Assessing the need for biological plausibility in cognitive modelling

a focus on basal ganglia without segregated pathways

What is at stake?

- Is biological plausibility needed for AI and cognitive modelling?

  → compare the results of a simple vs more detailed model

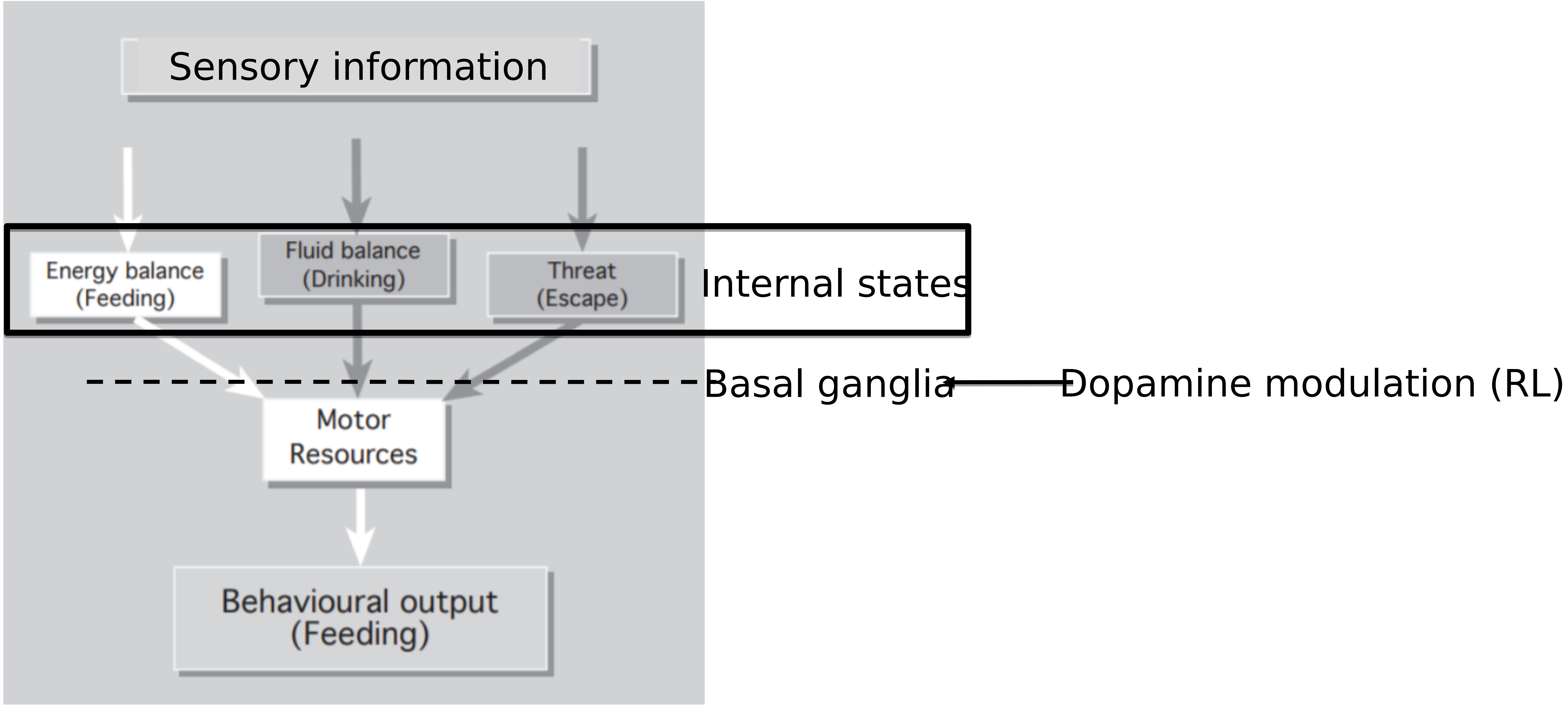
- How to interpret the evaluation of computational models?

  → use the models in a cognitive architecture that performs a naturalistic task

- How to model the relations between Parkinson's disease and high-level cognition?

  → simulate it within the cognitive architecture

Focus on basal ganglia



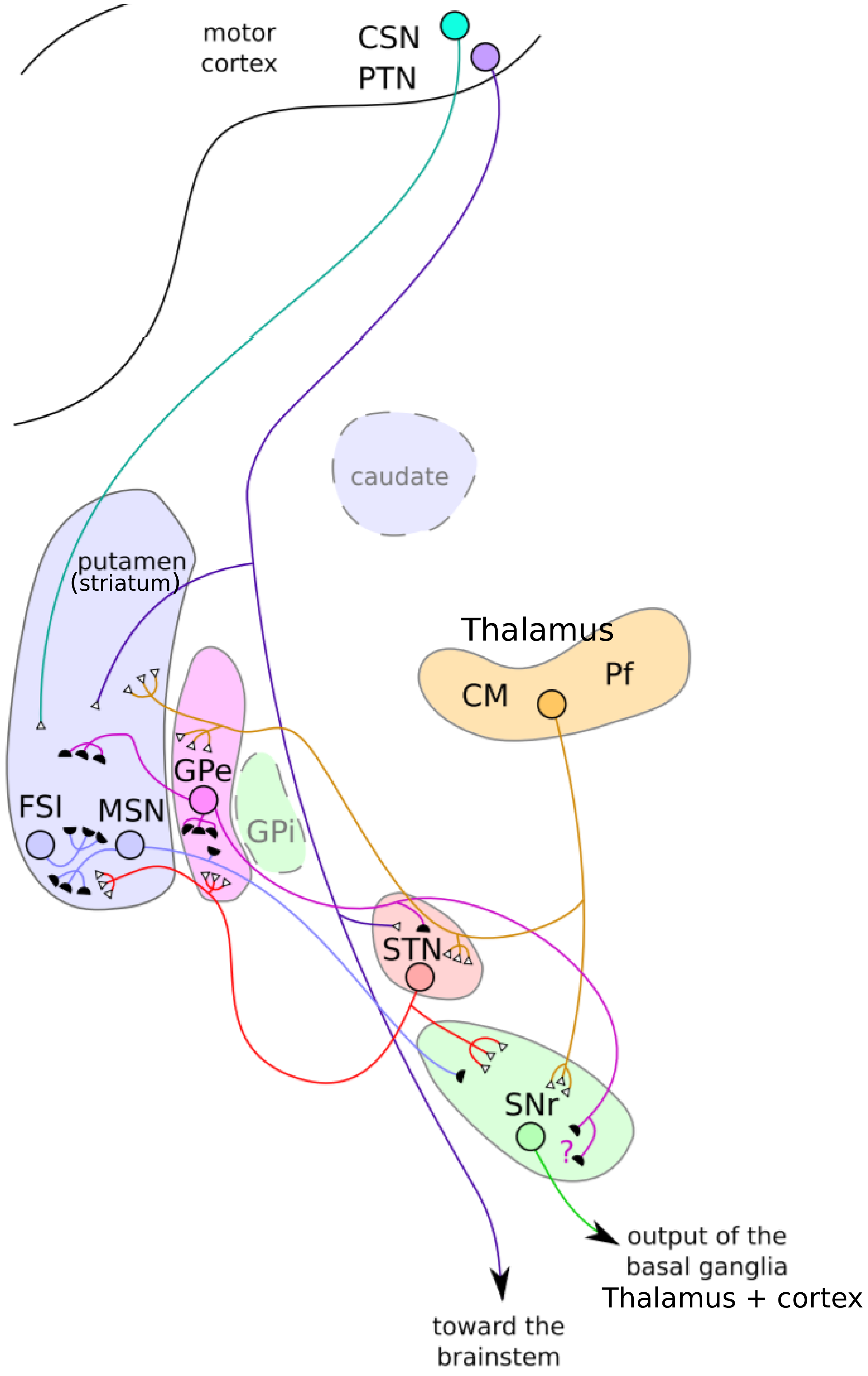
Adapted from Redgrave et al. (1999)

Focus on basal ganglia

- Inputs: cortex → Striatum
- Dopaminergic input: SNc Striatum (Parkinson’s disease)
- GPe
- STN
- Outputs: GPi/SNr → Thalamus → Cortex

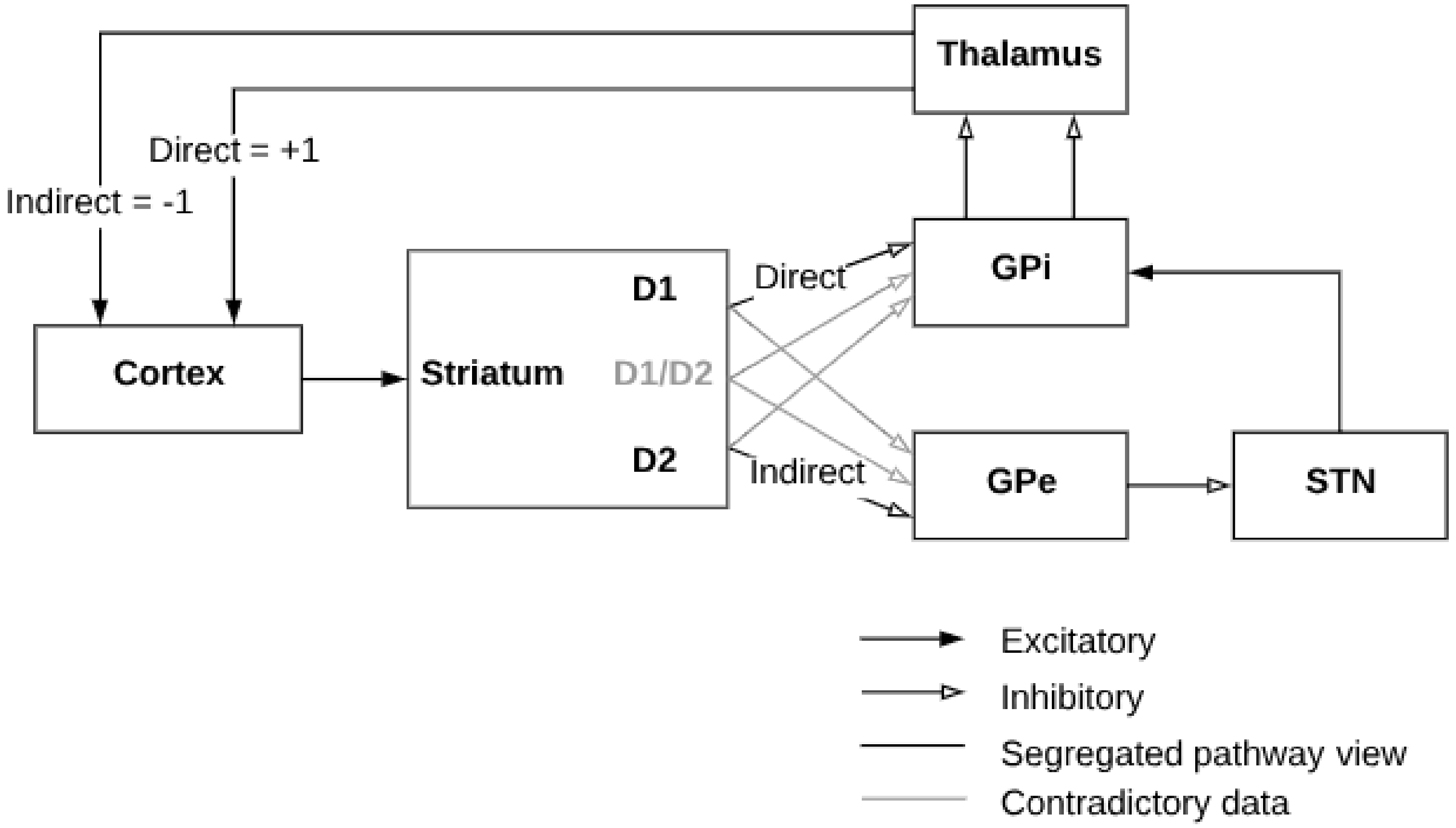
Anatomy of basal ganglia

- Inputs: cortex -> Striatum
- Computation in intrinsic nuclei:
  - GPe
  - STN
- Outputs: GPi/SNr -> Thalamus -> Cortex



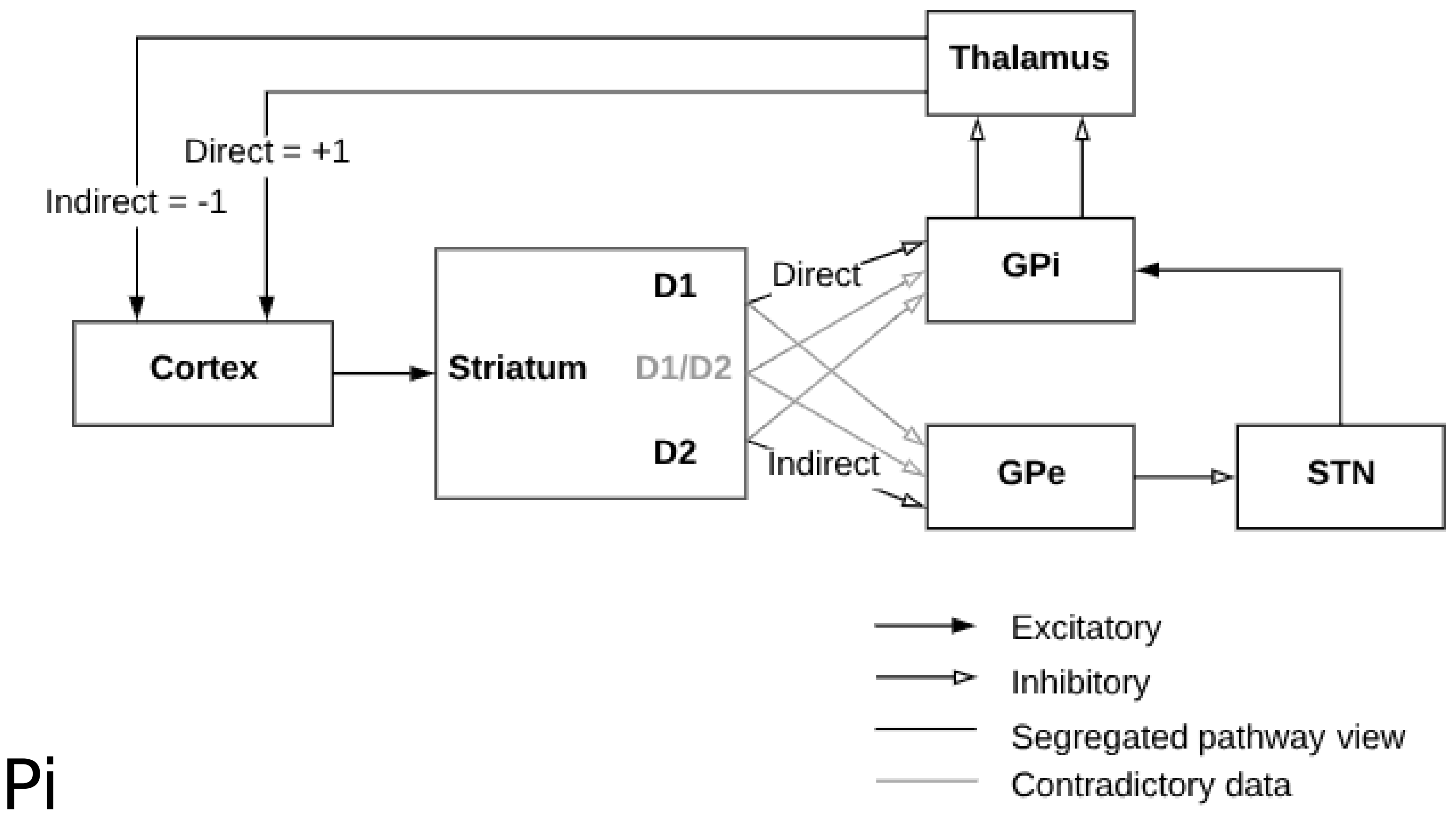
The myth of segregated pathways

- Canonical model: Albin et al. (1989) contains segregated pathways
  - Direct pathway: selects best action
  - Indirect pathway: inhibit concurrent actions
- Contradicted by anatomical data



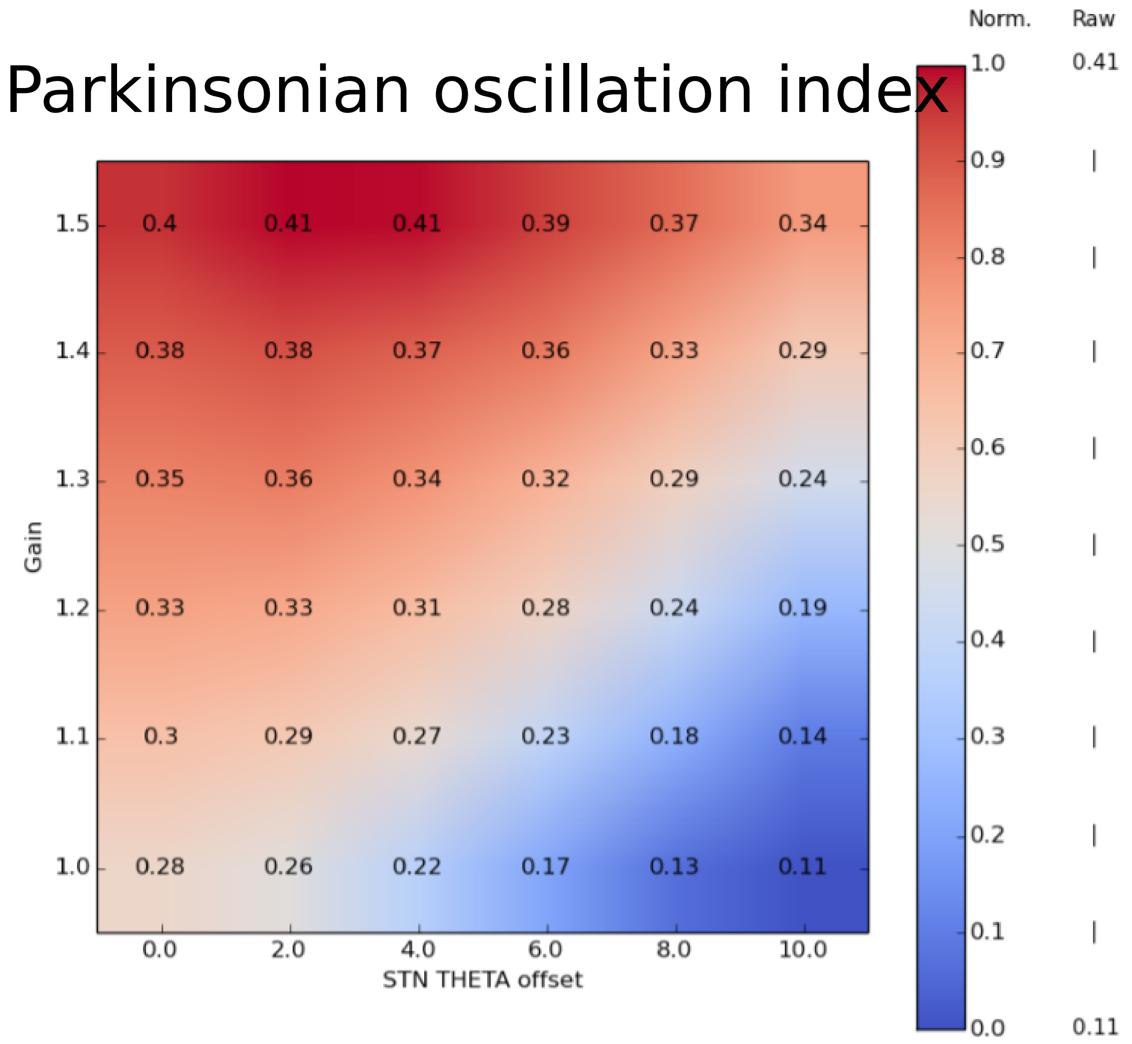
The myth of segregated pathways

- Canonical model: Albin et al. (1989) contains segregated pathways
  - Direct pathway: selects best action
  - Indirect pathway: inhibit concurrent actions
- Contradicted by anatomical data:
  - Almost every Striatum’s MSN → both GPi and Gpe in both primates and rats
  - Up to 60% of MSN express both D1 and D2



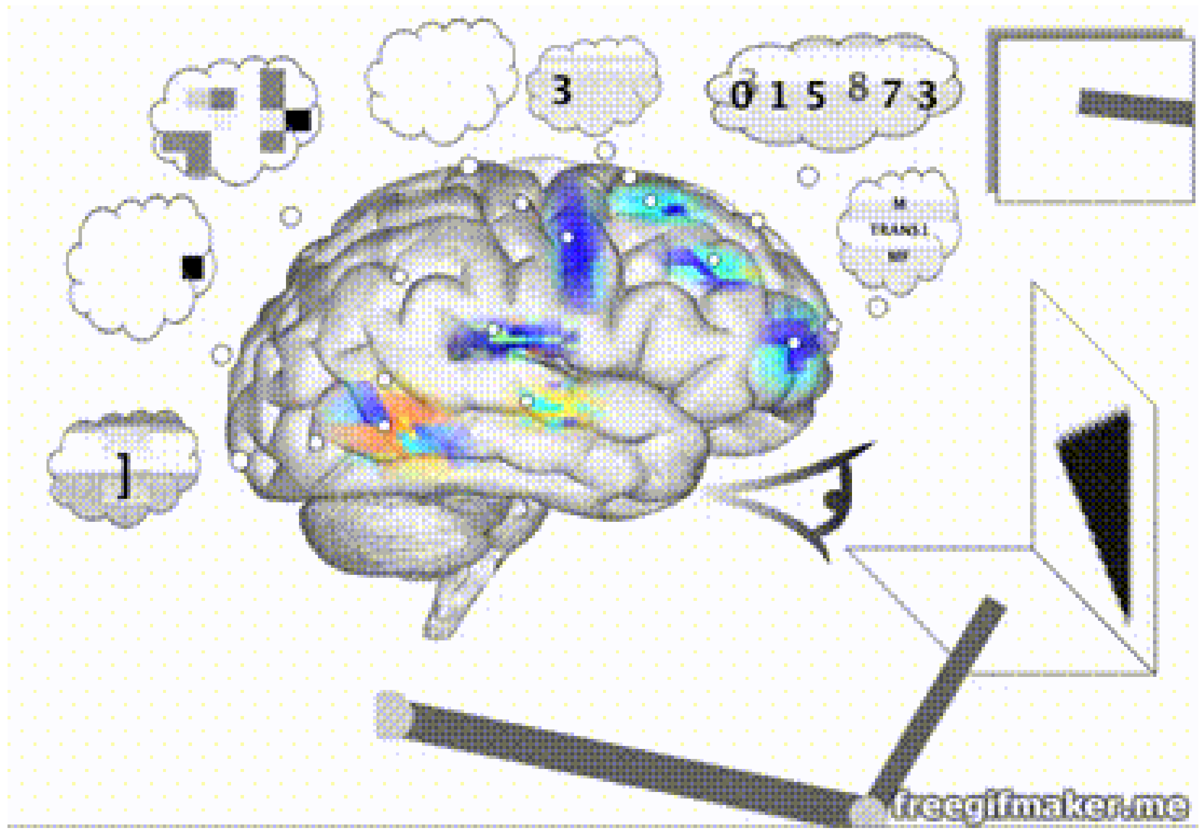
Biologically constrained model of Basal Ganglia (BioBG)

- Takes into account contradictory data
- Still capable of action selection
- Can exhibit parkinsonian behavior



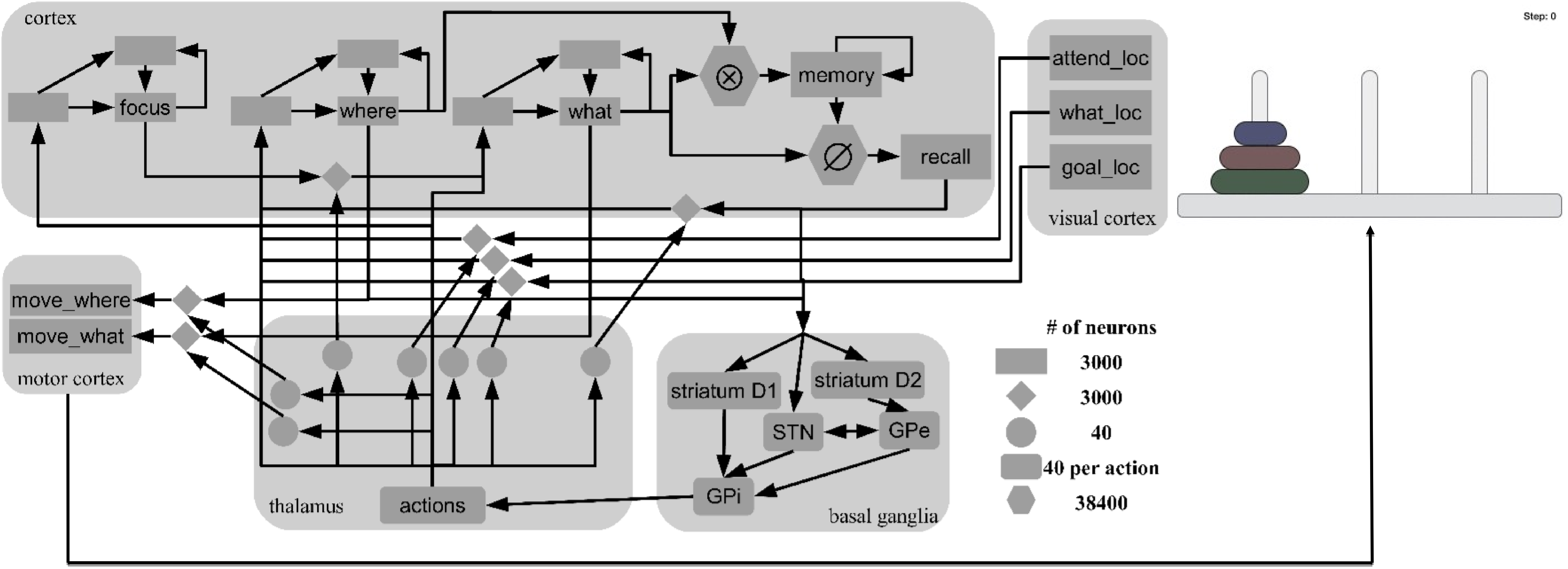
Project outline

1. Implementation BioBG in Nengo, a simulator of spiking neurons for cognitive modelling
2. Find a Nengo project which uses a BG model to solve a task, and use BioBG instead



A neural model of the Tower of Hanoi Task

- Visual input/Motor output
- Cortical states
- Basal ganglia to choose next cortical states
- Thal

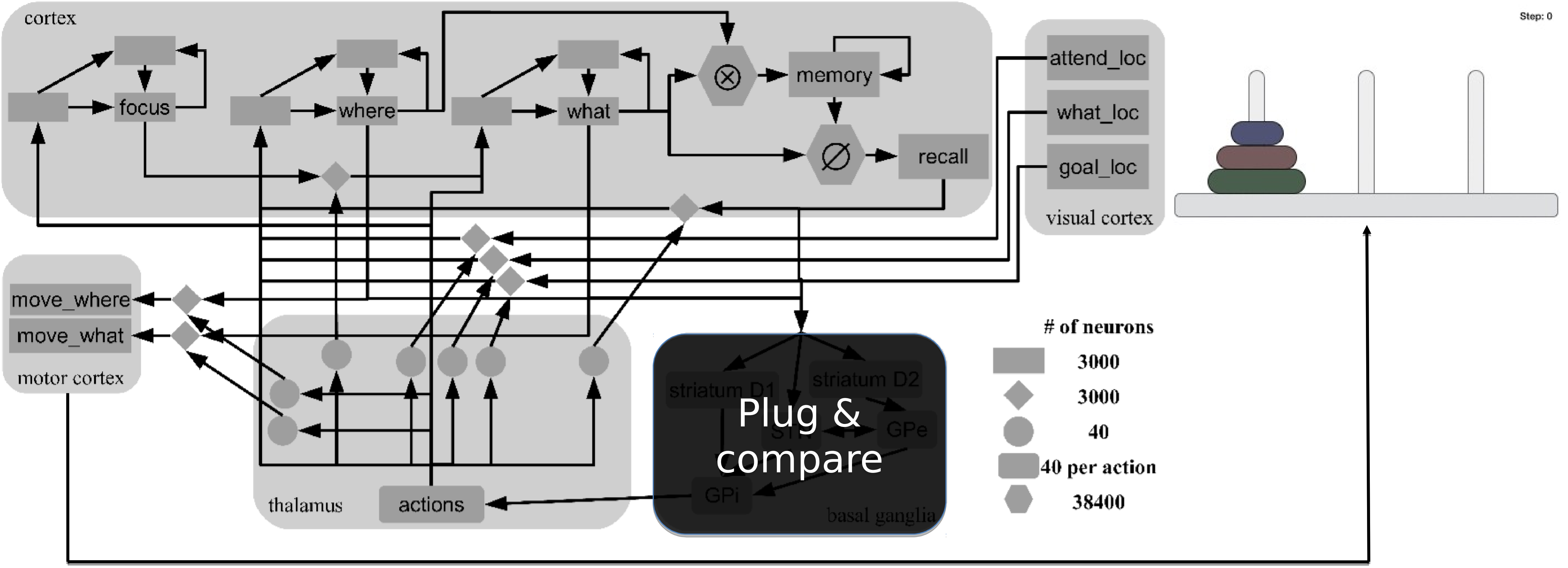


Adapted from Stewart and Eliasmith (2011)

Simple and general implementation → plug & compare

- Arbitrary number of actions
- No external dependency
- No modification to Nengo’s source code

→ can l



Adapted from Stewart and Eliasmith (2011)

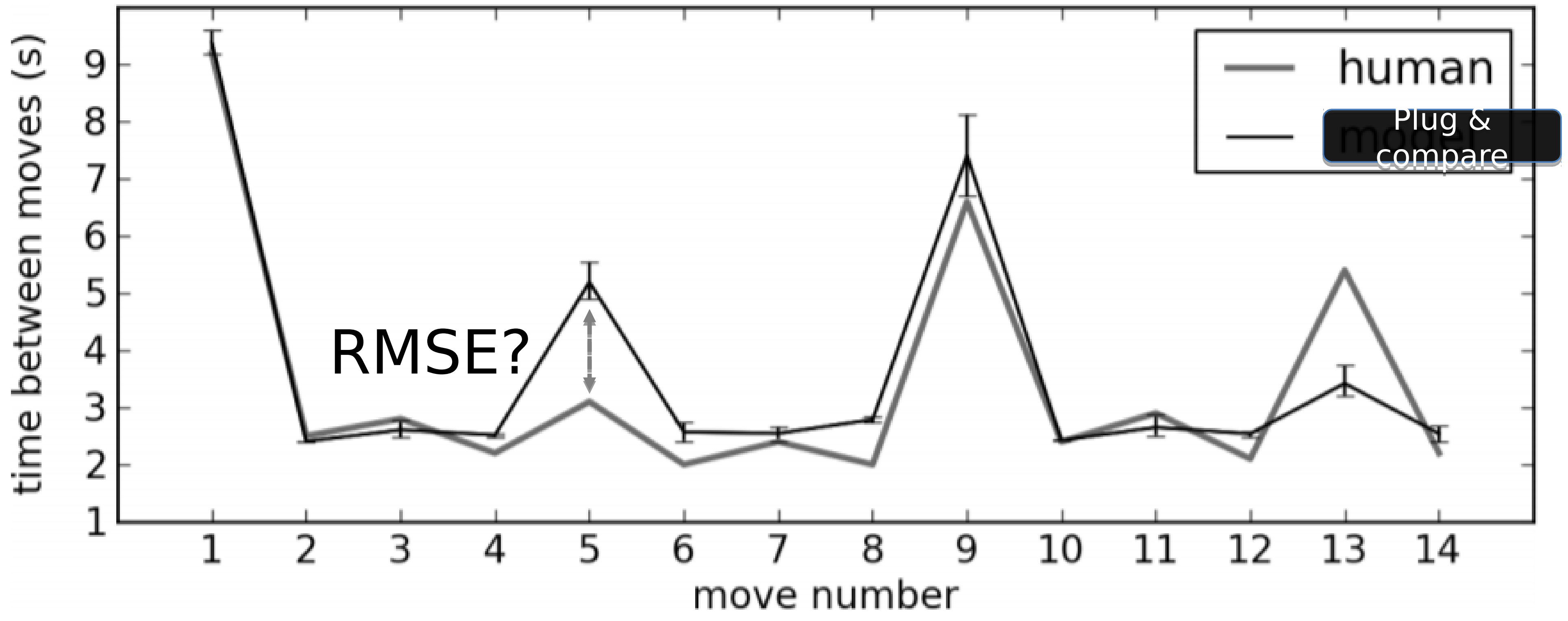
Hypothesis 1: BioBG is more efficient

Action selection:

- Accuracy
- Speed

Hypothesis 2: behavioral data fitting

BioBG better fits human data?



Hypothesis 3 (longer-term): BioBG+cognitive model can fit pathological behavioral data

ELSEVIER

Neuropsychologia
Volume 57, May 2014, Pages 12-19

A deficit in optimizing task solution but robust and well-retained speed and accuracy gains in complex skill acquisition in Parkinson׳s disease: Multi-session training on the Tower of Hanoi Puzzle

Eli Vakil [a], Sharon Hassin-Baer [b, c], Avi Karni [d]

⊞ Show more

https://doi.org/10.1016/j.neuropsychologia.2014.02.005

Eur J Neurol. 2007 Mar;14(3):300-4.

Behavioral persistence deficit in Parkinson's disease patients.

Schneider JS[1].

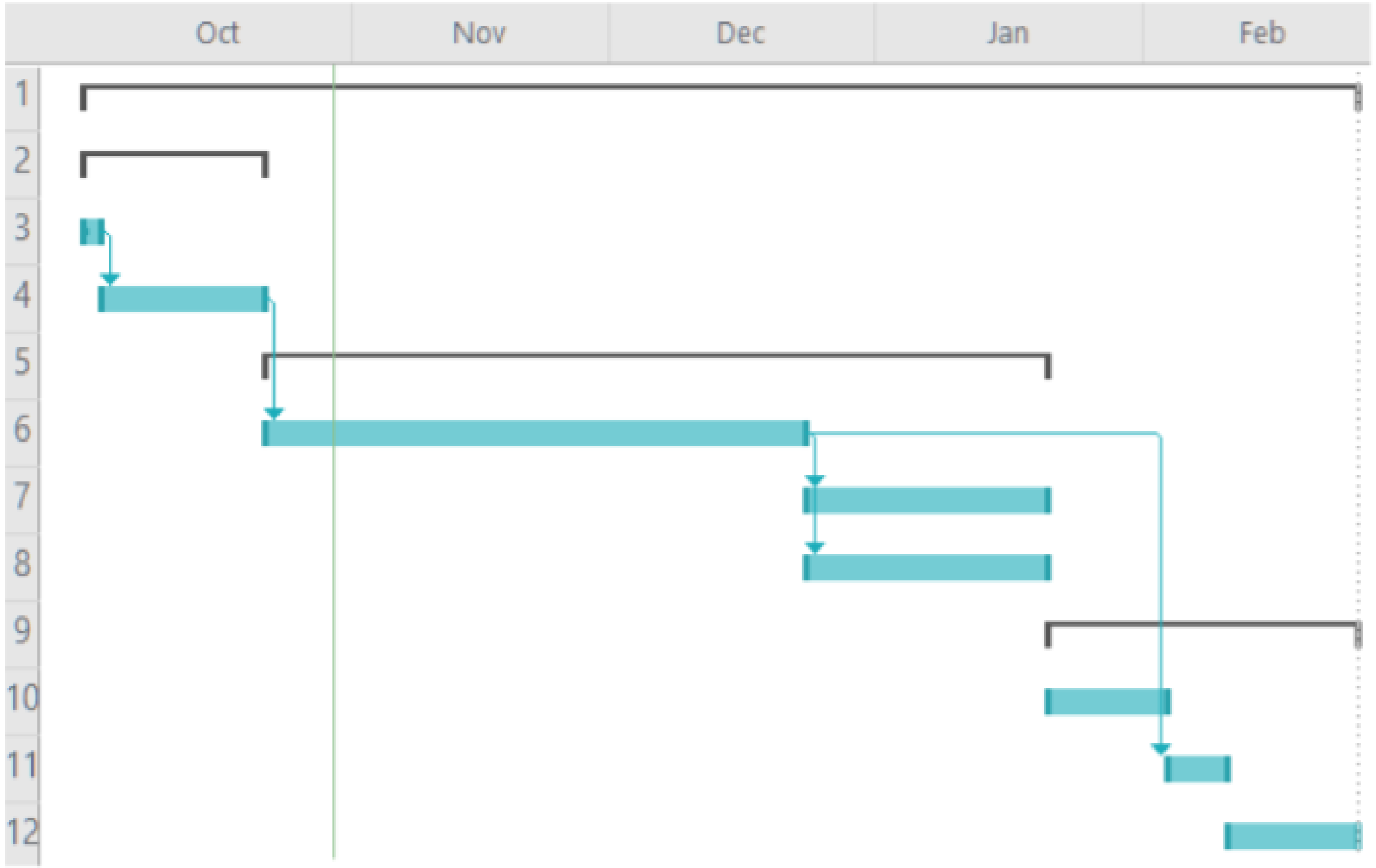
⊕ Author information

Abstract

The present study was performed to examine the degree to which decreased task persistence may contribute to deficits in the ability of Parkinson's disease (PD) patients to perform a problem solving task. Patients with mild/moderate PD performed a computerized Tower of Hanoi task in which they planned and verbalized moves to solve the puzzle but did not need to produce a limb motor response. All patients were tested at least 14 h off medication. As expected from previous studies of planning abilities in PD, patients had significant problems performing this task and accuracy decreased specifically when patients were presented with the most difficult puzzles in the sequence. PD patients solved fewer of the most difficult puzzles than did control subjects, but also made significantly fewer attempts to solve those puzzles than controls. These results suggest that PD patients not only have planning and problem solving deficits as have been documented previously, but that at least part of this and perhaps other cognitive performance problems may result from difficulty in maintaining adequate mental effort to successfully complete difficult tasks.

PMID: 17355551 DOI: 10.1111/j.1468-1331.2006.01647.x

Schedule



#	Task	Start	Finish	Workload (h)
1	**Total**	**01/10/2018**	**25/02/2019**	**168**
2	**Setup**	**01/10/2018**	**21/10/2018**	
3	Install Nengo	01/10/2018	02/10/2018	1
4	Familiarize with Nengo	03/10/2018	21/10/2018	24
5	**sBCBG**	**22/10/2018**	**20/01/2019**	
6	Implement sBCBG in Nengo	22/10/2018	23/12/2018	71
7	Test action selection	24/12/2019	20/01/2019	16
8	Test PD oscillations	24/12/2019	20/01/2019	16
9	**sBCBG in TOH model**	**21/01/2019**	**25/02/2019**	
10	Get familiar with TOH model	21/01/2019	03/02/2019	16
11	Replace BG with sBCBG	04/02/2019	10/02/2019	8
12	Analyze results	11/02/2019	25/02/2019	16

NB: “sBCBG”=“BioBG”

Take home message

I believe my project is a good framework for:

- comparing a **biologically plausible** model with a “**simpler**” one (Bottom-up vs Top-down)
- **Interpreting** the performance of **computational models**
- Studying the relations between **Parkinson’s** disease, **basal ganglia**, and high level **cognition**