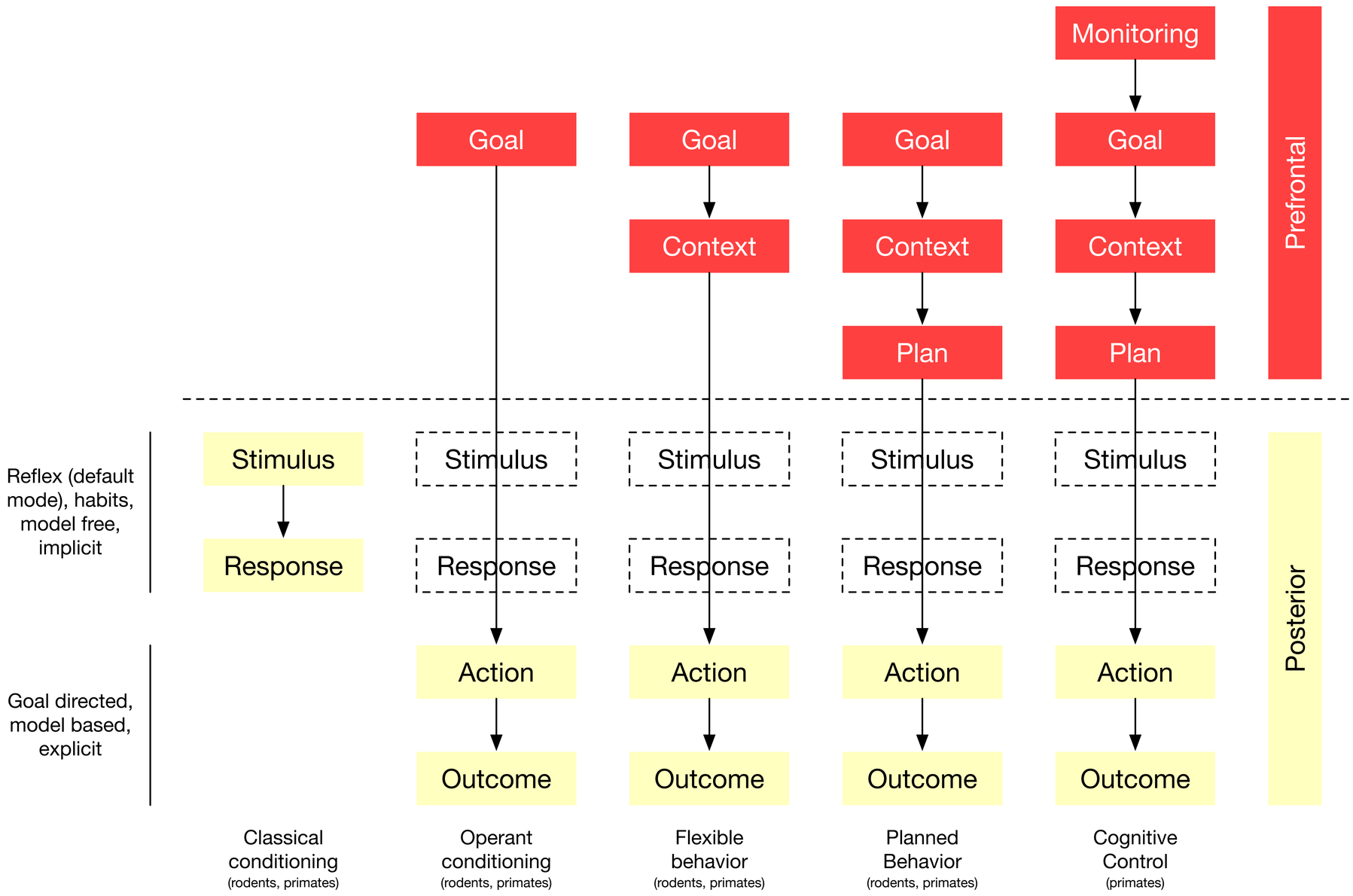
Computational models to explore constituents of Cognitive Control

Snigdha Dagar, Frédéric Alexandre, Nicolas P. Rougier
Institut des Maladies Neurodégénératives, Inria, Universite de Bordeaux
snigdha.dagar@inria.fr

Introduction



Central to nearly all definitions of executive function are two concepts : *rules* and *control*. The rules that guide human behavior are abstract and flexible.

Control processes allow us to engage rules appropriate to a particular context. The PFC is believed to provide the ability to contextualise concrete rules that leads to the acquisition of abstract rules. This involves two aspects

(1) creating and modifying rules for behavior

(2) engaging the appropriate rule for a particular context

Figure 1 : Schematic figure illustrating the gradients of Cognitive Control

Hierarchical model with Selective Attention

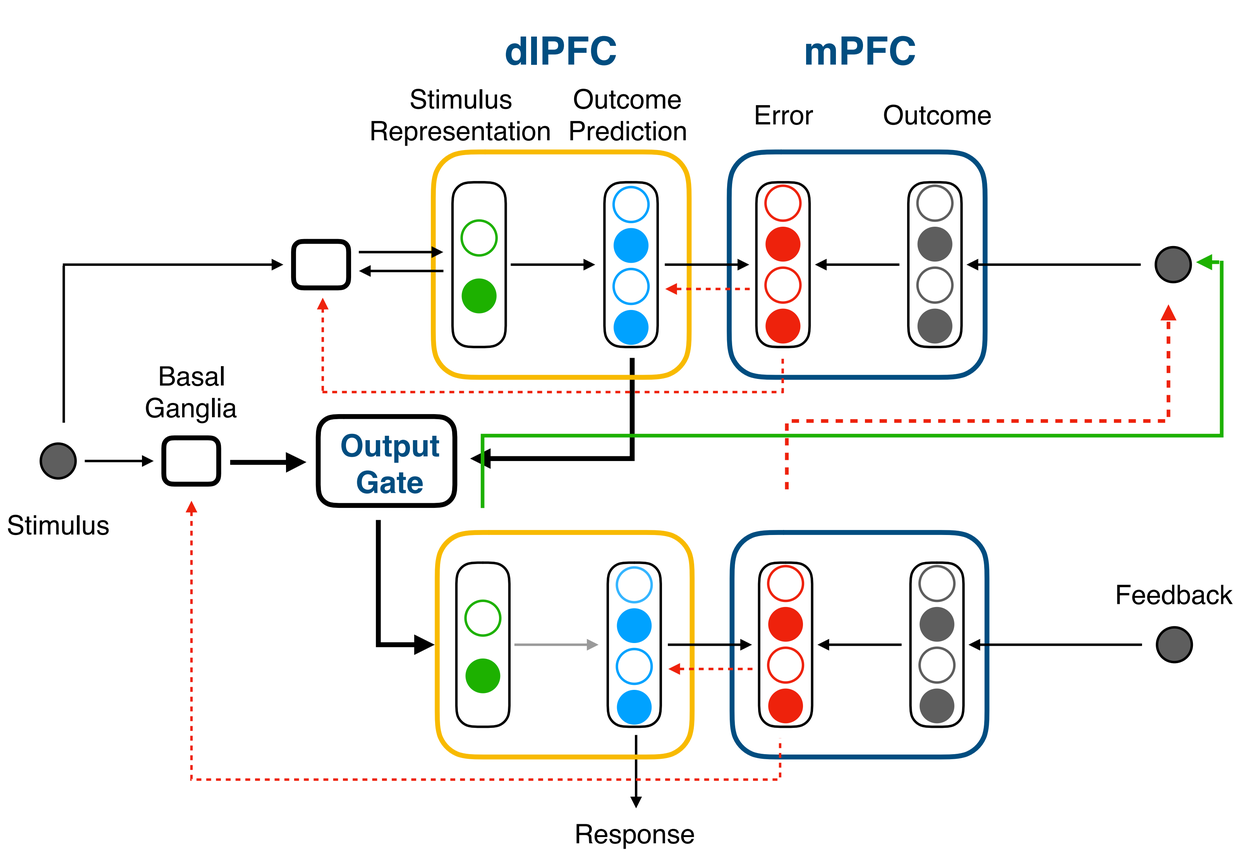


Figure 2 : A hierarchical model of the medial-lateral PFC interactions, with top-down control exerted through an output gate [1] [2]

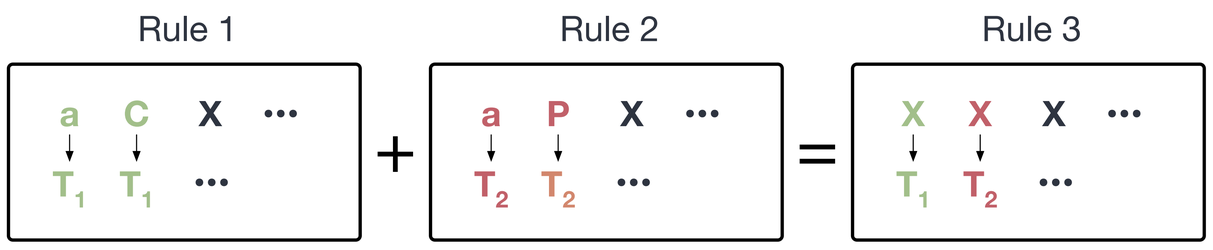
The **mPFC** is responsible for the prediction and monitoring of errors. The error representations are used to refine predictions about likely outcomes

The **dlPFC** is responsible for the elaboration of contextual rules by learning to maintain representations of stimuli that reliably co-occur with outcome prediction errors.

Bottom up : Errors are broadcasted through the network, using proxy outcomes

Top-down : The output gate is used to select when and which representations should influence downstream processing

Concrete to Abstract Rules



T_1 : Vowel / Consonant discrimination T_2 : Upper / Lower case discrimination

Figure 3 : Rule 1 and Rule 2 requires the subject to attend to a single dimension of the stimulus while Rule 3 requires to attend to both and decide which rule to apply based on the third dimension (color), making it an abstract rule.

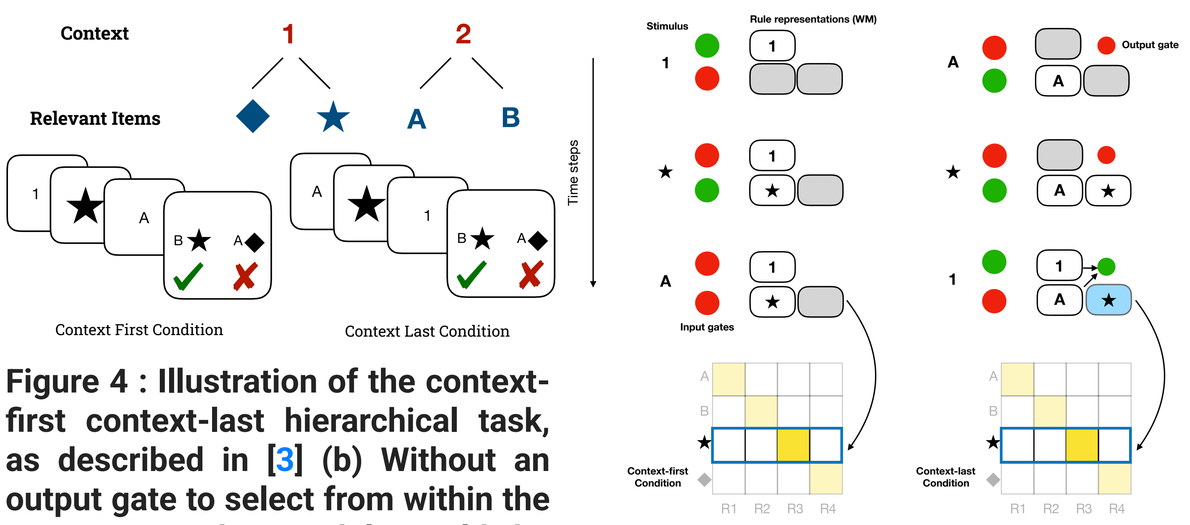
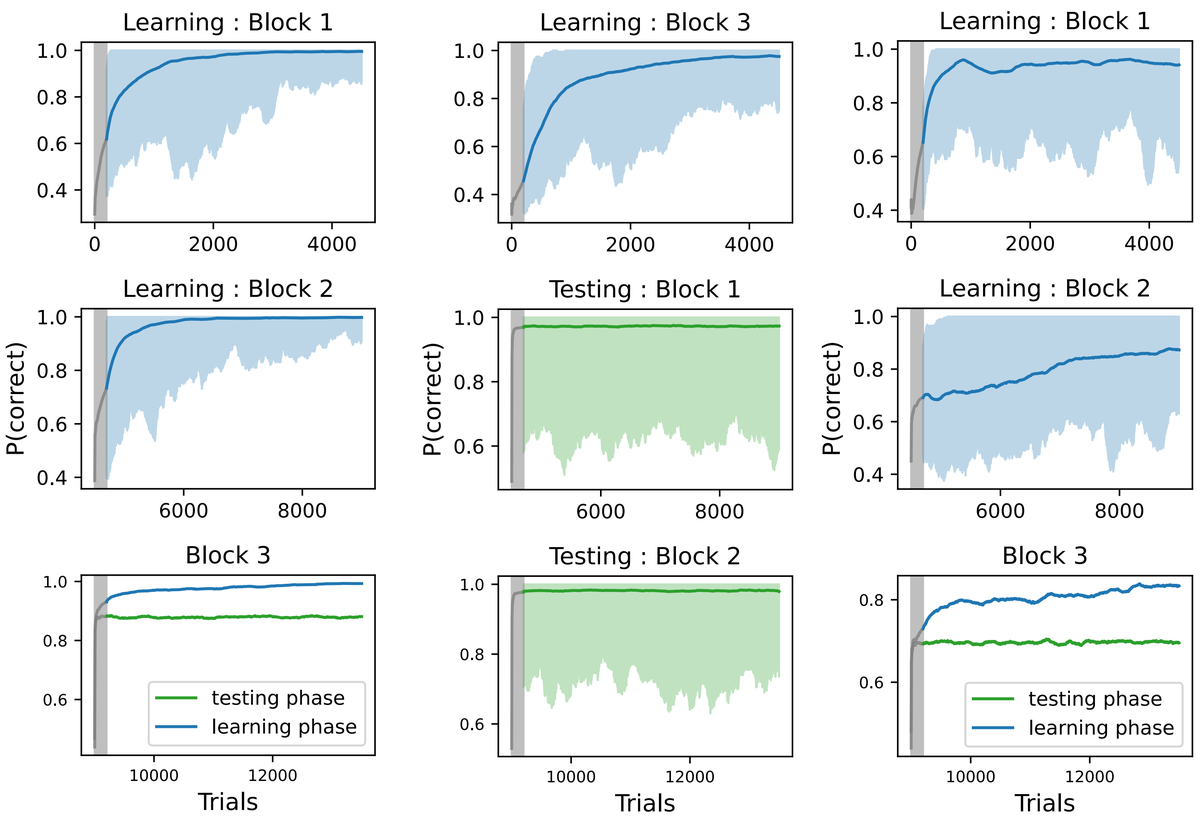


Figure 4 : Illustration of the context-first context-last hierarchical task, as described in [3] (b) Without an output gate to select from within the WM items, the model would be unable to select between the two maintained items in WM. The task of the higher layers is to select the appropriate mapping, based on the context.



References

[1] Dagar, S., Alexandre, F., Rougier, N. (2022). “From Concrete to Abstract Rules: A Computational Sketch”. *Brain Informatics. BI 2022*

[2] Alexander W. H. and Brown J. W. “Hierarchical error representation : a computational model of anterior cingulate and dorsolateral prefrontal cortex”. *Neural Computation 2015*

[3] Chatham C. H., Frank M. J., Badre D. “Corticostriatal output gating during selection from working memory”. *Neuron 2014*