

Does the subcortex make a decision?

Readings for today

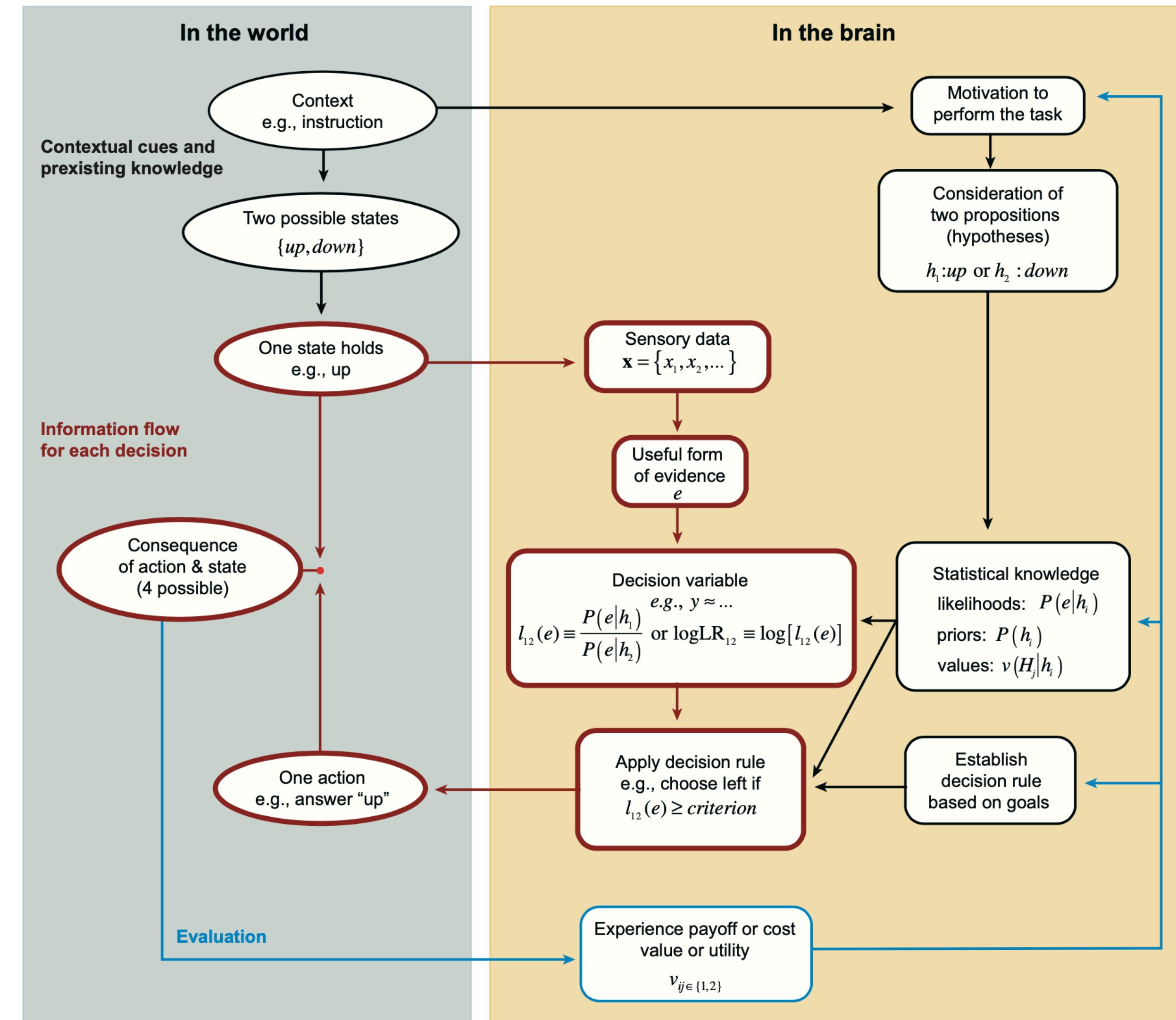
- Bogacz, R., & Larsen, T. (2011). Integration of reinforcement learning and optimal decision-making theories of the basal ganglia. *Neural computation*, 23(4), 817-851.
- Dunovan, K., Lynch, B., Molesworth, T., & Verstynen, T. (2015). Competing basal ganglia pathways determine the difference between stopping and deciding not to go. *Elife*, 4, e08723.

Topics

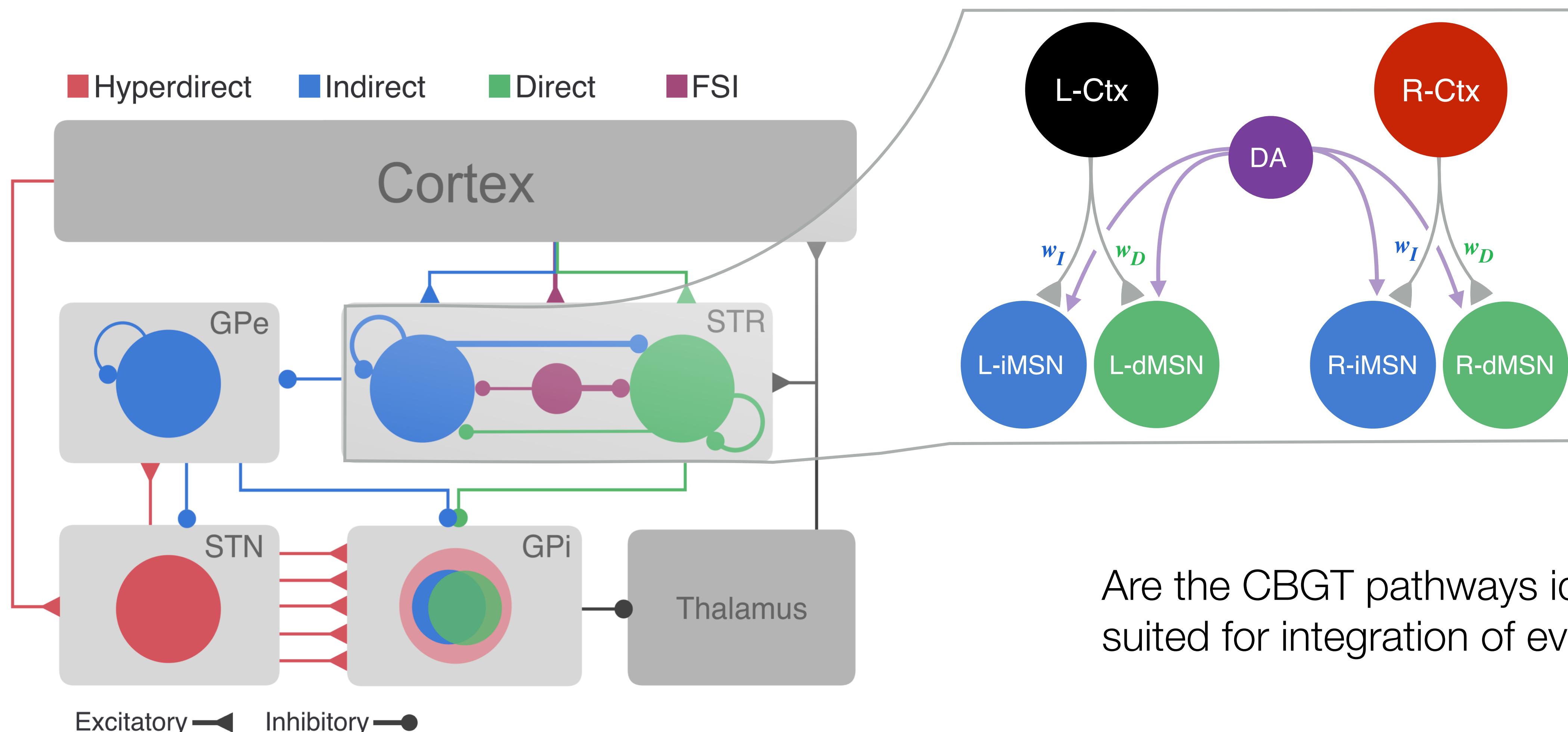
- Cortical-subcortical loops as accumulators
- Control of certainty

Cortical-subcortical loops as accumulators

Elements of making a decision



Cortico-basal ganglia thalamic pathways



Are the CBGT pathways ideally suited for integration of evidence?

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

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

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

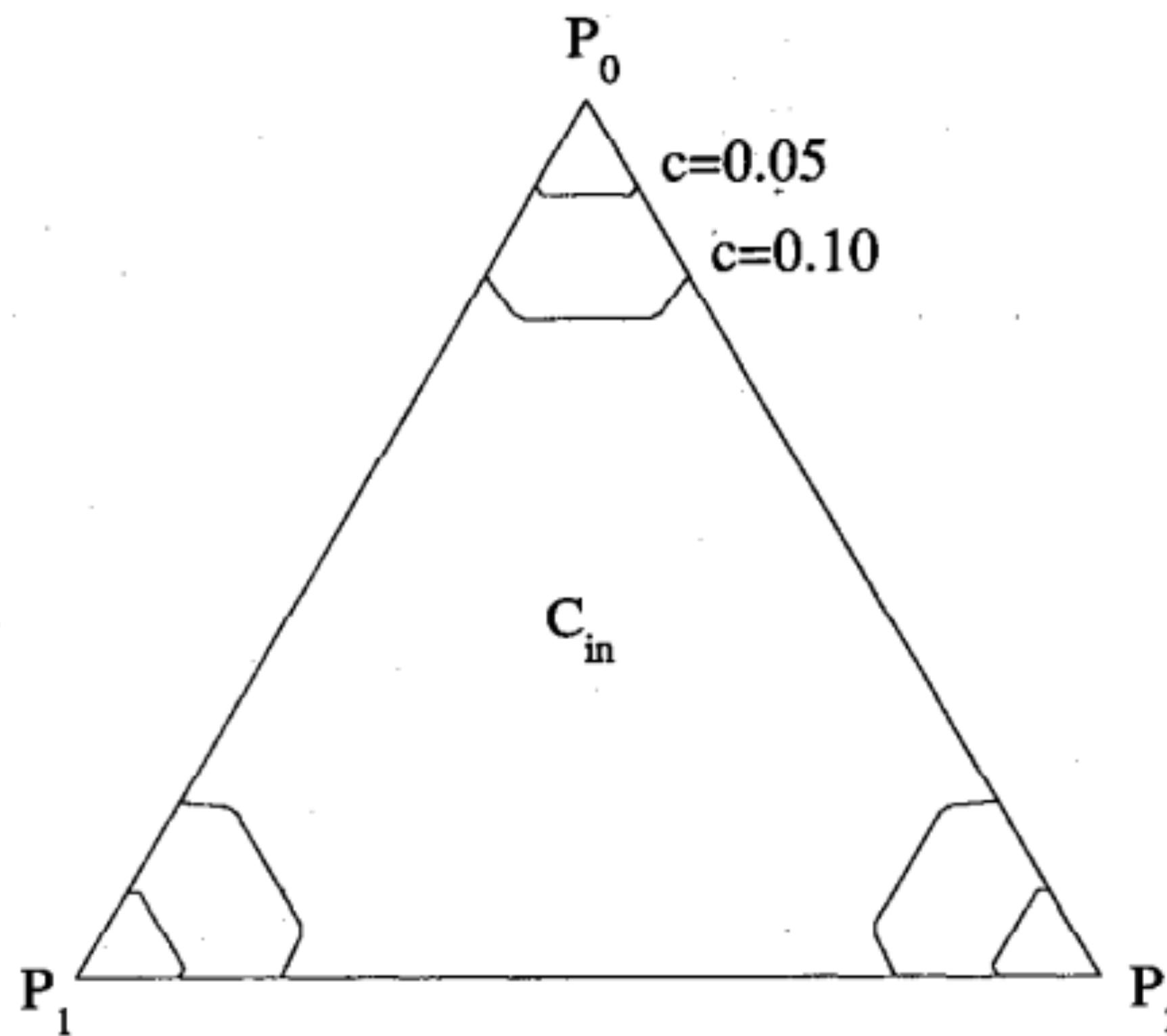
3. Determine stopping rule

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

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

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

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

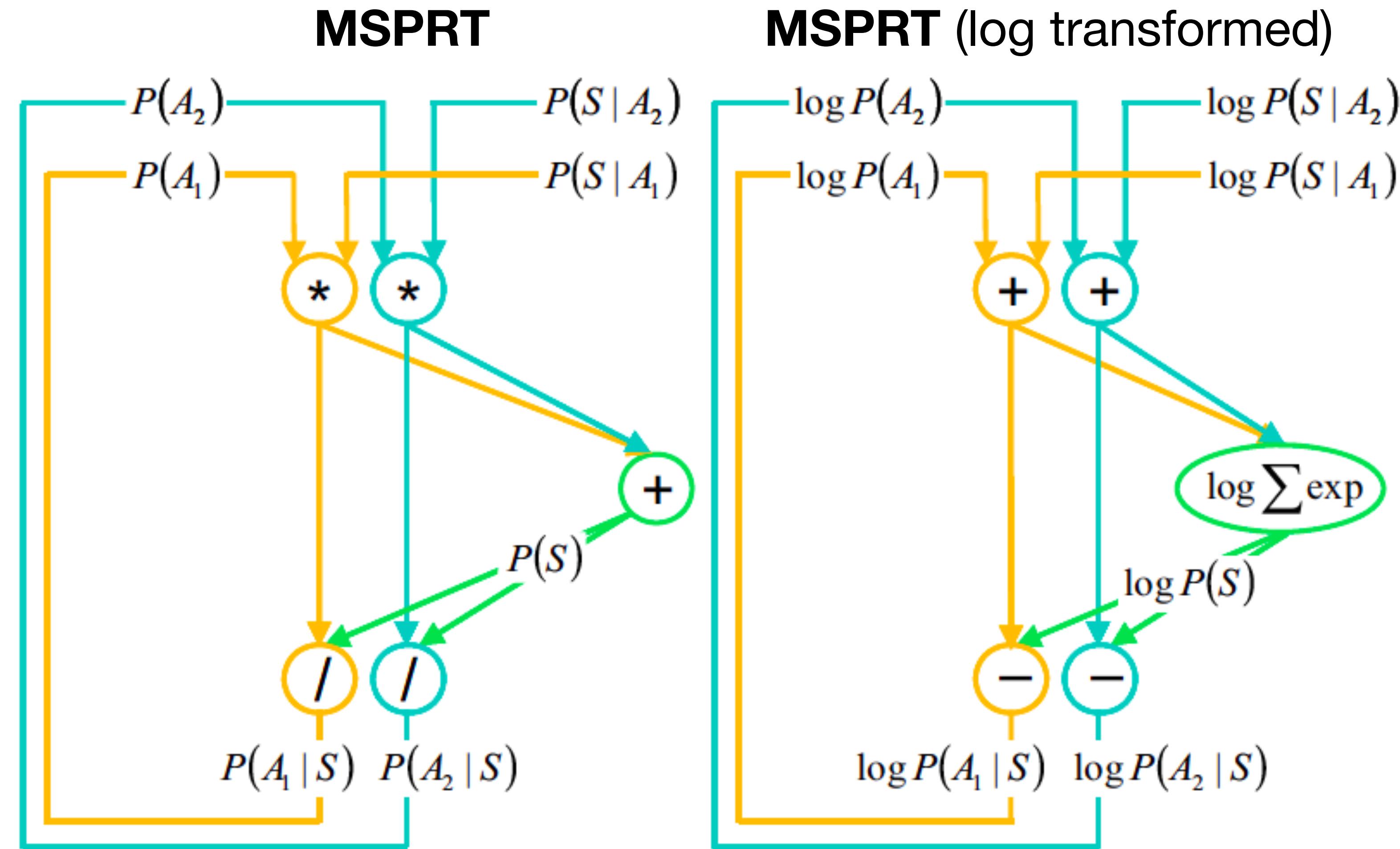
Applying a log transform allows for reframing this to being framed in neural firing rates

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

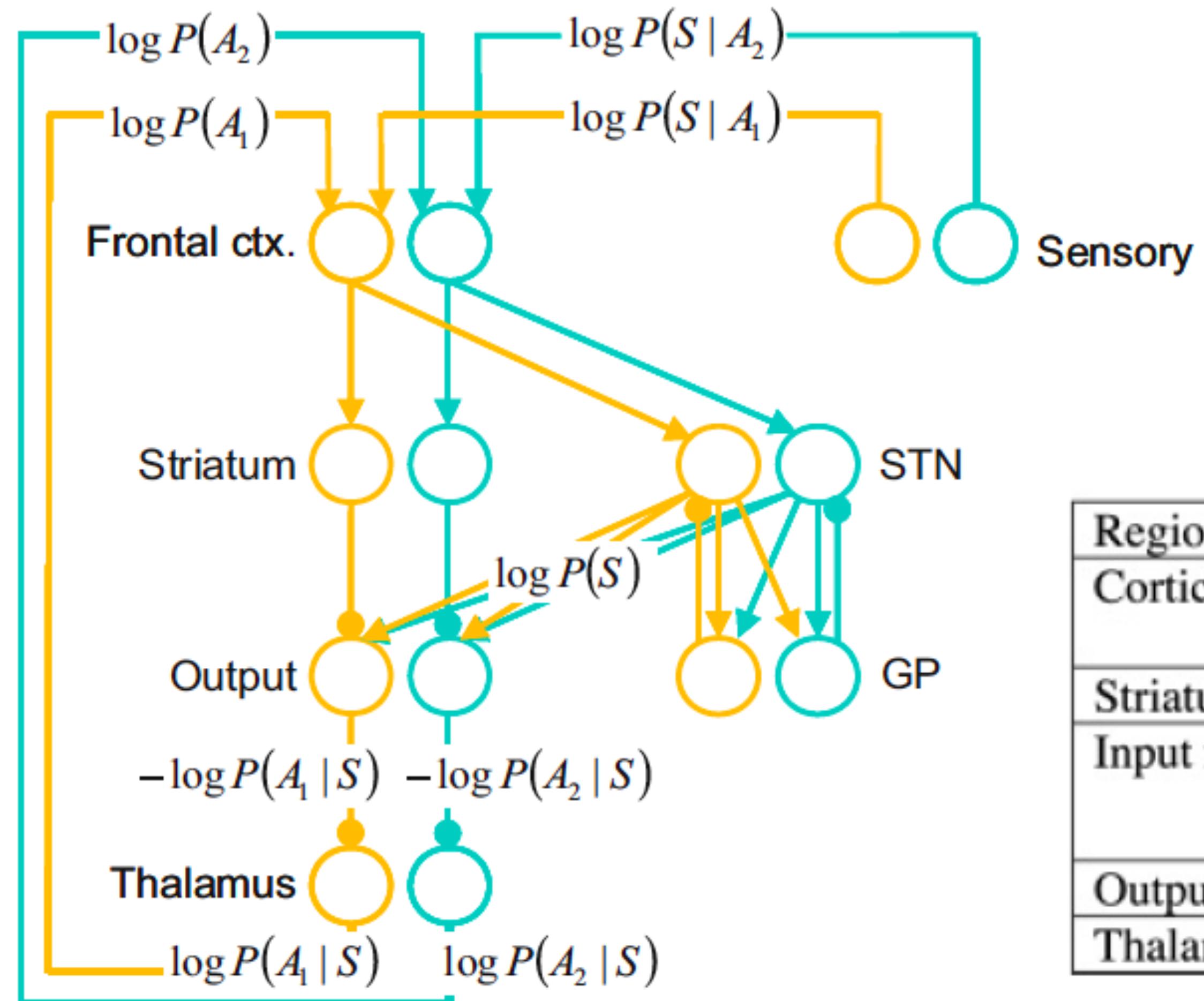
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$g = (I_+ - I_-)/\sigma^2$ Sensory evidence Scalar (same for all hypotheses)

The multihypothesis SPRT (MSPRT) algorithm



A neural instantiation of the MSPRT

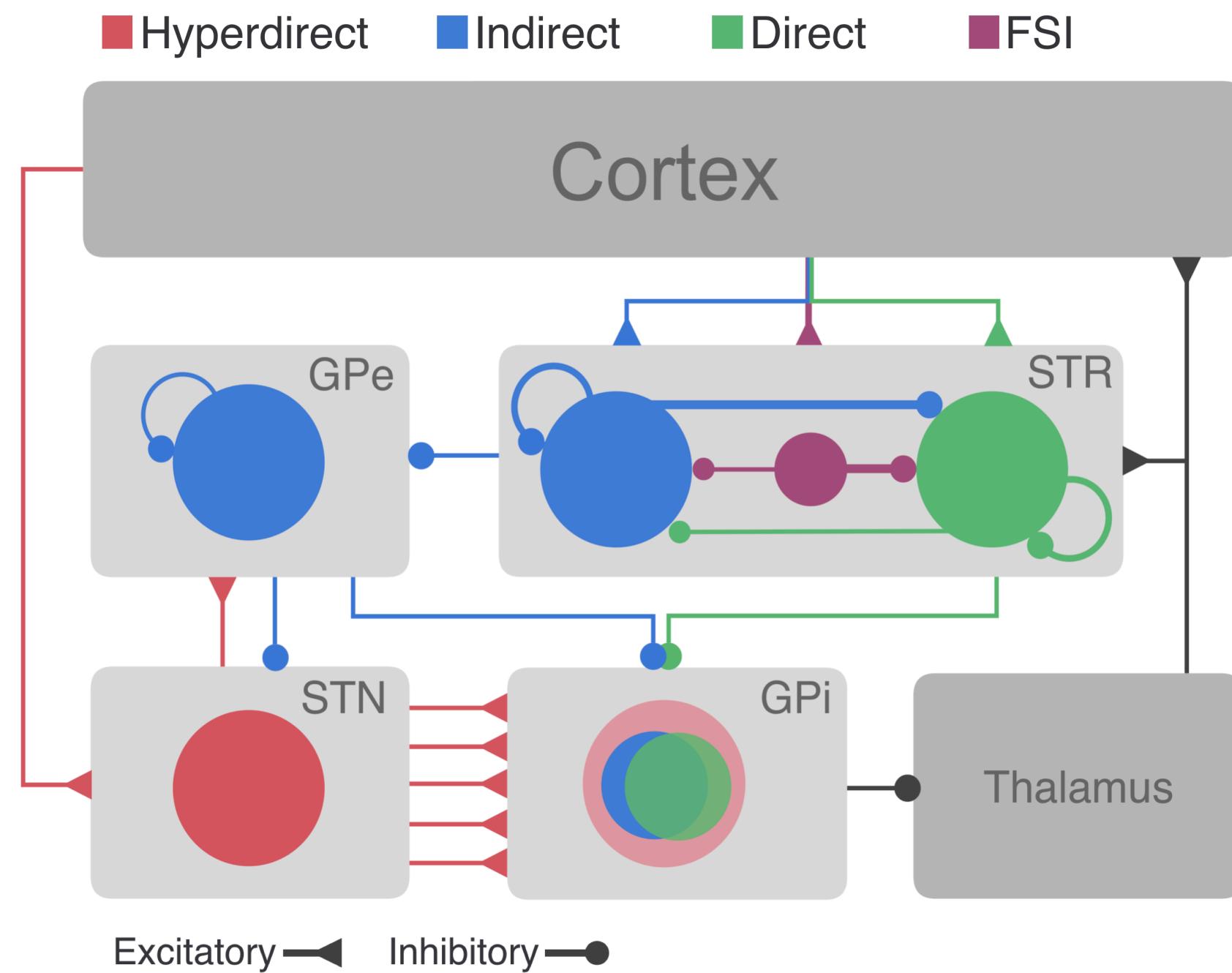


Based off of the topology of excitatory & inhibitory connections, you can map CBGT dynamics to the MSPRT algorithm.

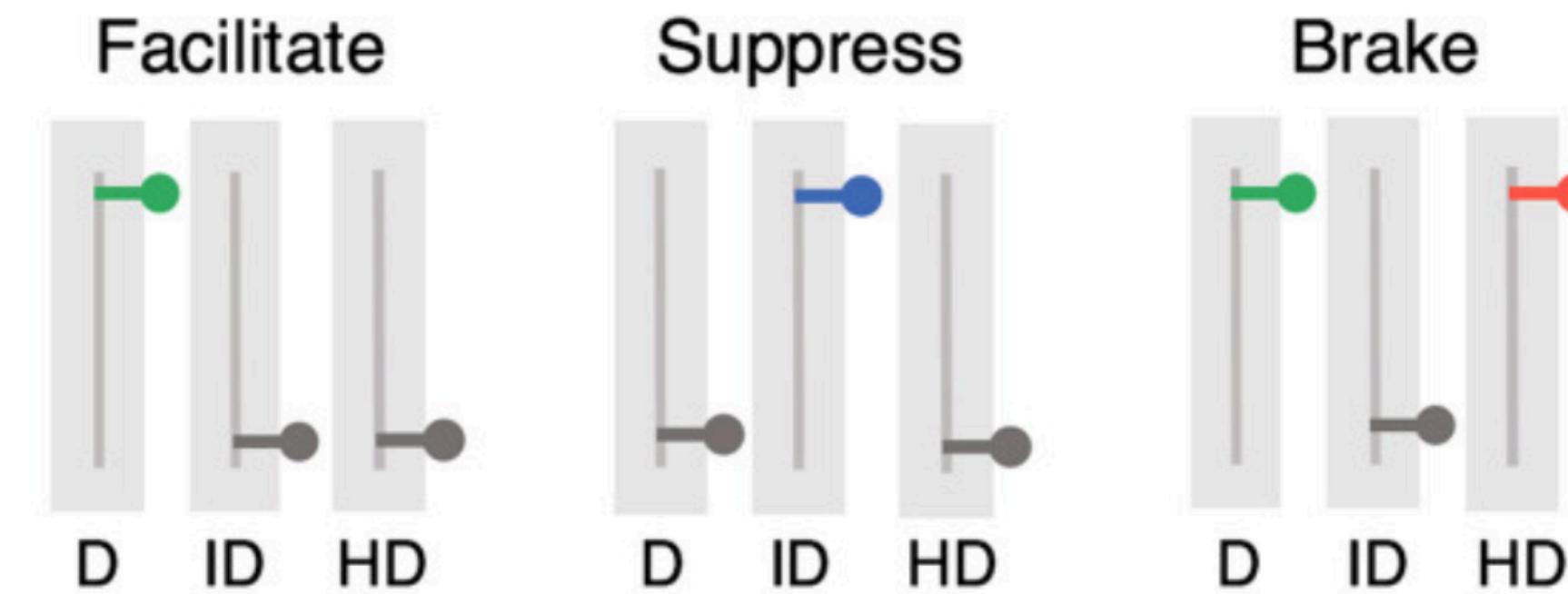
Region	Equation
Cortical integrators	$INT_i(0) = \log 1/N + c$ $INT_i(t) = TH_i(t-1) + g x_i(t), \text{ for } t > 0$
Striatum	$STR_i(t) = INT_i(t)$
Input from STN and GP	$SG(t) = \log \sum_{i=1}^N \exp INT_i(t)$
Output nuclei	$OUT_i(t) = -STR_i(t) + SG(t)$
Thalamus	$TH_i(t) = c - OUT_i(t)$

Control of certainty

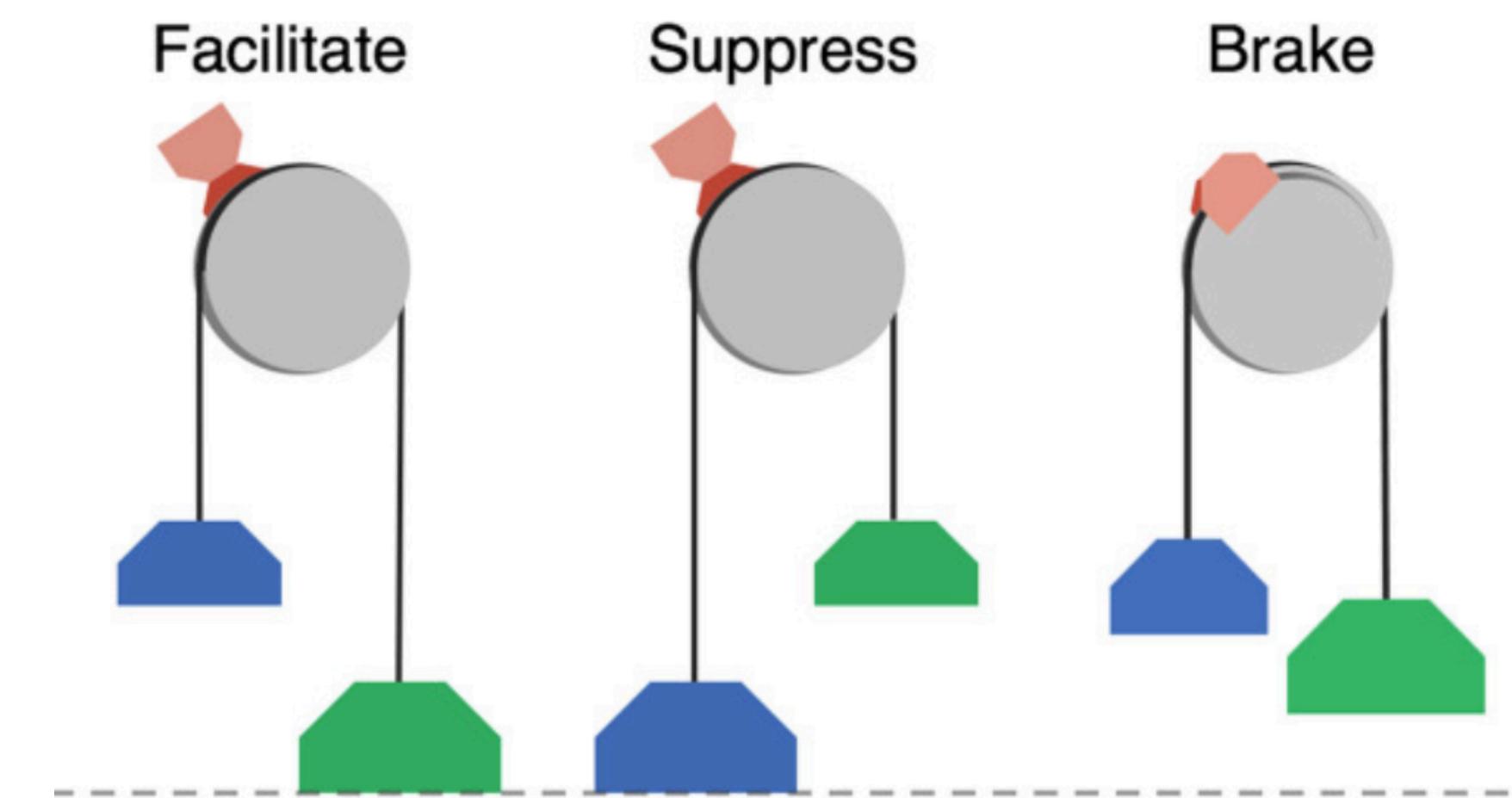
Believers & Skeptics



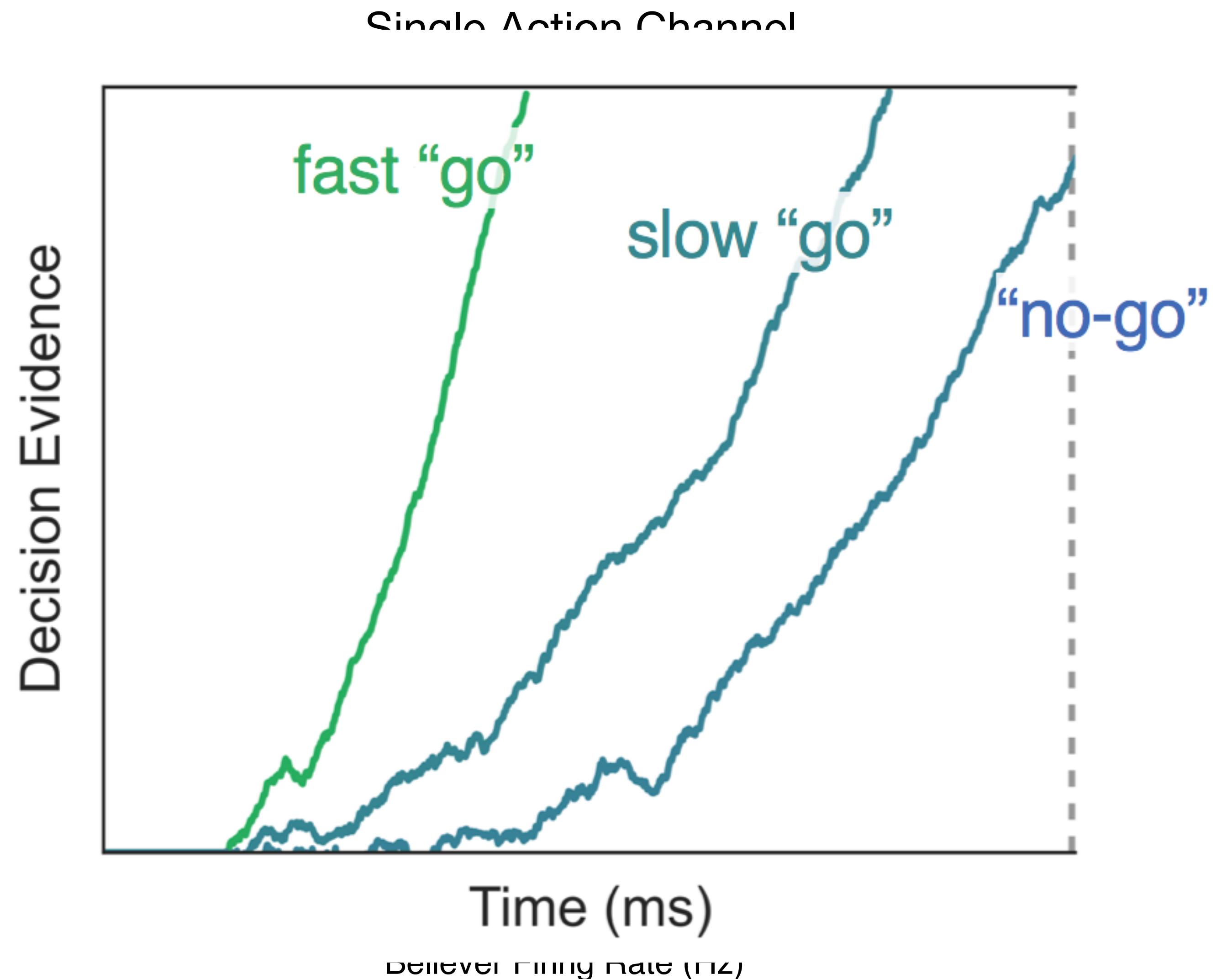
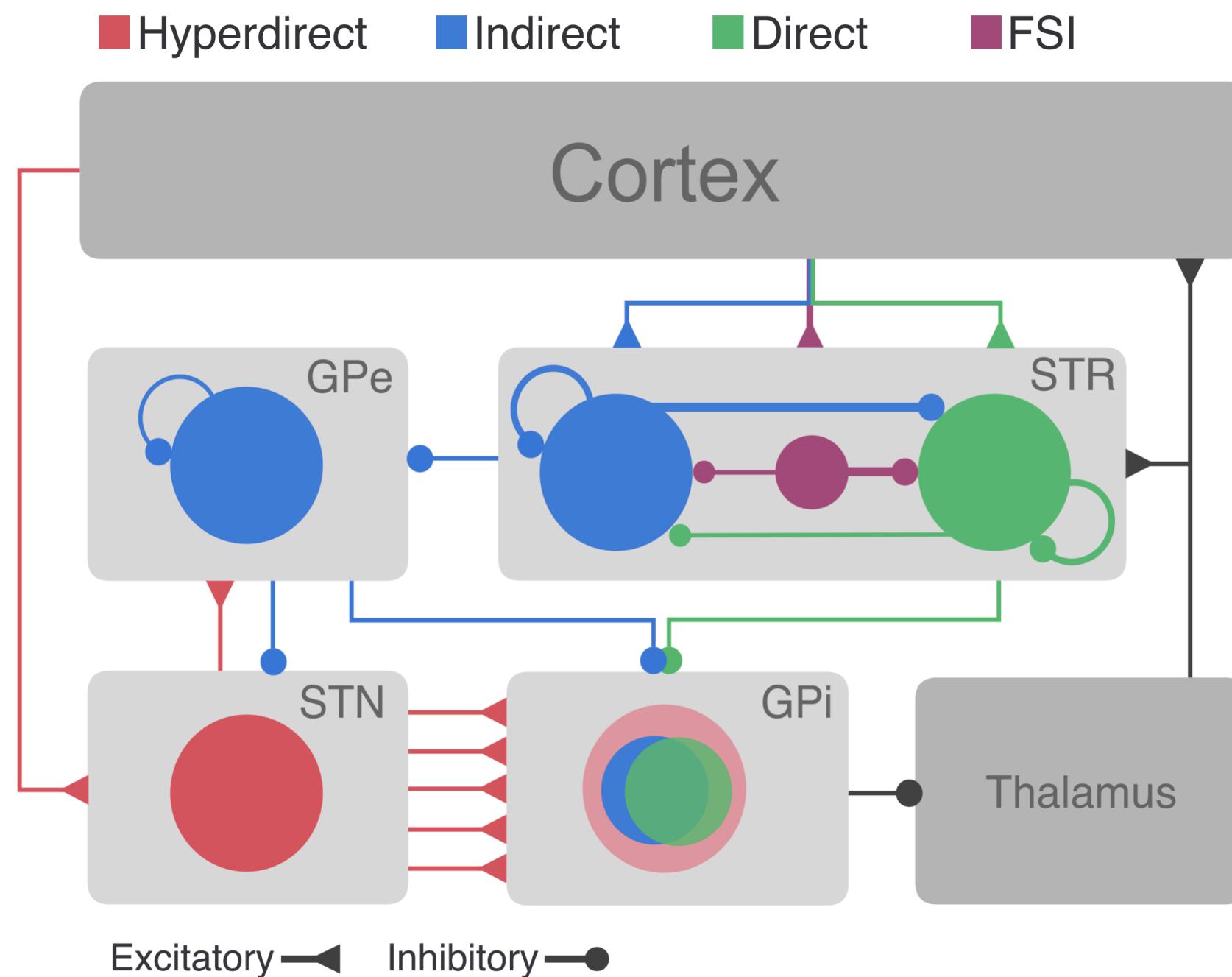
Independent Levers Model

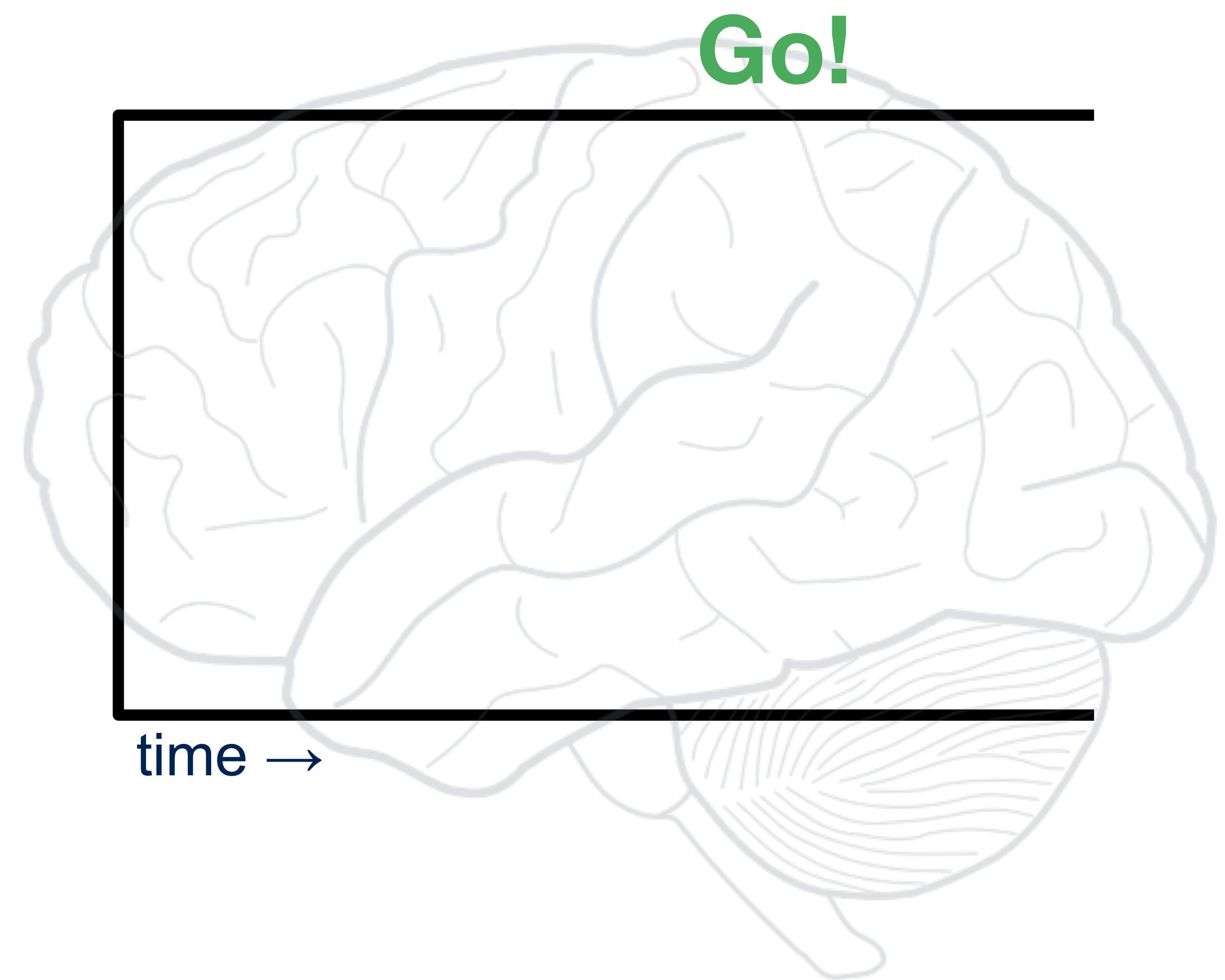
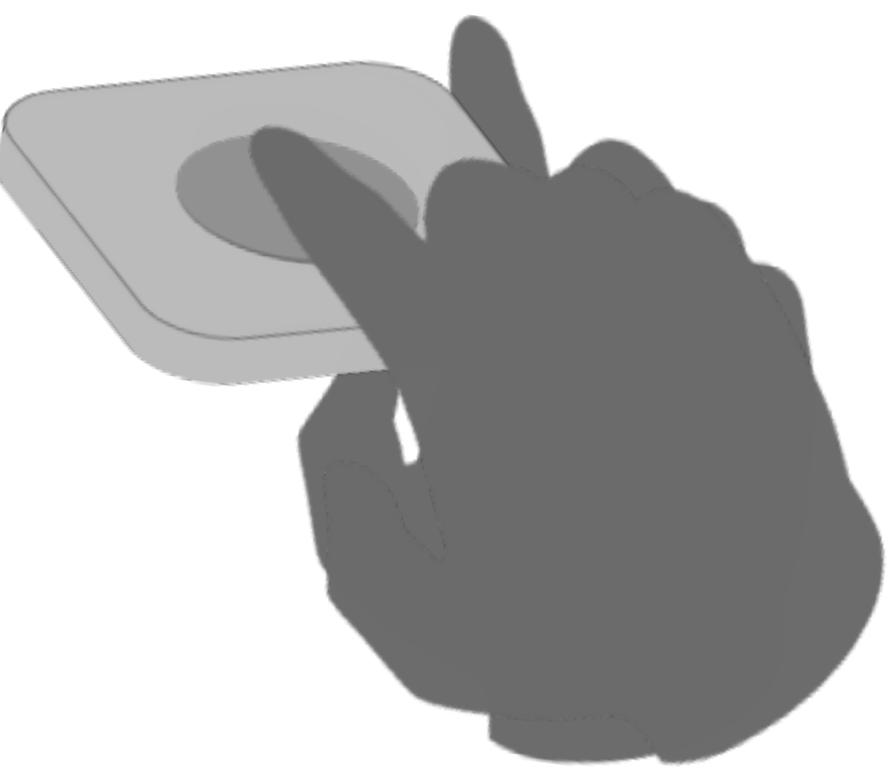
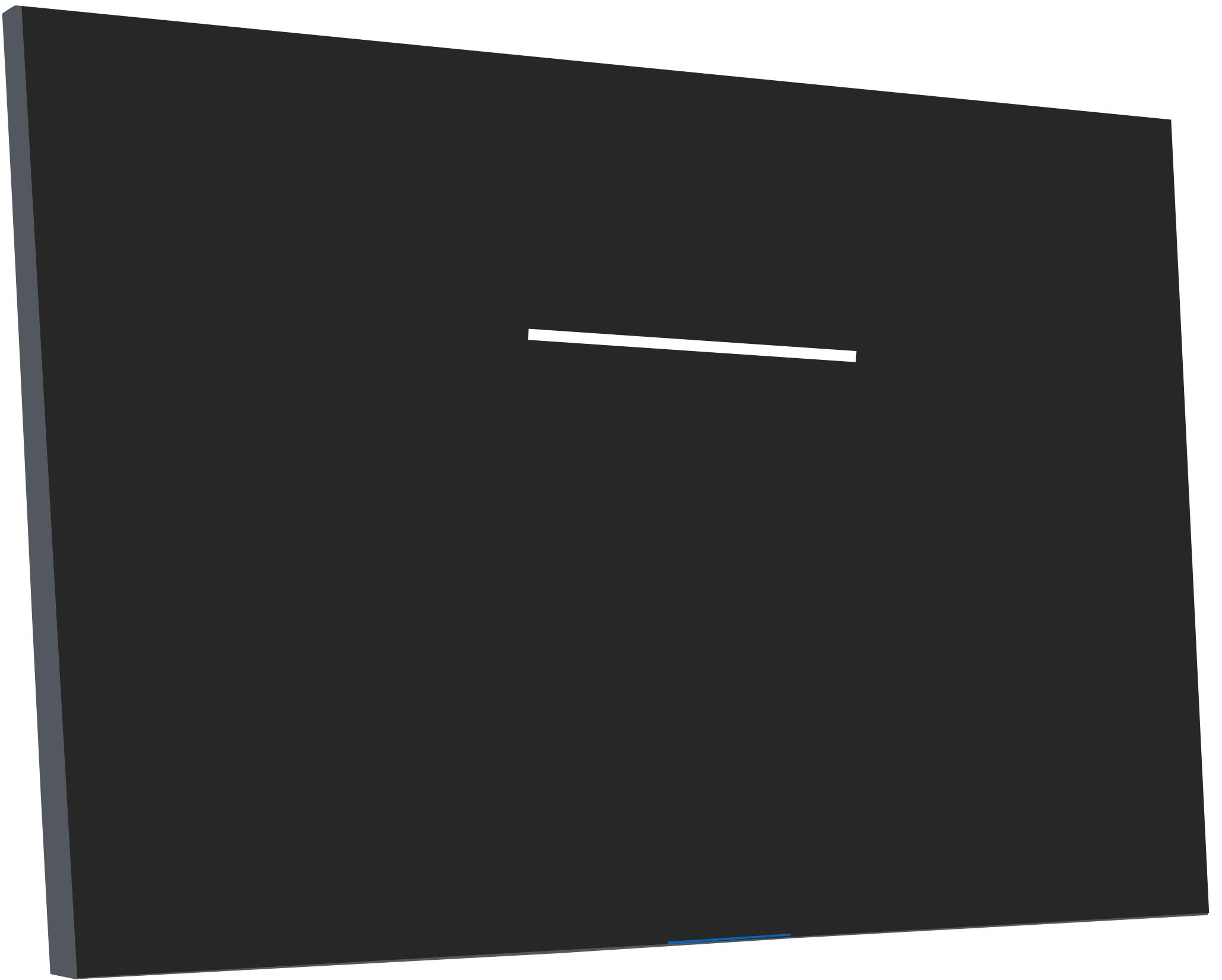


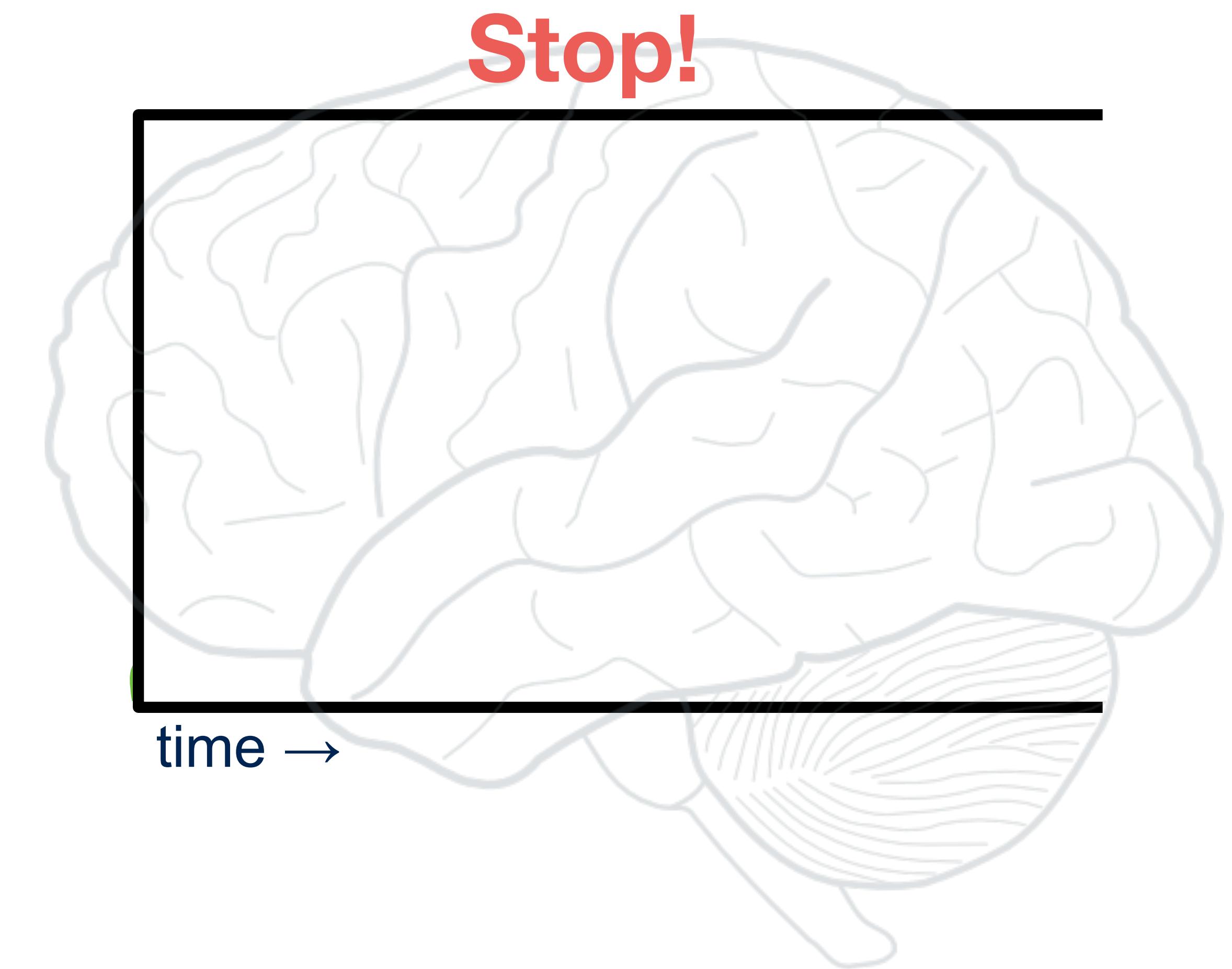
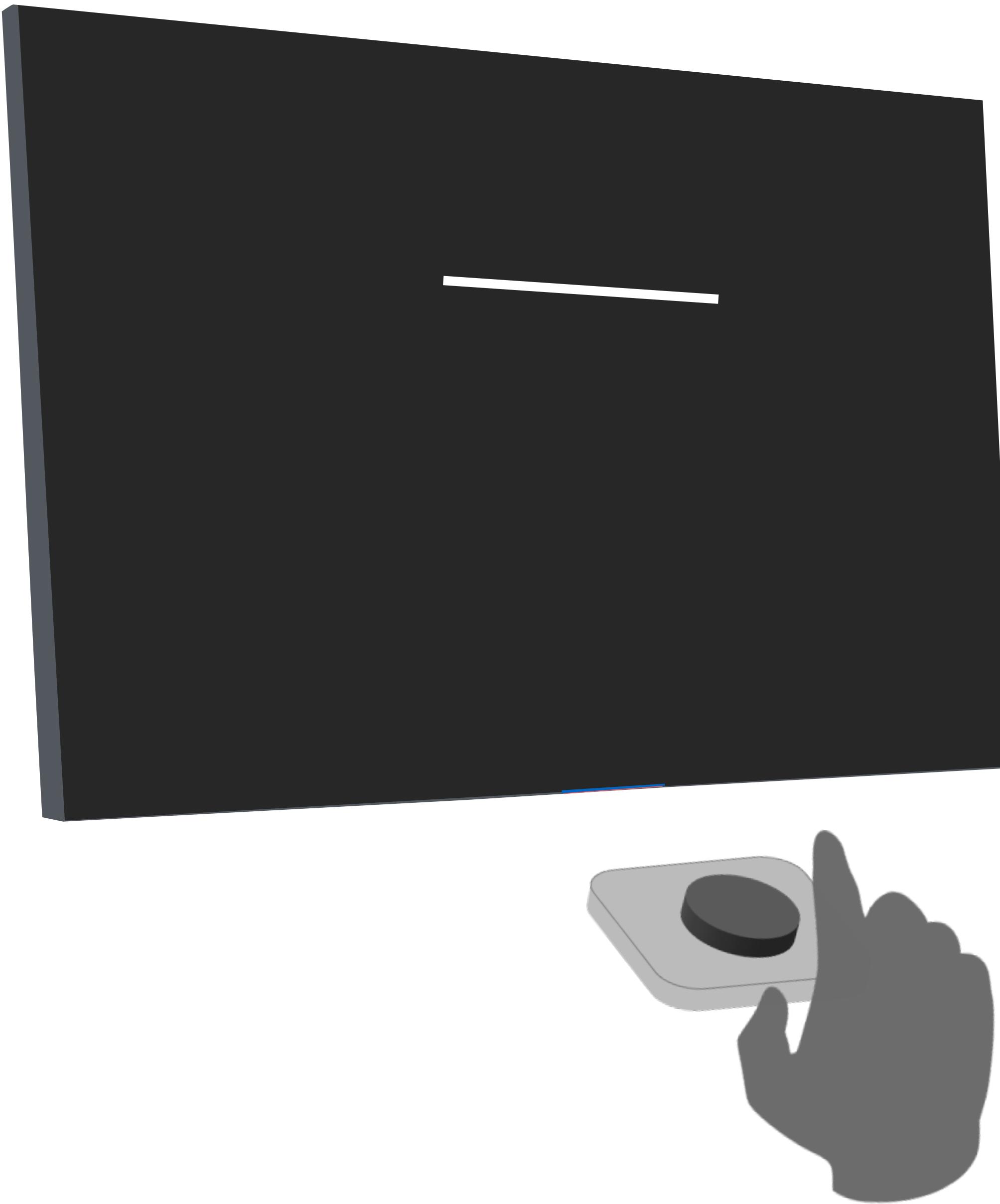
Pulley Competition Model

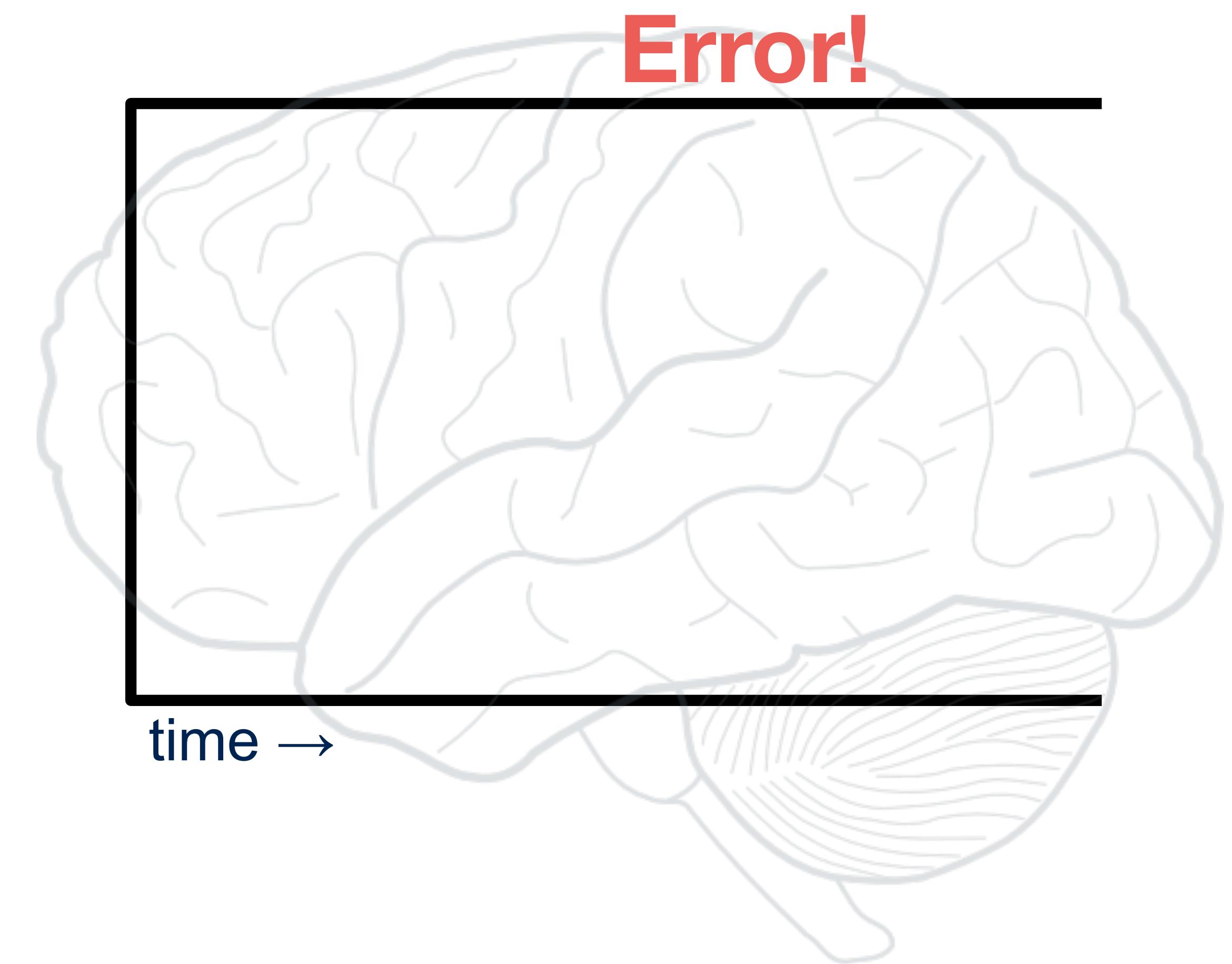
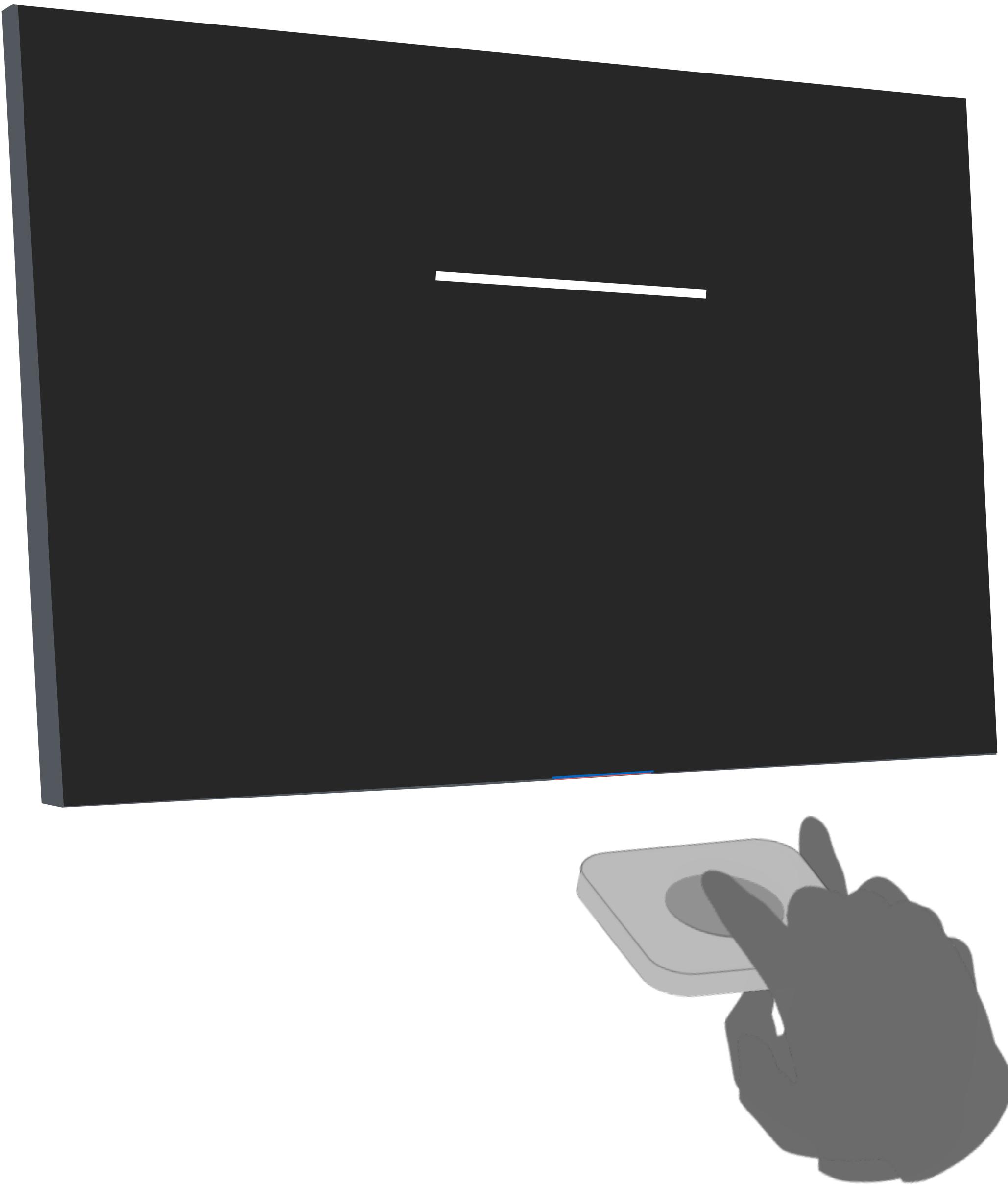


Competition to drift rates

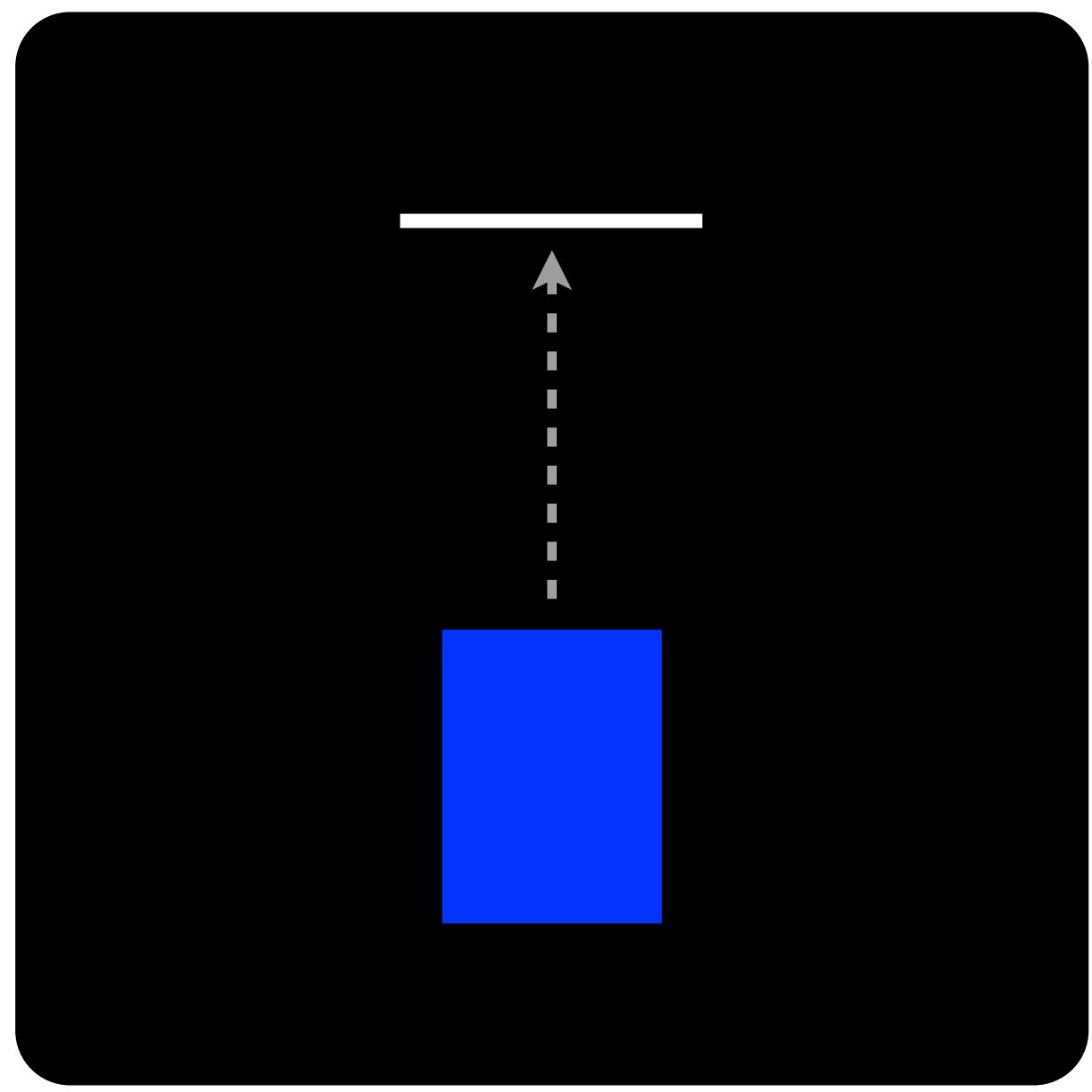




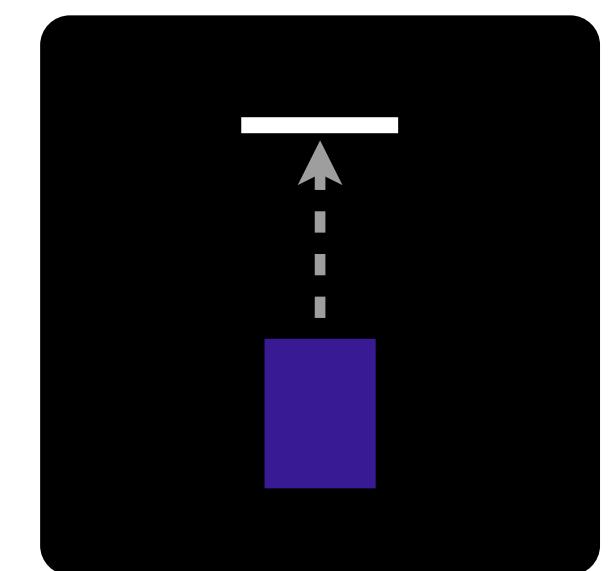




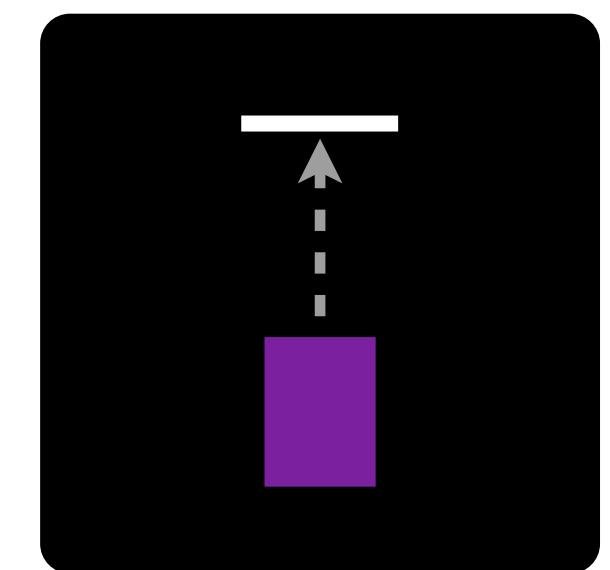
Proactive control



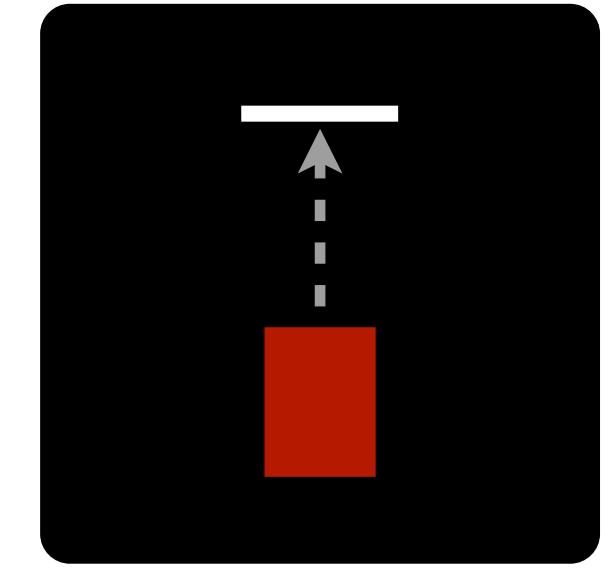
100% Go



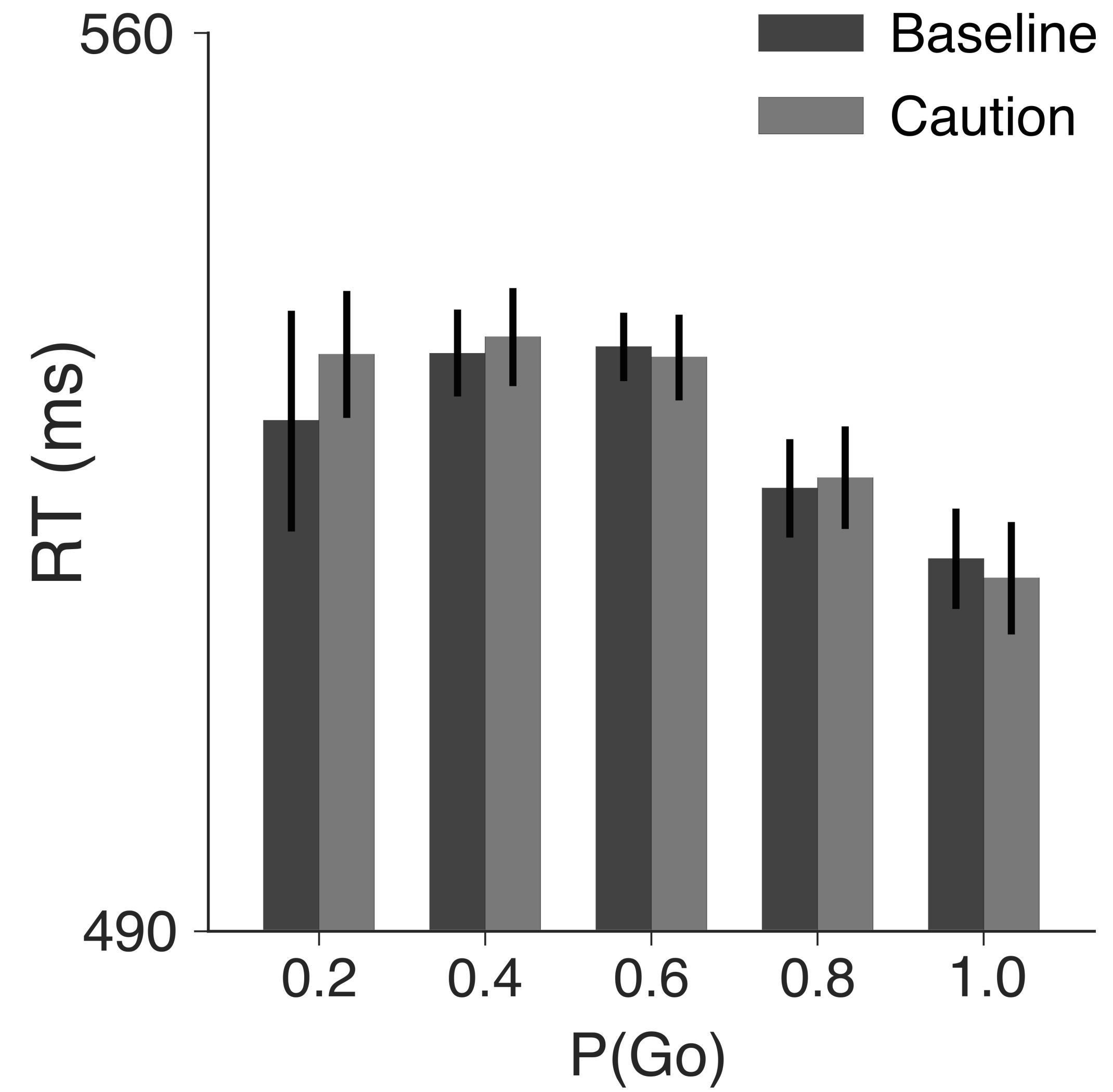
75% Go



25% Go

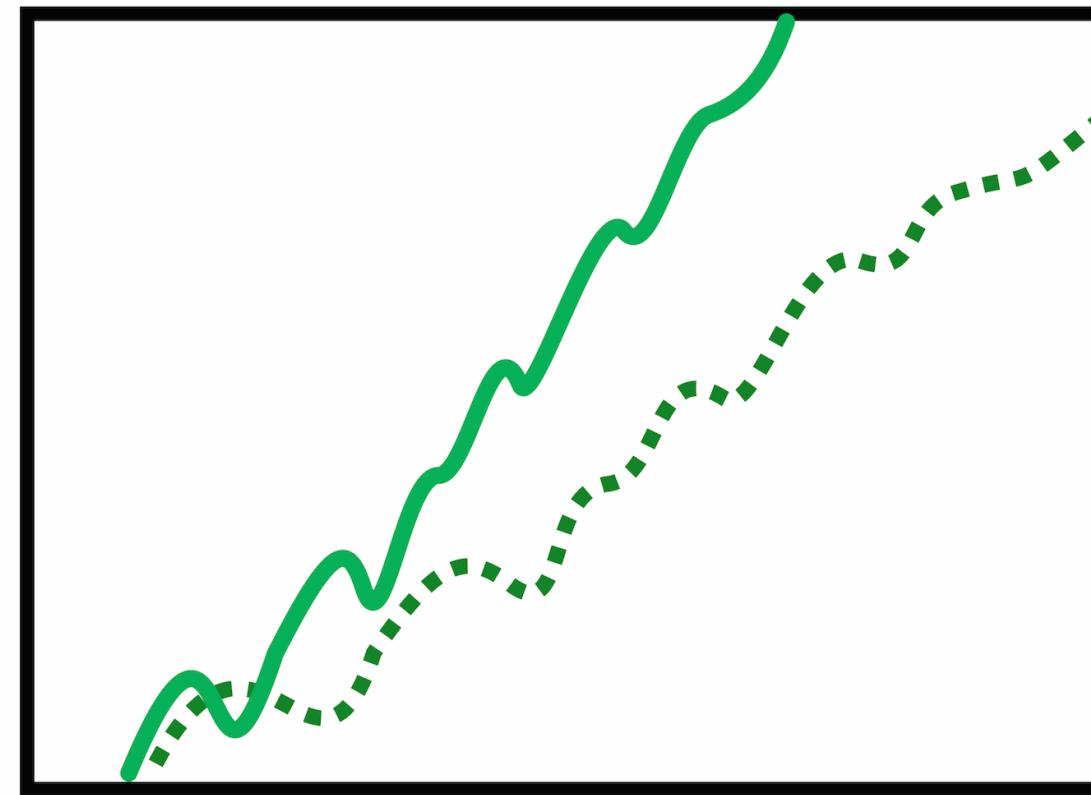


0% Go

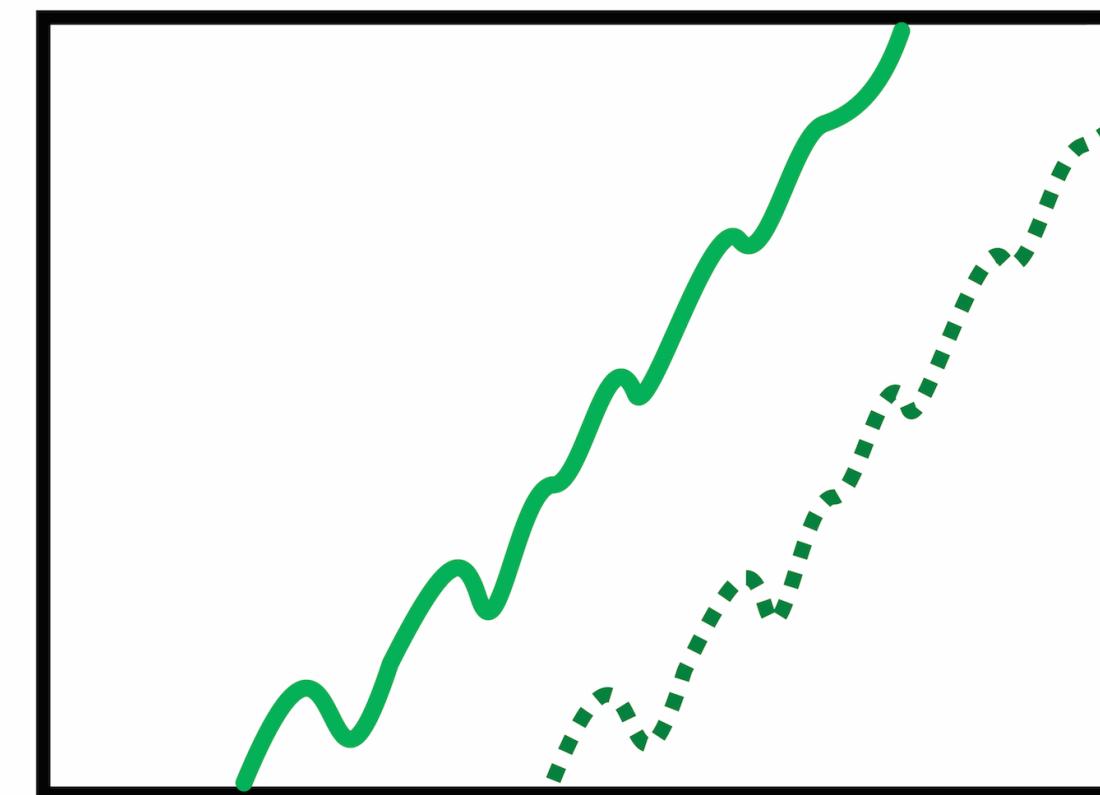


Models

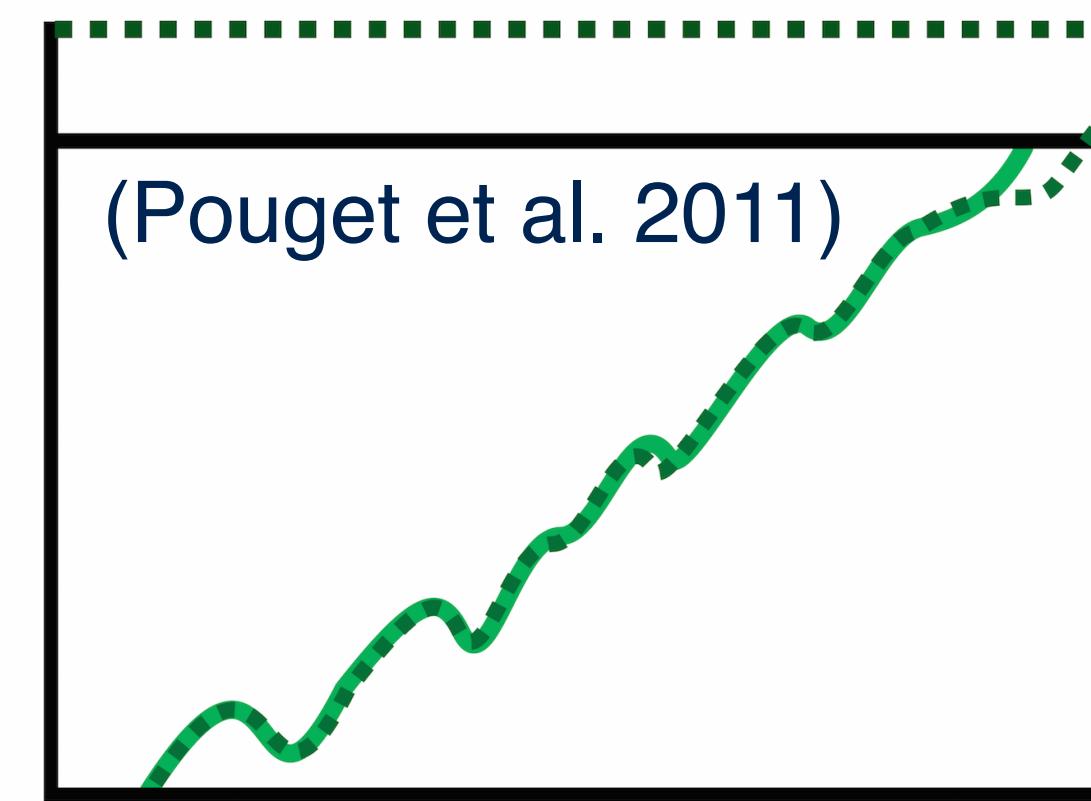
Drift-Rate



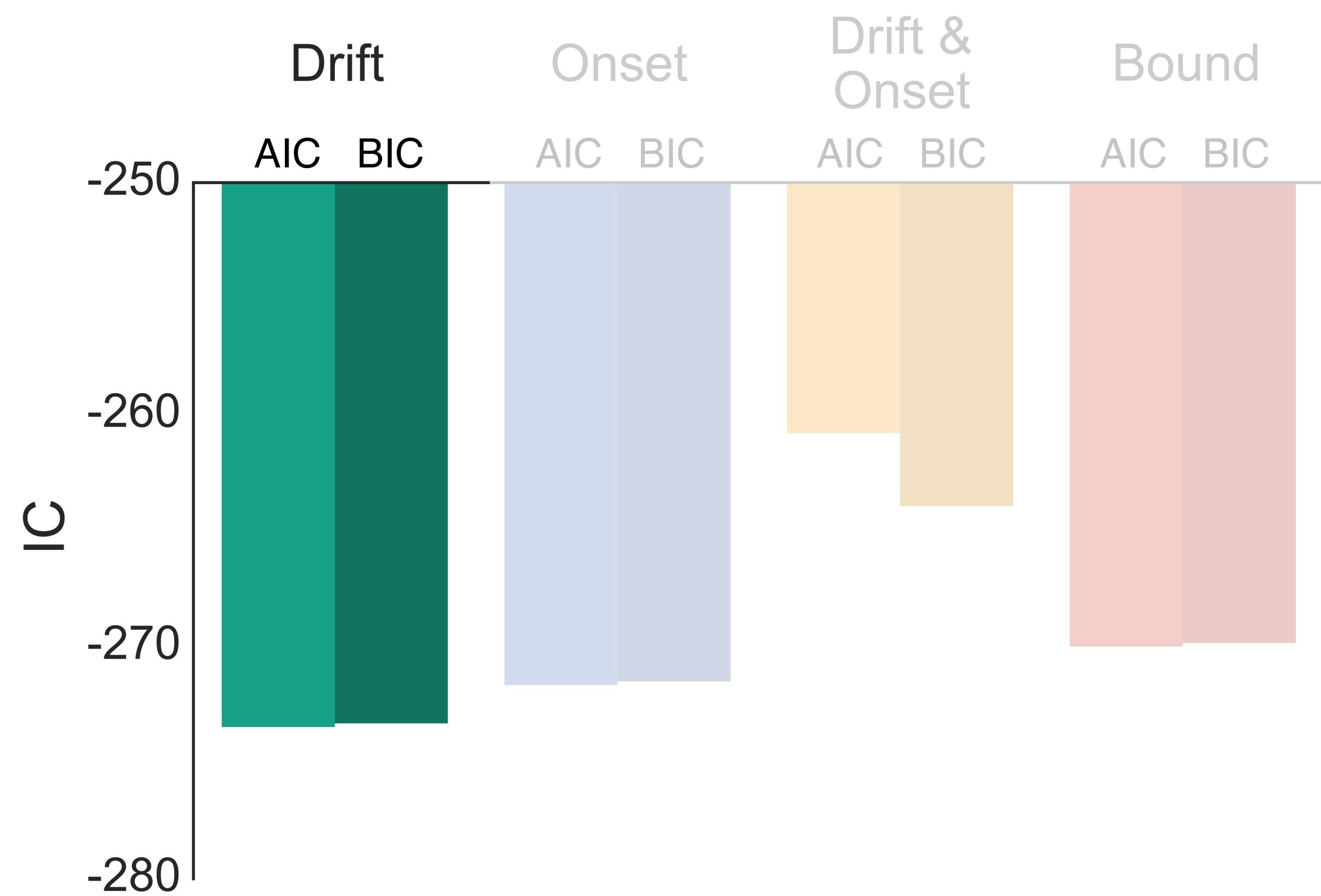
Onset Delay



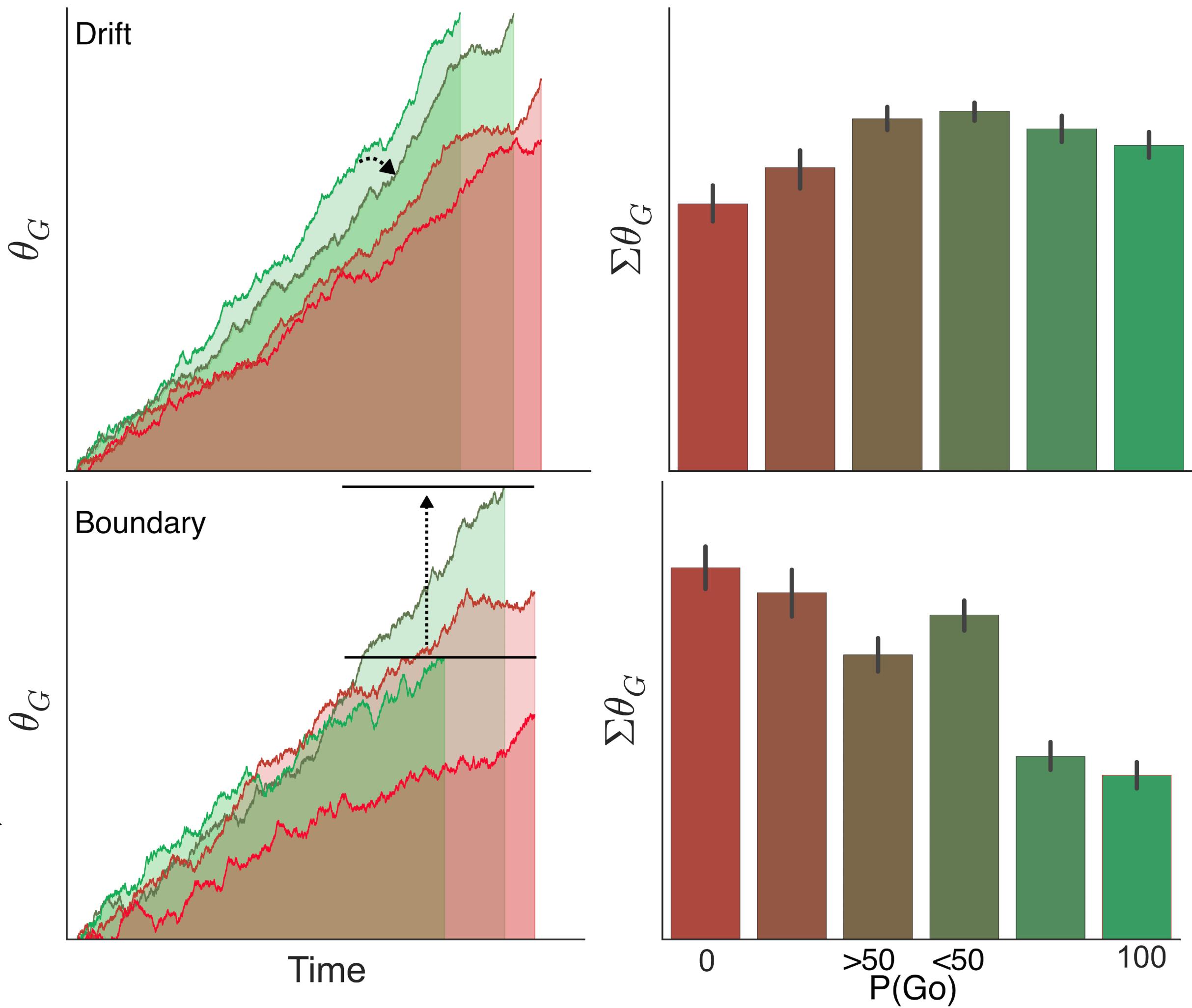
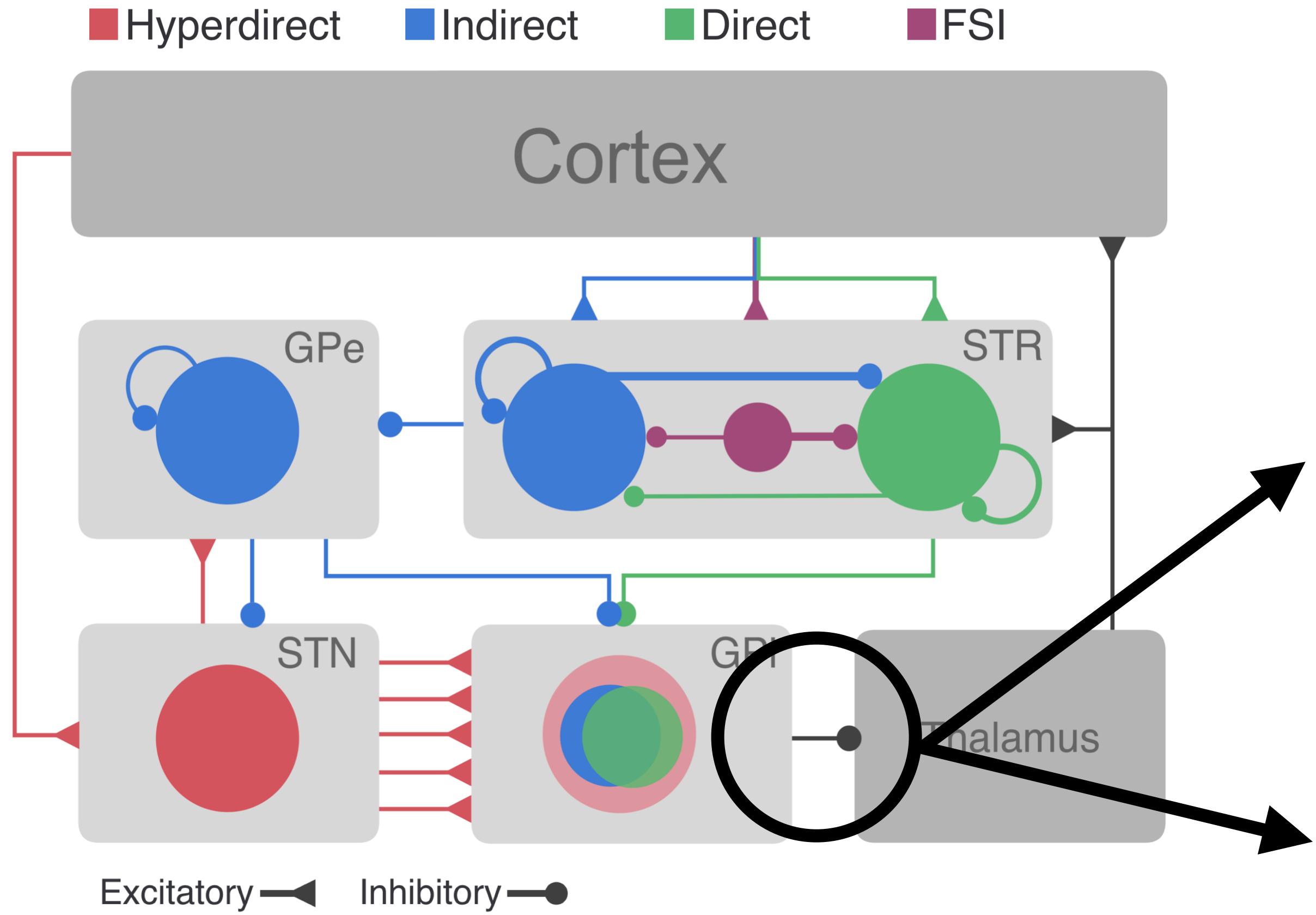
Decision Boundary



Model

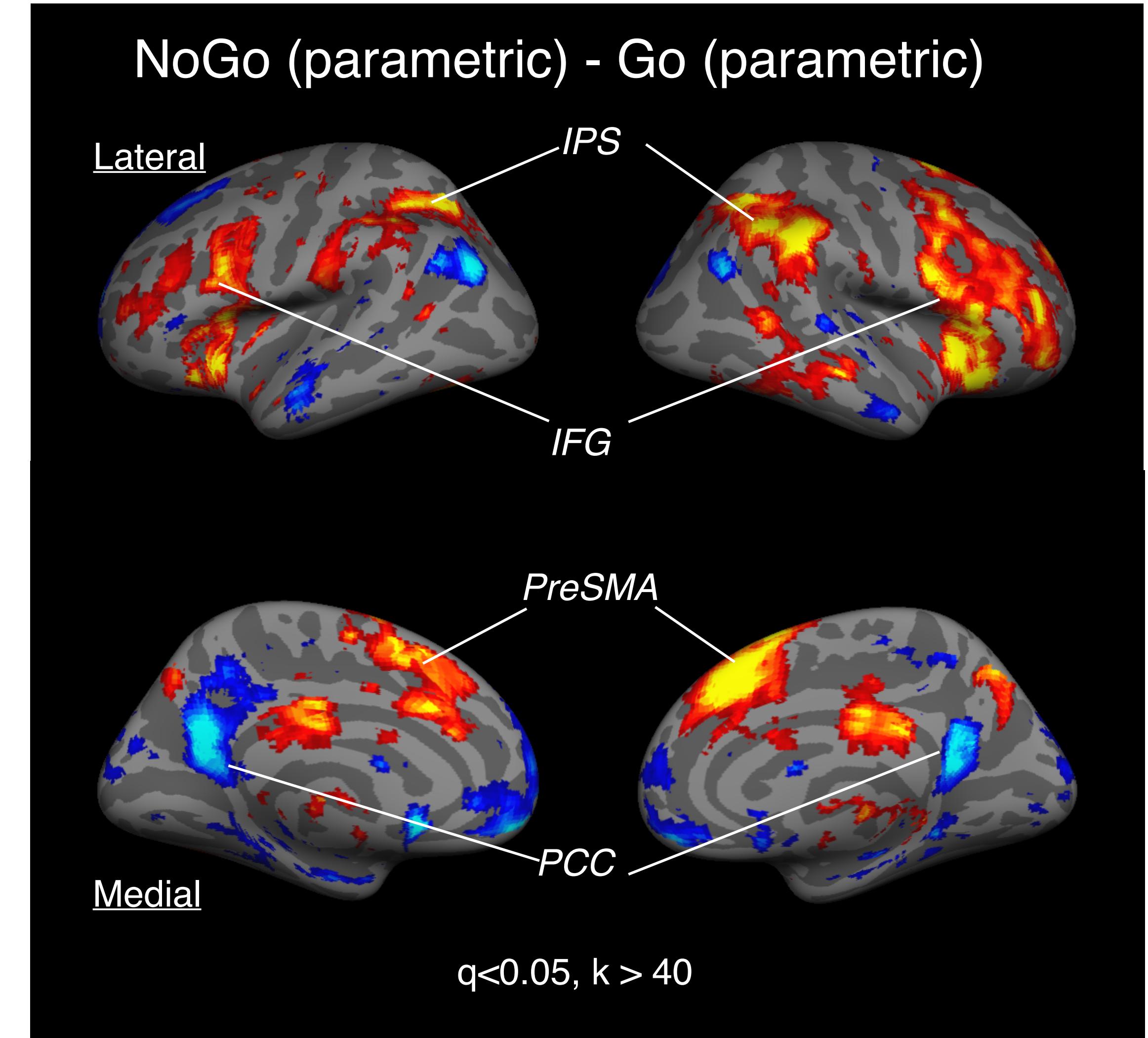
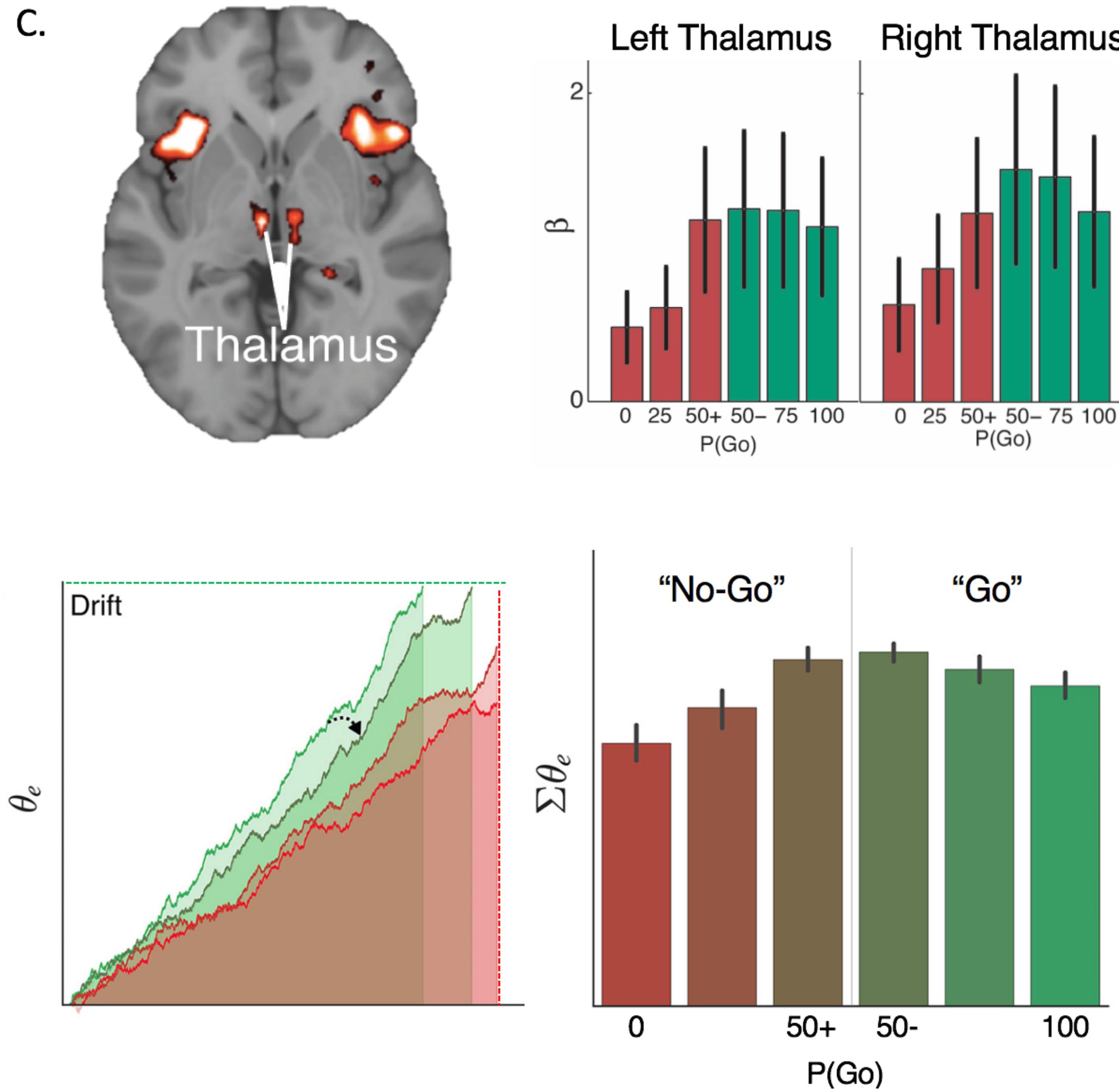


Predicting CBGT output



Predicting CBGT output

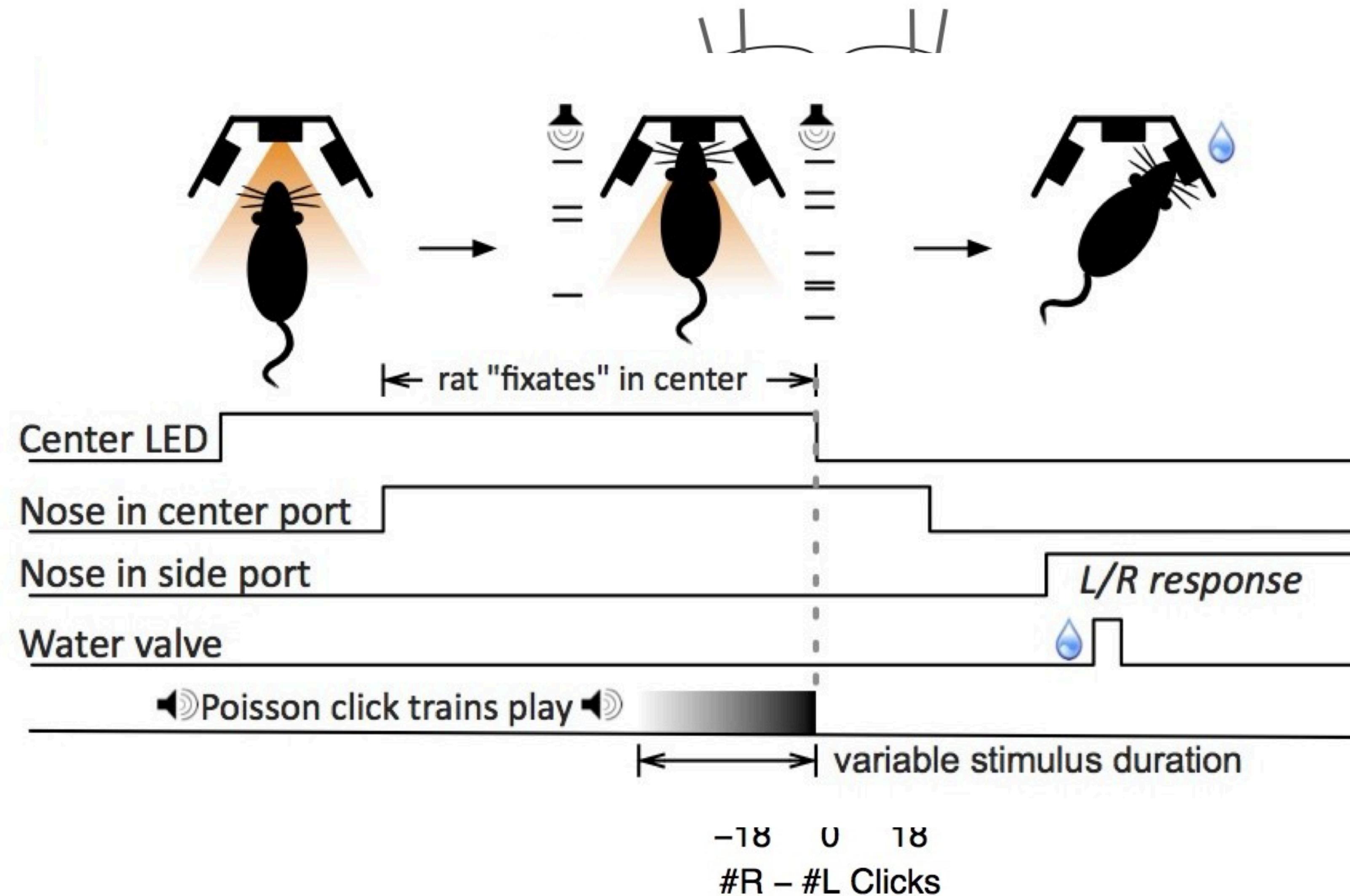
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Causal evidence?

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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://github.com/CoAxLab/BiologicallyIntelligentExploration/tree/main/Labs>

The screenshot shows a Google Colab notebook interface. The title bar reads "Lab5_CBGT_simulations.ipynb". The menu bar includes File, Edit, View, Insert, Runtime, Tools, Help, and a redacted "Cannot save changes". Below the menu is a toolbar with "+ Code", "+ Text", and "Copy to Drive". The main content area has a sidebar with icons for file operations. The content starts with a section titled "Lab 5 - CBGT decision-making simulations" which contains a description of the lab's purpose and three numbered steps for running simulations. Below this is a "Sections:" heading with a list of three items. Further down is another section titled "Section - Setup" with a descriptive paragraph.

Lab 5 - CBGT decision-making simulations

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.