

Does the subcortex make a decision?

Readings for today

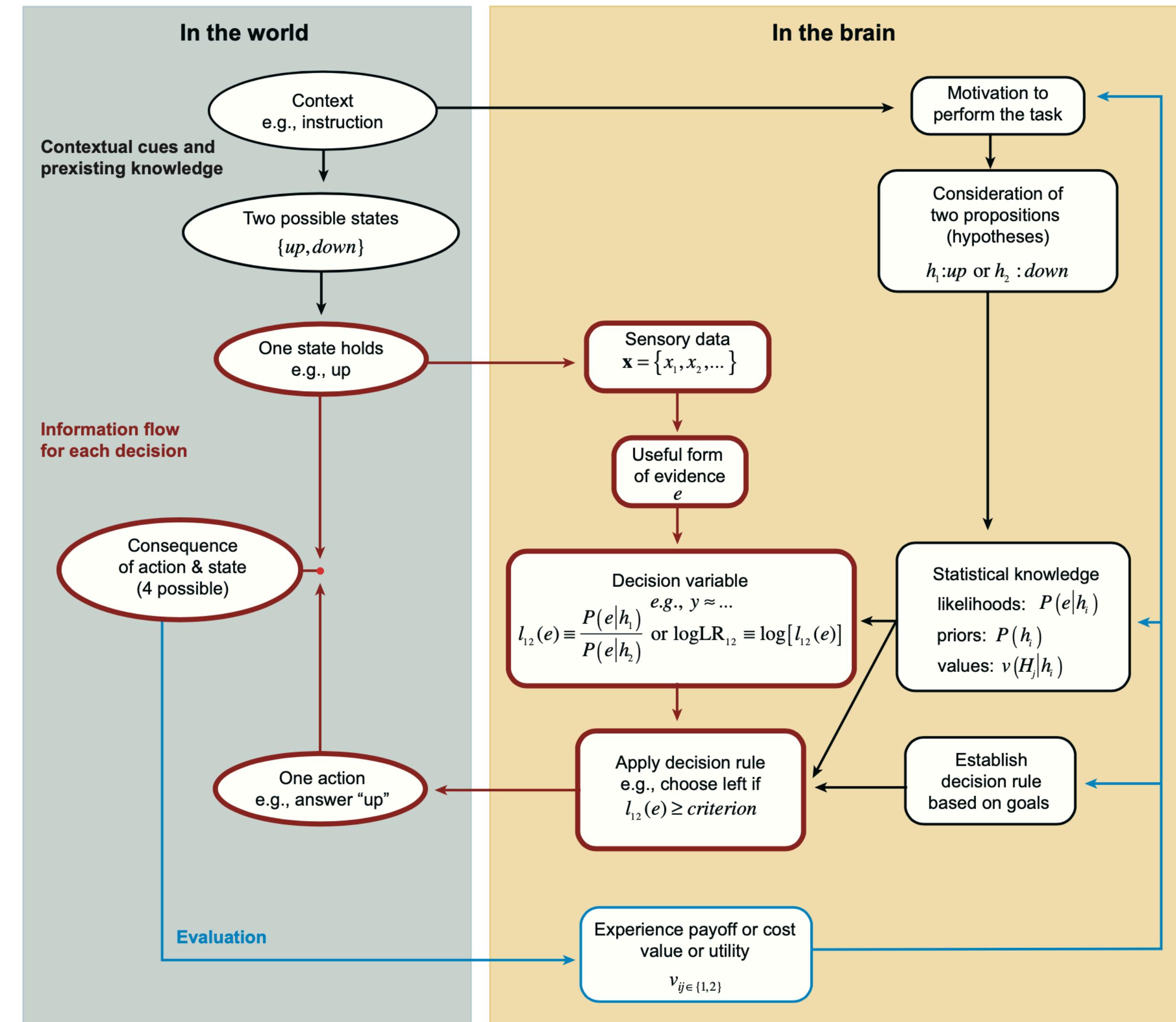
- Dunovan, K., & Verstynen, T. (2016). Believer-skeptic meets actor-critic: rethinking the role of basal ganglia pathways during decision-making and reinforcement learning. *Frontiers in neuroscience*, 10, 106.

Topics

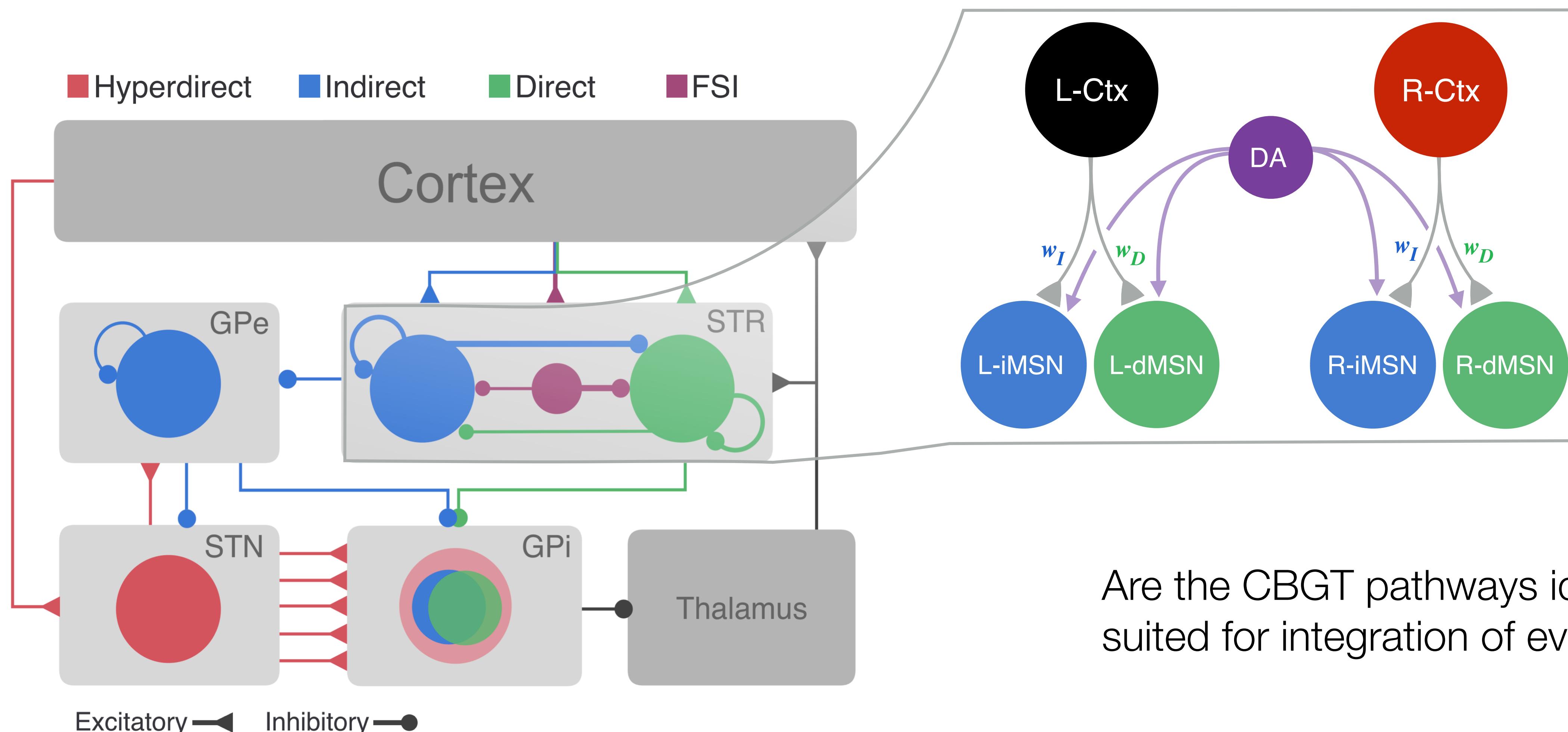
- Cortical-subcortical loops as accumulators
- Control of certainty

Cortical-subcortical loops as accumulators

Elements of making a decision



Cortico-basal ganglia thalamic pathways



Str: striatum; GPe: external globus pallidus;
GPI: internal globus pallidus; STN: Subthalamic nucleus

Are the CBGT pathways ideally suited for integration of evidence?

The sequential probability ratio test (SPRT)

1. On each sample i , evaluate logLR

$$w_i = \log \left(\frac{P(e_i | h_1)}{P(e_i | h_2)} \right)$$

2. Sum all logLR tests up to current observation

$$y_n = \sum_{i=1}^n w_i$$

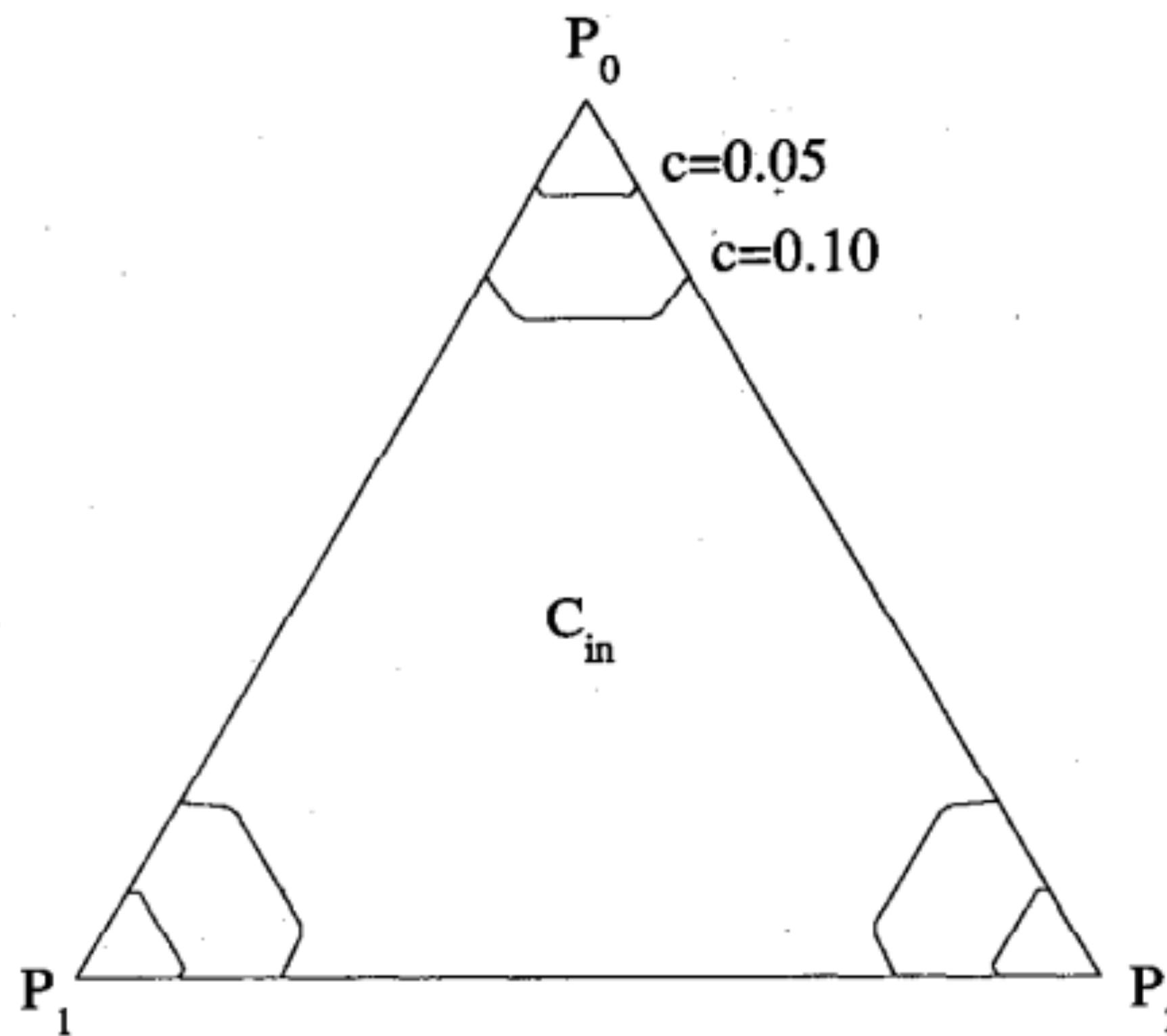
3. Determine stopping rule

$$y_n \geq \log \frac{1-\alpha}{\alpha}, \text{ then select } h_1$$

$$y_n \leq \log \frac{\beta}{1-\beta}, \text{ then select } h_2$$

$$\log \frac{\beta}{1-\beta} \leq y_n \leq \log \frac{1-\alpha}{\alpha}, \text{ continue sampling}$$

The multihypothesis SPRT (MSPRT) algorithm



Variant of the SPRT that allows for evaluating more than 2 hypotheses.

$$P(x(t)) = \sum_{i=1}^N P_i(t-1) P(x(t)|H_i).$$

posterior $i=1$ prior likelihood

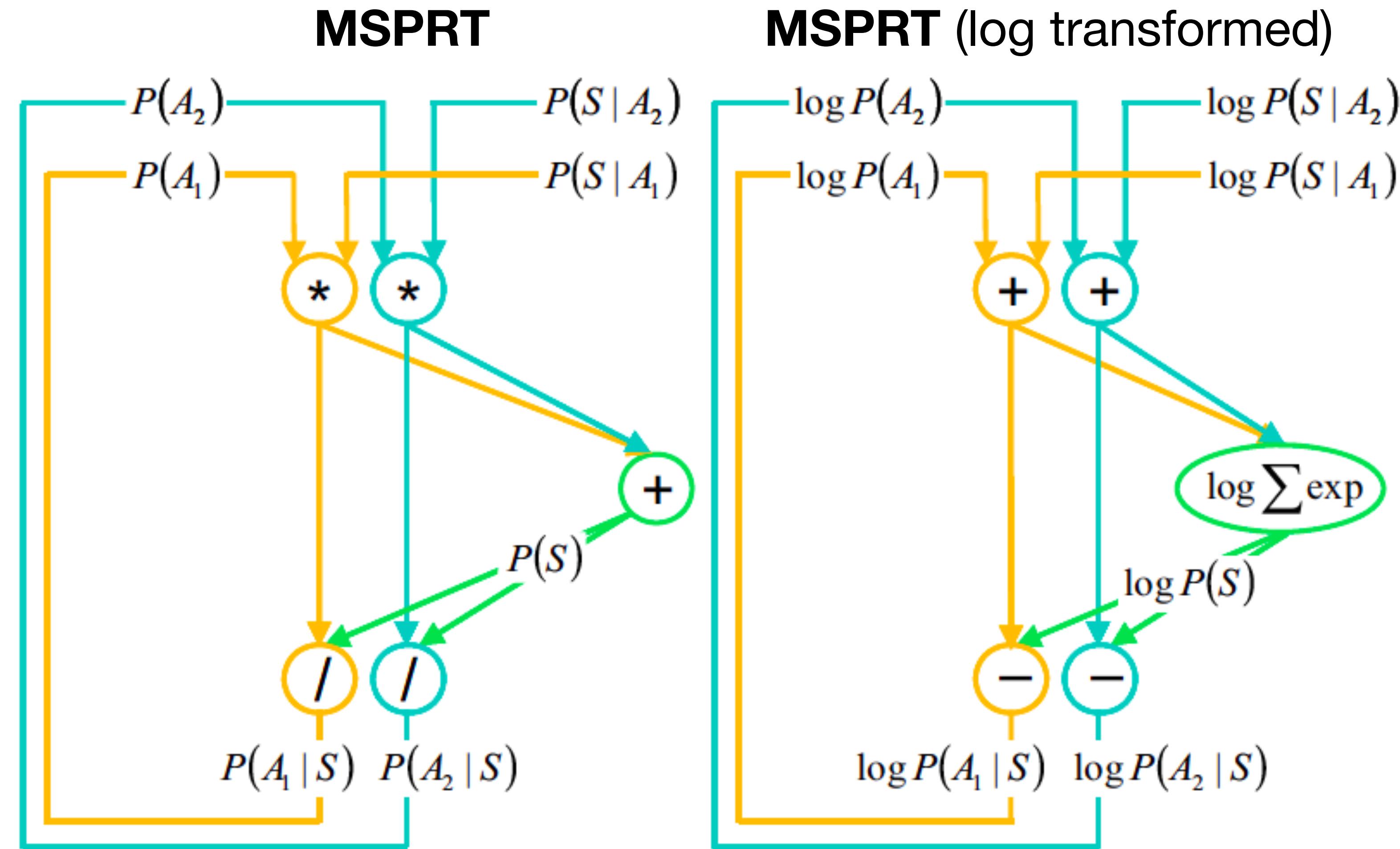
Applying a log transform allows for reframing this to being framed in neural firing rates

$$\log P(x(t)|H_i) = g x_i(t) - b(t),$$

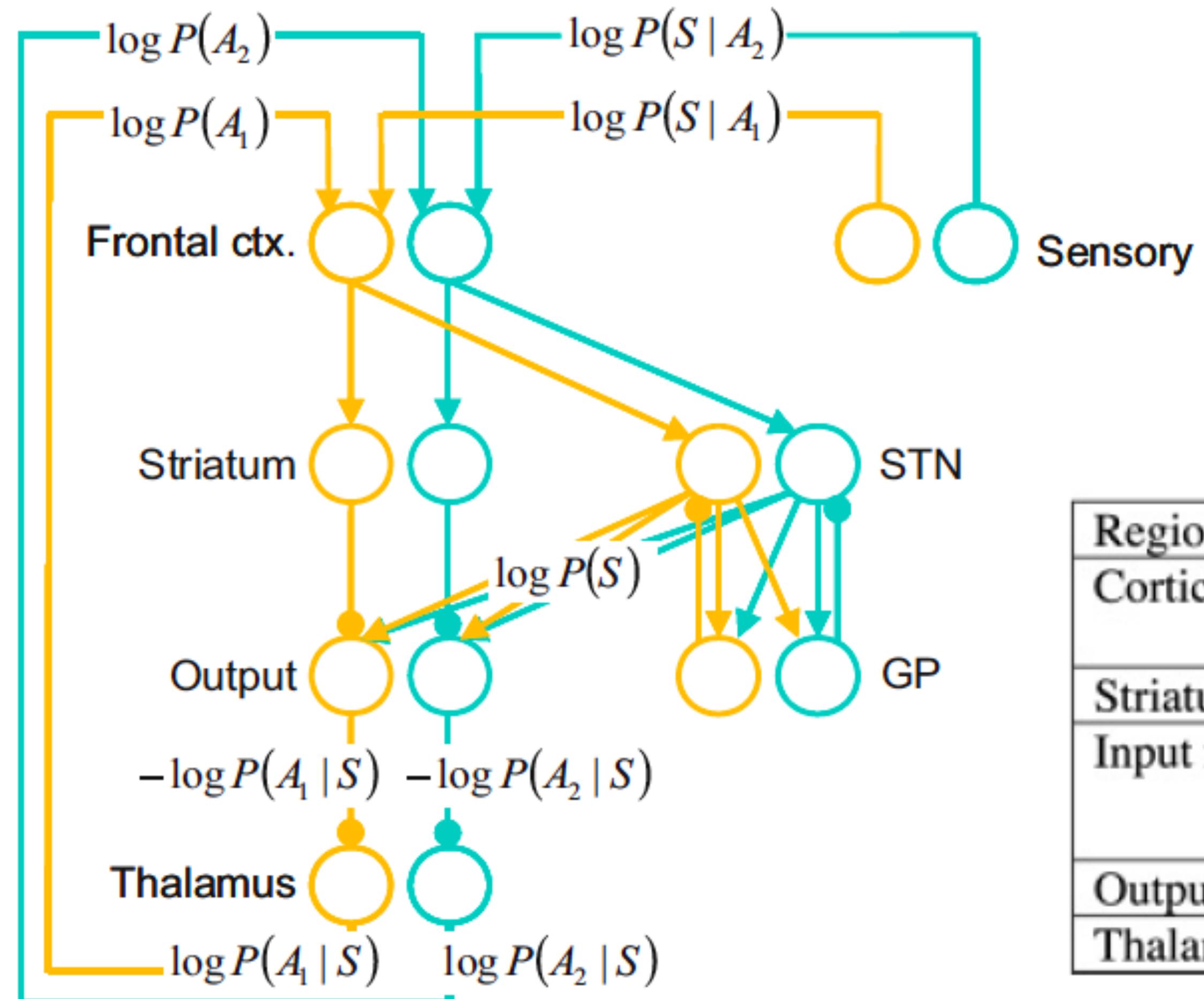
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$g = (I_+ - I_-)/\sigma^2$ Sensory evidence Scalar (same for all hypotheses)

The multihypothesis SPRT (MSPRT) algorithm



A neural instantiation of the MSPRT

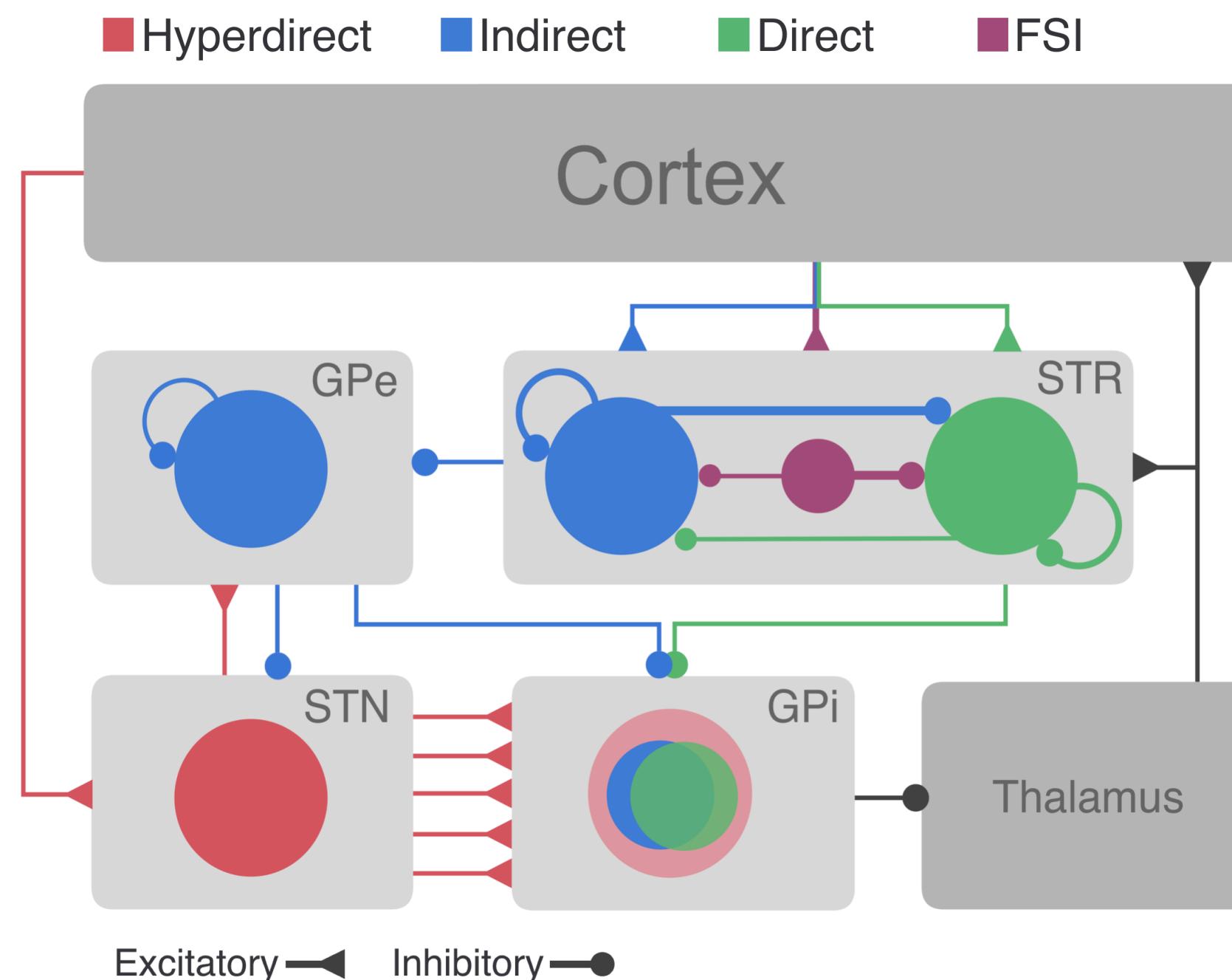


Based off of the topology of excitatory & inhibitory connections, you can map CBGT dynamics to the MSPRT algorithm.

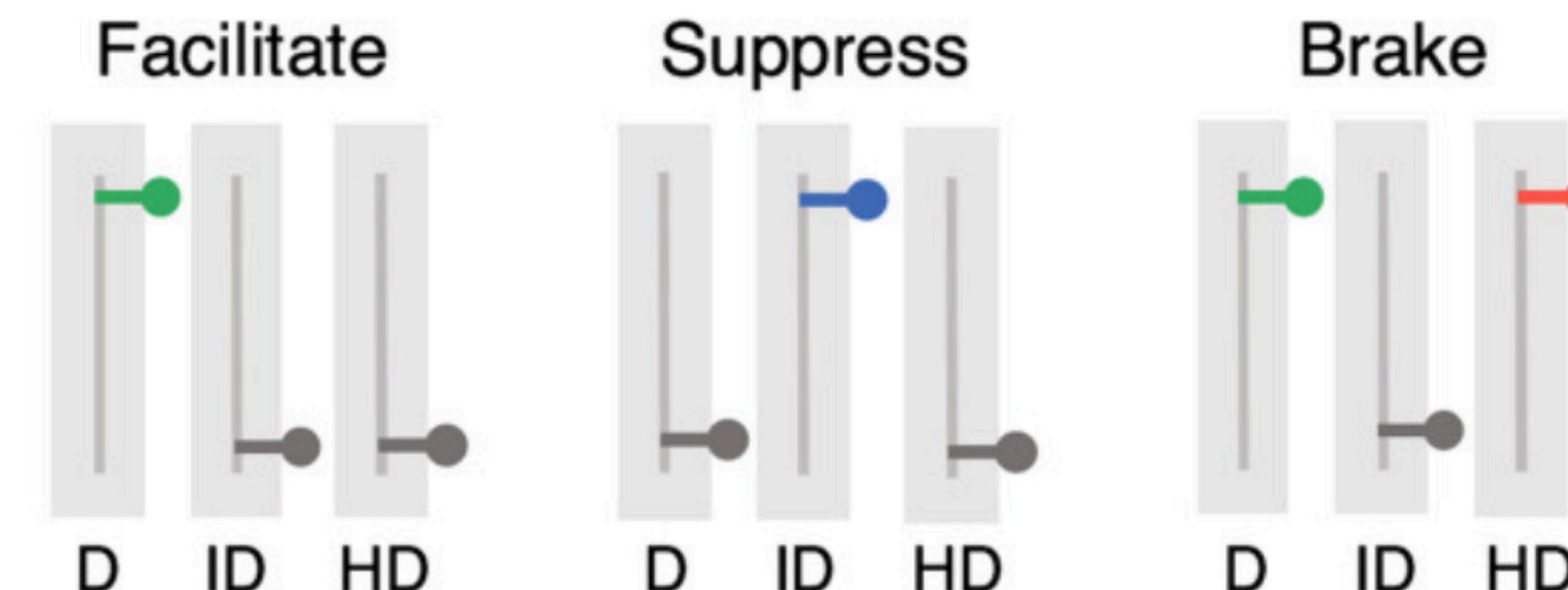
Region	Equation
Cortical integrators	$INT_i(0) = \log 1/N + c$ $INT_i(t) = TH_i(t-1) + g x_i(t), \text{ for } t>0$
Striatum	$STR_i(t) = INT_i(t)$
Input from STN and GP	$SG(t) = \log \sum_{i=1}^N \exp INT_i(t)$
Output nuclei	$OUT_i(t) = -STR_i(t) + SG(t)$
Thalamus	$TH_i(t) = c - OUT_i(t)$

Control of certainty

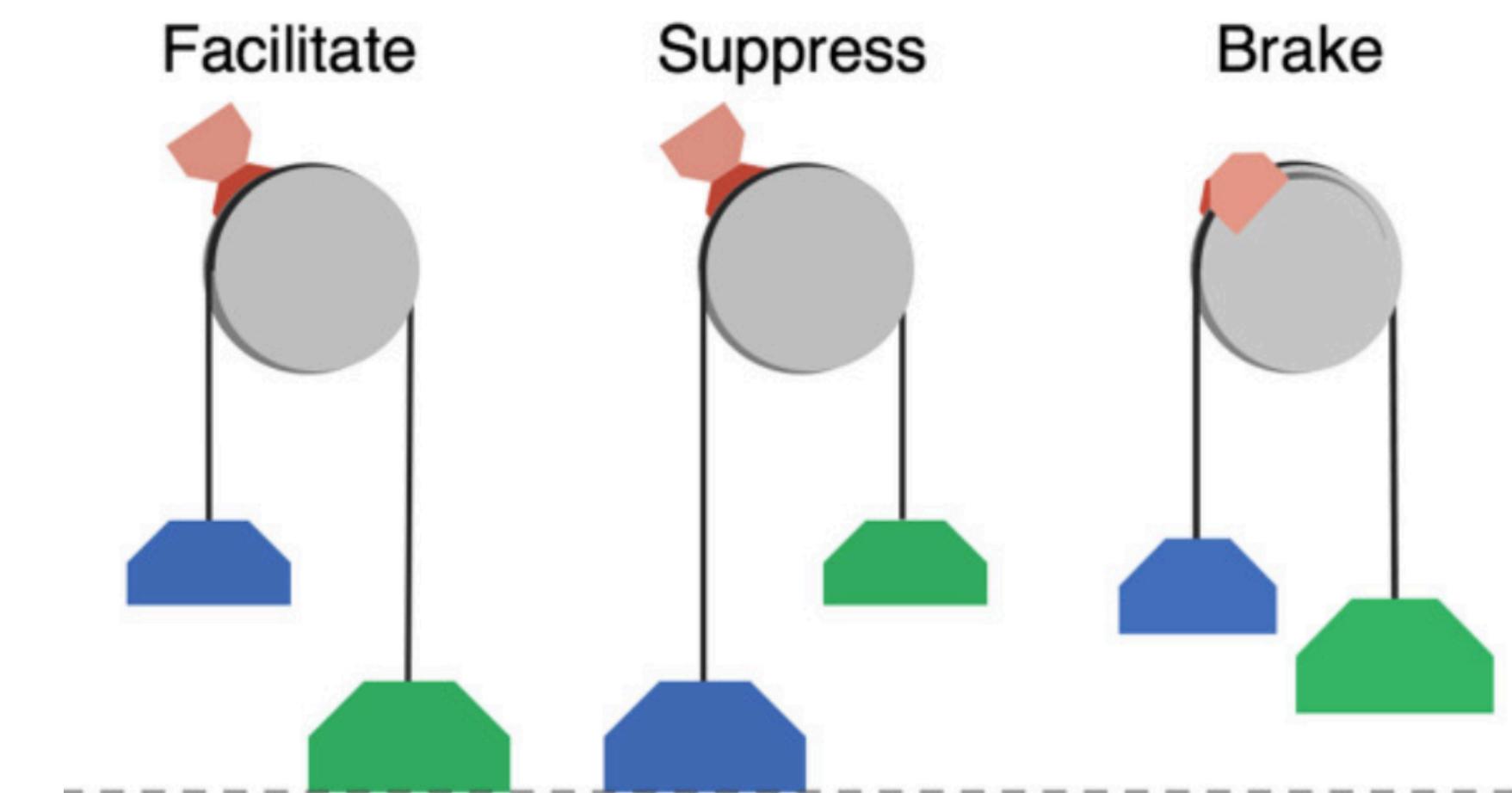
Believers & Skeptics



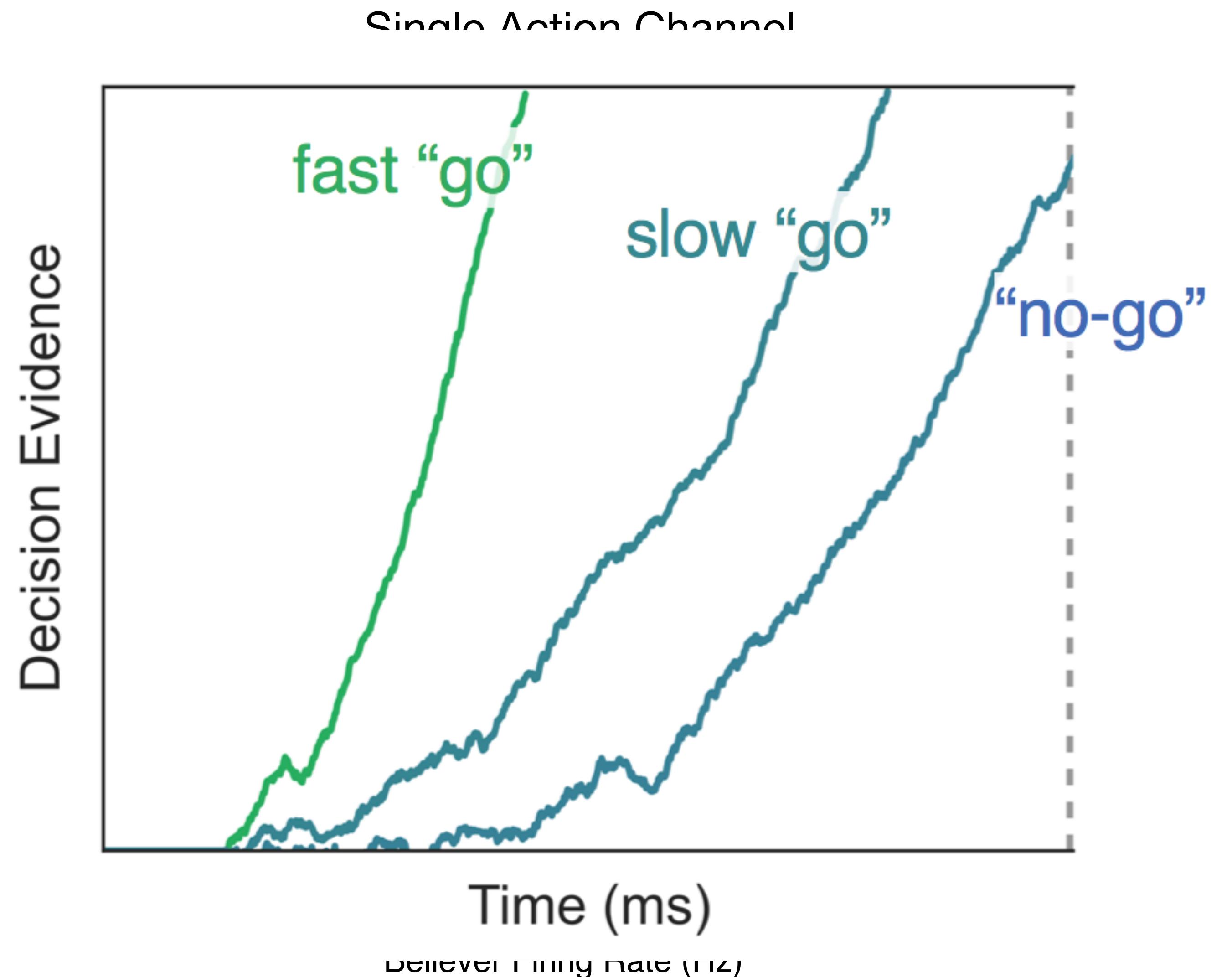
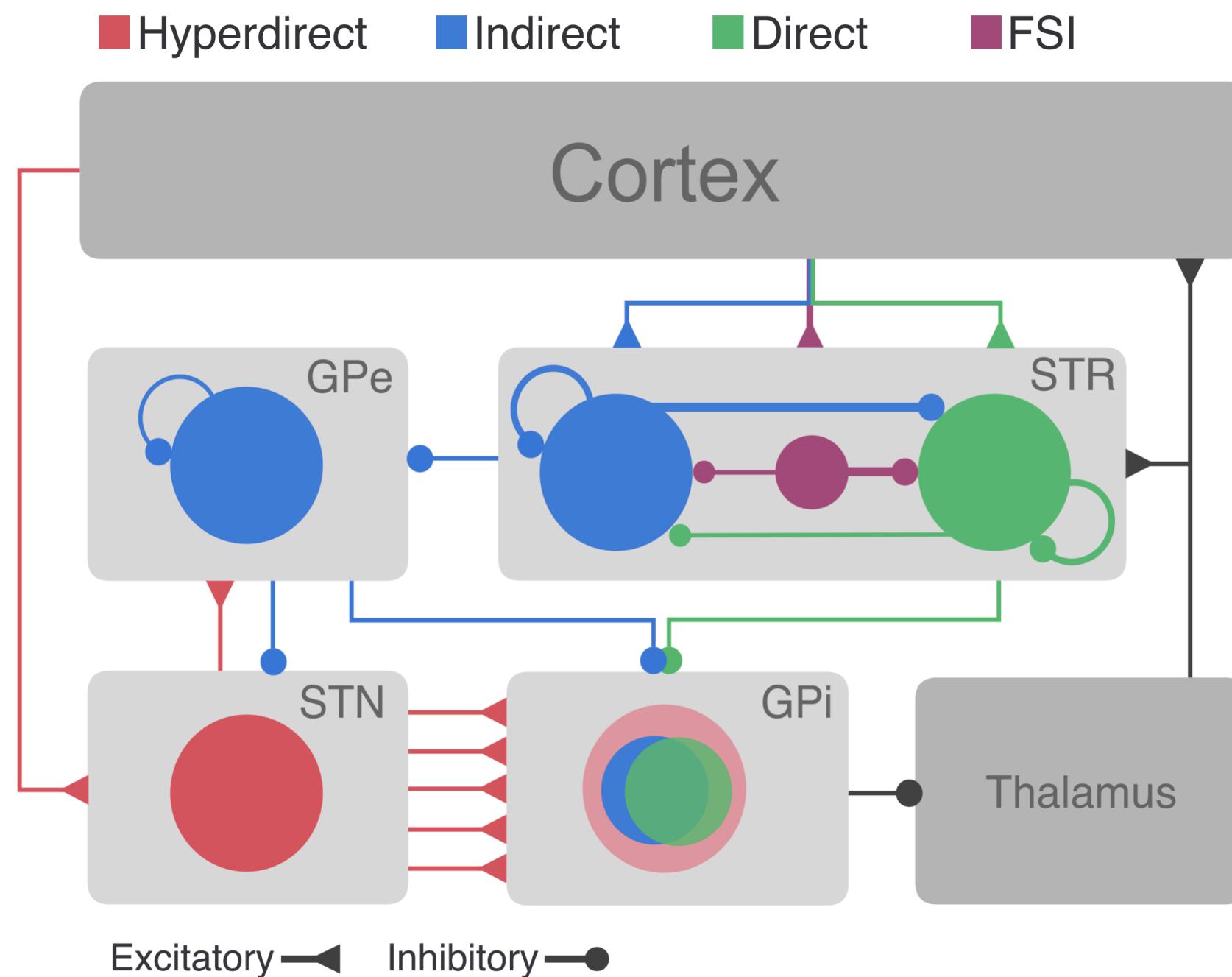
Independent Levers Model

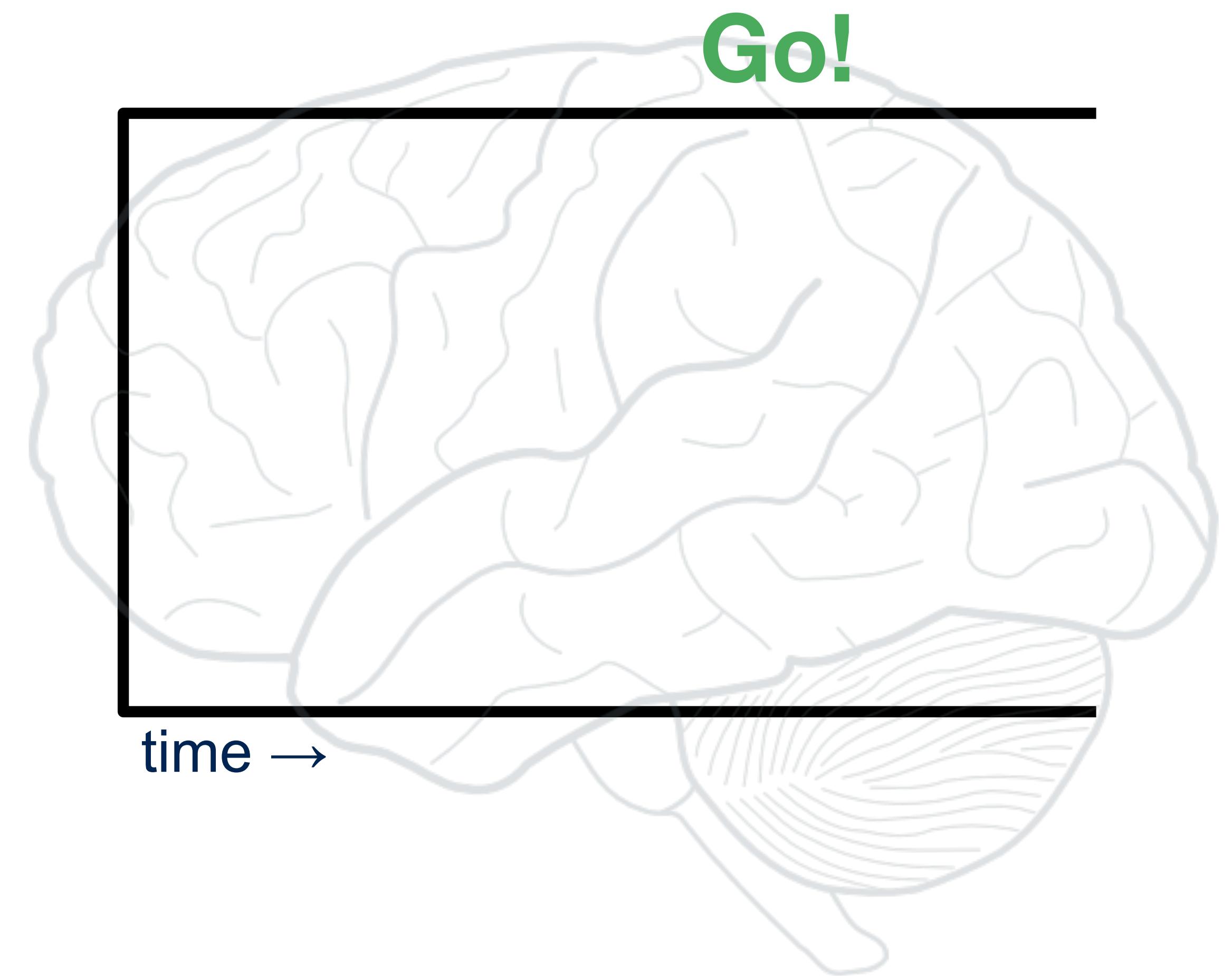
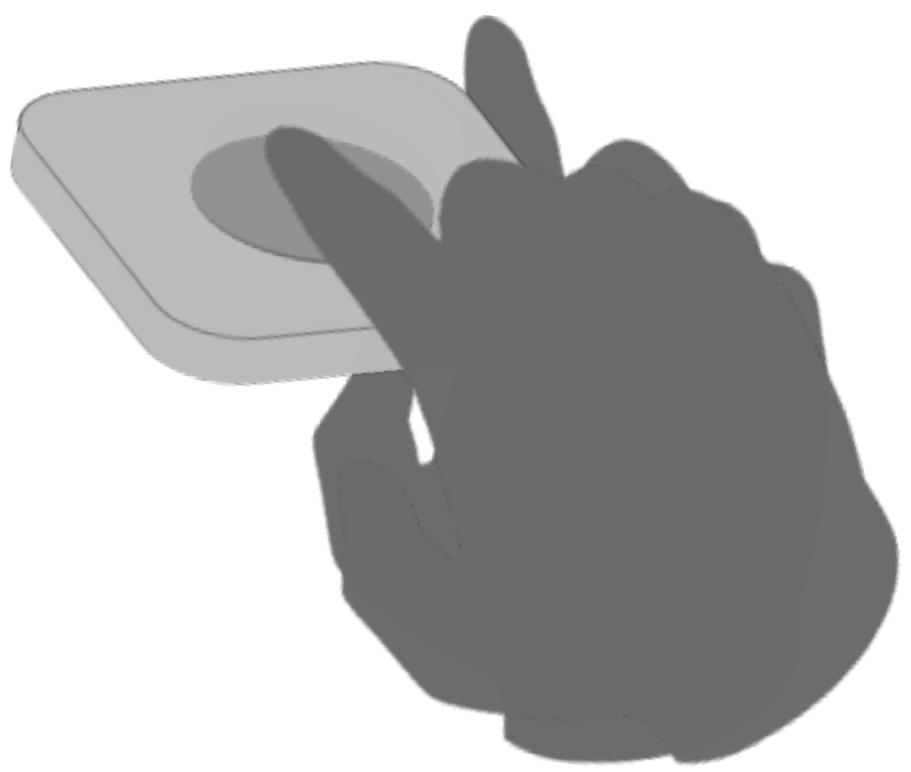
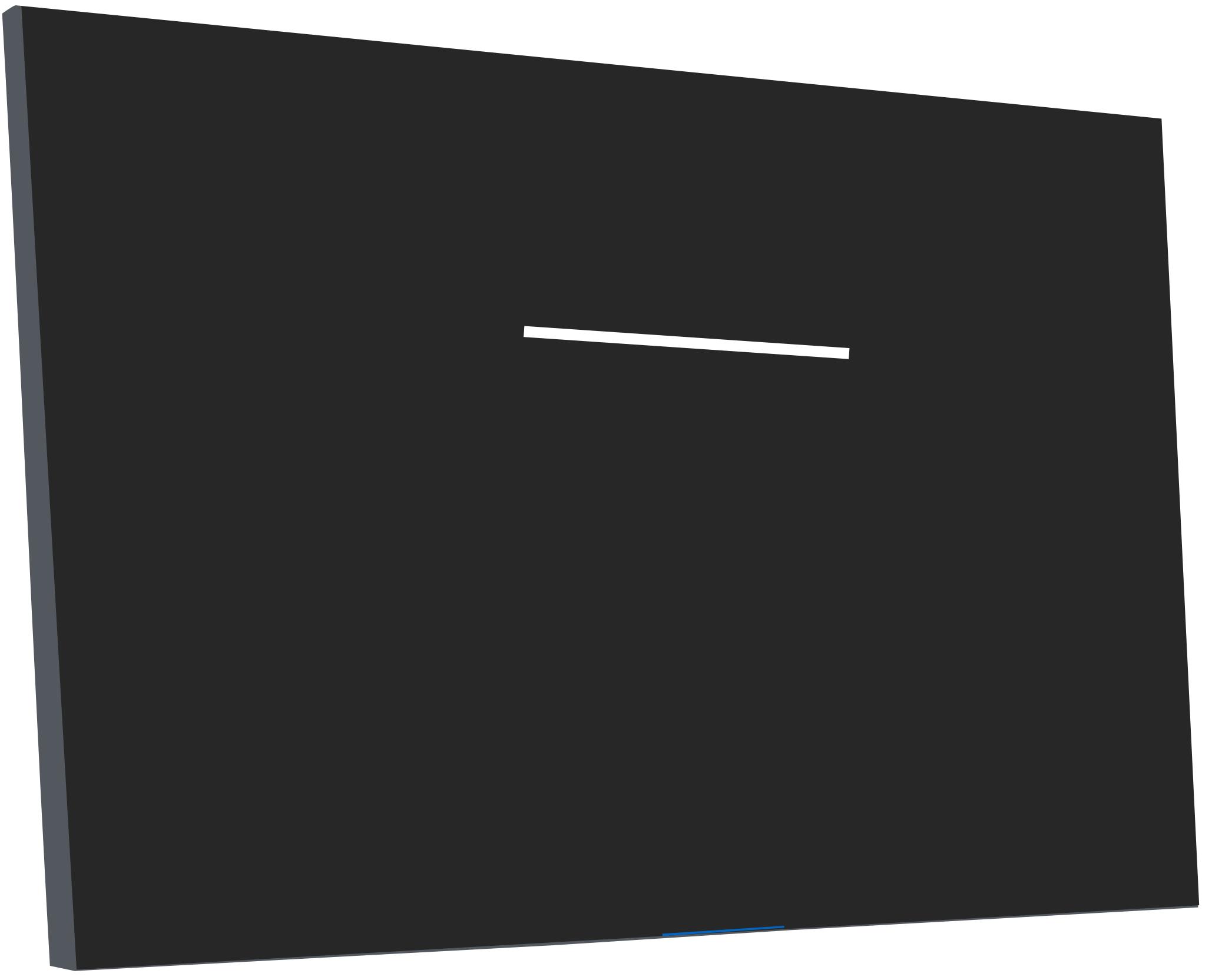


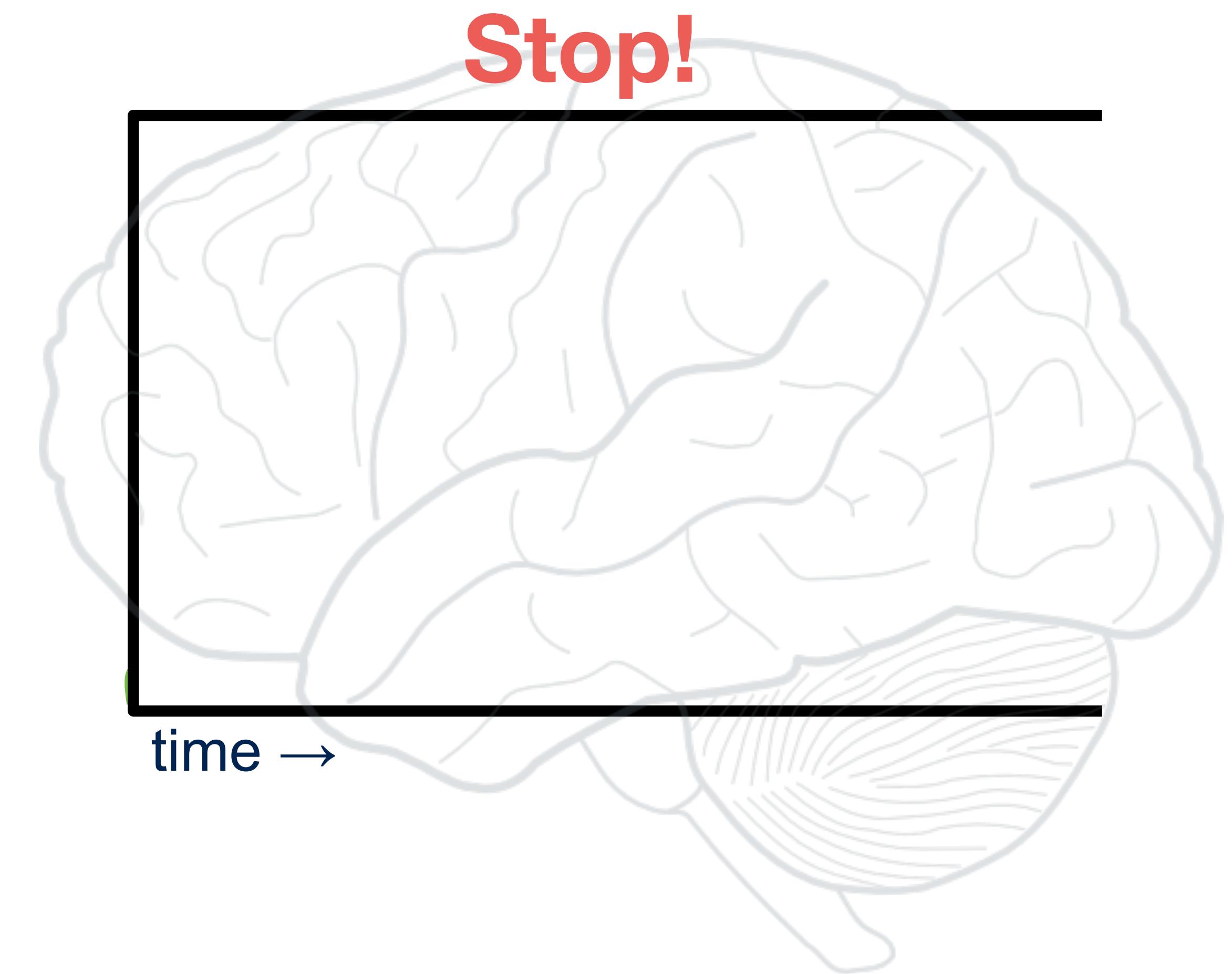
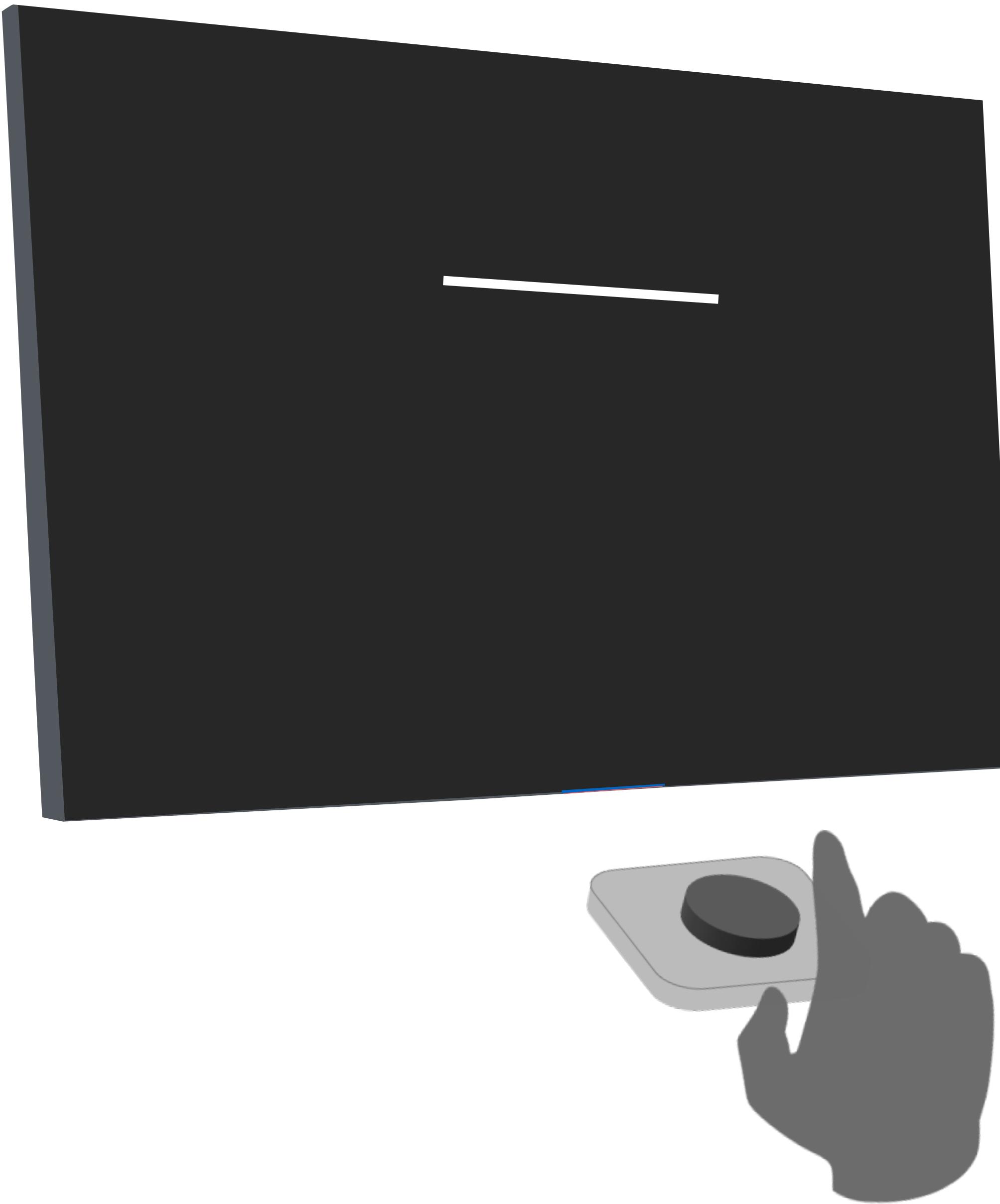
Pulley Competition Model

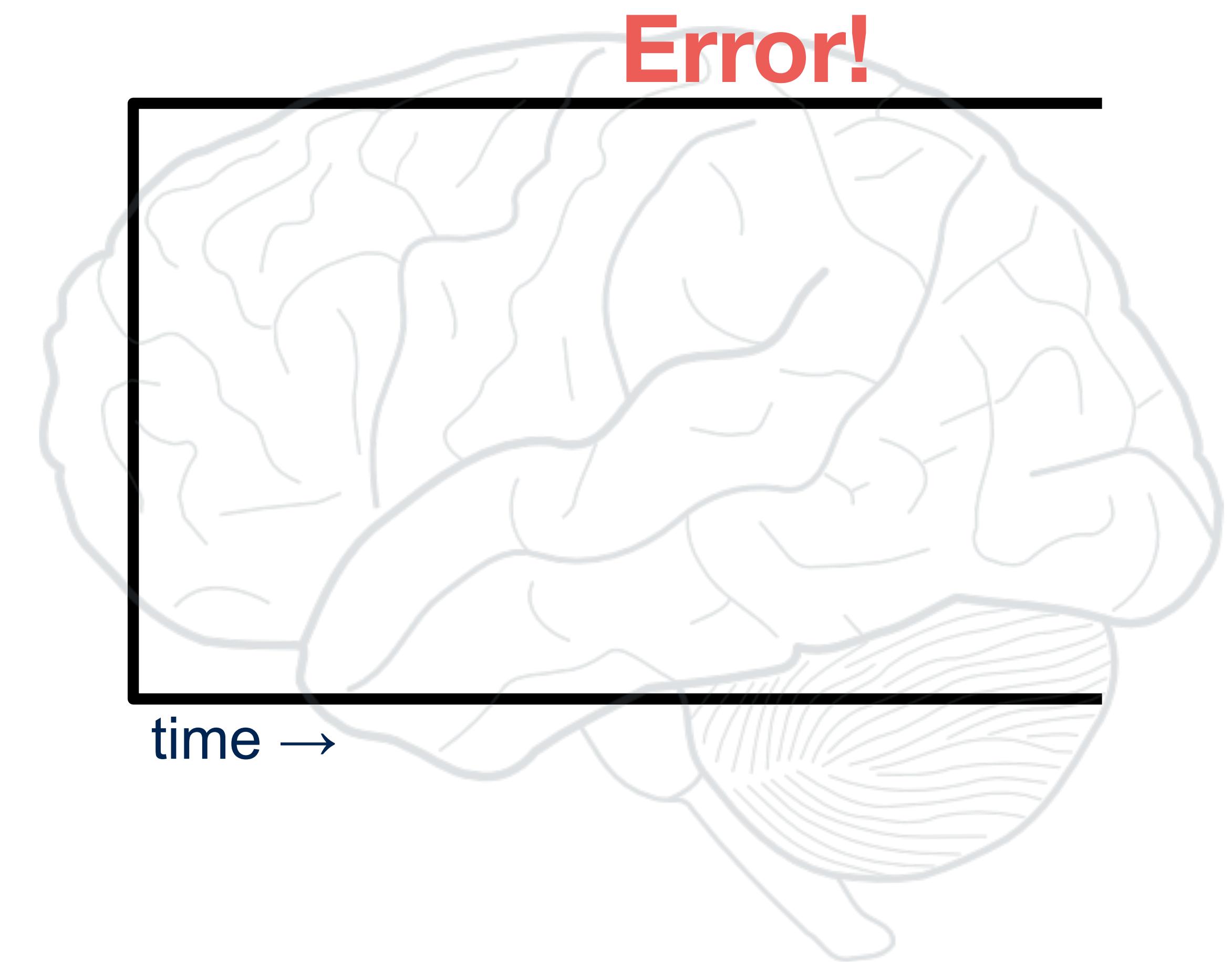
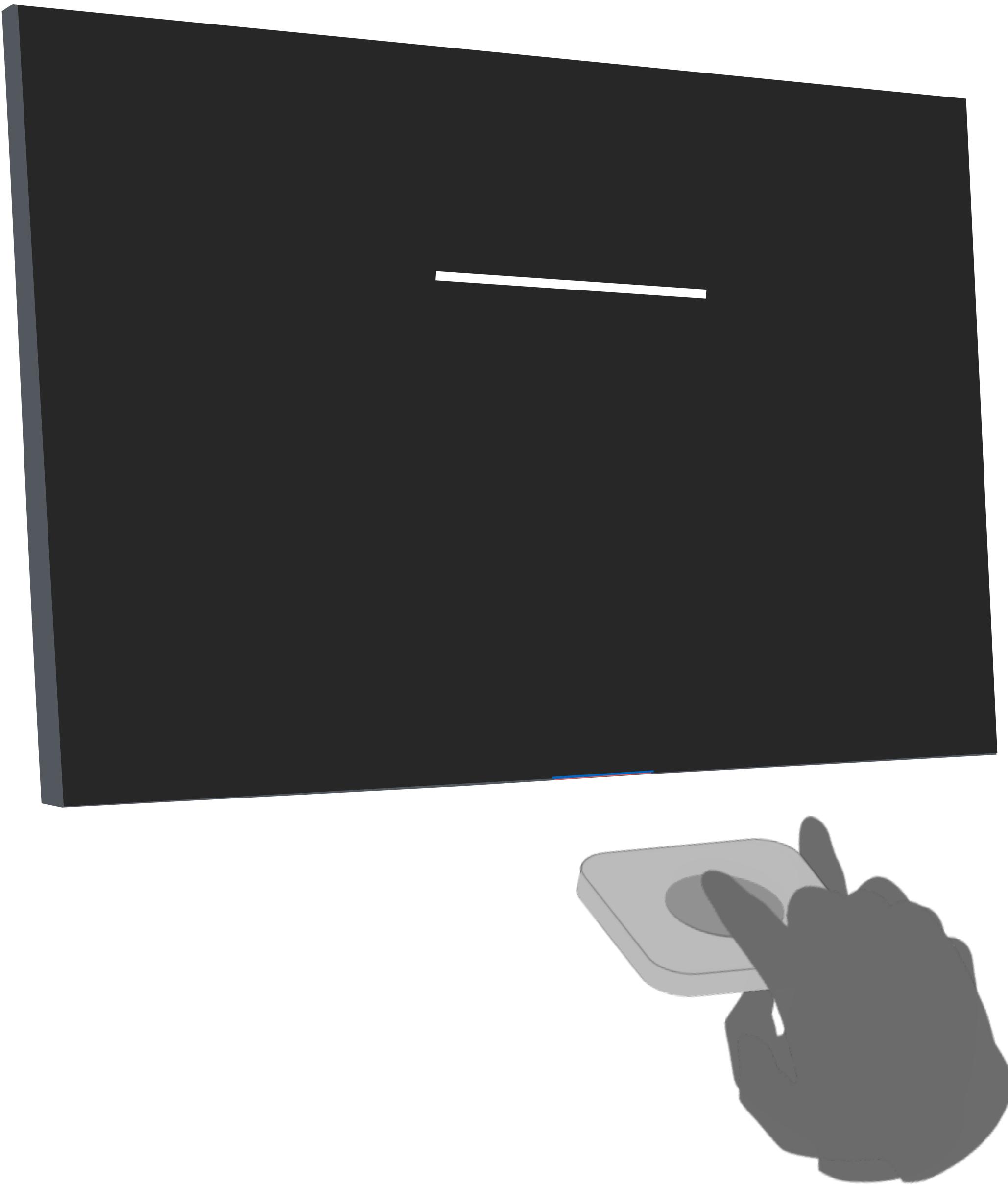


Competition to drift rates

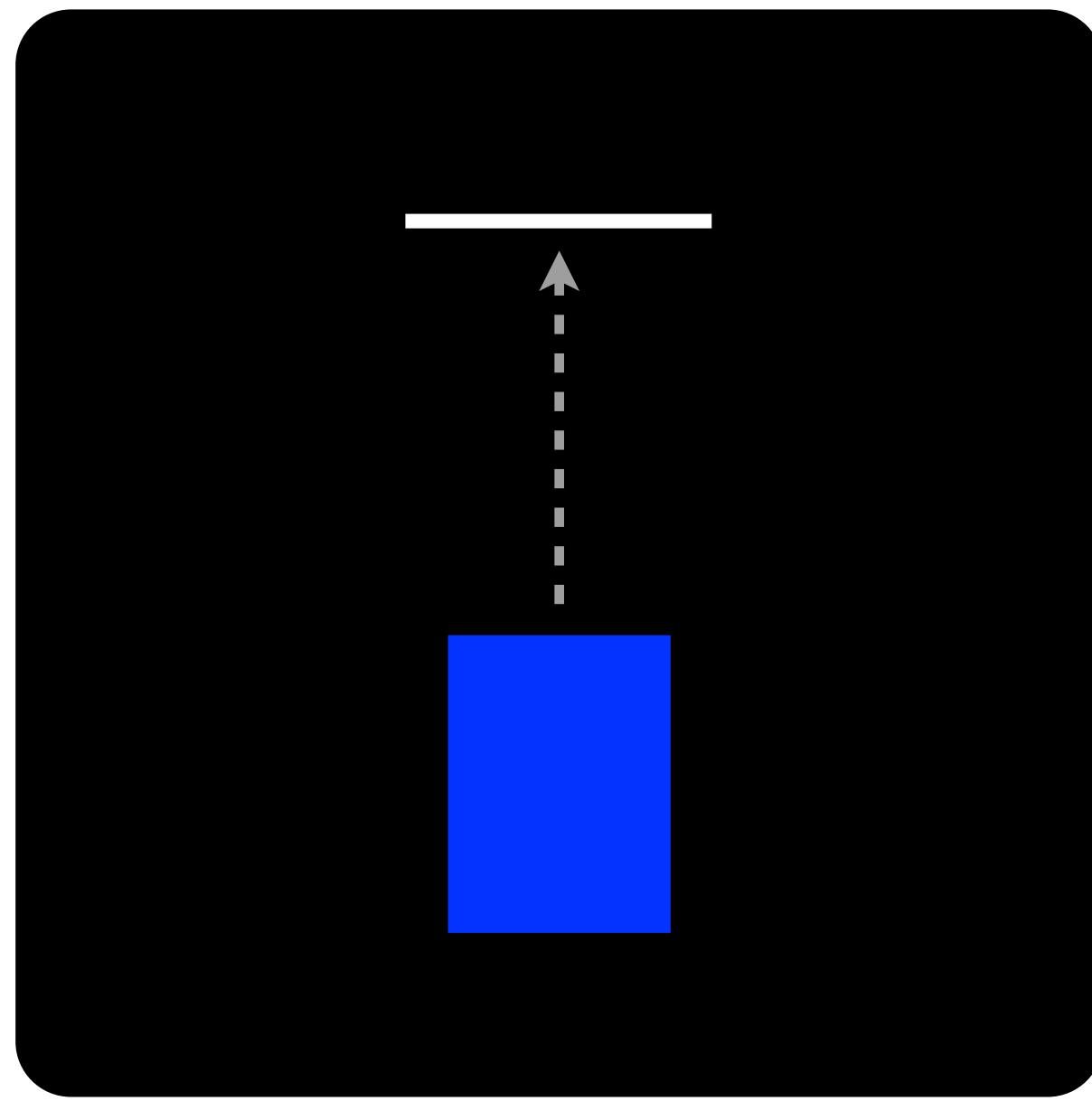




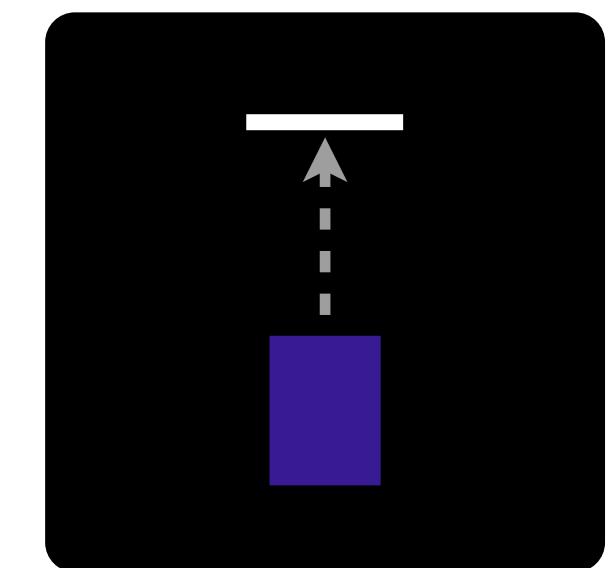




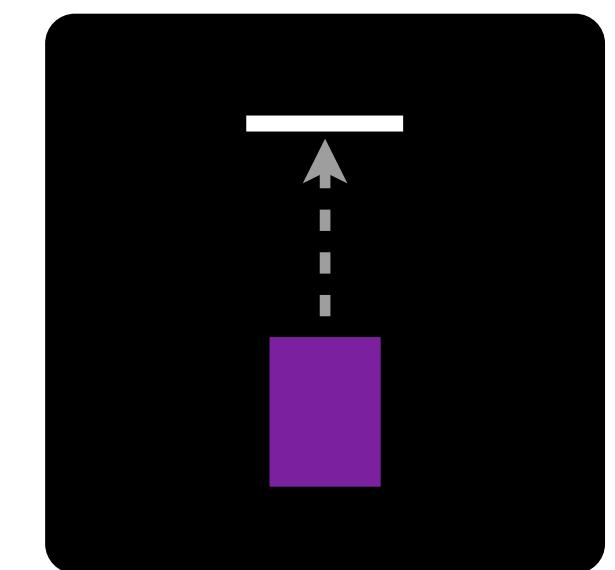
Proactive control



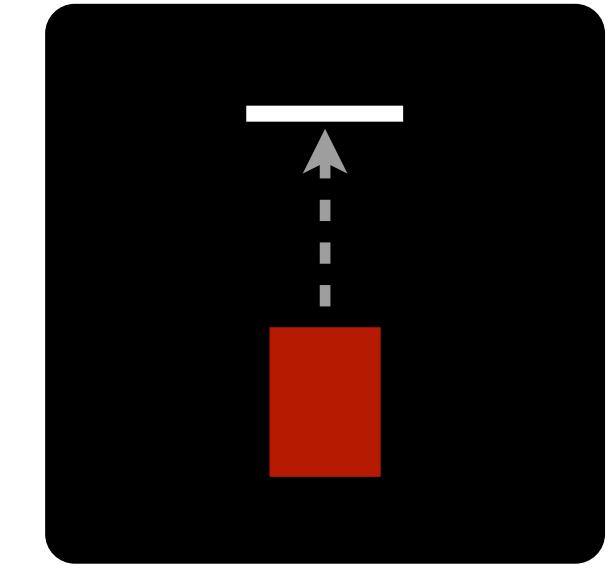
100% Go



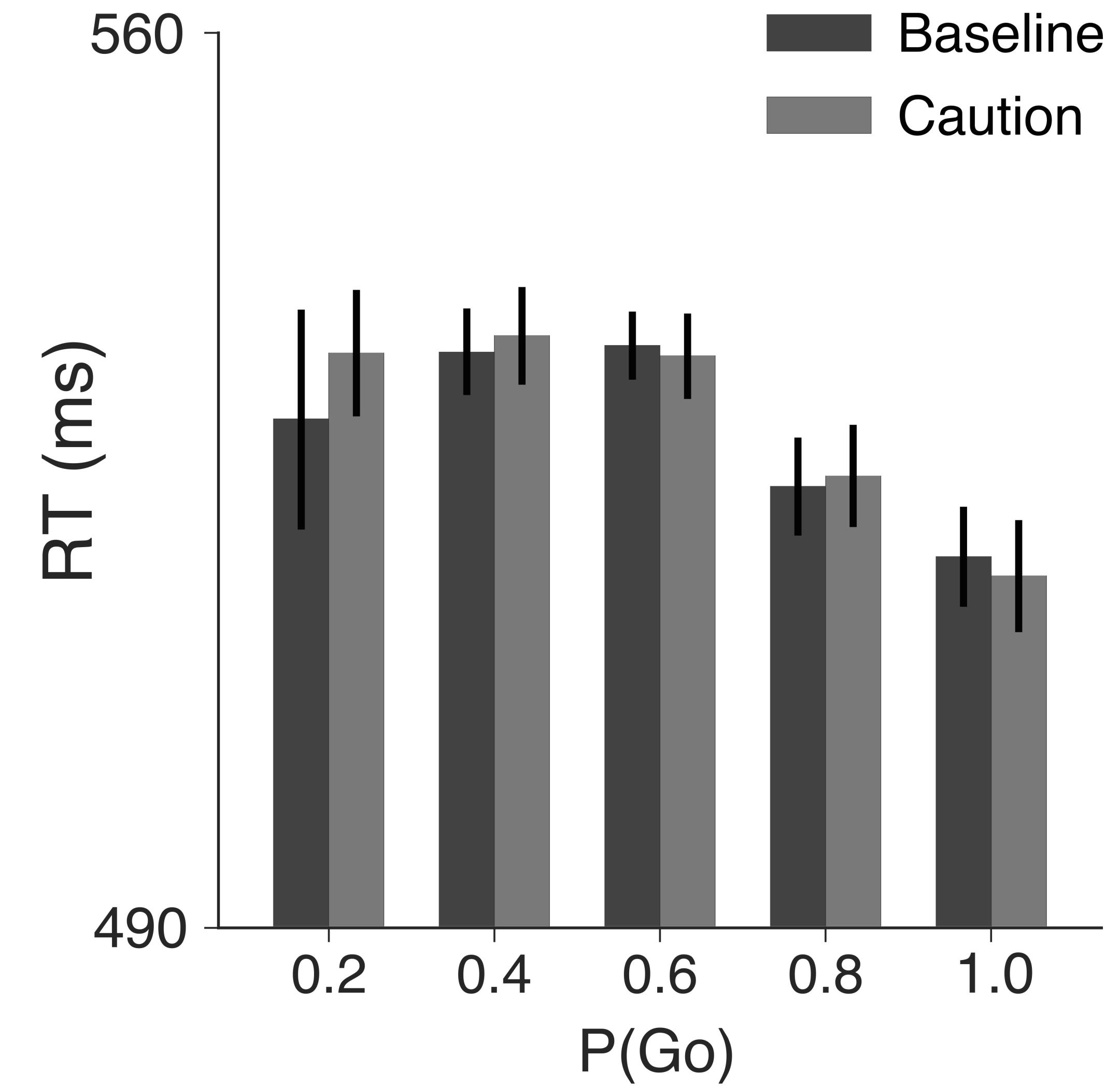
75% Go



25% Go

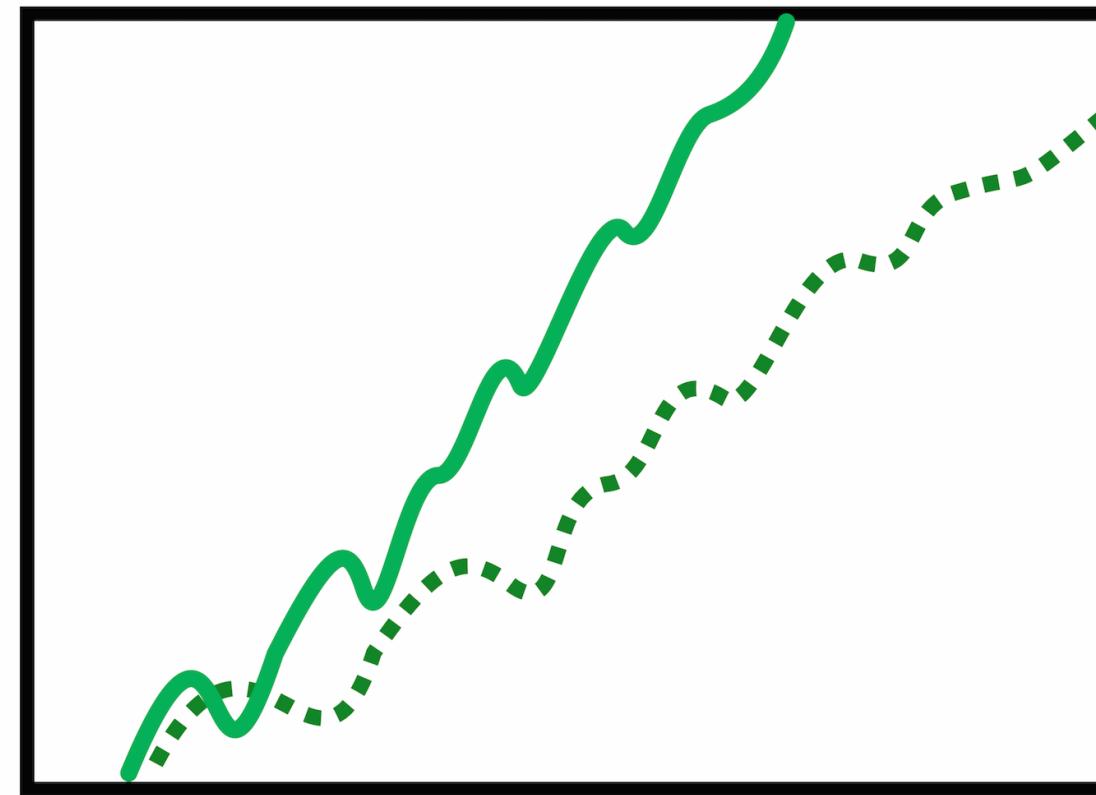


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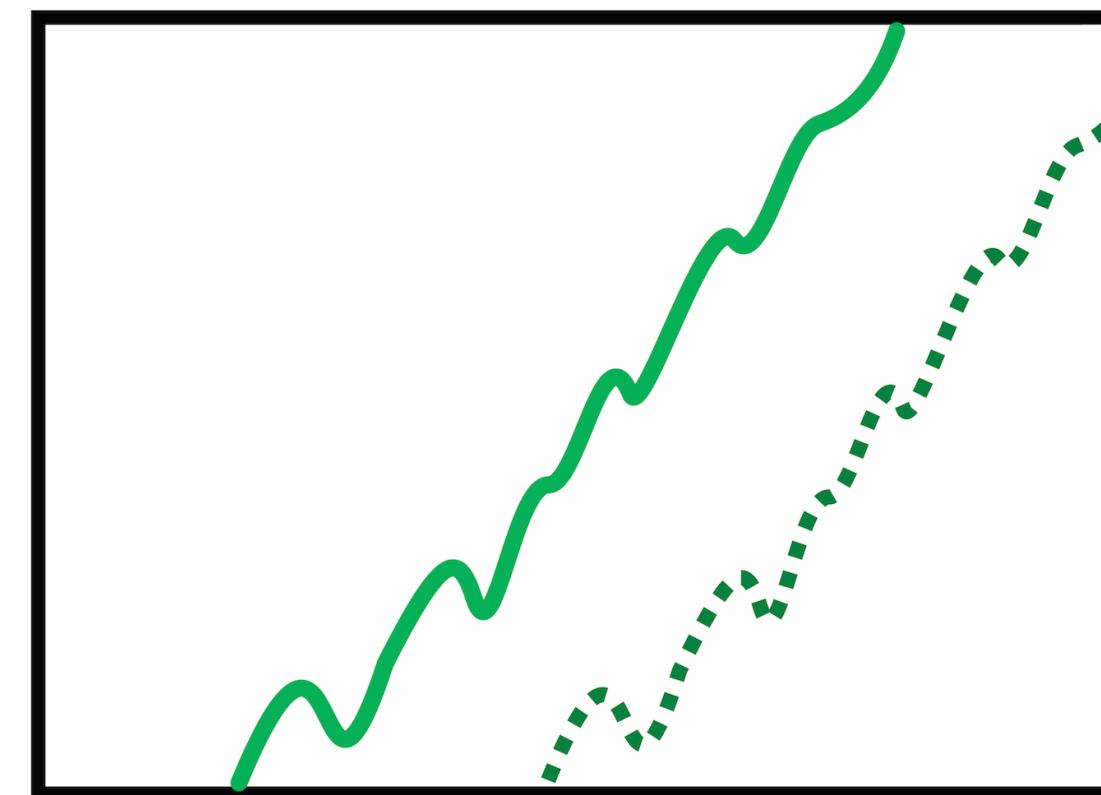


Models

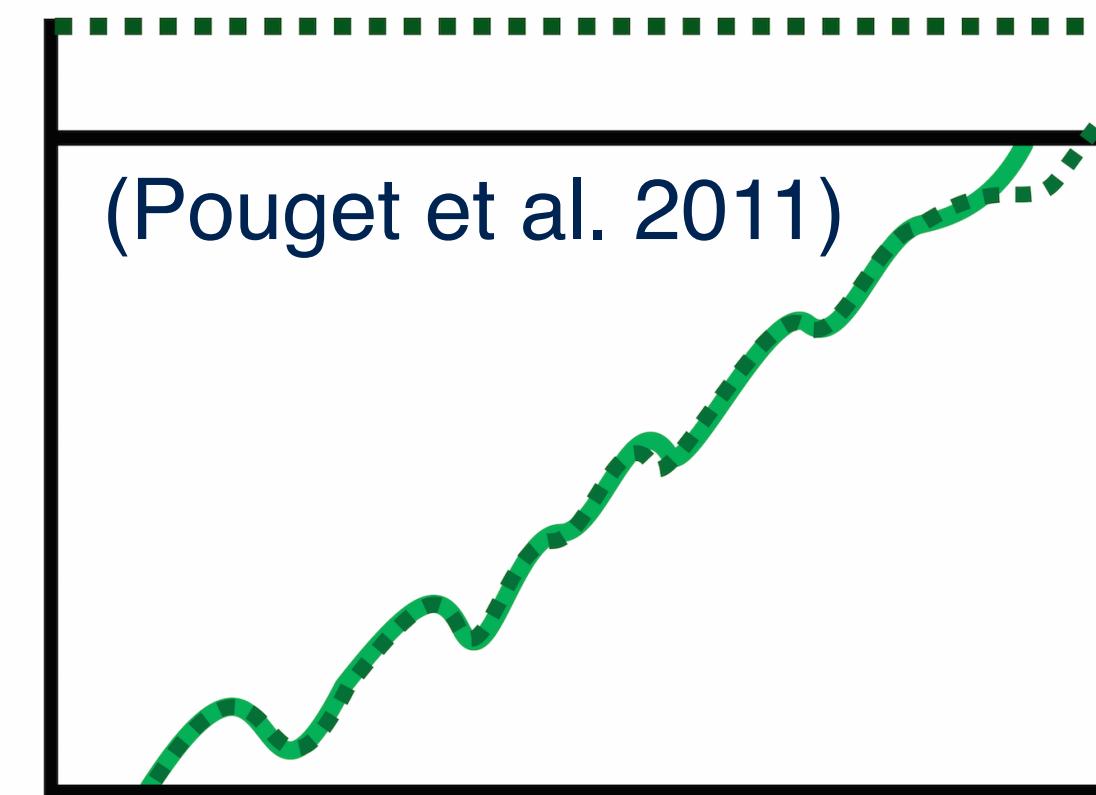
Drift-Rate



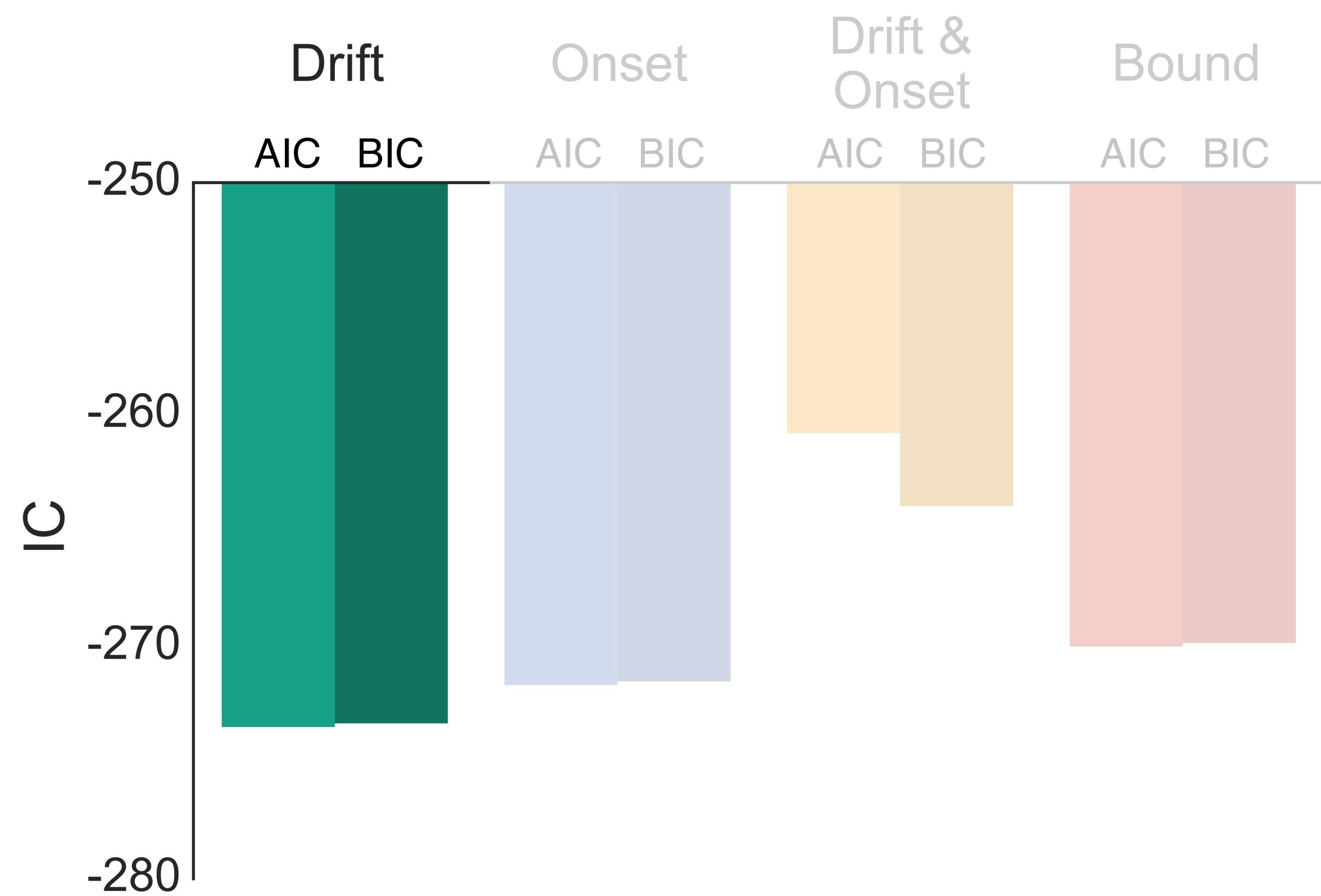
Onset Delay



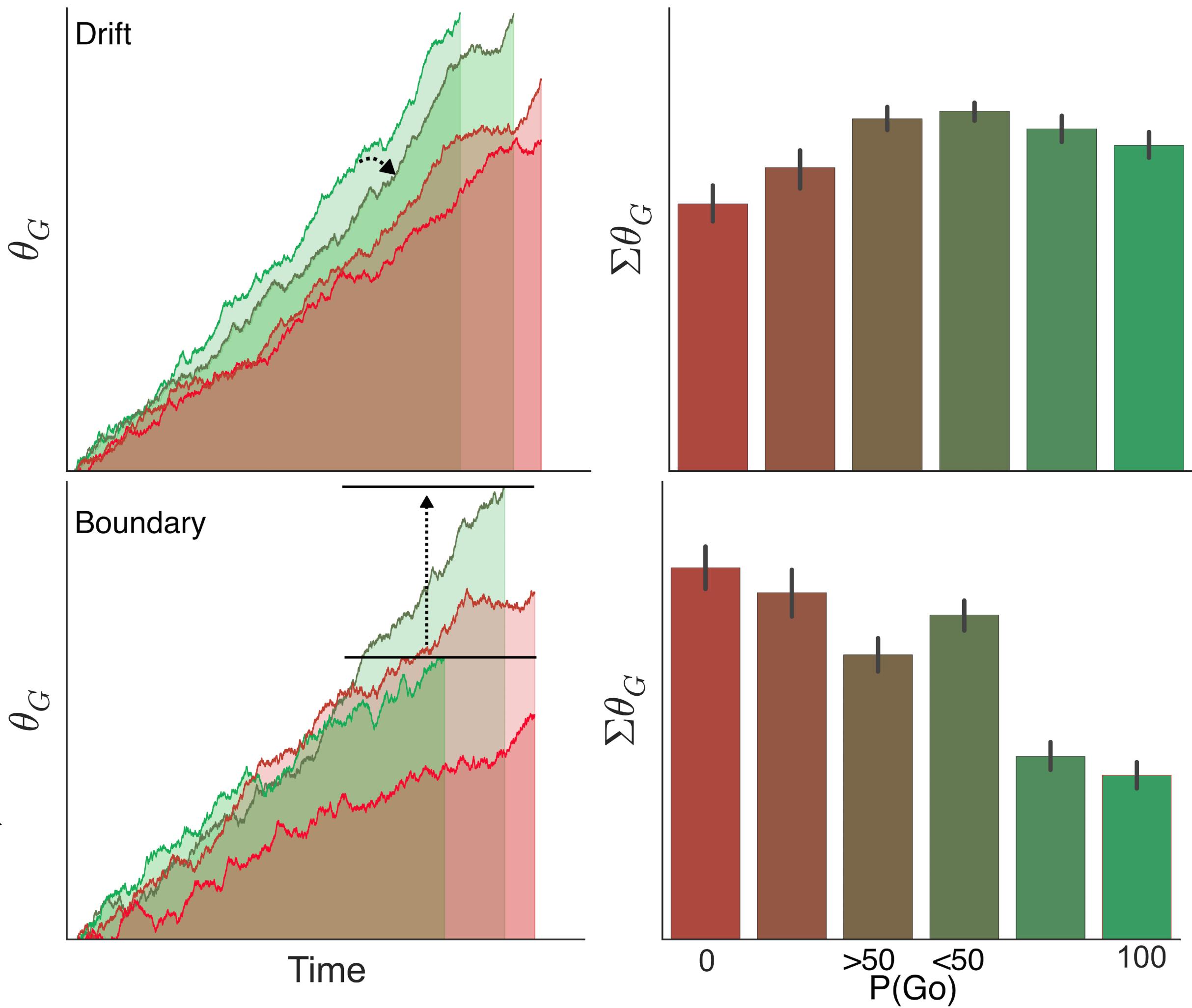
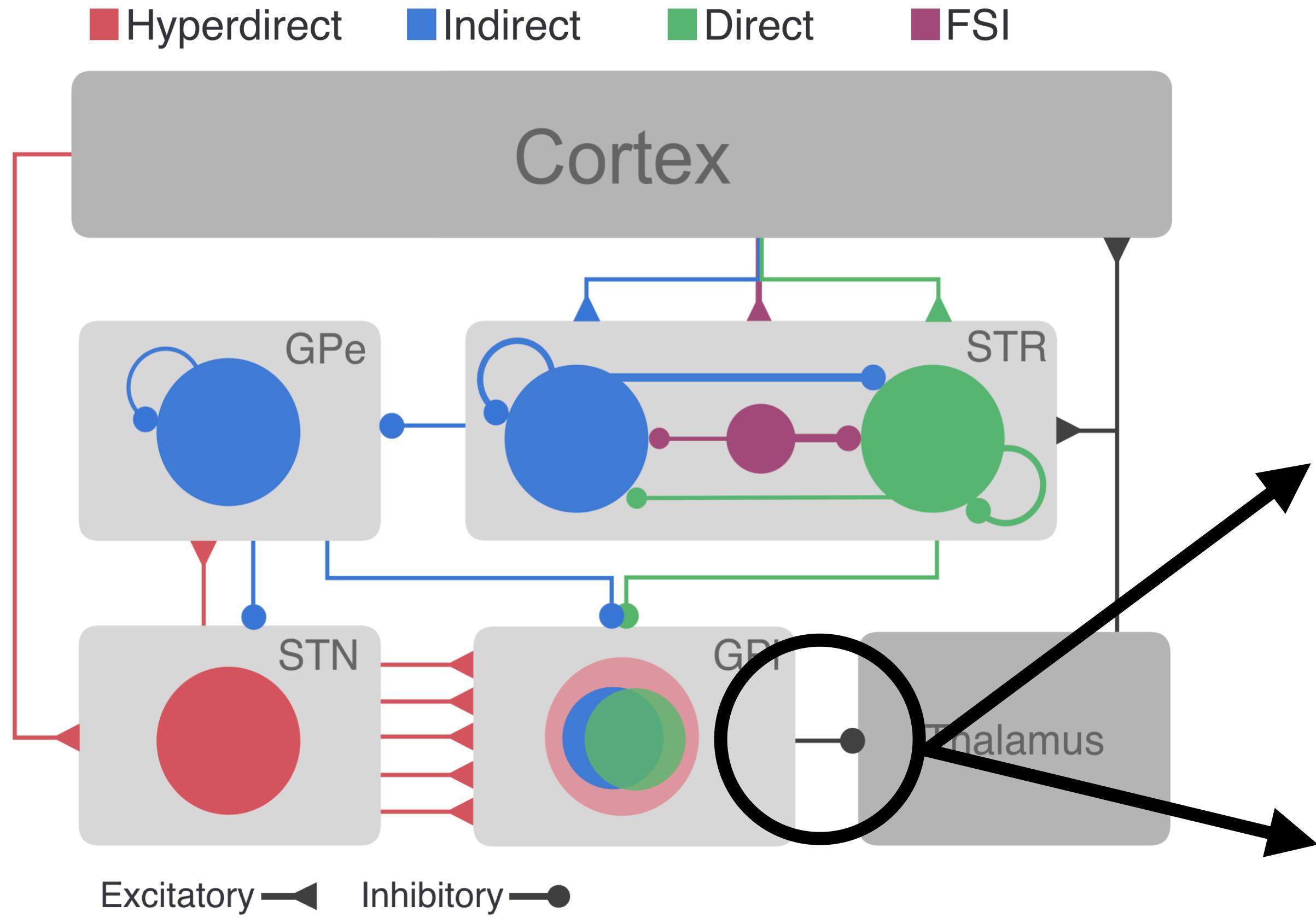
Decision Boundary



Model

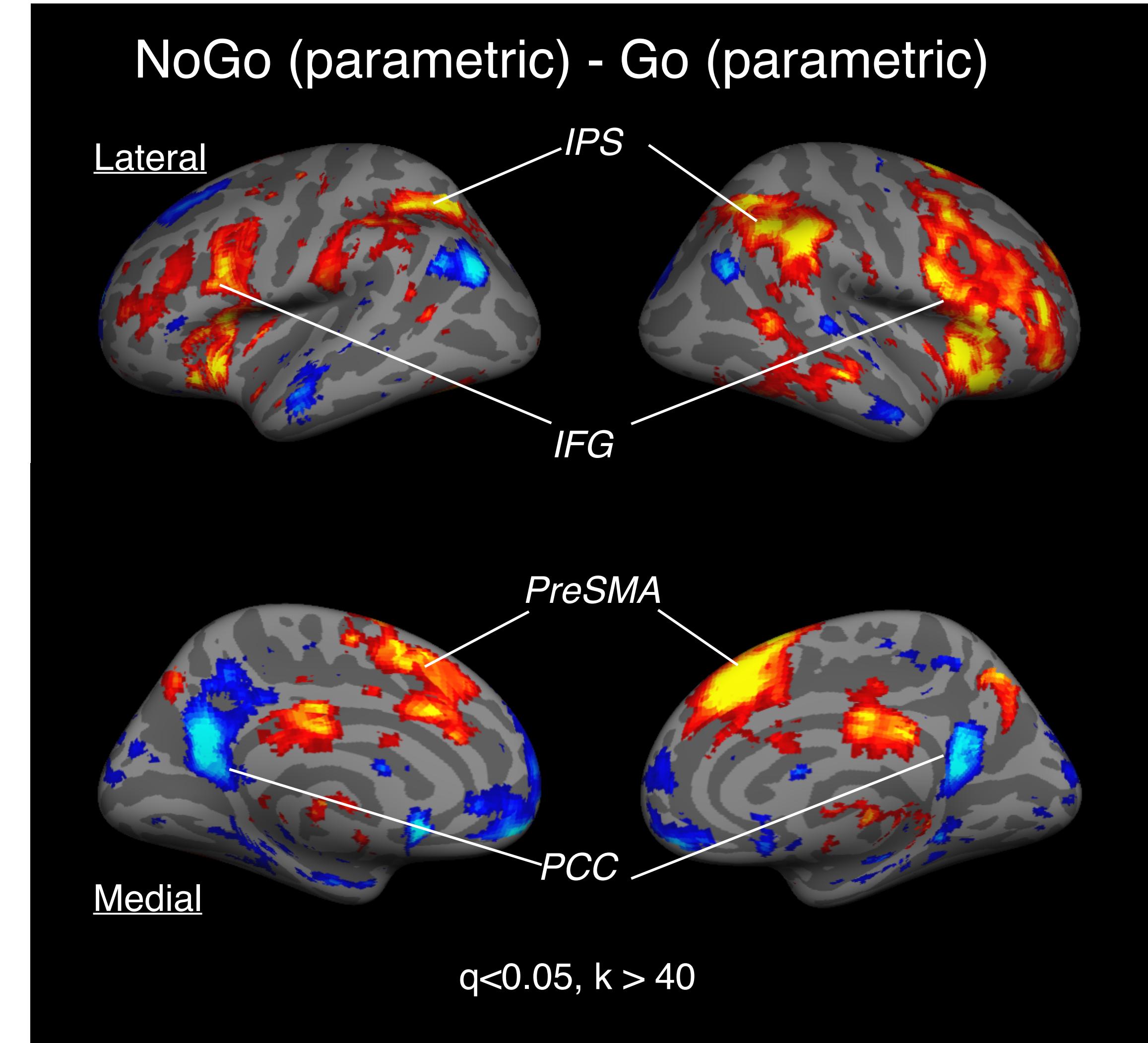
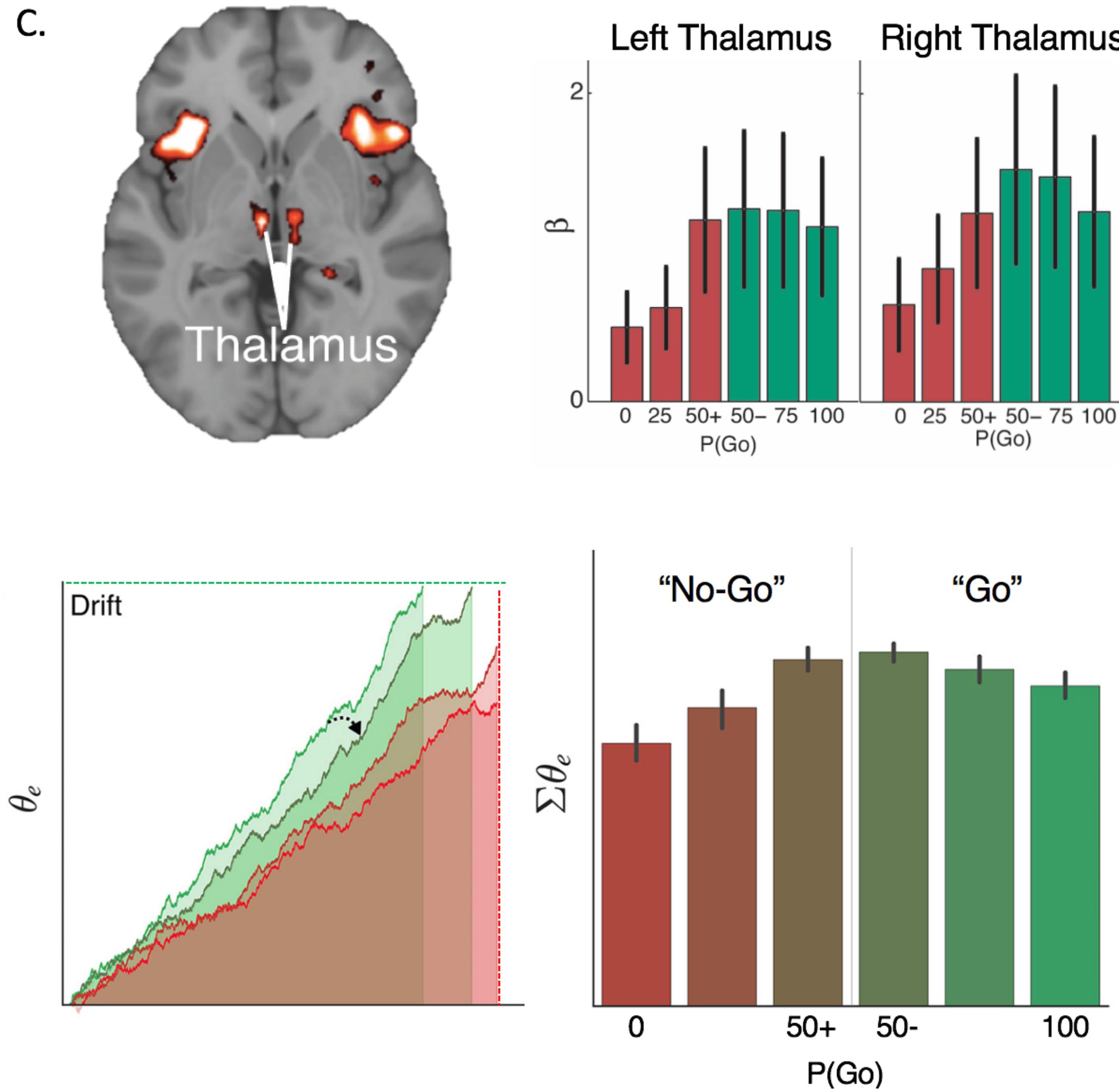


Predicting CBGT output



Predicting CBGT output

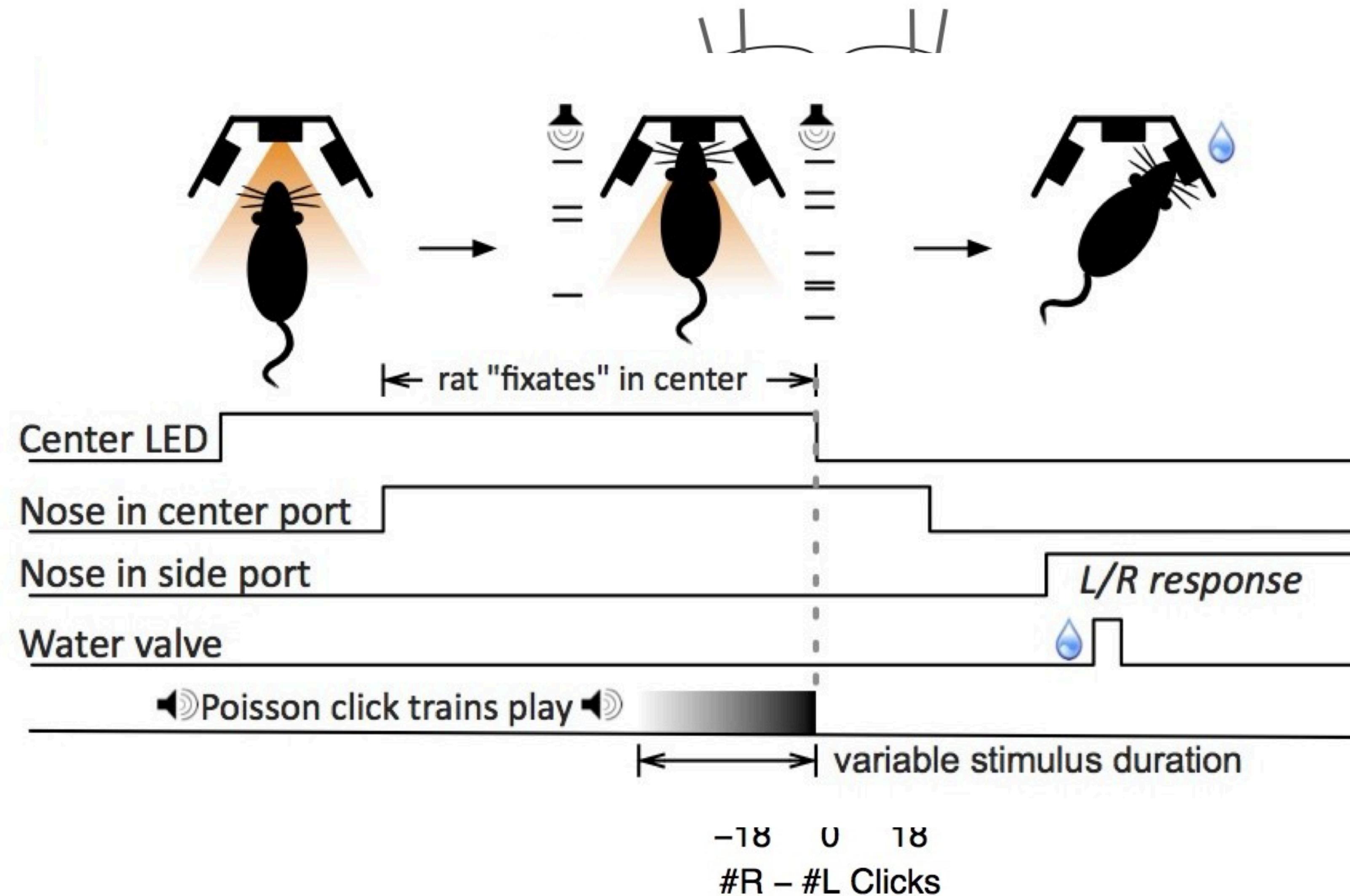
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Causal evidence?

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- Bilateral decision
- Change reducti accum



Take home message

- The CBGT loops have an ideal architecture for accumulating evidence.
- CBGT network activity tracks with certainty and the drift rate.
- Disruption of the CBGT network disrupts evidence accumulation.

Lab 5: CBGT networks

URL: <https://coaxlab.github.io/BIX-book/notebooks/lab5-cbgt.html>

The screenshot shows a web browser window with a dark theme. The address bar displays the URL: <https://coaxlab.github.io/BIX-book/notebooks/lab5-cbgt.html>. The main content area features a large, complex blue neural network diagram on the left. To its right, the title "Lab 5 - CBGT pathways" is displayed in a large, bold, white font. Below the title, a descriptive text block states: "This lab has 3 main components designed to go over how corticobasal ganglia-thalamic (CBGT) circuits make decisions. We will use a model of this system to run simulations and investigate the effects of tuning different aspects of the circuit." Further down, under the heading "Sections:", there is a numbered list of three tasks: 1. Run the baseline network, visualize simulated brain region activity patterns, and understand interactions. 2. Investigate the effects of direct pathway strength. 3. Investigate the effects of indirect pathway strength. Below this section, another heading "Section - Setup" is present, followed by a text block instructing the user to run code cells to set up the environment for CBGT decision simulations. At the bottom of the page, a section titled "Load in CBGT modeling code library" contains a note about setting the current working directory in Colab to load the CBGT library.

Biologically Intelligent eXploration (BIX)

Getting started

Introduction to python

Labs

Lab 1- Information theory

Lab 2 - Random exploration

Lab 3 - Chemotaxis

Lab 4 - Evidence Accumulation

Lab 5 - CBGT pathways

Lab 6 - Predator-prey dynamics

Lab 7 - Foraging

Lab 5 - CBGT pathways

This lab has 3 main components designed to go over how corticobasal ganglia-thalamic (CBGT) circuits make decisions. We will use a model of this system to run simulations and investigate the effects of tuning different aspects of the circuit.

Sections:

1. Run the baseline network, visualize simulated brain region activity patterns, and understand interactions.
2. Investigate the effects of direct pathway strength.
3. Investigate the effects of indirect pathway strength.

Section - Setup

Run all of the following code cells, which set up the environment and define several helper functions that we will use to run CBGT decision simulations.

Load in CBGT modeling code library

The code cell below sets the current working directory for Colab, into which we will load the CBGT library. This is the usual `/content` directory.