

# Artificial Cognitive Systems

## Module 6: Development and Learning

### Lecture 1: Development, motivation, and imitation; value systems

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### **Newborns**

Newborns gaze longer when a person looks directly at them [256].

Newborns are attracted to people (i.e. face and voice) [257].

Newborns prefer biological motion [258].

Newborns preferentially orient toward faces [259, 260].

Newborns prefer human voices to other sounds [261].

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### **Early Development**

2½ months: infants can discriminate a familiar adult's expressions if presented with multimodal expressions [262].

3 months: infants engage mutual gaze with adults, i.e. both agents attend to each other's eyes simultaneously [263].

3–4 months: infants have the ability to discriminate among a few photographed, static facial expressions [264].

4 months: infants presented with multimodal expressions can discriminate some adult's expressions [265, 266].

5 months: infants discriminate auditory-only displays of affect [266].

6 months: infants can perceive approximate direction of attention of others (i.e. to the left or to the right) [267].

10–12 months: infants show the first strong evidence of understanding the feelings of others.

9 months: infants can accurately detect the direction of the adult's gaze [263].

12 months: infants look at the object fixated by the adults [268].

12 months: infants consider eye rather than head direction [269].

12 months: Children start to understand pointing as an object-directed action [270].

12 months: Children anticipate with gaze the goal of a feeding action [271].

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### **Later Development**

18 months: children start to follow an adult's gaze outside their own field of view [263].

18 months: children perceive from emotions that a person wants something [272].

18 months: infants can infer what another person is trying to achieve (even if the attempt is unsuccessful) [273, 274].

18 months: infants altruistically (*instrumentally*) help adults when they are having problems achieving a goal [275].

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# Cognitive Development

## Learning to Help and Be Helped

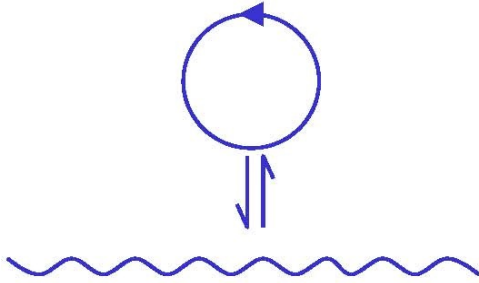
- 14 to 18 months: **instrumental helping behaviour**
- 2 years: start to solve **simple cooperation** tasks with adults
- 2-3 years: ability to **cooperate** with peers
- 3 years: complex **collaboration**
  - Sharing of intentions
  - Joint coordination of complementary actions
- 3 ½ years: Roles in the task can be reversed; & can teach new partners

# Cognitive Development

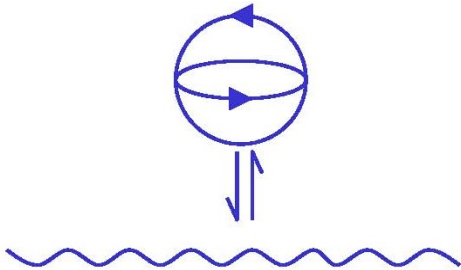
“Development is the result of a process with two foci,  
one in the **central nervous system** and  
one in the subject’s **dynamic interactions** with the environment”

*Claes von Hofsten*

# Cognitive Development



$t$



$t$

***Anticipation / Planning / Explanation / Prediction***

# Cognitive Development

- Development arises due to changes in the central nervous system as a result of dynamic interaction with the environment
  - Emergence of new forms of action
  - Acquisition of predictive control of these actions
- Mastery of action relies critically on **prospection**
  - Inference of upcoming events

# Cognitive Development

## Cognition

- **Anticipating** the need for action
- Formulating the motor commands required to act successfully (**effective action**)
- **Predicting the outcome** of those actions
- **Adaptively** and **prospectively** carrying out those actions

# Cognitive Development

## Scaffolding

- The progressive development of innate skills or skills that are learned early on

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# Cognitive Development

The prospective aspect of development is accelerated by **internal simulation**

- Mentally rehearsing — consciously or subconsciously — the execution of actions
- Inferring the likely outcome of those actions

# Cognitive Development

Development depends on **motives**

- These define the goals of actions
- **Exploratory motives**
  - Discovery of novelty and regularities in the world
  - Discovery of the potential of the agent's own actions

# Cognitive Development

Development depends on **motives**

- These define the goals of actions
  
- **Social motives**
  - Need to belong
  - Self-preservation
  - Cognitive consistency with others
  - Expressed from birth through tendency to
    - Fixate on social stimuli
    - Imitate basic gestures
    - Engage in social interaction



Jean Piaget (1896–1980)



Lev Vygotsky (1896–1934)

# Cognitive Development

Development depends on motives

- Discovery of what objects and events **afford** in the context of new actions is also a strong motivation



# Cognitive Development

Development depends on motives

- Expanding one's repertoire of actions is a powerful motivation
  - Often overrides efficacy in achieving a goal
    - Walking when crawling is already sufficient
    - Use of head motion in gaze even when ocular control would be more effective



# Cognitive Development

Development exploits **imitation and social interaction** (including teaching)

## Imitation

- (Rapid) learning of new behaviours by observing the actions of others
- Not **mimicry** (cf. replicate goal-directed action vs. copying movements)
- Present at birth but develops for >18 months
- 4 phases
  1. Body (motor) **babbling**
  2. Imitation of body movements
  3. Imitation of actions on objects
  4. Imitation based on inferring intentions of others: **theory of mind**



# Reading

Vernon, D. Artificial Cognitive Systems – A Primer, MIT Press, 2014, Chapter 6

Hsu, J. “Will the Future of AI Learning Depend More on Nature or Nurture?”

<https://spectrum.ieee.org/tech-talk/robotics/artificial-intelligence/ai-and-psychology-researchers-debate-the-future-of-deep-learning>

# Further Reading

Merrick, K. E. A Comparative Study of Value Systems for Self-motivated Exploration and Learning by Robots, IEEE Transactions on Autonomous Mental Development, Vol. 2, No. 2, 119–131 (2010).

Merrick, K. E. Value Systems for Developmental Cognitive Robotics, Cognitive Systems Research, Vol. 41, Issue C (2017).

Vernon, D., von Hofsten, C., and Fadiga, L. A Roadmap for Cognitive Development in Humanoid Robots, Cognitive Systems Monographs (COSMOS), Springer, ISBN 978-3-642-16903-8 (2010); Chapter 6