

On The Role of the Multi-Level and Multi-Scale Nature of Behaviour and Cognition

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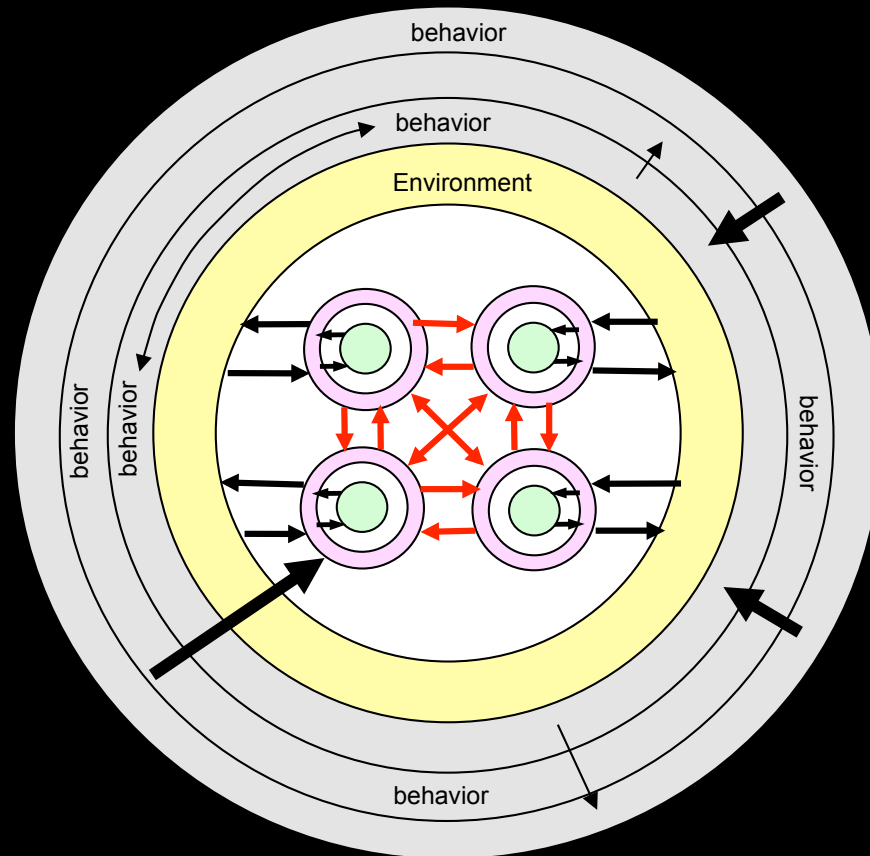
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Behavior and cognition are dynamical process with a multi-level and multi-scale organization

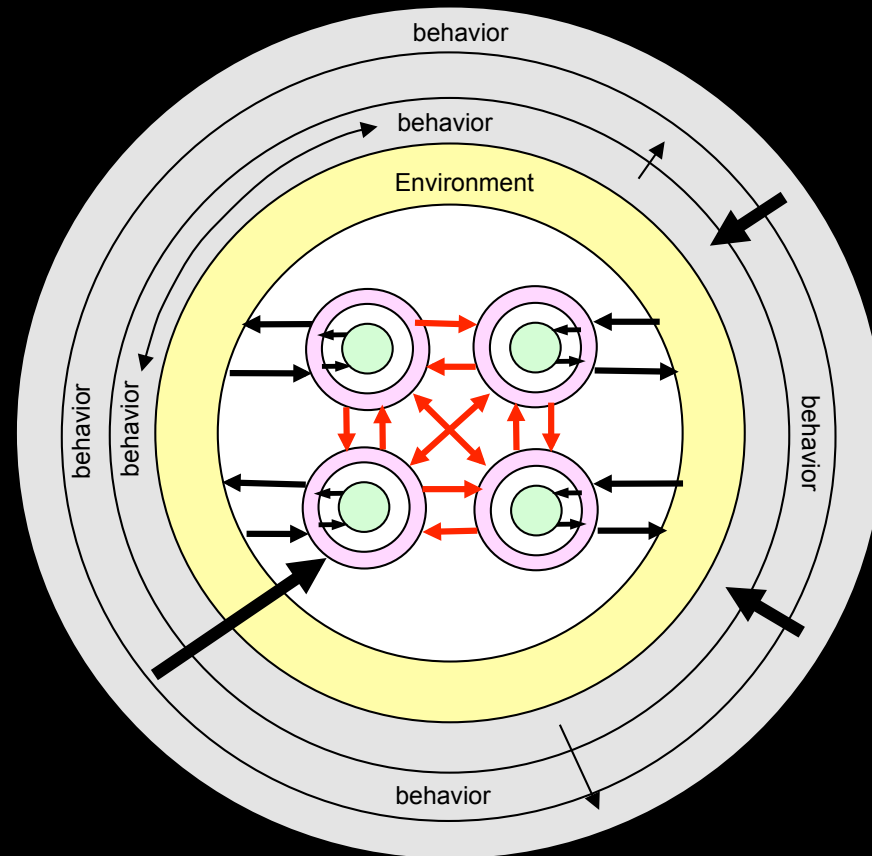


Outline

How the behaviour of adaptive robots typically have a multi-level and multi-scale organization

1. How the interaction between lower-level behaviours enable generalizations at the level of behaviour
2. How existing behavioural skills can establish the conditions for the development of new higher-levels skill
3. How the multi-level and multi-scale organization of behaviour enable compositionality and behaviour generalization

1. How the interaction between lower-level behaviours enable behaviour generalizations



Evolving coordinated locomotion in self-assembled Swarm-Bots



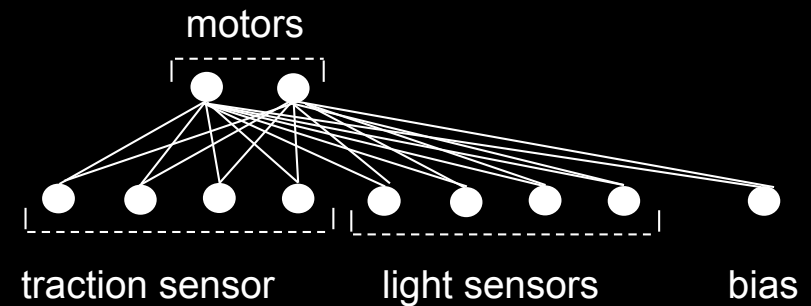
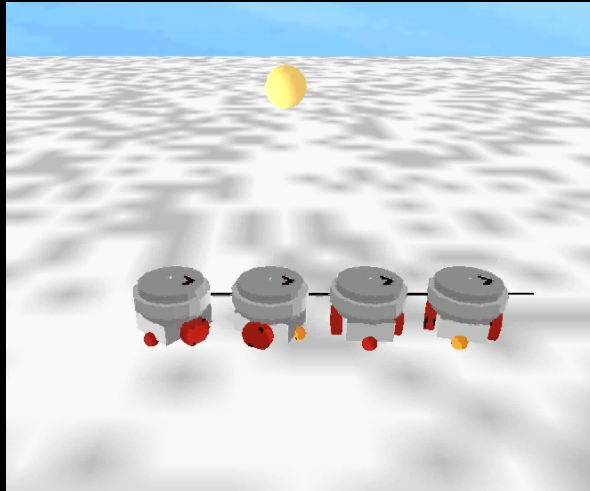
2002-2004]

Denebourg, Dorigo, Floreano, Gambardella, Mondada, Nolfi,

coordinated motion

[Baldassarre, Trianni, Bonani,
Mondada, Dorigo, Nolfi, 2006]

Experimental Scenario & Emergent Behaviours

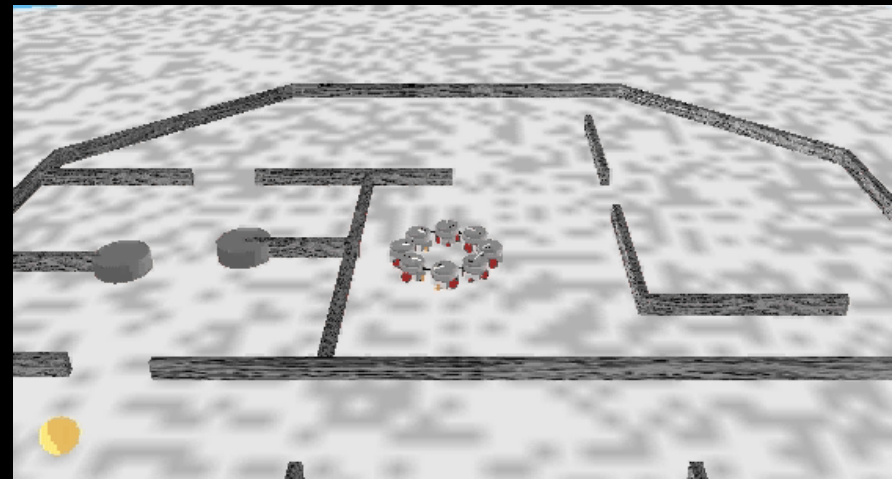


Robots generalize with respect to:

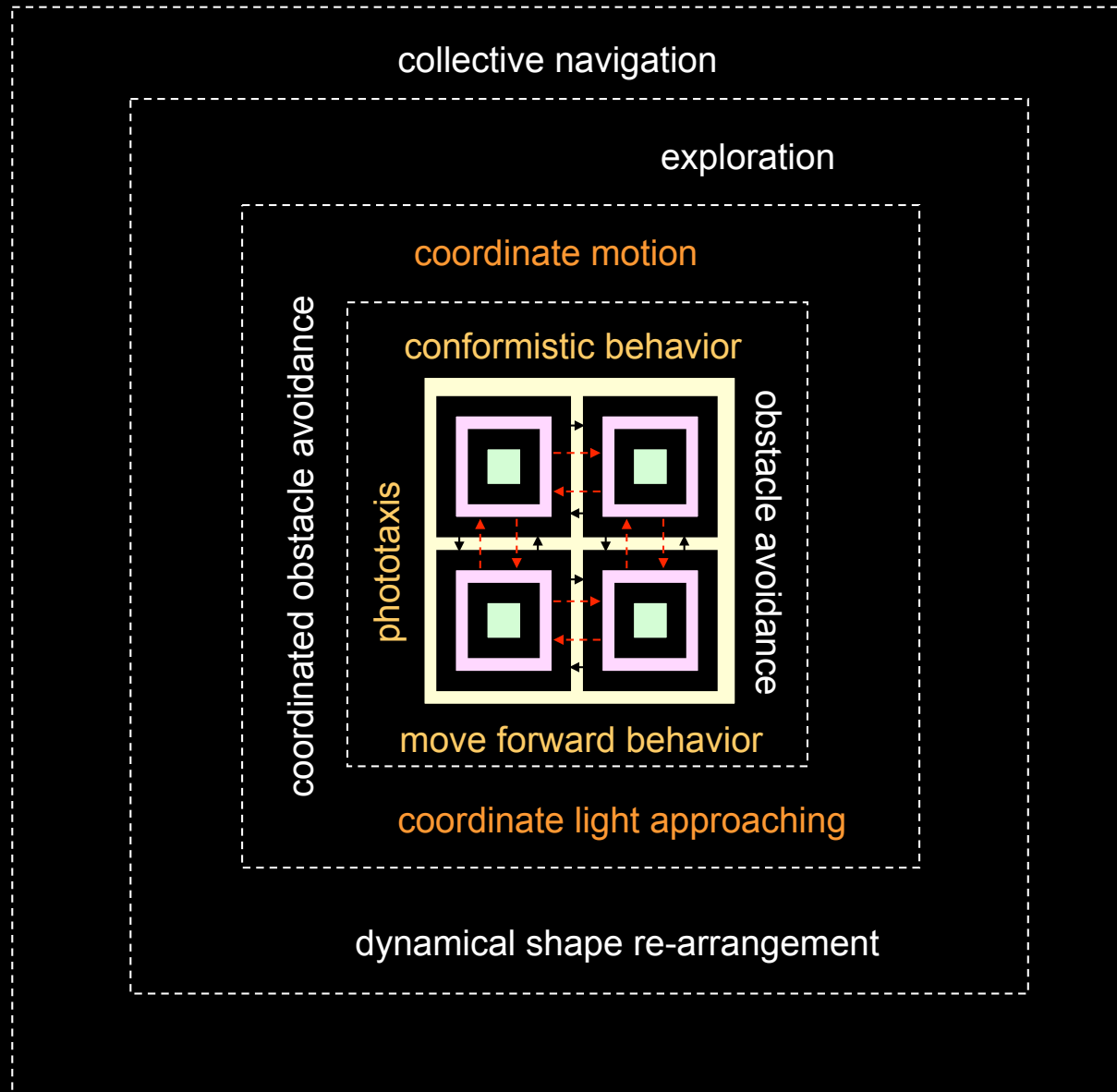
- 1) The number of assembled robots
- 2) The shape of the swarm-bot
- 3) The type of links

Display additional behavioral capabilities:

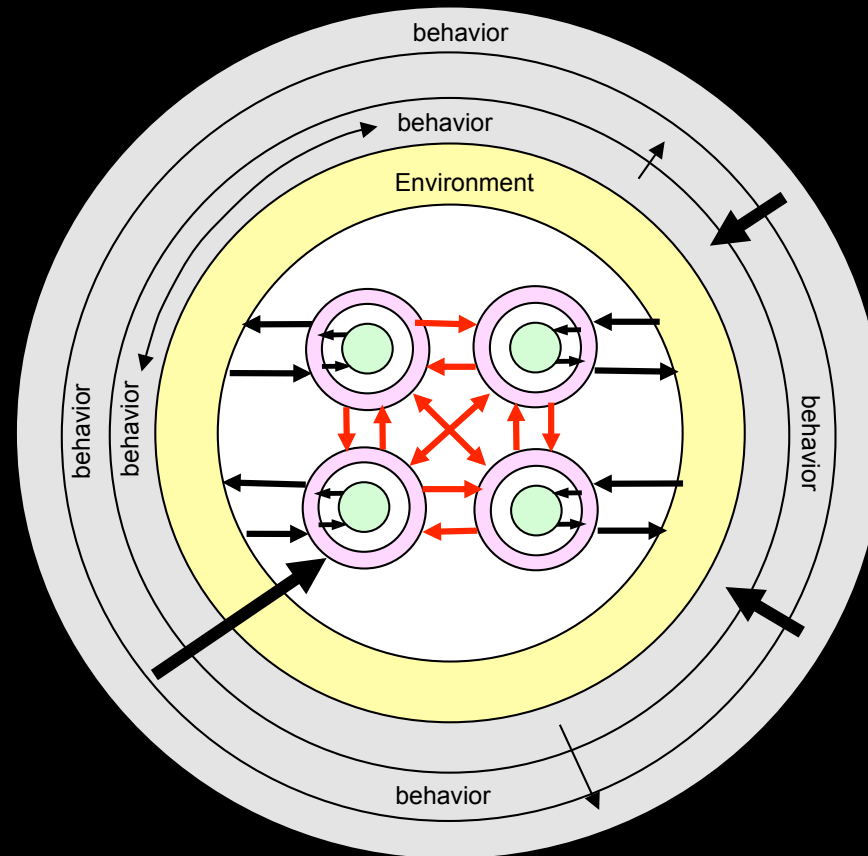
- 1) Collective obstacle avoidance
- 2) Collective object-pushing pulling
- 3) Dynamical shape re-arrangement



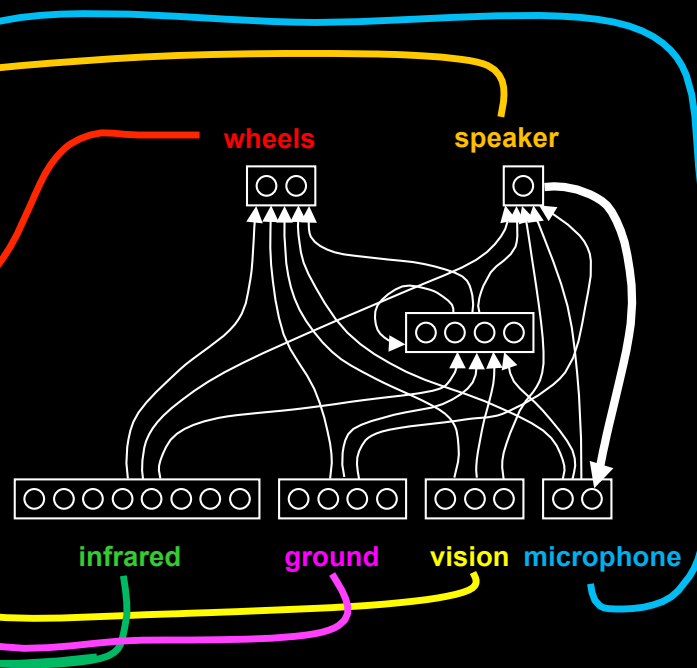
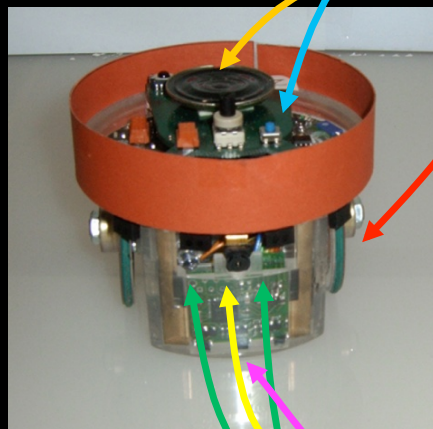
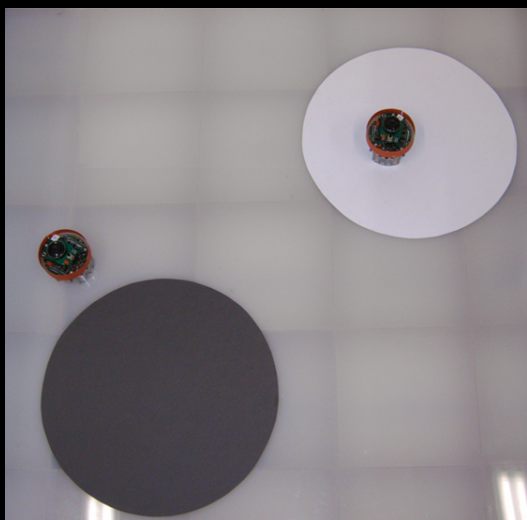
The multi-level structure of the behavior displayed by the robots



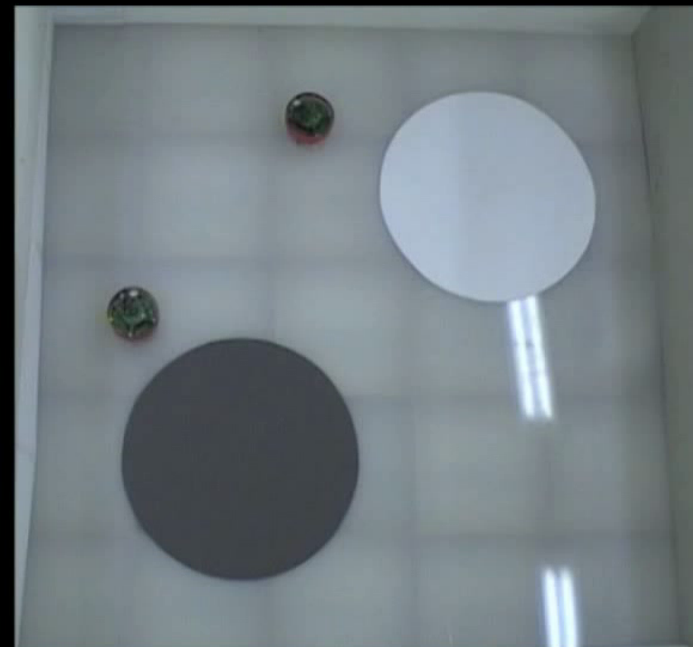
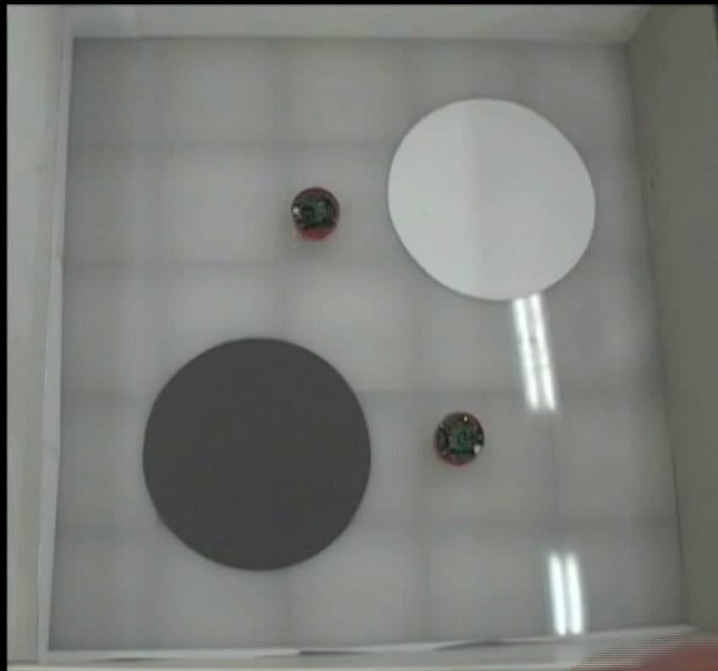
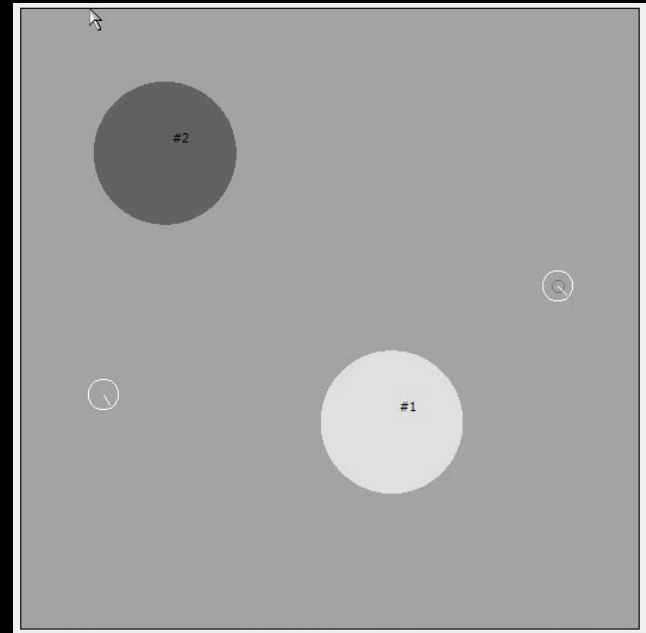
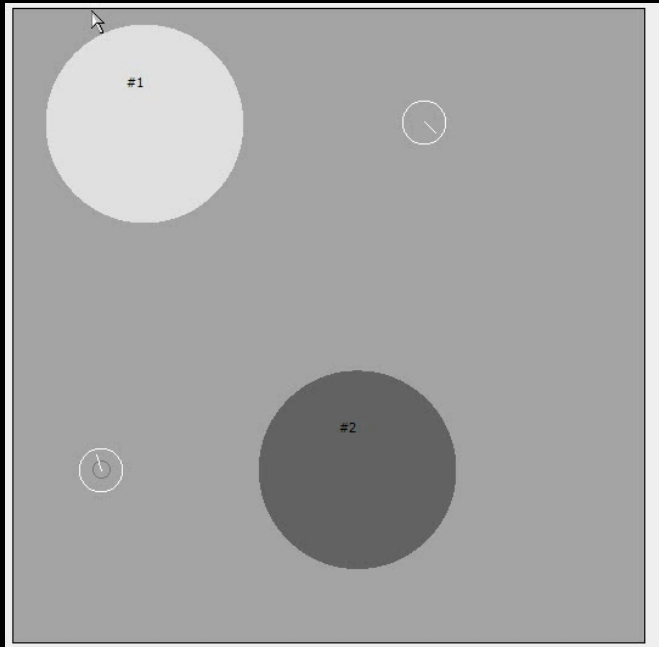
2. How the development of behavioral skills establish the conditions for the development of new higher-levels skills



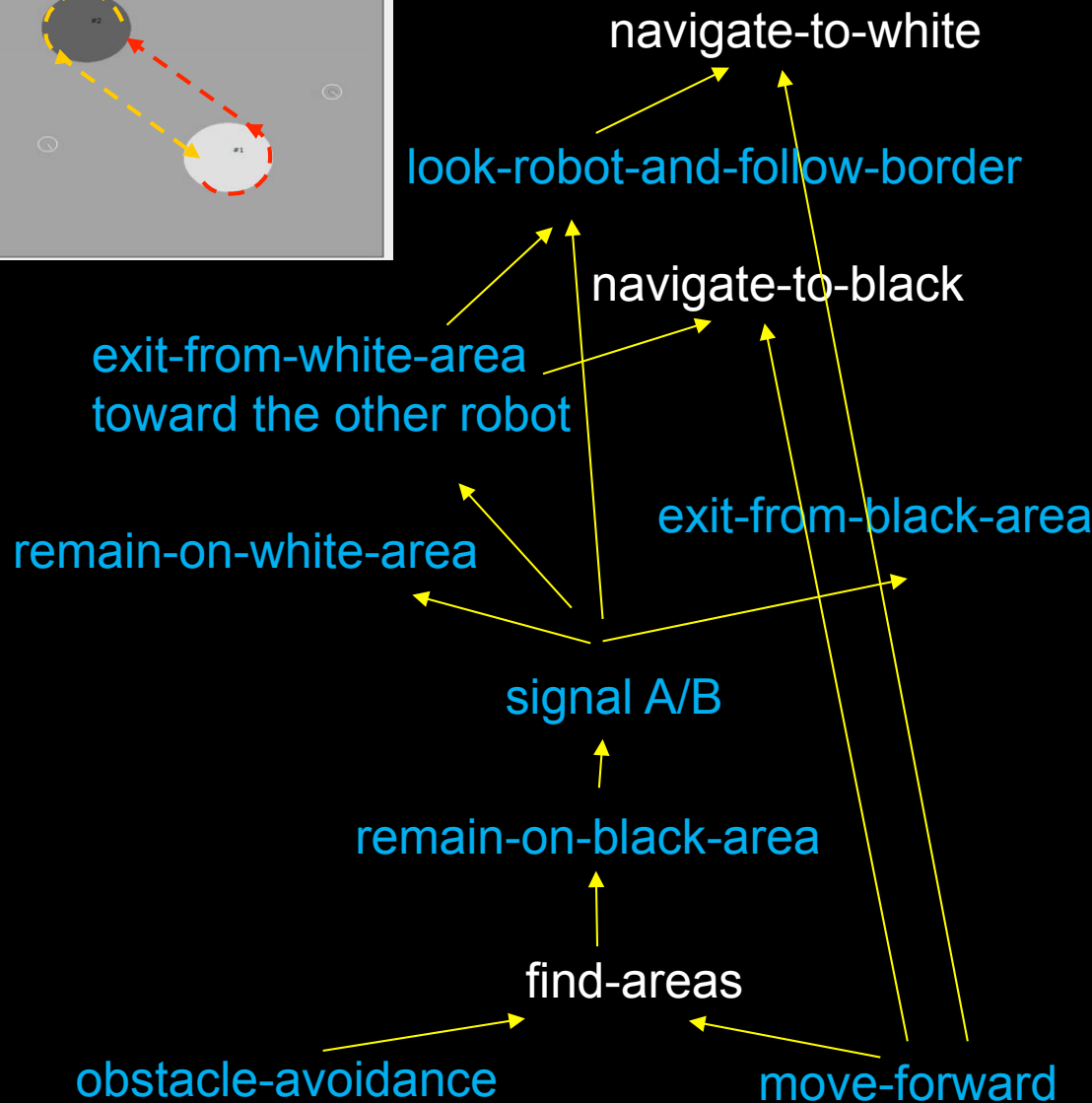
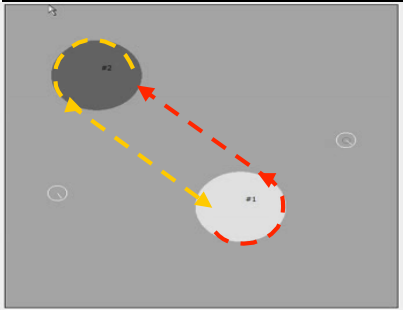
Evolution of behavioral and communication skills in groups of cooperating robots



Fitness Function: The group is reward with 1 point every time the robots are concurrently located in the two areas for the first time or after a switch



Summary of the main evolutionary progresses



Infrared-off -> move-forward

Infrared-on -> avoid-obstacles

move-f. & avoid-ob. -> find areas

ground-black -> remain on the black area look-robot-and-follow-border

ground-white/black -> signal A/B

Sound-B & ground-black -> exit from black area

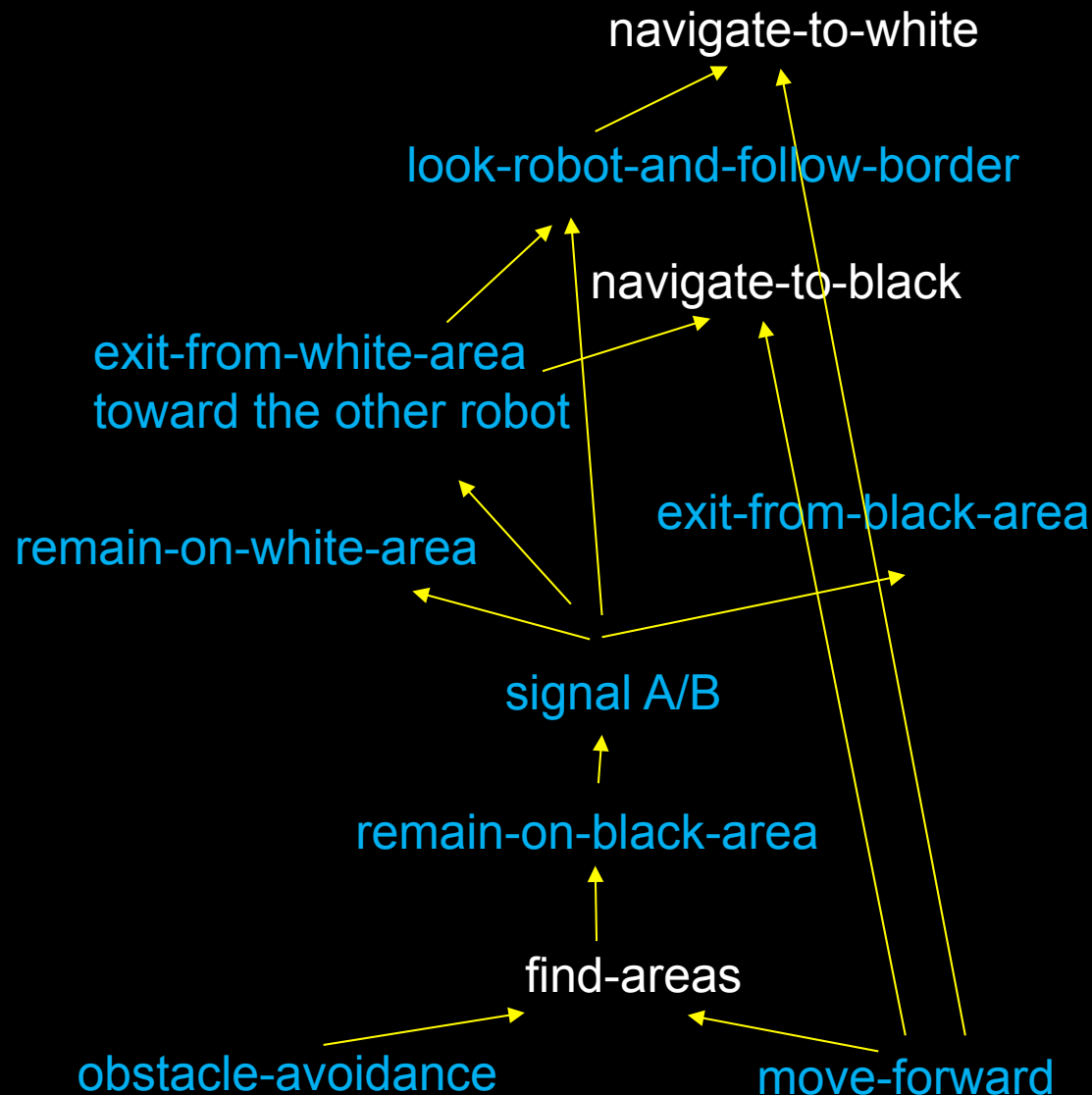
Sound-A & ground-white -> remain on white area follow border

Sound-B & ground-white & see-robot -> exit from white area toward the other robot

exit from white & move-f -> navigate-to-black

look-r.-follow-b. & & move-f -> navigate-to-white

Multi-level formation, innovations, incrementality & complexification

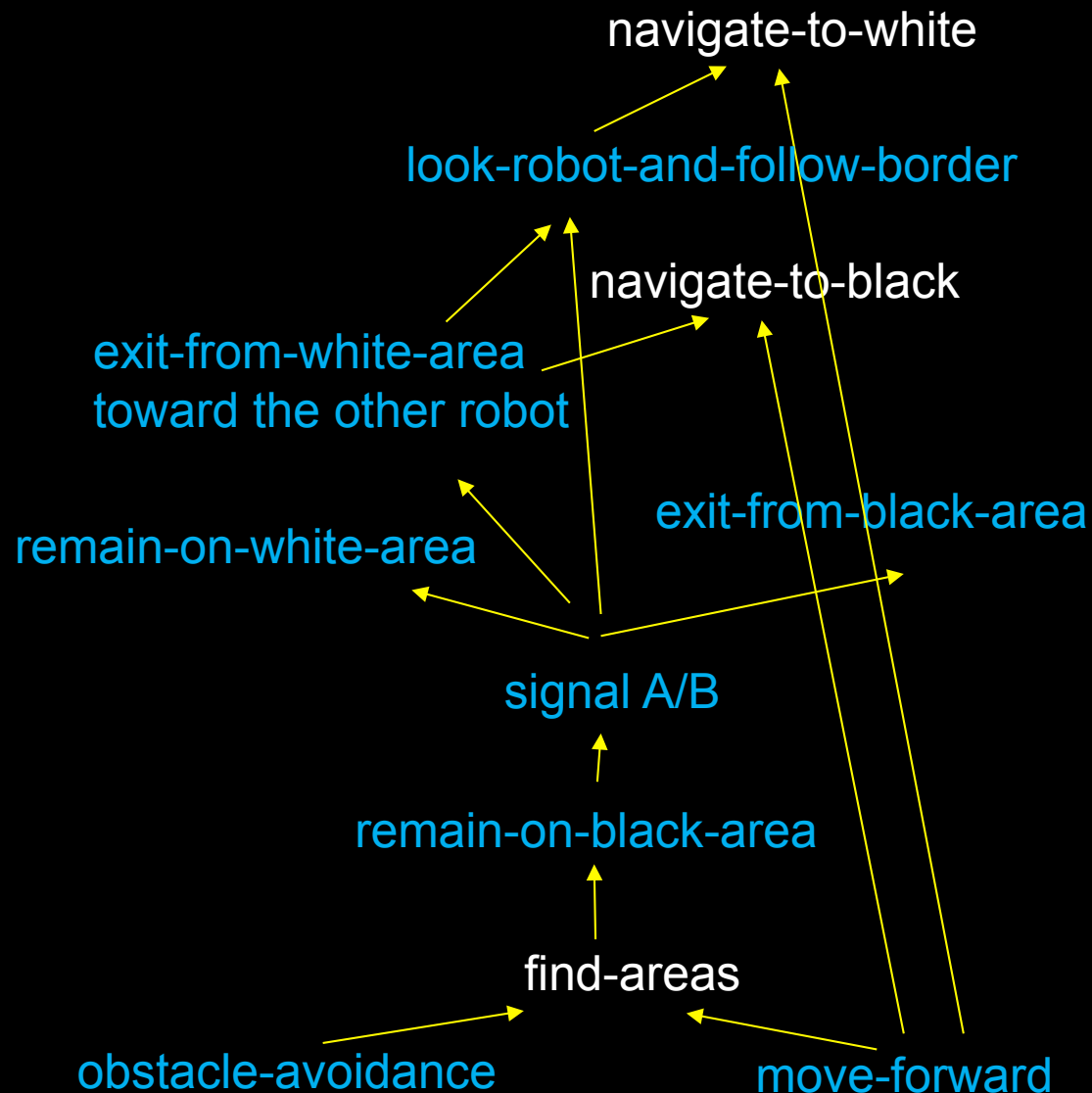


New higher-level capacities emerge through the interactions between pre-existing skills or through new traits combined with skill re-use

Innovations are enabled by the new adaptive opportunities created by the effects of agents' behaviors and by the possibility to re-use existing capacity

Established skills (assuming new functions) tend to be preserved thus leading to an incremental process and to a complexification of agents skills

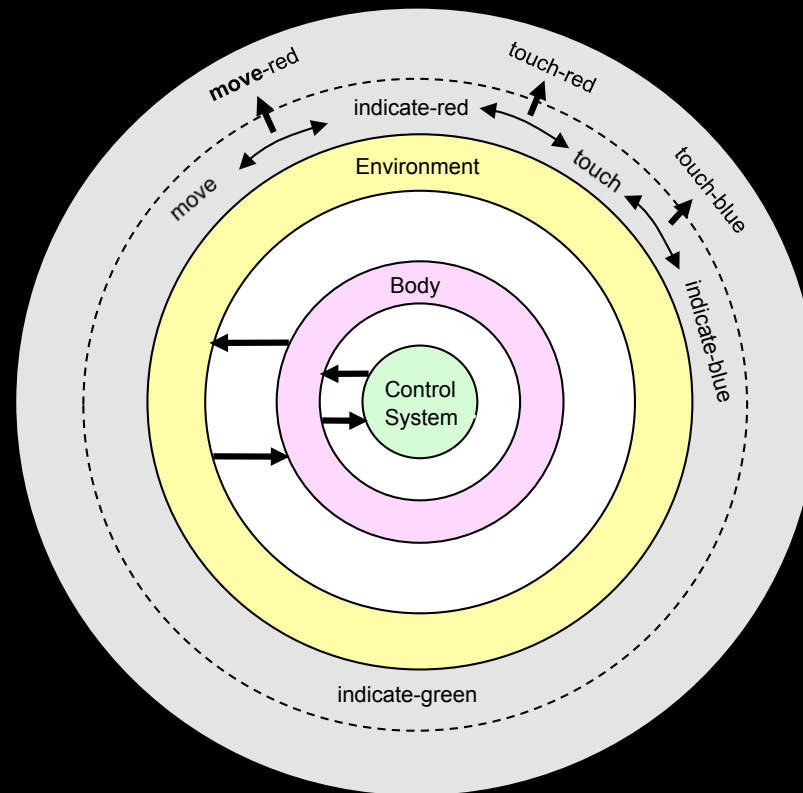
Language and action integration and synergies between language and action development



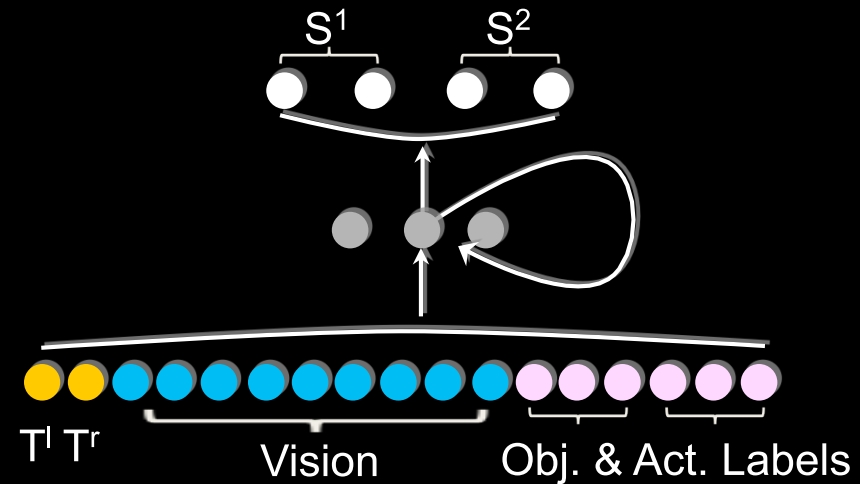
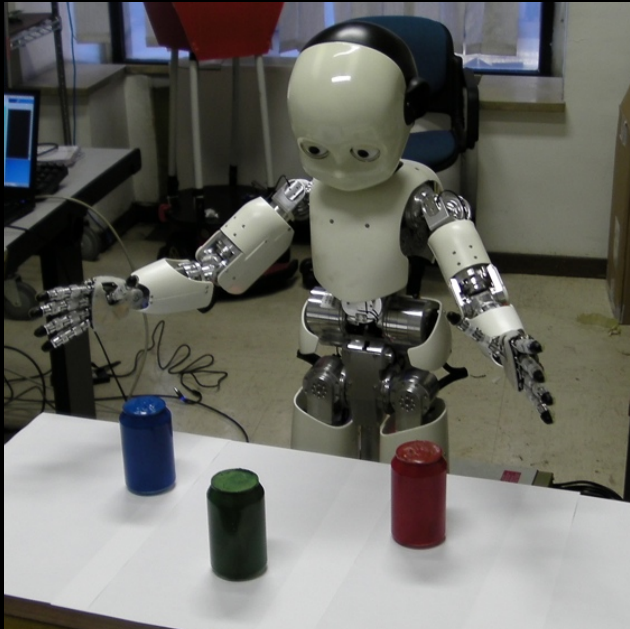
Signals are grounded in behavioral skills

The 'meaning' of a signal is constituted by the action/s triggered by the signal in a specific context.

3. How the multi-level and multi-scale organization of behavior enable compositionality and behavior generalization



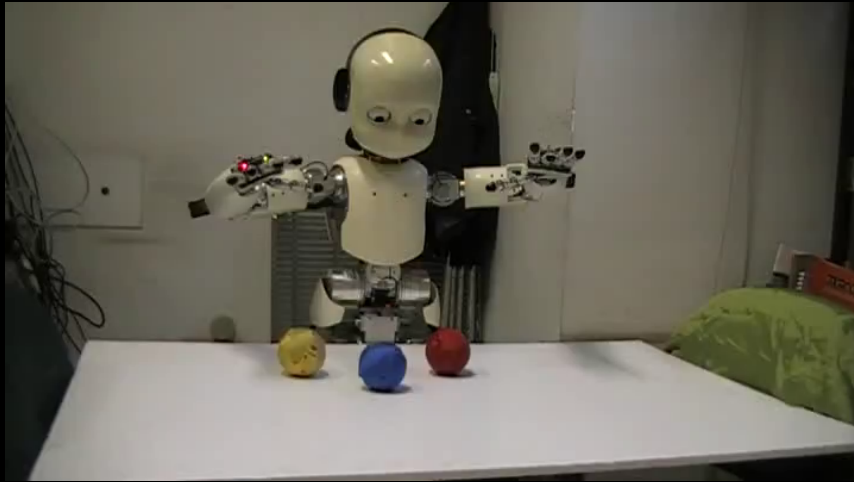
Development of early language comprehension capabilities



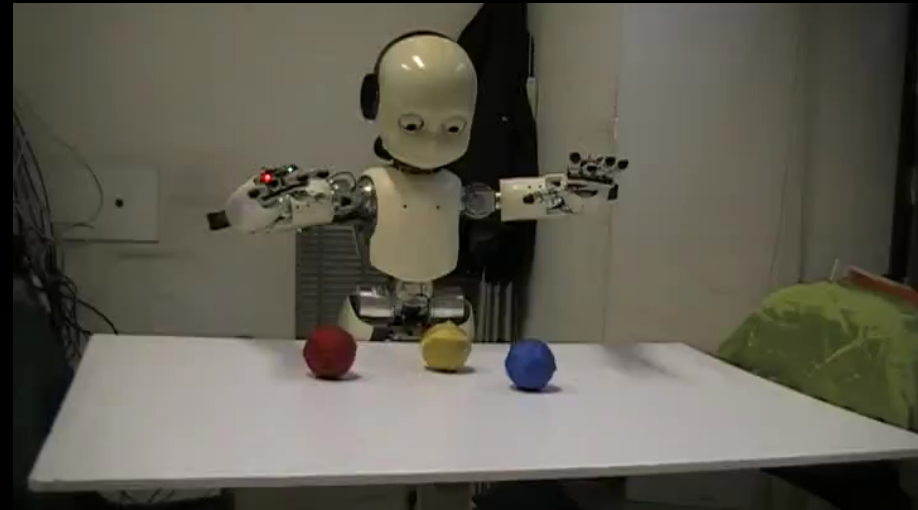
Fitness: The robot is rewarded for the ability to realize the goals of the experienced utterances.

	BLUE	RED	GREEN
IGNORE	YES	YES	YES
TOUCH	YES	YES	NO
MOVE	NO	YES	YES

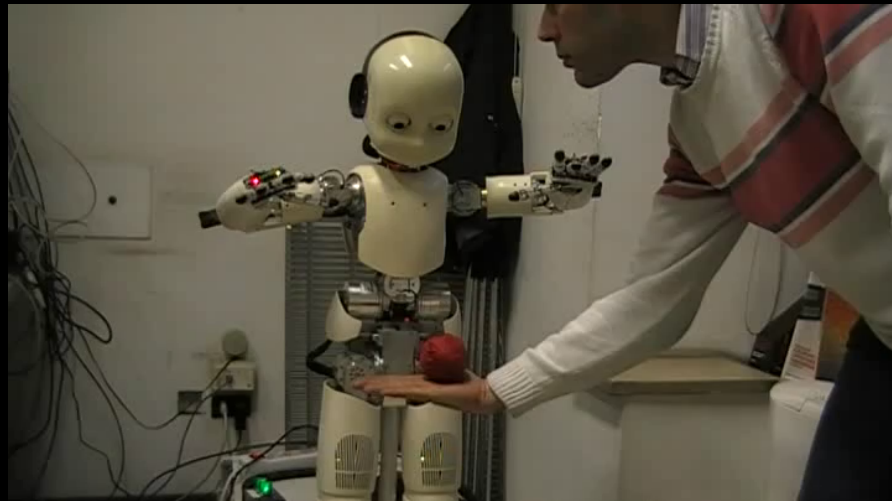
Development of early language comprehension capabilities



INDICATE RED



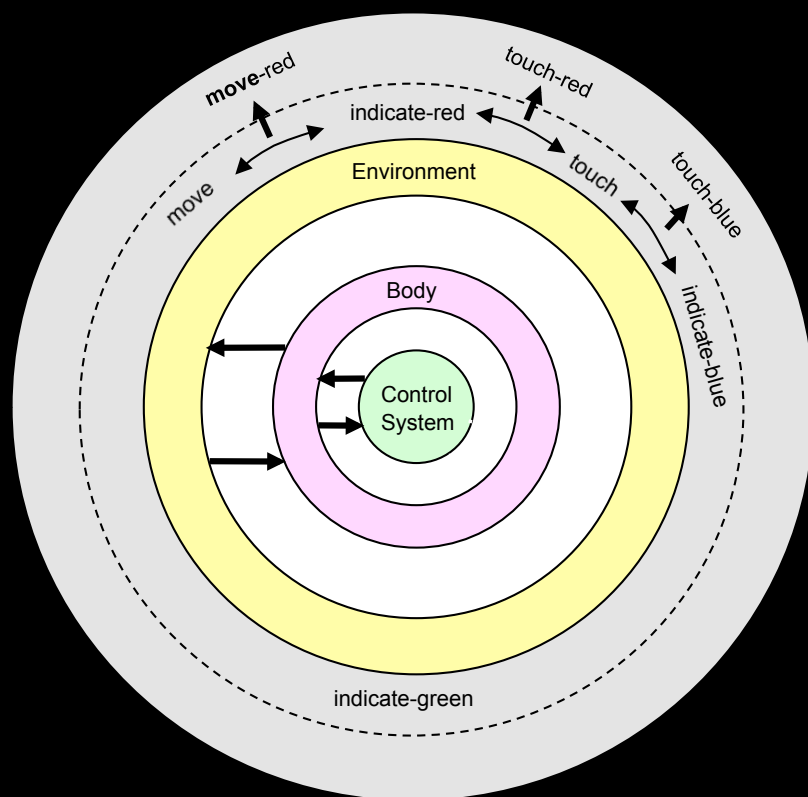
TOUCH YELLOW



GRASP RED

Generalization in Comprehension and Action Production

By post-evaluating the robots at the end of the training process with observed that some of them display an ability to comprehend the two new utterances by displaying the corresponding appropriate behaviors.



Robots trained to produce related skills tend to lead to solutions based on multi-level organizations supporting skill re-combination and re-use.

thank you for your attention