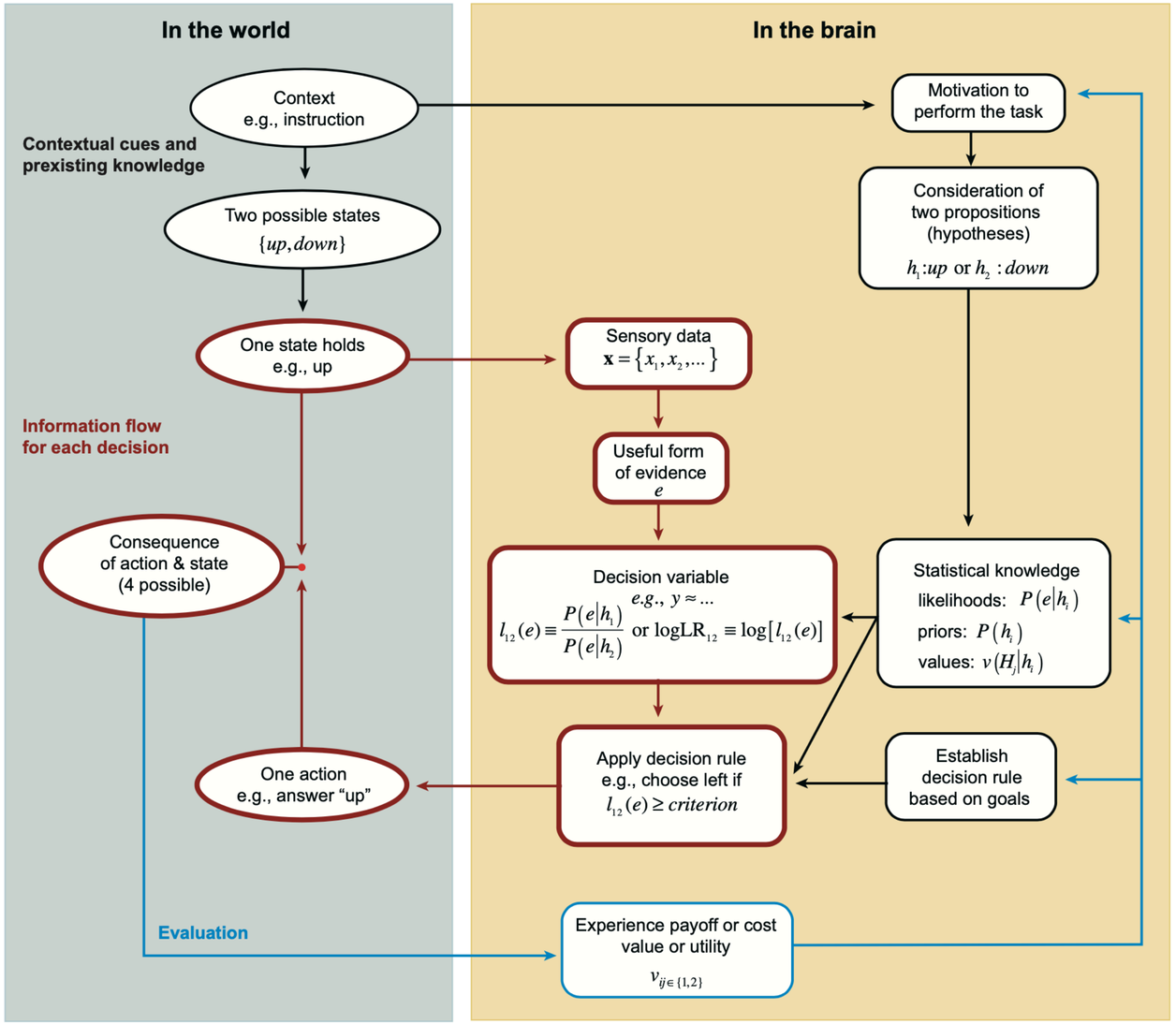
Does the subcortex make a decision?

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.

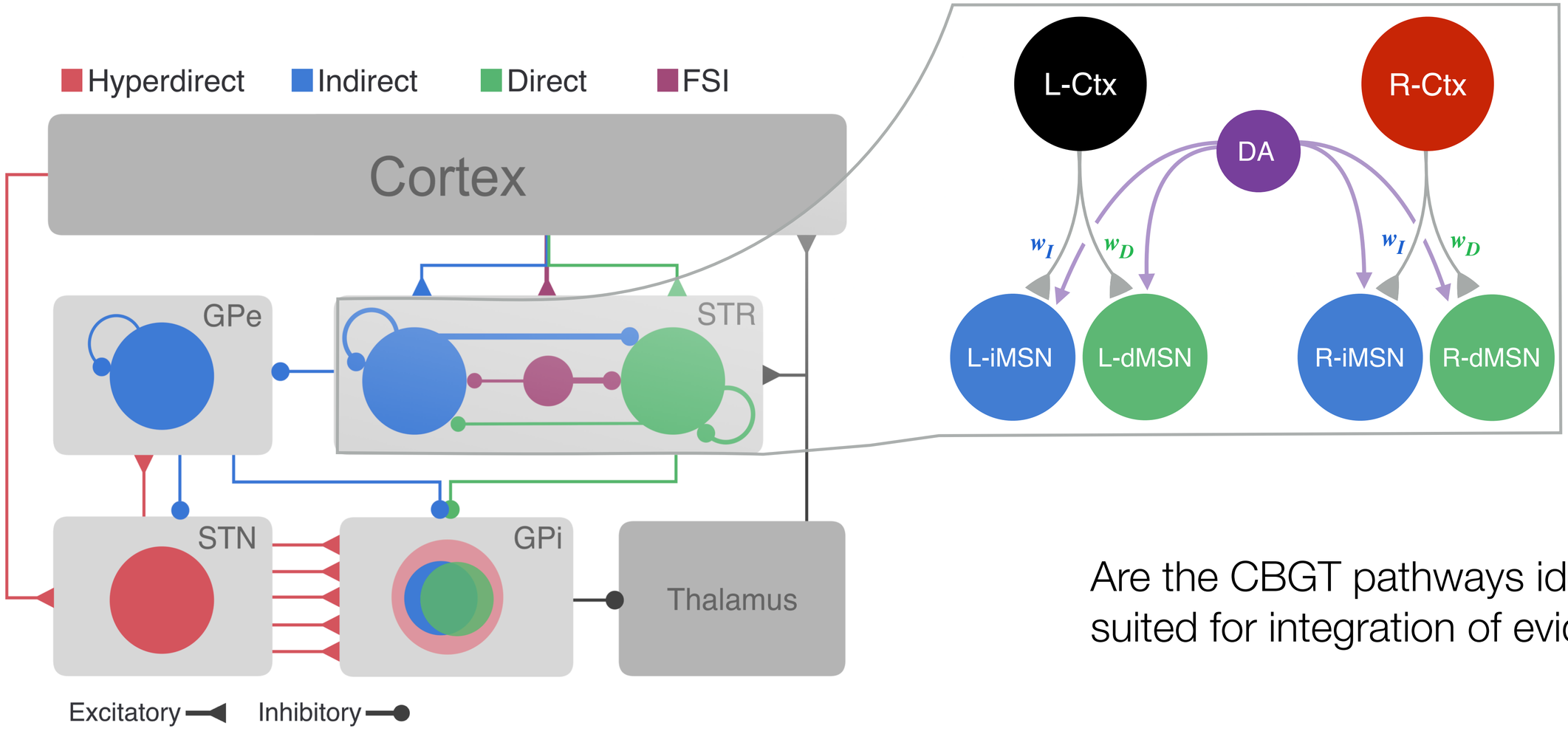
- Dunovan, K., Lynch, B., Molesworth, T., & Verstynen, T. (2015). Competing basal ganglia pathways determine the difference between stopping and deciding not to go. Elife, 4, e08723.

Elements of making a decision



(Gold & Shadlen, 2007)

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

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

2. Sum all logLR tests up to current observation

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

3. Determine stopping rule

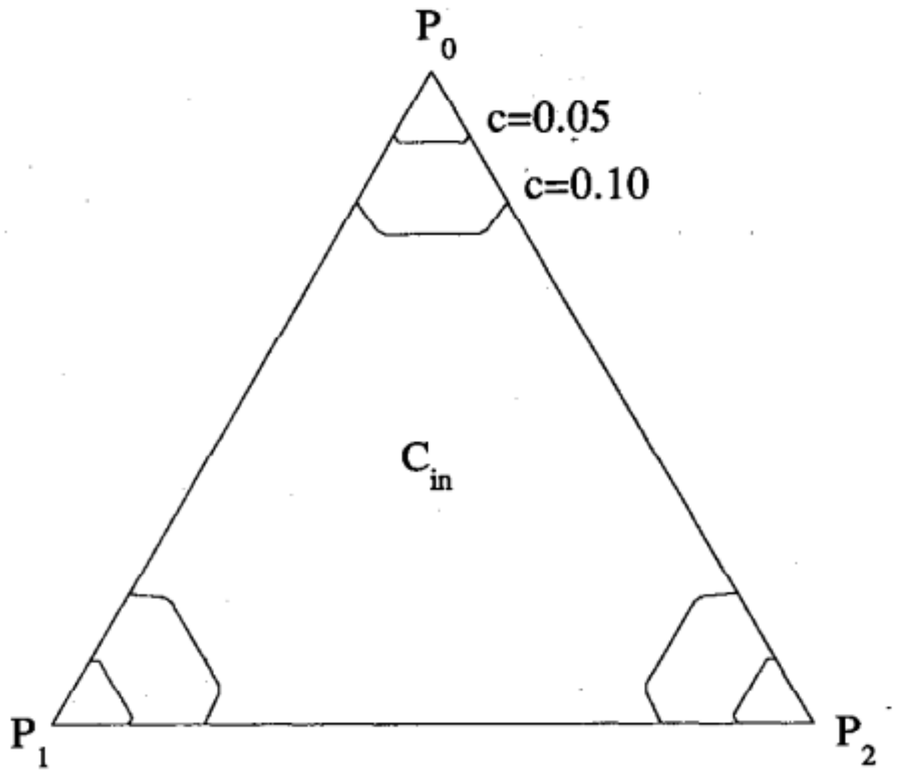
$$y_n \geq \log\frac{1-\alpha}{\alpha}, \text{ then select } h_1$$

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

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

(Gold & Shadlen, 2007)

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 prior likelihood

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

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

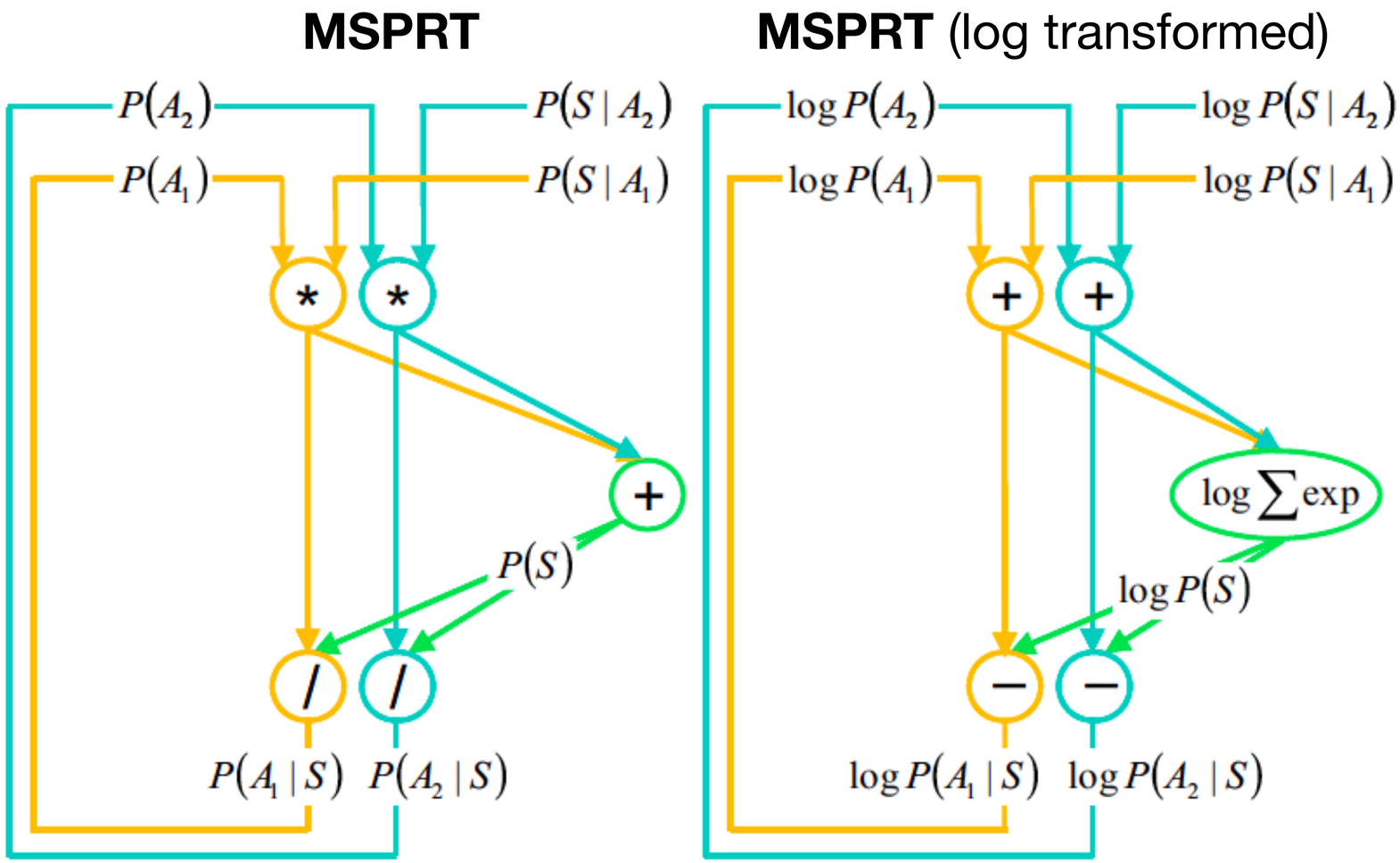
$g = (I_+ - I_-)/\sigma^2$

Sensory evidence

Scalar (same for all hypotheses)

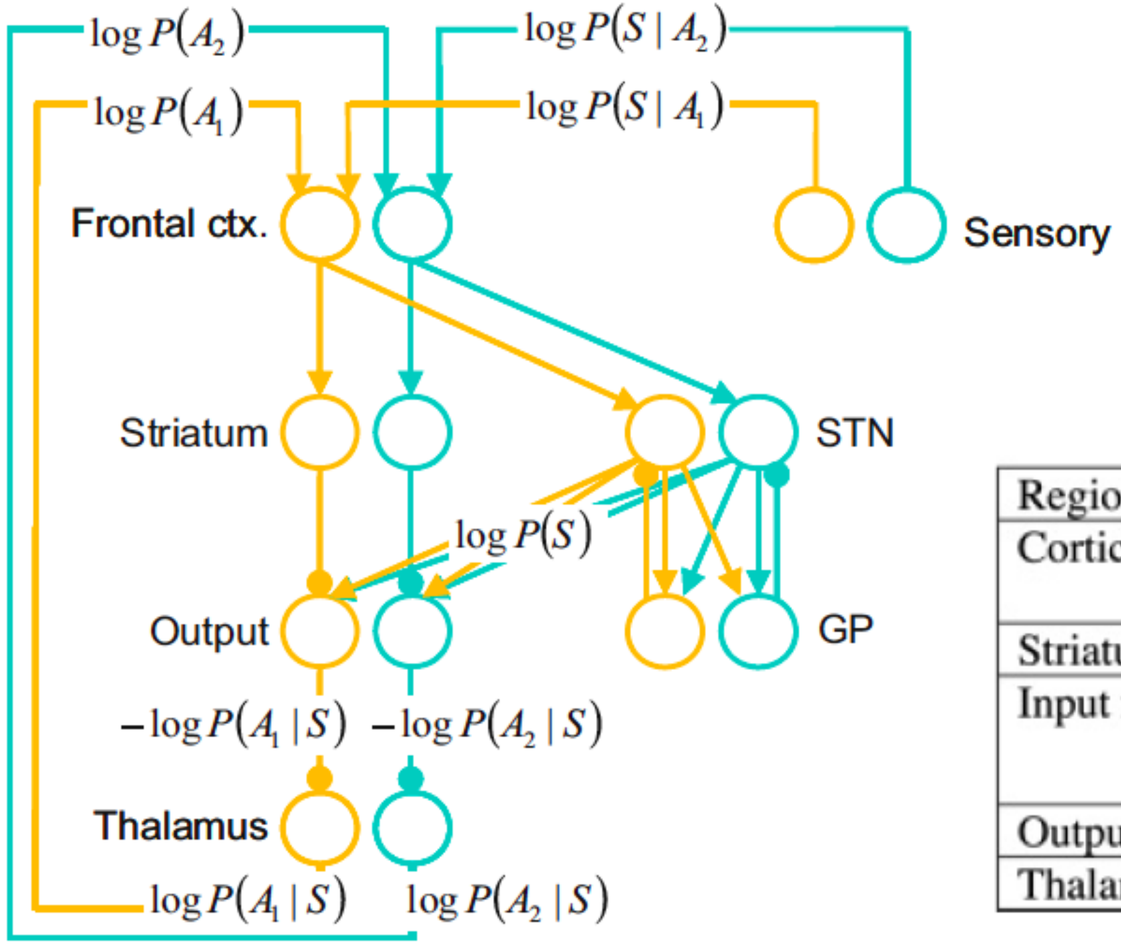
(Baum & Veeravalli, 1994)

The multihypothesis SPRT (MSPRT) algorithm



(Bogacz & Larsen, 2011)

A neural instantiation of the MSPRT

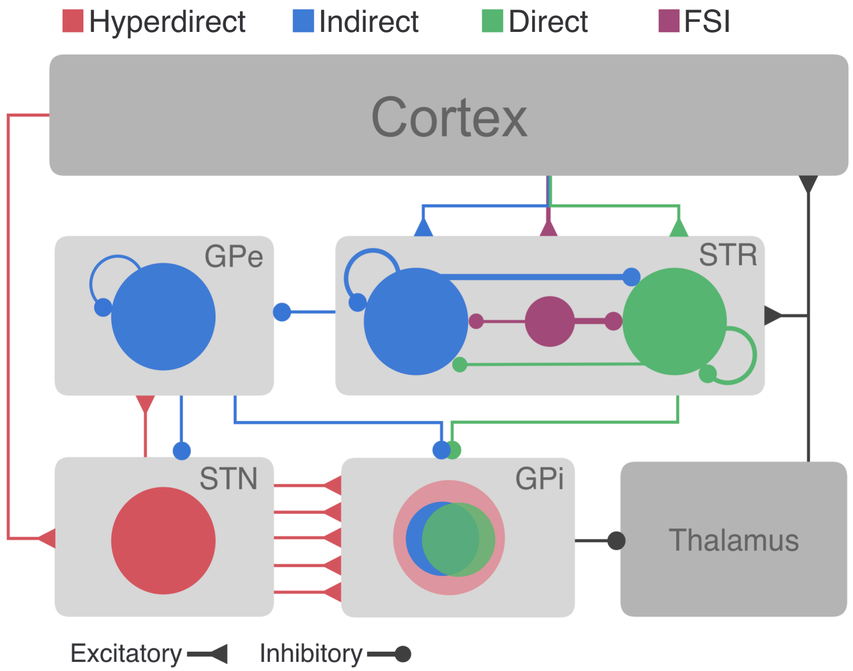


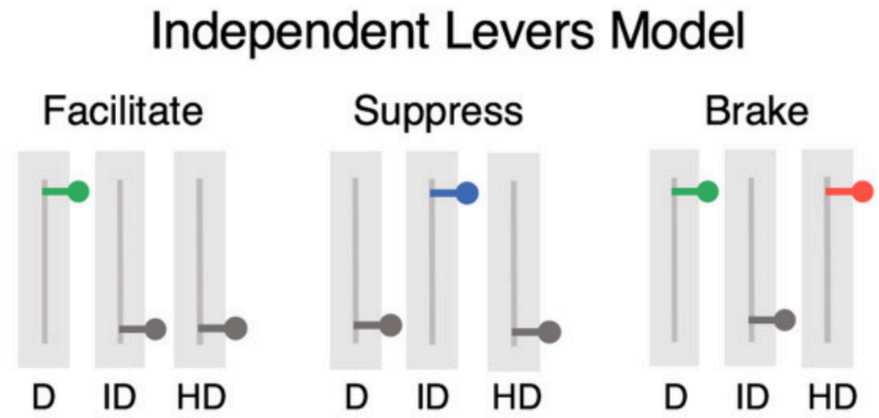
Based off of the topology of excitatory & inhibitory connections, you can map CBGT dynamics to the MSPRT algorithm.

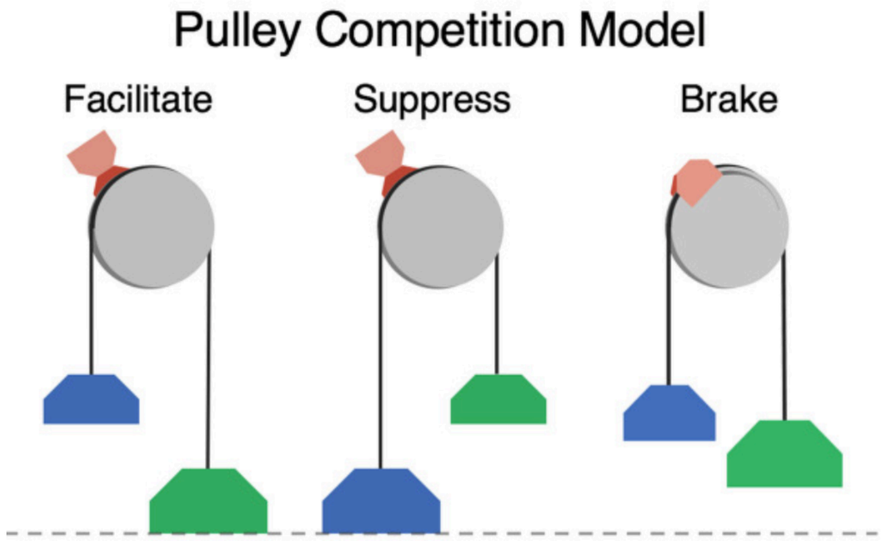
Region	Equation
Cortical integrators	$INT_i(0) = \log 1/N + c$ $INT_i(t) = TH_i(t-1) + g\, x_i(t)$, for $t>0$
Striatum	$STR_i(t) = INT_i(t)$
Input from STN and GP	$SG(t) = \log \sum_{i=1}^{N} \exp INT_i(t)$
Output nuclei	$OUT_i(t) = -STR_i(t) + SG(t)$
Thalamus	$TH_i(t) = c - OUT_i(t)$

(Bogacz & Larsen, 2011)

Believers & Skeptics

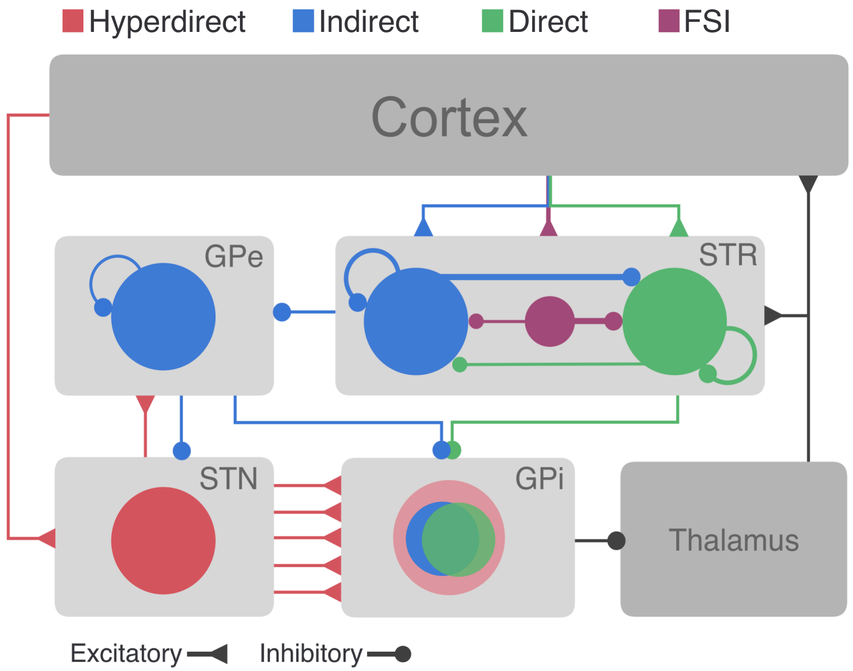


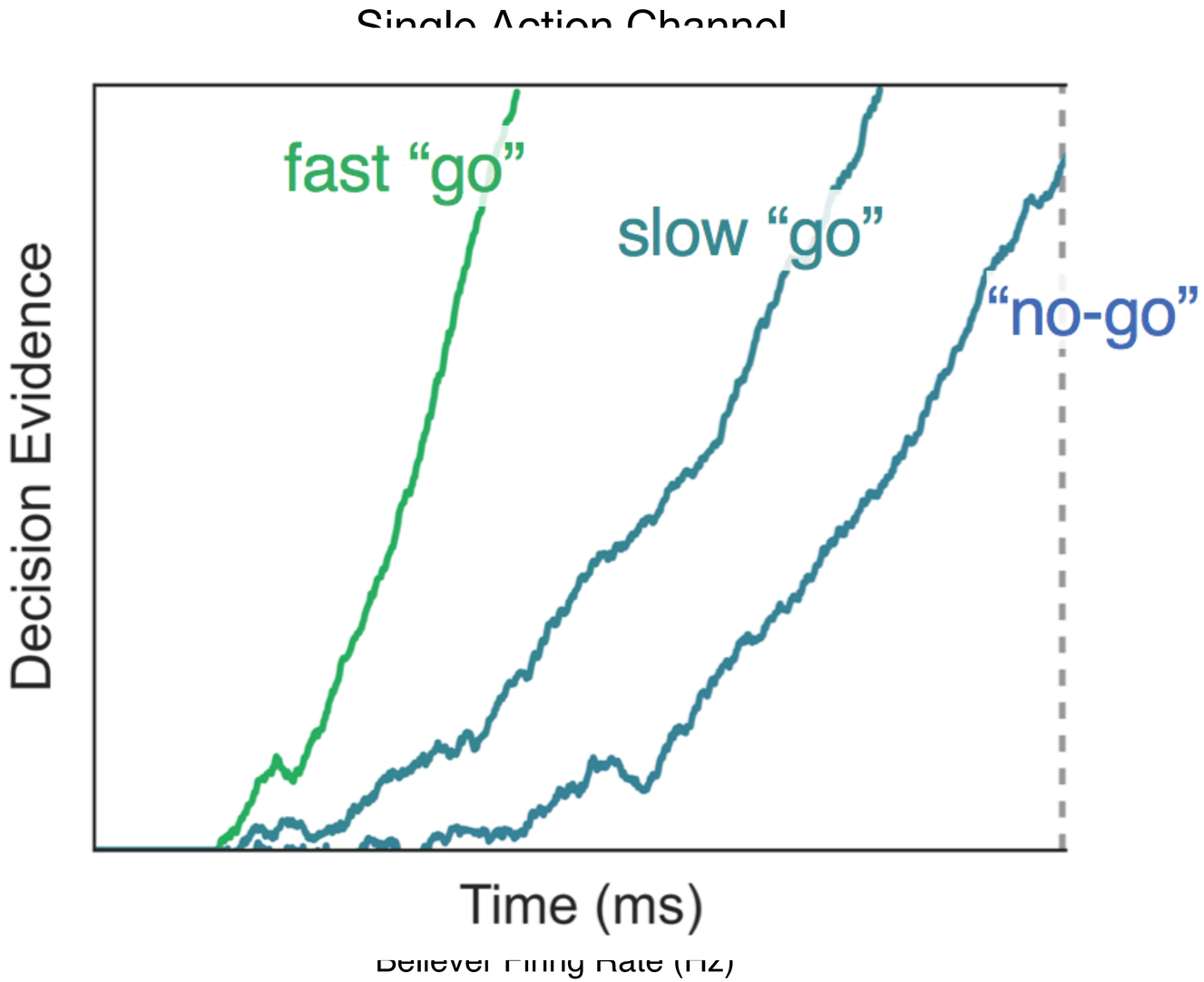




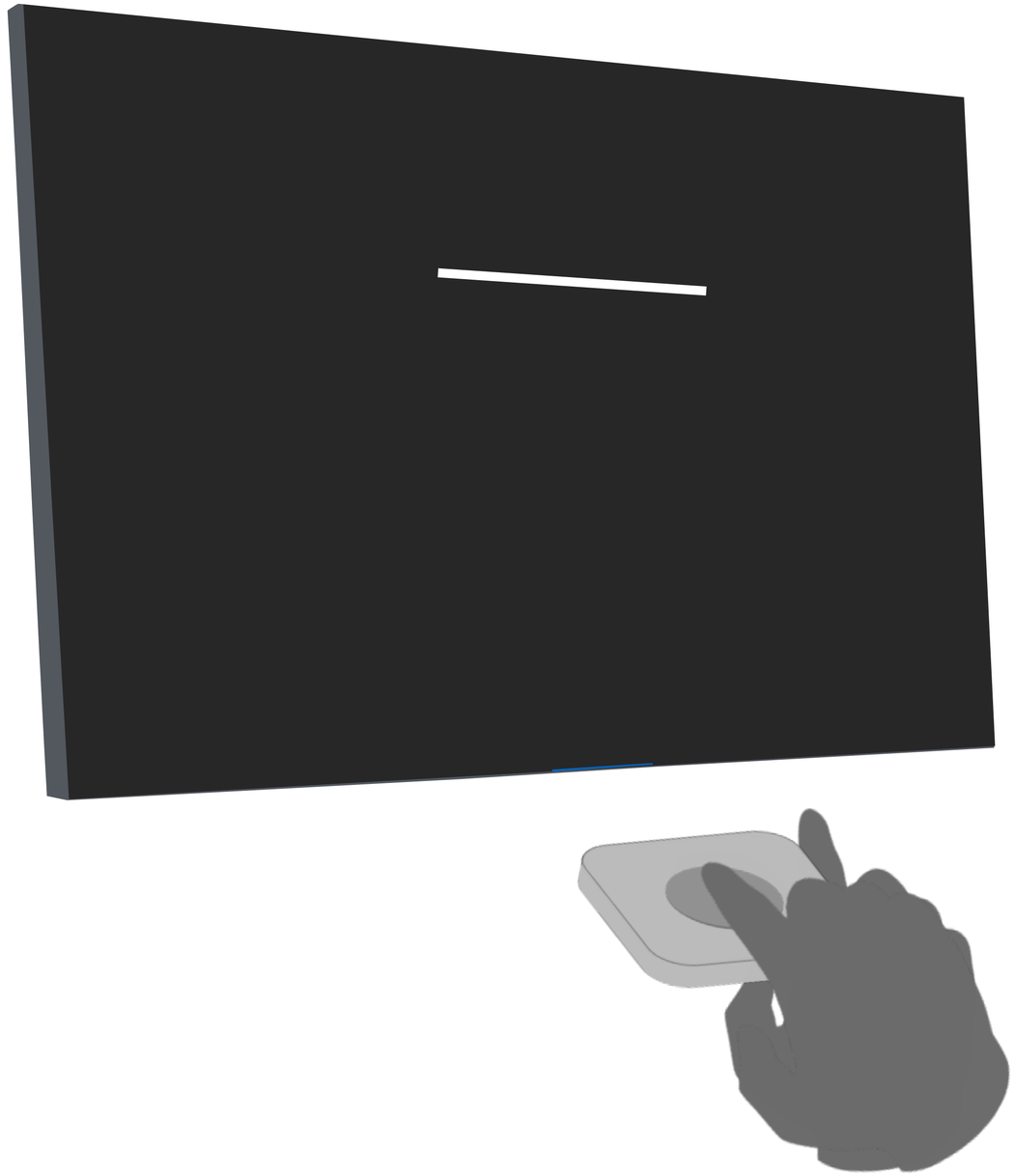
(Dunovan & Verstynen, 2016)

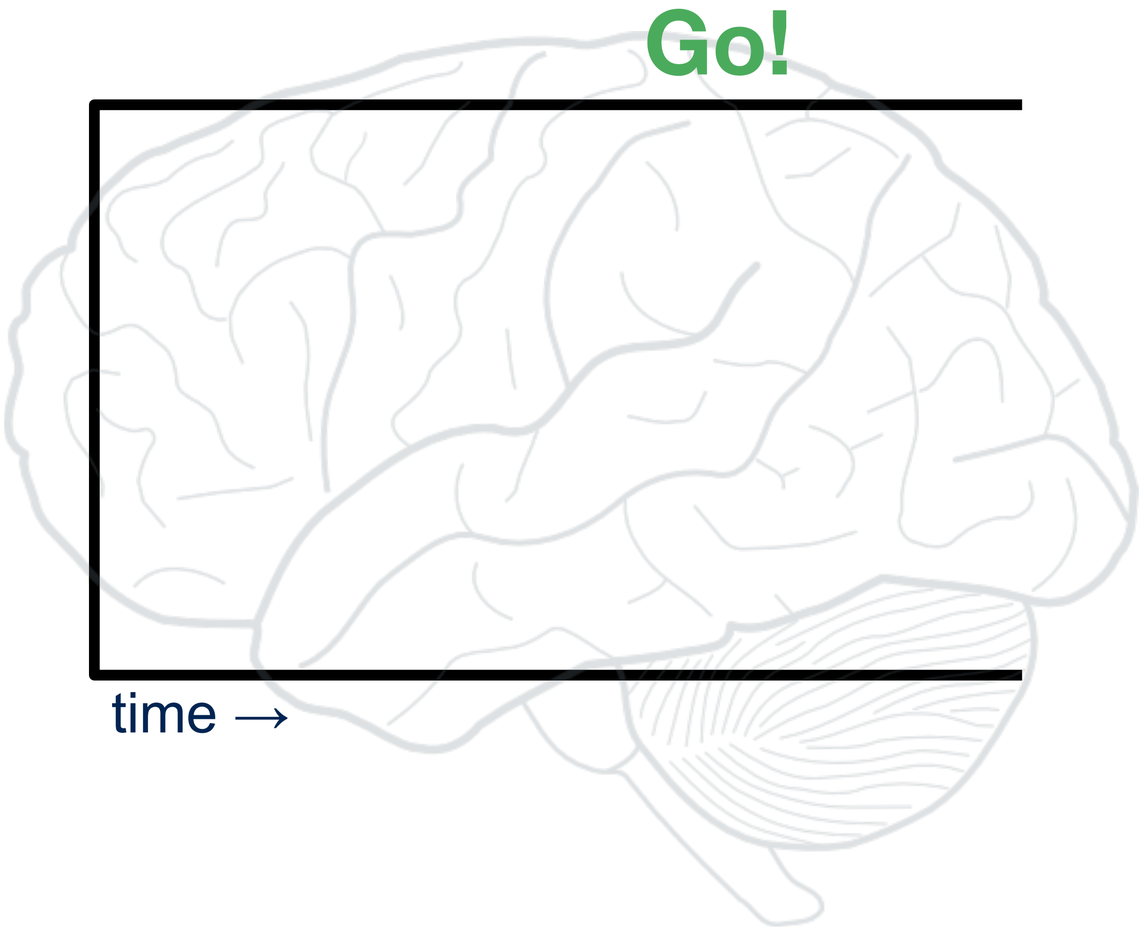
Competition to drift rates

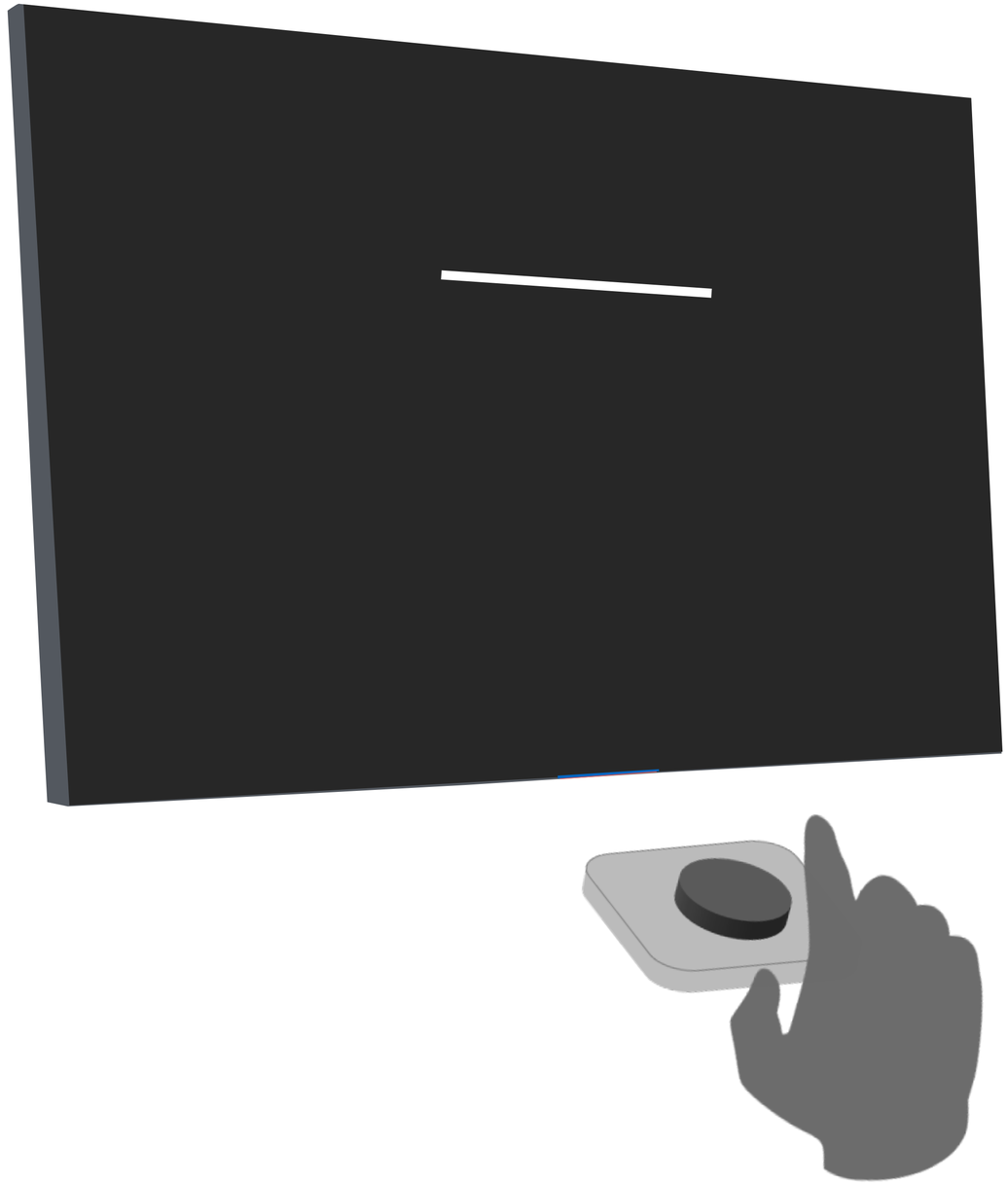




(Dunovan & Verstynen, 2016)

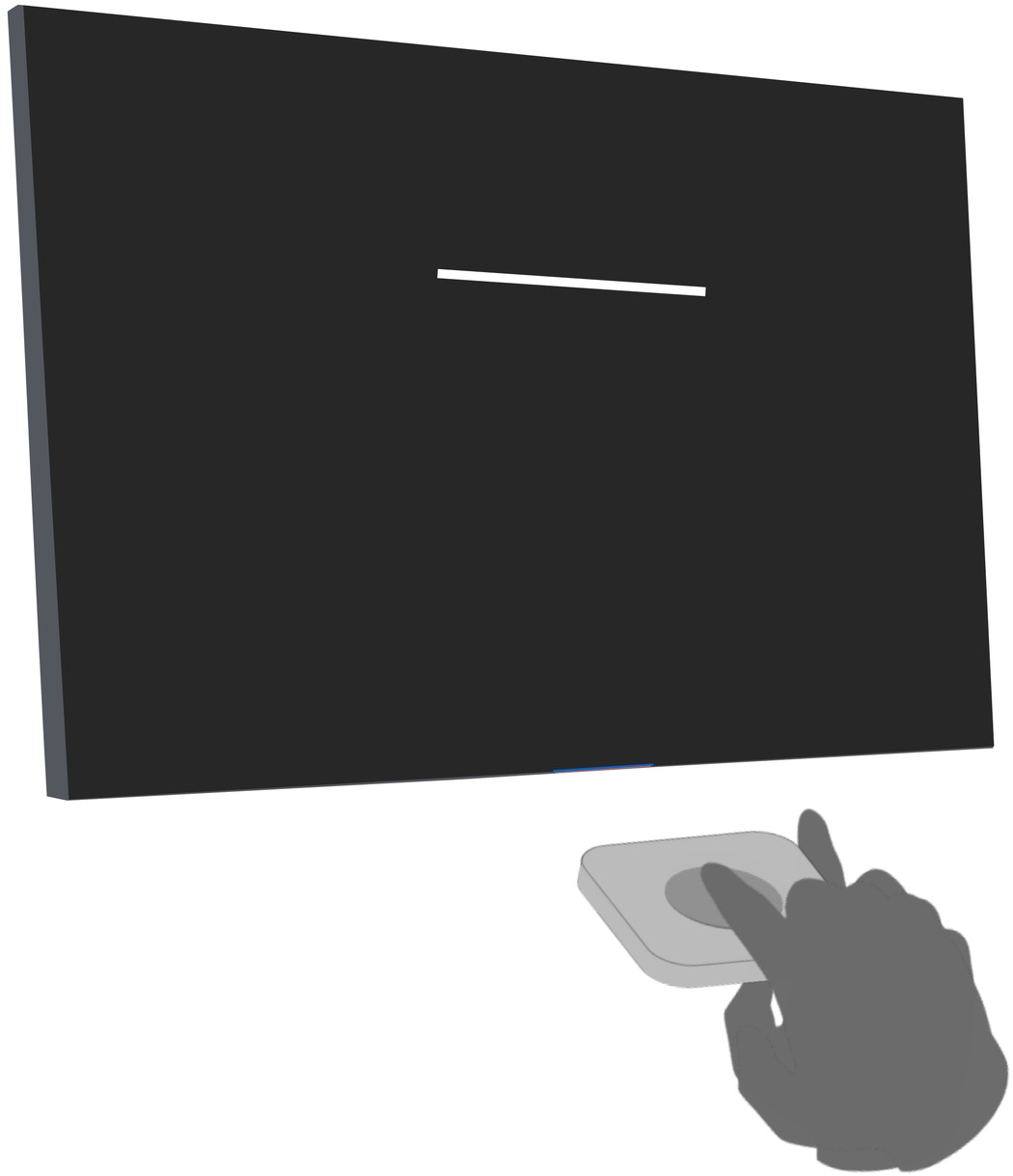


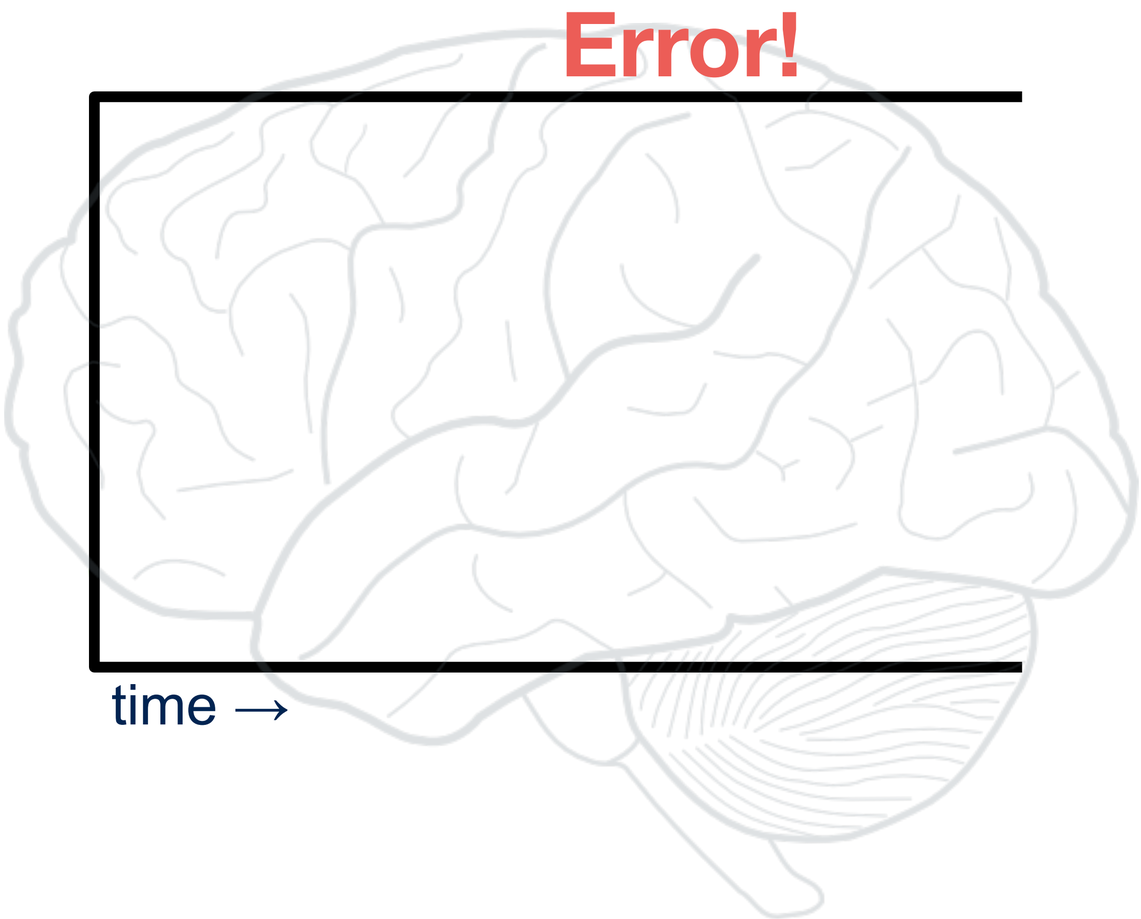

Go!
time →



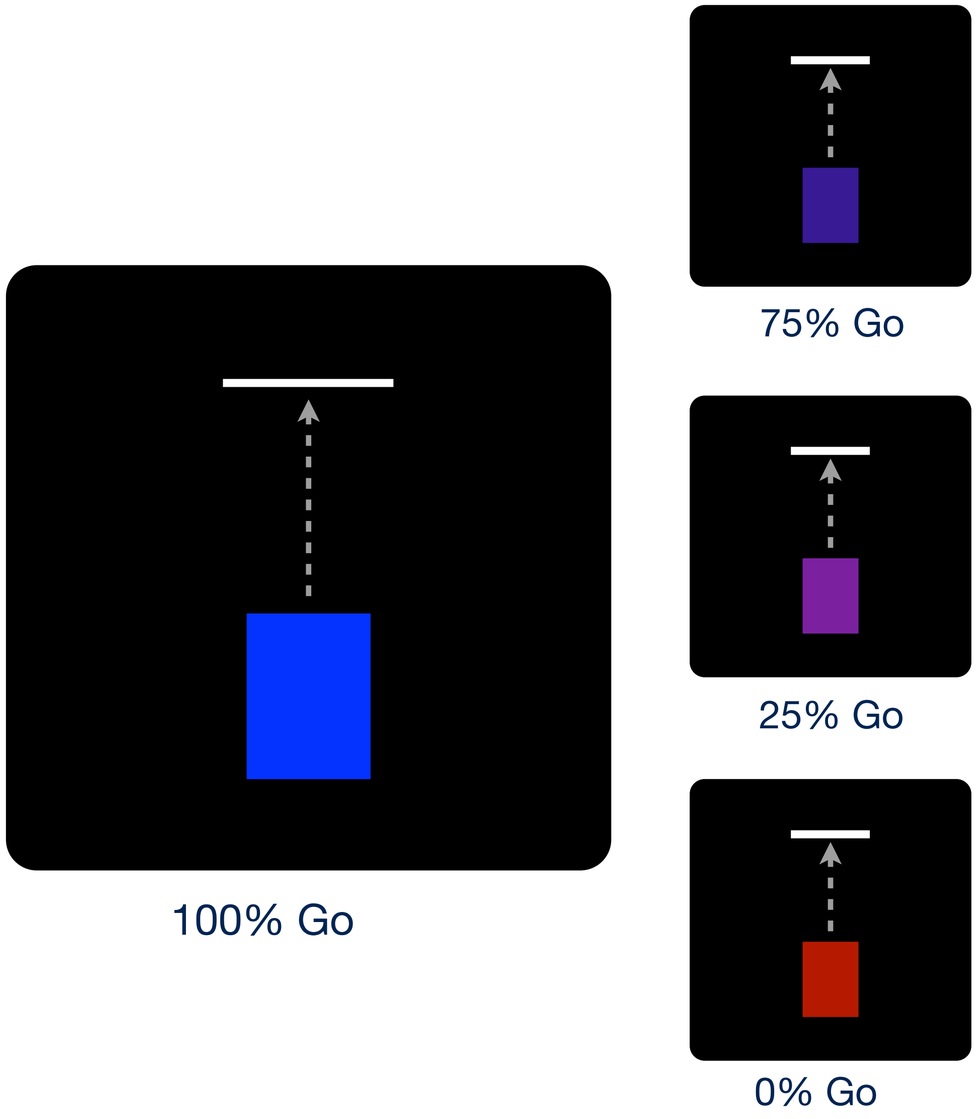
Stop!

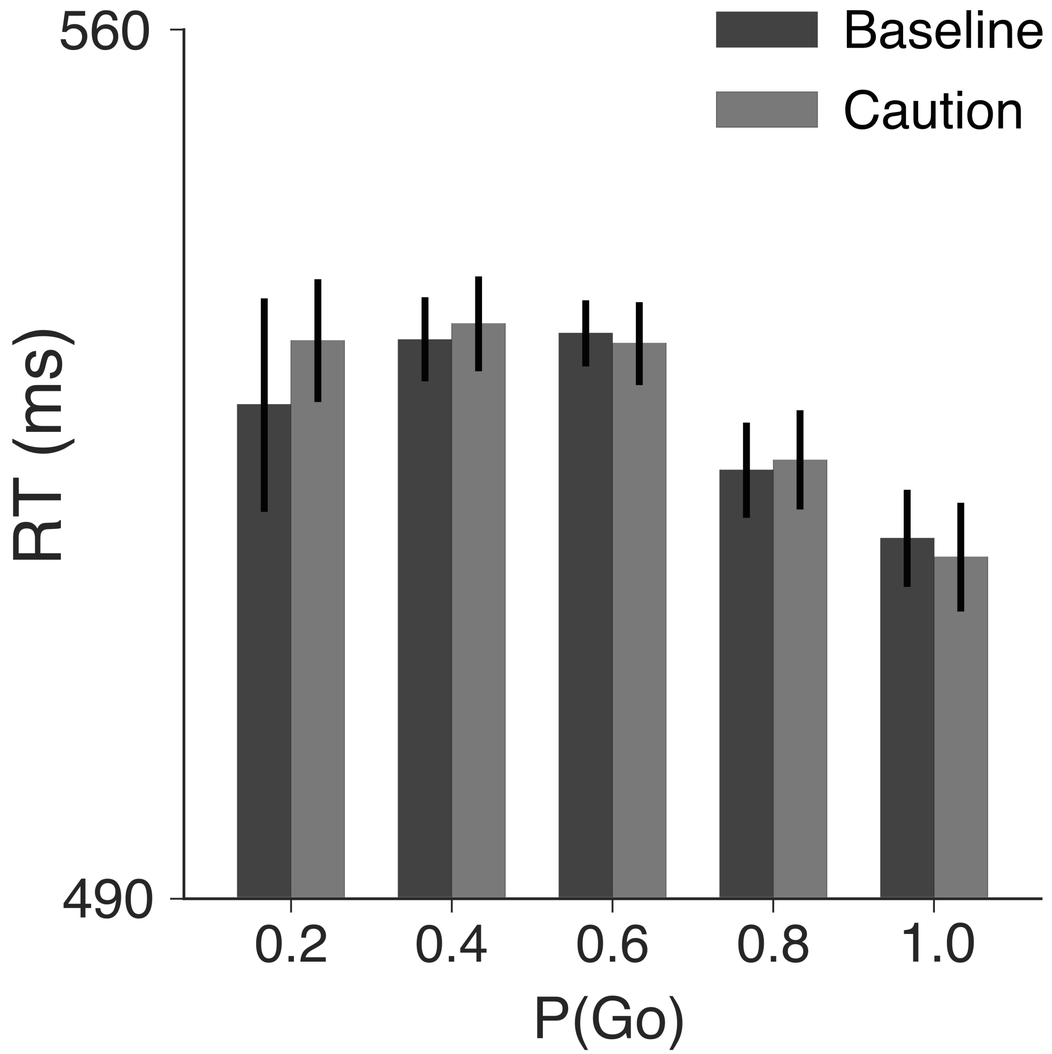
time →




Error!
time →

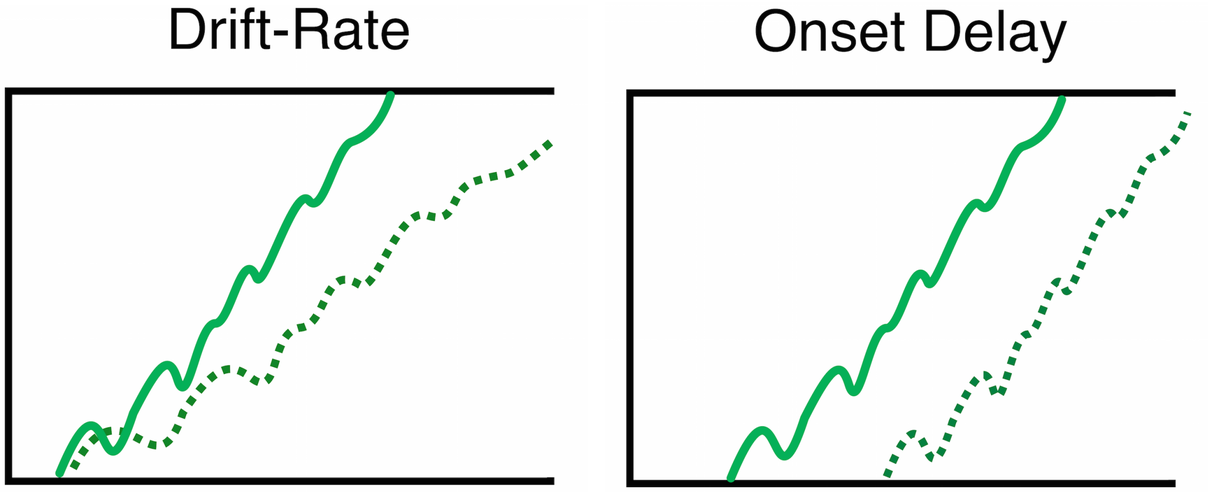
Proactive control

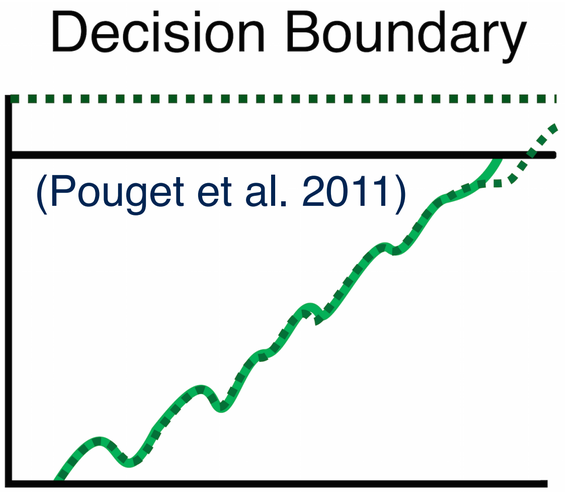


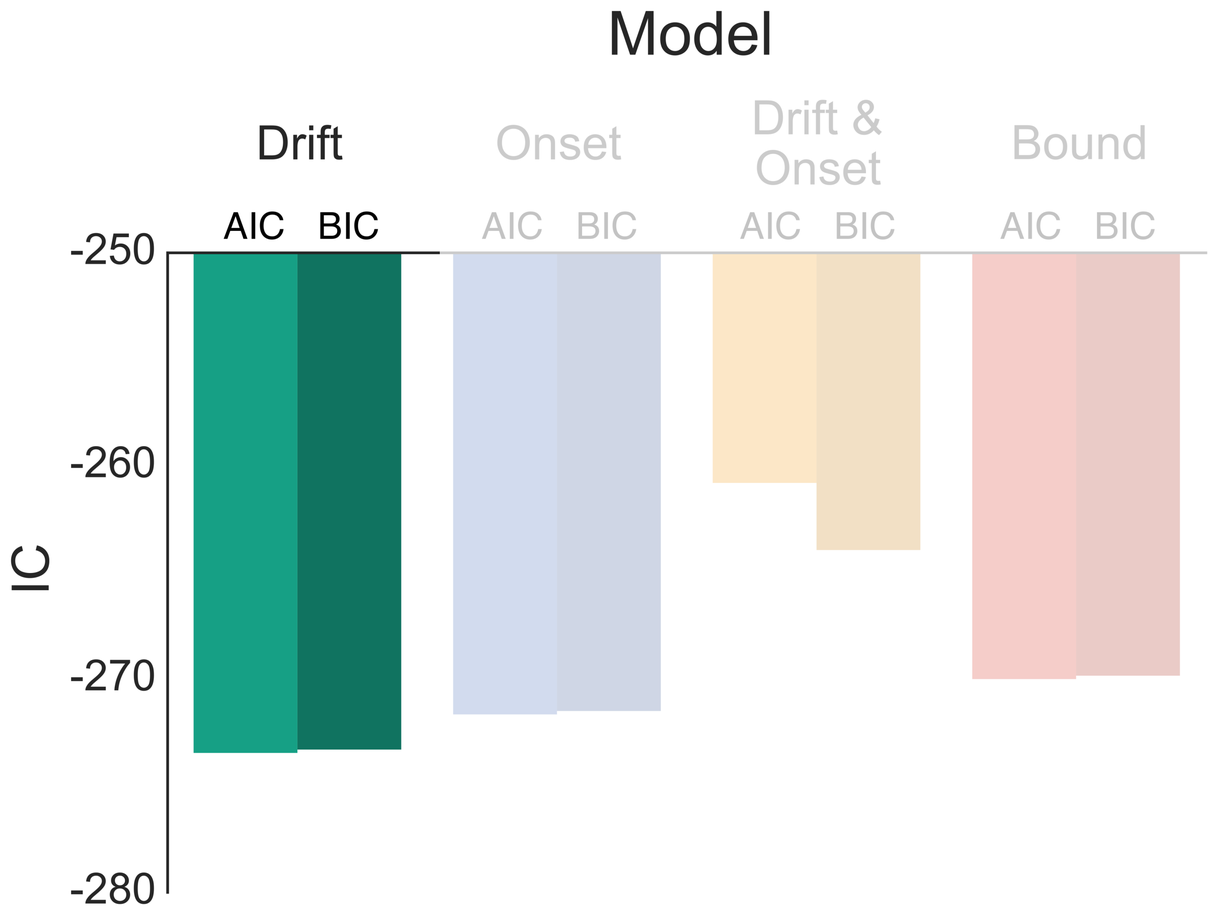


(Dunovan et al. 2015)

Models

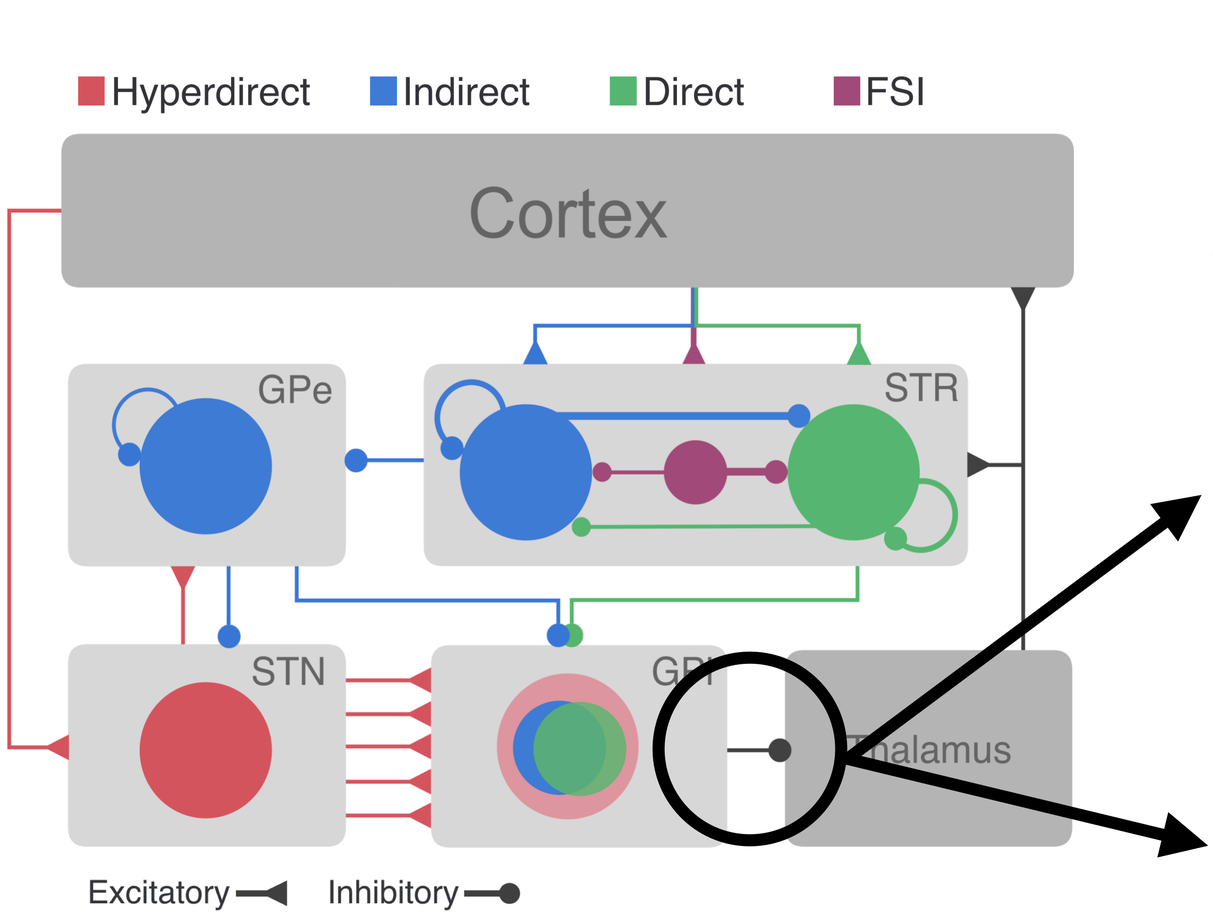


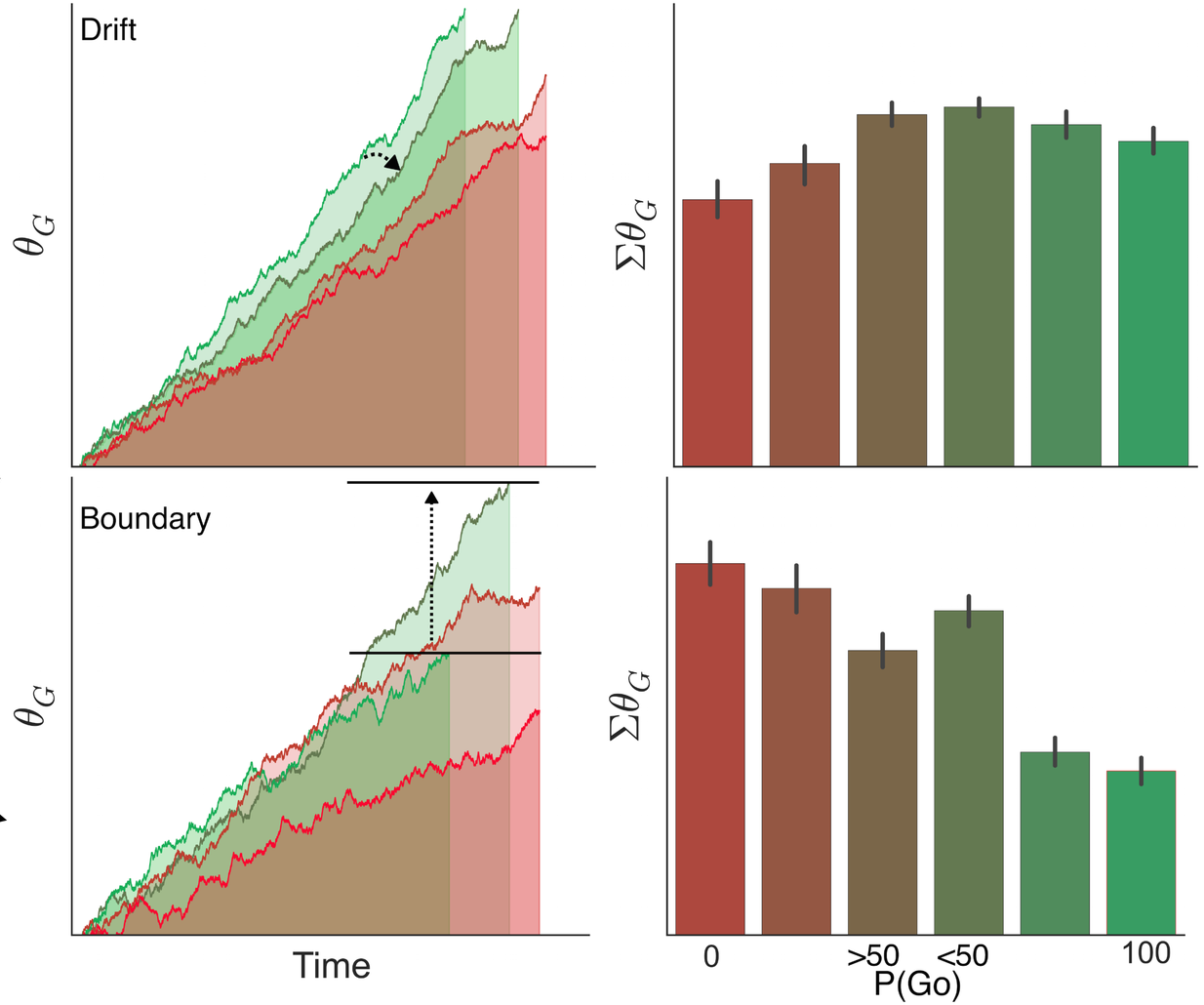




(Dunovan et al. 2015)

Predicting CBGT output

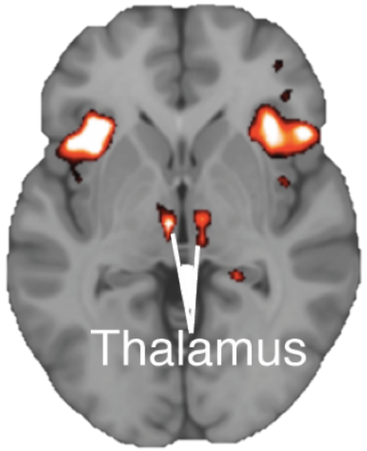


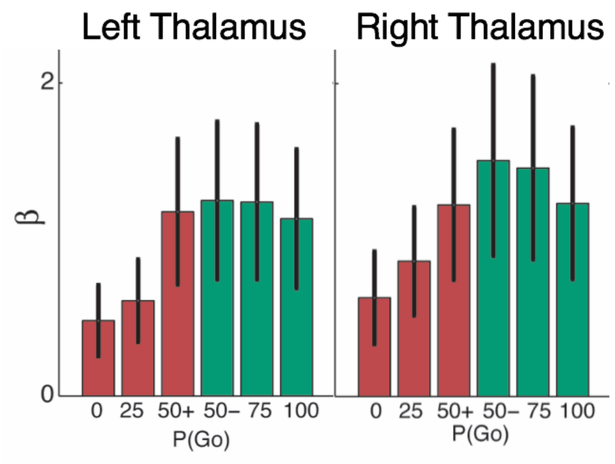


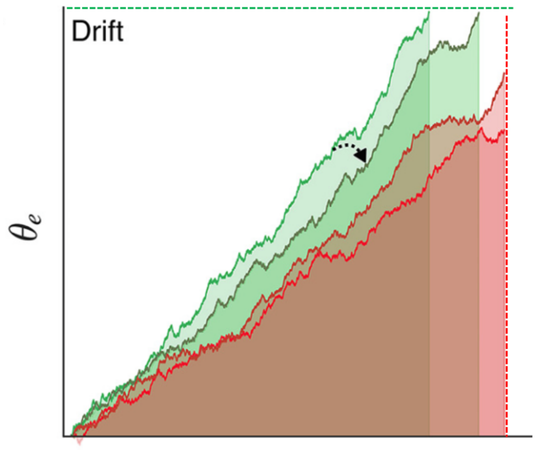
(Dunovan et al. 2015)

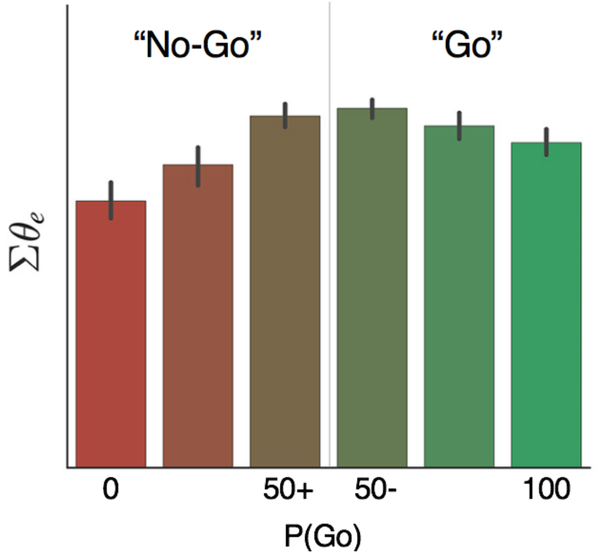
Predicting CBGT output

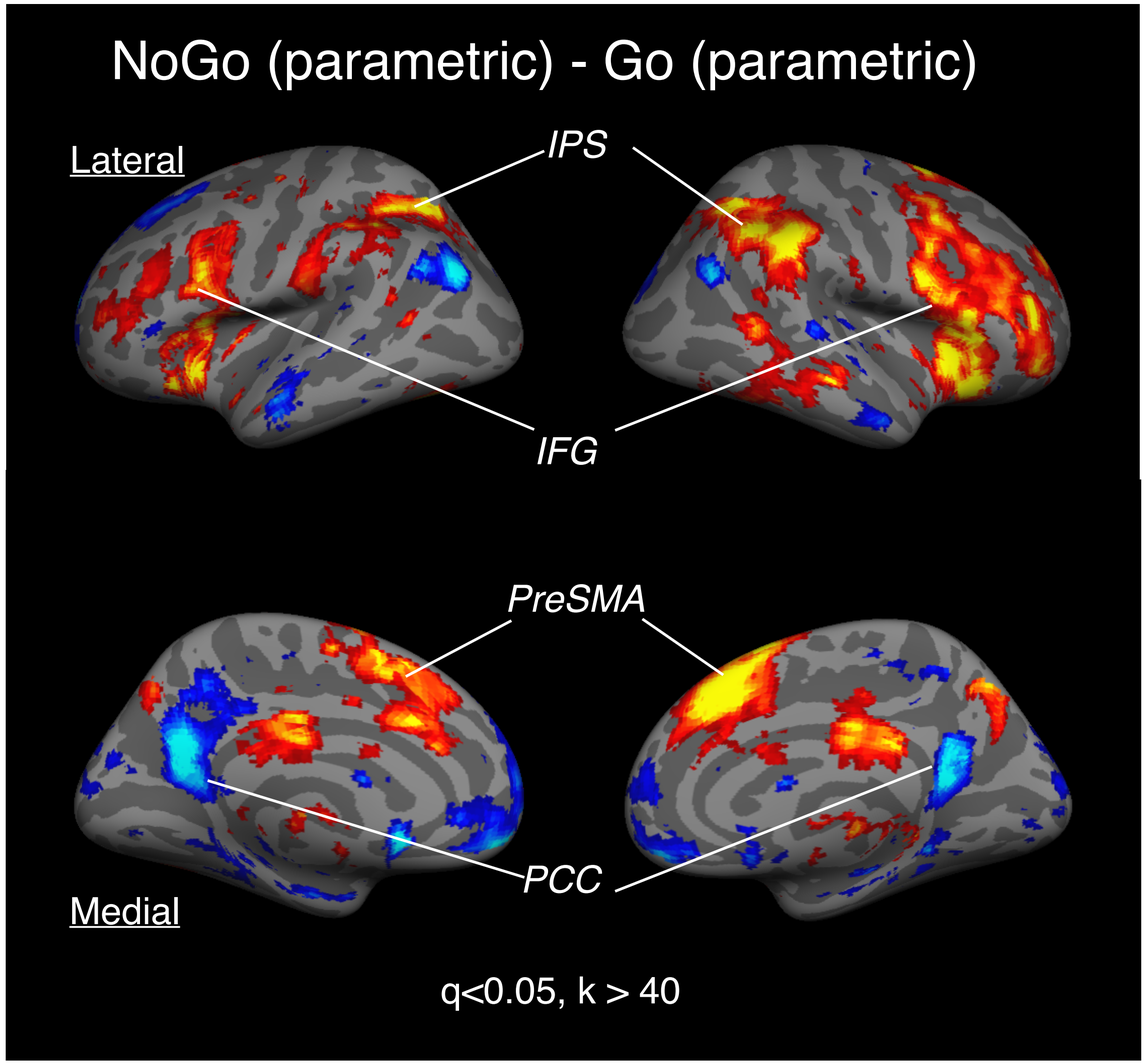
C.









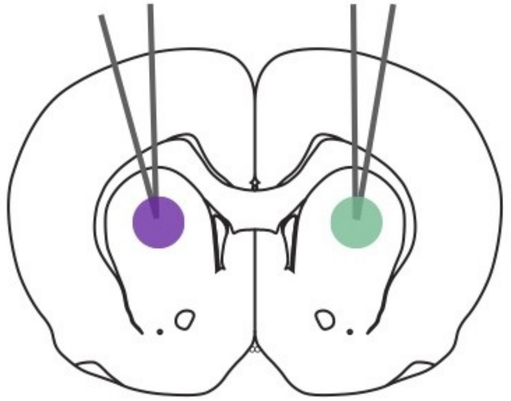


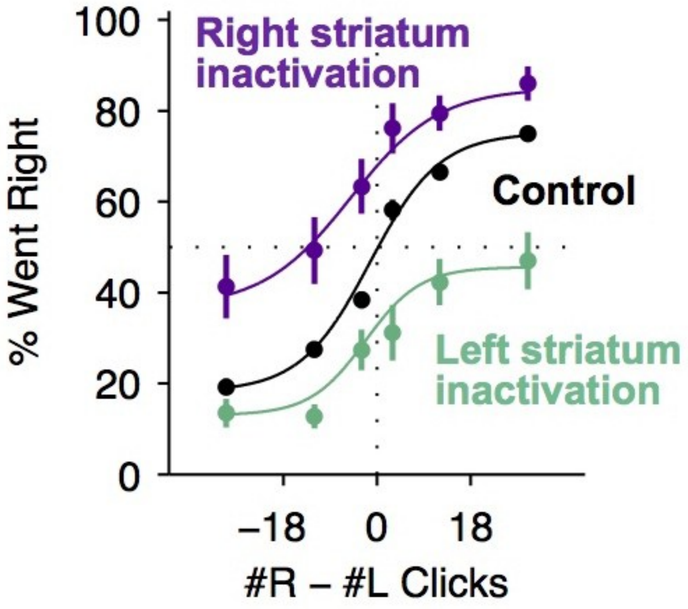
(Dunovan et al. 2015)

Causal evidence?

Unlike cortical areas, such as LIP (Latimer et al. 2015) …

- Unilateral inactivation of striatum biases decisions biases decisions to the ipsilateral side.
- Bilateral inactivation reduces decision precision.
- Change in behavior tied to reduction in rate of evidence accumulation.





(Yartzev et al. 2018)

Believer-Skeptic debate

- Both readings made the case that the architecture of neural circuits can provide insights into the algorithms that they implement. Is this a reasonable assumption to have when trying to map from implementation levels to algorithmic levels?

Believers: Provide an argument for why this is a reasonable assumption.

Skeptics: Provide an argument for why this may be a fallacy.