Modeling Social Interaction for Baby in Simulated Environment for Developmental Robotics (SEDRo)

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Demo of SEDRo

In [ ]:

```
# print(state_size, action_size)
# agent = Agent(state_size=state_size, action_size=action_size, dqn_type='DQN')
```

In [23]:

```
touchHappened = False;
visualObservationNames = ["Common Central View", "Common Peripheral View",
                          "Left Central View", "Left Peripheral View",
                          "Right Central View", "Right Peripheral View"]
for episode in range(1000):
    env.reset()
    step_result = env.get_steps(group_name)[0]
    done = False
    episode_rewards = 0
    step = 0
#     print(step)
    voiceTxt = ""

#     while not done:
    while not done:
        action_size = group_spec.action_size
#         print( group_spec.is_action_continuous())
        if group_spec.is_action_continuous():
            action = np.random.randn(len(step_result), group_spec.action_size)
#             action = np.zeros((step_result.n_agents(), group_spec.action_size))
#             action[0][40] = .5;

#             action[0][41] = .0002
#             print("action shape: ", action.shape)

        # Set the default brain to work with
#         group_name = env.get_agent_groups()[0]
#         print(group_name)
#         group_spec = env.get_agent_group_spec(group_name)
#         print(group_spec.observation_shapes)

        if group_spec.is_action_discrete():
            branch_size = group_spec.discrete_action_branches
            print("branch_size", branch_size)
            action = np.column_stack([np.random.randint(0, branch_size[i], size=(step_result.n_a
#         print(action)
        env.set_actions(group_name, action)
```

Key Characteristics of SEDRo

1. Open-ended tasks with No Reward
2. Human-like Experience
3. Longitudinal Development

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1. Open-ended tasks with No Reward
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In this talk

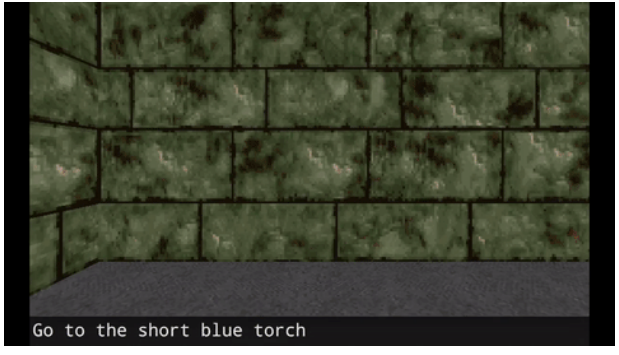
1. Why No Reward
2. Why Human-like Experience
3. Why Longitudinal Development

1. Why No Rewards?

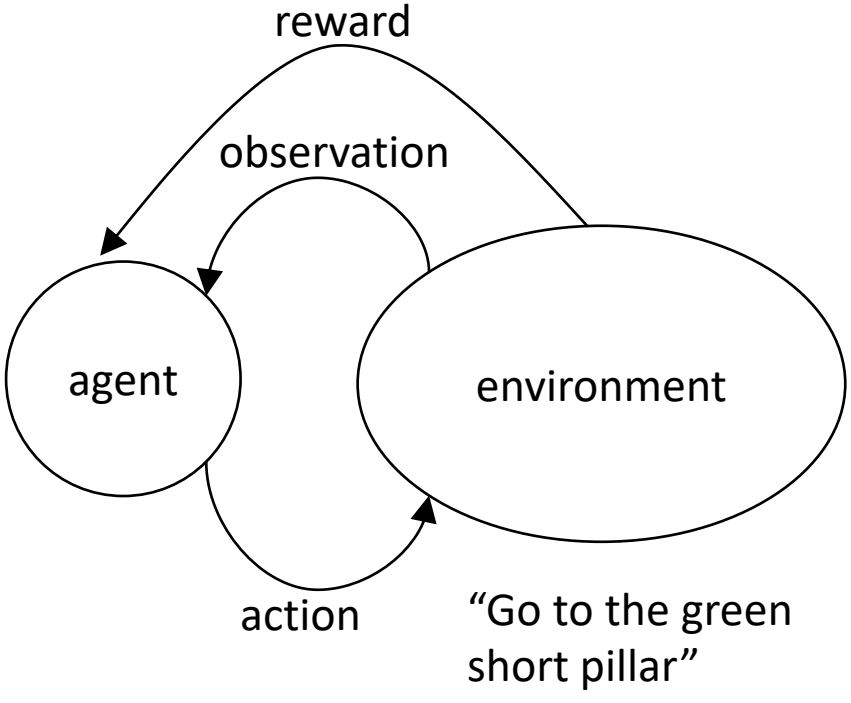
“Mommy, look, it’s doggy”

“Good job. Here is your candy.”

Grounded Language Acquisition



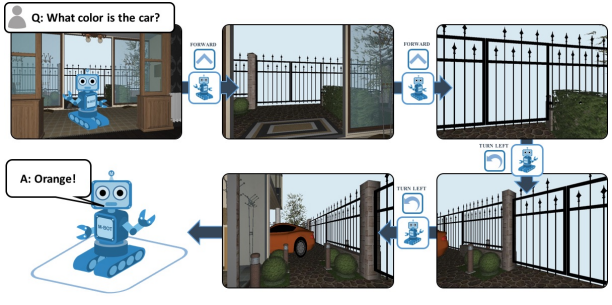
Chaplot 2018



Chaplot 2018

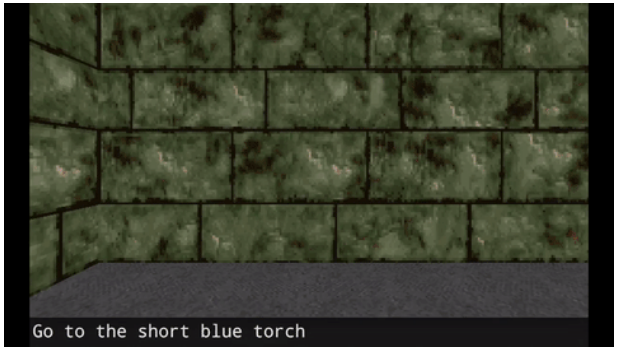
"Put the cereal, the sponge, and the dishwashing soap into the cupboard above the sink."

CHALET, Yan et al 2018



Embodied Q&A

Orient yourself so that the umbrellas are to the right. Go straight and take a right at the first intersection. At the next intersection there should be an old-fashioned store to the left. There is also a dinosaur mural to the right. Touchdown is on the back of the dinosaur.



Transferring language skill

Navigation
Question and Answering

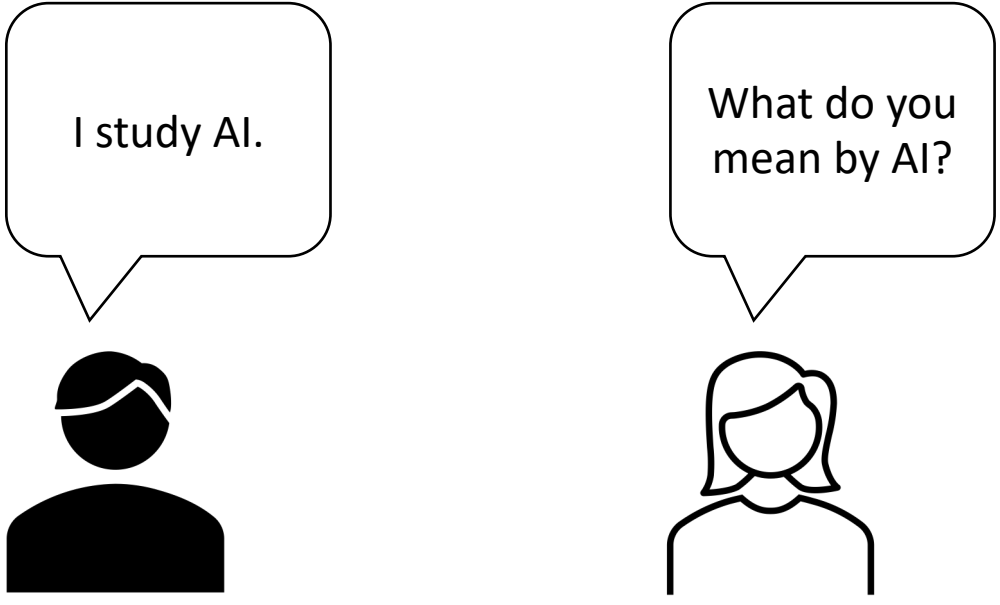
- Conversation
- Status reporting
- Book reading
- Knowledge acquisition

Value function (State, action) is overfitted to specific application.

State = being heard some words
Action = doing some stuff

State = Being in certain state
Action = Saying some words

Is the reward the culprit?

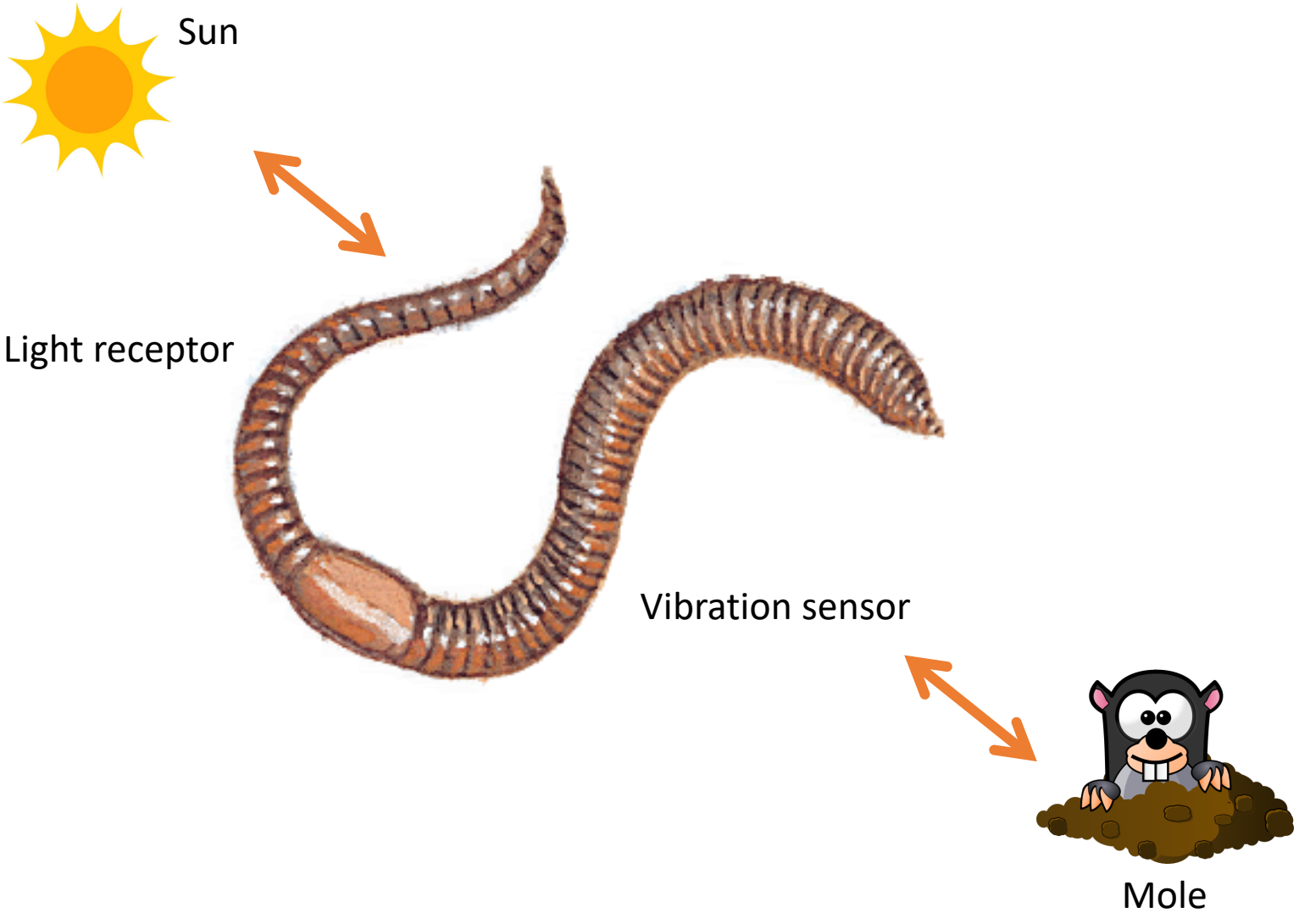

I study AI.
What do you mean by AI?

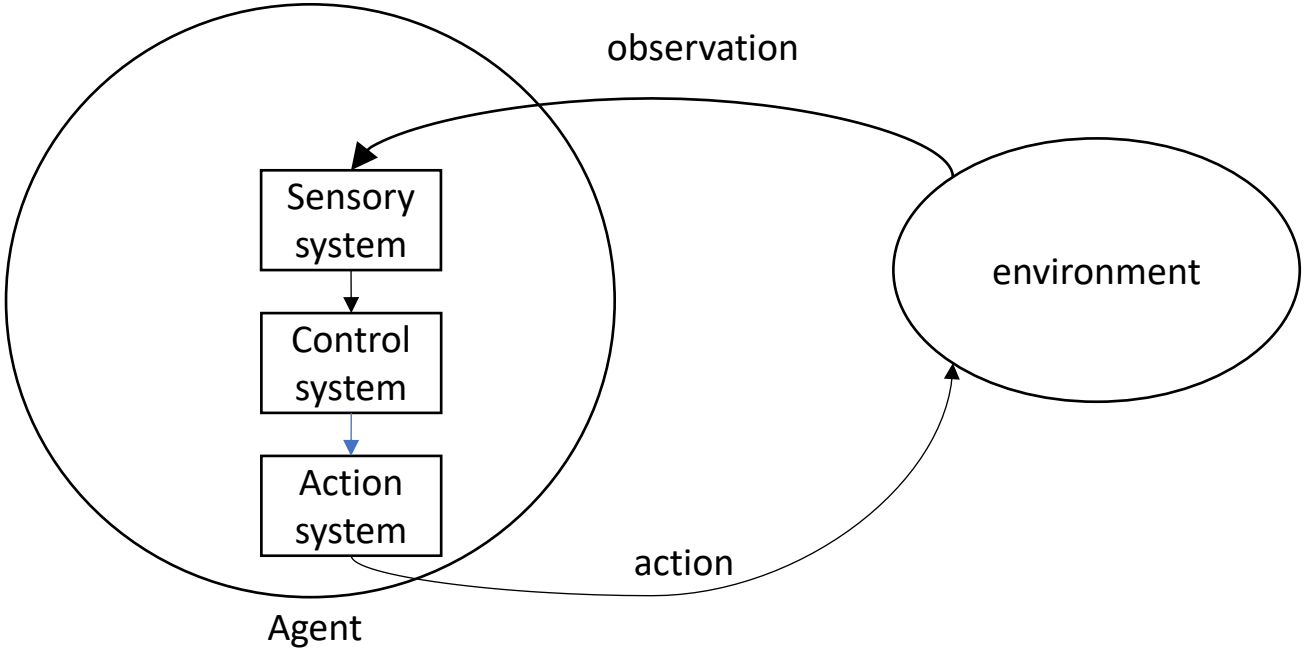
Universal Intelligence

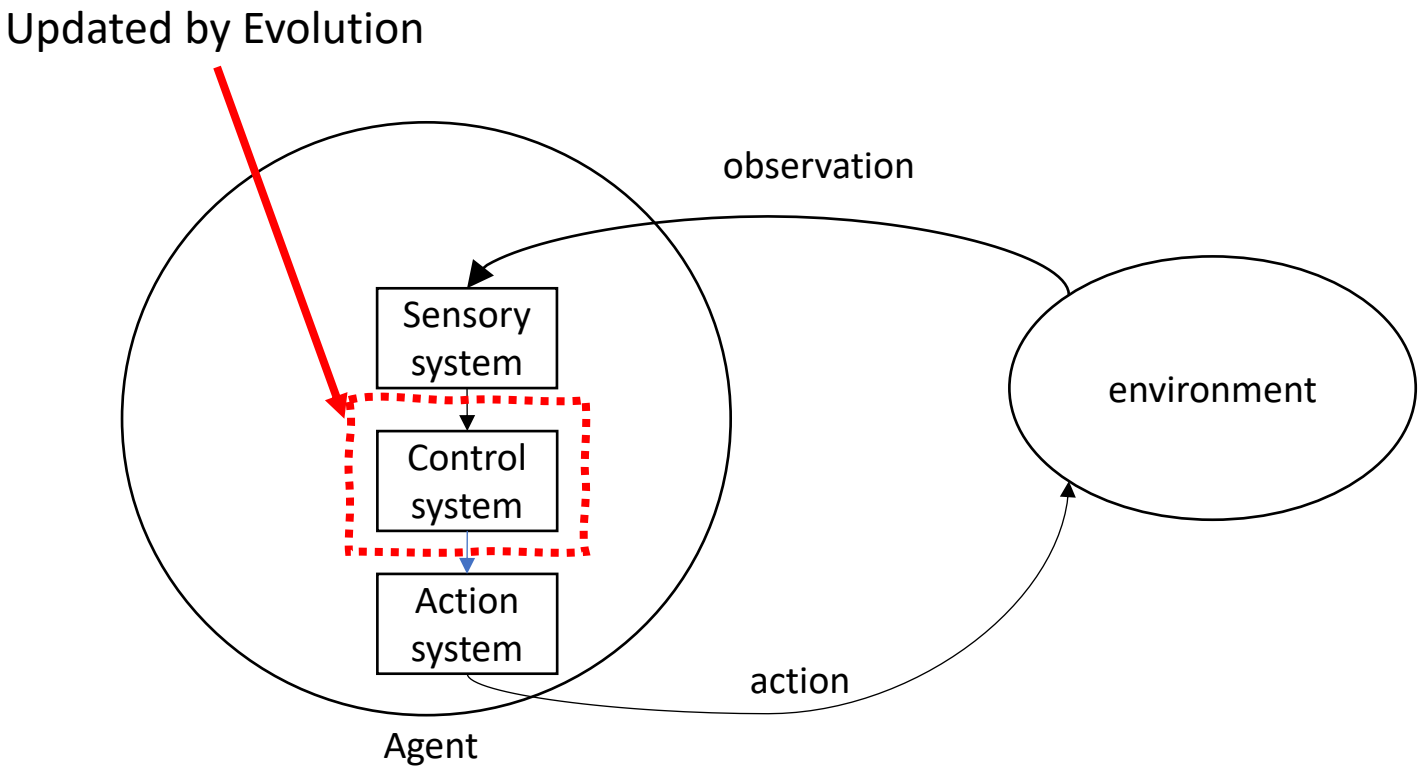
"Intelligence measure an agent's ability to achieve goals in a wide range of environments."

Legg, Shane, and Marcus Hutter. "Universal intelligence: A definition of machine intelligence." *Minds and machines* 17.4 (2007): 391-444.

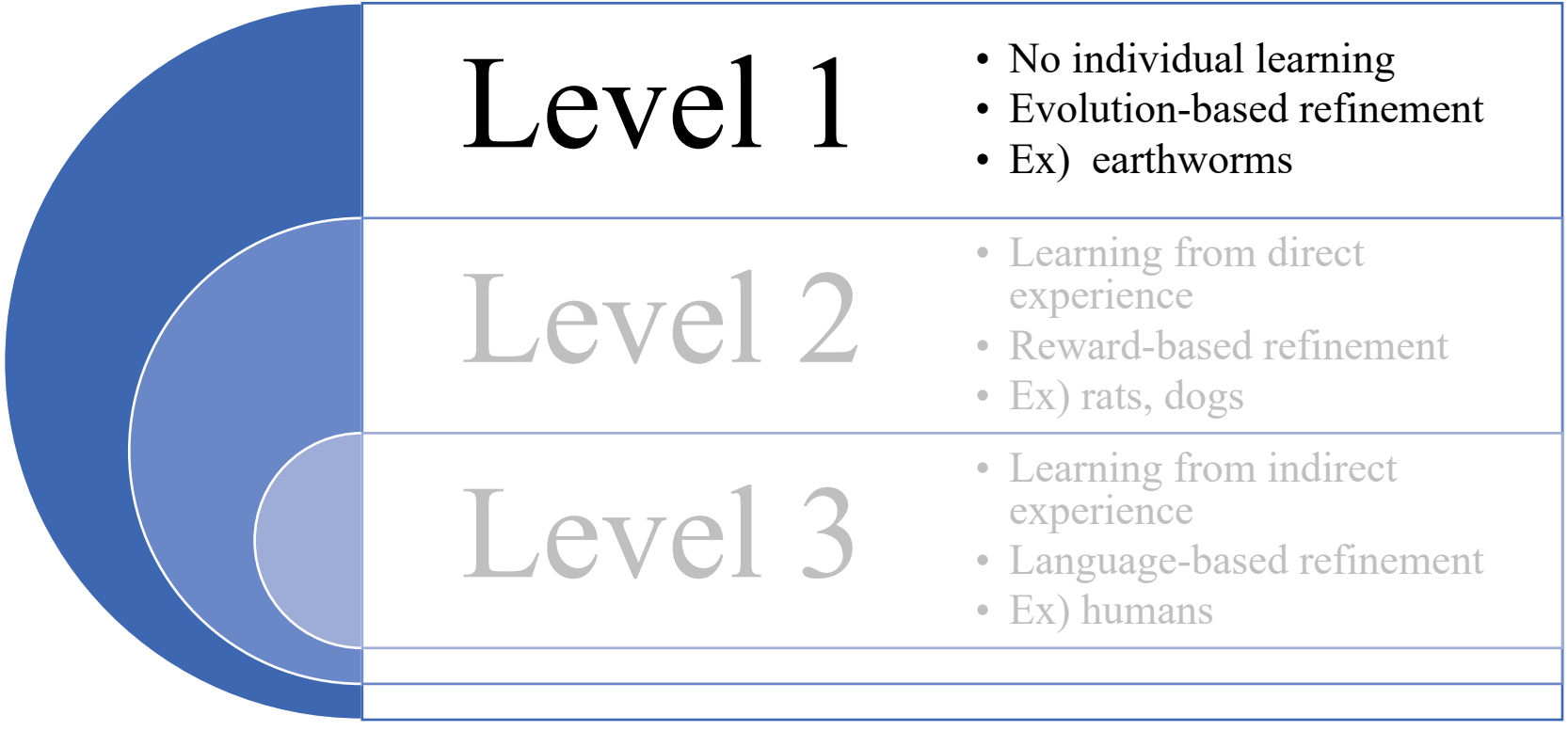
Earthworm


Sun
Light receptor
Vibration sensor
Mole

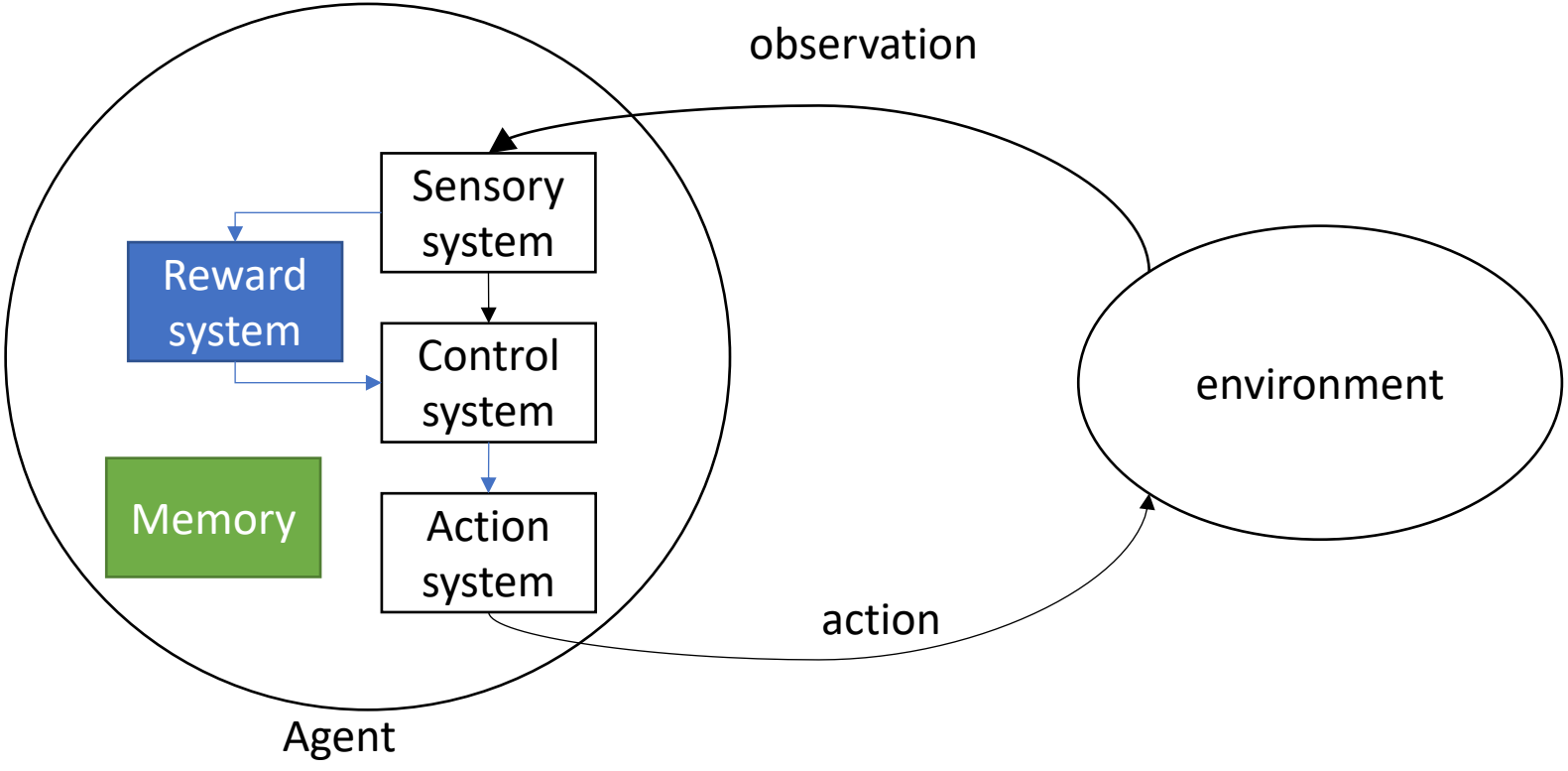

observation
Sensory system
Control system
Action system
environment
action
Agent


Updated by Evolution
observation
Sensory system
Control system
Action system
environment
action
Agent

Three levels of Intelligence

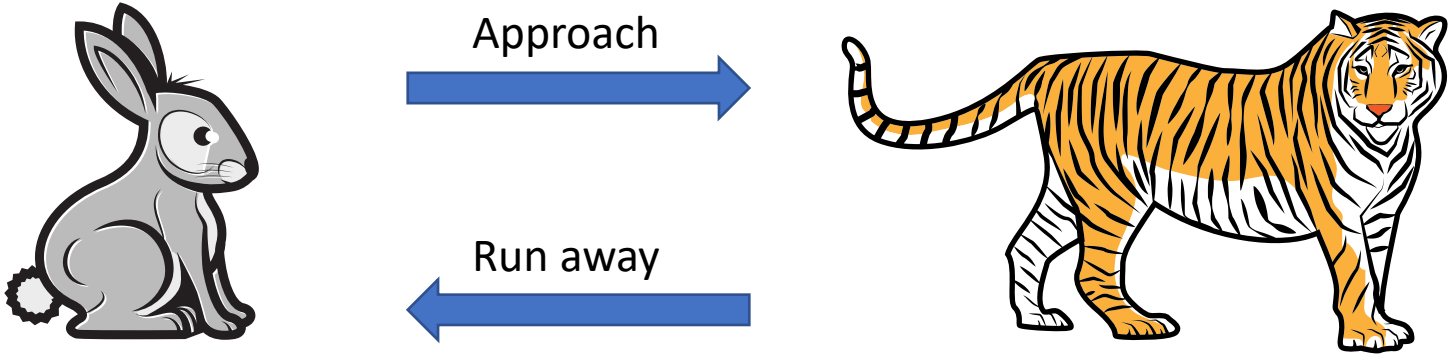


Level 2 Intelligence

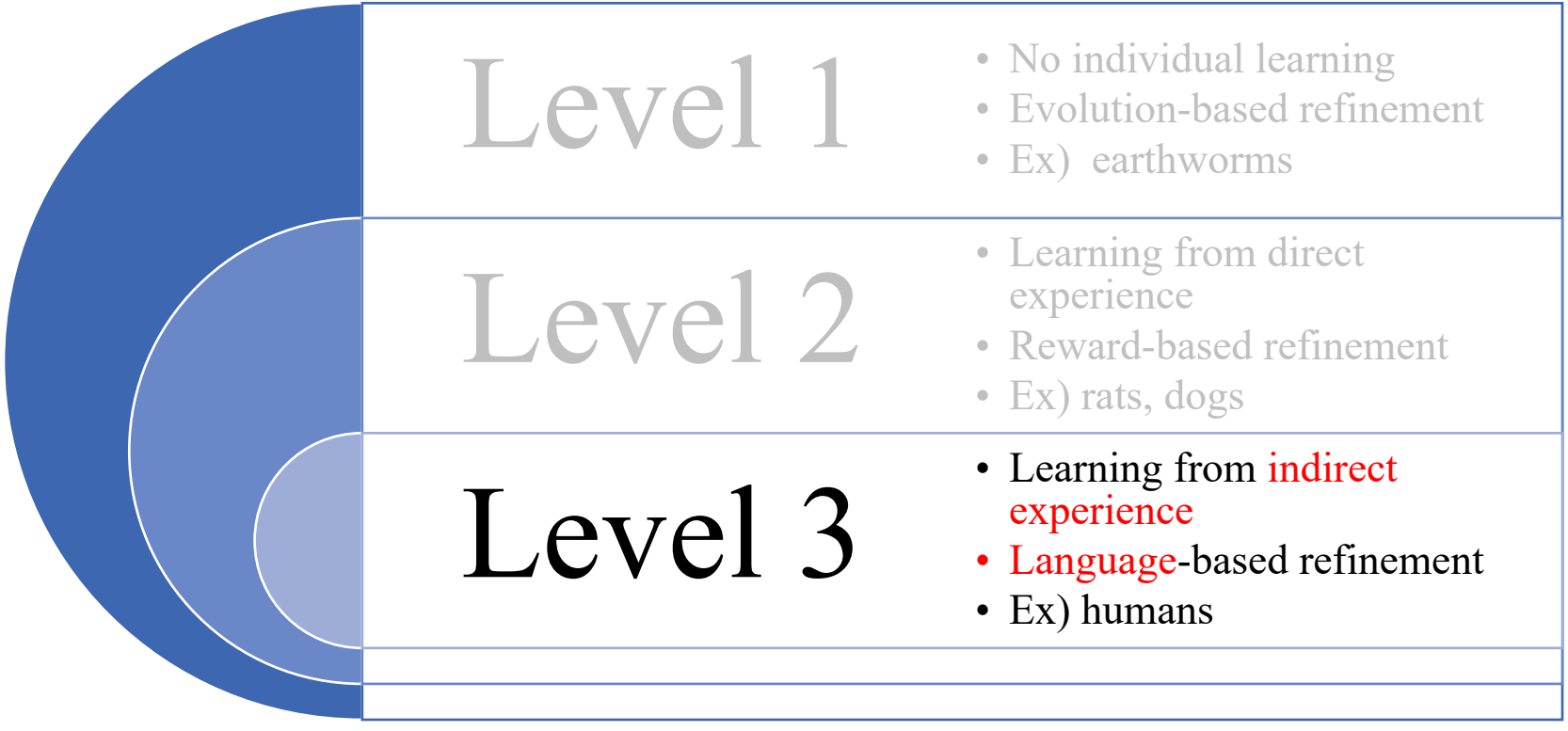


Three levels of Intelligence

Limitation of Direct Experience



Three levels of Intelligence

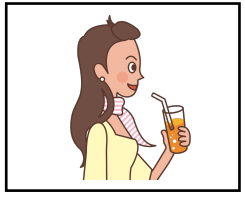


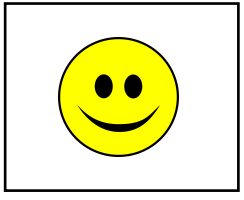
Clarifying Language Skills

- Dolphins use a verbal sign to communicate
- Monkeys learned a sign language
- Voice assistant - Siri, Alexa, Google assistant
- Agents navigate or answer questions using RL
- GPT-3 can write human-like article
- Models do multi-task in GLUE or DecaNLP

The essence of using language

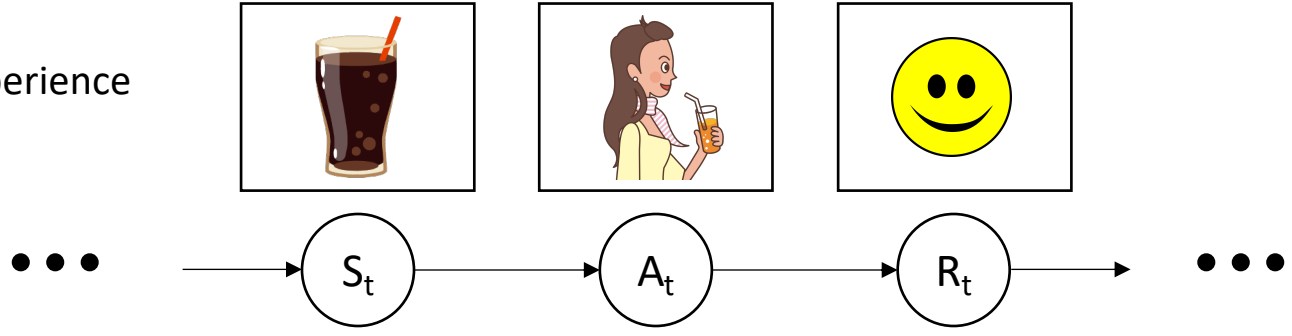
Direct Experience



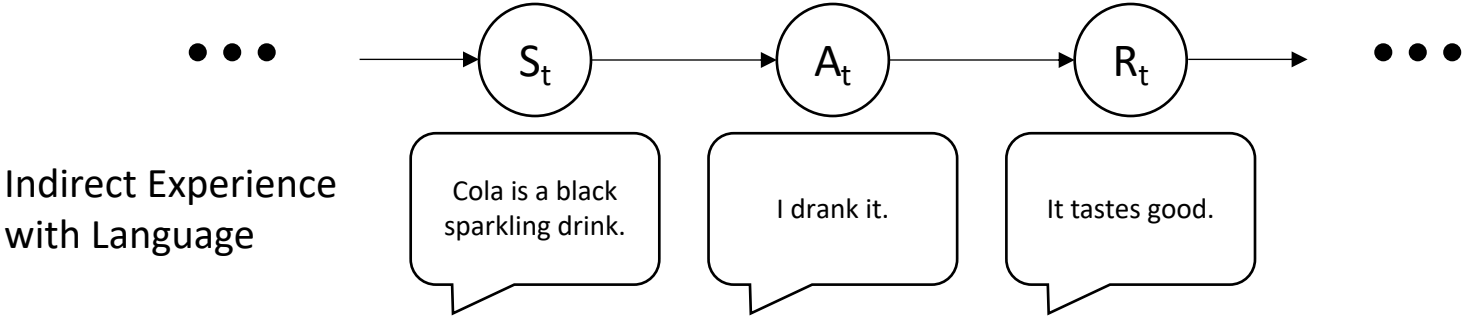


The essence of using langauge

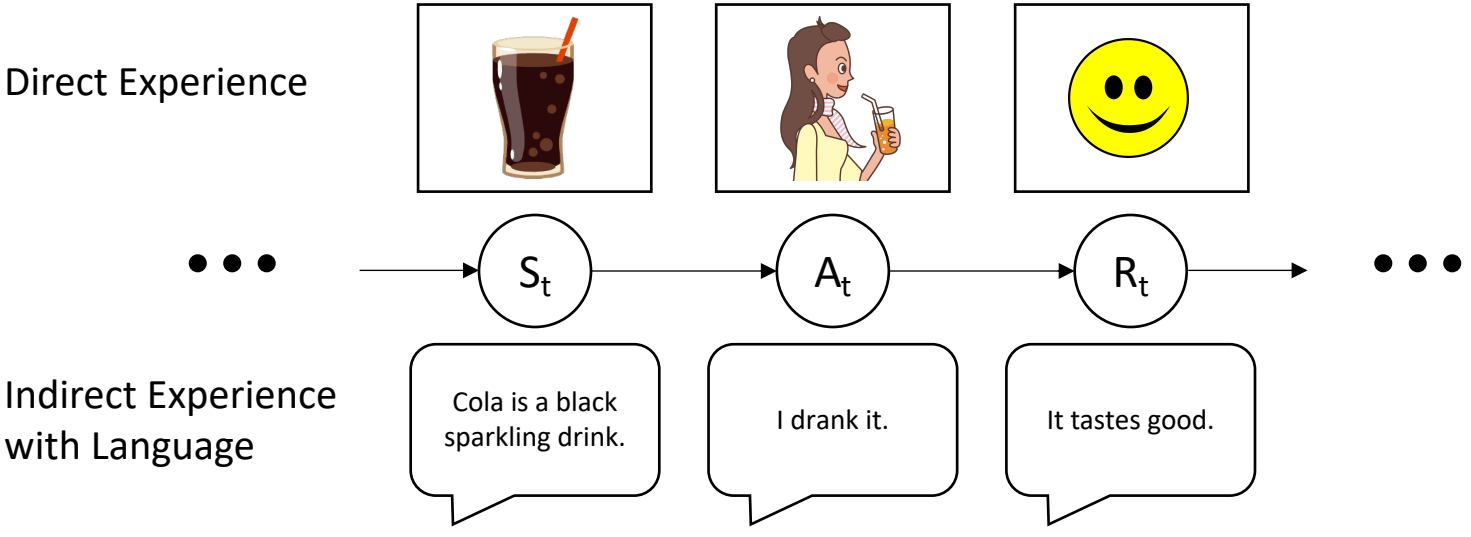
Direct Experience



The essence of using langauge



The essence of using langauge

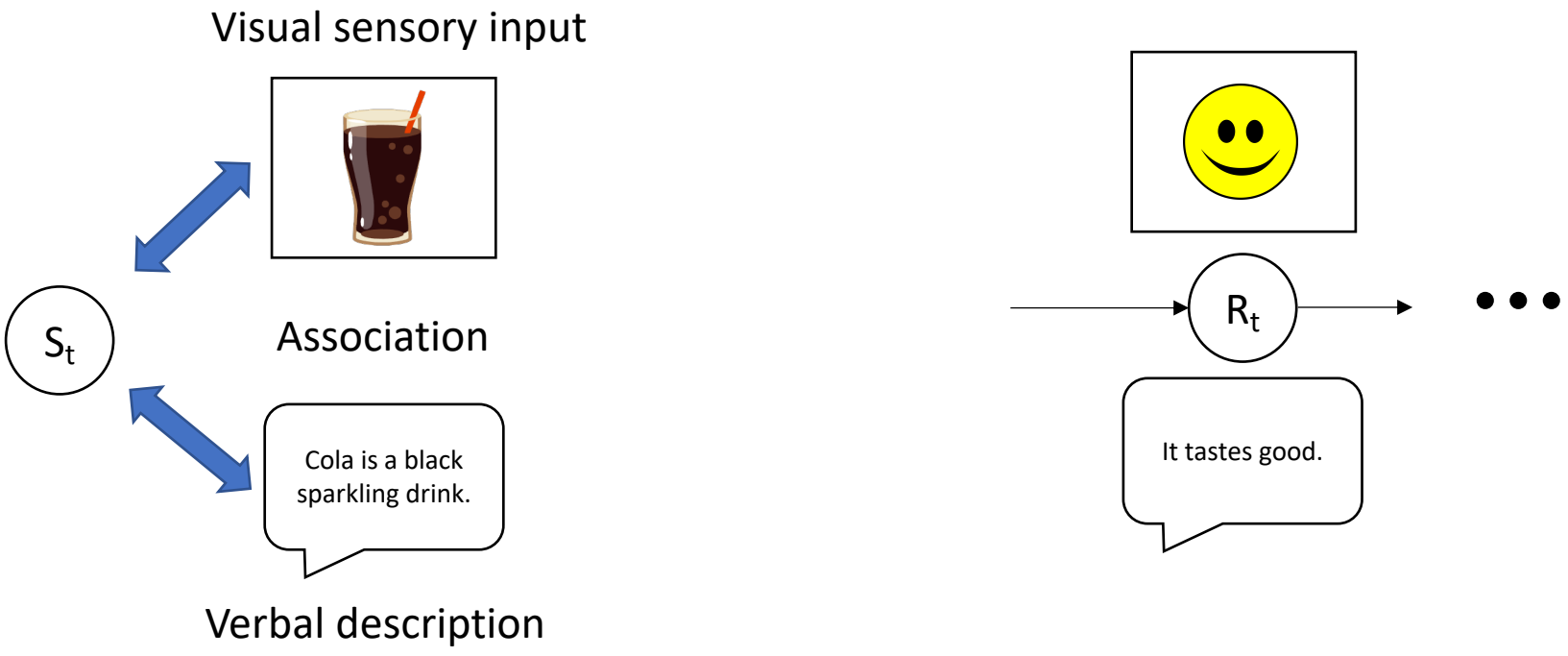


Visual sensory input

S_t

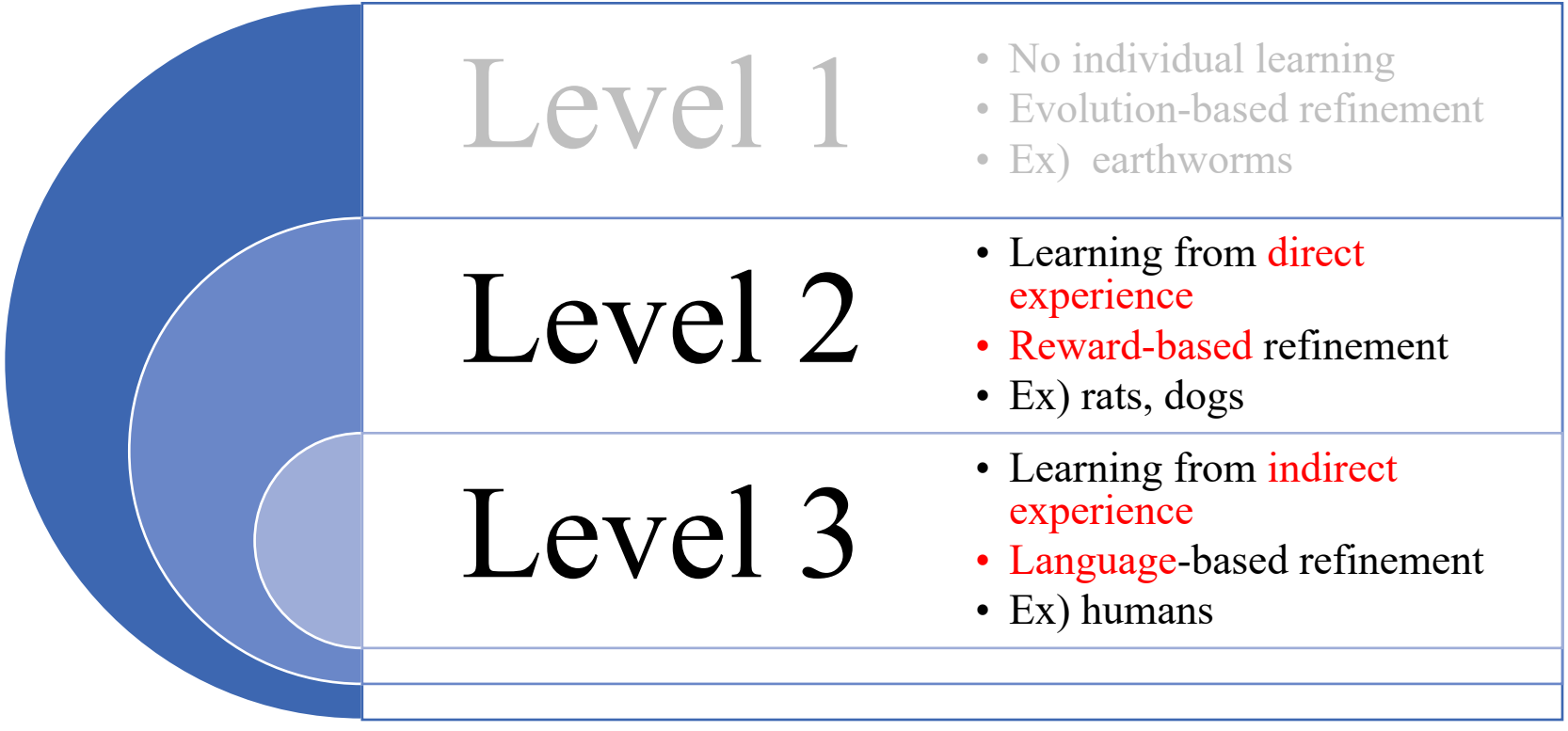
Cola is a black sparkling drink.

Verbal description



Previous RL updates Value function with Rewards
Association between sensory input and language cannot be learned.

Three levels of Intelligence



So far

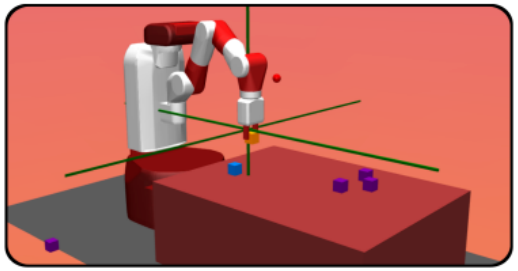
1. Why No Reward
    1. Overfitting
    2. Association between sensory input and language cannot be learned
2. Why Human-like Experience
3. Why Longitudinal Development

2. Why Human-like Experience?

Intrinsic rewards or motivation (Curiosity)

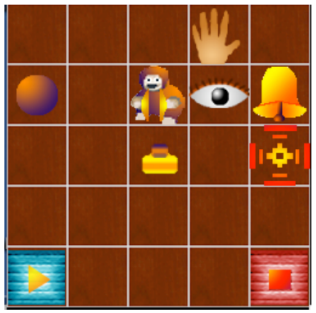
Self-Supervised Learning

Manipulation

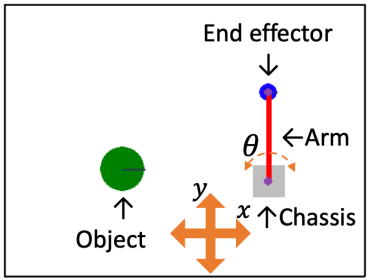


Colas, Cédric, et al. "CURIOUS: intrinsically motivated modular multi-goal reinforcement learning." *International conference on machine learning*. 2019.

Exploration

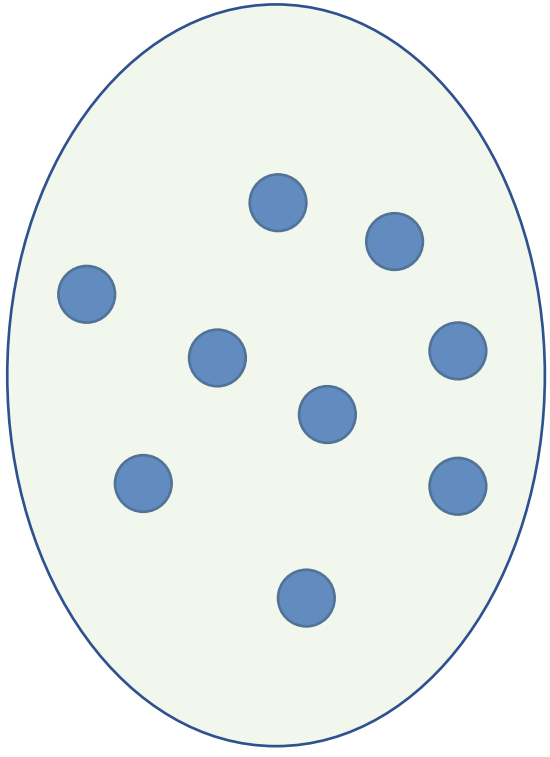


Chentanez, Nuttapong, Andrew Barto, and Satinder Singh. "Intrinsically motivated reinforcement learning." *Advances in neural information processing systems* 17 (2004): 1281-1288.



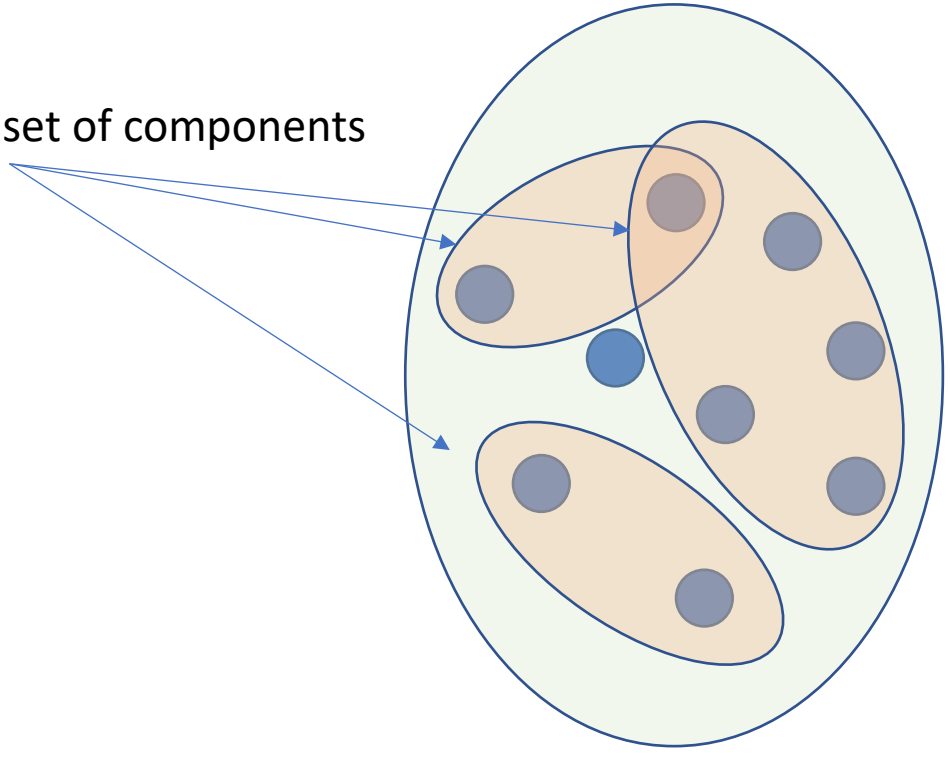
Hiroki Mori, Masayuki Masuda, Tetsuya Ogata: Tactile-based curiosity maximizes tactile-rich object-oriented actions even without any extrinsic rewards, Proceeding of IEEE International Conference on Development and Learning and on Epigenetic Robotics

Bellemare, Marc, et al. "Unifying count-based exploration and intrinsic motivation." *Advances in neural information processing systems*. 2016



Sufficient set of
Components for
Human-level AI

Partial: Necessary set of components

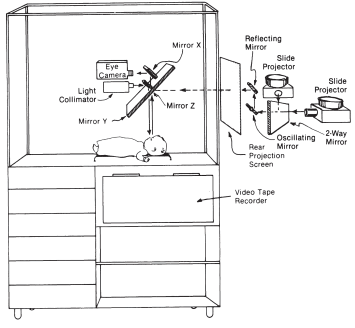


Sufficient set of
Components for
Human-level AI

Interpretability

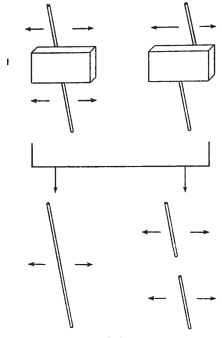
How can we evaluate the development of the agents exploring with babbling?

Evaluation of Non-Verbal Agent

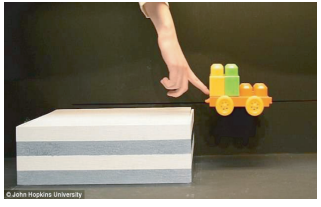


(a)

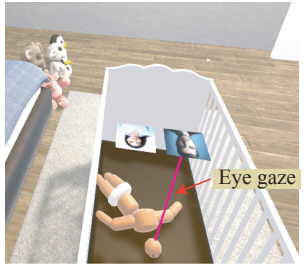
(b)



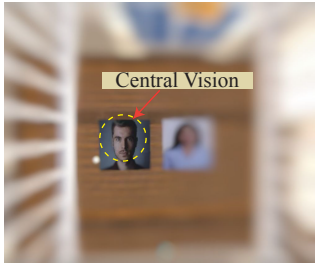
(c)



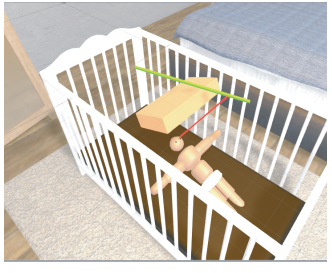
(d)



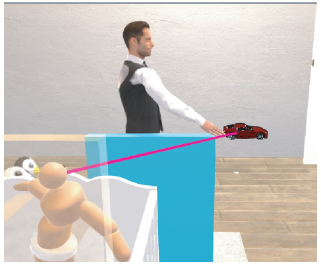
(e)



(f)

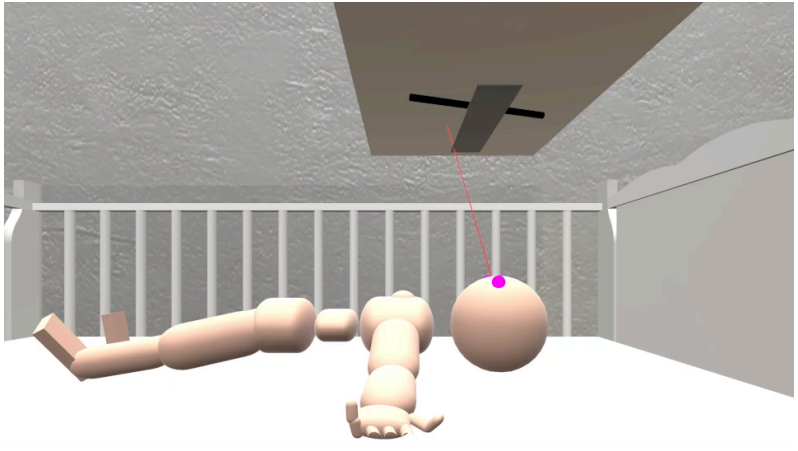


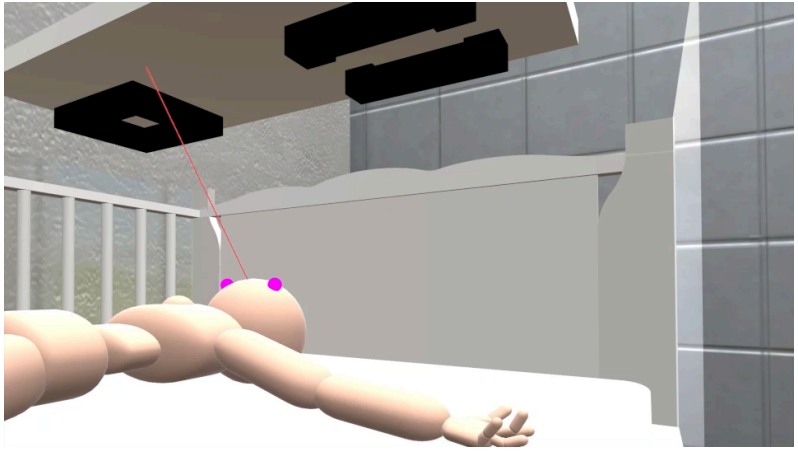
(g)



(h)

Unity Perception





Slater, Alan, et al. "Newborn and older infants' perception of partly occluded objects." *Infant Behavior and Development* 13.1 (1990): 33-49.

Evaluation

Stage	Fetus Stage	Immobile Stage (Less than 3 Months)	Crawling Stage (4-10 Months)	Walking Stage (11-18 Months)
Description	No vision	Near sighted vision.	Fully developed vision. Sit and interact with objects. Interact with other persons by babbling.	Fully developed mu cles. First words
Vision		Imitate facial motion (new born) [75], Visual expectation of regular pattern(2 vs 3.5 Months) [51, 70, 71, 72], face preference(new born, 1 vs 2 Months) [76, 77, 57, 78], mother face preference(2 3 days) [54, 79] ,face gender detection(newborn vs 3 Months) [80, 81], depth perception by visual cliff(newborn vs 2 months) [82]	Visual scan pattern (2 vs 11 weeks) [83], Attending face (1 vs 2 Months) [76], tracking occluded objects(4 vs 6 Months) [84], egocentric vision(9 months)	Novelty pref ence inversion (6-1 months) [85, 86], 1 ability to distingu faces of differ gender(3 months vs months) [81]
Joint attention	Mutual gaze through eye contact [87]	left/right attention manipulation	Gaze angle detection, fixation of first salient object	Fixation of any salie object, declarat pointing, drawi attention
Motor	Hand/face contacts (11 gestation weeks) [46]	Open hand grasping [88, 89]	Recognizing own motion vs others(3 vs 5 Months) [90, 91]	Partial integration visual and motor sk (9 Months) [92]
Memory	Hand/face contacts (11 gestation weeks) [46]	Mobile paradigm(3 Months) [93]		
Language		Differentiate mother tongue and for- eign language [47], marginal babbling	canonical babbling	intentional g tures, single wor word-gesture com nation [94]
Reasoning		Self-perception at mirror(3 Months) [58]	Fear of heights (after crawling)[95, 96], Allocentric spatial frame of reference (9 Months) [97, 98, 99]	Mark test(Months) [1(adapted use hook(12 Months) [1(

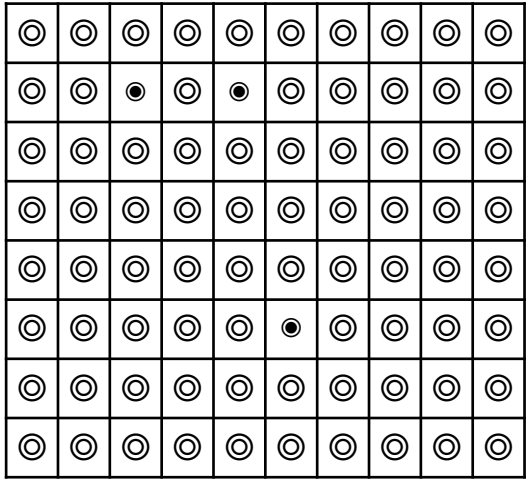
So far

1. Why No Reward
   1. Overfitting
   2. Association between sensory input and language cannot be learned
2. Why Human-like Experience?
   1. Non-Partial: Requires sufficient mechanisms
   2. Interpretability: Easy to evaluate the behavior
3. Why Longitudinal Development

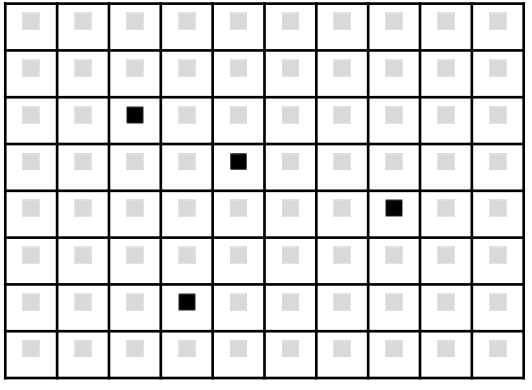
3. Why Longitudinal Development?

From fetus to 12 months

What does it feel like to be a baby brain?

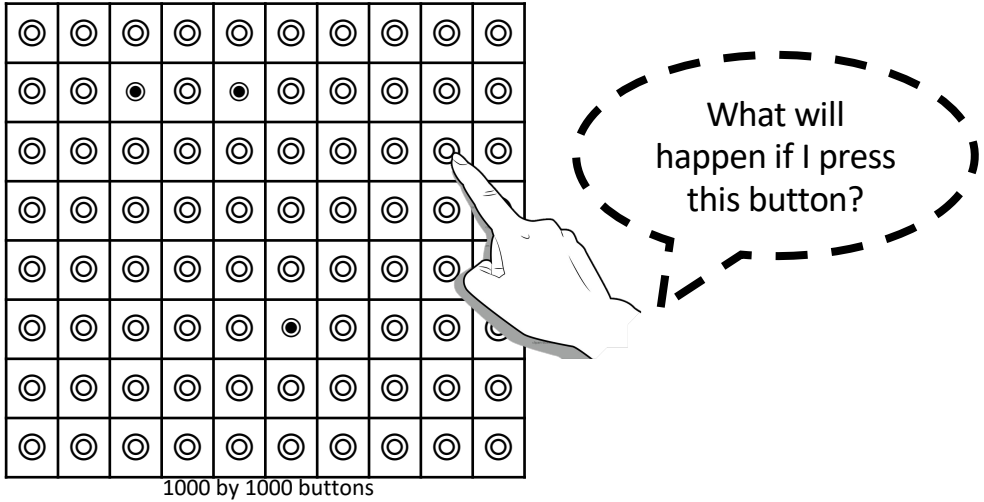


1000 by 1000 buttons

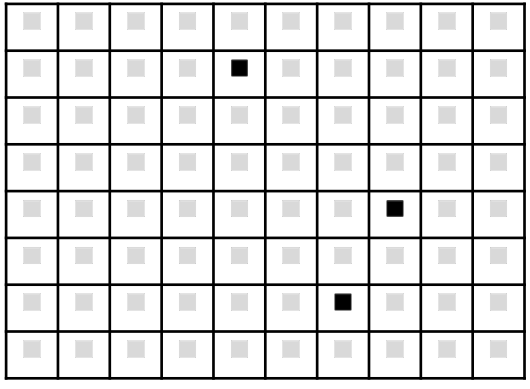


1000 by 1000 LEDs

Piaget’s sensory-motor stage

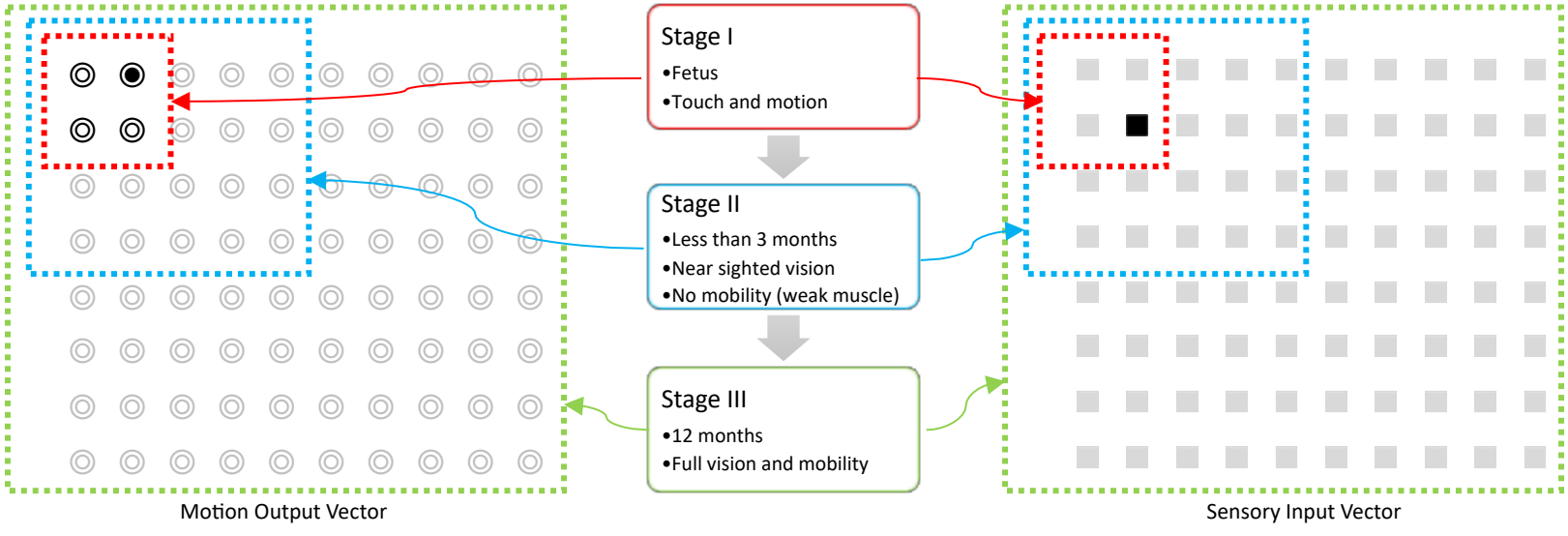


1000 by 1000 buttons

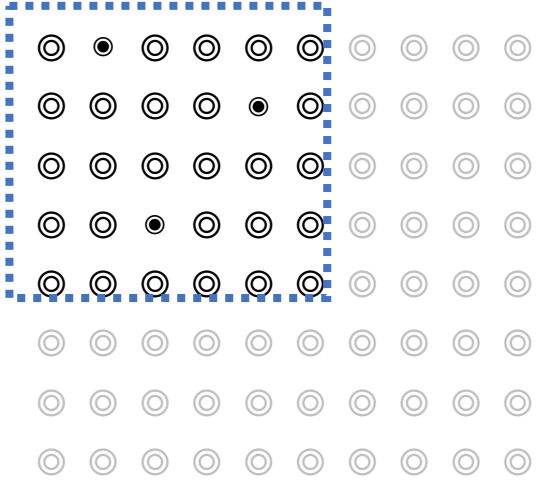


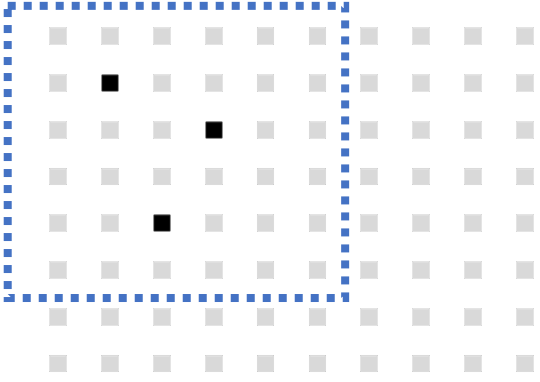
1000 by 1000 LEDs

Progressive development



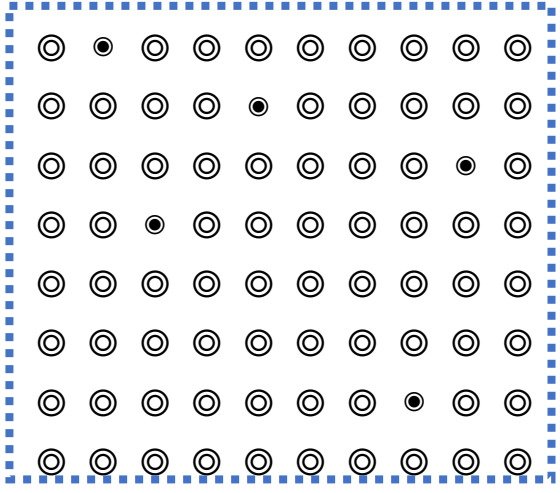
Vygotsky’s zone of proximal development

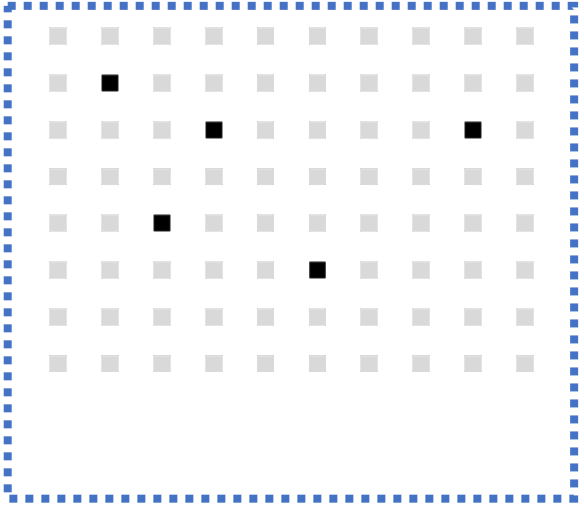




Earlier months

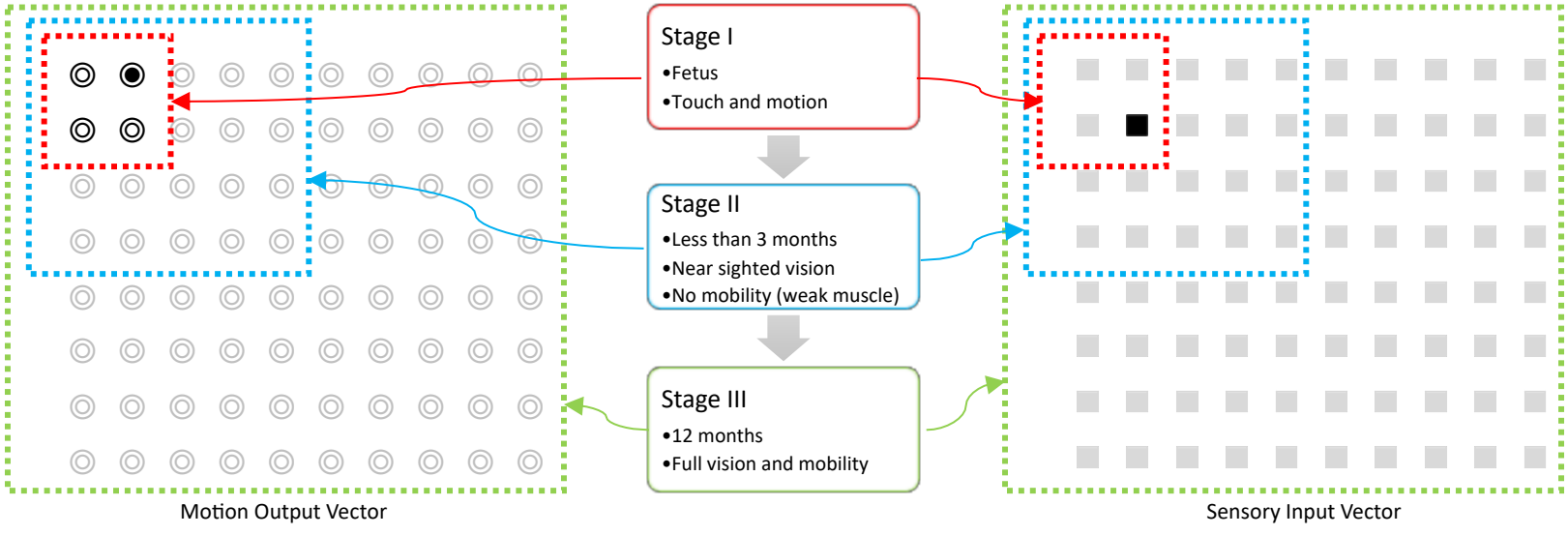
Vygotsky’s zone of proximal development





Later months

Progressive development



Language Acquisition

- Joint Attention
  - Requires face recognition and eye contact
  - This skill develops with careful schedule of constraints

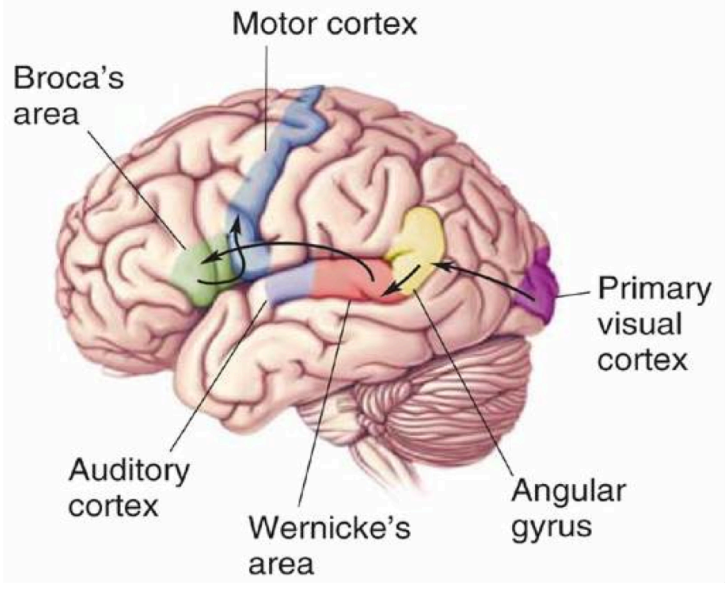
Motor constraint
- Incapable of moving neck and torso

Sensory constraint
- Nearsighted till 3 months (< 20 cm)

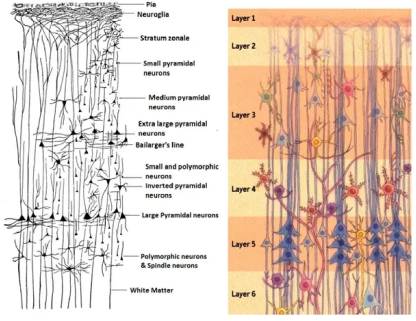
Developmental stage	"Age" (months)	Eyes			Neck				Torso				Saturation criteria	Observed behavior
		tilt	version	vergence	pitch	roll	yaw	torque	roll	pitch	yaw	torque		
1 Eye saccade	0	d	d										Low occurance of unknown saccades	Eye saccades to fixate on stimuli
2 Vergence	0			d									Low occurance of unknown vergence movements	Both eyes converge onto a single stimuli
3 Neck movements	0				d	d	d	d					Low occurence of unknown movements	Neck roll pitch and yaw movements
4 Eye & head visual search	0	d	d	d	d	d	d	d					Low occurance of unknown combinations of movements	Head and eyes move together to fixate on a stimulus
5 Torso pitch	2									d		d	Low occurence of unknown movements	Torso bends foraward and backward
6 Eye, head & torso pitch visual search	2	d	d	d	d	d	d	d		d		d	Low occurance of unknown combinations of movements	Fixations incorporate bending movements at the waist
7 Torso pitch & yaw	3									d	d	d	Low occurence of unknown movements	Torso bends forwards, backwards, and sideways at waist
8 Eye, head & torso pitch & roll visual search	3	x	x	d	d	d	d	d		d	d	d	Low occurance of unknown combinations of movements	Fixations incorporate bending and leaning movements
9 Eye, head & torso pitch & roll visual search	4	x	x	x	x	x	x	x		d	d	x	Few improvements in eye and neck movements	Looking whilst bending and leaning
10 Torso roll, pitch & yaw	5								x	d	d	x	Low occurence of unknown movements	Torso bends, leans and rotates at waist
11 Full body visual search	5	x	x	x	x	x	x	x	x	d	d	x	Low occurance of unknown combinations of movements	Looking with whole body movement
12 Improvement of torso pitch	7	x	x	x	x	x	x	x	x	x	d	x	Few improvements in torso pitch	Less jerky bending movement whilst looking
13 Improvement of torso yaw	10	x	x	x	x	x	x	x	x	x	x	x	Few improvements in torso yaw	Smoother body rotation whilst looking

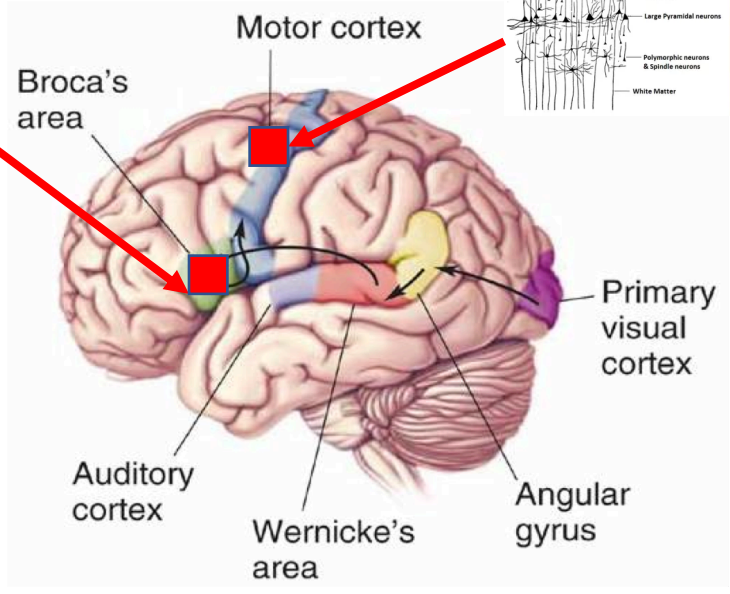
Figure 4. Constraints architecture for staged development of visual fixation coordinated with eye, head, and torso movements. At each stage the system is constrained so that it only has access to systems marked d or x, where d denotes a system under development, and x is a fully developed system.

Law, James, et al. "The infant development timeline and its application to robot shaping." *Adaptive Behavior* 19.5 (2011): 335-358


Motor cortex
Broca's area
Primary visual cortex
Auditory cortex
Wernicke's area
Angular gyrus

Histological Structrure of the Cerebral Cortex





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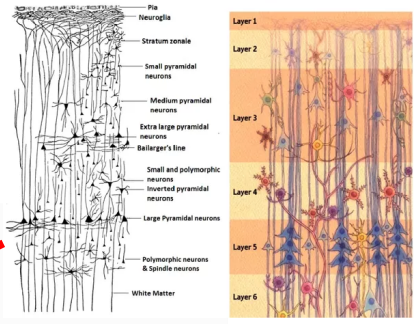
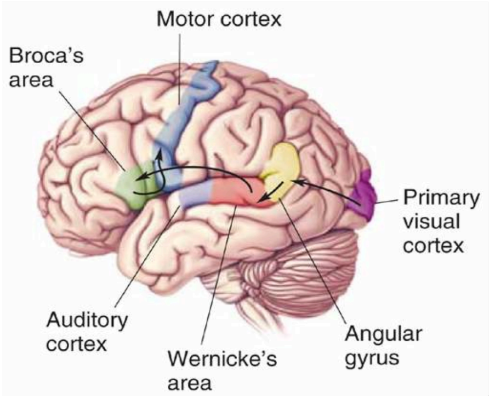
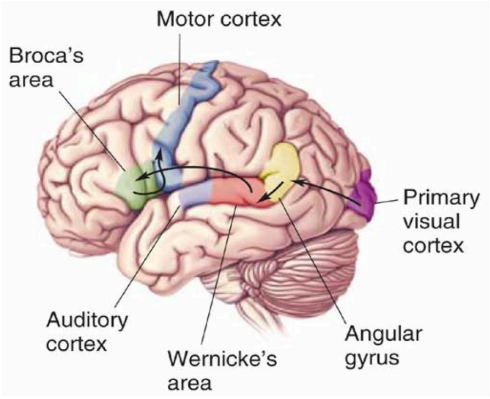




Universal Module



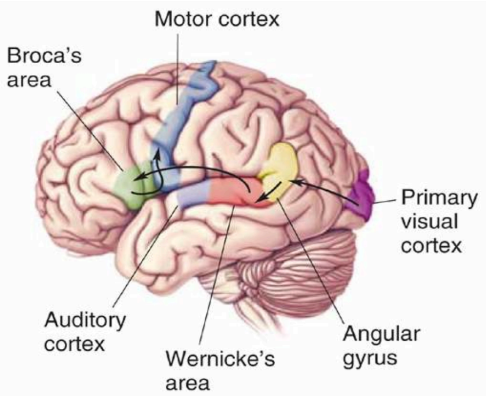
Universal Module

Bronca's area
Language function

Auditory

Vocal tract

Context



Universal Module

Bronca's area
Language function

Motor cortex
Motor function

Auditory

Vocal tract

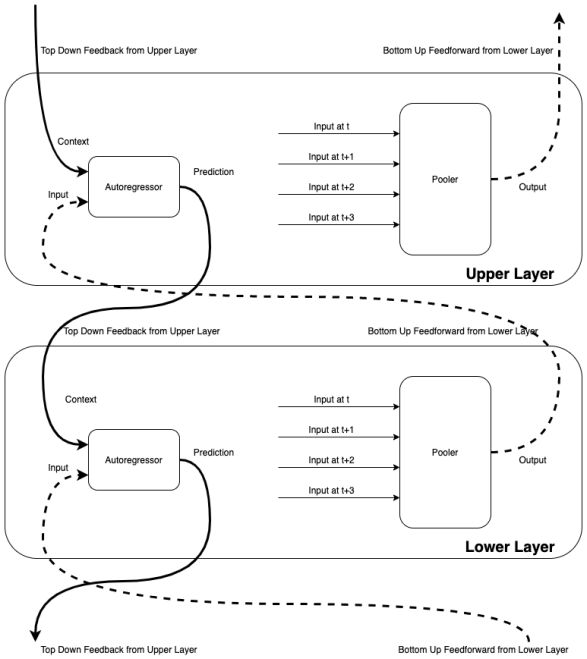
Context

Tactile

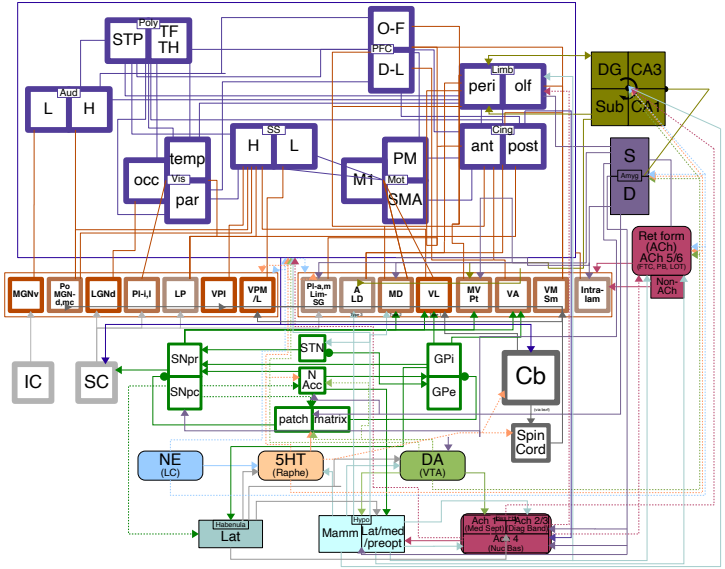
Proprioceptor

Vision

Mountcastle, V. B. (1978), "An Organizing Principle for Cerebral Function: The Unit Model and the Distributed System", in Gerald M. Edelman; Vernon B. Mountcastle (eds.), *The Mindful Brain*, MIT Press



Universal Module



Heterarchical Network

So far

1. Why No Reward
    1. Overfitting
    2. Association between sensory input and language cannot be learned
2. Why Human-like Experience?
    1. Non-Partial: Requires sufficient mechanisms
    2. Interpretability: Easy to evaluate the behavior
3. Why Longitudinal Development?
    1. Staged constraint is required
    2. Language Skills are dependent on the earlier skills

Conclusion

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Thank you!

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Check out SEDRo project at https://anur0n.github.io/sedro-website/