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

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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 acquire 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 orientated to. 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.

REFERENCES

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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: When exploring the environment, multiple stimuli can be perceived by the agent. The evaluation 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 the environment.

Opportunistic: In a typical goal-directed behavior, when the agent encounters stimuli 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 implement dopaminergic modulated learning within each loop as well as across the loops to modulate each other.

Model and Experimentation
Framework of generic cortico-basal loops
Each cortico-basal loop consists of a region belonging to (i) Frontal cortex (ii) Sensory cortex (iii) Basal Ganglia.

Limbic loops
- What?
  - Preference
  - Need
- Why?
  - Orbito Frontal Cortex (OFC), Anterior Cingulate Cortex (ACC)
- Where?
  - Where?
- How?
  - Orientation
- Item?
  - Stimulation?
- Sensory-motor loops
  - Make the stimulus accessible to the agent either by reaching the stimulus or consuming it.

Ongoing work and Acknowledgements
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.