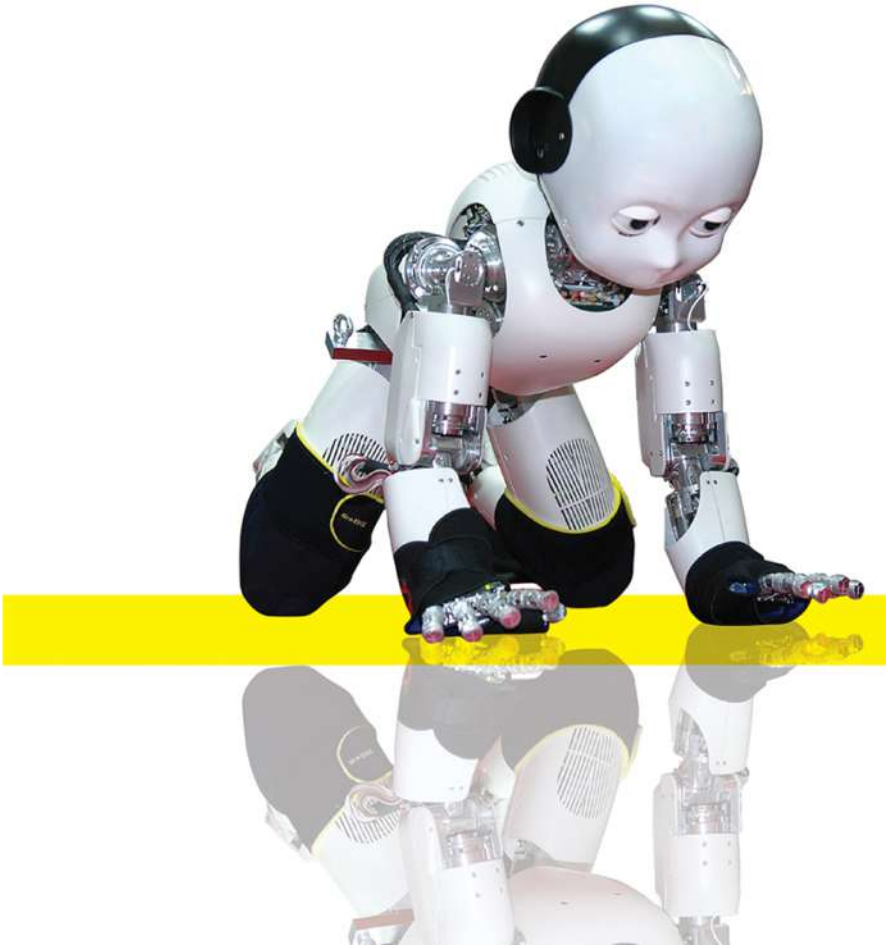
DEVELOPMENTAL ROBOTICS

Language, Trust and Theory of Mind

Angelo Cangelosi

University of Manchester



MANCHESTER 1824
The University of Manchester

The Alan Turing Institute

Robots, Language & Cognition

How can we **design robots** that are capable of using and **understanding language** to communicate with humans and other robots?

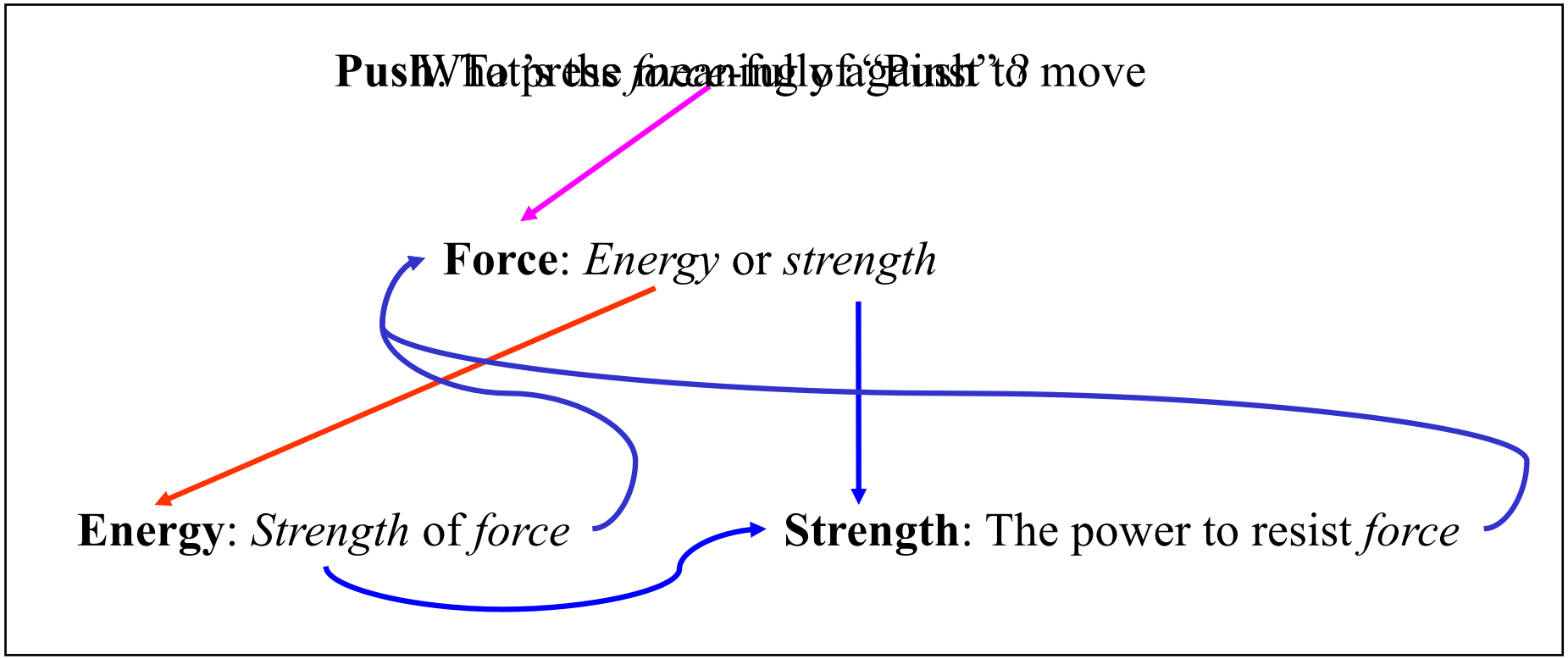
What can cognitive scientists **learn from robot experiments** on embodied language learning?

Gavagai
Quine (1960)

Talking to Robots

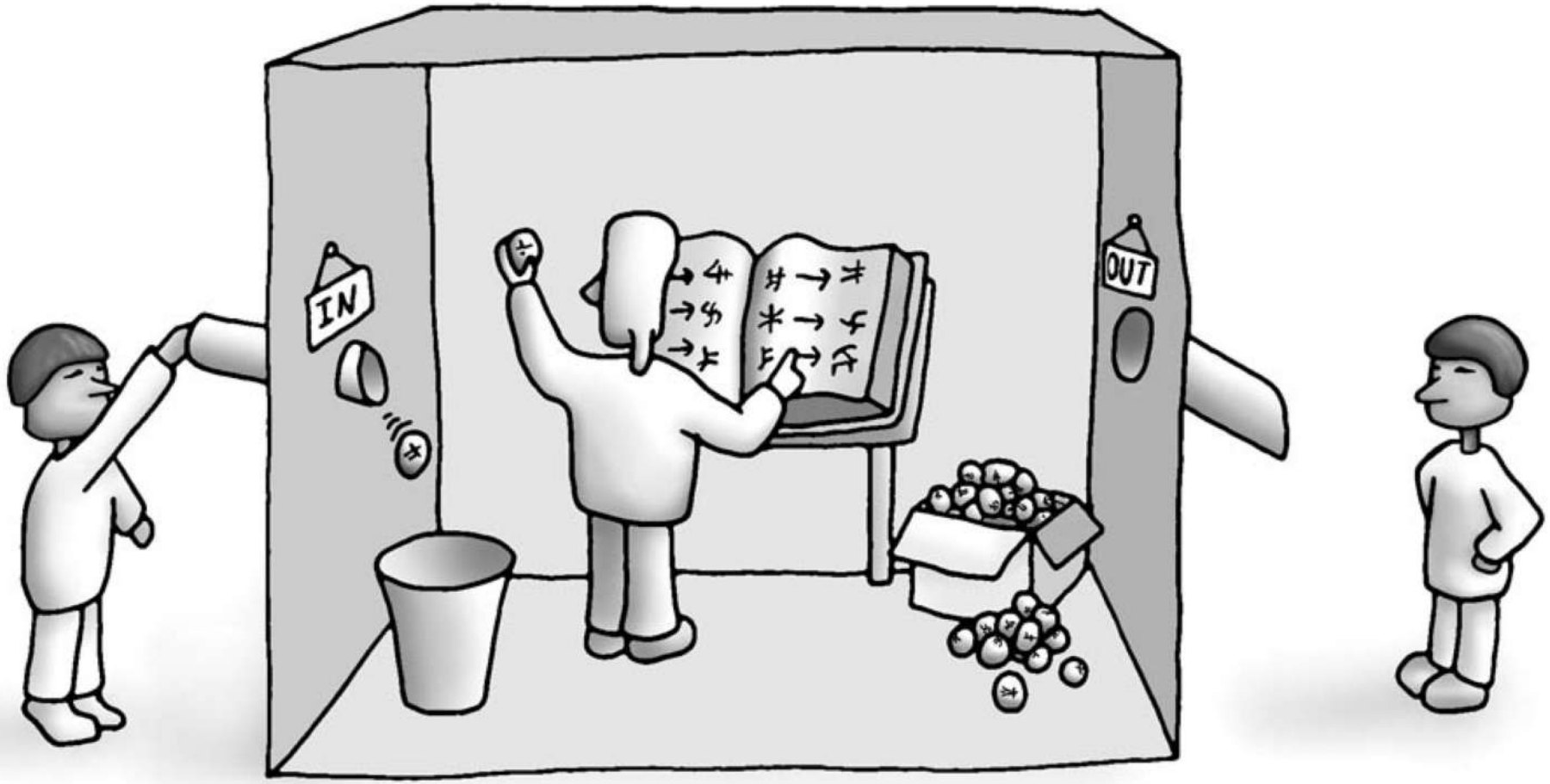
- Computers and robots can be easily **pre-programmed** to memorise a dictionary, but cannot understand the language they use

"Merry-Go-Round" of Amodal Symbol Systems



Example of self-referential, amodal network of word definitions in Webster's Dictionary (Roy 2005) ⇒ Chinese Room (Searle 1980)

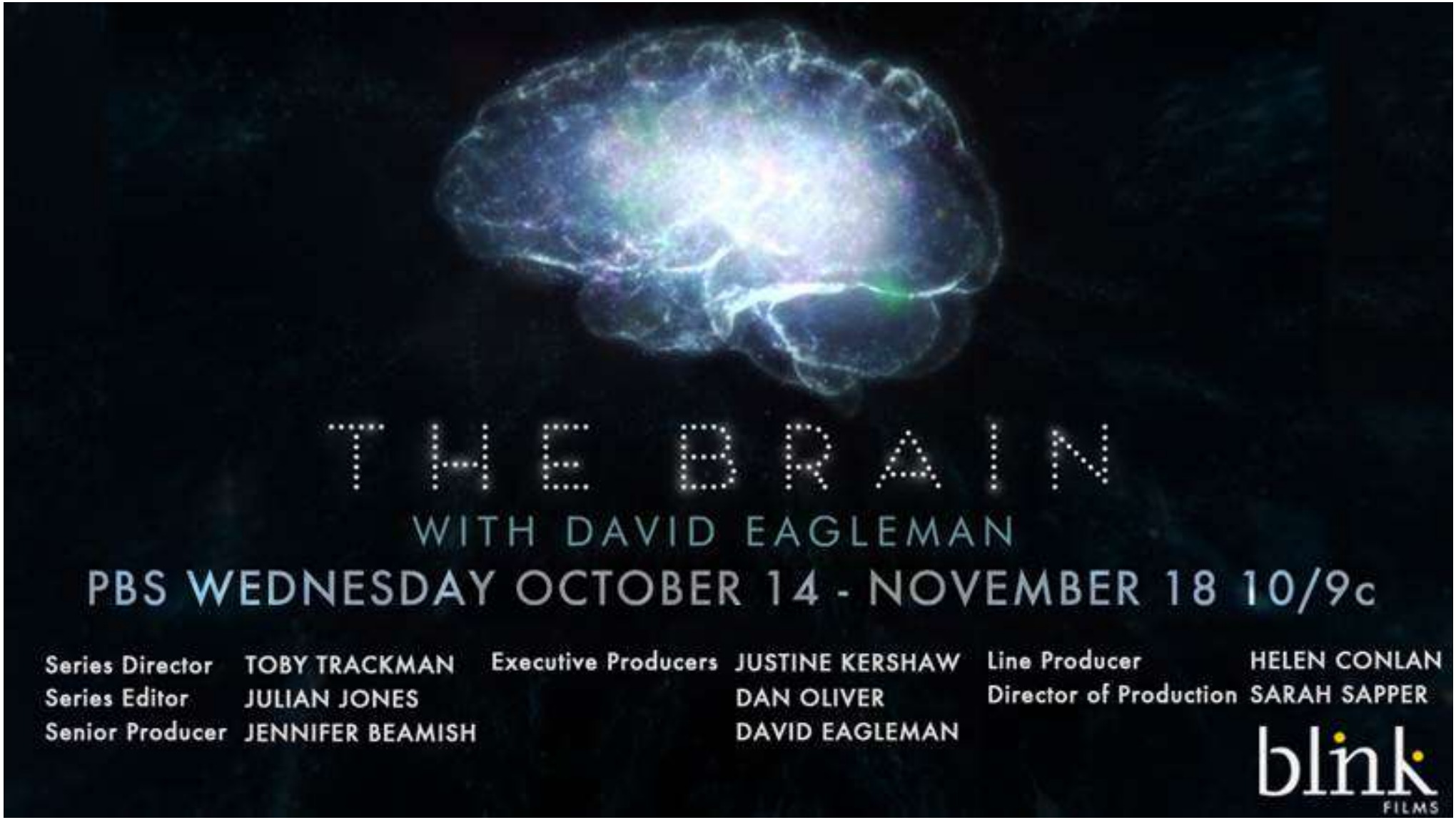
Chinese Room Thought Experiment
(Searle 1980)



jolyon.co.uk

Searle, J.(1980), "Minds, Brains and Programs", Behavioral and Brain Sciences 3 (3): 417–457
Harnad, S (2005), "Searle's Chinese Room Argument", Encyclopedia of Philosophy, Macmillan

Chinese Room Experiment



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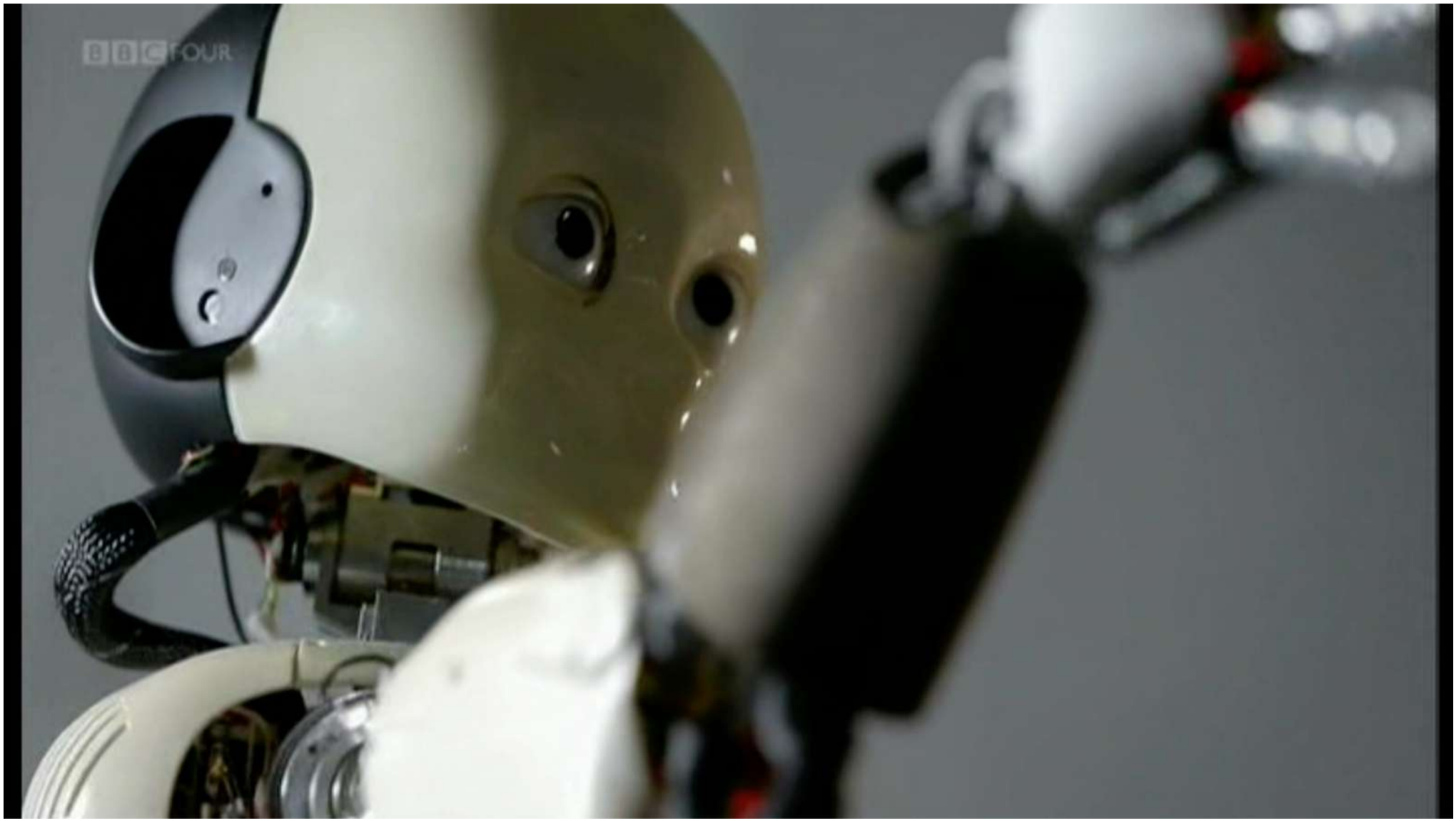
Chinese Room Experiment



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Angelo's Room Experiment

Question: *quanti anni havi la picciotta ?*

Dictionary

- *picciotta*: setti anni, picca pitittu, maciari hovu
- *za'nzina*: settanta anni, assai pitittu, manciari haddina
- *haddina*: dui anni, assai pitittu, maciari simenza
- *anni*: dui, setti, settanta
- *pitittu*: assai, picca
- *manciari*: hovu, haddina, simenza

Reply Rule Book

- *quanti anni havi la X ?* ➔ la X havi A anni
- *quantu pitittu havi la X ?* ➔ la X havi B pitittu
- *soccu voli manciari la X ?* ➔ la X voli manciari C

Angelo's Room Experiment - Grounding

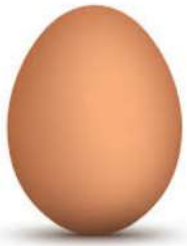
Dictionary

- *picciotta*: setti anni, picca pitittu, maciari hovu
- *za nzina*: settanta anni, assai pitittu, manciari haddina
- *haddina*: dui anni, assai pitittu, maciari simenza
- *anni*: dui, setti, settanta
- *pitittu*: assai, picca
- *manciari*: hovu, haddina, simenza

picciotta

za'nzina

haddina



hovu

simenza

picca

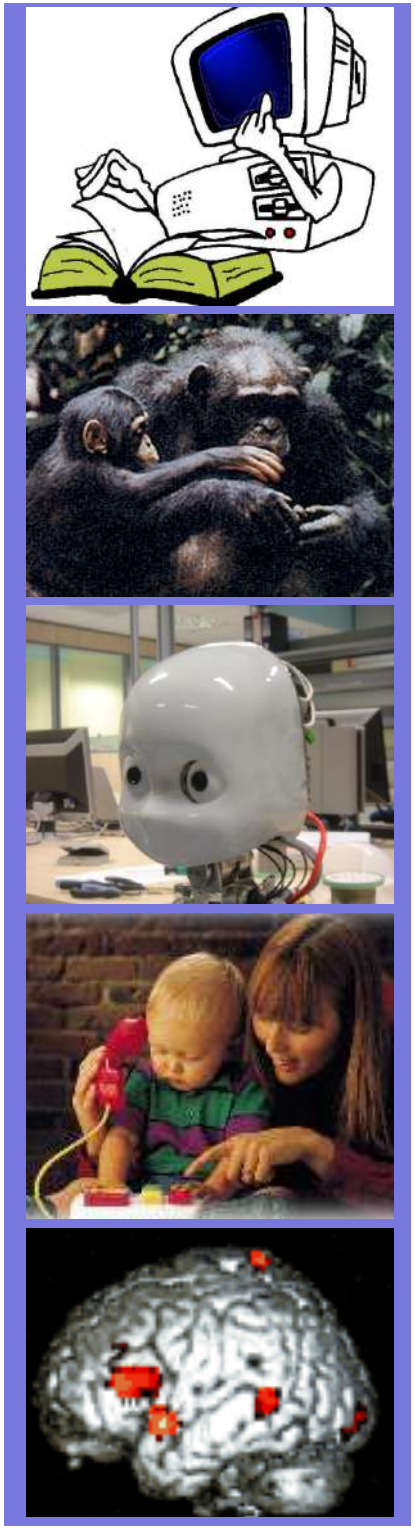
assai

manciari

Learning & Development

Robots can be easily **pre-programmed** to memorise a dictionary, **but** cannot fully understand the language they use

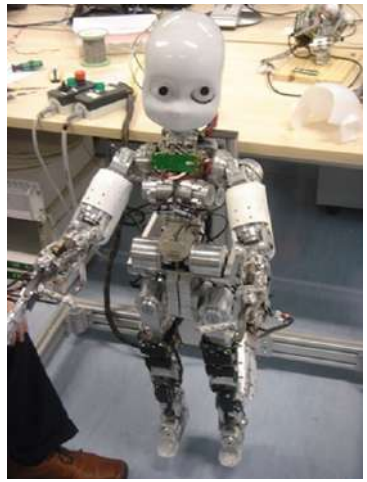
- ✓ Children are **slow**, but efficient at learning a language (vocabulary spurt) (Tomasello 2008)
- ✓ Children use their **body** for situated interaction (Smith & Samuelson 2010)
- ✓ The **brain** integrates language and sensorimotor knowledge (Pulvermueller 2003)
- ✓ Children develop **Theory of Mind** (ToM) for social interaction

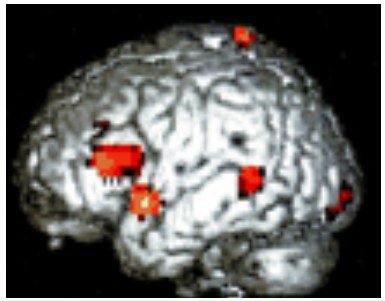


Ethology

Computer science

Robotics





Neuroscience

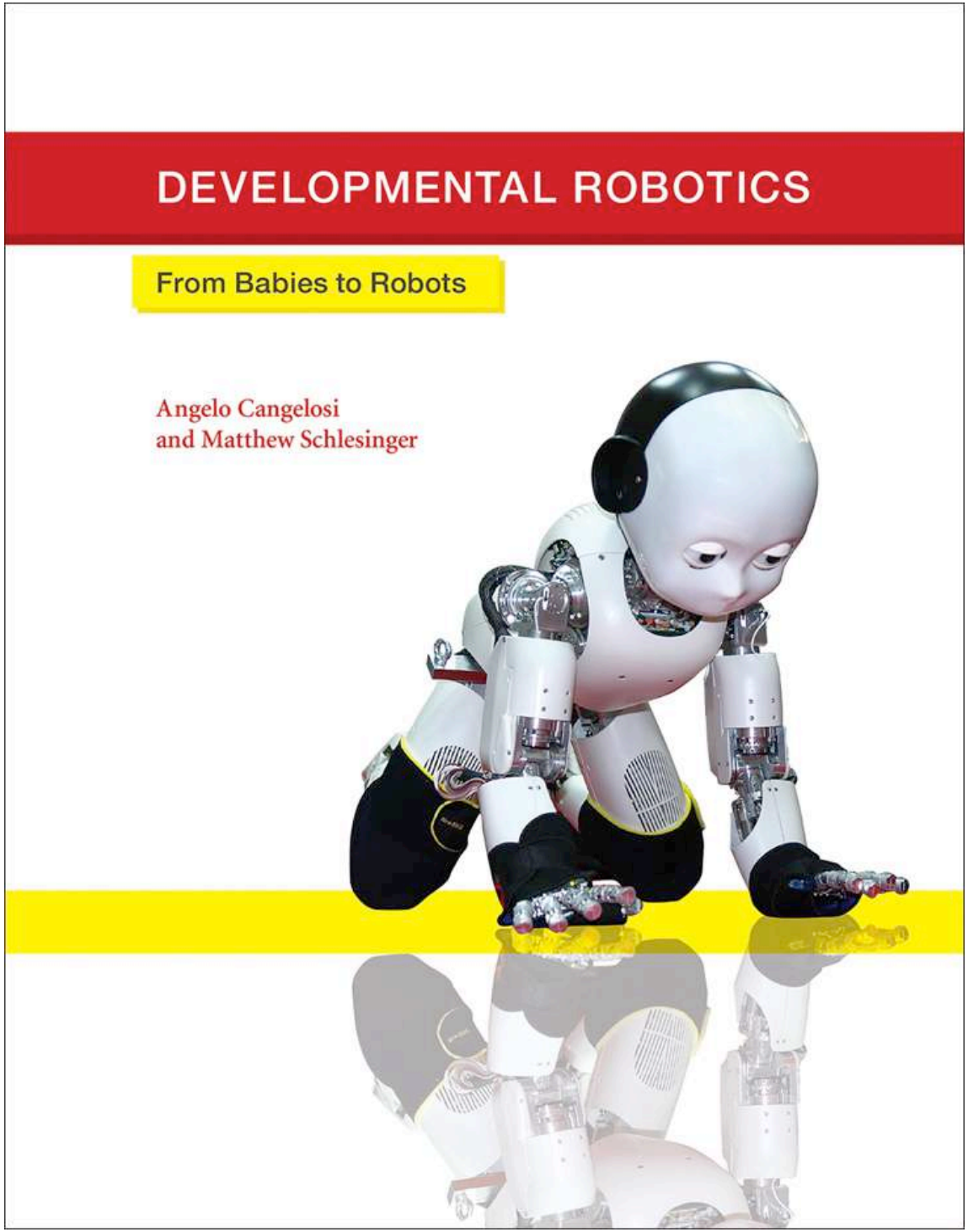
Cognitive Developmental Robotics

Child Psychology

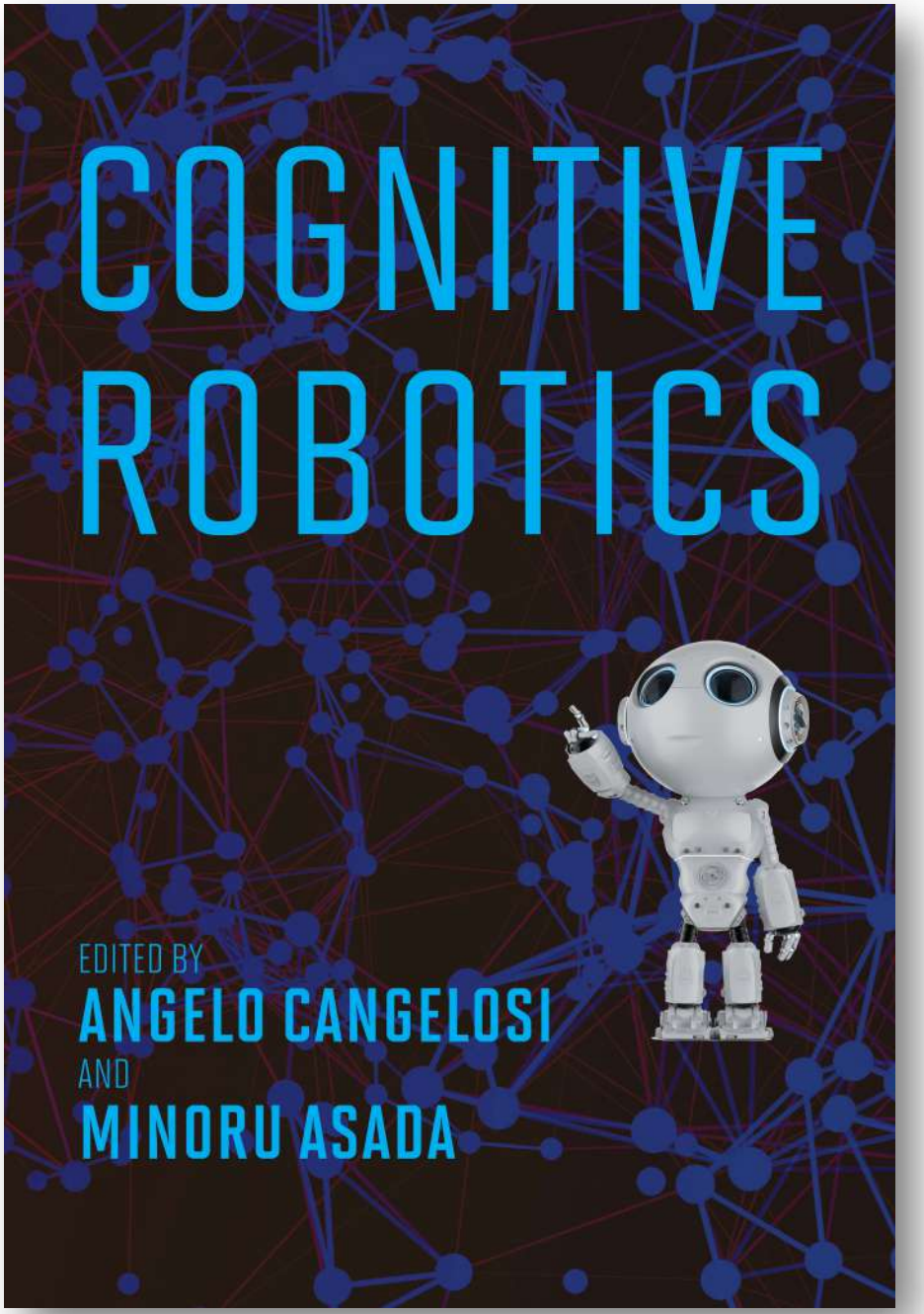
Cognitive Psychology

Linguistics

2015


DEVELOPMENTAL ROBOTICS
From Babies to Robots
Angelo Cangelosi
and Matthew Schlesinger
The MIT Press

2022

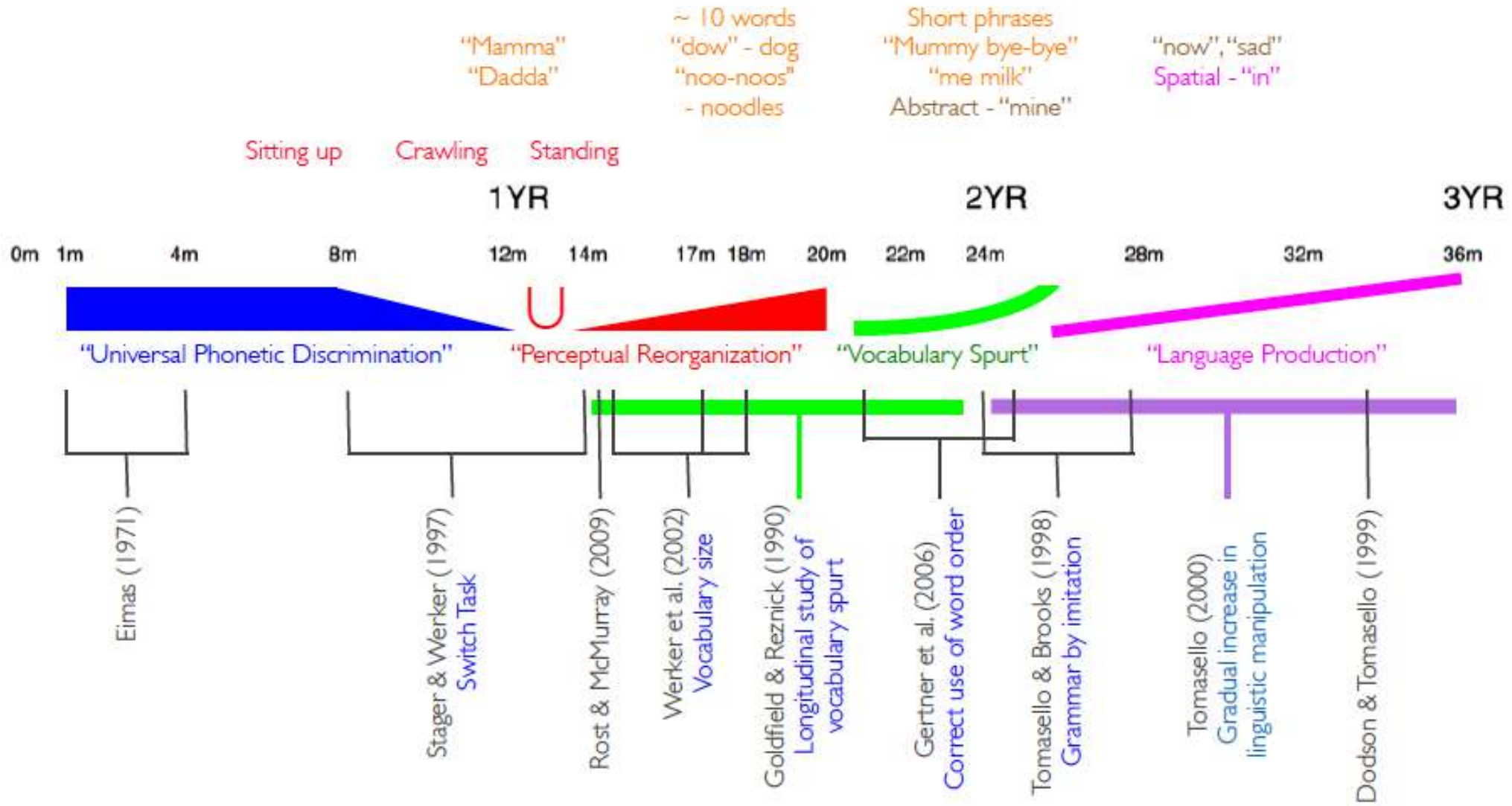


direct.mit.edu/books/oa-edited-volume/5331/Cognitive-Robotics

MIT Press Direct

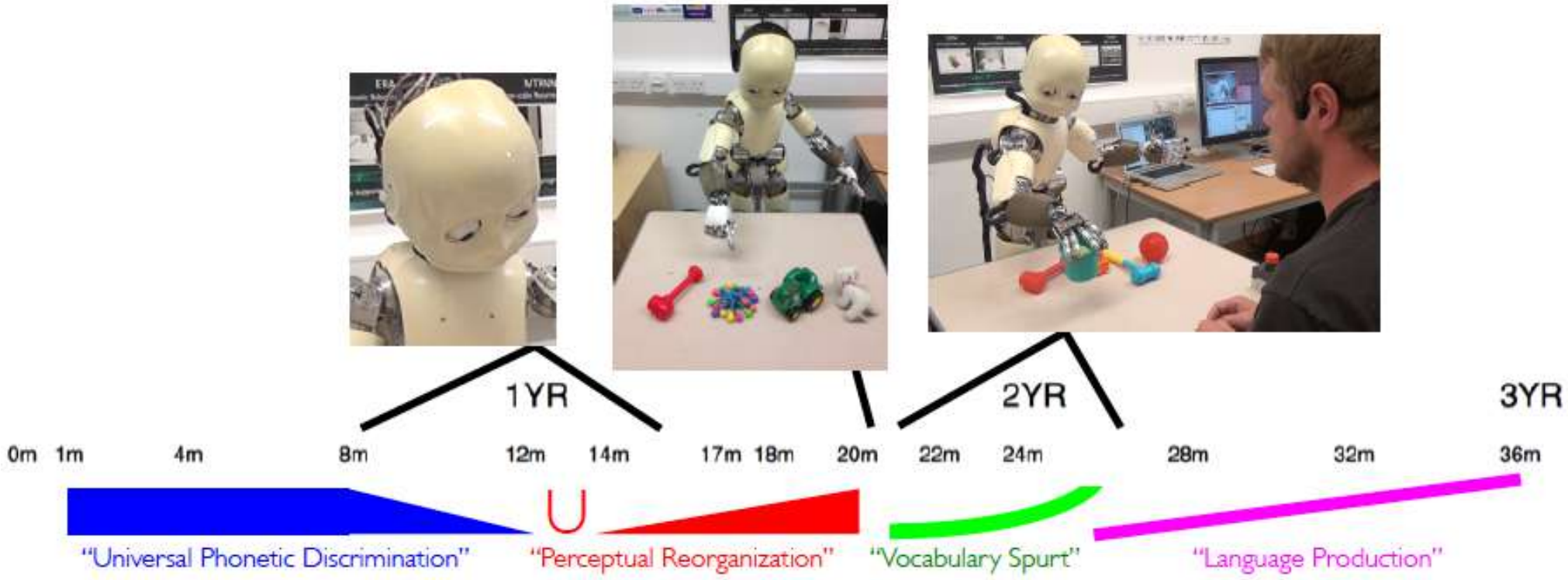
Embodied Language Learning

Developmental Psychology of Language Acquisition

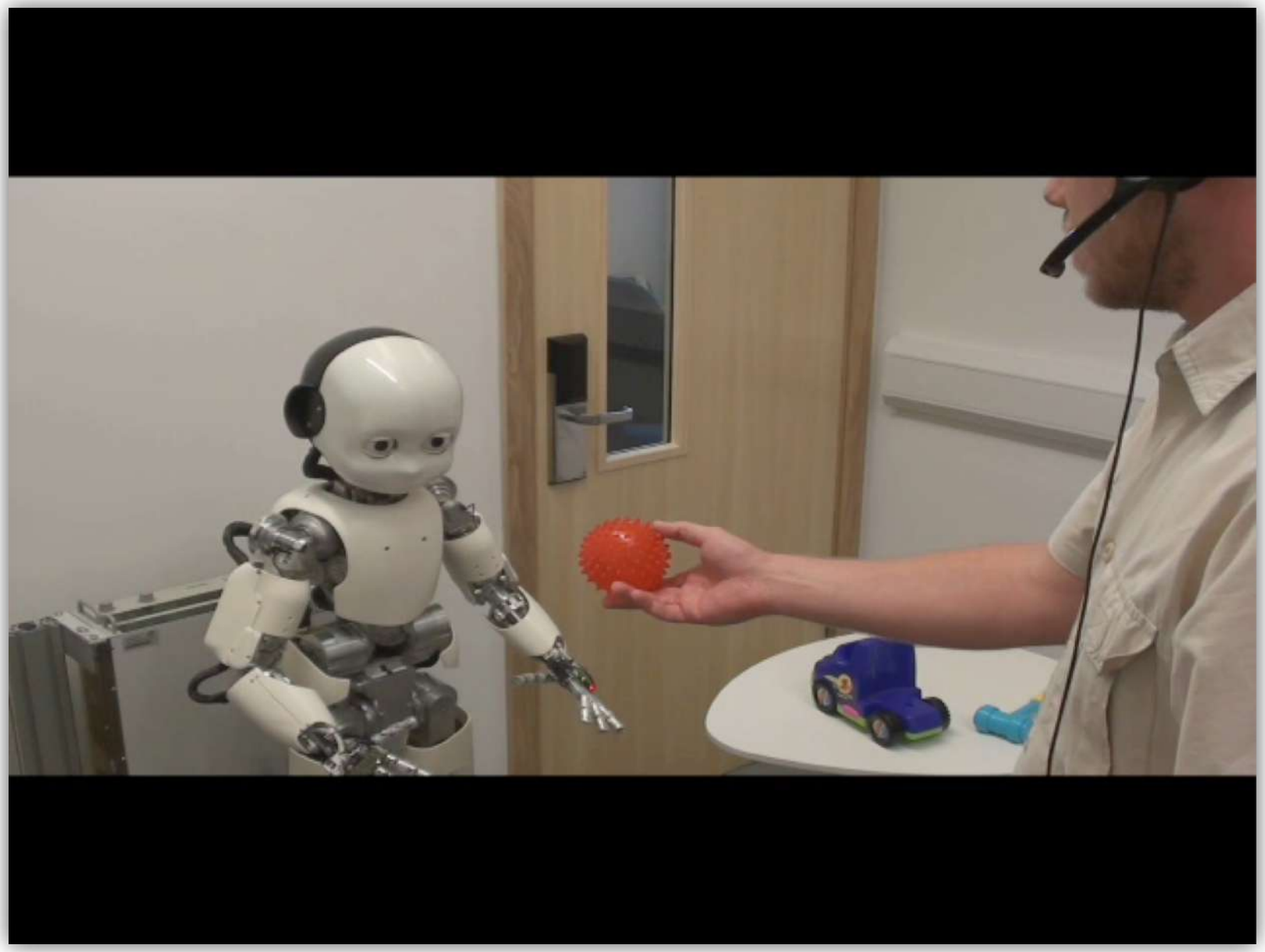


Developmental Robotics of Language Acquisition

- ERA architecture for cumulative learning
  - 5+ Experiments: first words, mutual exclusivity, U-learning,
  - **Collaboration with BabyLabs**: Smith (Indiana), Horst (Sussex), Floccia (Plymouth), Twomey (Manchester), Marchetti (Cattolica Milan)

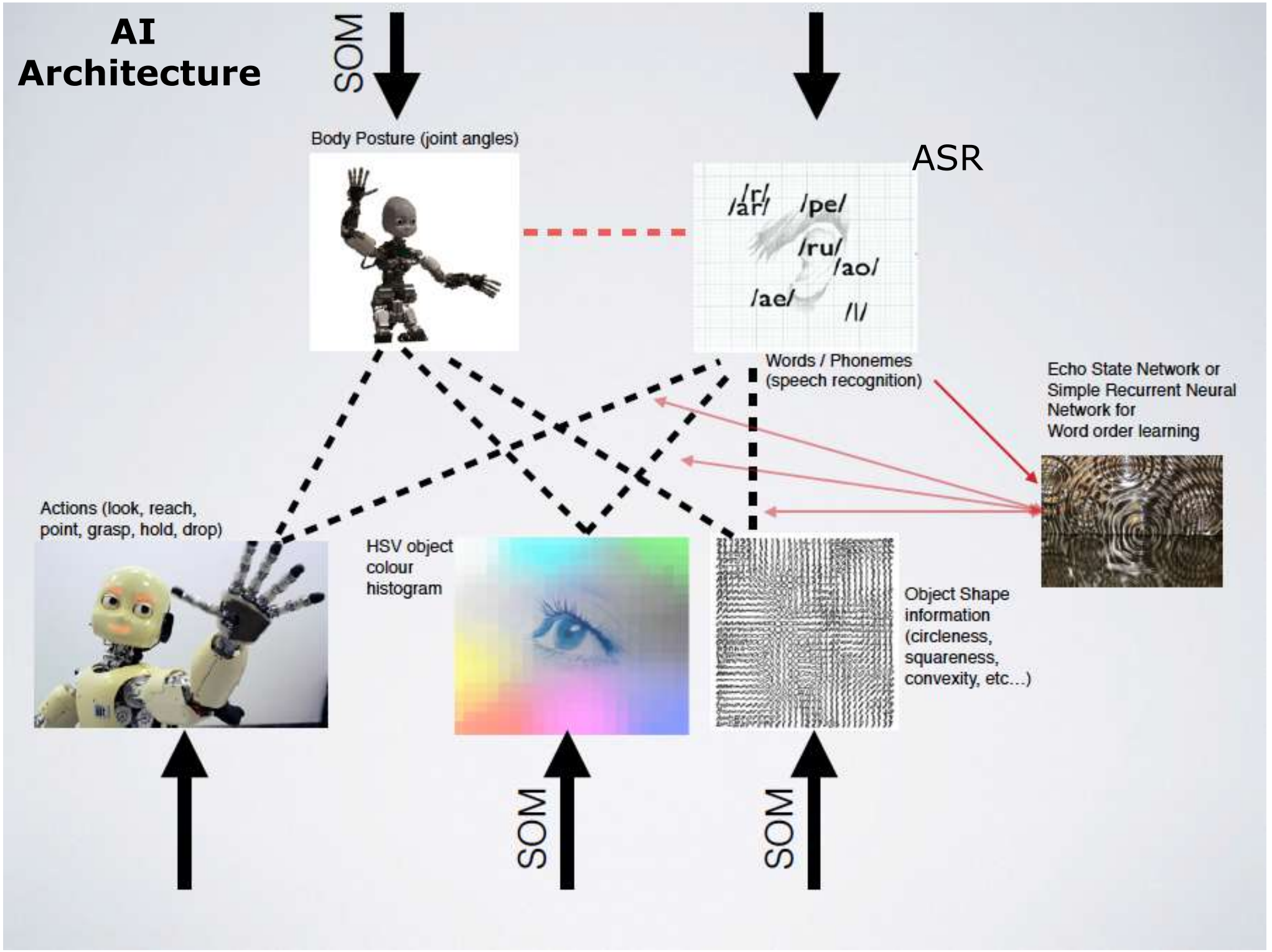


iCub's Modi Experiment

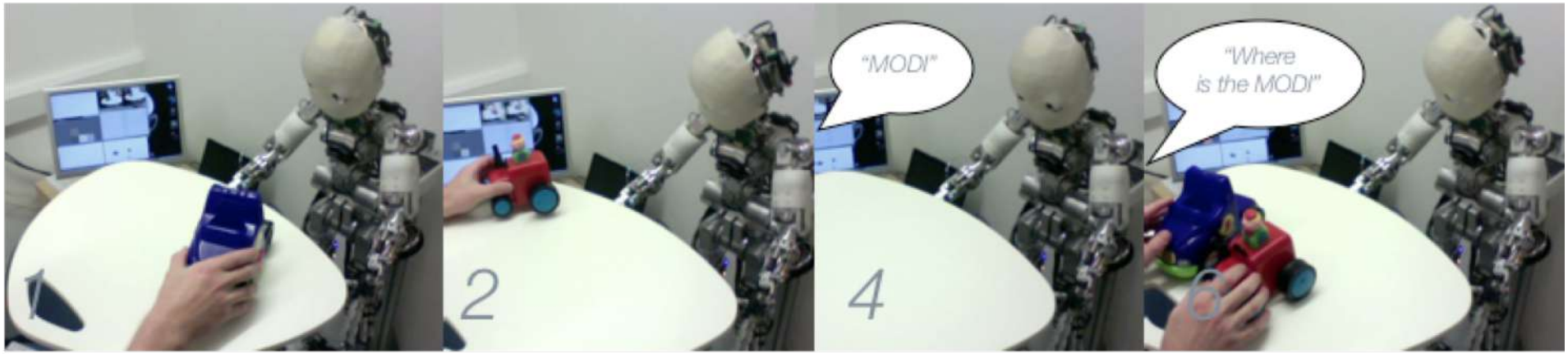


Morse et al. (2015) *PLoS ONE*

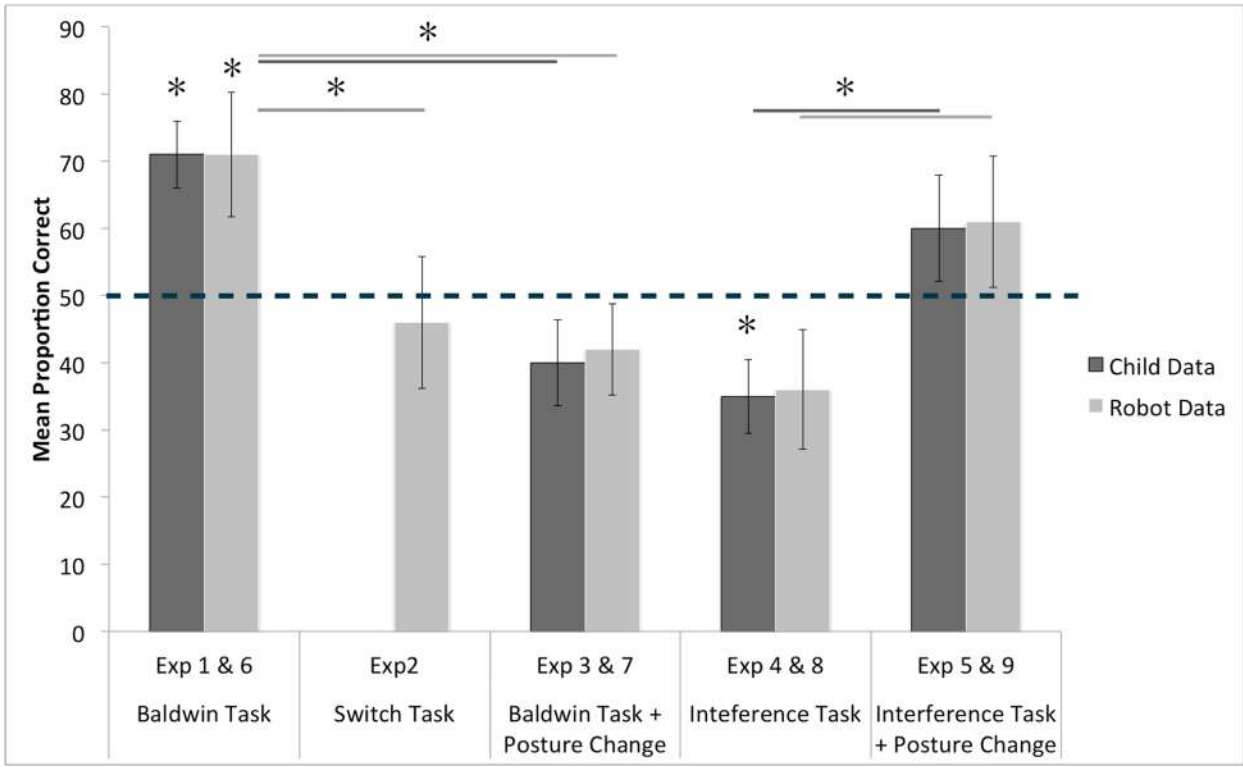
AI Architecture



iCub 'Modi' : Predictions



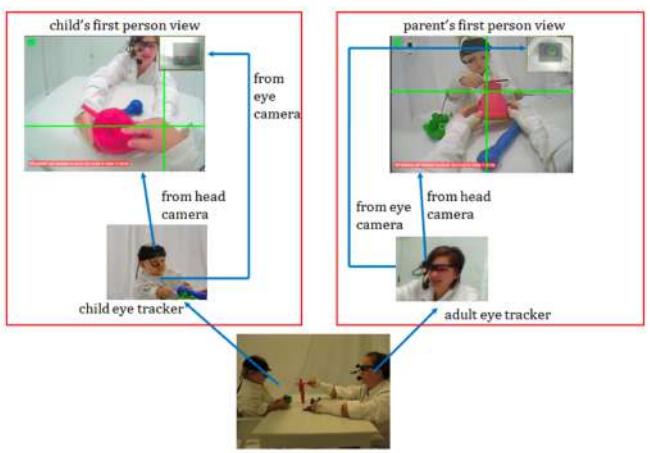
- 6 robot/baby Experiments
- Model prediction
  - Changes in posture (e.g. from sitting to standing) will remove task interference effect despite the target location remaining consistent.



Embodied Attention & Word Learning

- Background

Yu & Smith (2012). Embodied attention and word learning by toddlers. *Cognition*

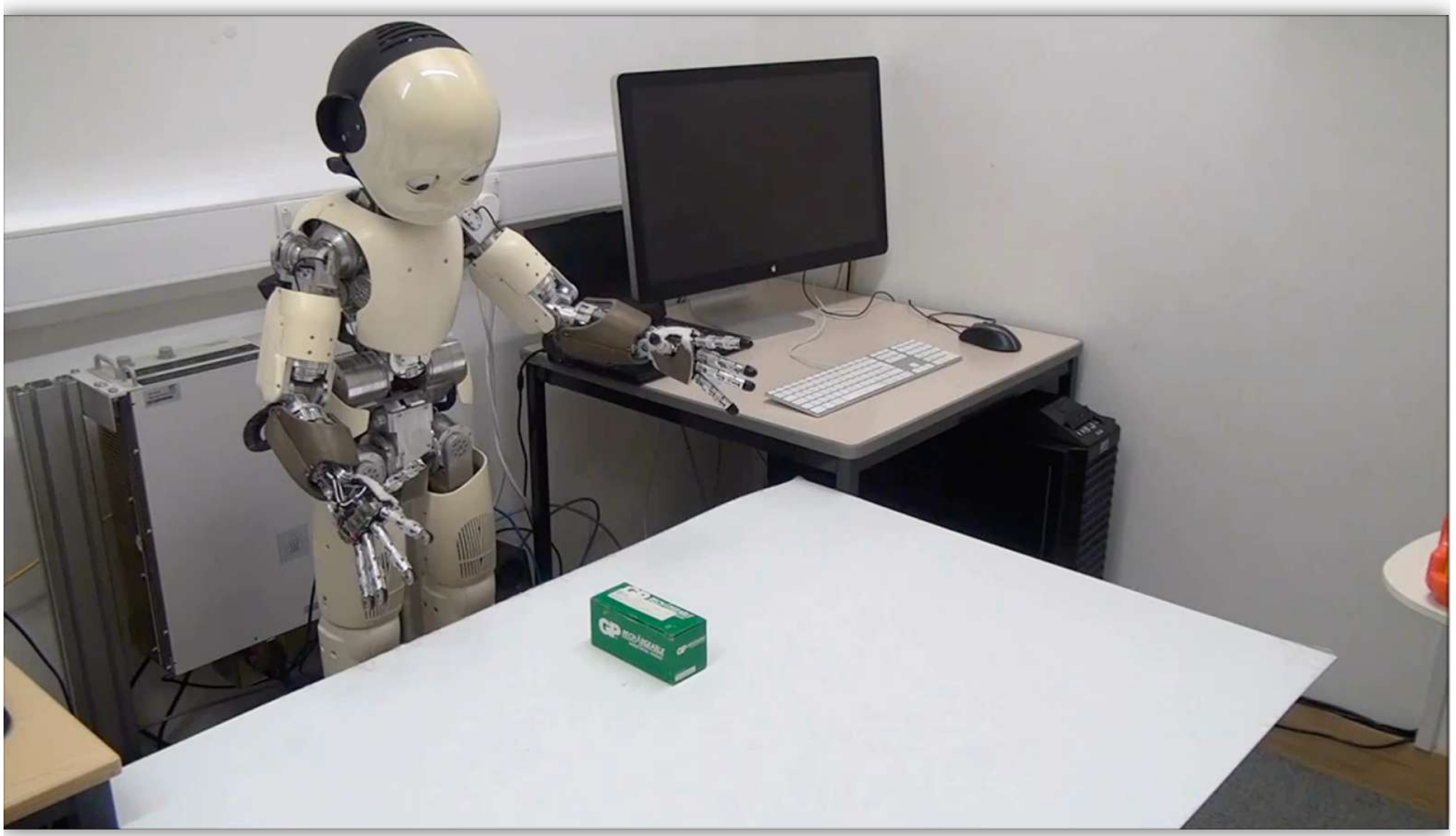


* Linda B. Smith, Indiana University Bloomington: How Infants Break Into Language -- Keynote Address at the 2017 International Convention of Psychological Science, Vienna, Austria. (https://www.youtube.com/watch?v=NRtGKgm2Pz8)

Embodied Attention & Word Learning

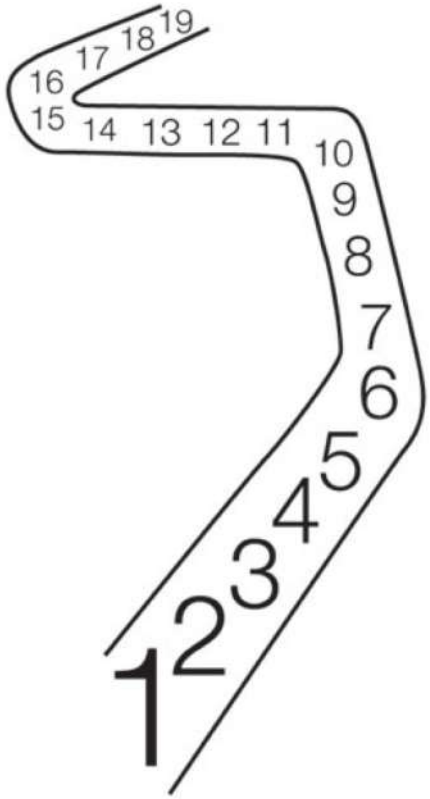
Raggioli & Cangelosi (2022) *ICDL*

Open-Ended Cumulative Learning



Morse & Cangelosi (2016) *Cognitive Science*

Learning Abstract Words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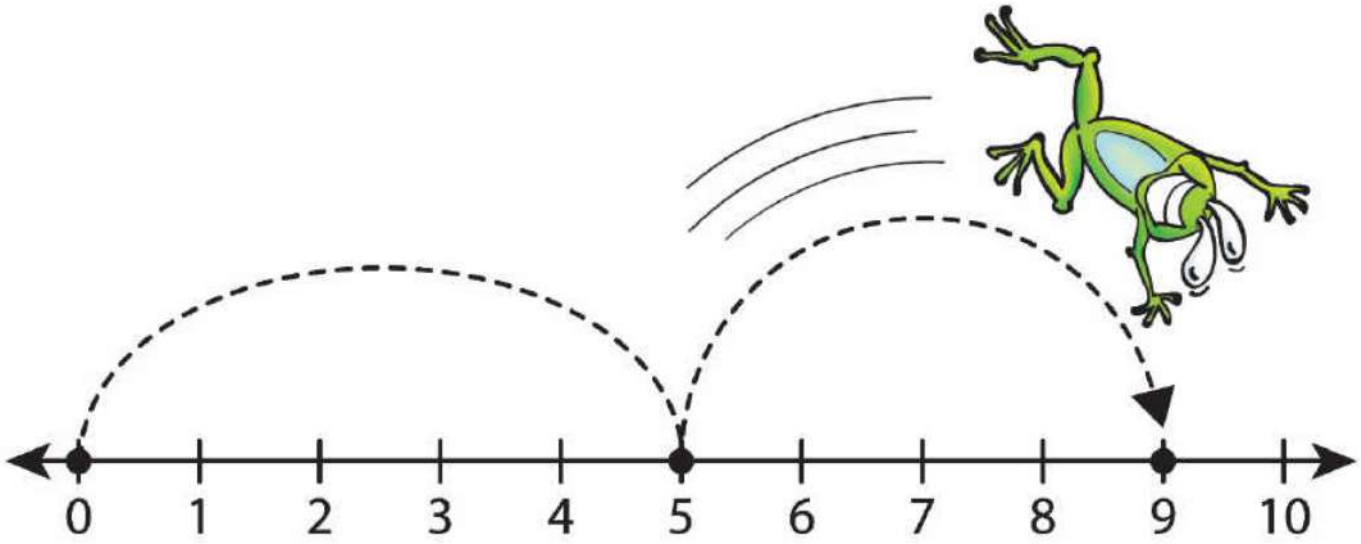
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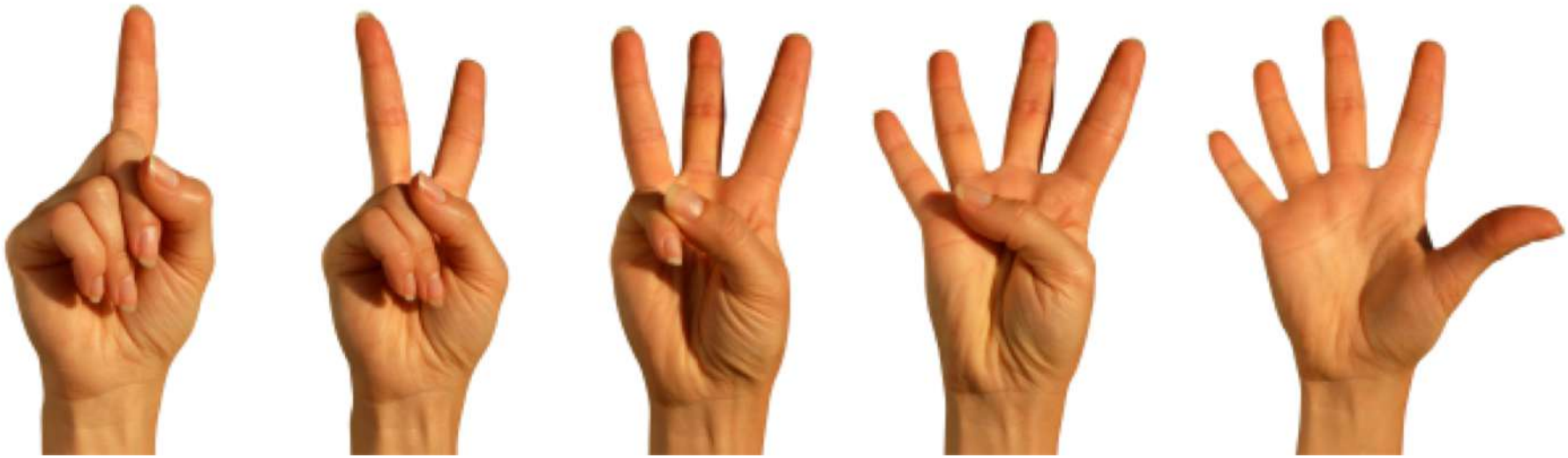
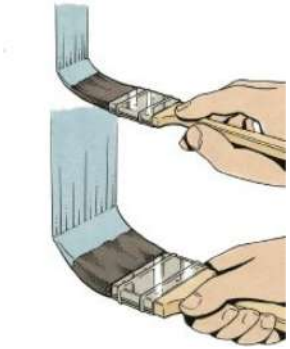
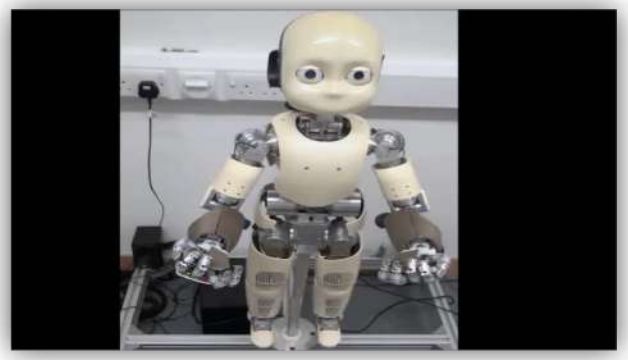
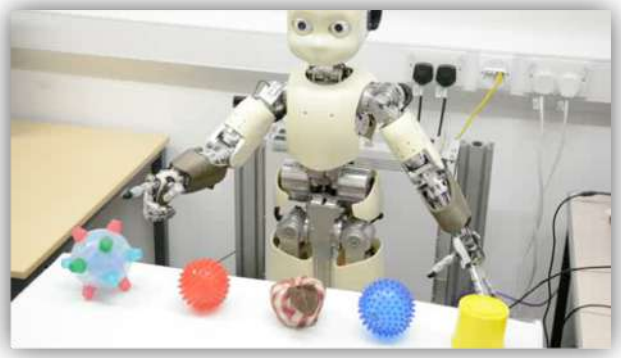


Learning Abstract Words







Finger counting

De la Cruz et al. (2014)

Gesture and counting

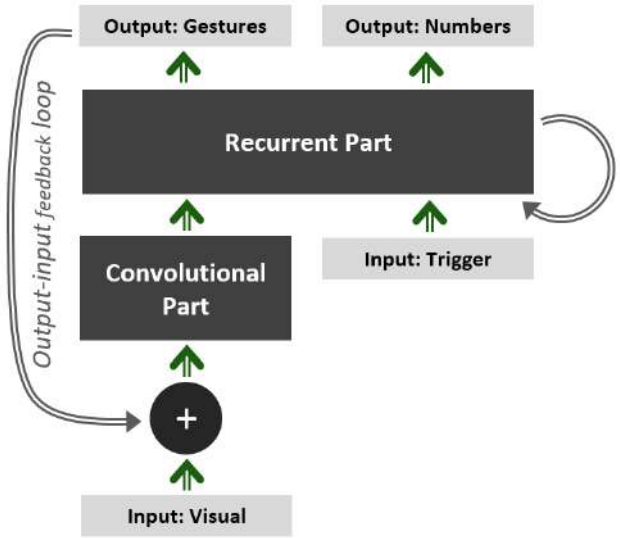
Rucinski et al. (2012)

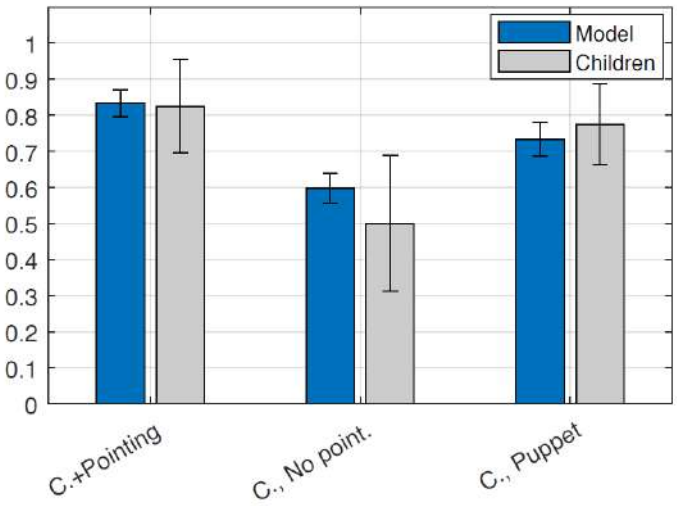
Abstract words:
Use, Make

Stramandinoli et al (2016)

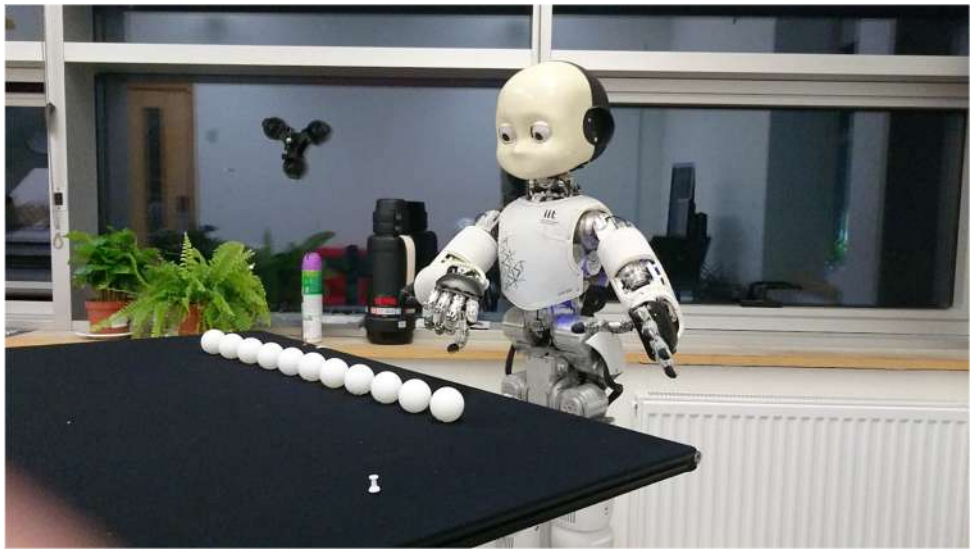
Counting Gestures/Pointing

- Skills development
  - Pointing (pretraining)
  - Recitation (pretraining)
  - Counting with/out pointing
  - Puppet pointing
  - Integrate all skills





Alibali & DiRusso & Pecyna et al.



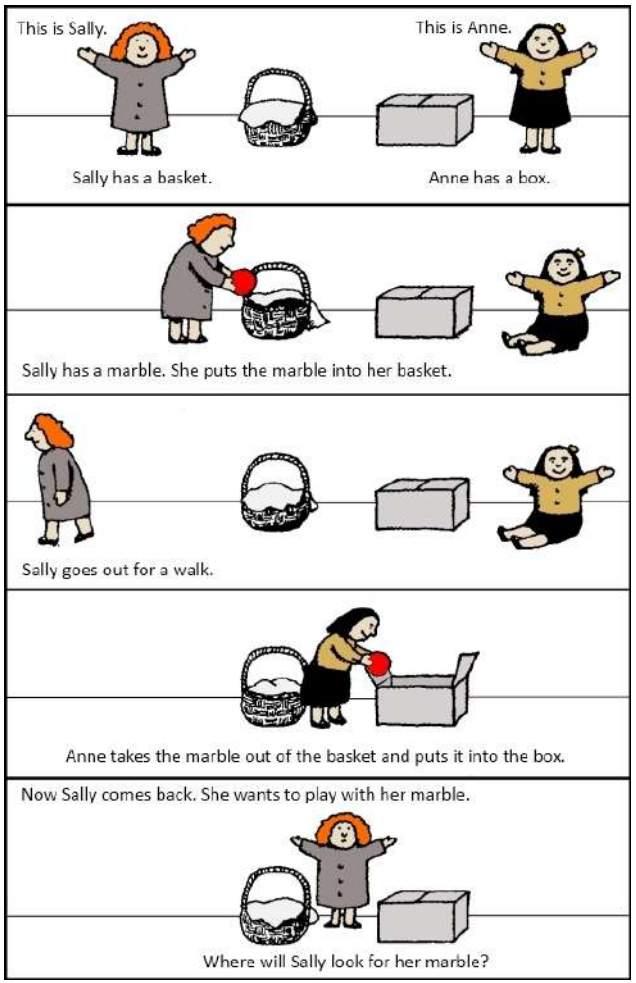
Pecyna al. (2021)

Trust in Human-Robot Interaction

Towards a Theory of Mind

Development of ToM (Theory of Mind)

- Wimmer & Perner (1983). "Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception". *Cognition*



Sally-Anne test

- Sally puts an object into a location x
- In her absence, Anne moves the object to location y.
- Ann returns
- Child asked where Anne believes the object is

Results – deception detection:

- None of the 3-4-years old children
- 86% of 6-9-years old children

Trust in Human-Robot Interaction

Vinanzi, Cangelosi et al. (2018) Phil. Trans. Royal Society B

Intention Reading

- Cognitive architecture for intention reading from action and social gaze

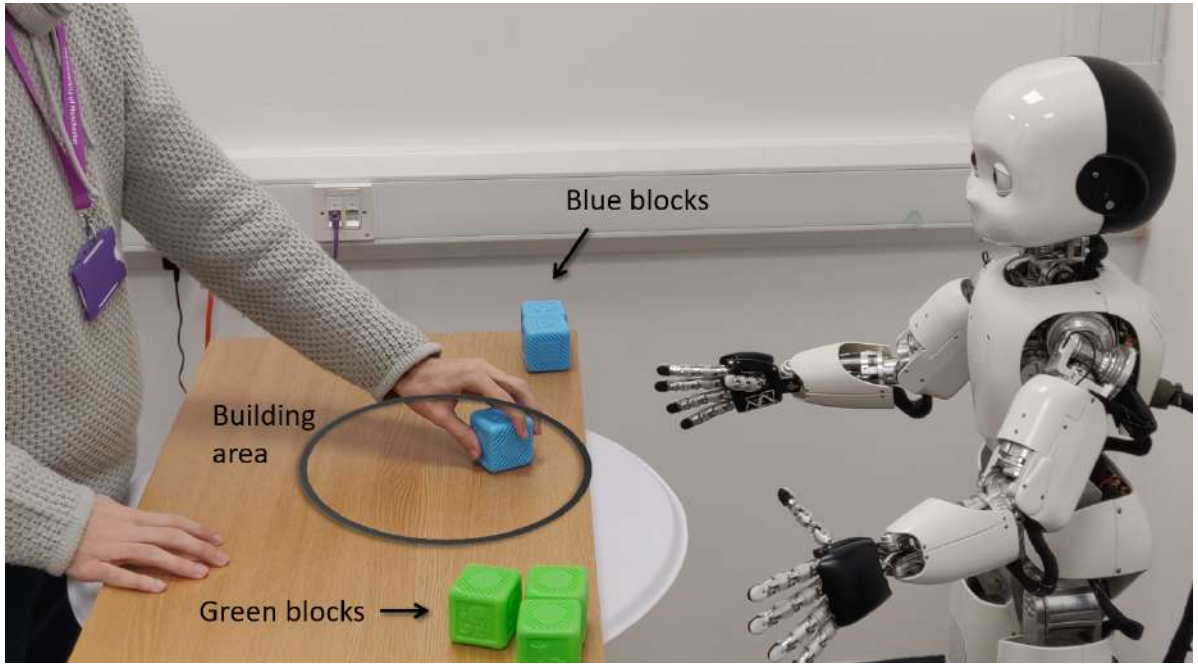
- Intention (Mind)-reading is the ability to understand a goal pursued by someone through the observation of physical clues (mostly postural and gaze)

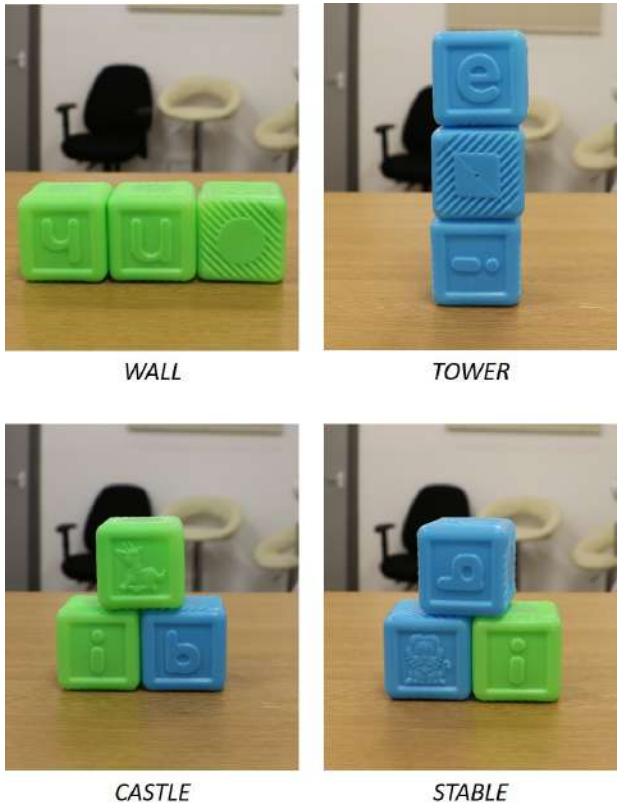
- Key factor in human survival and basis for every other cognitive ability; Developed with experience (Woodward, 2009)

Which object is she going to grasp?
(Ambrosini, 2015)

Vinanzi, Cangelosi & Goerick (2019, 2020, 2021)

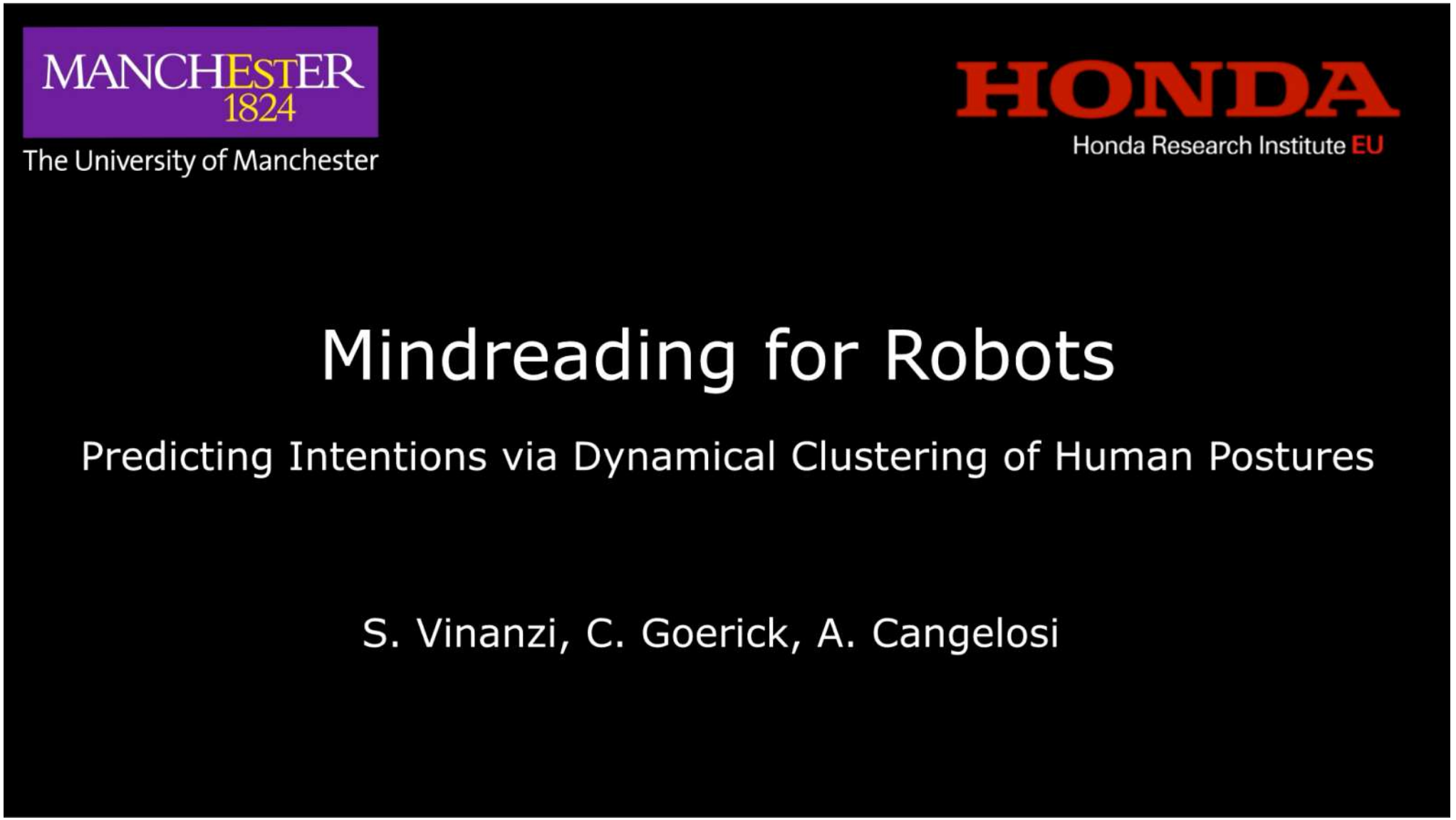
Experimental Setup





Vinanzi, Cangelosi & Goerick (2019, 2020, 2021)

Intention Reading



Vinanzi, Cangelosi & Goerick (2019, 2020, 2021)

Take Home Message

- Developmental approaches
  - Interdisciplinary approach
  - Embodiment cues in development
  - Multiple developmental phenomena
  - Close match with empirical data
- Open challenges
  - Open-ended learning and larger lexicons
  - Explainable AI for Trustworthy Robots
  - Robot companion and personal robotics applications