Model based inference of synaptic plasticity rules

Yash Mehta, Danial Tyulmankov, Adithya Rajagopalan, Glenn Turner
James Fitzgerald*, Jan Funke*

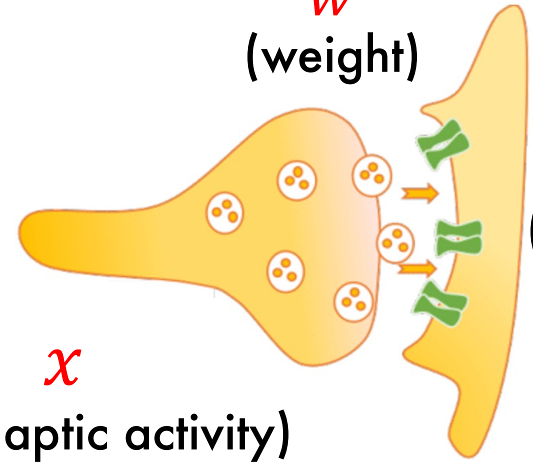
NEURAL INFORMATION PROCESSING SYSTEMS

Paper Website

Standard forms of synaptic plasticity

Δw

Hebbian.................... xy
Anti-Hebbian .... $-xy$
Oja's .... $xy - y^2w$
Dopamine-based?........... xr



$$\Delta w = g_\theta(x, y, w, r) = ?$$

NEURAL INFORMATION
PROCESSING SYSTEMS

$$g_\theta^{\text{Taylor}} = \sum_{\alpha,\beta,\gamma=0}^{2} \theta_{\alpha,\beta,\gamma} x_i^\alpha y_j^\beta w_{ij}^\gamma.$$

Note,

Hebbian.................... xy $\theta_{110} = 1, \quad \theta_{rest} = 0$

Anti-Hebbian .... $-xy$ $\theta_{110} = -1, \quad \theta_{rest} = 0$

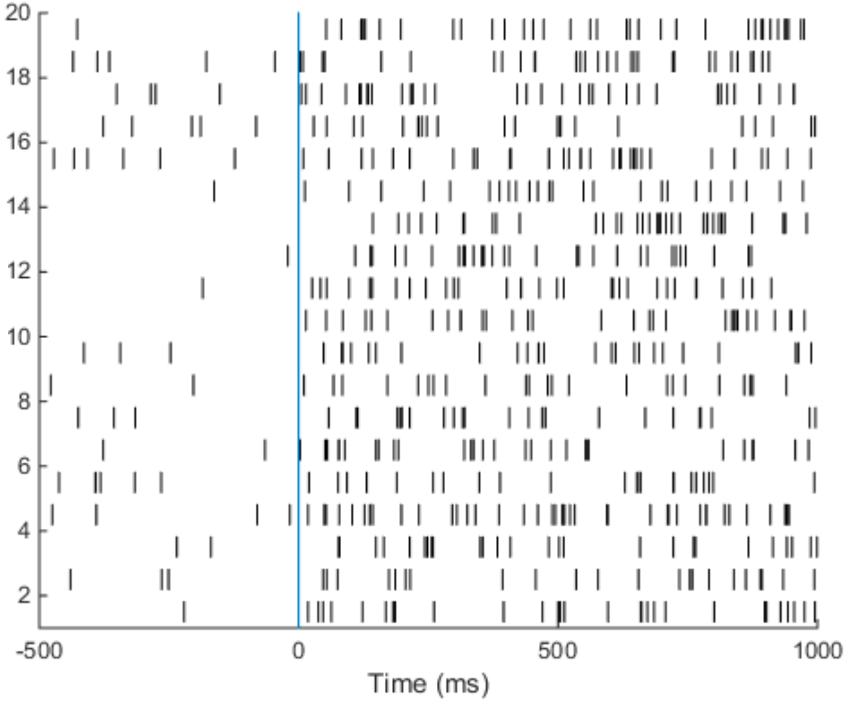
Oja's .... $xy - y^2 w$ $\theta_{110} = 1, \quad \theta_{021} = -1, \quad \theta_{rest} = 0$

NEURAL INFORMATION PROCESSING SYSTEMS

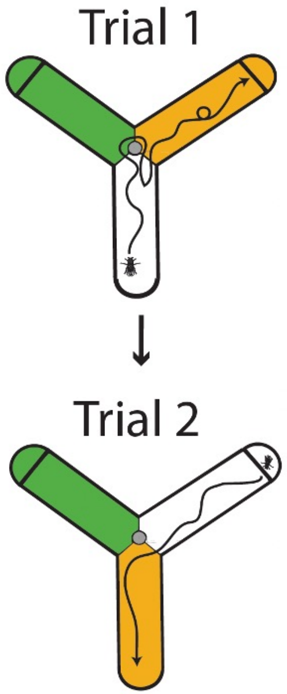
🚨 We can't directly measure the changes in synaptic weights during learning!

Obtainable measurements:

A. Neural activity



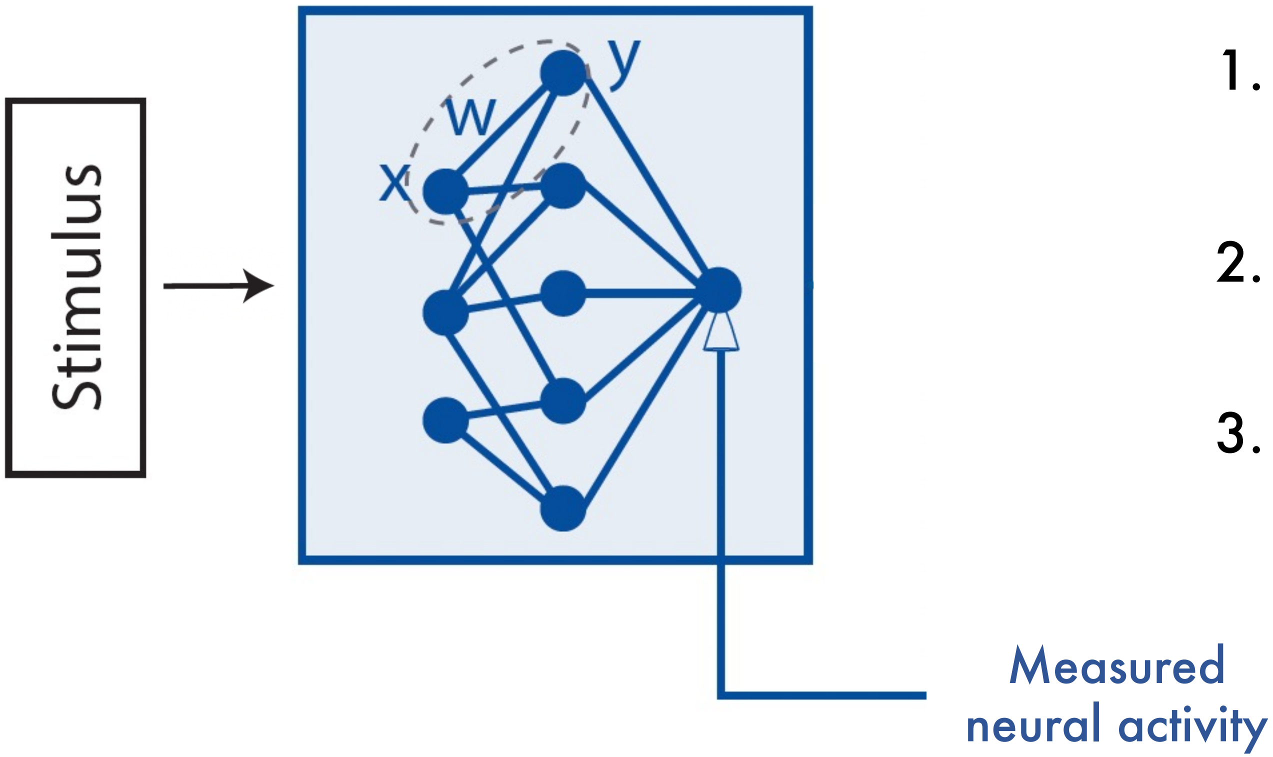
B. Behavior



NEURAL INFORMATION PROCESSING SYSTEMS

Model (plasticity from neural activity)

$$\Delta w_{ij} = g_\theta(x_j \; , y_i \; , w_{ij} \, , r_j \,)$$

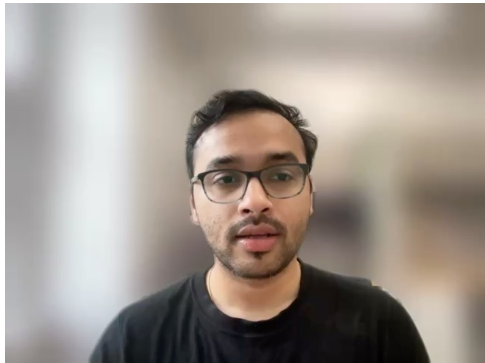


Assumptions

1. Single layer of feed forward neural network with plasticity

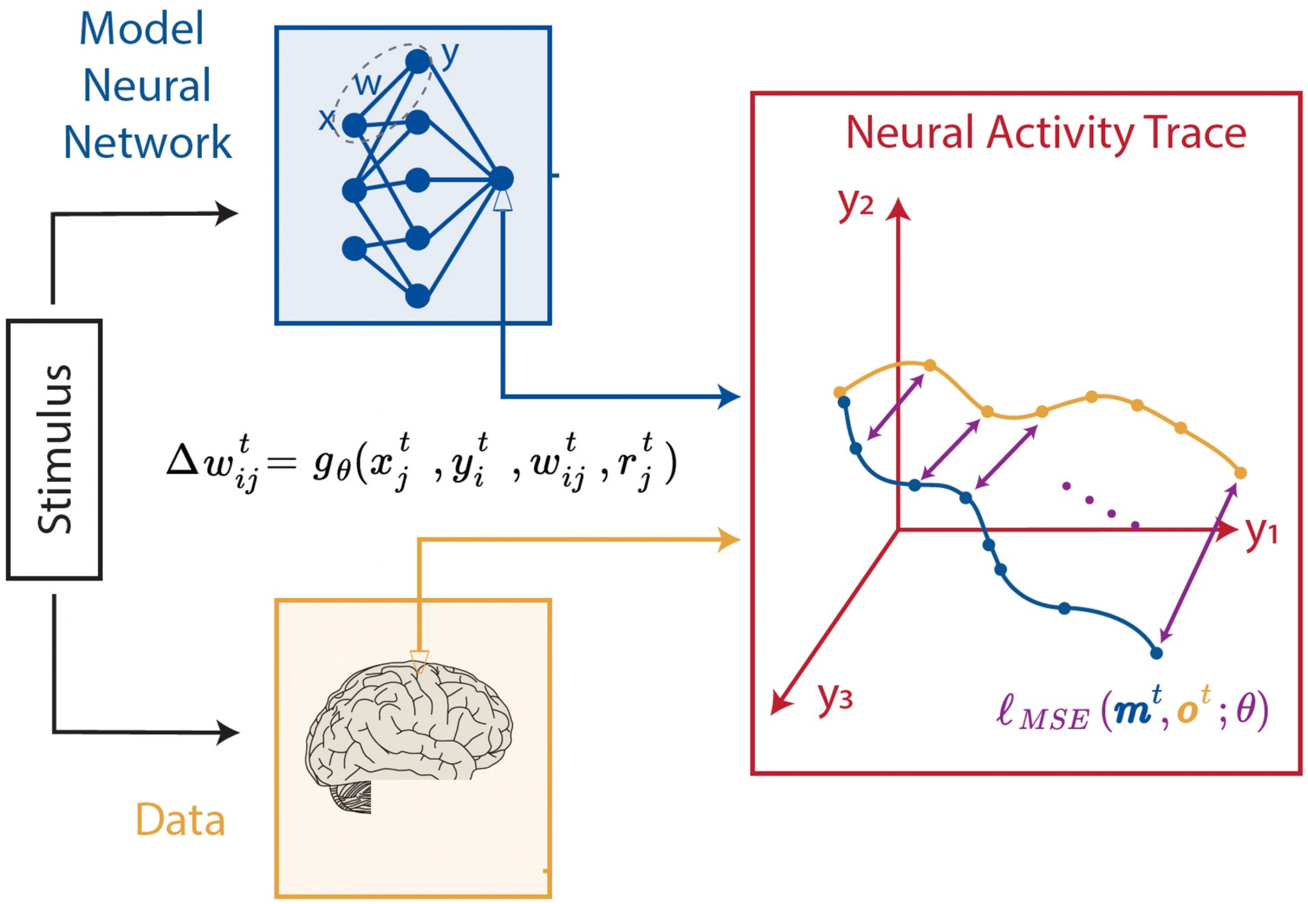
2. All weights evolve according to same plasticity rule, g_θ

3. Plasticity (g_θ) depends only on state (x, y, w, r) of the current time step



NEURAL INFORMATION
PROCESSING SYSTEMS

Method overview (neural activity)



Infering
Learning Rule

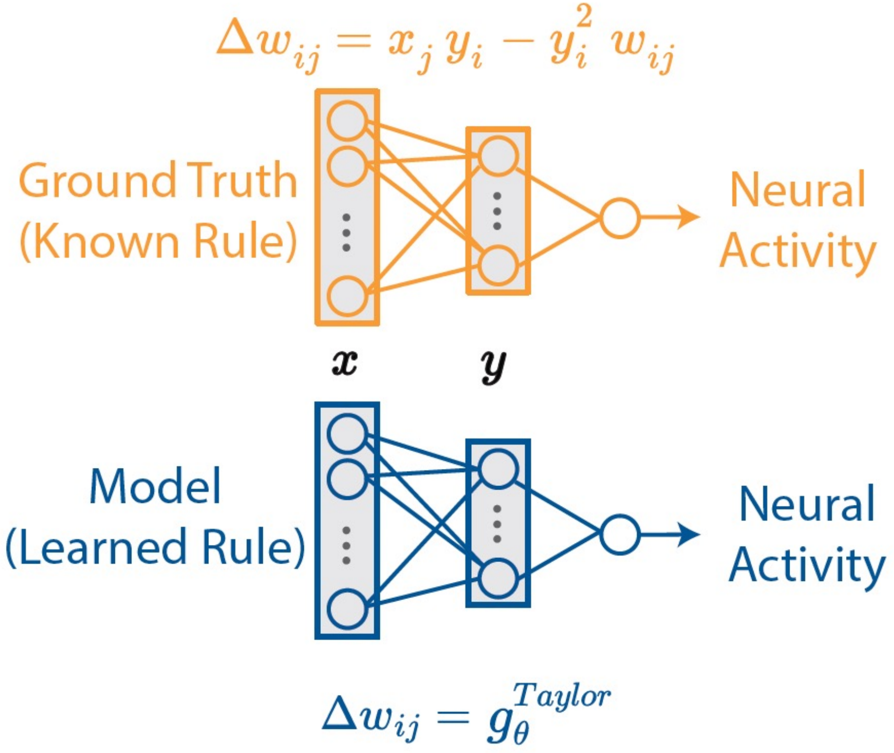
$$\theta \leftarrow \theta - \eta \nabla_\theta \mathcal{L}(M, O; \theta)$$

NEURAL INFORMATION PROCESSING SYSTEMS

Method validation: simulated data

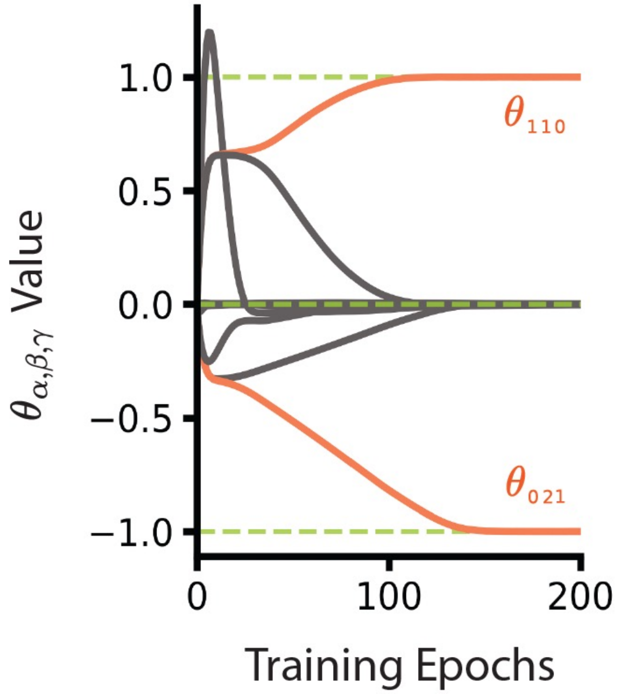
💡 Generate a trajectory with a known plasticity rule, then try to infer it.

Oja's



$xy \; - y^2 w$

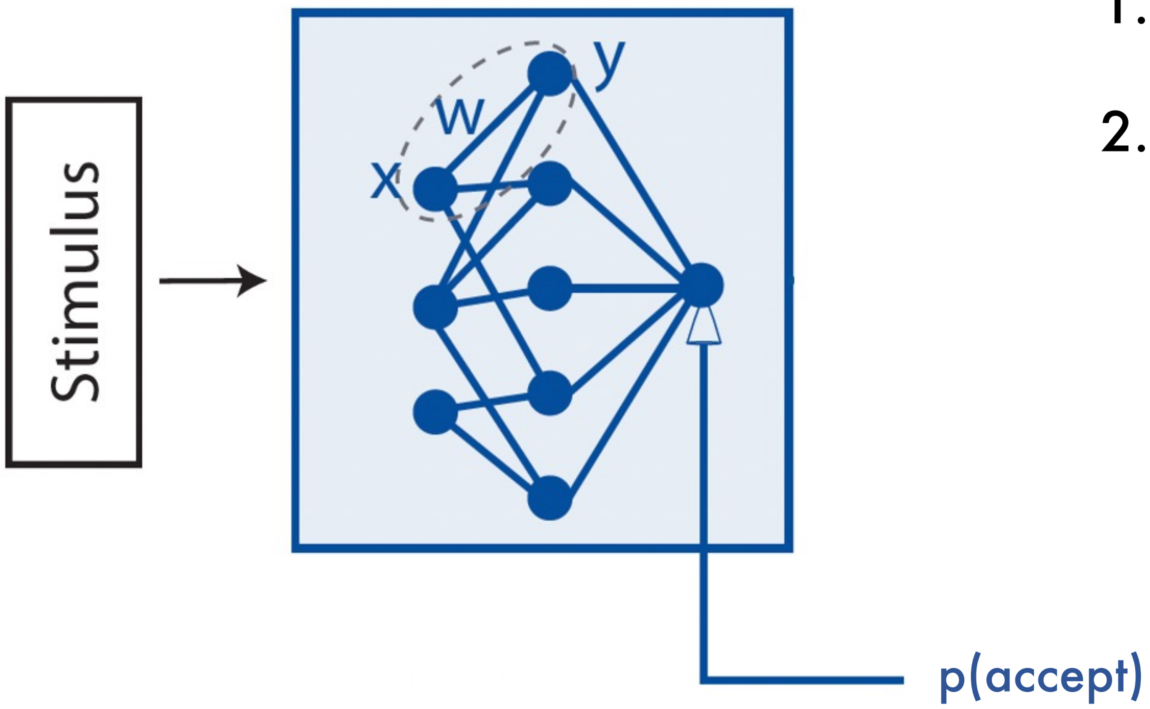
$\theta_{110} = 1, \quad \theta_{021} = -1, \quad \theta_{rest} = 0$



NEURAL INFORMATION PROCESSING SYSTEMS

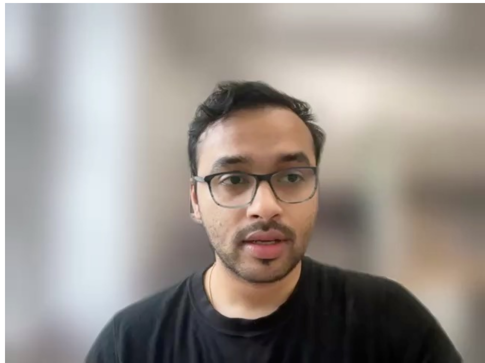
Model (plasticity from behavior)

$$\Delta w_{ij} = g_\theta(x_j, y_i, w_{ij}, r_j)$$



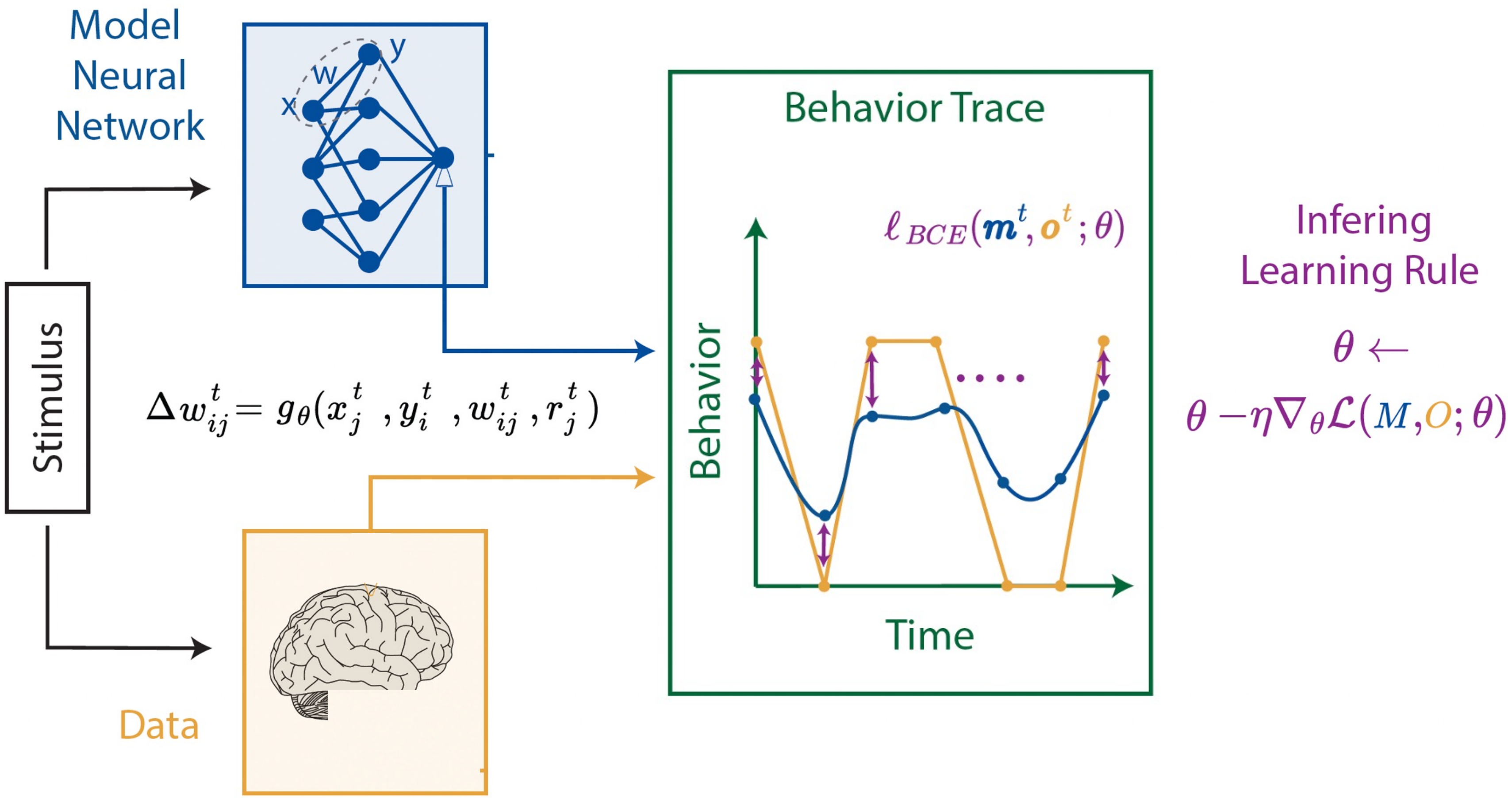
Assumptions

1. Behavior: accept, reject decisions. Given by network output
2. Plasticity happens in the first layer, last layer is fixed (averages neural activity)

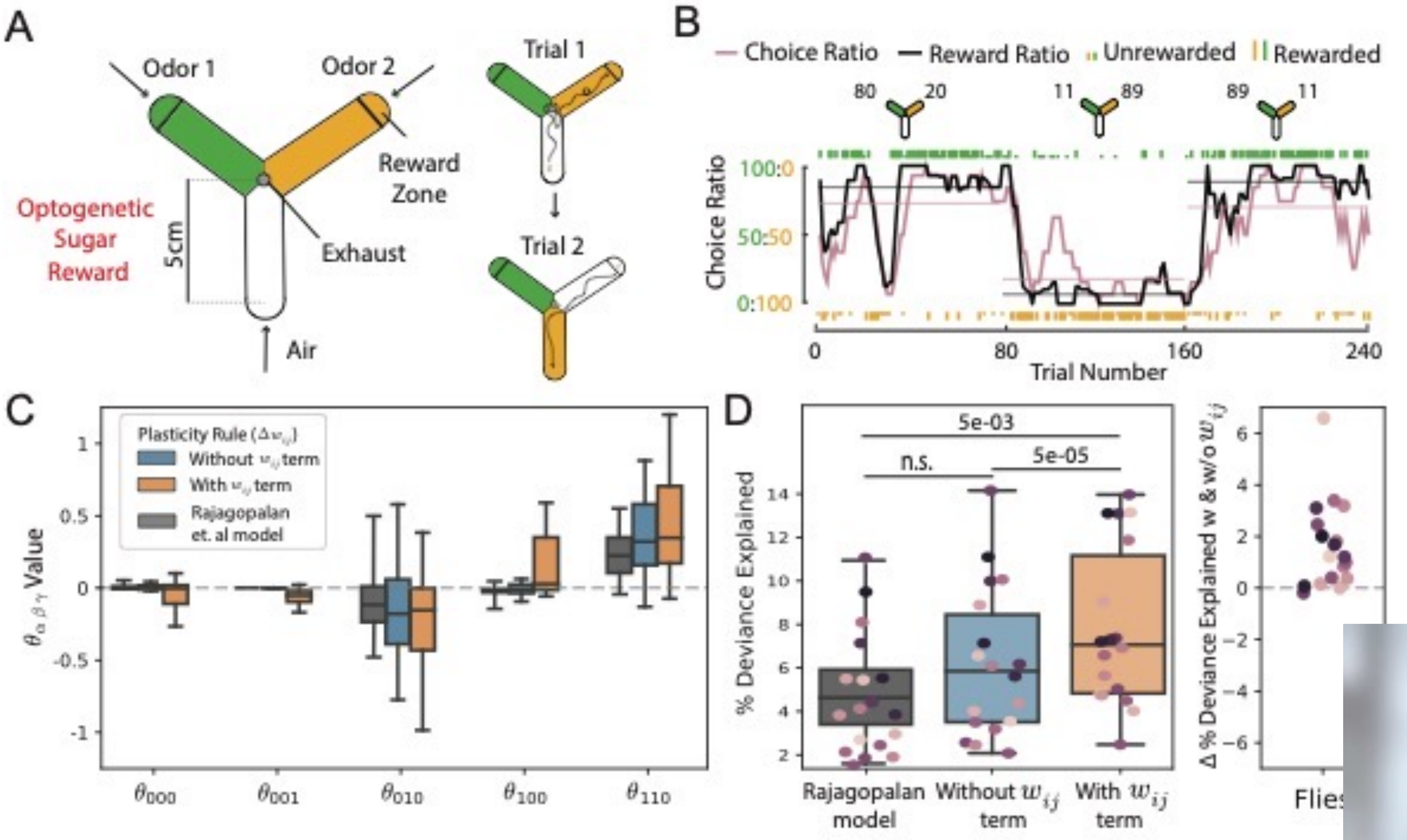


NEURAL INFORMATION PROCESSING SYSTEMS

Method overview (behavior)



Fly experimental setup



NEURAL INFORMATION PROCESSING SYSTEMS

Yash Mehta,
Cognitive Science PhD student,
Johns Hopkins

Paper Website

GitHub Repo