Autonomie constitutive et generation de comportements intelligents

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Introduction

Références

- Olivier L. Georgeon, Alexander Riegler. CASH Only: Constitutive Autonomy through Motorsensory Self-Programming. *Cognitive Systems Research*, Elsevier, 2019, 58, pp.366-374.

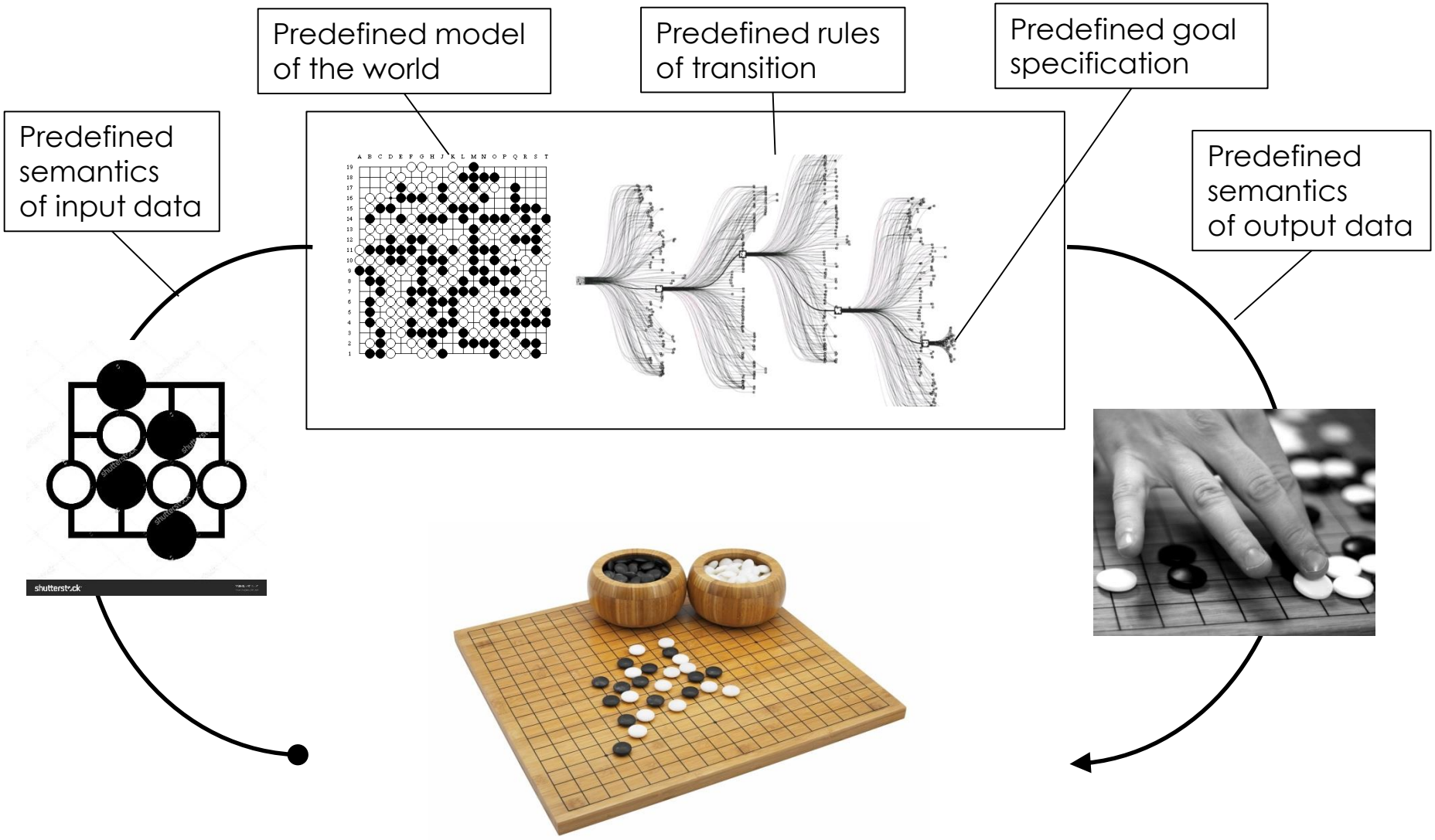
- Georgeon O., Robertson P., Xue, J. (2020). Generating Natural Behaviors using Constructivist Algorithms. Fist International Workshop on Self-Supervised Learning (IWSSL). February 27-28 2020. Boston, MA.

IWSSL Boston February 2020

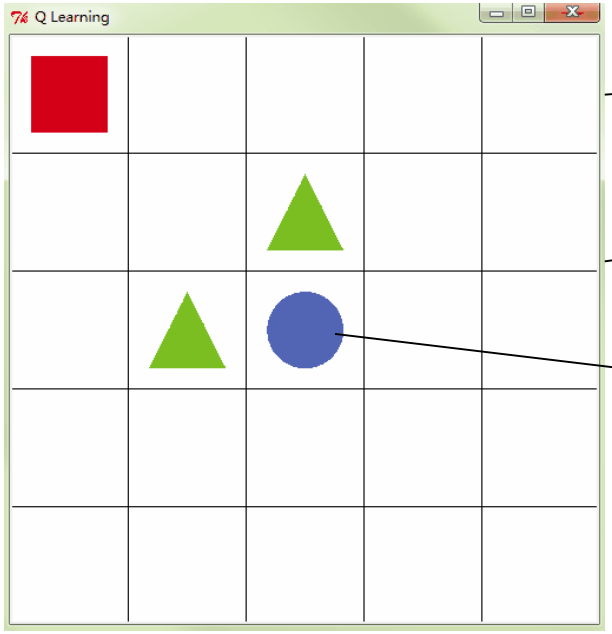
Générer des comportements intelligents

- **Difficile de dire ce que c'est**
  - Evaluation par un observateur (test de Turing)
- **On peut dire que ce n'est pas:**
  - Des comportements pré-programmés
  - Des comportements aléatoires
  - Résolution de problème modélisé a priori

AI in a predefined domain



Reinforcement learning



Predefined set of states

Predefined transitions

Predefined final goal and reward

Example Q-learning
https://youtu.be/gOwU3aoEAmg

Résolution de problème et scalability

- **Résolution de problème modélisé à priori:**
  - « *untractable* » quand la complexité du problème augmente
- **Le système devrait modéliser les problèmes au fur et à mesure de son activité et ne tenter de résoudre que les problèmes « tractable »**
  - Principes motivationnels propres
  - Données d'entrée contrôlées (pas de surcharge informationnelle)

Système de valeur et motivation

- **Ce qu'on ne veut pas:**
  - Des objectifs définis comme des états à atteindre dans un ensemble d'états prédéfinis
  - « Tout est égal »
- **Motivation propre**
  - Essayer des nouveaux comportements (curiosité)
  - Augmenter la maitrise des comportements (« flow »)
  - Préférences interactionnelles innées
  - Etc…

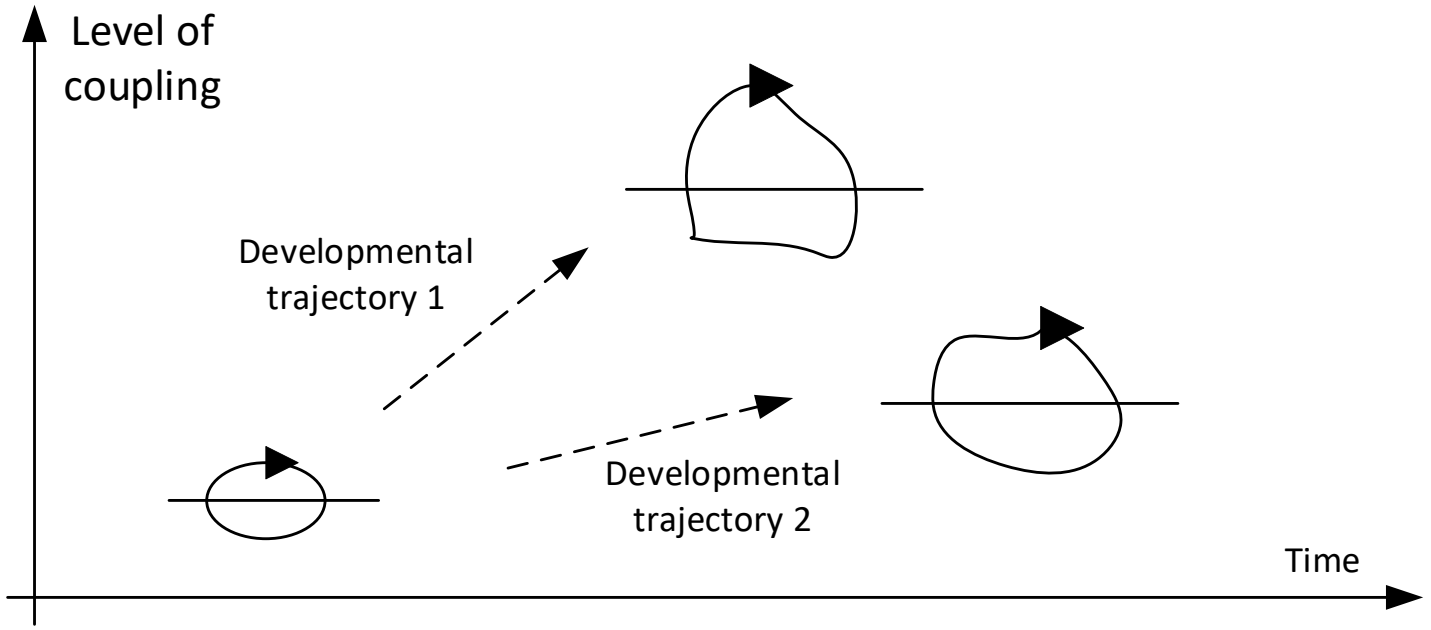
Autonomie constitutive et comportements

Pour générer des comportements nouveaux (non pré-programmés), le système doit acquérir par lui-même de nouvelles structures de génération de comportements.

= autonomie constitutive

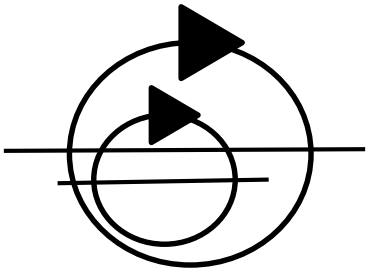
Autonomie constitutive

Capacité d'un système a développer individuellement sa structure interne et son couplage avec son environnement.

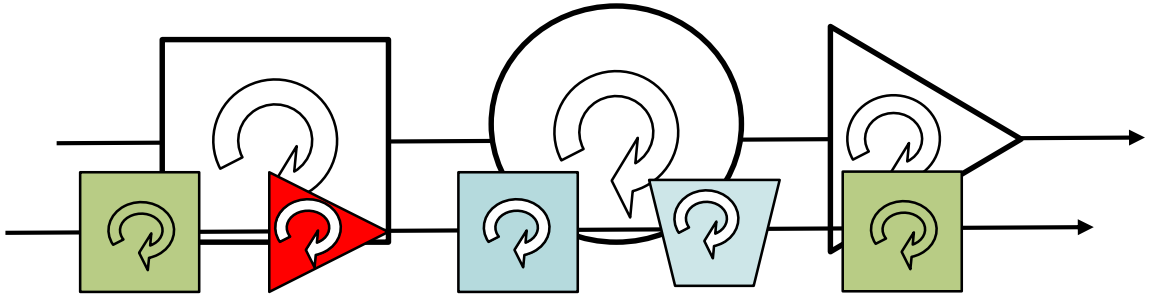


Comportement et couplage

Différentes échelles temporelles:
Actions et résultats de différents niveaux



Boucles de contrôle



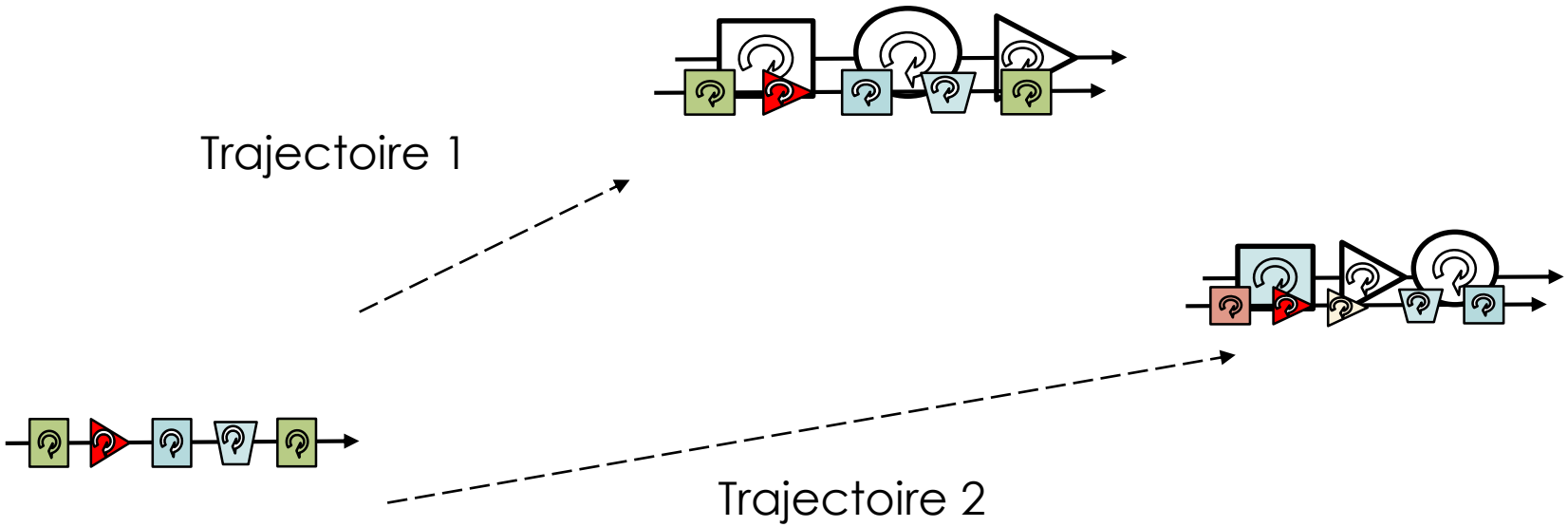
Evénements d'interaction

Développement des comportements

Trajectoire 1

Trajectoire 2

Développement des comportements



Autonomis constitutive, bibliographie

- David Vernon (2015) Embodied Cognition and circular causality: on the role of constitutive autonomy in the reciprocal coupling of perception and action.
  - Behavioral autonomy focuses on the external caracterisitics of the system
  - […] Constitutive autonomy focuses on the internal organisation and the organizational process
- Ezequiel Di Paolo (2005)
  - Evolution of the structural coupling

Pourquoi est-ce important ?

- Ezequiel Di Paolo (2005) Autopoiesis, adaptivity, teleology, agency
  - Individuation
- Tom Froese & Tom Ziemke (2009) Enactive artificial intelligence: Investigating the systemic organization of life and mind
  - "Constitutive autonomy is necessary for sensemaking"

CA through self-programming

- Constitutive autonomy of computational entities amounts to learning new programs through their existence
  - Internal structure of computer programs can change as a result of perturbation (Winograd & Flores 1987)
  - Structural coupling with the environment is not necessarily limited to the physical domain (Riegler 2002)
- Acquiring new executable code
- Executing the learned code in the appropriate situation

Self-modifying process

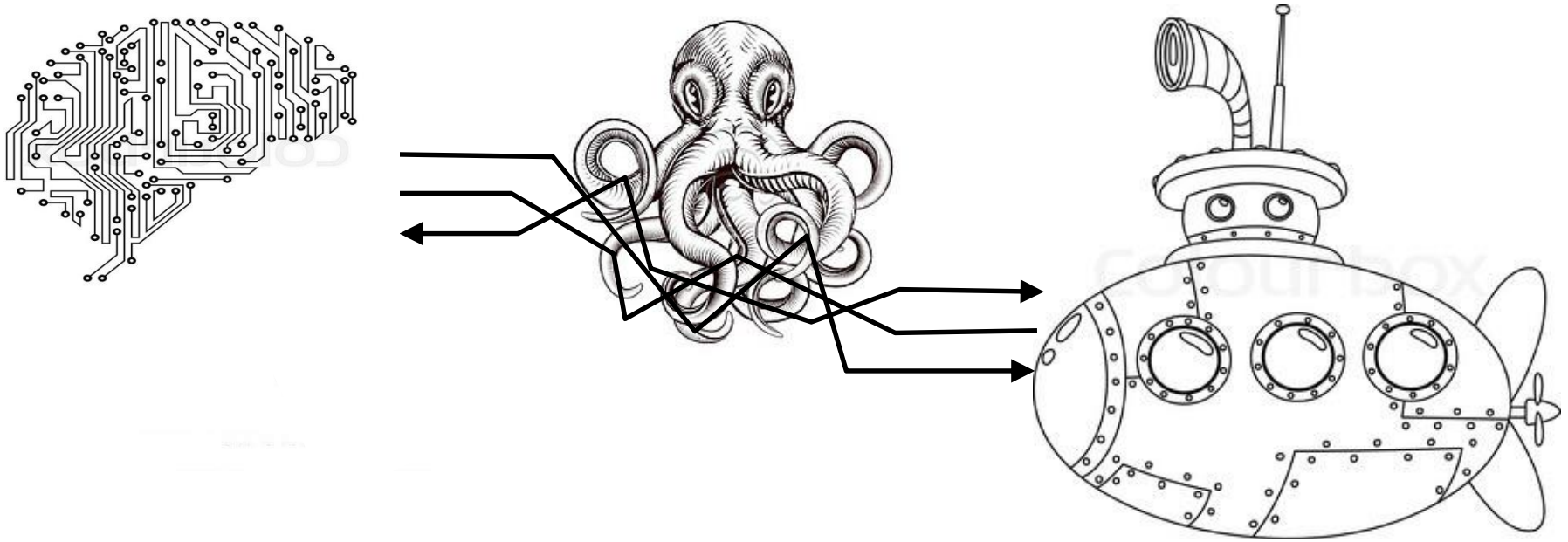
- Allan Newell & Herbert Simon (1976)
  - Turing award lecture
- John Weng (2004)
  - Self affecting cognitive architecture
- Kristinn Thórisson
  - Constructivist AI (2002)
- N’ont pas produit de demonstration !

Many open questions

- Self programming to do what?
  - How to define preferences without defining final goal?
  - Intrinsic motivation
  - Impulse, predilection, hutzpa
- In which programming language?
- Should it create new instructions?
- Is it ok if the execution engine is pre-programmed?
- How to assess self-programming?

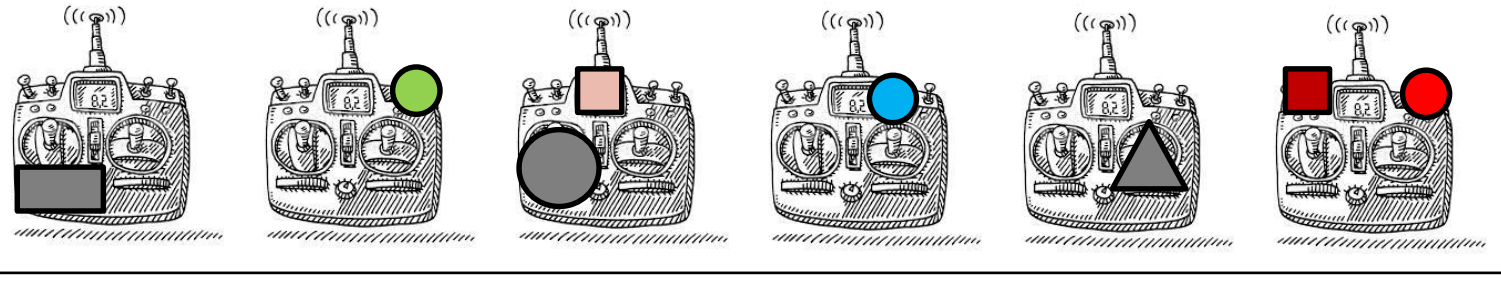
Notre approche

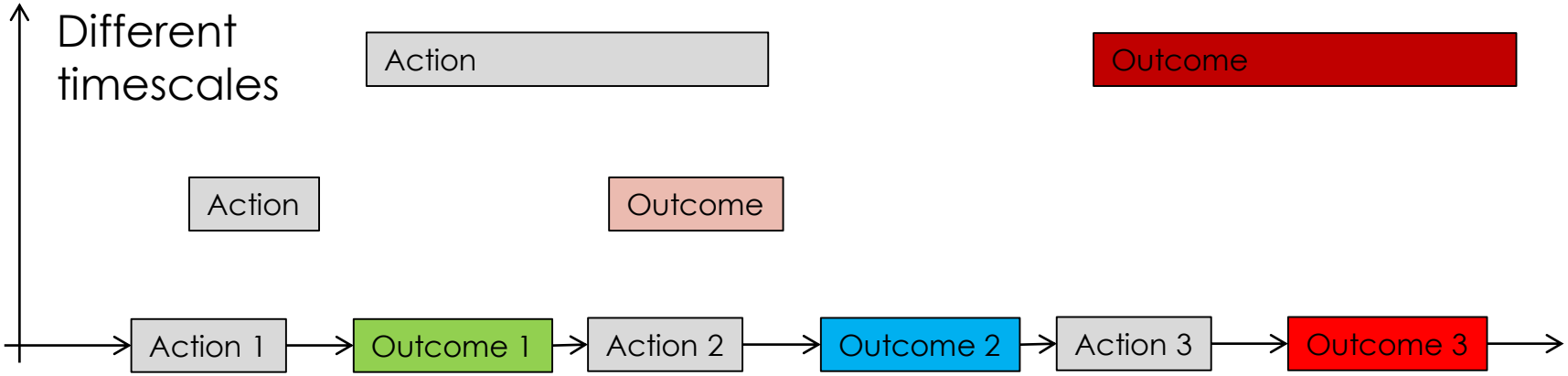
IA without any predefined domain



Maturana H. R. & Varela F. J. (1987) The tree of knowledge: The biological roots of human understanding. Shambhala, Boston.
O'Regan & Noë (2001) A sensorimotor account of vision and visual consciousness

Action-outcome timeline

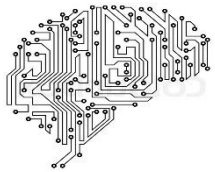


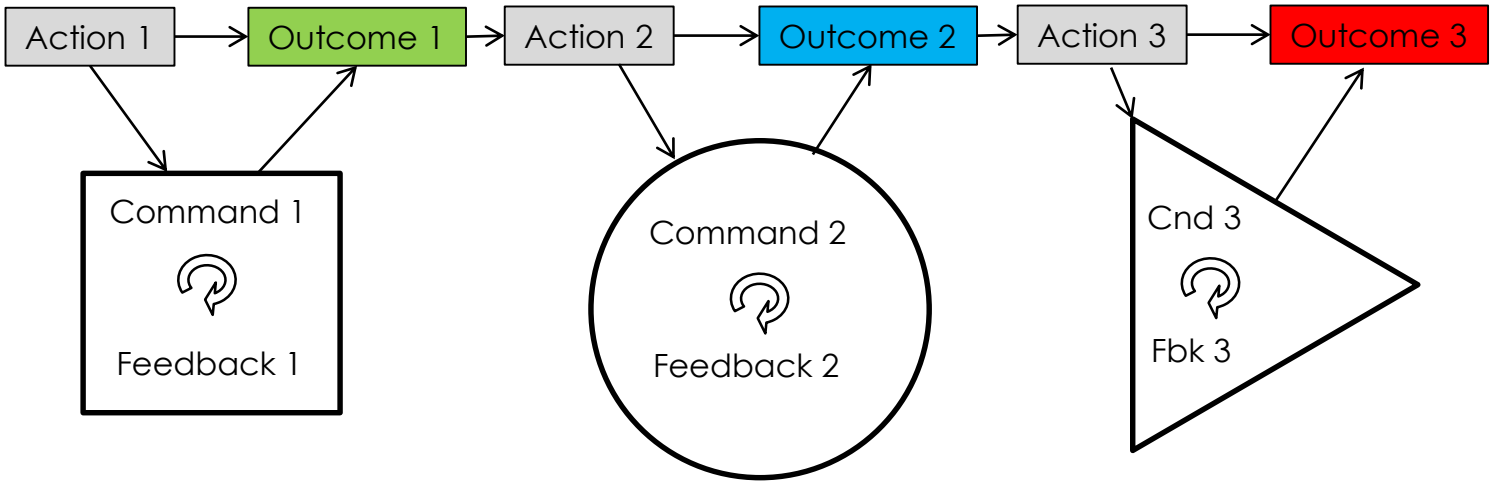


Actions and outcomes are intertwined

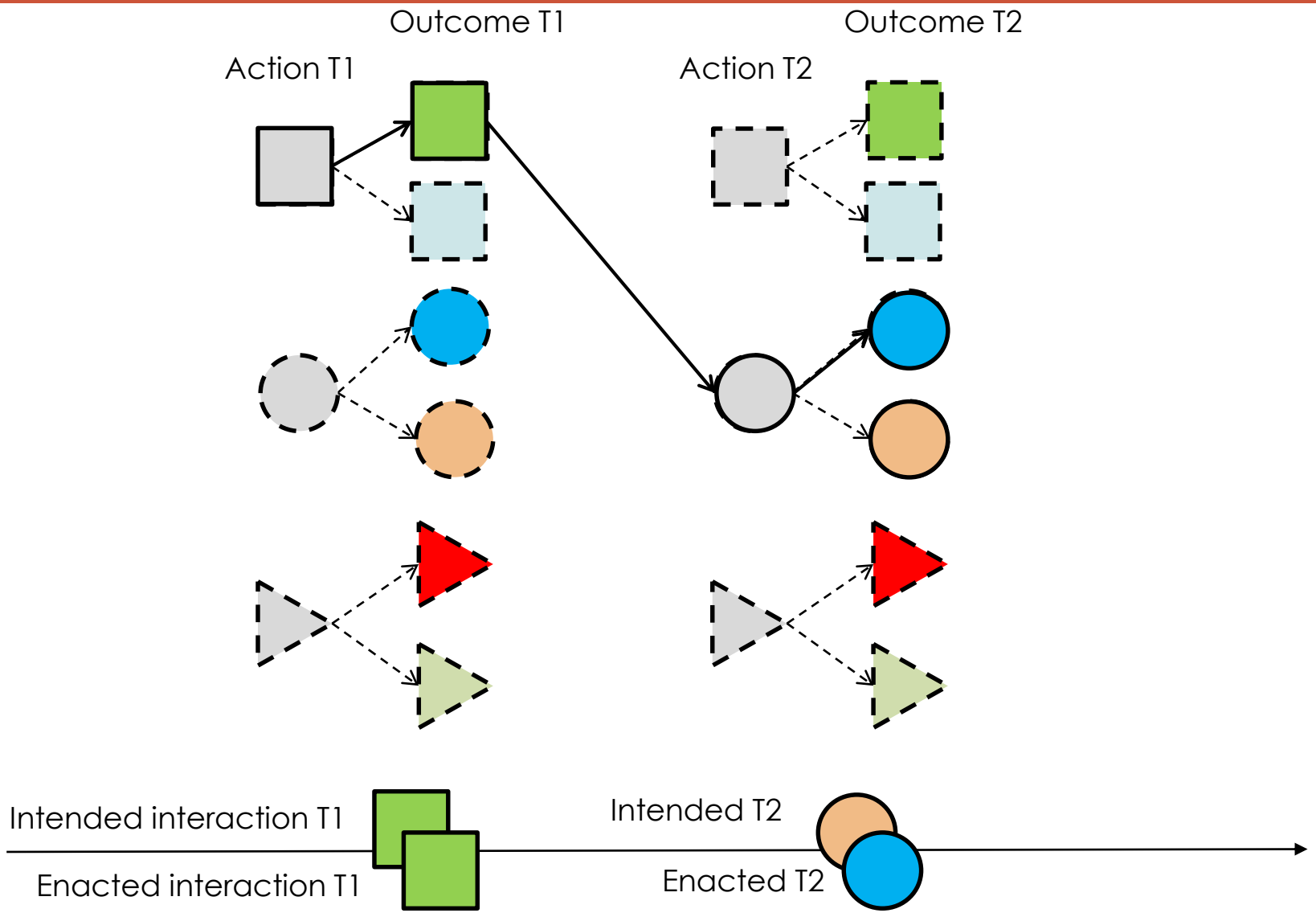
- **We studied**
  - Simple "action -> outcome" patterns
  - Learning higher levels of hierarchical sequences
  - Some kind of agent self-programming
  - Generating interesting behaviors
- **We have not addressed yet**
  - Delayed outcome
  - Synchronic/parallel actions and outcomes
  - Construction of representational knowledge
  - Self-construction of the cognitive architecture

Primitive control loops

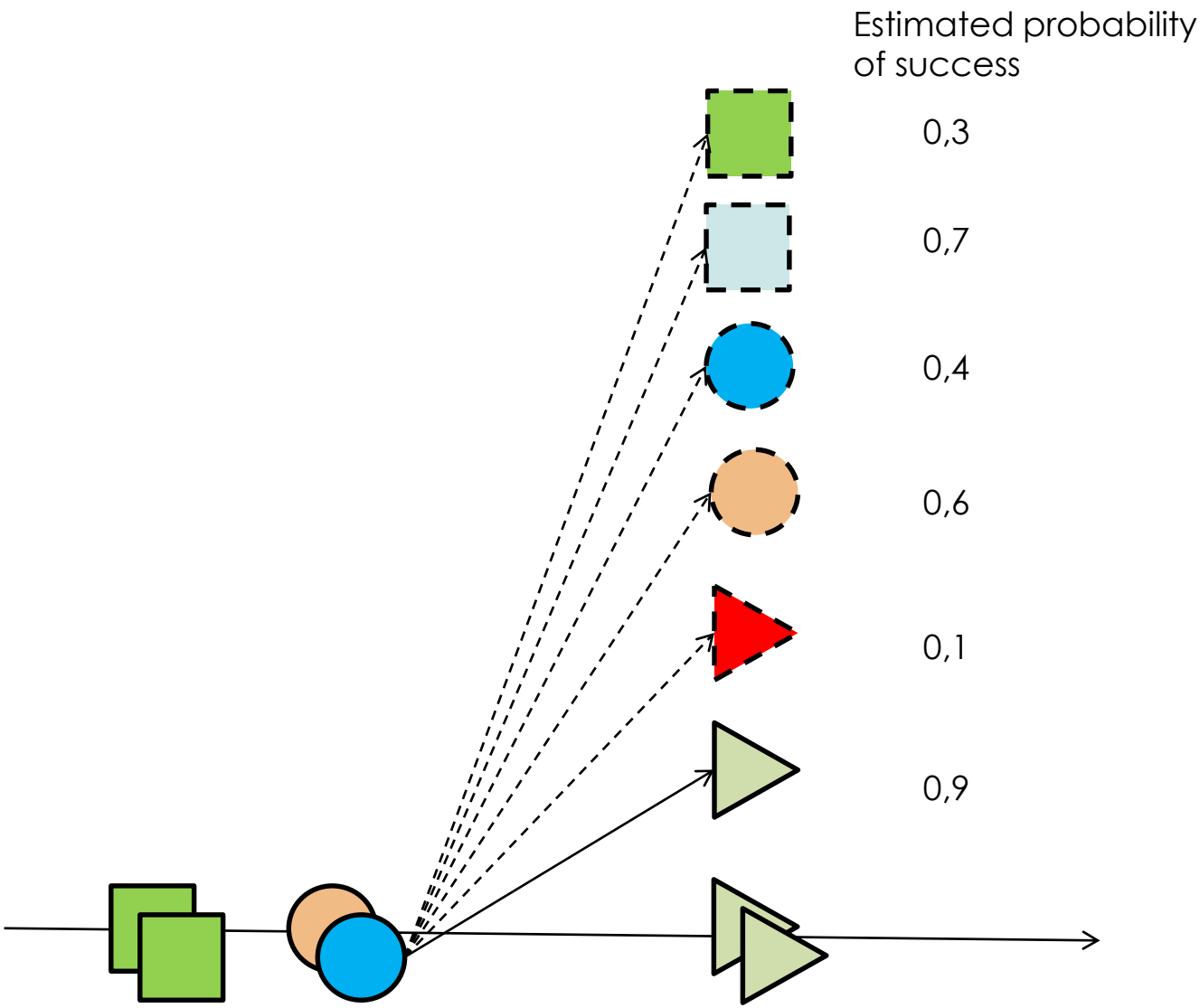




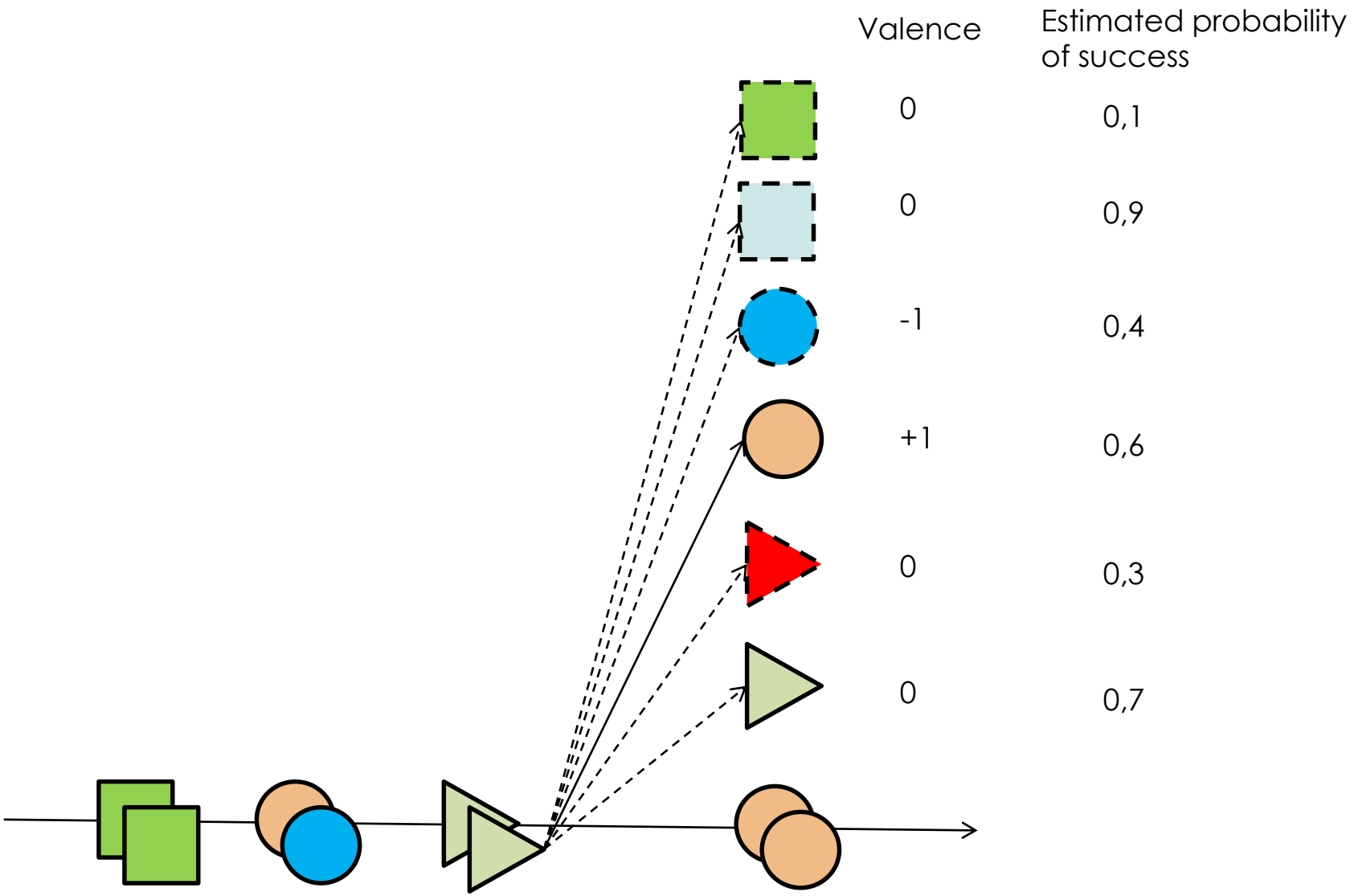
Intention and enaction



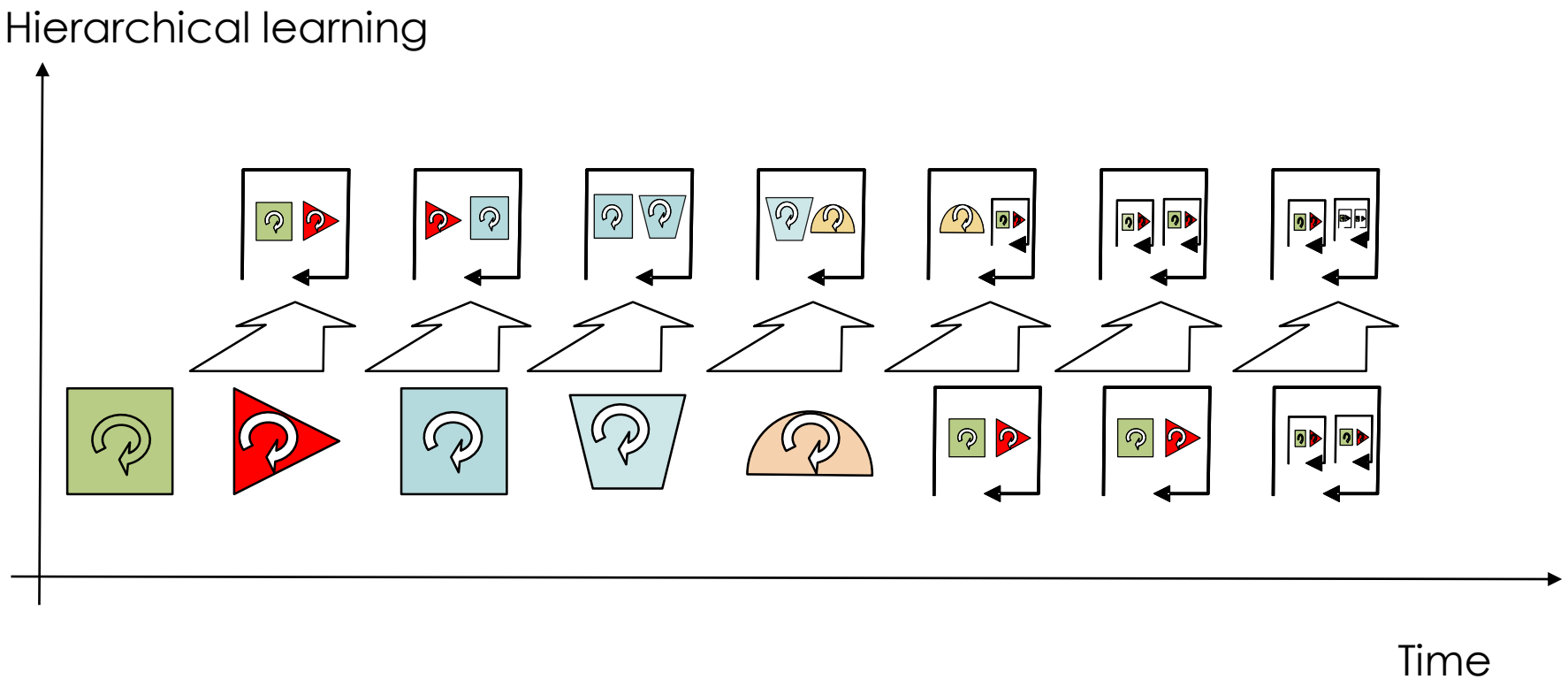
Estimated probability of success



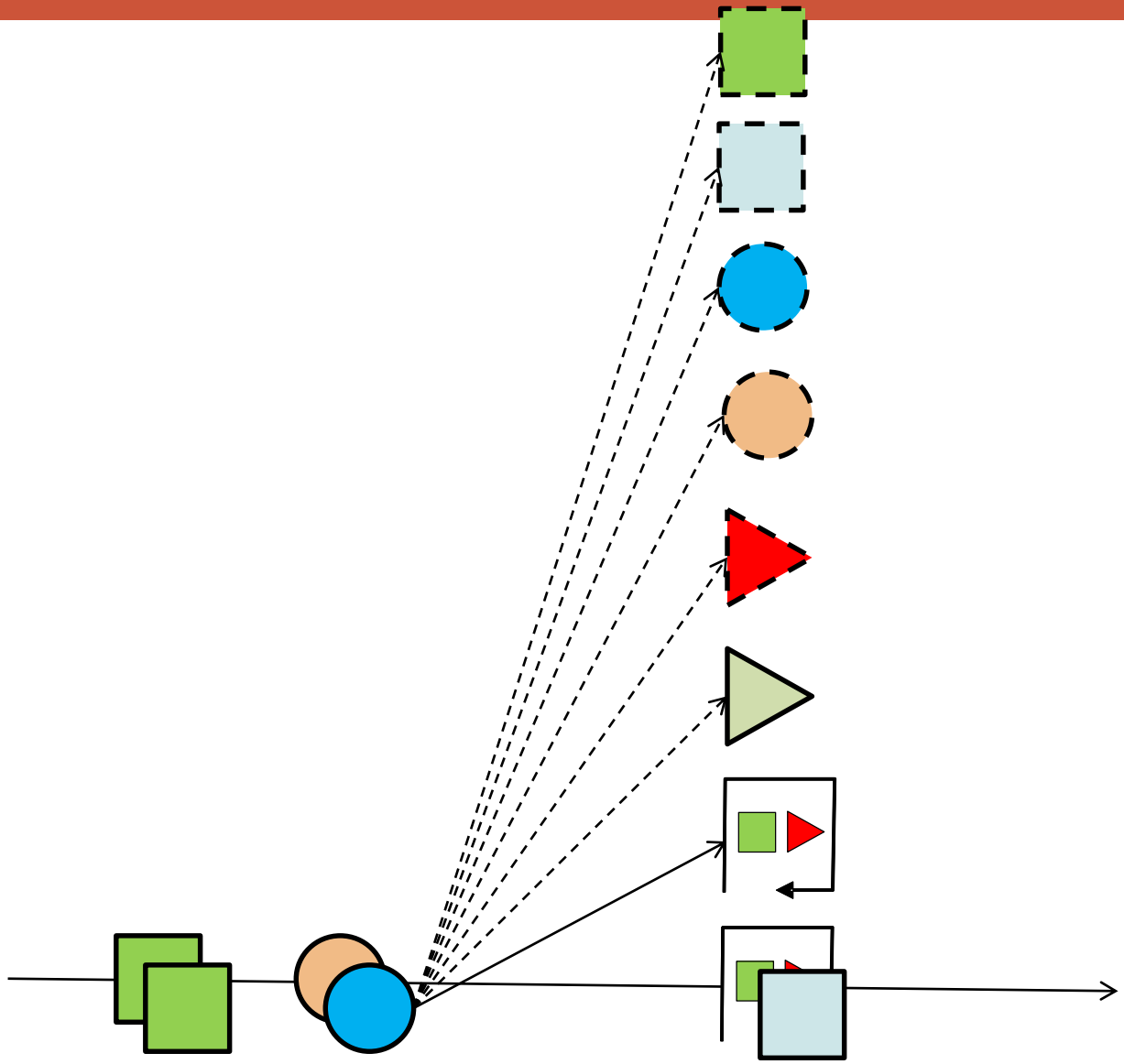
Estimation expected valence

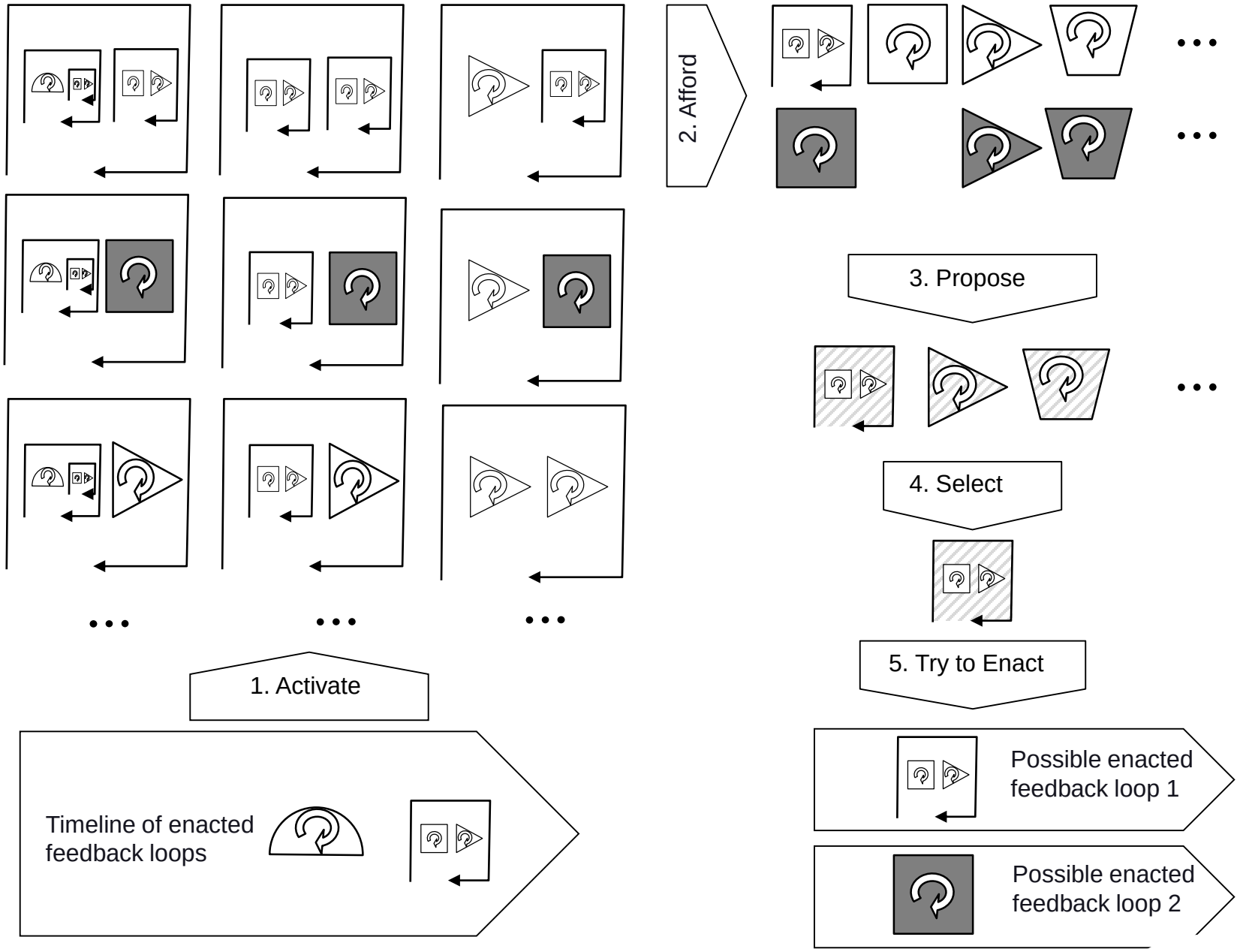


Bottom up hierarchical learning

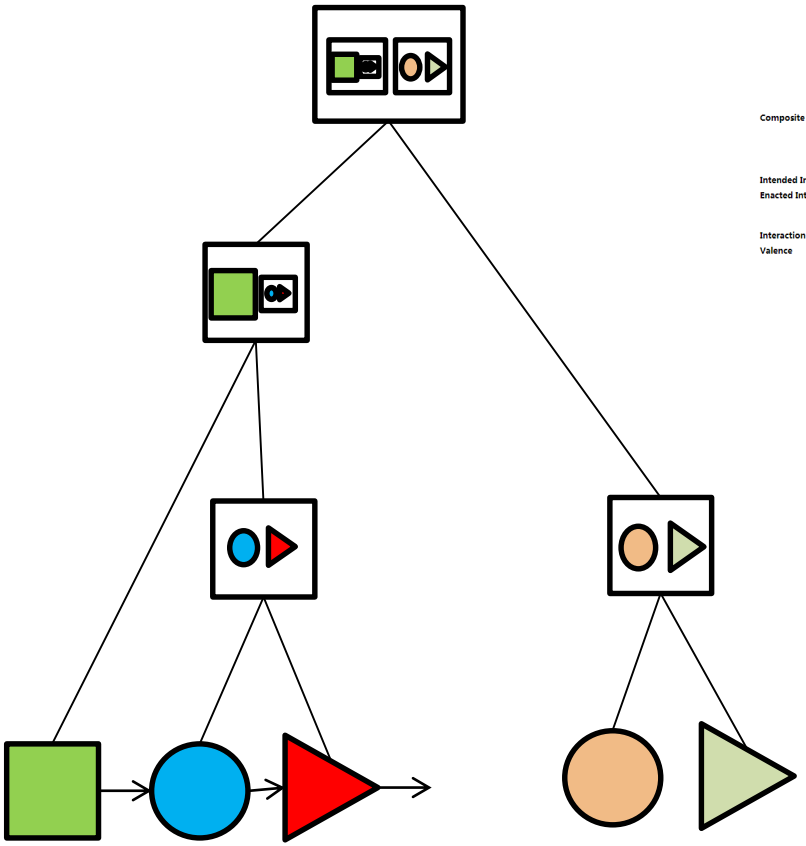


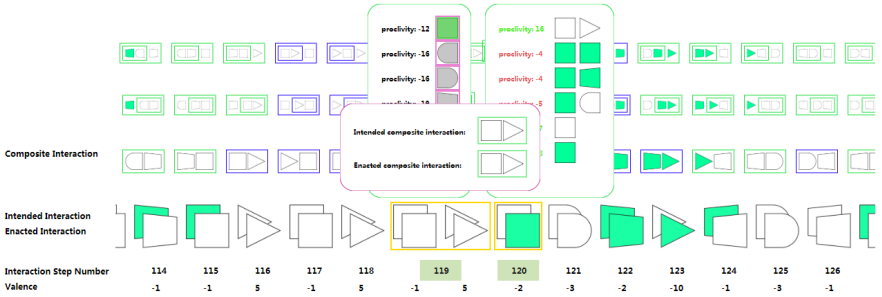
Selection of composite interaction




2. Afford
3. Propose
4. Select
5. Try to Enact
1. Activate
Timeline of enacted feedback loops
Possible enacted feedback loop 1
Possible enacted feedback loop 2

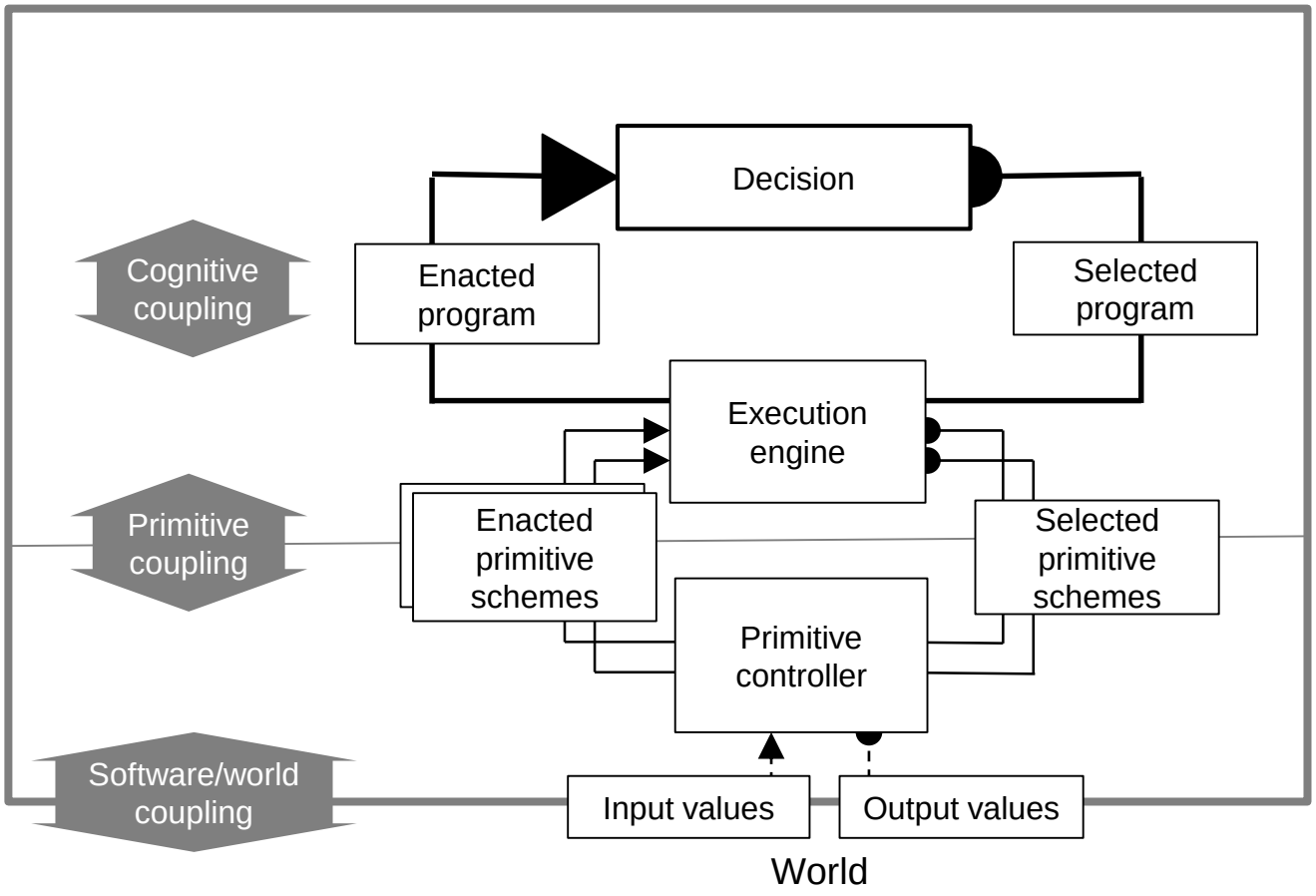
Bottom up hierarchical learning



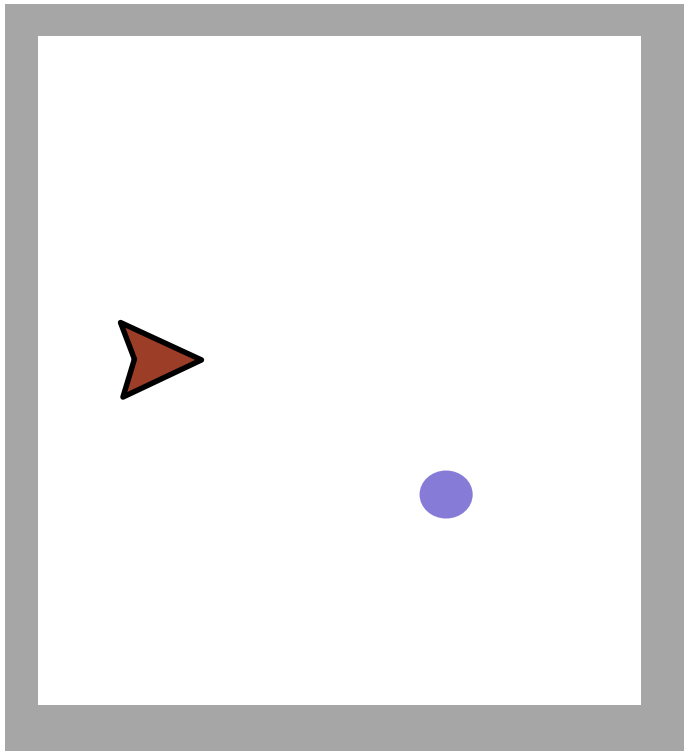


Generate and Analyse Interaction Toolkit

Evolution du couplage



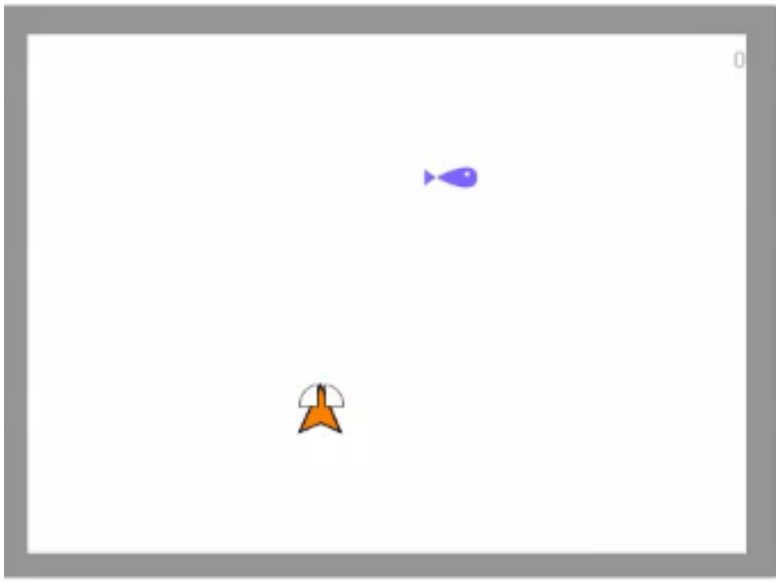
Demonstration

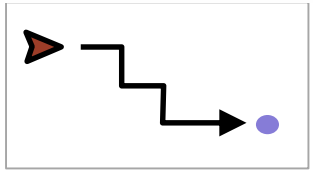


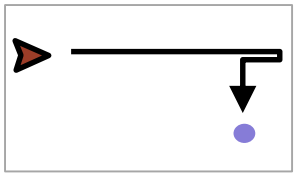
- 3 actions:
  - move forward 1 cell
  - Turn left 90°
  - Turn right 90°
- 4 possible results:
  - increase smell left
  - increase smell front
  - increase smell right
  - decrease smell

Different behaviors learned

https://youtu.be/91kKzybt8XY







Transfer in robot

Le projet INIT

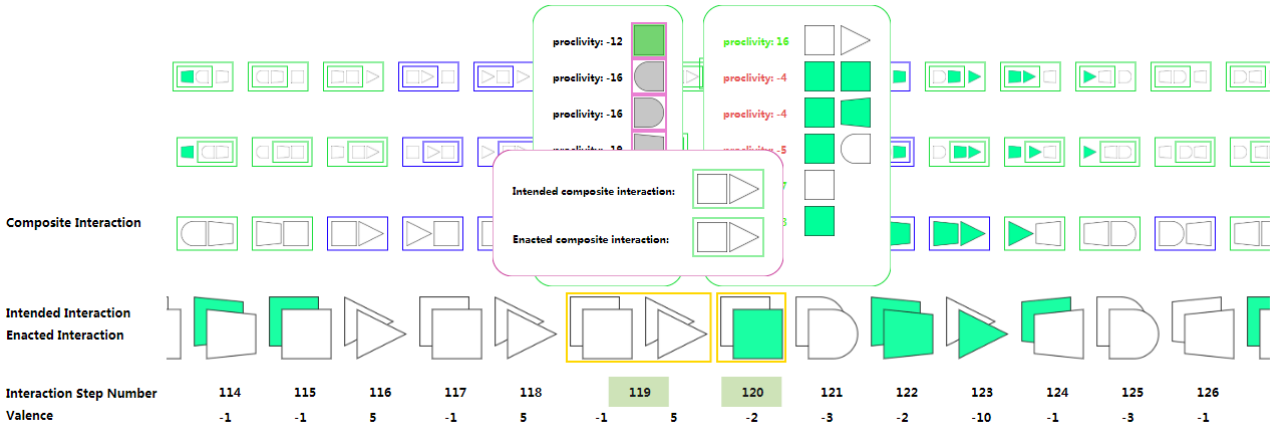
Interactions Naturelles Incrémentales sur Turtlebot

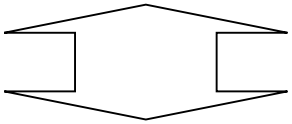
Generating and Analysing Interaction Traces

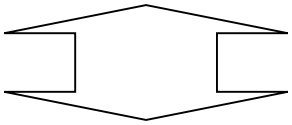
Projet INIT

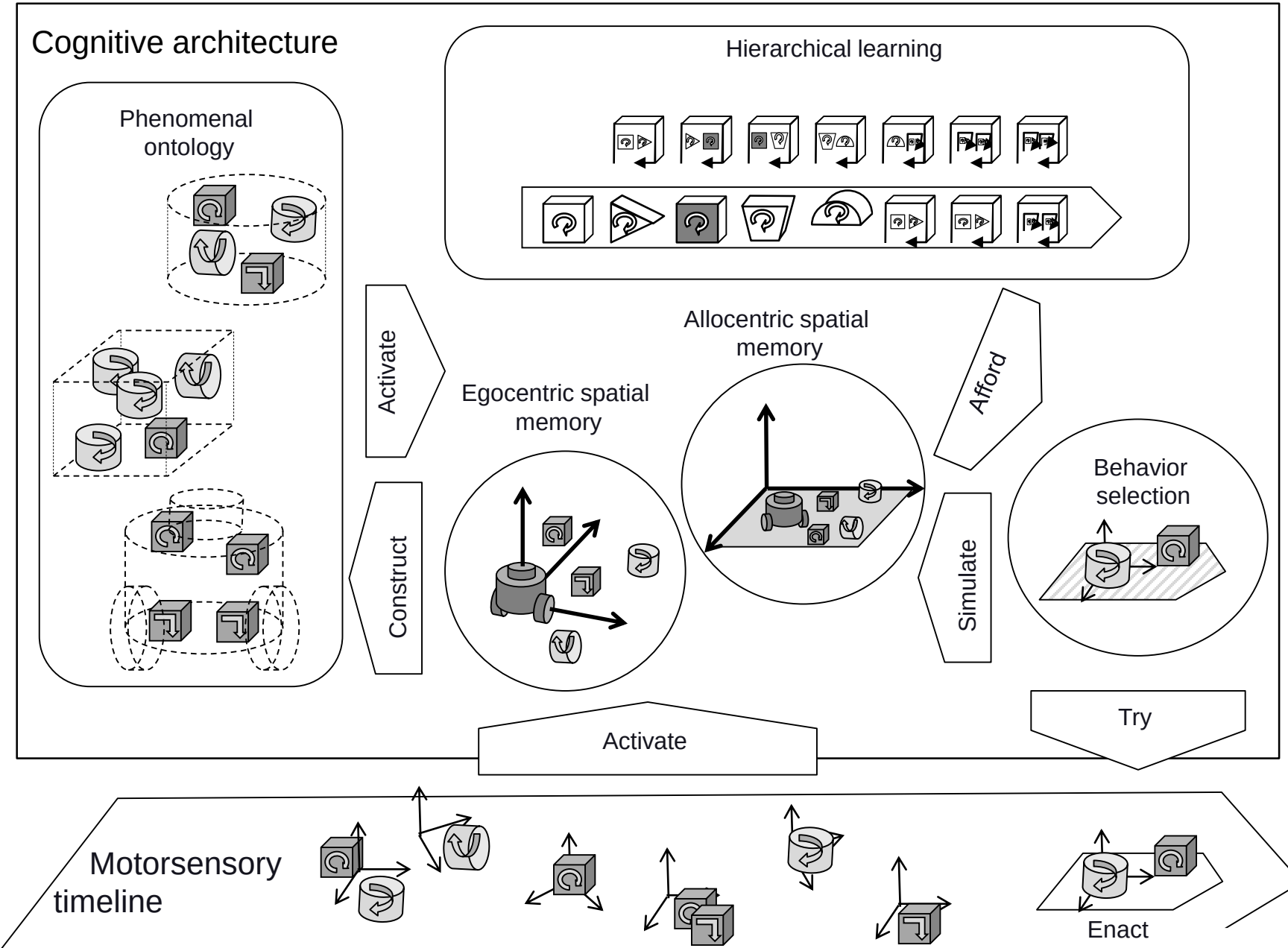
IWSSL Boston February 2020

GAIT + Device

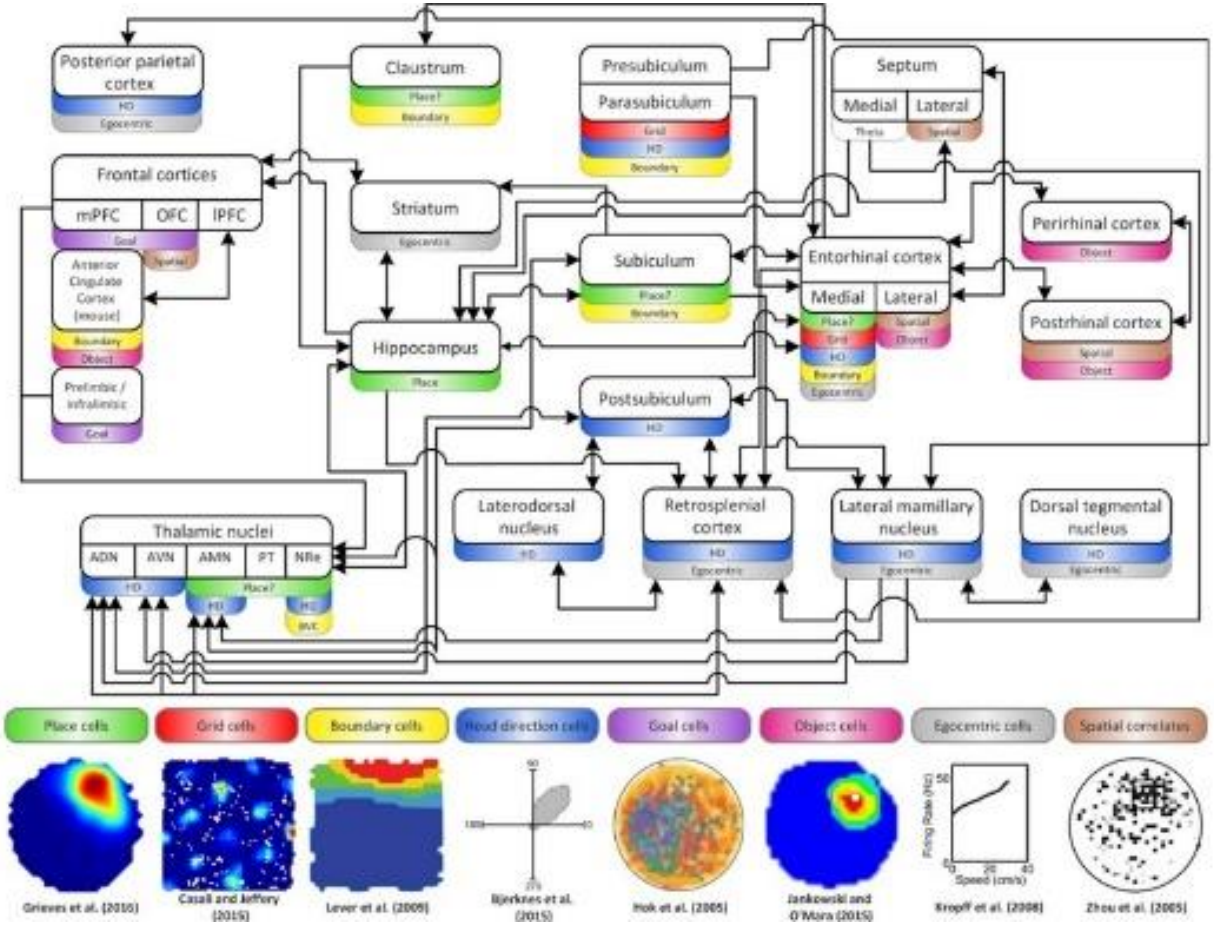

proclivity: -12
proclivity: -16
proclivity: -16
proclivity: 16
proclivity: -4
proclivity: -4
Intended composite interaction:
Enacted composite interaction:
Composite Interaction
Intended Interaction
Enacted Interaction
Interaction Step Number
114 115 116 117 118 119 120 121 122 123 124 125 126
Valence
-1 -1 5 -1 5 -1 5 -2 -3 -2 -10 -1 -3 -1






Cognitive architecture
Hierarchical learning
Phenomenal ontology
Activate
Allocentric spatial memory
Egocentric spatial memory
Afford
Behavior selection
Construct
Simulate
Try
Activate
Motorsensory timeline
Enact

Inspiration du cerveau



The representation of space in the brain. Grieves & Jeffery (2017)

Merci !