Neurorobotics

Module 2: Neurorobot Design Principles

Lecture 2: Design Principle1 Case Study

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Action Selection in a Neurorobotic Model of the Basal Ganglia

Basal ganglia

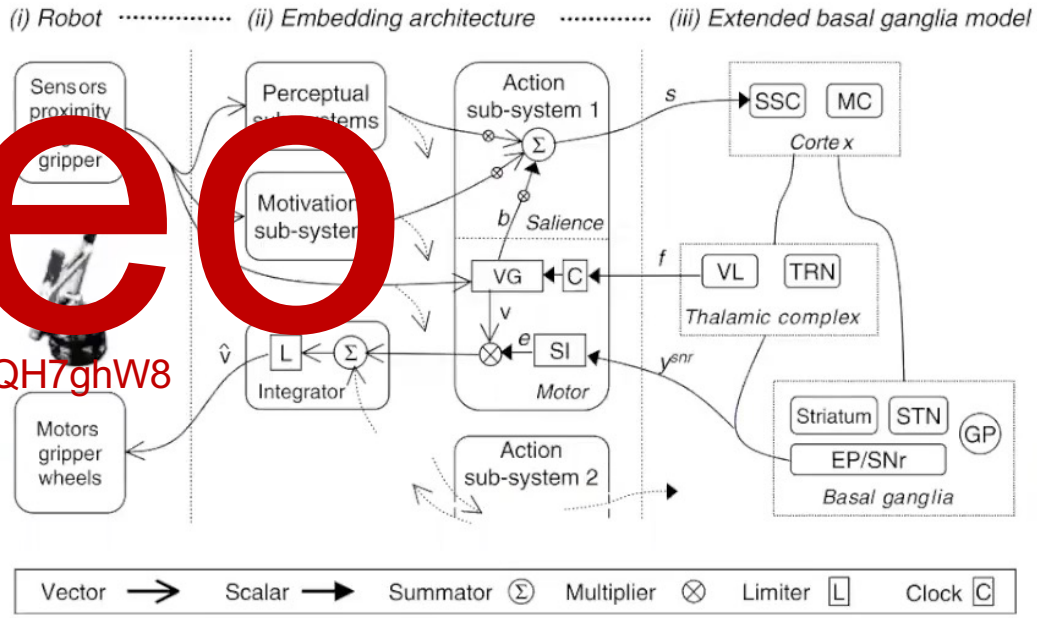
- Structures in the brain that
  - Release inhibition of desired actions
  - Maintain or increase inhibition of undesired actions
- Mechanism for action selection
- "resolving conflicts between functional units that are physically separated within the brain but are in competition for behavioral expression"

TransAIR Workshop on Cognitive Architectures for Robot Agents

https://transair-bridge.org/workshop-2021/

Neurorobotic Design Principles I - Every Action Has a Reaction

- Multi-Tasking and Event-Driven Processing

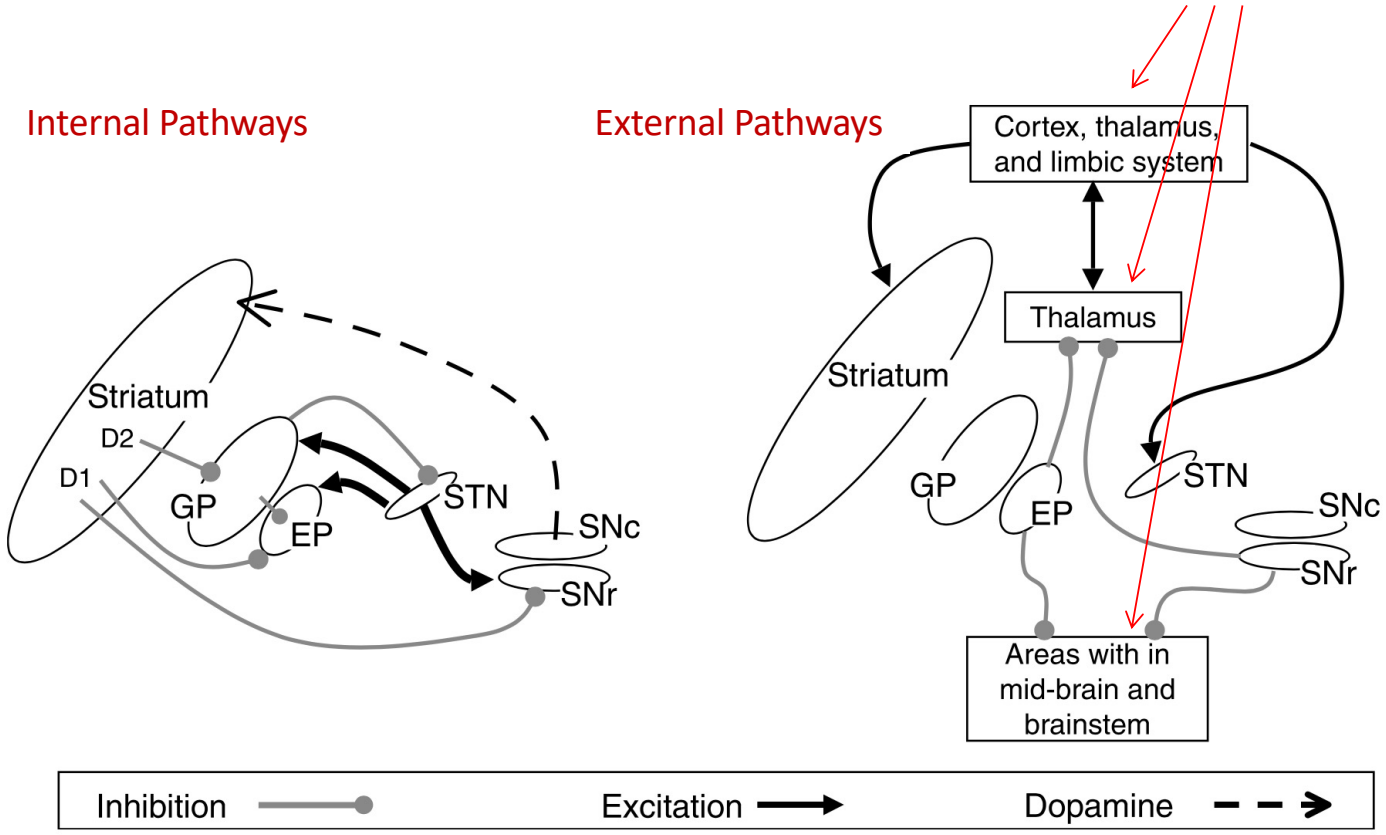


Prescott, T.J., et al., P. Neural Networks, 2006.

Basal Ganglia Anatomy of the Rat

The basal ganglia structures are interconnected with the wider brain architecture

STN	Subthalamic nucleus
EP	Entopeduncular nucleus
GP	Globus pallidus
SNc	Substantia nigra pars compacta
SNr	Substantia nigra pars reticulata
D1, D2	Striatal neurons expressing dopamine receptors subtypes



(Prescott et al., 2006)

System-level model of the basal ganglia and associated thalamocortical connections

- Control architecture for a foraging mobile robot
- Foraging task requires the robot to select appropriate actions under changing conditions
  - Sensory
  - Motivational

Eight infrared proximity sensors capable of discriminating between objects (cylinders) and walls

Two intrinsic drives: analogies of hunger (increases with time) and fear (decreases with exposure to the environment)
These drive the behavioral choices

- Several sensory and cognitive streams operate in parallel
- This gives rise to the need for an action selection mechanism
  - Select (disinhibit) one
  - Inhibit others

System-level model of the basal ganglia and associated thalamocortical connections

Five behaviors / action subsystems

1. Searching for cylinders
2. Picking up a cylinder
3. Looking for a wall
4. Following alongside a wall
5. Depositing the cylinder in a corner

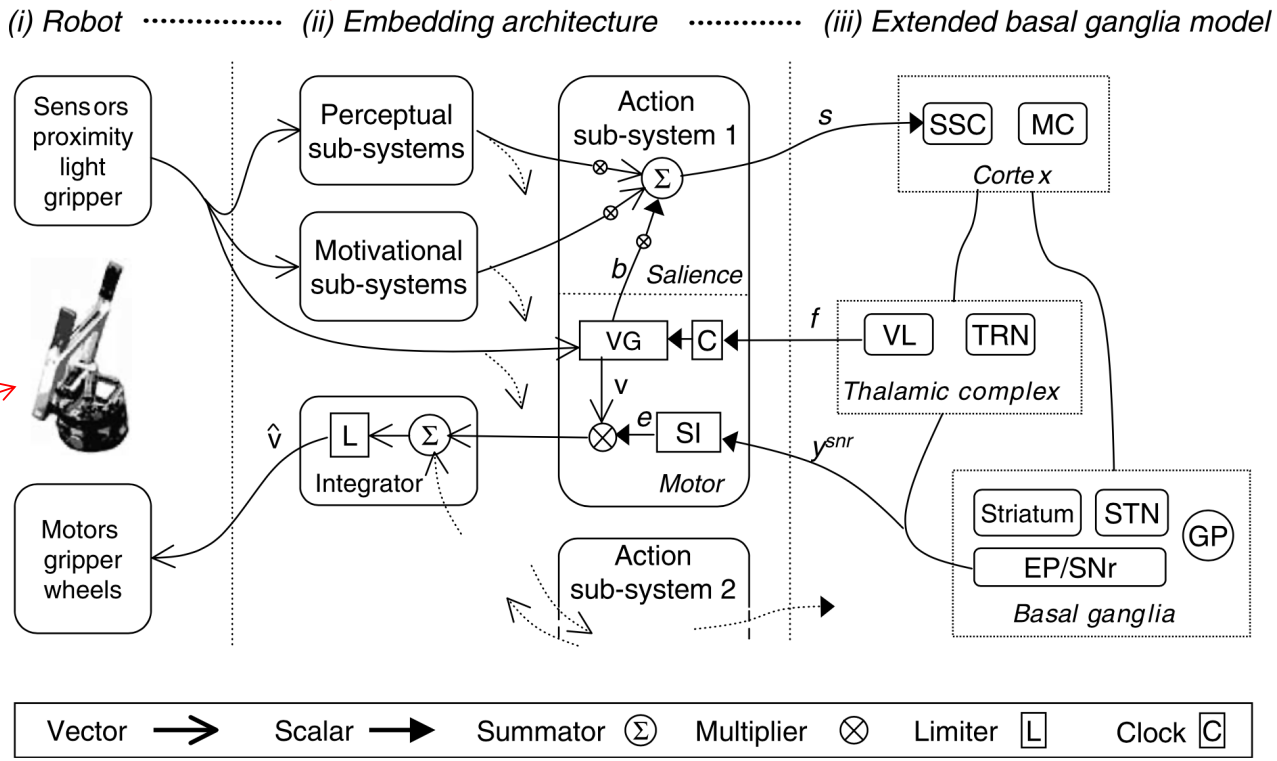
Each operates independently

Resolves action selection conflicts

Arbitrate at each time-step between the five available action sub-systems

Generate a pattern of action selection over time

Resulting in coherent sequences of behavior



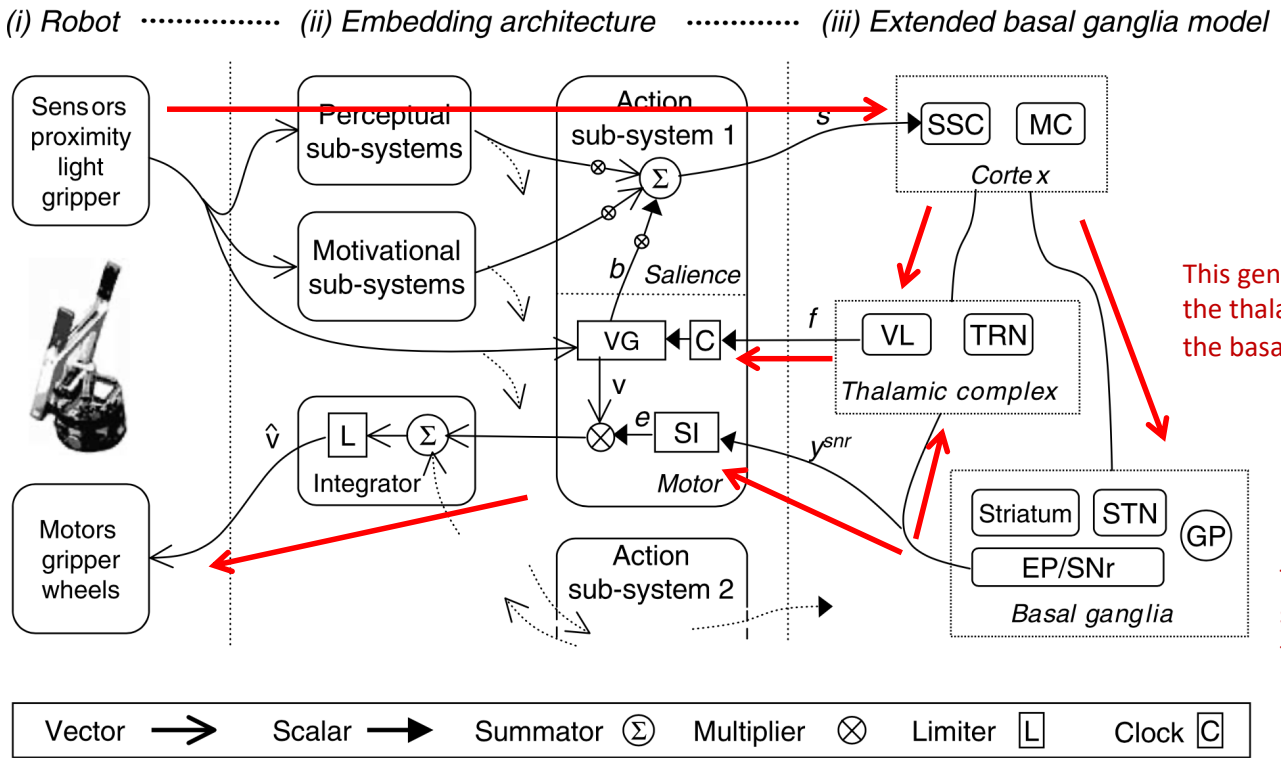
Kephera two-wheeled robot wtih eight infrared proximity sensors and a gripper arm

VG	Vector generator
SI	Shunting inhibition
b	Busy signal
s	Salience signal
f	Feedback signal
y^{SNR}	Basal ganglia output
e	Gating signal
v	Motor vector
$\hat{v}$	Aggregate motor vector

(Prescott et al., 2006)

System-level model of the basal ganglia and associated thalamocortical connections

Sensor data received by the robot provides input to the cortex



This generates activity in the thalamic complex and the basal ganglia

Once an action is selected, all other actions are suppressed until the action (i.e. behavioral pattern) is complete

The most active action sub-system has the smallest output from the basal ganglia y^{snr}

Resulting in the appropriate action

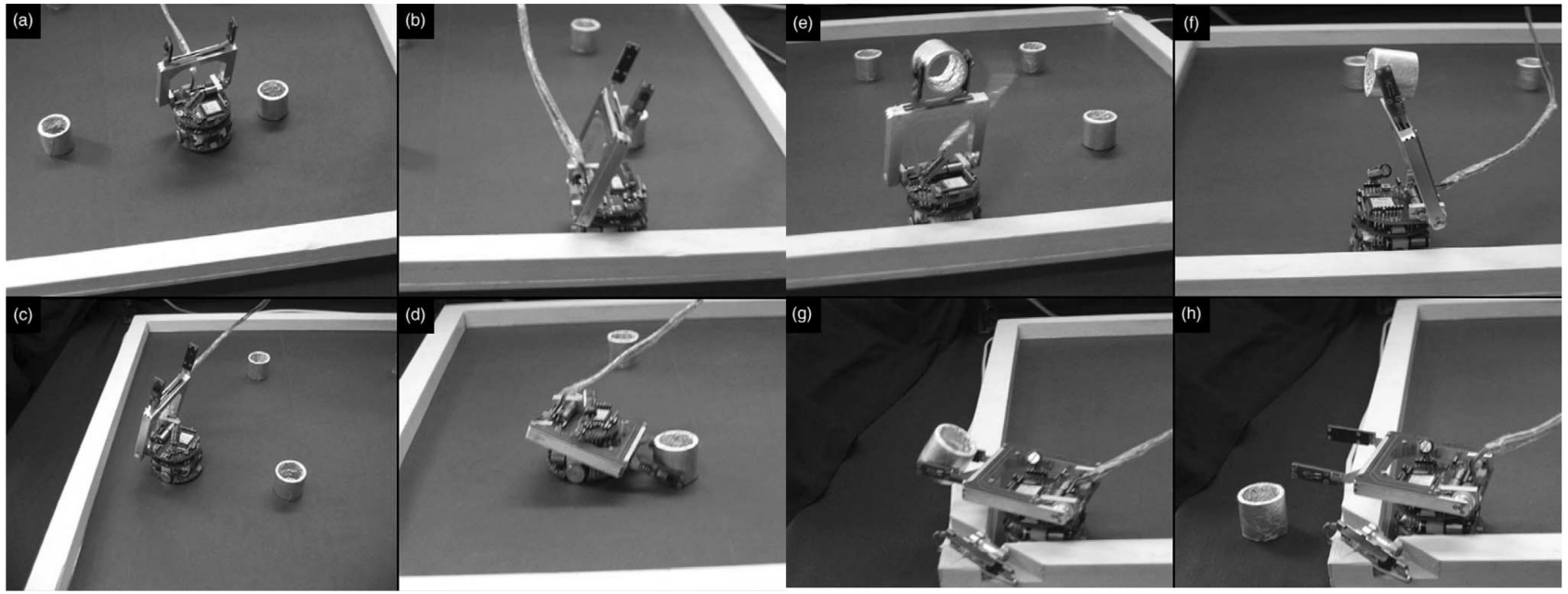
Which releases the inhibition from the thalamic complex

System-level model of the basal ganglia and associated thalamocortical connections

- Fear reduces with the time spent in the environment
  - Wall seeking and following is driven by fear
- Hunger increases gradually with time
- Hunger decreases as cylinder objects are deposited in the nest corner of the arena
  - Cylinder object seeking is driven by hunger
  - Cylinder object deposit is driven by proximity to a nest (corner) and having a cylinder to deposit

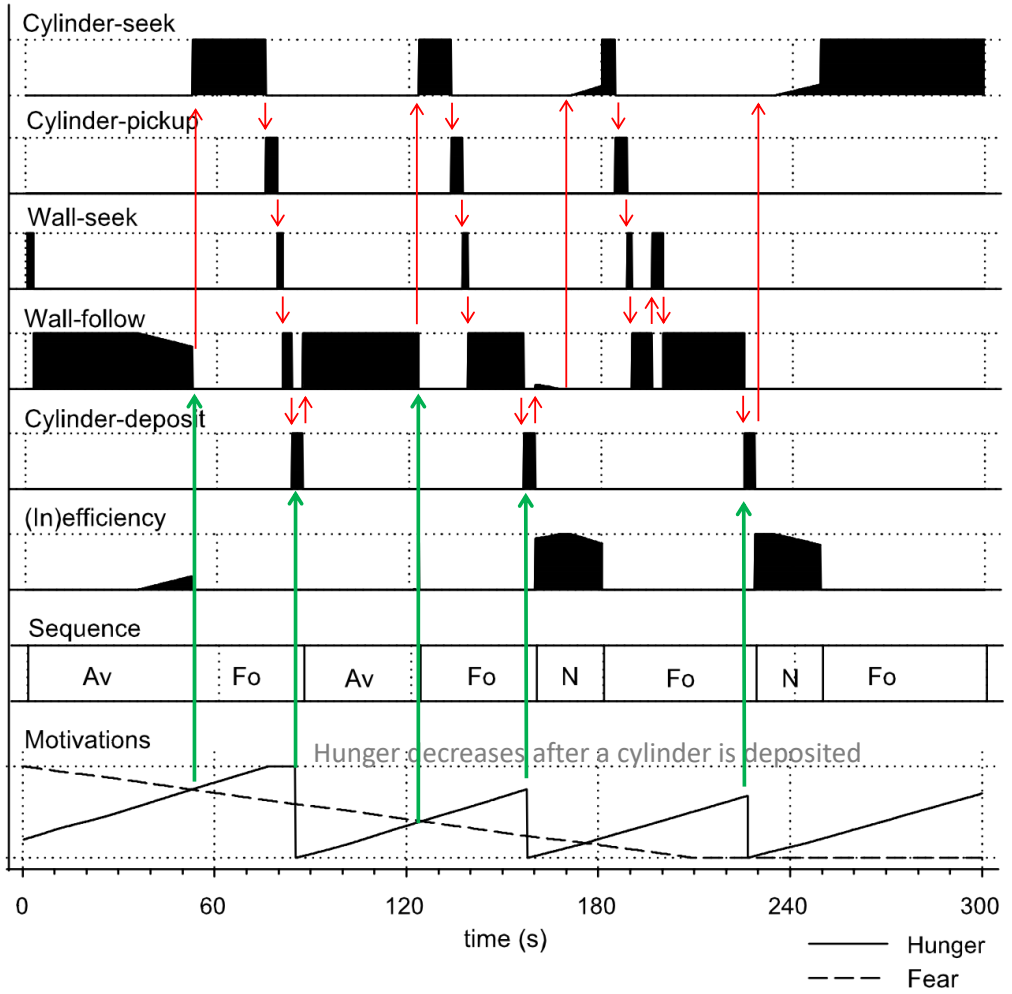
System-level model of the basal ganglia and associated thalamocortical connections

Wall-seek | Wall-follow | Wall-seek with cylinder | Wall-follow with cylinder



Cylinder-seek | Cylinder-pickup | Cylinder-deposit | Cylinder-deposit

System-level model of the basal ganglia and associated thalamocortical connections



Avoidance or Foraging

Reading

Hwu, T. and Krichmar, J. (2022). Neurorobotics: Connecting the Brain, Body and Environment, MIT Press.

Chapter 5, Sections 5.6 - 5.8, pp. 99 - 104