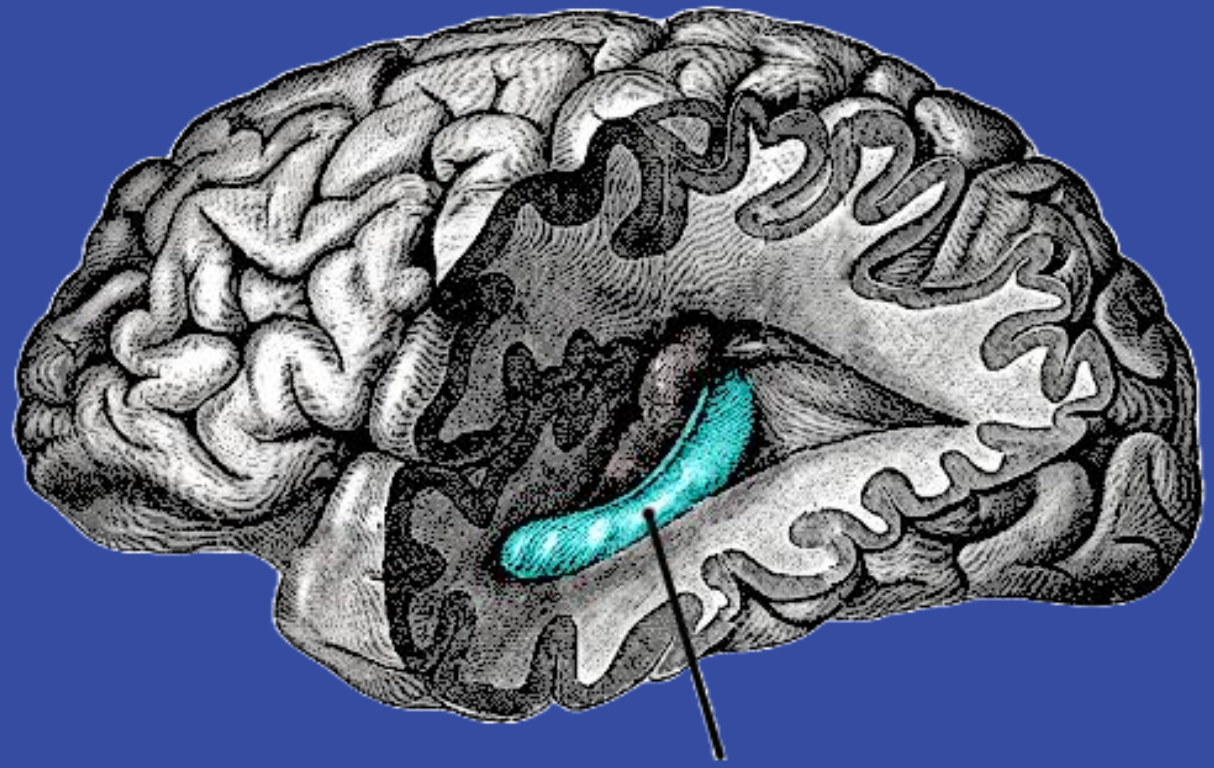
Modeling Hippocampal Replays with Short-Term Facilitation

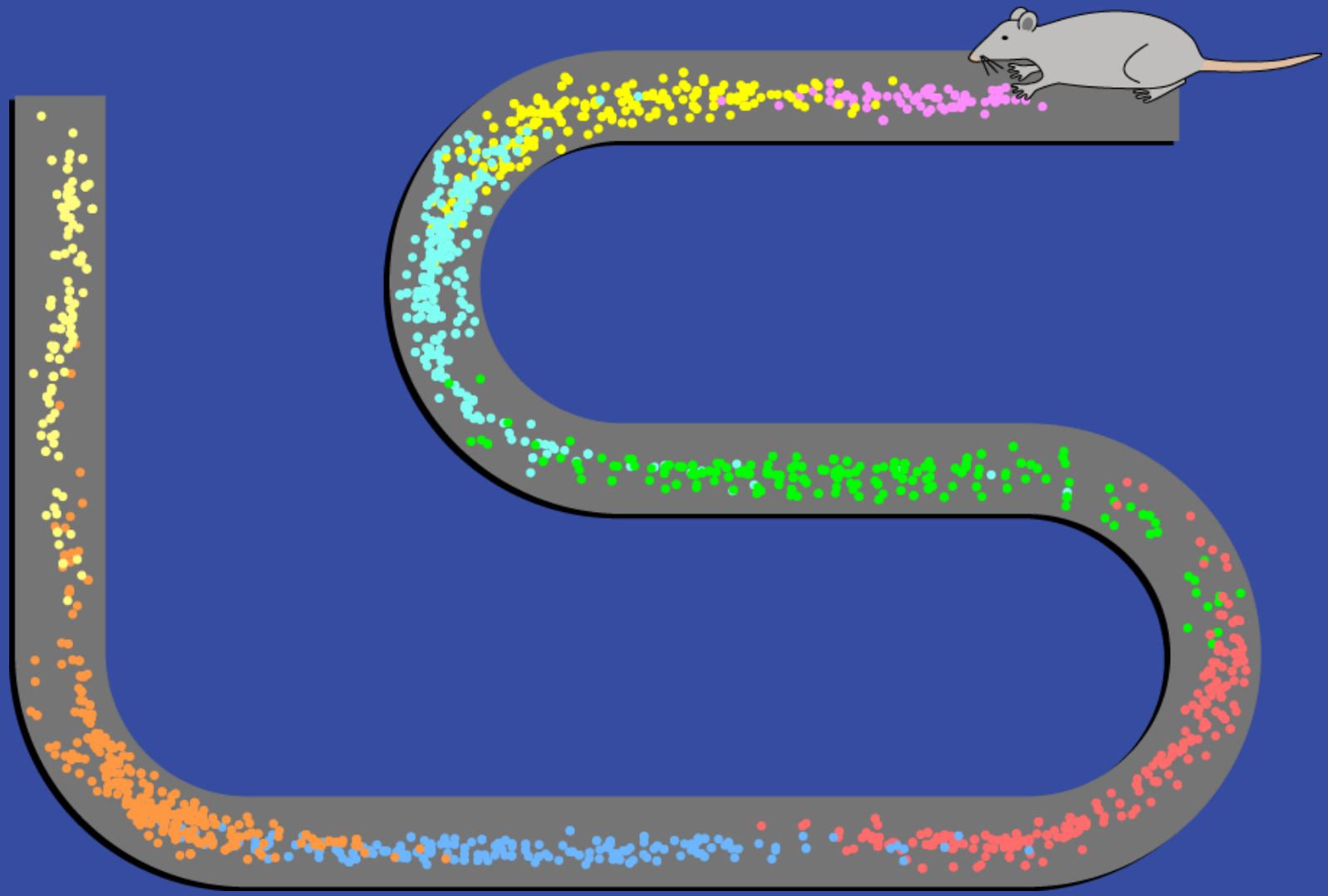
Luke Voinov

Background - Hippocampus

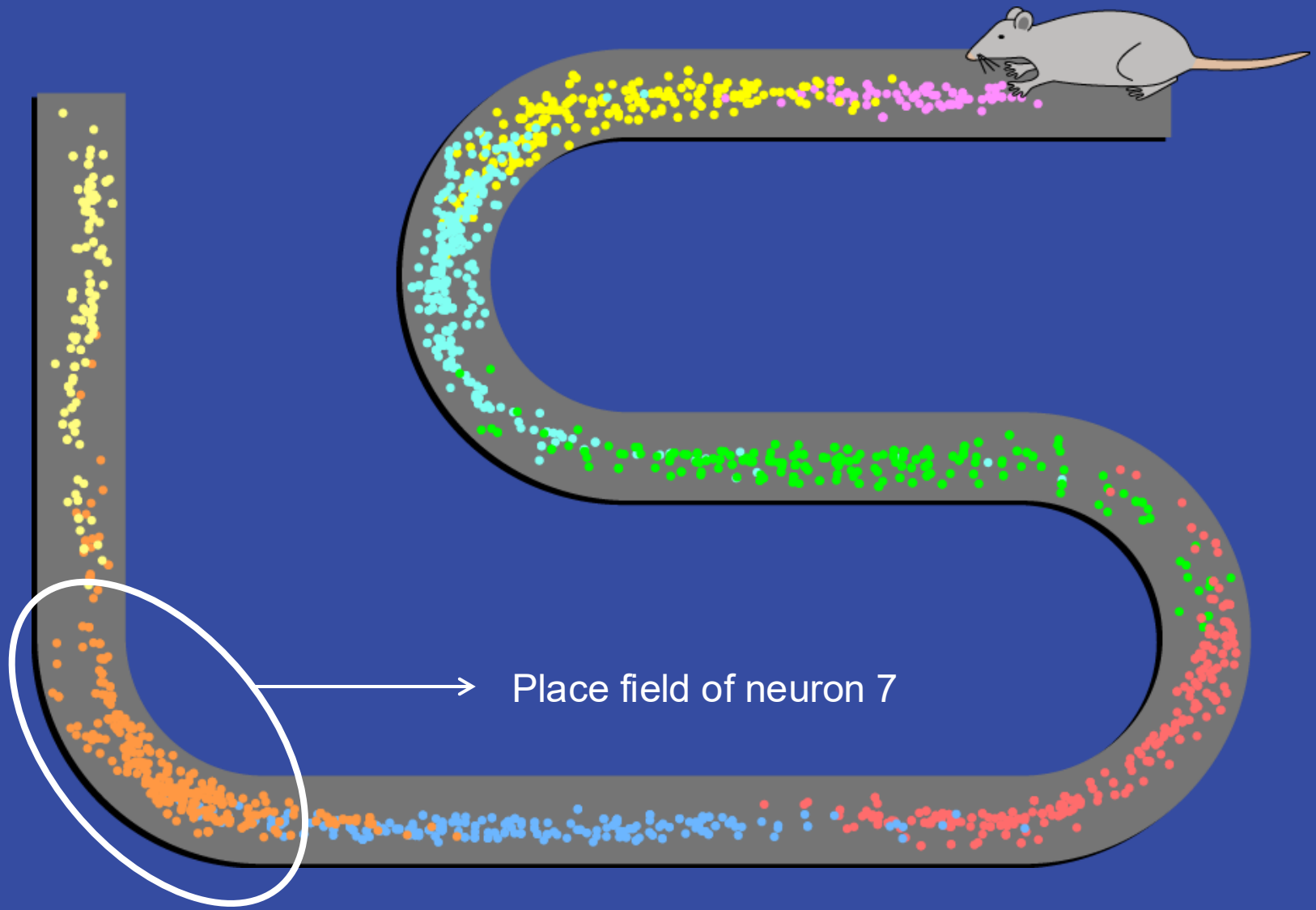


Stores short-term memory and transfers long-term memories into cortex

Background – Place Cells



Background - Place Fields



Background - Replays

- Forward Replays

  Associated with memory consolidation and potentially planning.

- Reverse Replays

  Associated with memory consolidation and possible mechanism for remembering important paths.

- Preplays

  Replay events that occur before the animal has run.

- Awake Replays

  Forward and backward replays during a restful yet awake state.

Romani – Tsodyks Model (2015)

$$\tau \frac{dm_i}{dt} = -m_i(t) + f(I^R{}_i(t) + I^E{}_i(t))$$

$$\frac{dn_i}{dt} = \frac{1 - n_i(t)}{\tau_R} - U n_i(t) m_i(t)$$

$$I^R{}_i(t) = \frac{1}{N} \sum_j^N W_{ij}\, m_j(t) n_j(t)$$

$$W_{ij} = J_1 \cos(\theta_i - \theta_j) - J_0$$

Romani – Tsodyks Model (2015)

Has (due to STD):

- Replays
- Novel-environment seeking
- Phase precession

Does not have (biologically accurate):

- Facilitation
- Reverse replays

Objective:

Adjust the model to incorporate facilitation and reverse replays

My Implementations & Ideas

- Short-term facilitation component

$$\frac{dn_i}{dt} = \frac{1 - n_i(t)}{\tau_R} - p_i(t)n_i(t)m_i(t)$$

$$\frac{dp_i}{dt} = \frac{U - p_i(t)}{\tau_f} + a_f(1 - p_i(t))\, m_i(t)$$

- 2 stages: Movement - Sleep

  Allows me to see how sleep replays will be affected by movement through a novel environment.

- Replay Mechanism Hypothesis

  The most recently facilitated neuron should be the most likely to activate once the animal is asleep, then the next most facilitated, and so on. Thus, recent facilitation could allow a signal to trace its way back toward the first place cells, consolidating those connections.

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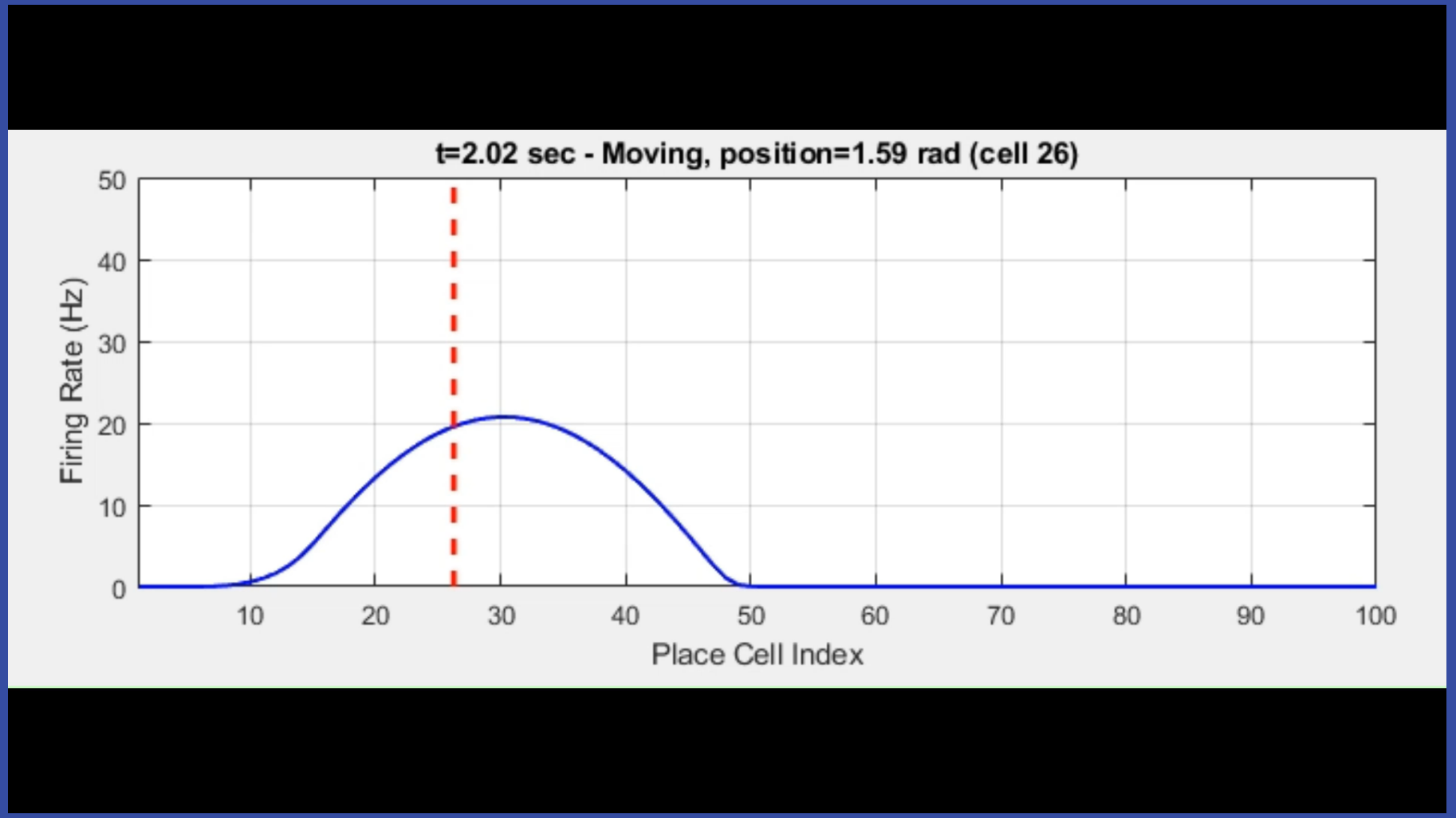
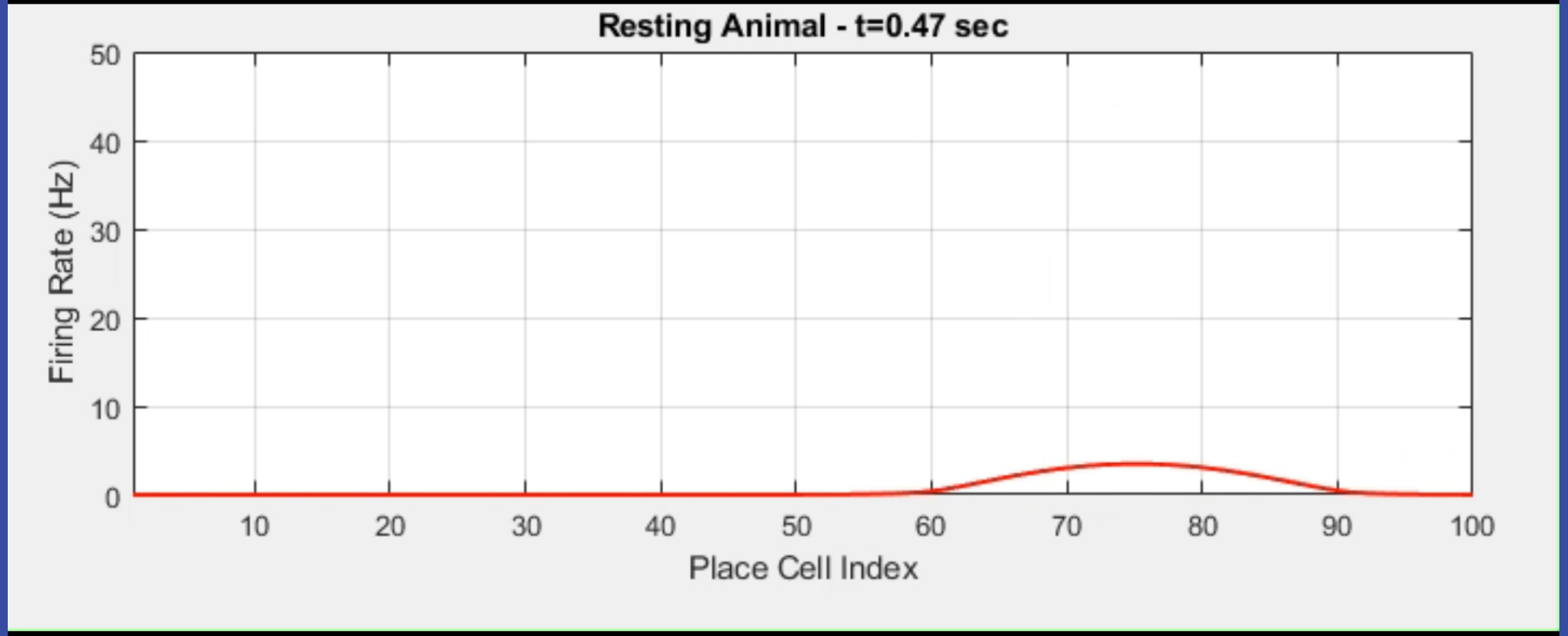
Results


t=2.02 sec - Moving, position=1.59 rad (cell 26)
Firing Rate (Hz)
0
10
20
30
40
50
10
20
30
40
50
60
70
80
90
100
Place Cell Index

Results


Resting Animal - t=0.47 sec
Firing Rate (Hz)
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
Place Cell Index

Future Work

- Fit other experimental findings to the model (e.g. reverse replays directly proportional to amount of reward)
- Plot and interpret how I_R changes when the animal rests
- Tinker with facilitation and depression parameters
- Implement hypothesis for mechanism behind reverse replays
- Consider making facilitation activity dependent

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