Interaction between the limbic and sensori-motor cortico-basal loops : a systemic framework to explain animal behaviour

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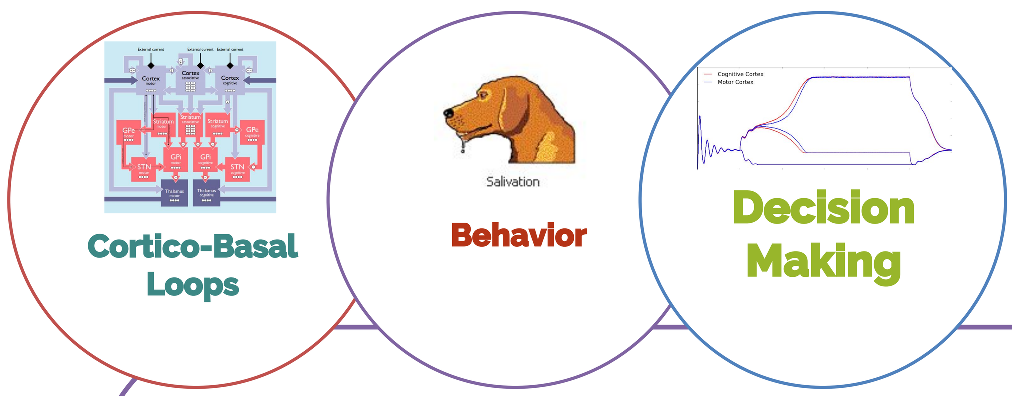
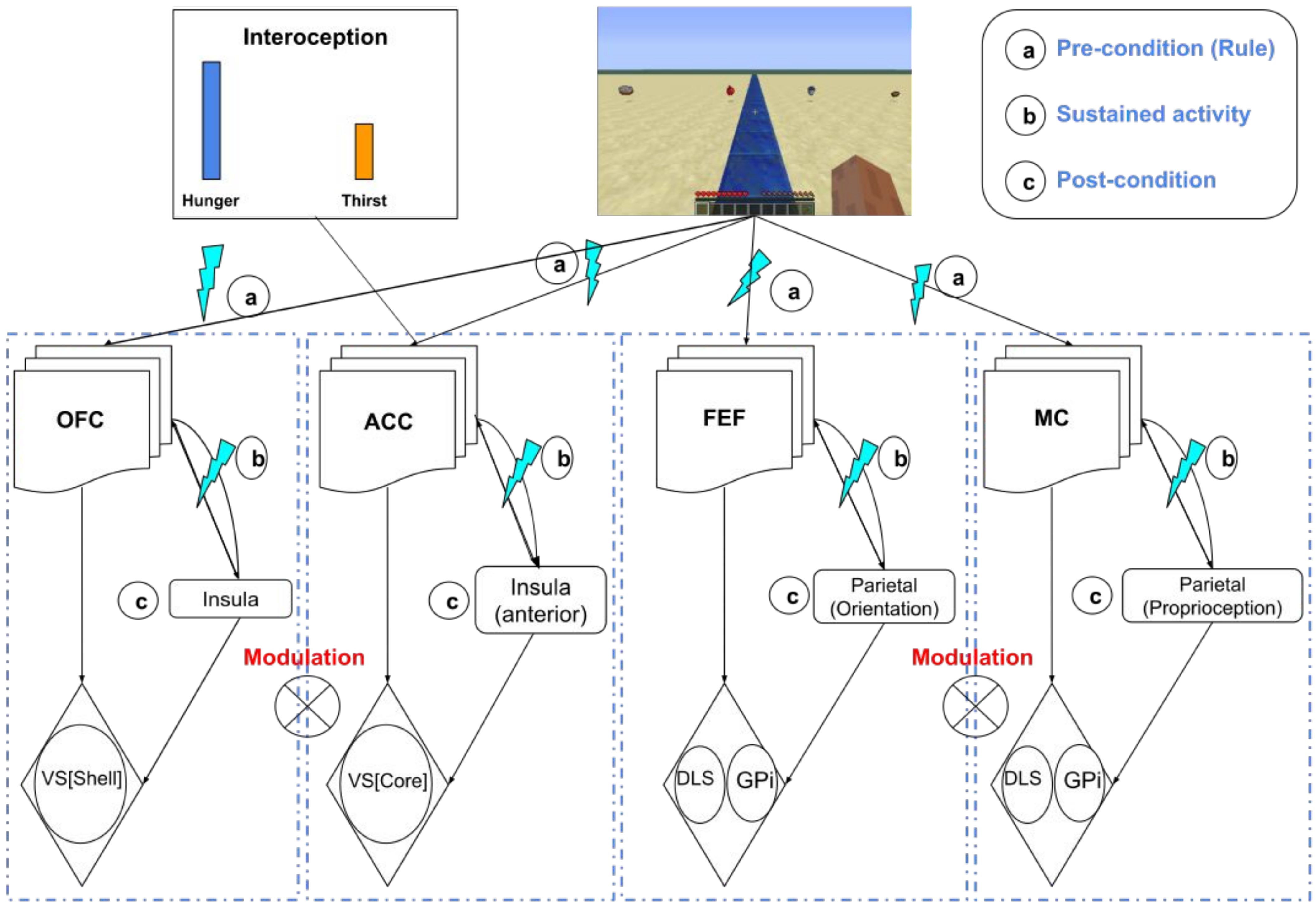


Abstract

We propose an integrated framework of interaction between cortico-basal loops, described as the projection of specific regions of sensory and frontal cortex, experimentally observed to be involved in the generic functioning of decision making and action selection of a primate [Alexander et al., 1986]. These loops, acquiring stimulus information and possible actions, project towards respective regions of the striatum and connect back to the initial frontal areas to trigger the selected action. We implement a framework of such cortico-basal loops, adapting a well established neuronal model proposed in [Hazy et al., 2006], as a set of two limbic loops and two sensori-motor loops. Two limbic loops include (i) a preferential loop through the Orbito Frontal Cortex (OFC, widely understood to represent states of the environment and their learned preference value) and (ii) a motivation-guided loop through the Anterior Cingulate Cortex (ACC), influencing the decision with the agent's internal needs and motivation. Two sensori-motor loops consist of (i) an orientation loop through the Parietal Cortex to orient towards the chosen stimulus and (ii) a motor loop through the supplementary motor area to evoke an action to reach the stimulus that is oriented towards. We study the dynamics of hierarchy and competition among these cortico- basal loops, with stronger emphasis on the role of internal emotional characteristics (goal-driven behavior) and the external stimuli characteristics (stimulus driven behavior) in the decision. We take into account the distributed consensus among the loops depending on the dynamic situation [Pezzulo and Cisek, 2016], role of neuromodulation and learning across these loops and the role of external world. For experimentation, We demonstrate how a virtual agent, considering a survival task, can interact with an unknown and dynamic external environment. We use Malmo ([Johnson et al., 2016]), a platform on the top of Minecraft (the well-known immersive world game) to evaluate the framework and explore realistic scenarios that mimic survival tasks.

Model and Experimentation



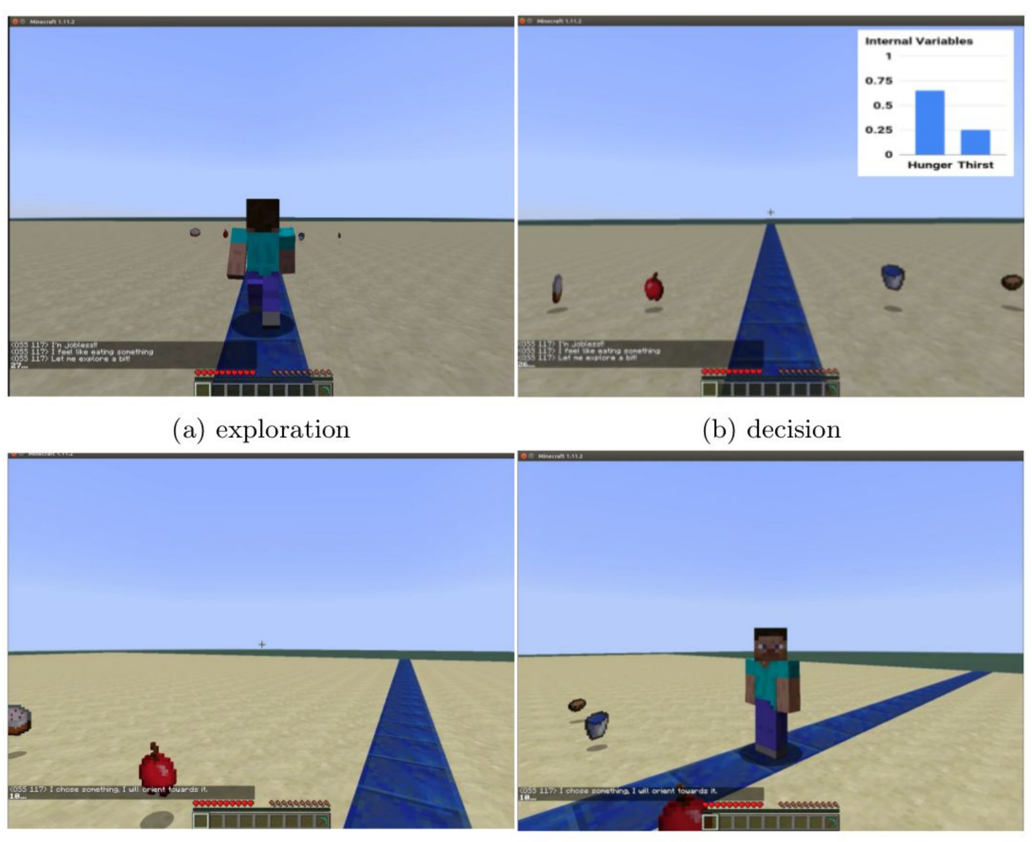
Framework of generic cortico-basal loops

Each cortico-basal loop consists of a region belonging to
- **Frontal cortex**
- **Sensory cortex**
- **Basal Ganglia**

The model is a distributed framework of generic loops, each making its own computations but affecting (by modulation) the computation in the others.

Limbic loops	
What?	*Why?*
Preference	Need
Orbito Frontal Cortex (OFC),	Anterior Cingulate Cortex (ACC)
Previously learned attributes like preference values towards each of the stimuli In the environment	Agent's current internal need and the stimuli that are known to be relevant to the need.

Sensori-motor loops	
Where?	*How?*
Orientation	Location
Frontal Eye Fields (FEF),	Motor Cortex (MC)
Locate the stimuli so as to orient the agent towards the chosen stimulus	Making the stimulus accessible to the agent either by *reaching* the stimulus or *consume* if accessible.



(a) exploration (b) decision (c) orienting (d) (before) approaching

MALMO

AI Experimentation platform on the top of Minecraft game
World - procedurally generated 3D world, Floor made up of **blocks** which serve as a **context** when required
Agent - has vital variables to be maintained within bounds, aware of **position** and **orientation** w.r.t the **World**
Items - present in the environment, carry reward values. E.g : **apple, cake, water** etc.
Actions - *move, turn , jump*
State - both internal (*life, position*) and external (*items* in the vicinity and their *positions*, *floor type* etc.)

Adaptations : Embodiment of the agent

Needs and preferences - Agent Internal : hunger, thirst, Items External : preference of the agent
Visibility - From the agent's POV, **Reach, See, Appear** zones in the decreasing order of visibility of the items

Figure : Snapshots at different stages in the task. The figure shows several steps involved in a goal-directed behavior of the agent.
(a) ***exploration*** until the agent finds some stimuli in the *Appear* zone.
(b) ***decision*** among the stimuli in the *See* zone, corresponding to the current need (inset : hunger).
(c) ***orienting*** towards the selected stimulus until it is in the line of sight.
(d) ready to ***approach*** towards the oriented stimulus.

Ongoing work and Acknowledgements

Versatile Behavior

With the above mentioned model and software environment, our aim is to demonstrate multiple animal behaviors using the same framework, with different internal and external states resulting in different behaviors.
Stimulus-driven : While exploring the environment, multiple stimuli can be perceived by the agent. The relevance of the stimuli to the agent's internal variables contributes to the agent's motivation in accessing it.
Goal-directed : With the constant monitoring of internal needs, from previous learning, the agent selects the stimuli that are relevant, as current goals and starts exploring in the environment.
Opportunistic : In a typical goal-directed behavior, when the agent encounters stmuli that are not relevant to the current need, but perceived to be rewarding for a possible future need, the agent should be able to put the initial goal on hold, opportunistically exploit the current situation, and then proceed with the ongoing goal.

Learning

GIven the diverse role of ventral striatum (VS) across the loops, we plan to integrated **dopamine** modulated learning within each loop as well as across the loops to modulate each other.

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