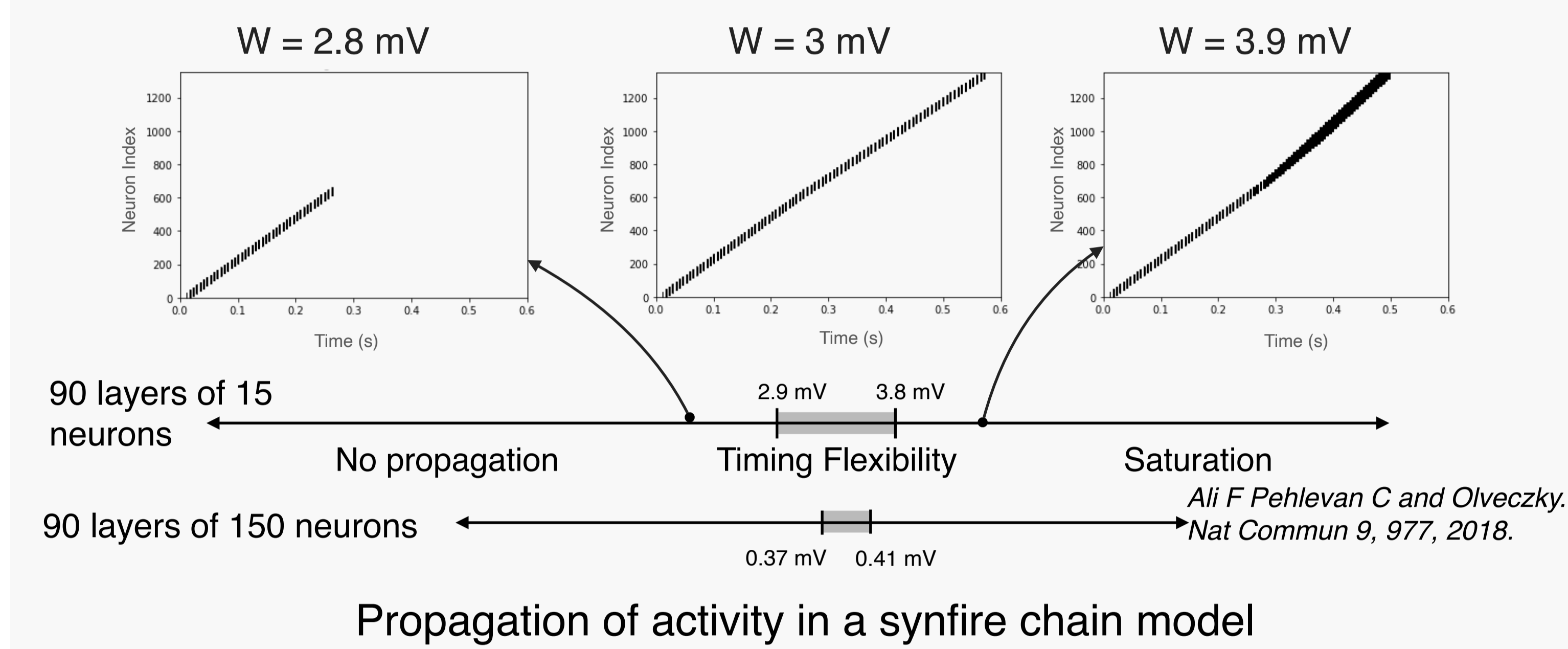
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What do songbirds tell us about timing?



Temporal control is crucial for the generation of coordinated movements during sensorimotor tasks. Like human speech, birdsong relies on a tight muscle coordination, and songbirds have proven to outstandingly model the neural substrate of action timing. In songbirds, premotor nucleus HVC is responsible for the precise control of song tempo. Current computational models of HVC rely on synfire chains.

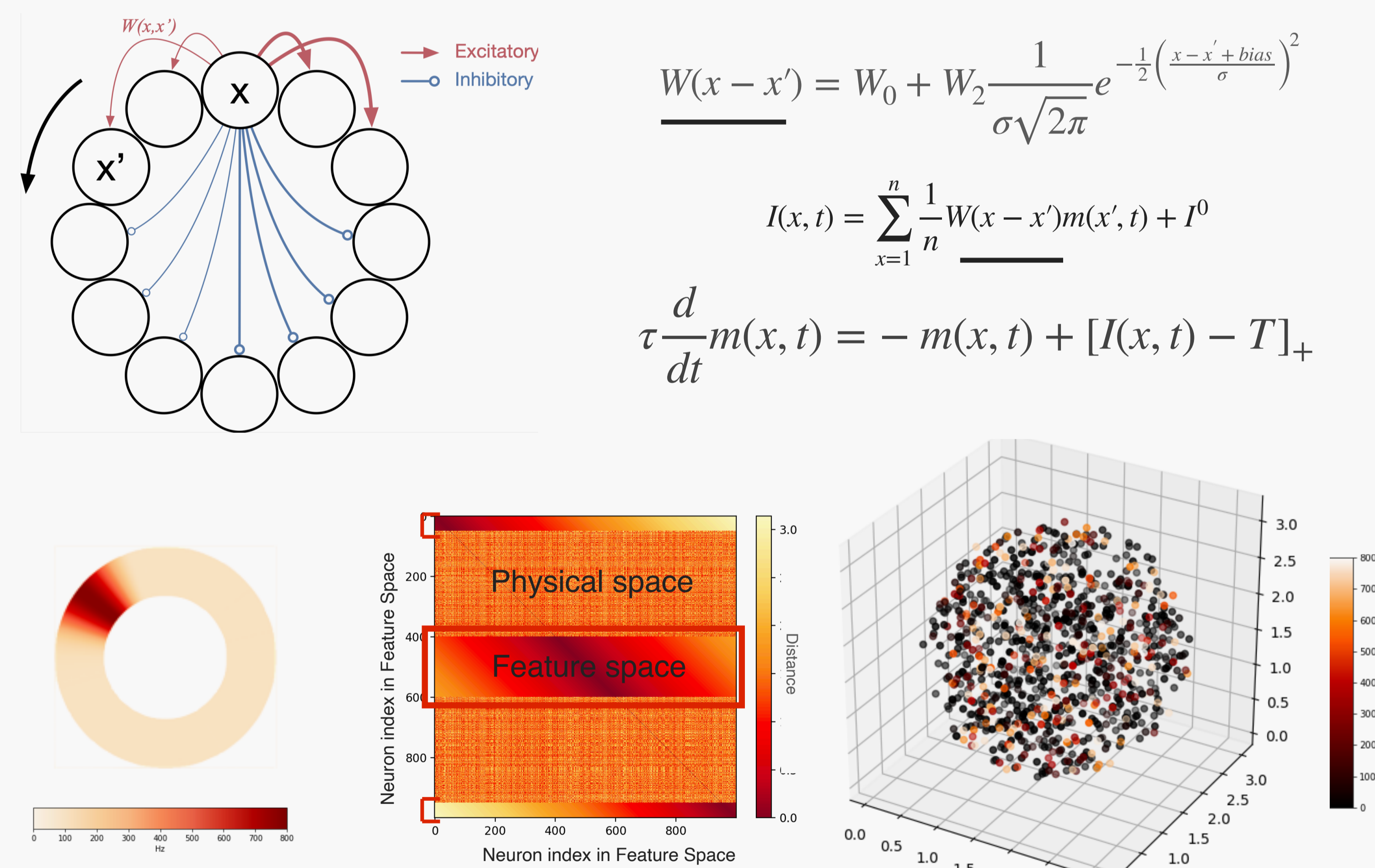
Synfire chains are however not robust to noise and function for a narrow range of feedforward weights (W , see figure below), requiring fine tuning during learning.



Attractors dynamics and timing

Here, we propose that HVC neuronal dynamics may be modelled by attractor dynamics, where recurrent connections allow the formation of a travelling activity bump with robust functional properties.

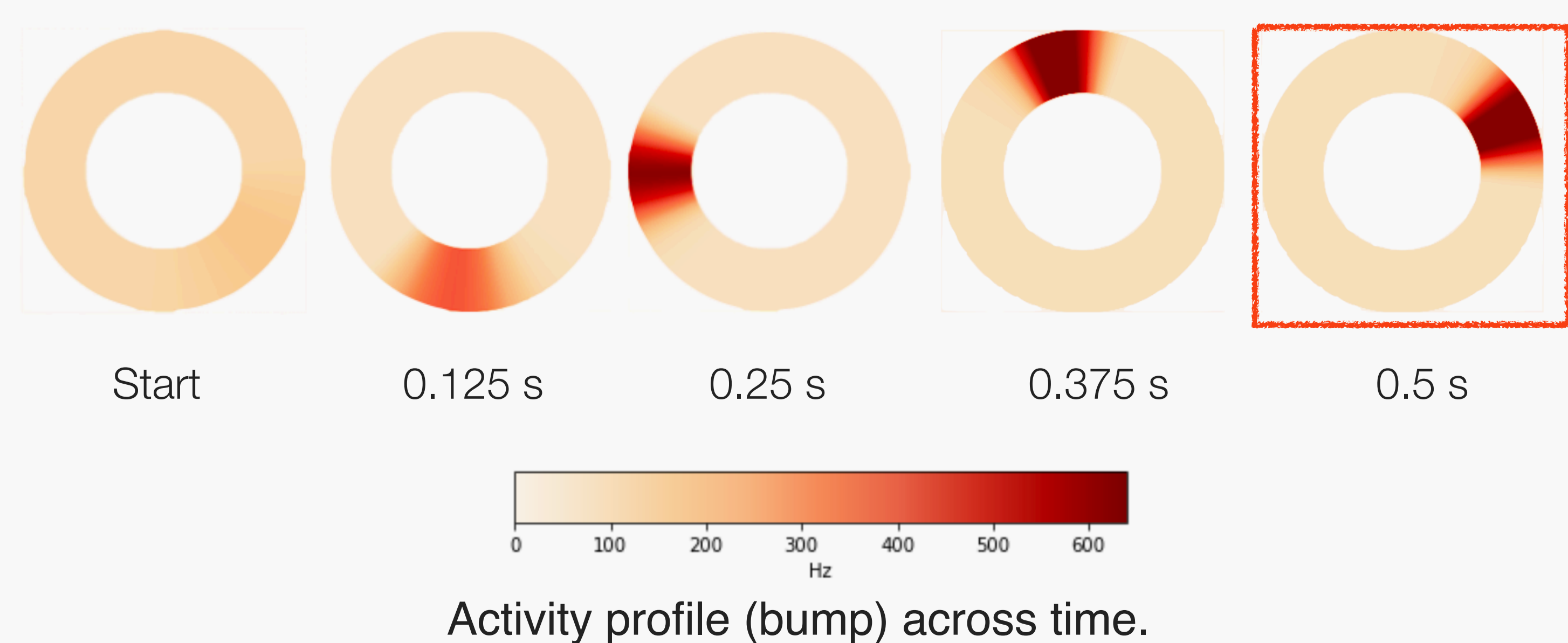
Net Connectivity Profile Feature space (x : preferred timing during song)



Activity profile (bump) in the Feature space (left) and Physical space (right).

1. Activity profile in HVC

The width of the activity bump, and thus the duration of transient neuronal activation, can be decreased to reproduce the brief activity bursts of HVC neurons.



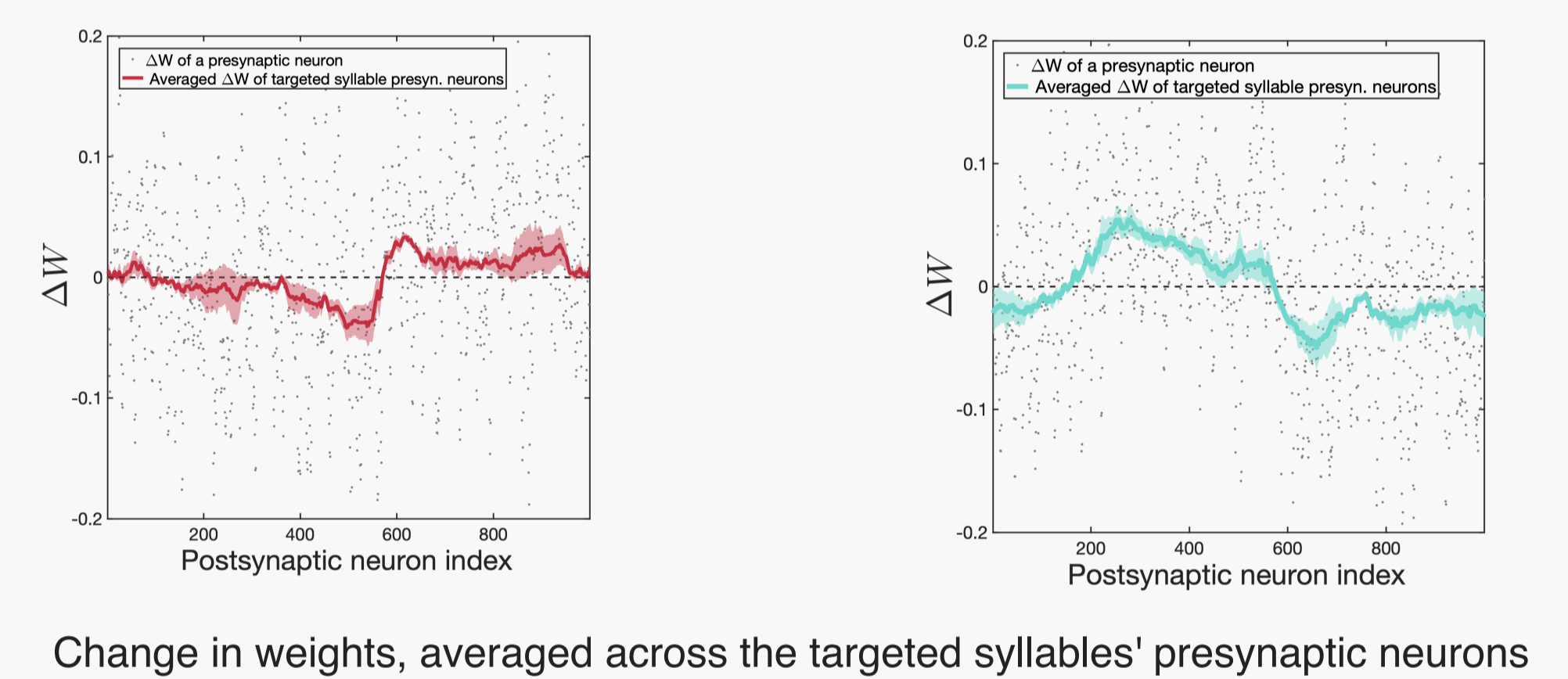
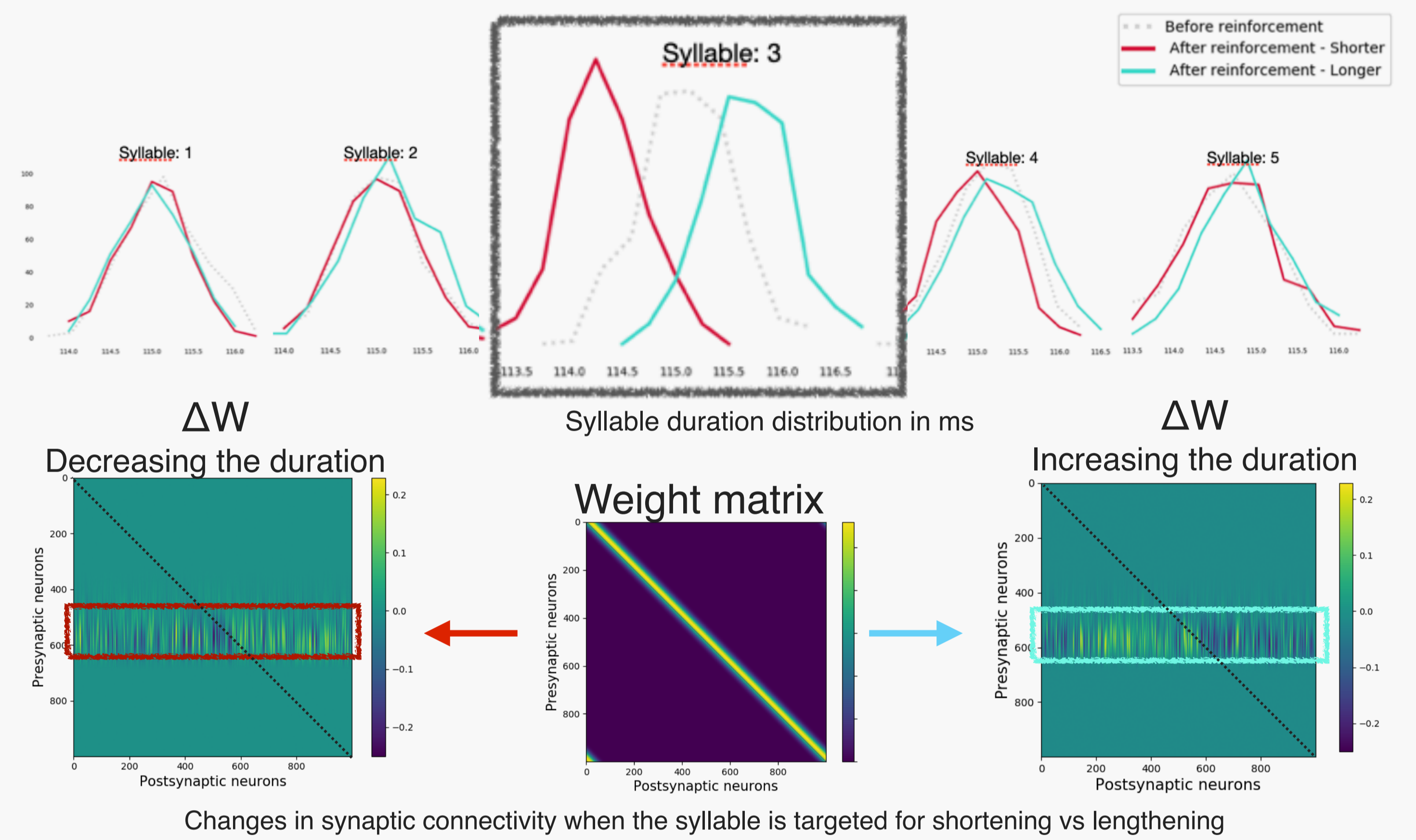
2. Modifying syllable duration

Relying on a reward covariance rule, we show that the duration of a syllable can be modified in response to a perturbed reward profile, as implemented in a widely used lab conditioning paradigm.

$$\Delta W_{ij} = \gamma \int_0^{t^{(k)}} \frac{R(t) e_{ij} dt}{\tau_e}$$

γ : learning rate parameter, $R(t)$: the reward, η : noise at the postsynaptic neuron, r_j : rate of the presynaptic neuron.

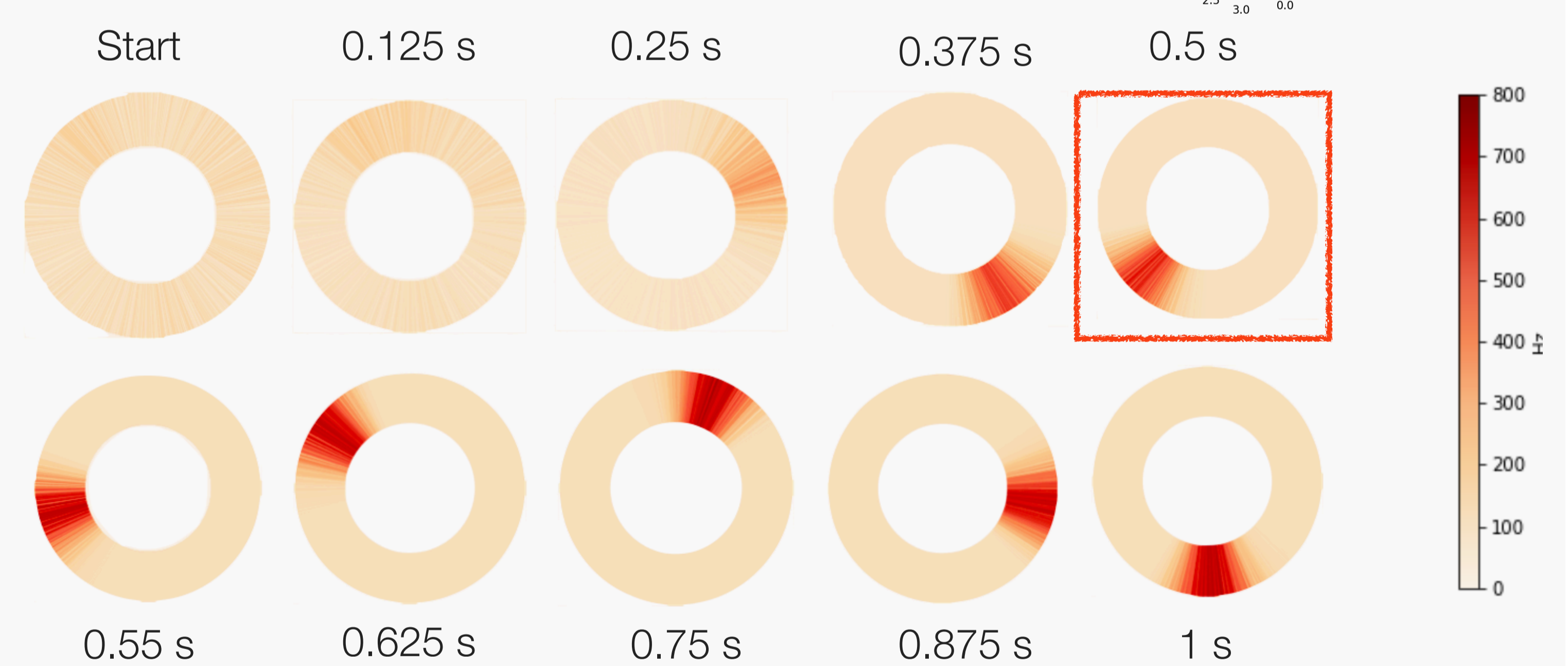
$$e_{ij} = \int_0^t \frac{dt'}{\tau_e} e^{-(t-t')/\tau_e} \eta_i(t') r_j(t')$$



3. Local inhibition in HVC

Local inhibition administered to the HVC.

$$\text{Inhibition} = \alpha \frac{1}{\sigma \sqrt{2\pi}} \exp \left(-\frac{1}{2} \left(\frac{x - \mu}{\sigma} \right)^2 \right)$$



The behavior of the model when we locally inhibit mimicking a Muscimol injection and the effect on the bump formation and consequently the song.

Conclusion

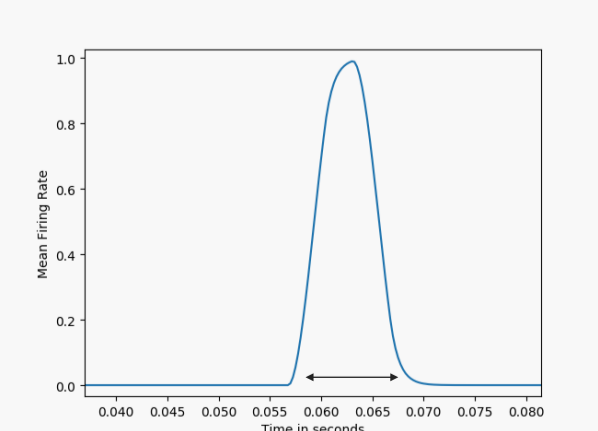
We propose that HVC neuronal dynamics may be modelled using the ring model.

The duration of a syllable can be modified in response to a perturbed reward profile and consistent with behavioral data, the change in duration is specific to the target syllable.

We derive a new prediction from the model. Following local muscimol (GABA_A agonist) injection in HVC, in contrast to the synfire chain, a perturbation in the initial phase of the pattern formation would delay song initiation, but singing would be sustained.

Future perspectives:

A spiking network (with adapting LIF neurons) to replicate the behaviours acquired from the rate model, i.e 10ms bump width, learning and prediction.



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