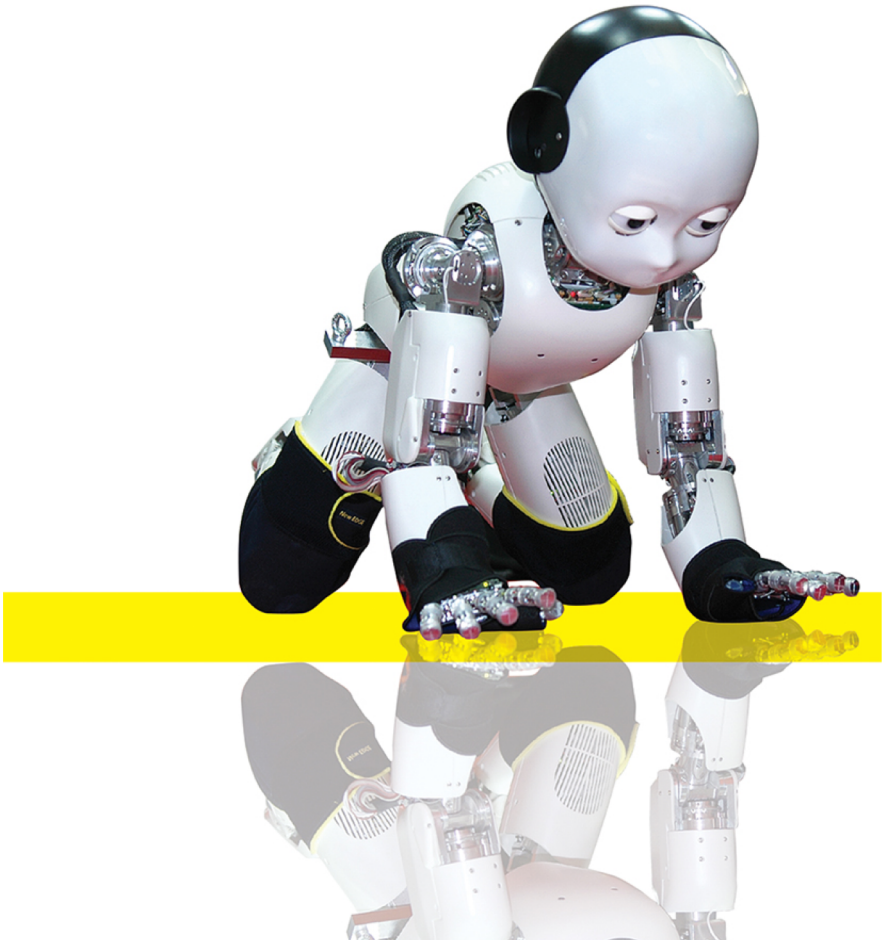
DEVELOPMENTAL ROBOTICS

Language Learning, Trust and Theory of Mind

Angelo Cangelosi

University of Manchester



MANCHESTER 1824
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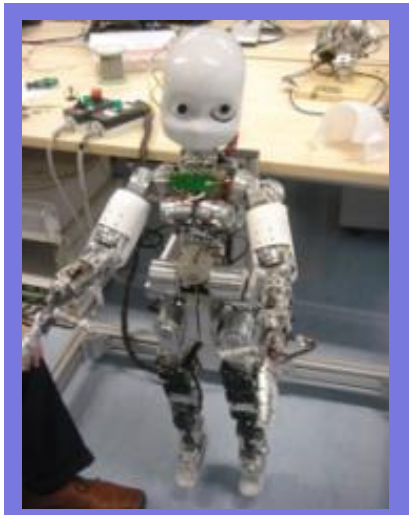
Robots, Language & Cognition

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

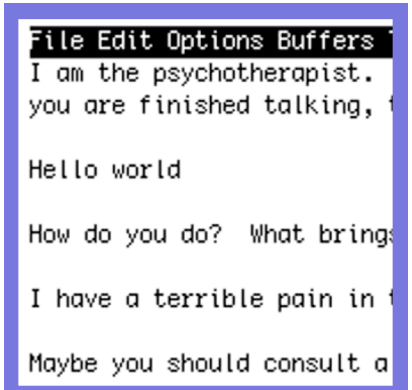
What can cognitive scientists **learn from robot experiments** on embodied language learning?

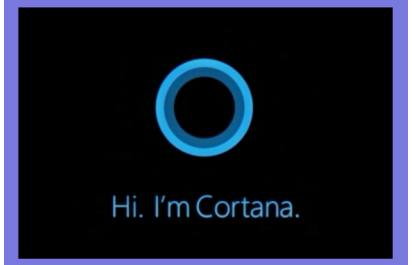


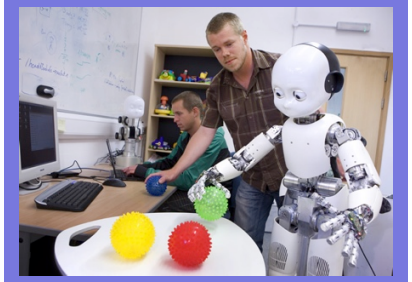

Gavagai
Quine (1960)

Talking to Robots

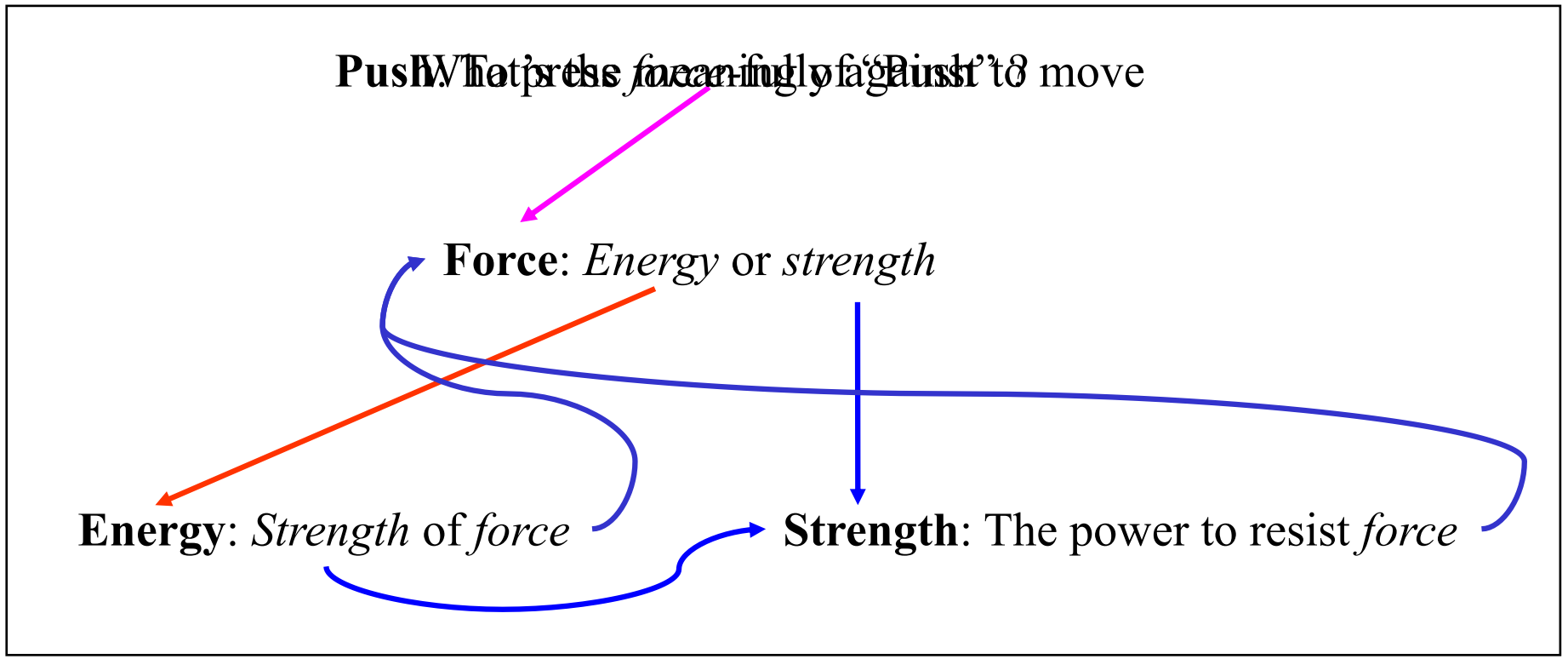
- Computers and robots can be easily **pre-programmed** to memorise a dictionary, but cannot understand the language they use





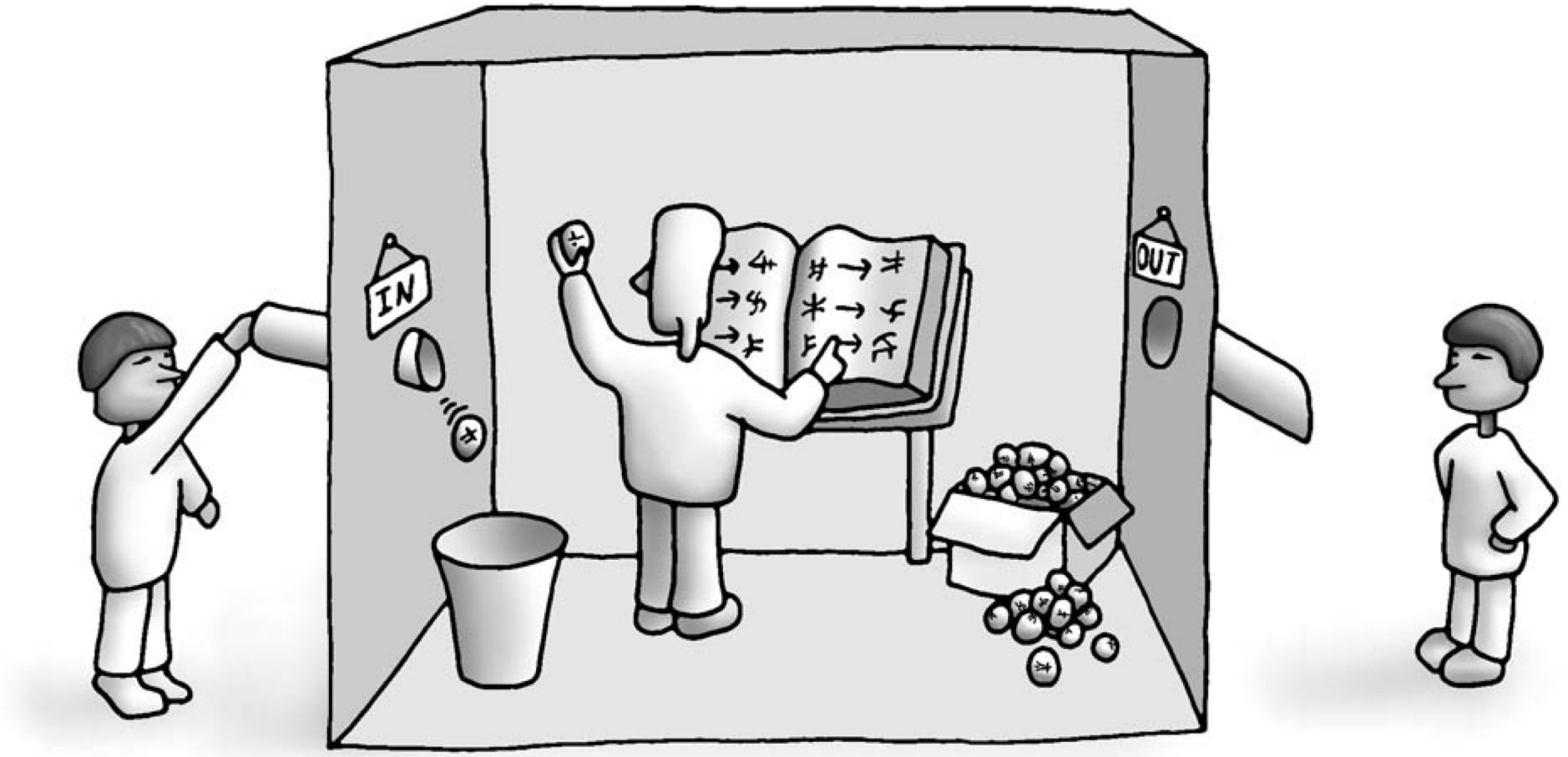


"Merry-Go-Round" of Amodal Symbol Systems



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)

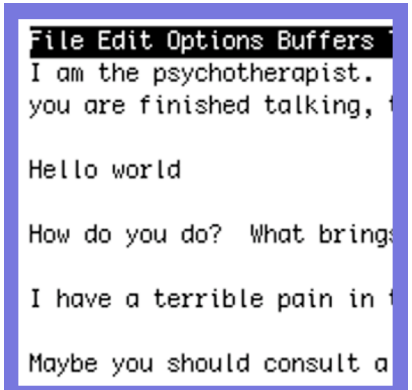


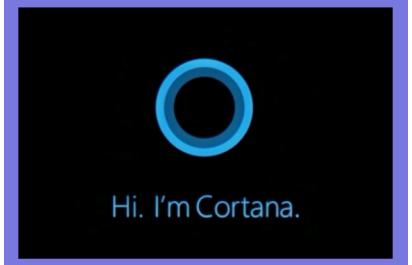
jolyon.co.uk

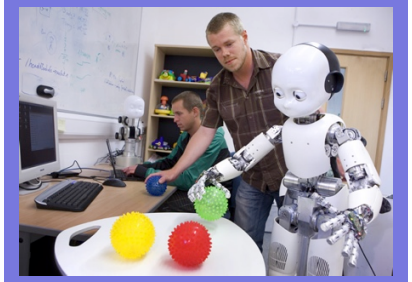
Searle, J.(1980), "Minds, Brains and Programs", Behavioral and Brain Sciences 3 (3): 417–457
Harnad, S (2005), "Searle's Chinese Room Argument", Encyclopedia of Philosophy, Macmillan

Talking to Robots

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



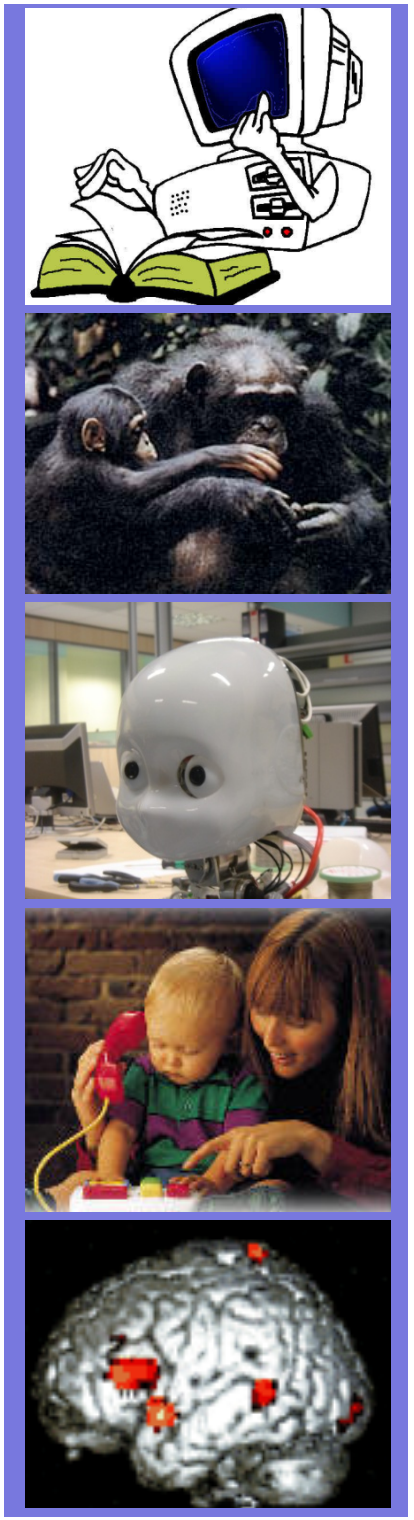




Learning & Development

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

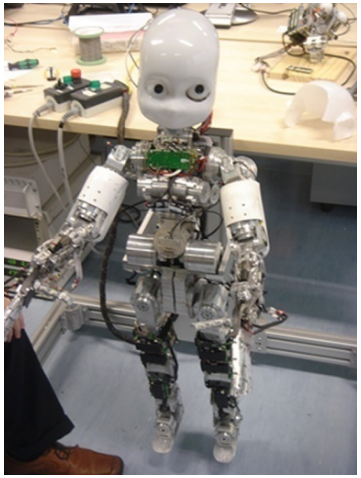
- ✓ Children are **slow**, but efficient at learning a language (vocabulary spurt) (Tomasello 2008)
- ✓ Children use their **body** for situated interaction (Smith & Samuelson 2010)
- ✓ The **brain** integrates language and sensorimotor knowledge (Pulvermueller 2003)
- ✓ Children develop **Theory of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

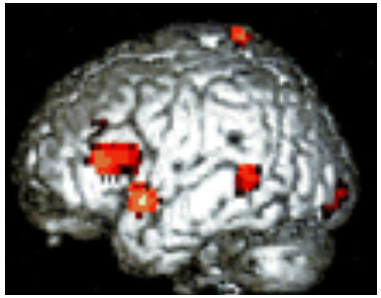


Ethology

Computer science

Robotics



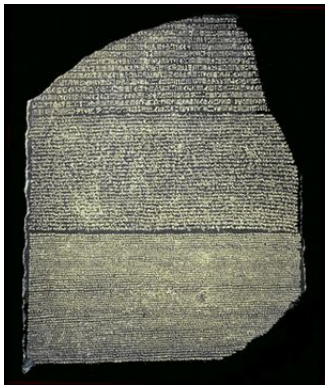


Neuroscience

Cognitive Developmental Robotics

Child Psychology

Cognitive Psychology



Linguistics

DEVELOPMENTAL ROBOTICS

From Babies to Robots

Angelo Cangelosi
and Matthew Schlesinger

The MIT Press

CHILD DEVELOPMENT PERSPECTIVES

Article

From Babies to Robots: The Contribution of Developmental Robotics to Developmental Psychology

Angelo Cangelosi, Matthew Schlesinger

First published:20 February 2018 | https://doi.org/10.1111/cdep.12282 | Citations: 14

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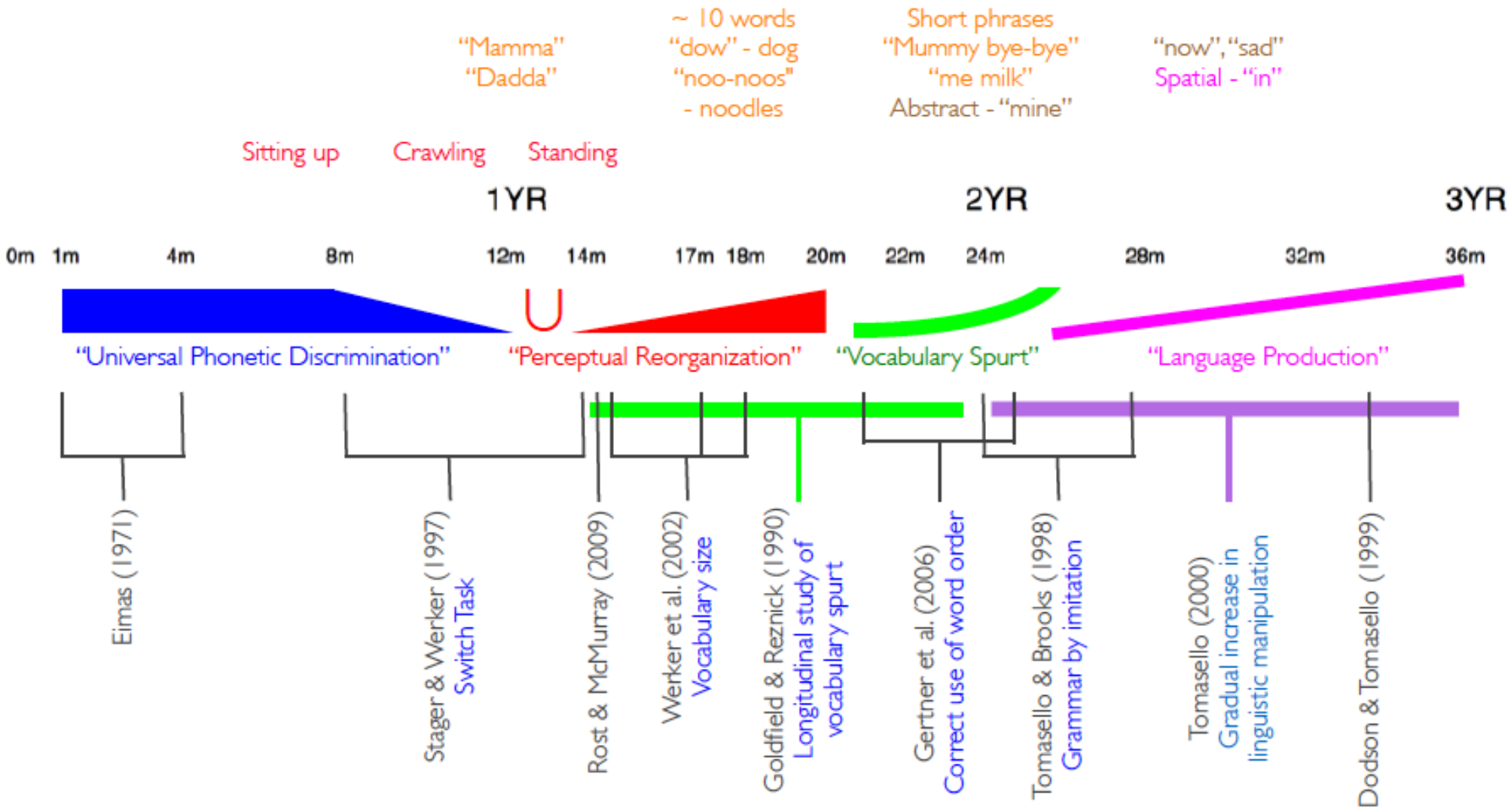
Abstract

The latest developments in artificial intelligence (AI) and machine learning, and the parallel advances in robotics, have contributed recently to a shift in the scientific approach to modeling human intelligence. These innovations, accompanied by the new emphasis on embodied and grounded cognition in AI and psychology, have led to the establishment of the field of developmental robotics. This field features an interdisciplinary approach, built on collaboration between cognitive robotics and child psychology, to the autonomous design of behavioral and cognitive capabilities in artificial cognitive agents, such as robots, which is inspired by developmental principles and mechanisms observed in children. In this article, we illustrate the benefits of this approach by presenting a case study of a baby robot with a focus on the role of embodiment during early word learning, as well as an overview of several developmental robotics model of perceptual, social, and language development.

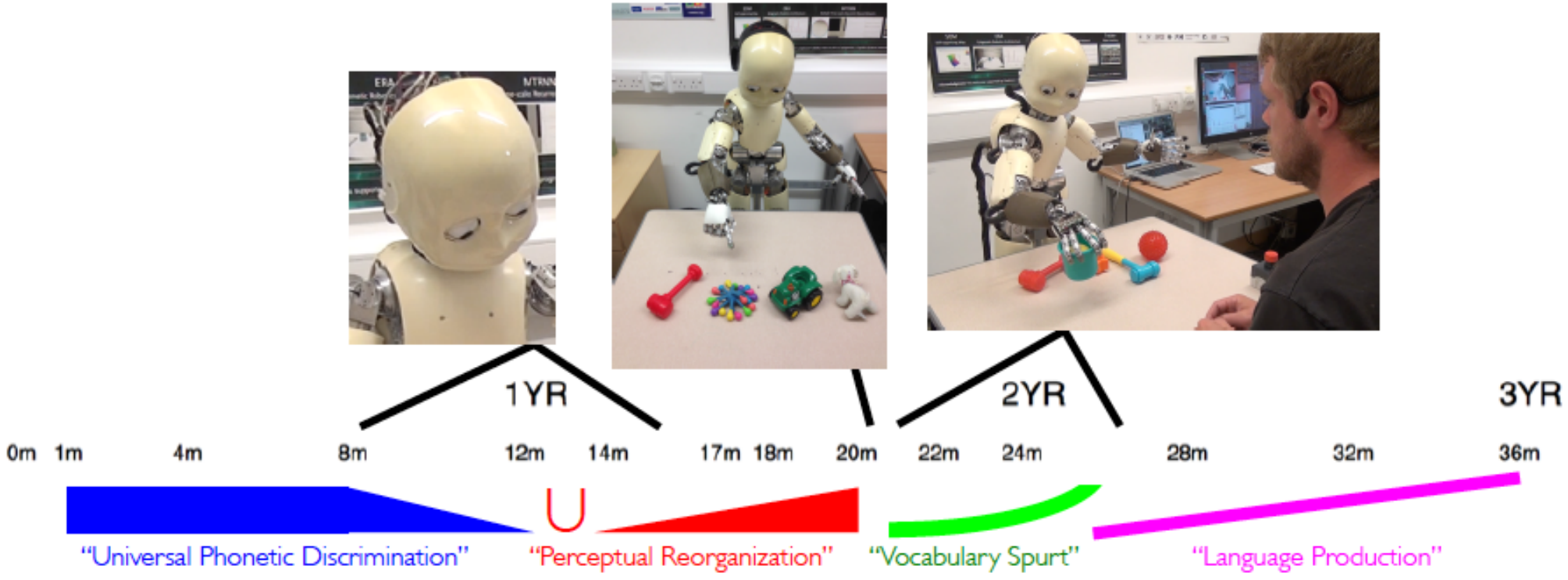
Embodied Language Learning

Developmental Psychology of Language Acquisition



Developmental Robotics of Language Acquisition

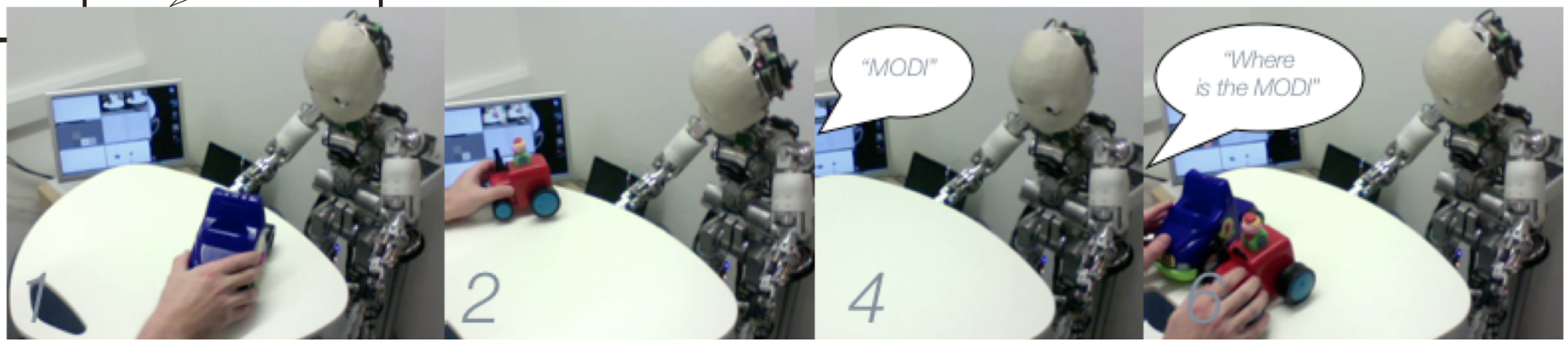
- Cognitive architecture for cumulative learning
  - 5+ Experiments: first words, mutual exclusivity, U-learning, word order, trust …
  - **Collaboration with BabyLabs**: Smith (Indiana), Horst (Sussex), Floccia/Cattani (Plymouth), Twomey (Manchester), Antonelli (Milan Cattolica)



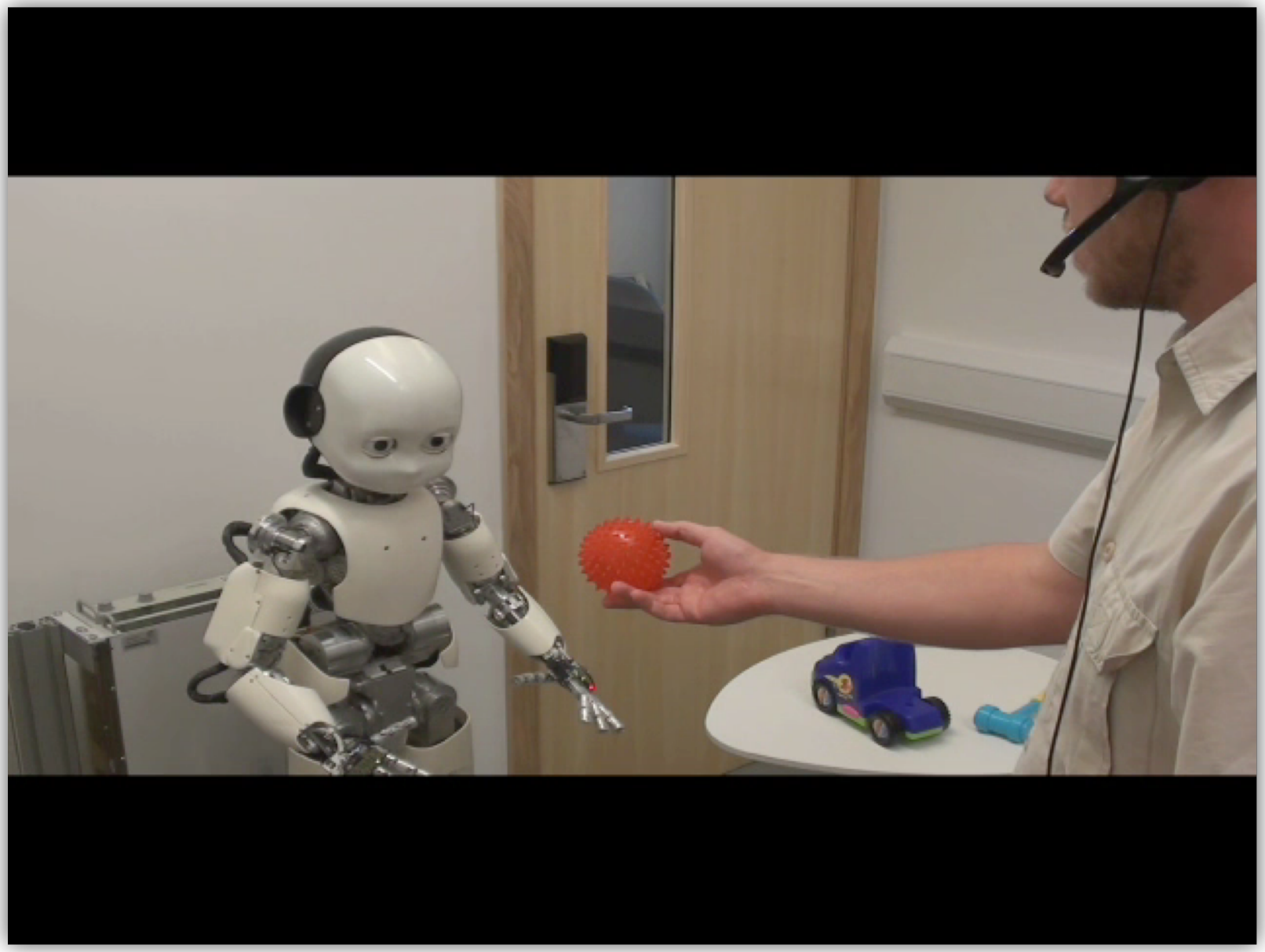
Posture Affects Word Learning

Smith & Samuelson (2010); Morse, Cangelosi, Smith et al. (2015)

	Left	Right
Step 1		
Step 2		
Step 3		
Step 4		
Step 5	*look at the MODI*	
Step 6		
Step 7		
Test	 *Where's the MODI ?*	

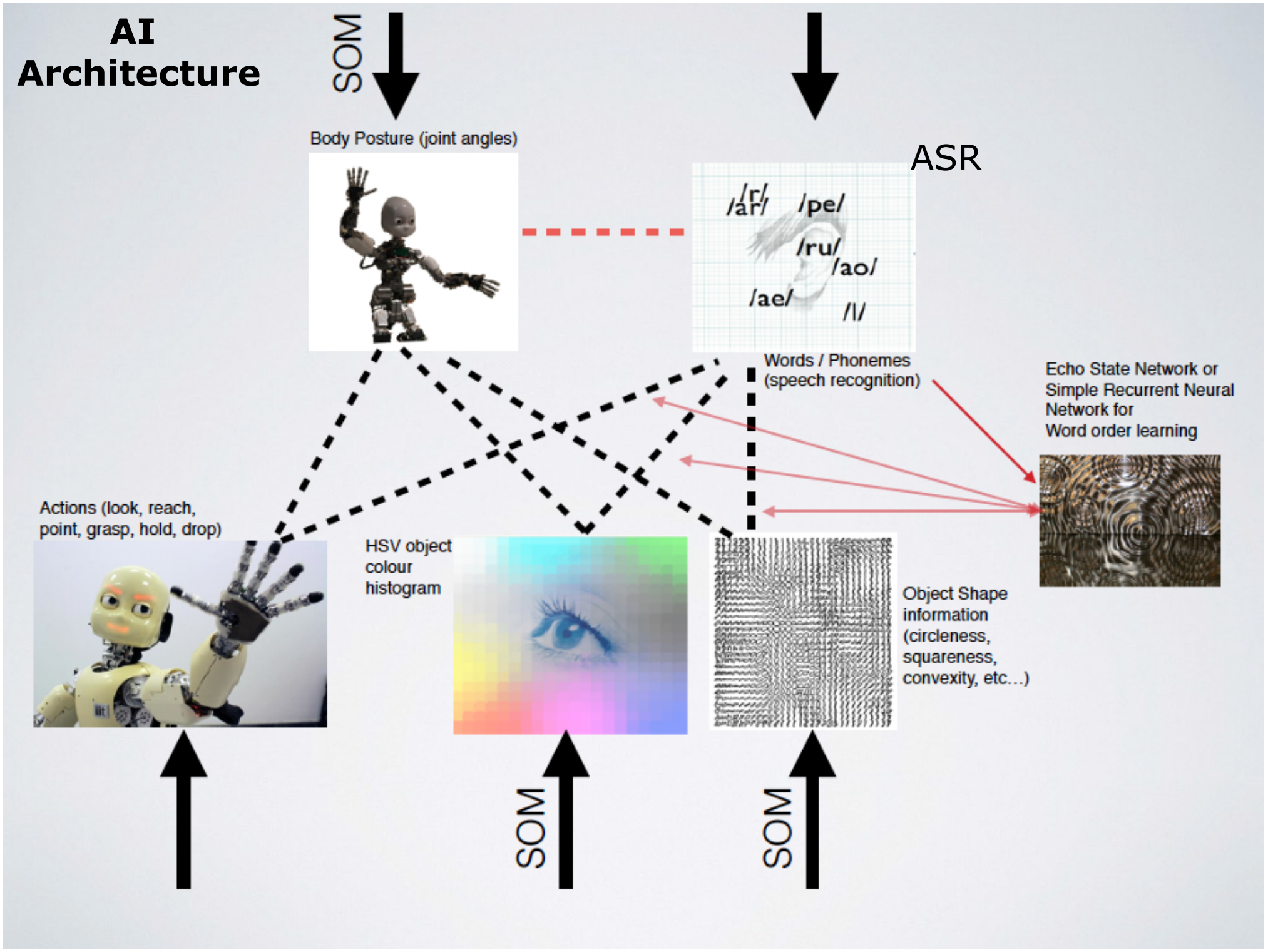


iCub's Modi Experiment

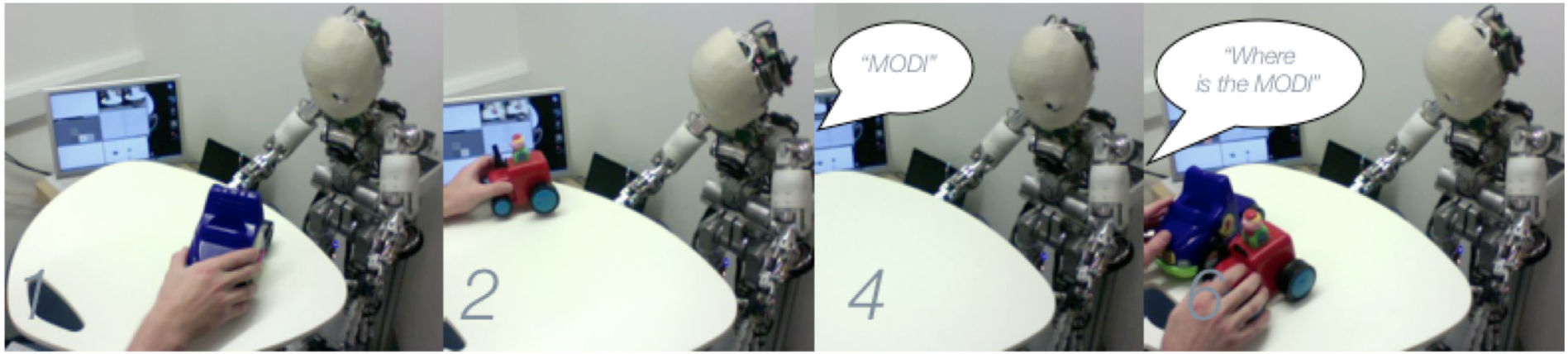


Morse et al. (2015) *PLoS ONE*

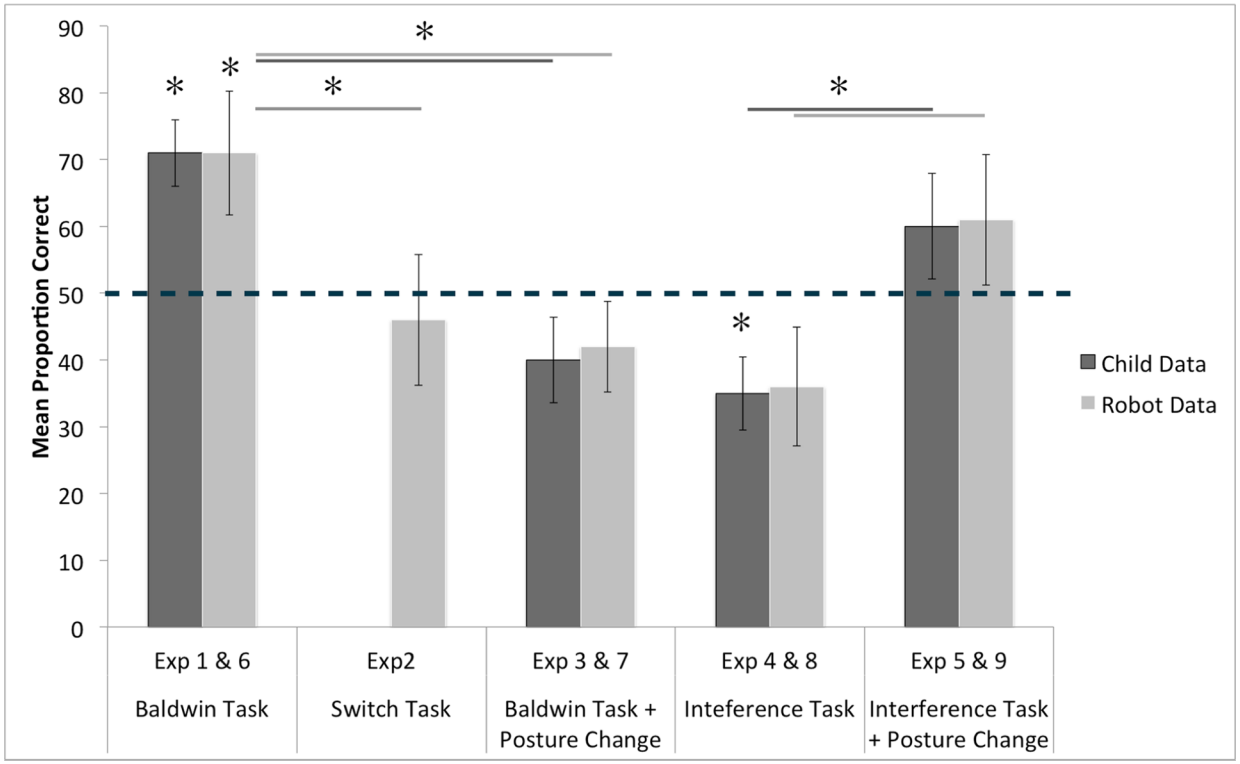
AI Architecture



iCub 'Modi' : Predictions

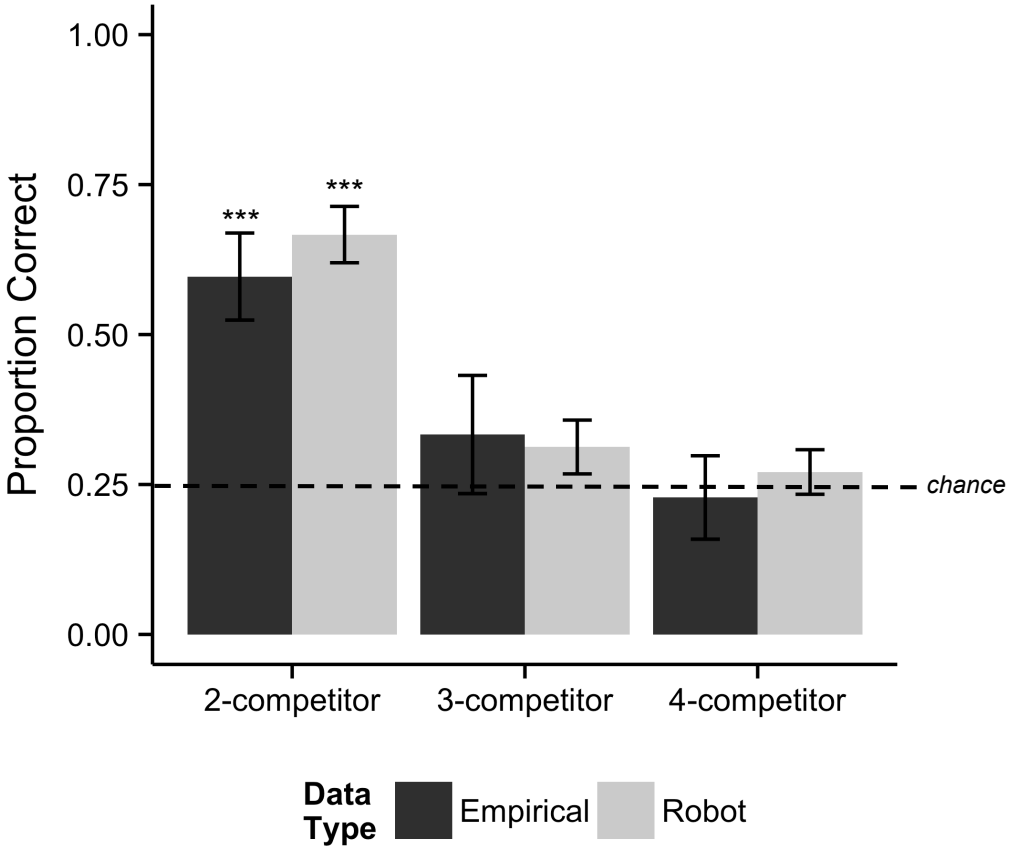


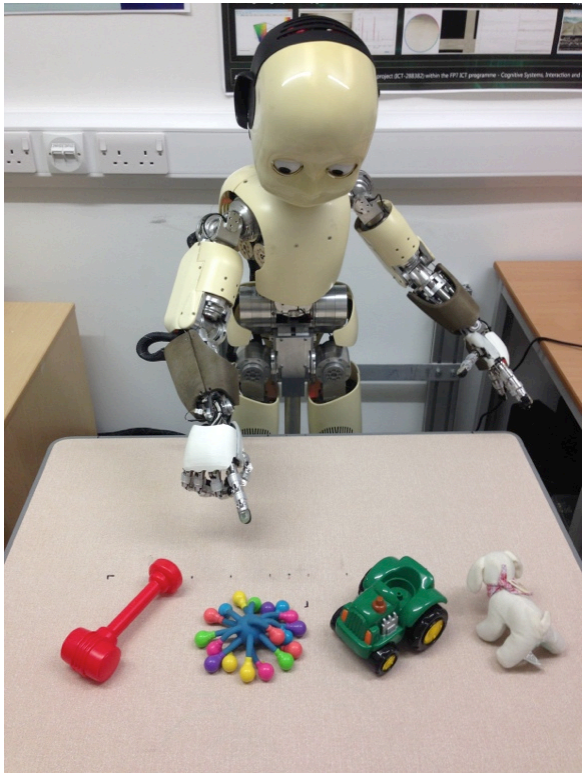
- 6 robot/baby Experiments
- Model prediction
  - Changes in posture (e.g. from sitting to standing) will remove task interference effect despite the target location remaining consistent.



Mutual Exclusivity

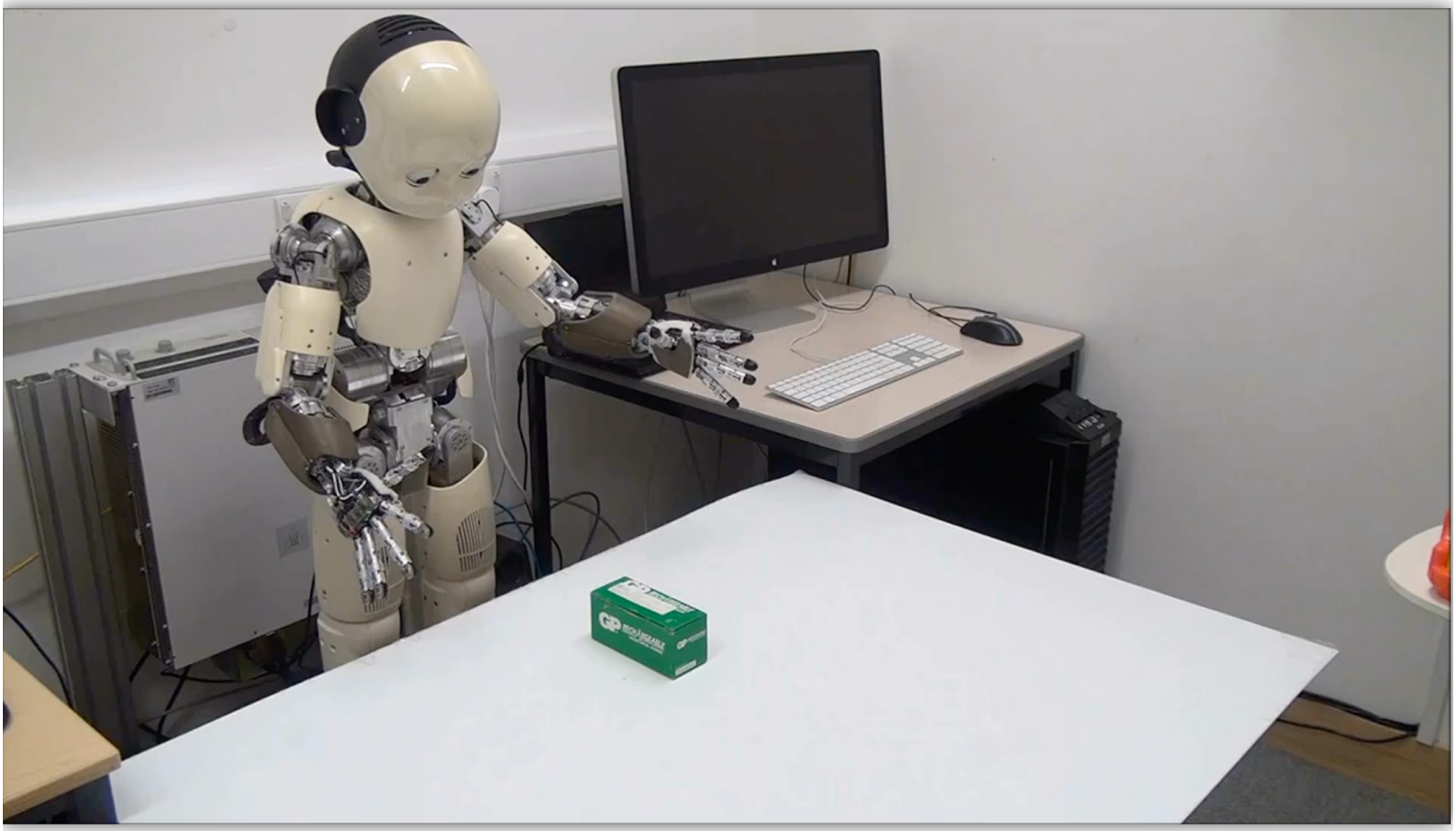
- Mutual exclusivity (Horst et al. 2010)
  - Effects of competitors





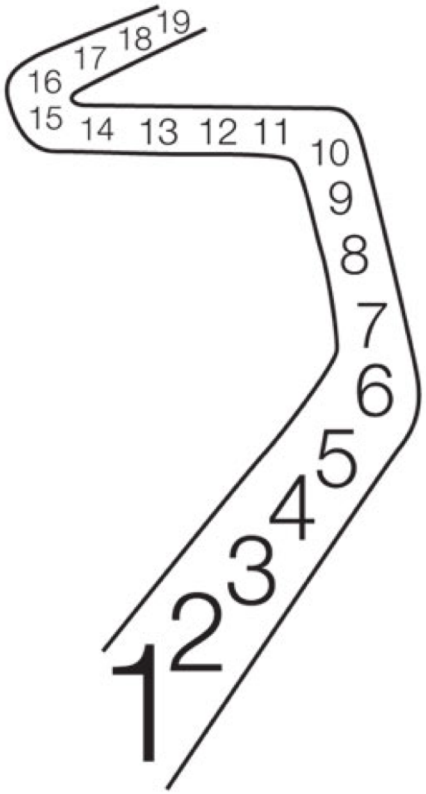
Twomey et al. (2016) *Interaction Studies*

Open-Ended Cumulative Learning



Morse & Cangelosi (2016) *Cognitive Science*

Learning Abstract Words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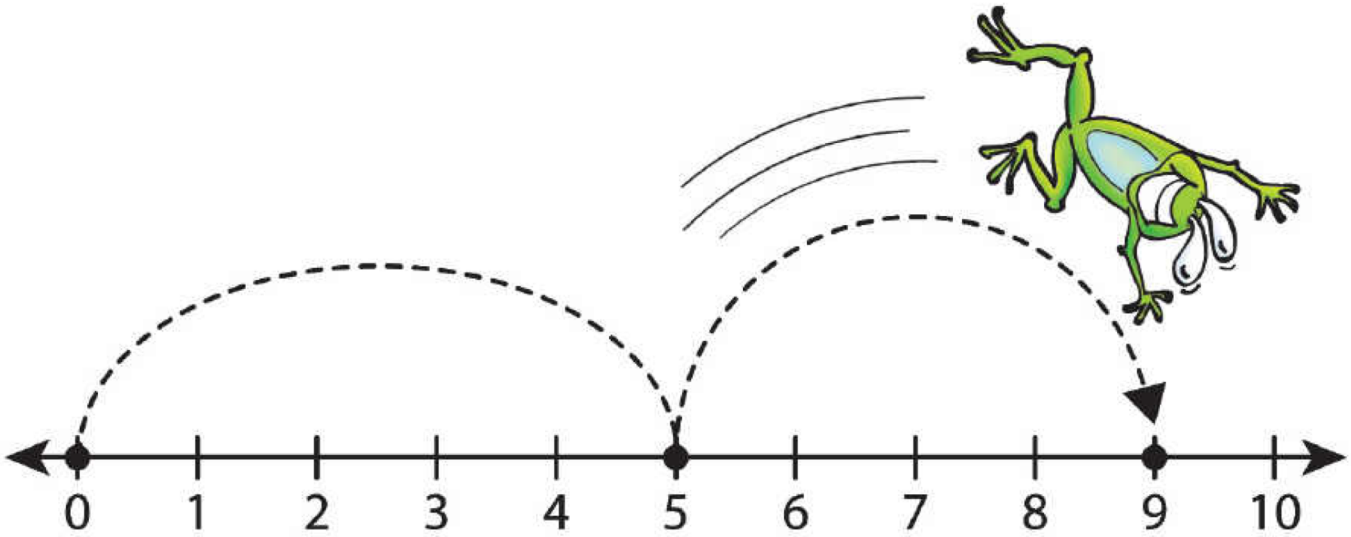
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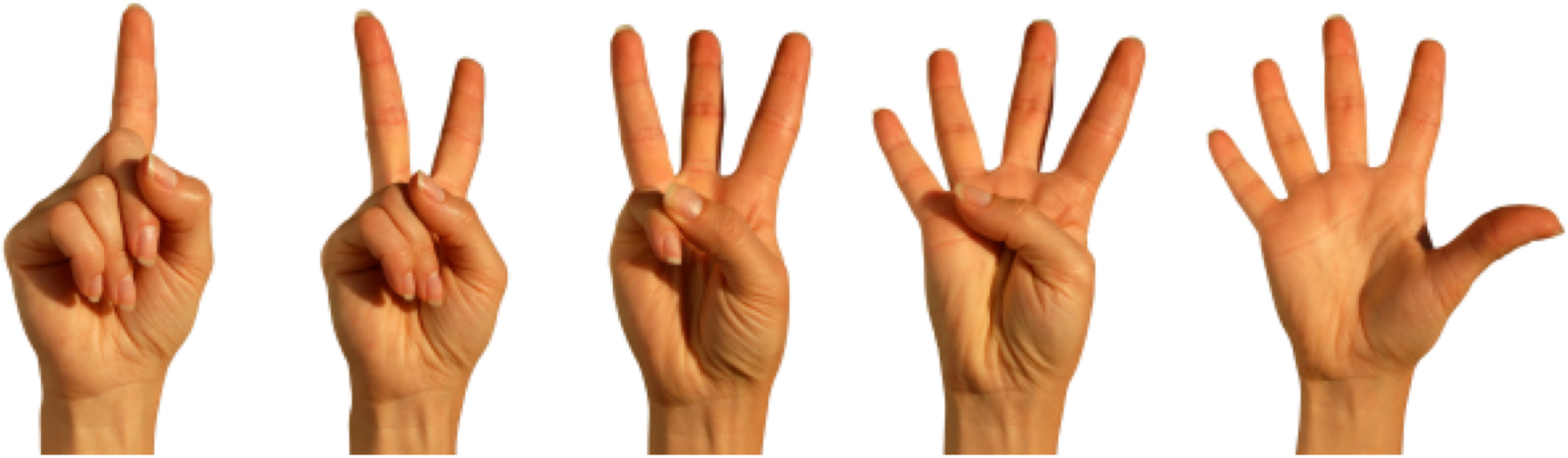
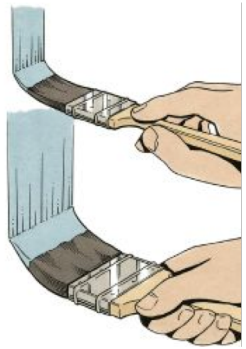
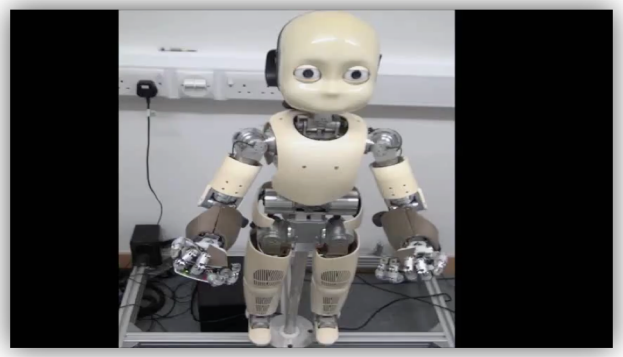
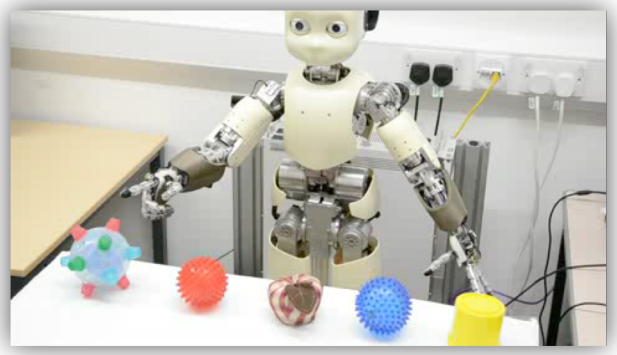


Learning Abstract Words







Finger counting

De la Cruz et al. (2014)

Gesture and counting

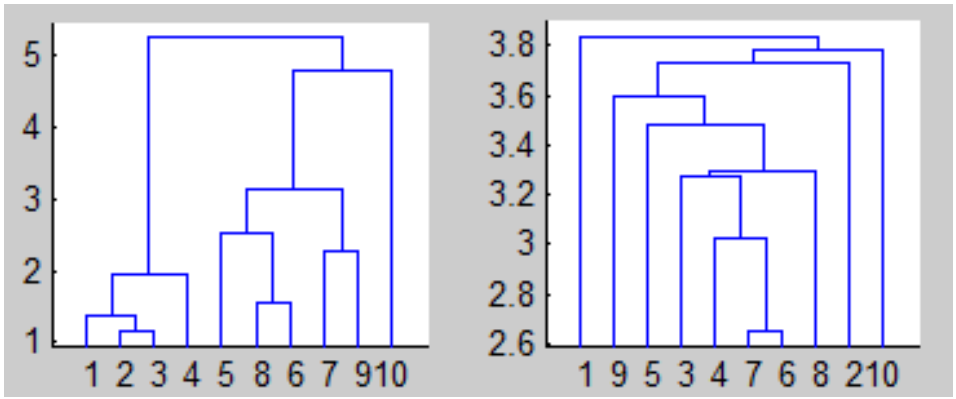
Rucinski et al. (2012)

Abstract words:
Use, Make

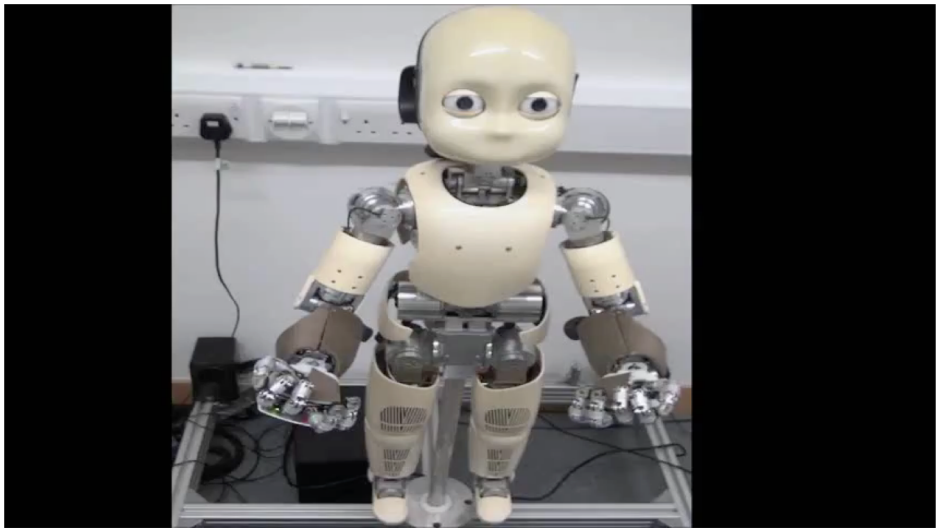
Stramandinoli et al (2016)

Finger Counting: Model

- Robot counting its fingers
- Learning architecture (deep neural networks)
  - Finger and number words
- Training
  1. Finger sequence only
  2. Number sequence only
  3. Finger & Number sequences



Finger&Number Number sequence only



De La Cruz, A. Di Nuovo et al. (2014)

Trust in HRI

Theory of Mind and Intention Reading

Trust for Human-Machine Interaction

- Cognitive architecture for trust in humans and machines
  - Robot's trust of other agents (humans, robots)
  - Human's trust of autonomous robot

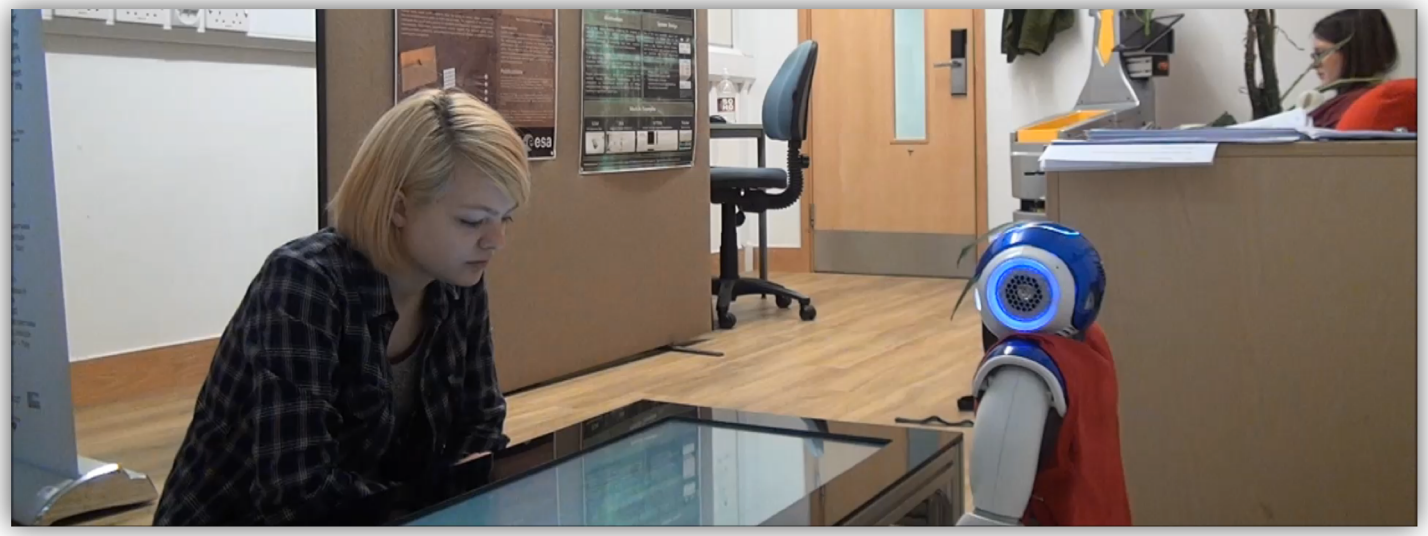
- Inspiration from developmental psychology experiments on Theory of Mind (ToM) and Trust
  - Bayesian model for belief and ToM

- HRI experiments on social and anthropomorphic factors in trust

Trust for Human-Robot Interaction

- Price judgement game

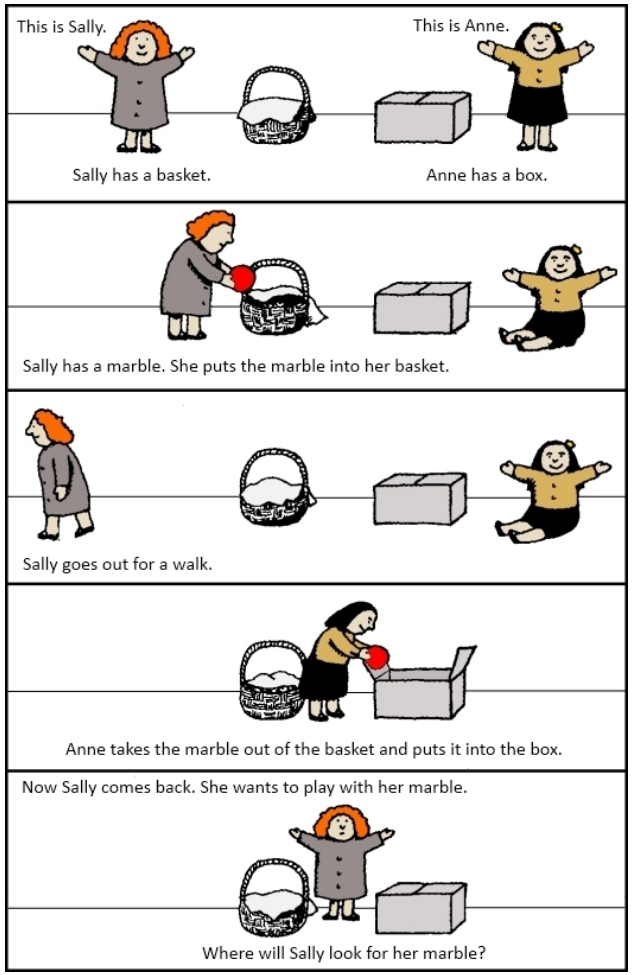
- Investment game



Zanatto et al. 2016, 2019, 2020

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

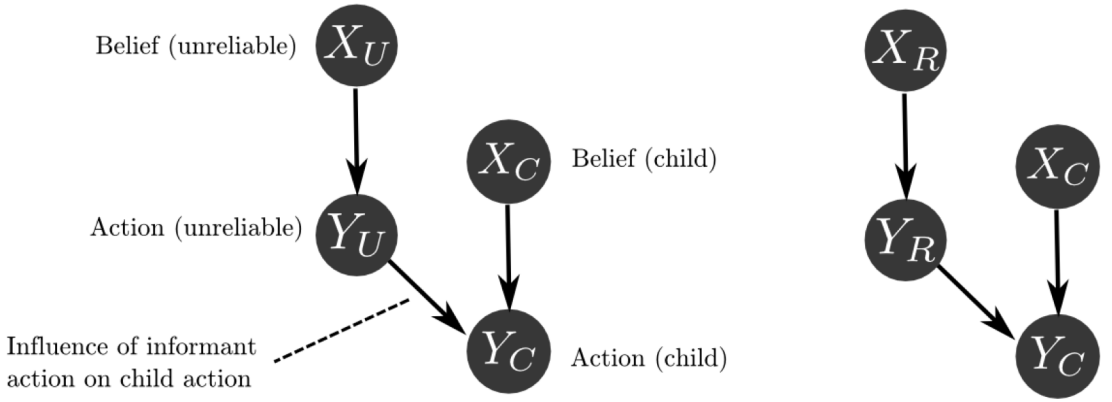
Results – deception detection:

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

Bayesian ToM Trust Model

- Bayesian Network (BN): Separate BN for reliable (R) and unreliable (U) speaker

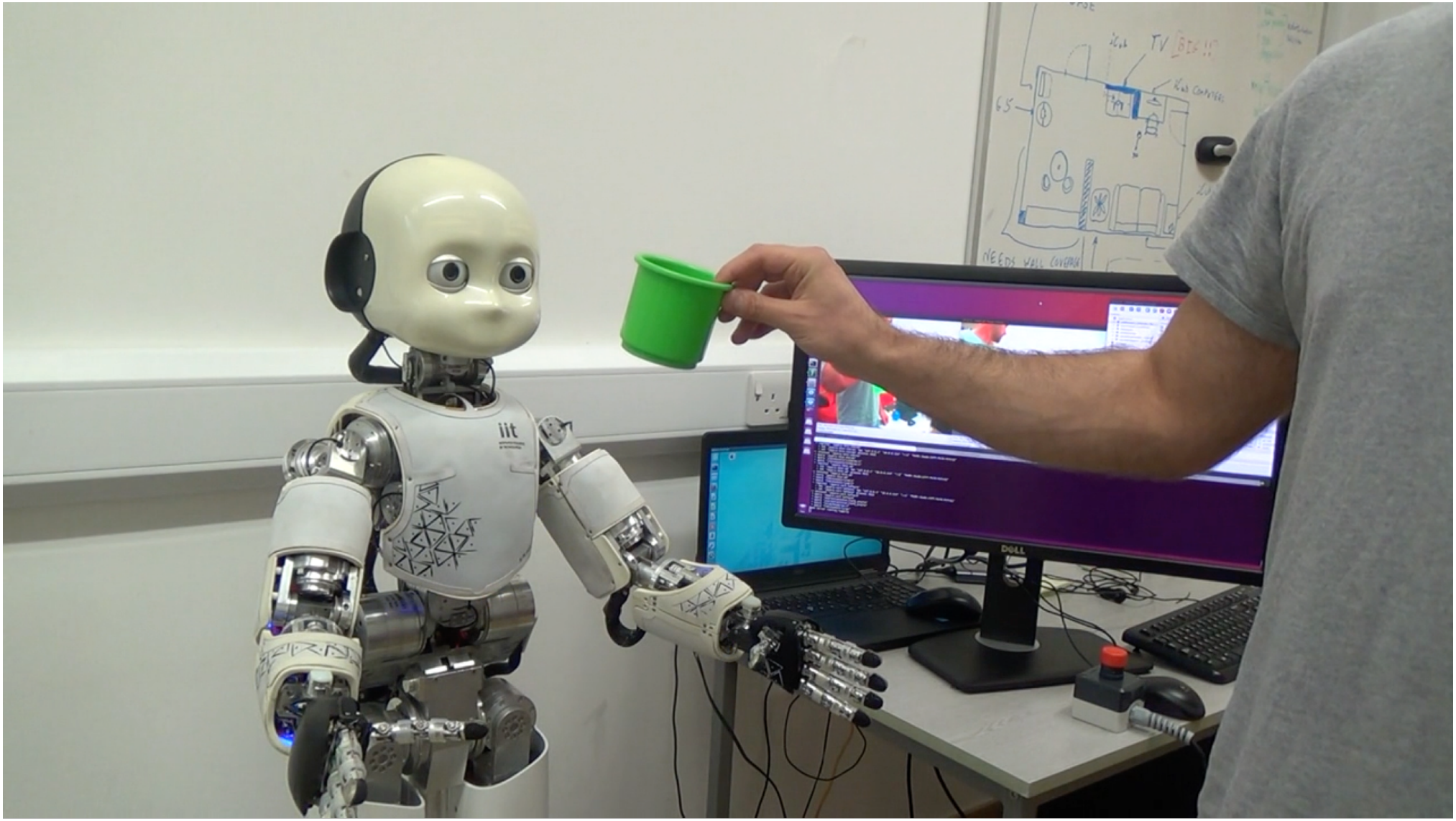
- The action of the child is a consequence of her internal belief X_C and the informant's action Y_R or Y_U .



- Children collect statistical information for tracking the reliability of agents (MLE Maximum Likelihood Estimation for the setting of BN parameters).

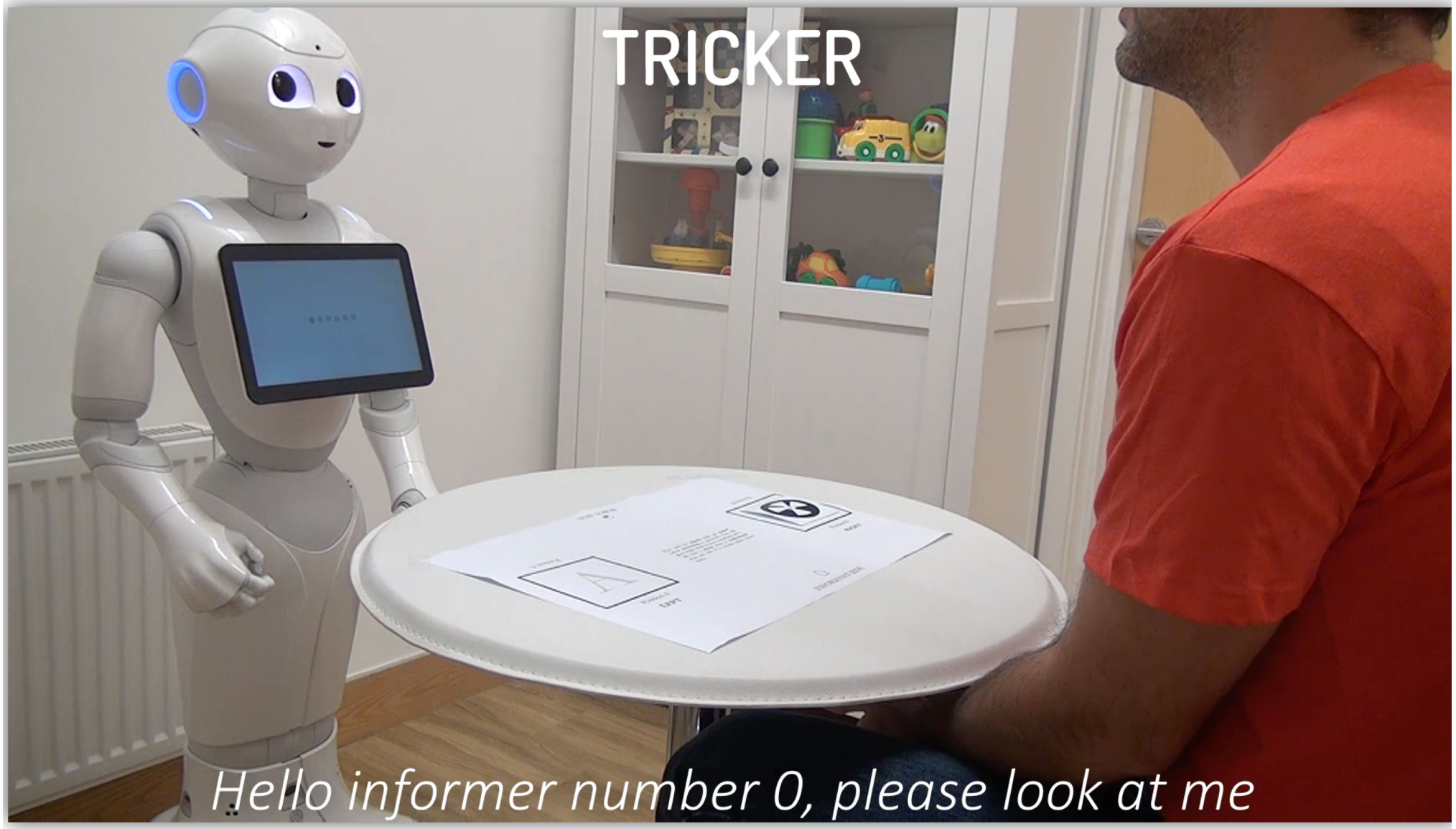
Patacchiola & Cangelosi (2016, 2020)

iCub Trust and Language



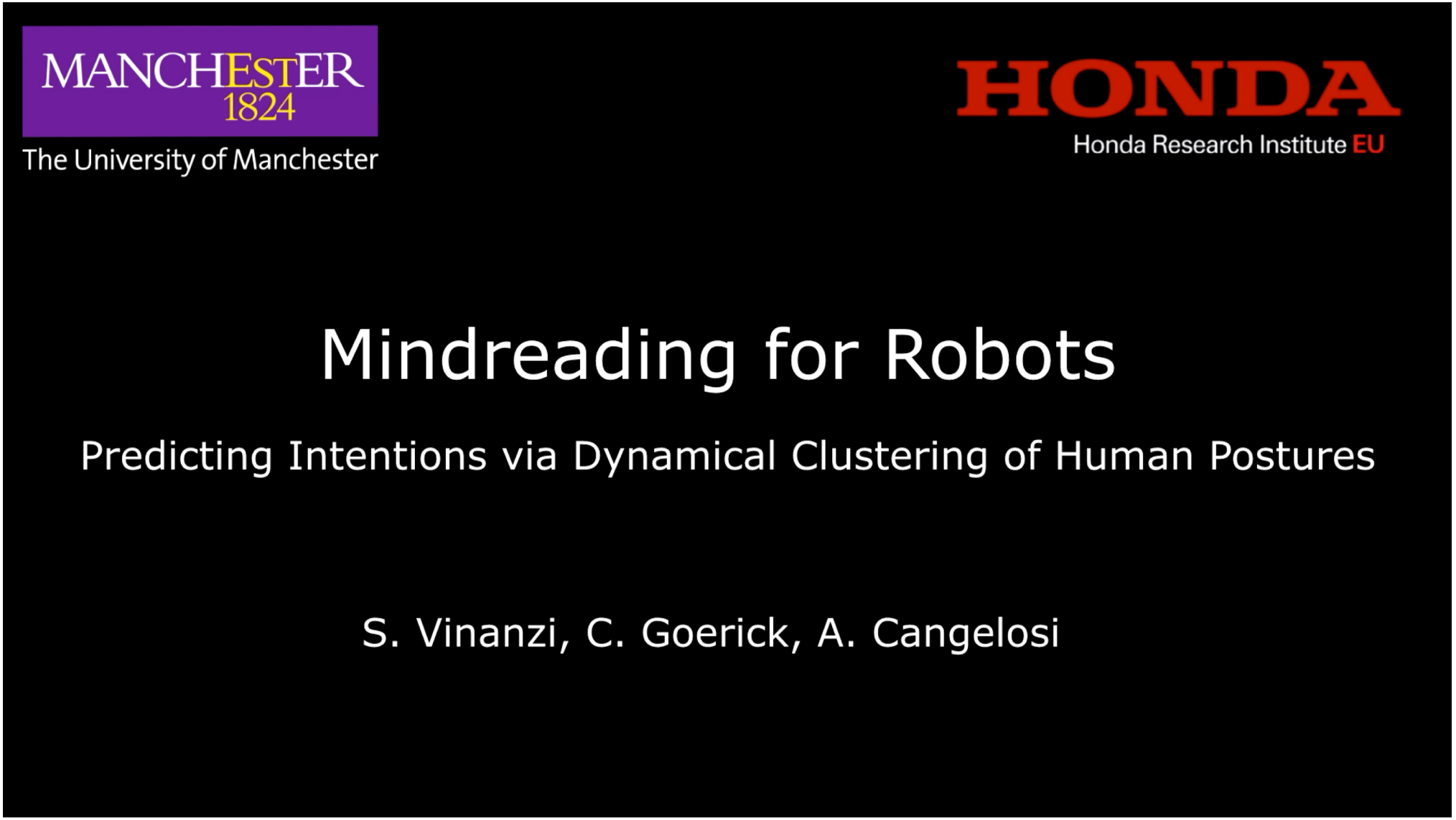
Patacchiola & Cangelosi (2020) *IEEE trans Cybern*

Trust in Human-Robot Interaction



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

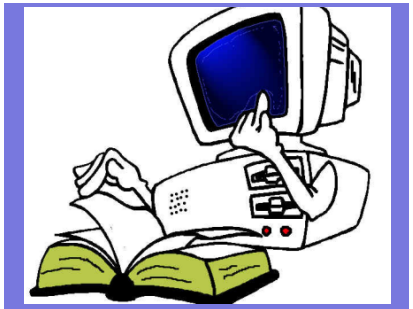
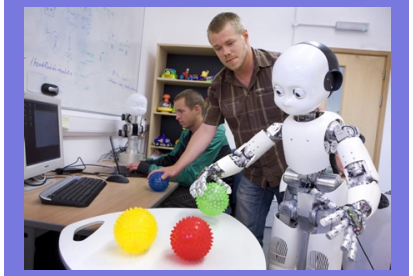
Intention Reading

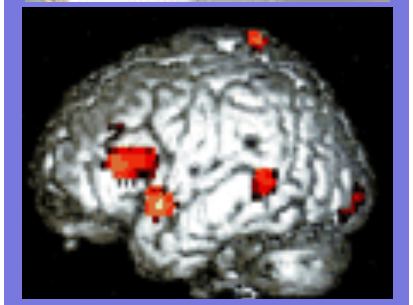
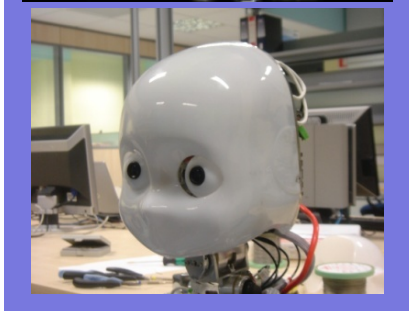


Vinanzi, Cangelosi & Goerick (2019, 2020)

Take Home Message

- Developmental approaches
  - Embodiment cues in development
  - Multiple developmental phenomena
  - Close match with empirical data
  - ToM and Intention reading
- Open challenges
  - Open-ended learning and larger lexicons
  - Explanatory AI for Trustworthy Robots
  - Brain models of social/language development
  - Robot companion and personal robotics applications

CoRo Lab @ UoM