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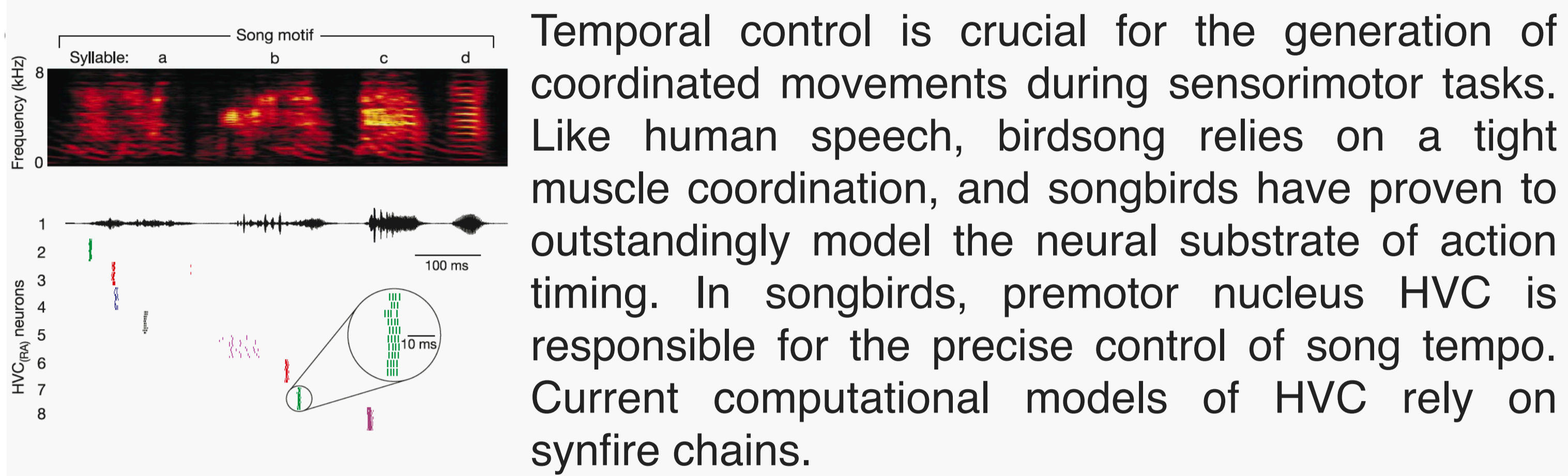
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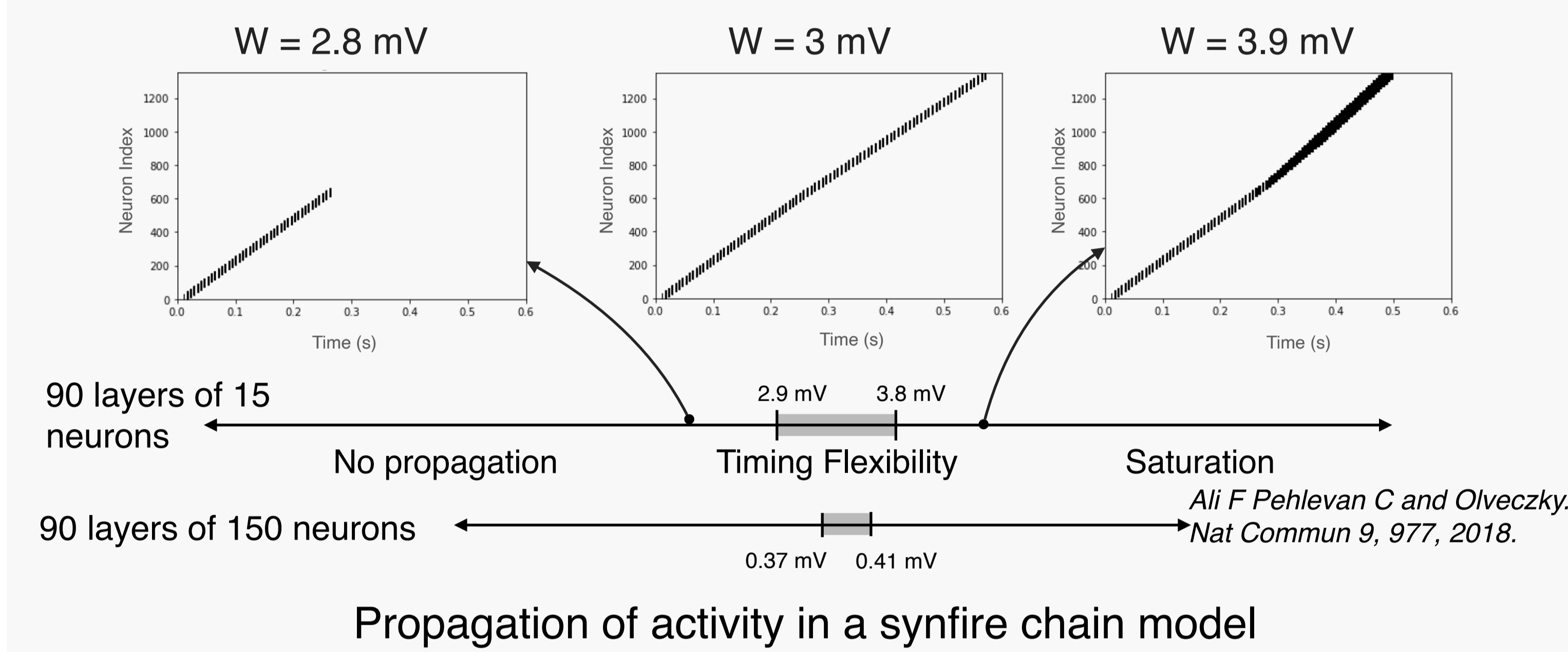
# Temporal Dynamics in an Attractor Model of the Songbird's Premotor Nucleus

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## What do songbirds tell us about timing?



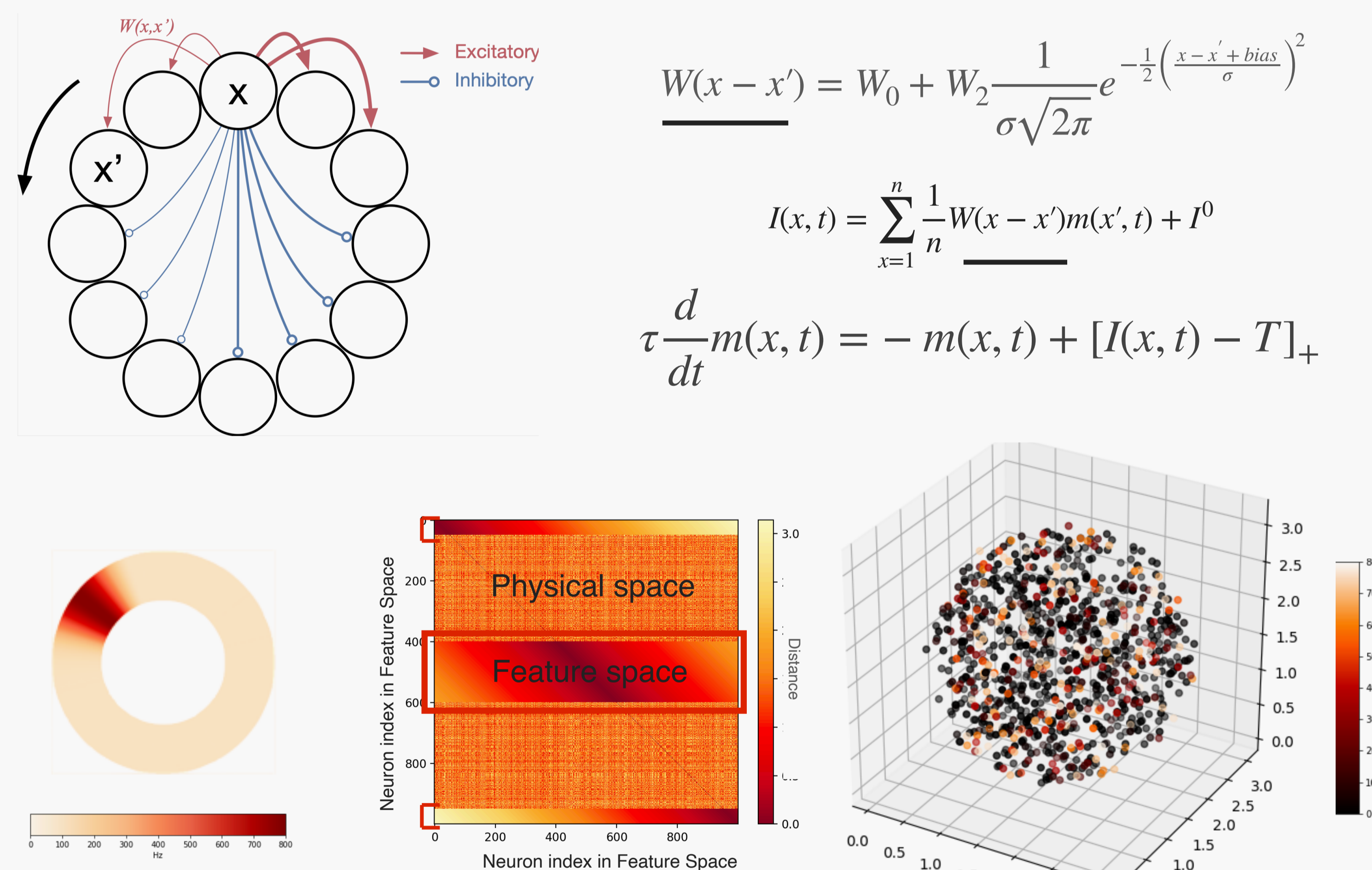
Synfire chains are however not robust to noise and function for a narrow range of feedforward weights ( $W$ , see figure below), requiring fine tuning during learning.



## 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.

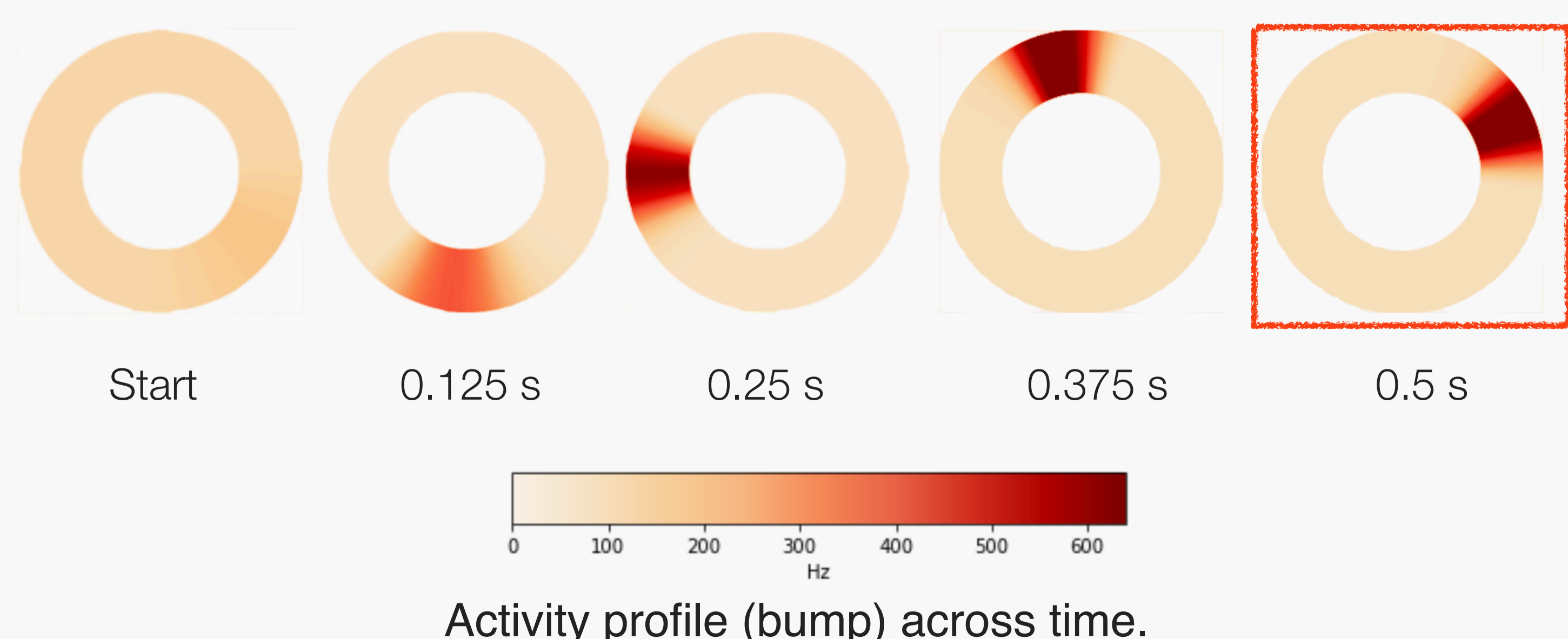
Net Connectivity Profile Feature space ( $x$ : preferred timing during song)



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.



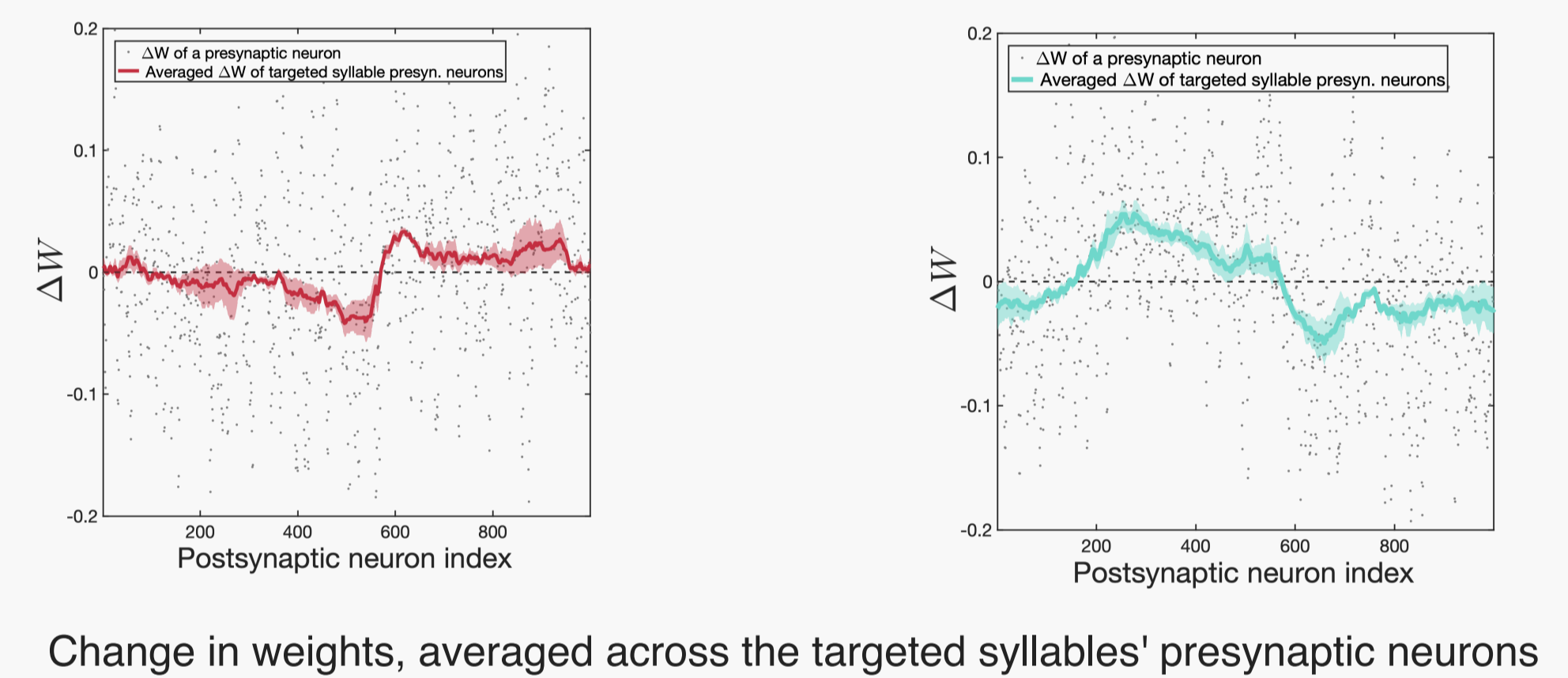
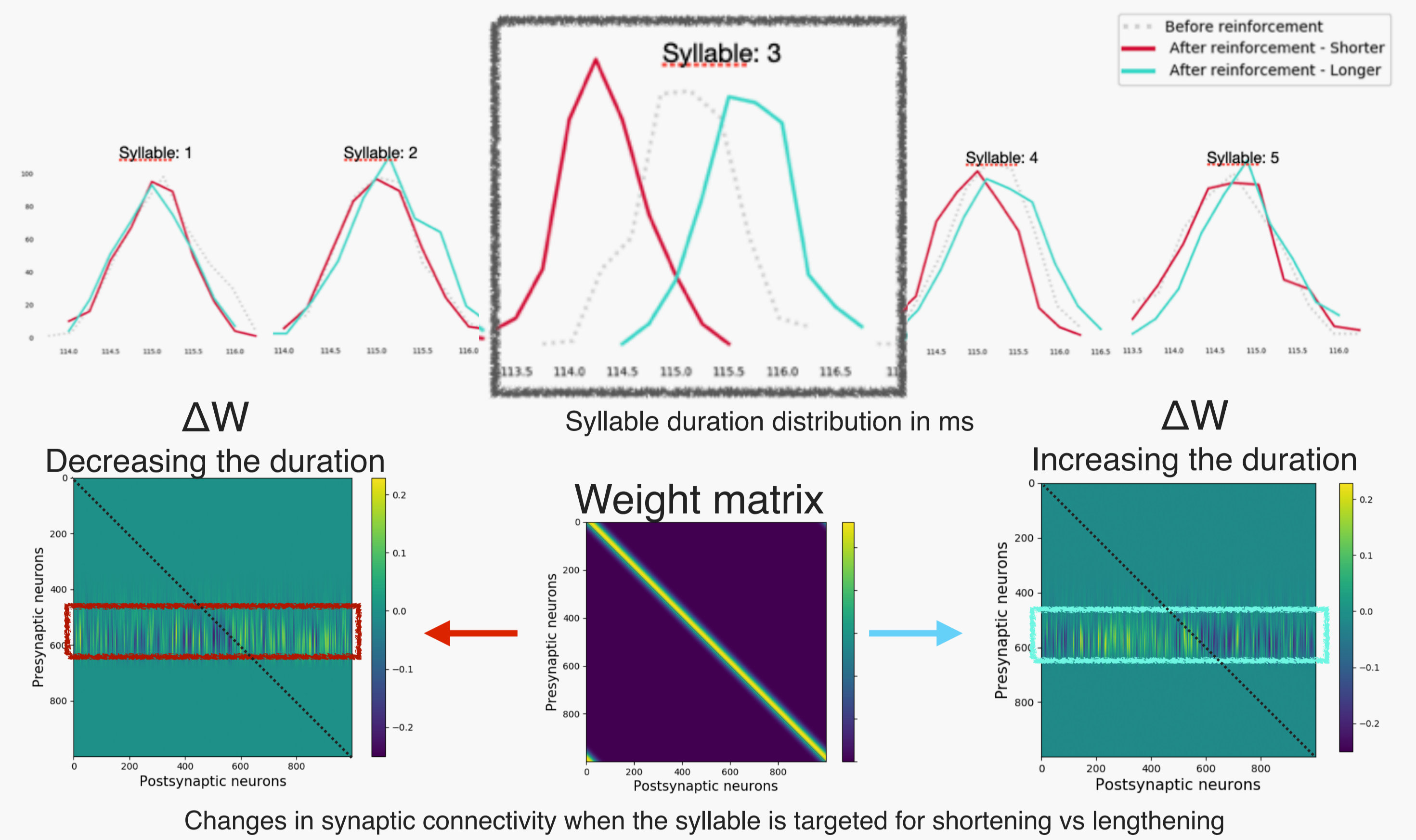
## 2. Modifying syllable duration

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.

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

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

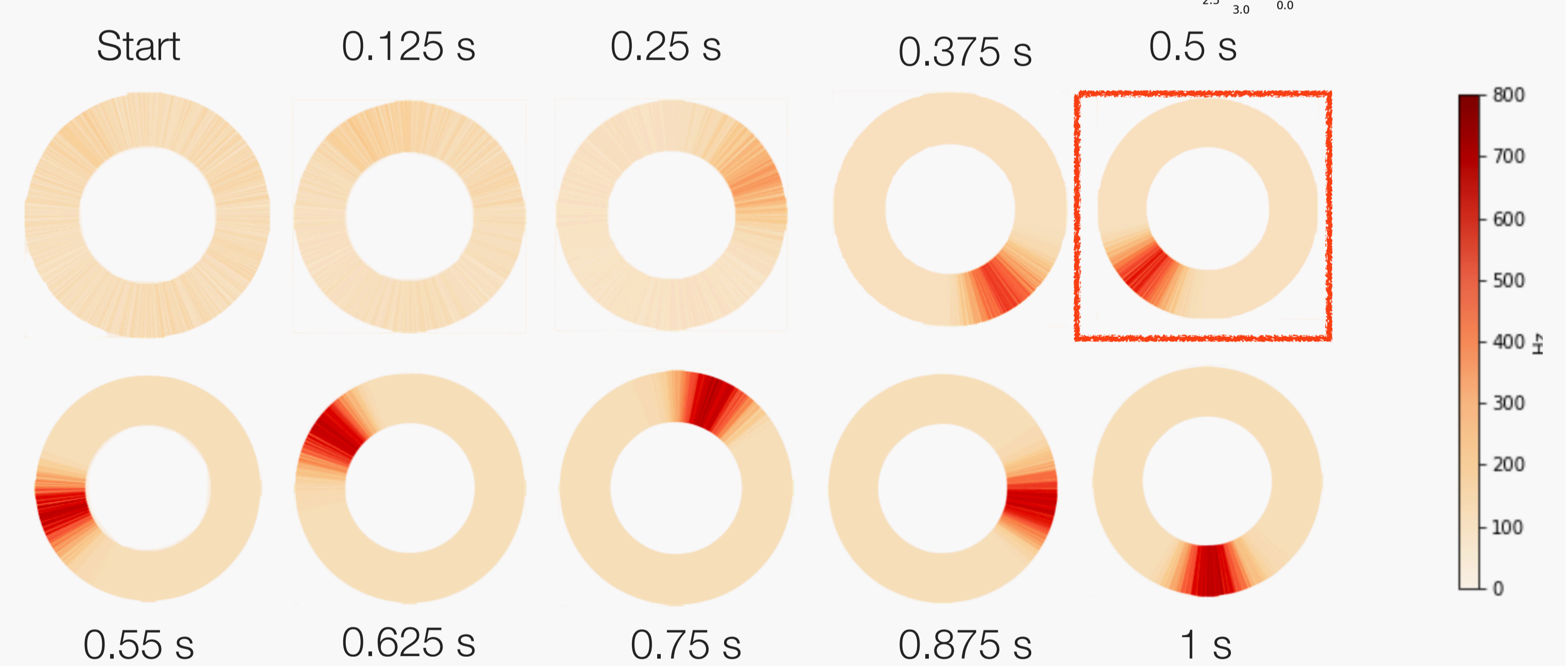
$$e_{ij} = \int_0^t \frac{dt'}{\tau_e} e^{-(t-t')/\tau_e} \eta_i(t') r_j(t')$$



## 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

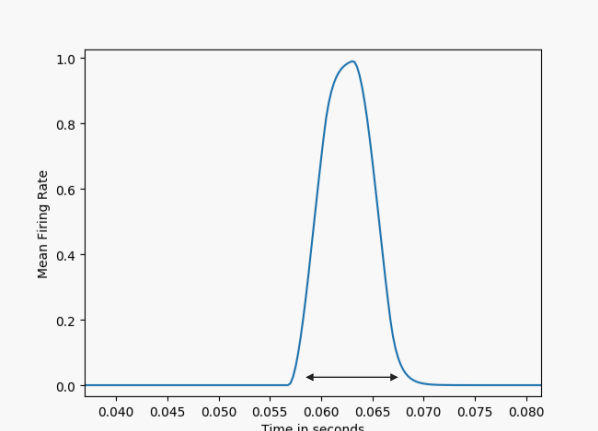
We propose that HVC neuronal dynamics may be modelled using the ring model.

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<sub>A</sub> 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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