Language Learning in Children and Robots: a Developmental Robotics Approach

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COGNITIVE ROBOTICS WITH PLYMOUTH UNIVERSITY

MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

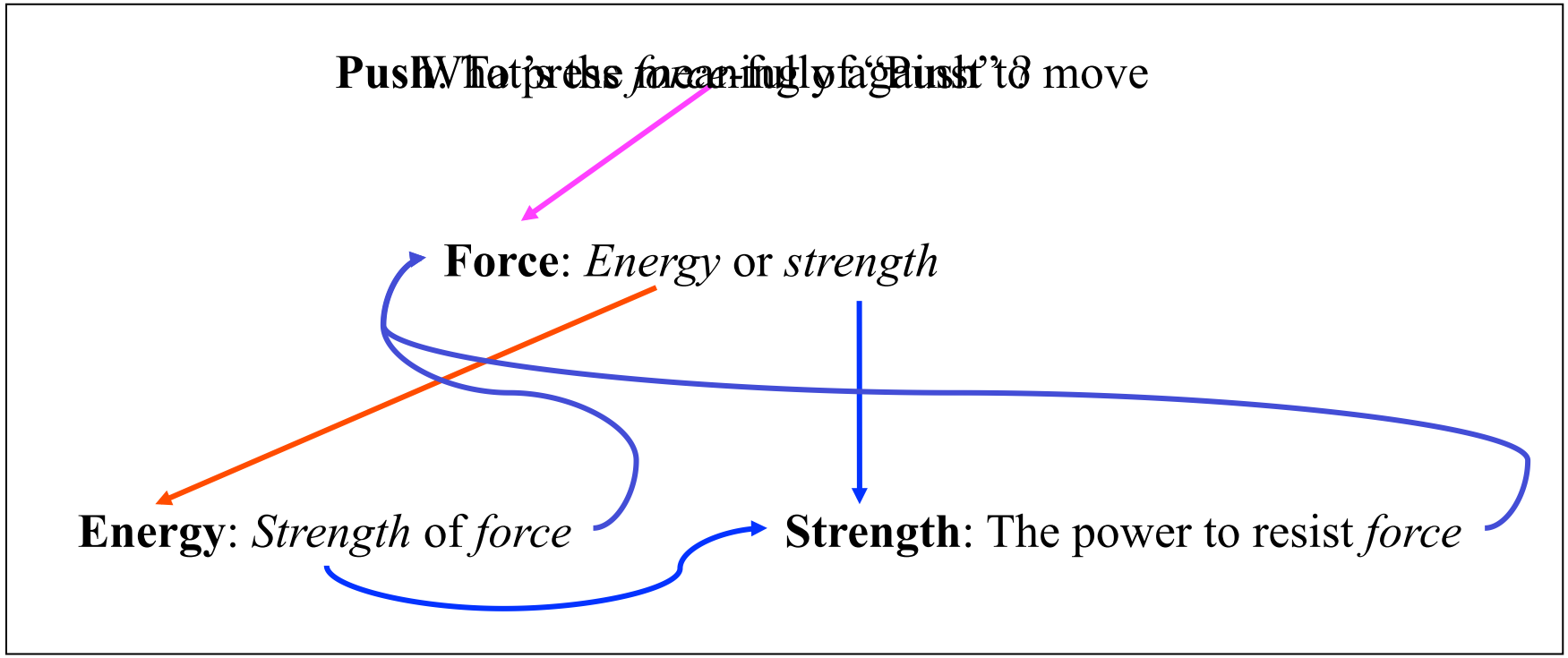

Gavagai


Gavagai

Learning & Development

- Robots can be easily **pre-programmed** to memorise a dictionary, but cannot fully 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)

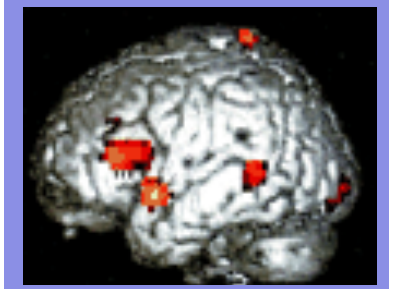
Learning & Development

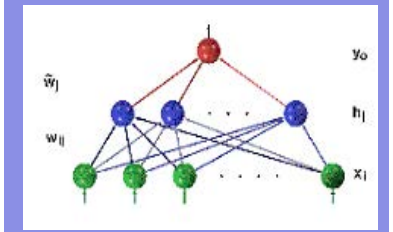
- Robots can be easily **pre-programmed** to memorise a dictionary, but cannot fully understand the language they use

✓ Children are **not** born with the knowledge of a language (Tomasello 2003)

✓ Children are **slow**, but efficient at learning a language

Action and Language



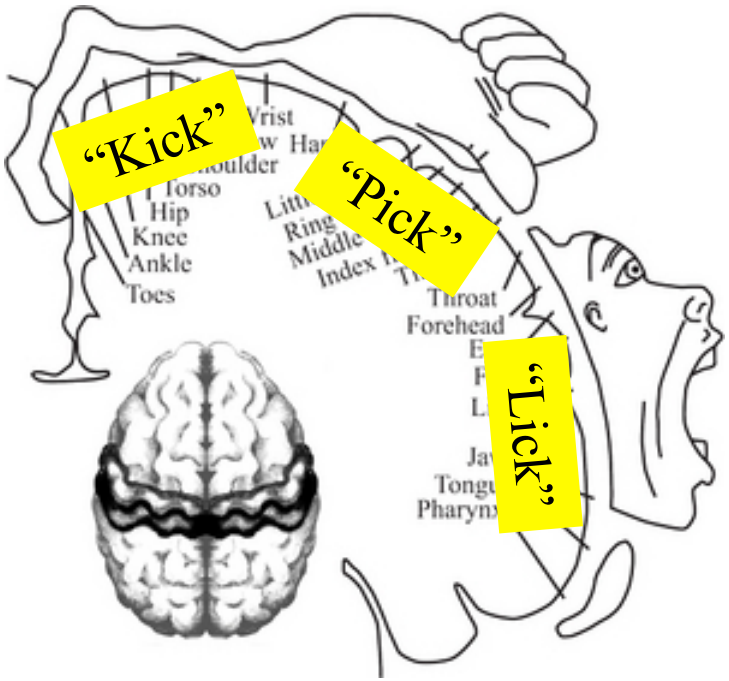


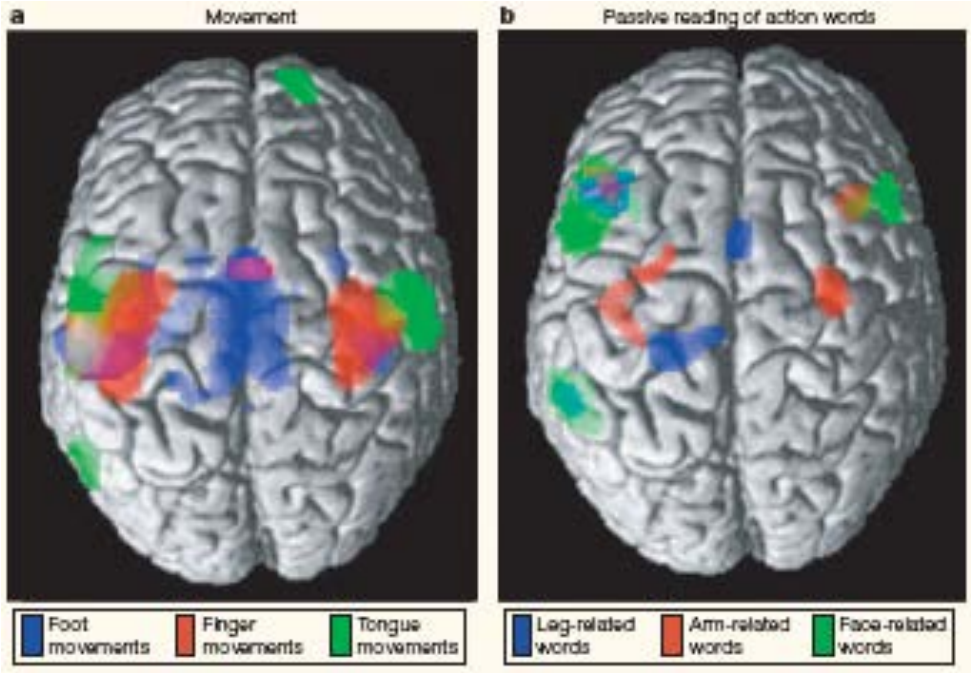
Robots are **separately** trained to handle linguistic and motor capabilities, but…

- ✓ The **brain integrates** language and sensorimotor knowledge (Pulvermuller 2003)
- ✓ Action and perception are **intrinsically linked** – microaffordances (Ellis et al. 2004)

Words and Actions in the Brain

Verbs/Nouns and Abstract/Concrete words (Cappa & Perani 2003)
Semantic Somatotopy of action words (Pulvermuller 2003)



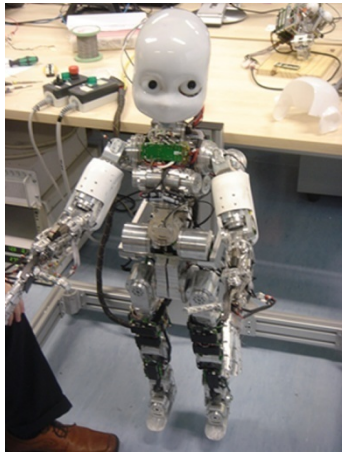


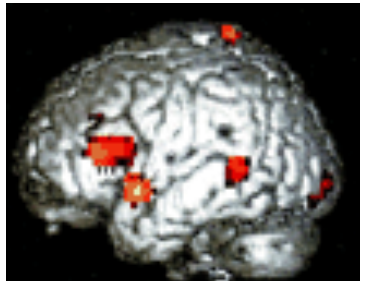
"Kick", "Pick", "Lick"

Ethology

Computer science

Robotics



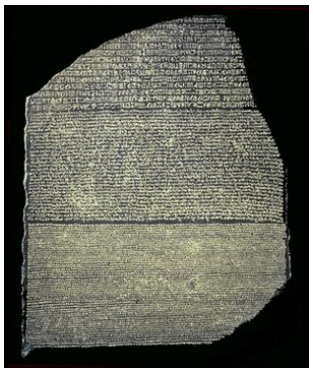


Neuroscience

Cognitive Developmental Robotics

Child Psychology

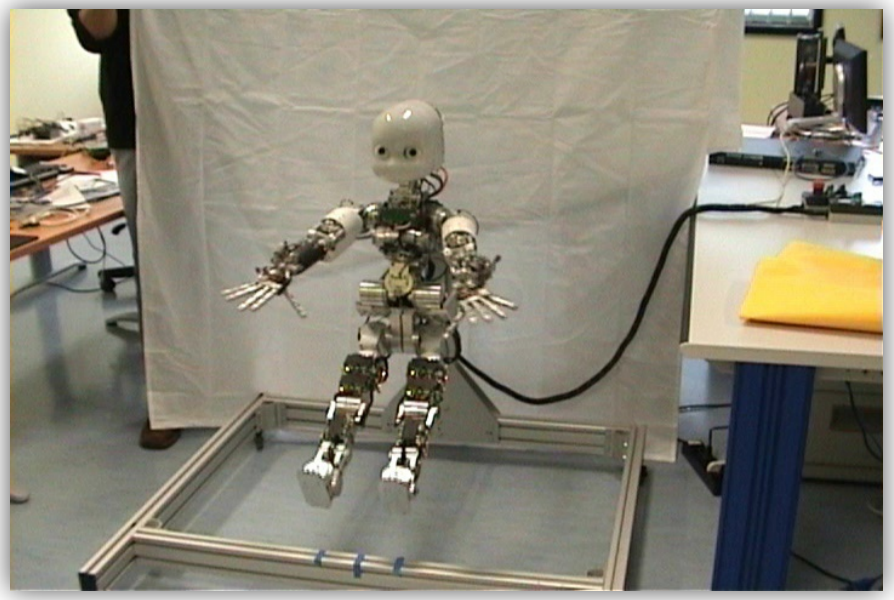
Cognitive Psychology

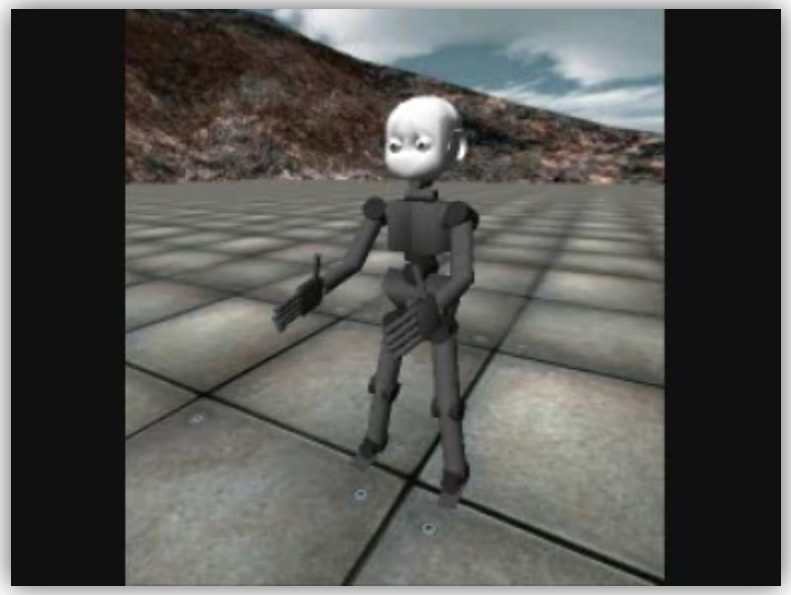


Linguistics

Simulated and Physical iCub

- Toddler robot (Metta et al. 2004)
- Physical and simulated iCub (Tikhanoff et al. 2004)
- Action/Language studies in ITALK project





www.robotcub.org

Space, Posture and Language

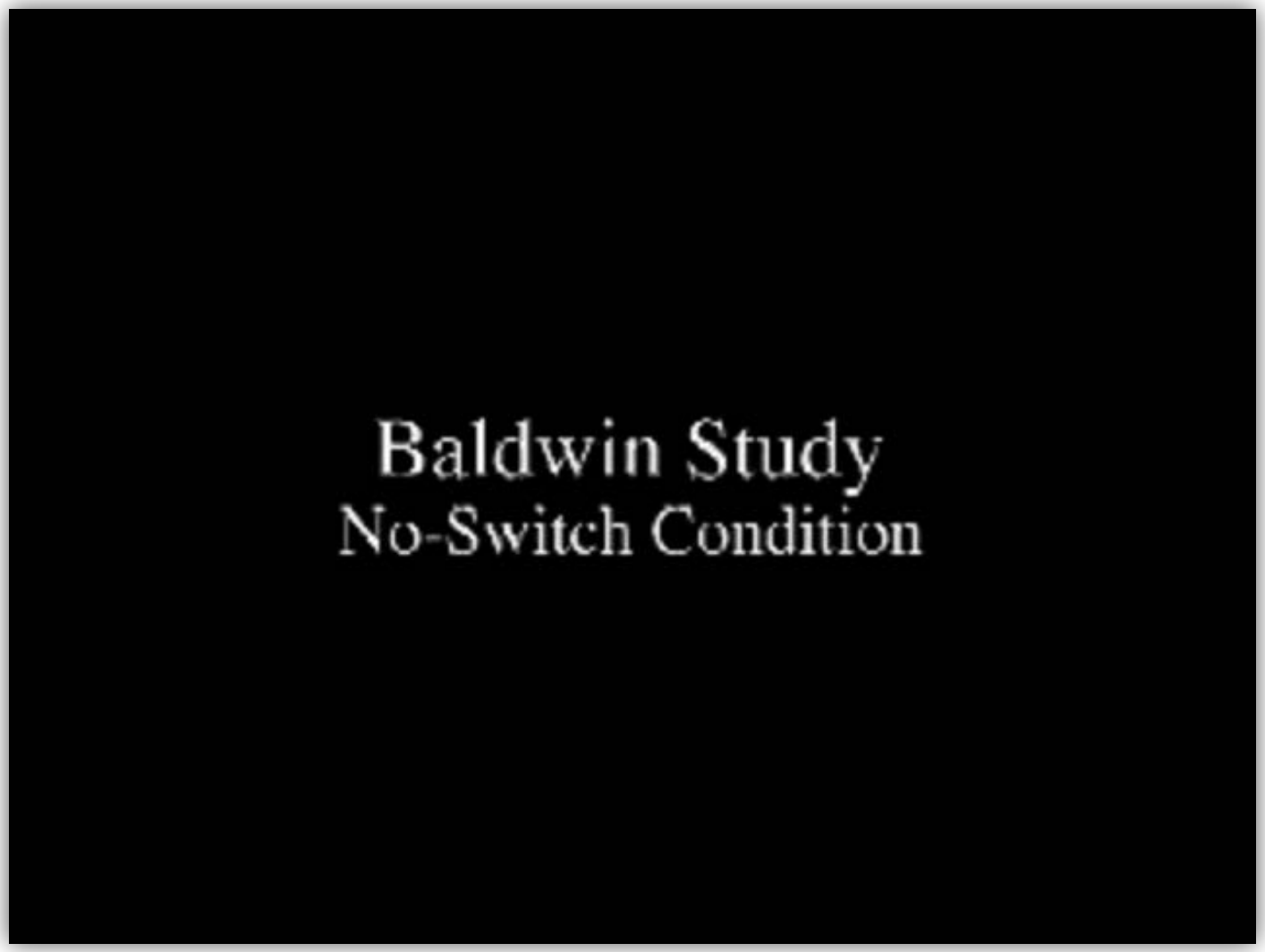
- Spatial location plays a key role in binding new words to objects (Smith & Samuelson 2010) -> posture changes

“Body as cognitive hub” Hypothesis

(Smith 2005; Morse et al. 2010, submitted)

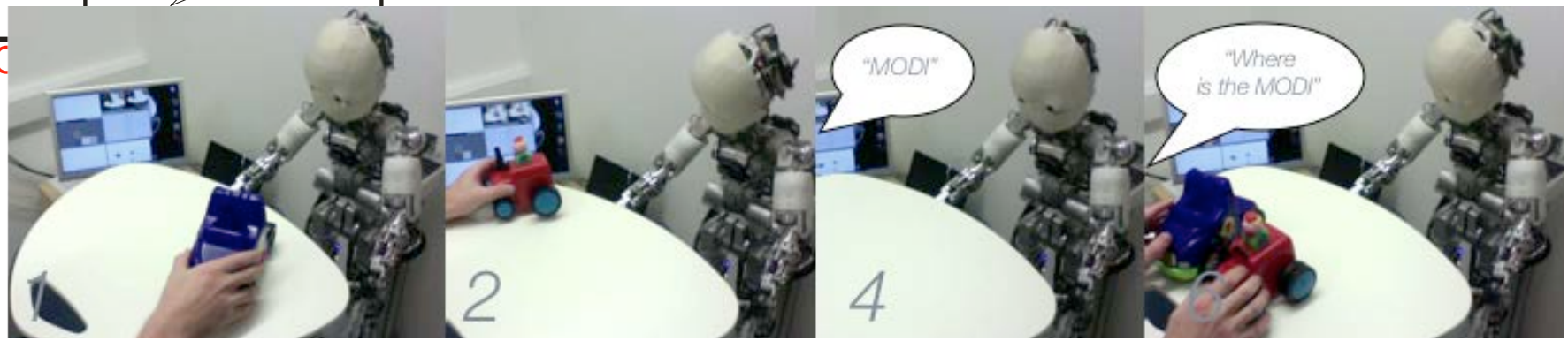
- *The body - and its momentary posture - may play a fundamental role in orchestrating cognitive functions, dynamically integrating multiple cognitive components in the service of a task.*
- *Bodily changes may appropriately segment events that should not be bound together.*

Baldwin 'Modi' Experiment

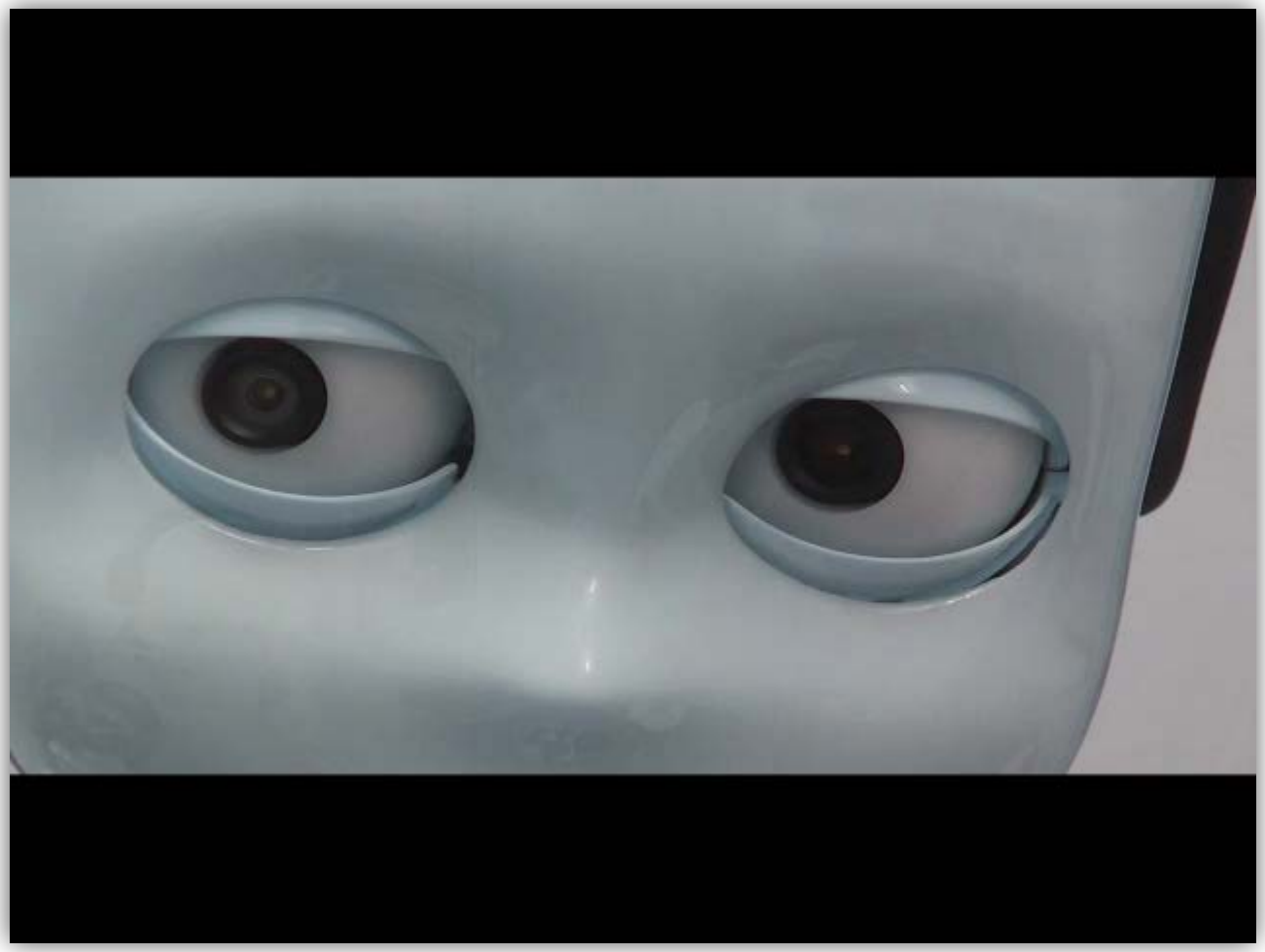


D. Baldwin (1993); Smith & Samuelson (2010)

	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 ?*	

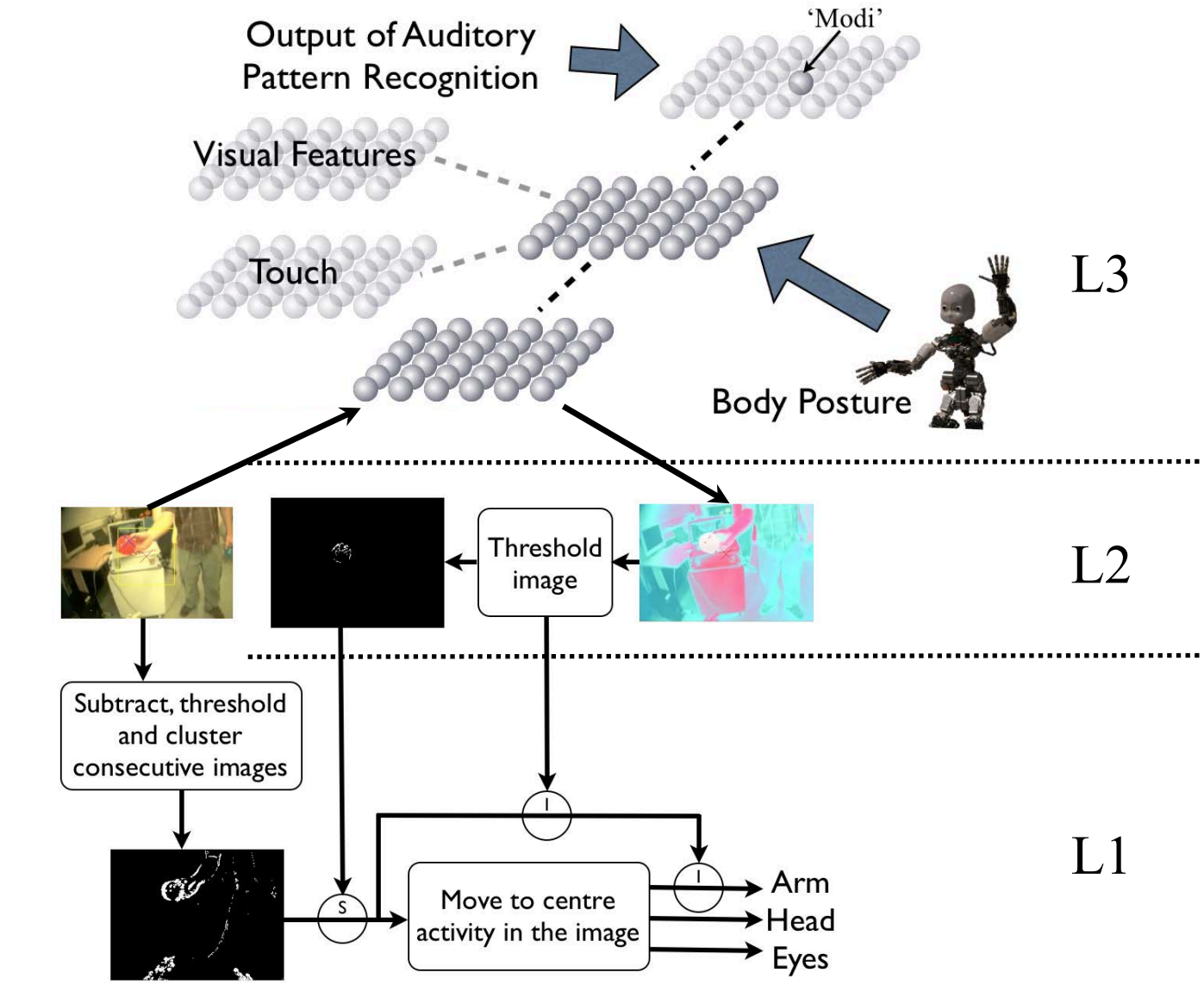


iCub's First Words: Naming objects in sight



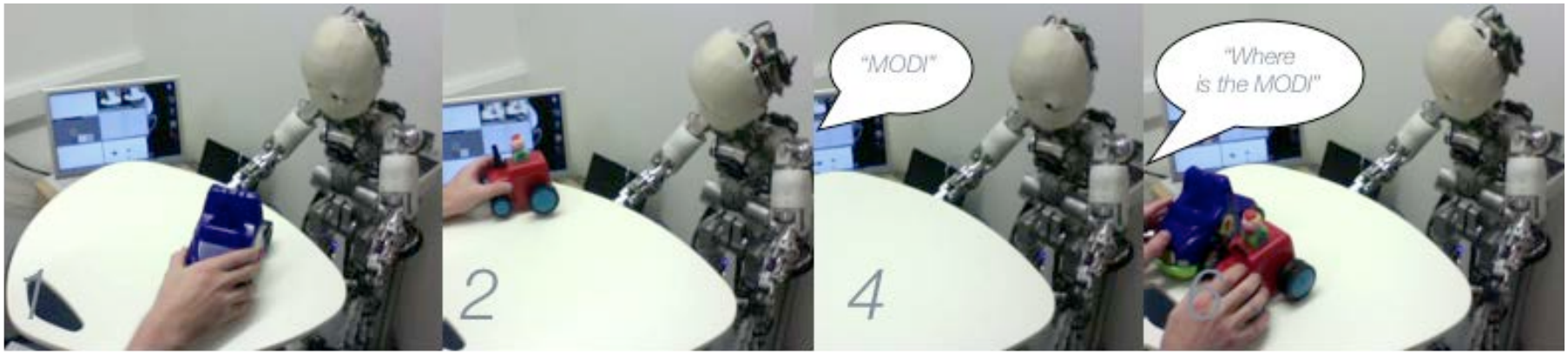
Morse et al. (CogSci-2010)

Epigenetic Robotics Architecture

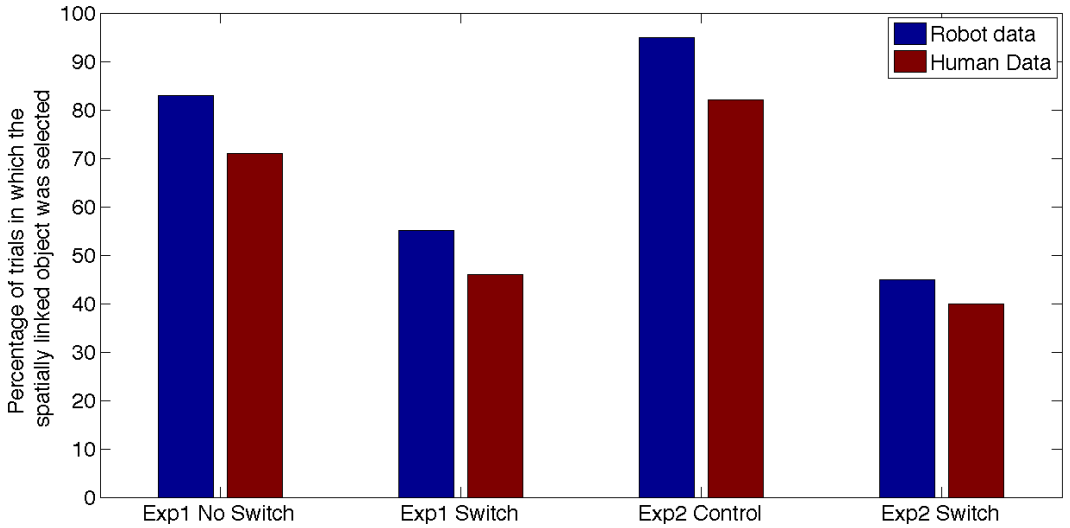


Morse, de Greeff et al. (2010)

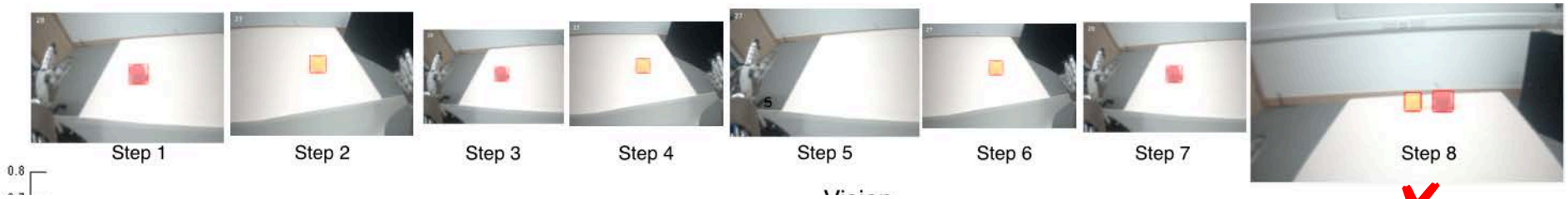
iCub 'Modi' : Predictions



- 4 Experiments
  - S&S Exp1: No switch
  - S&S Exp1: Switch
  - S&S Exp2: Control
  - S&S Exp2: Switch
- Model prediction
  - Changes in posture (e.g. from sitting to standing) will remove the interference effect despite the target location remaining consistent.

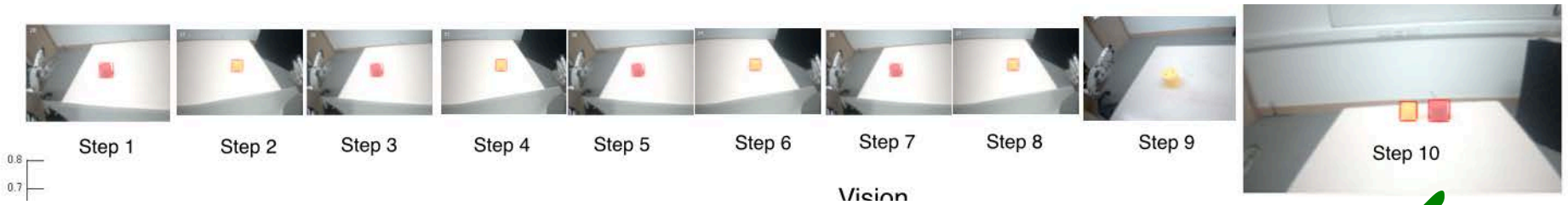


Effects of posture changes



Standing | **Sitting** | Standing ✗

Effects of posture changes: Interference Task



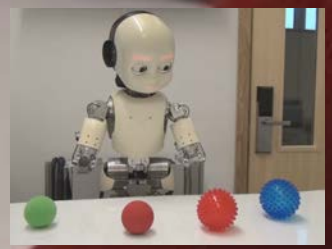
Standing | **Sitting** ✔

Morse et al. (submitted)

Psychological modelling & Developmental learning for action-language integration and generalization

Epigenetic Robotics Architechure (ERA)

- Posture/Space biases
- Mutual exclusivity
- Fast-Mapping
- Language and variability effects
- Proto-Compositionality and generalization



Embodied Category Learning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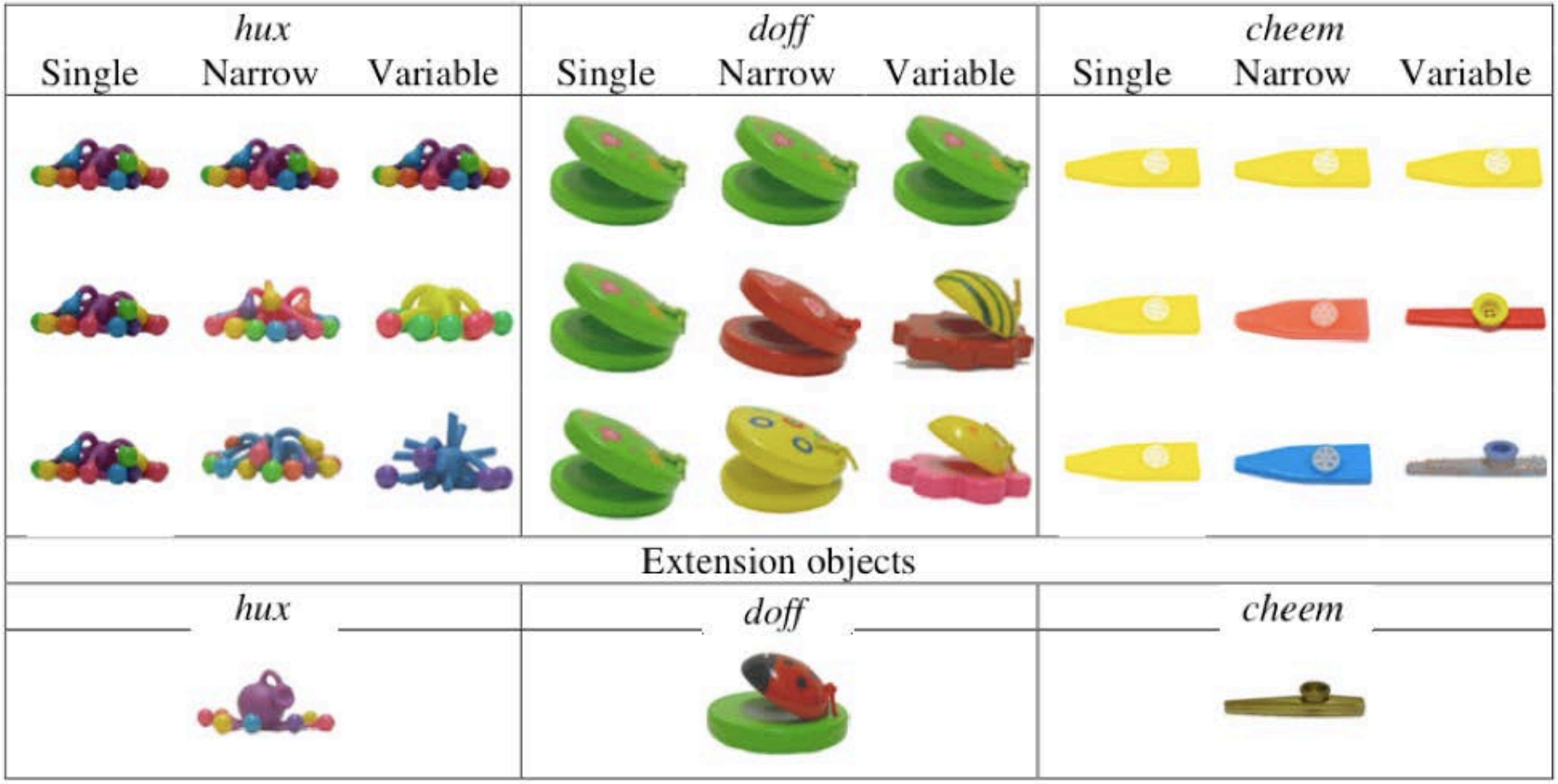
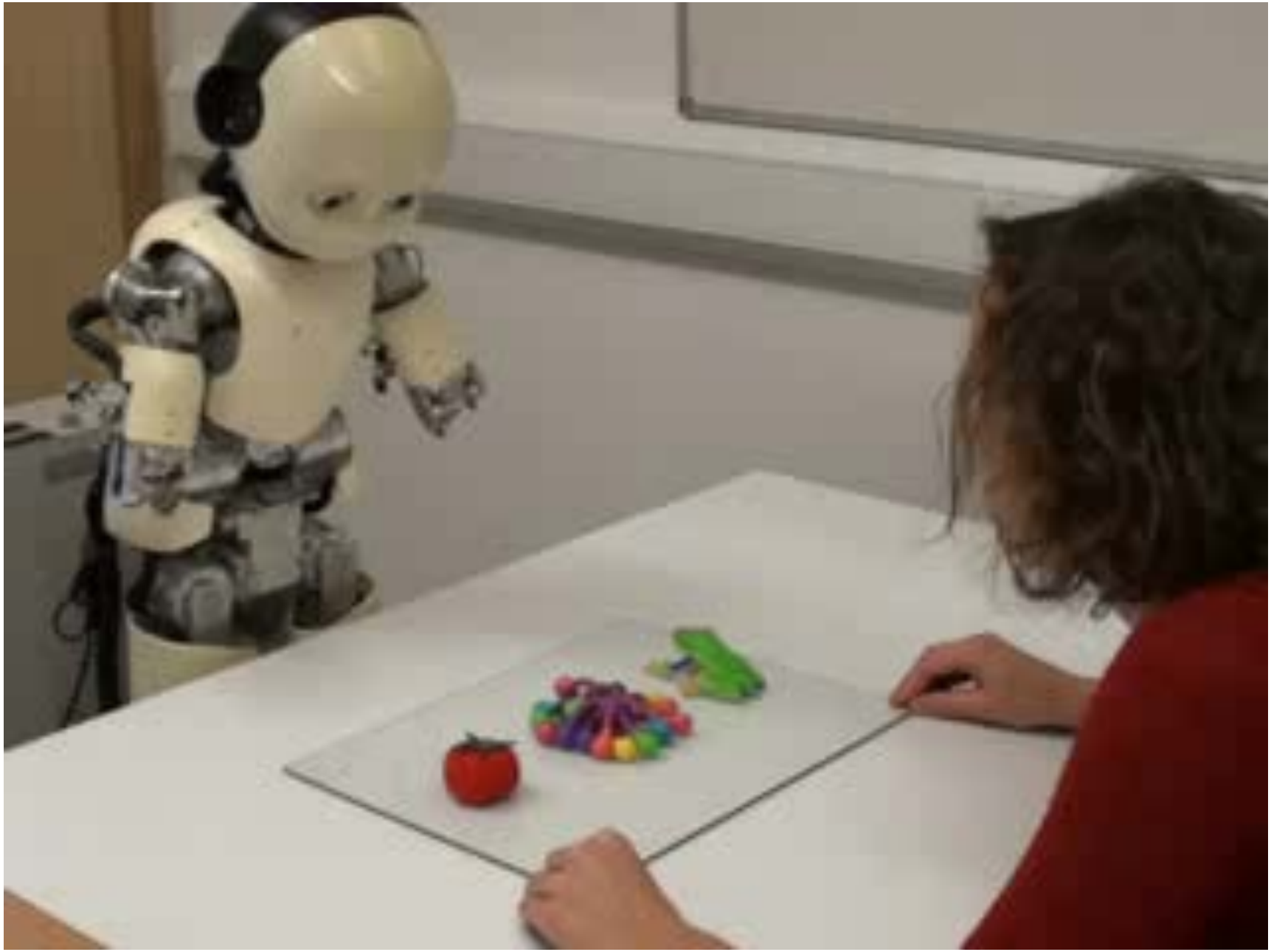
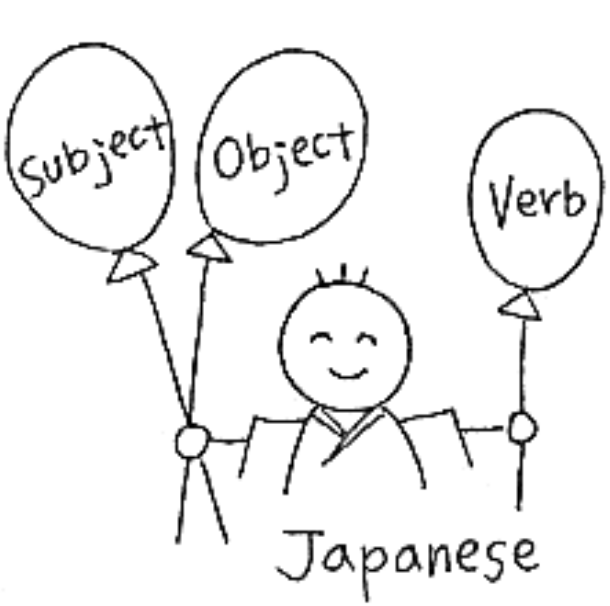
CAMERA01

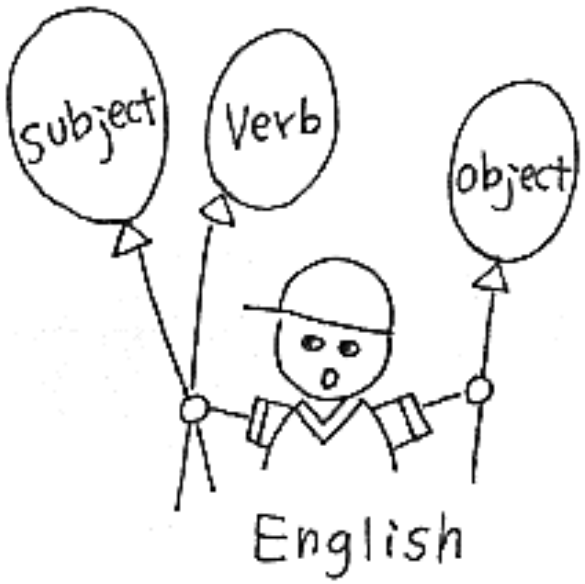
Mutual Exclusivity And Category Variability



With K. Twomey (Sussex Babylab)




Subject
Object
Verb
Japanese


Subject
Verb
Object
English

Learning from Word Order

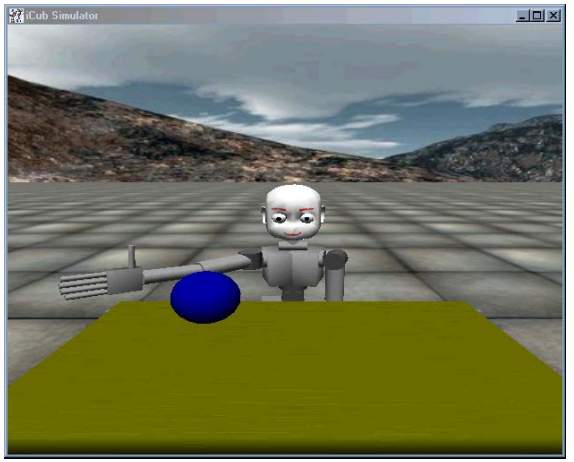
- Language development: Meaning from a **structural cue** like word order:
  - category information, e.g. *the N*, *look at the N*
  - semantic roles, e.g. *John kisses Mary*
  - children use such cues (Gomez 2007; StClair et al. 2010)

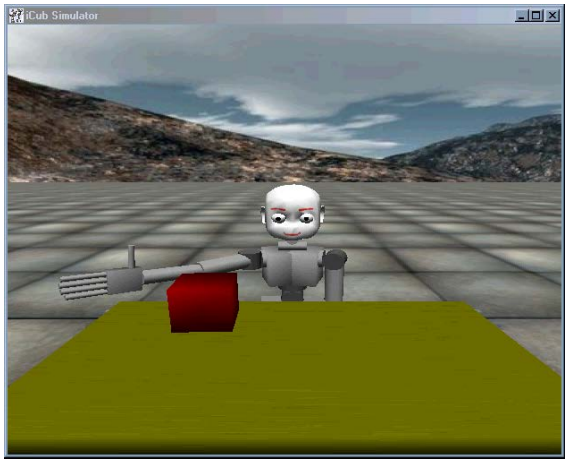
- iCub modelling of word order for information on
  - grammatical category (adjective - noun)
  - semantic category (colour - shape)

with 

Kerstin Fischer

Learning from Word Order Cues:



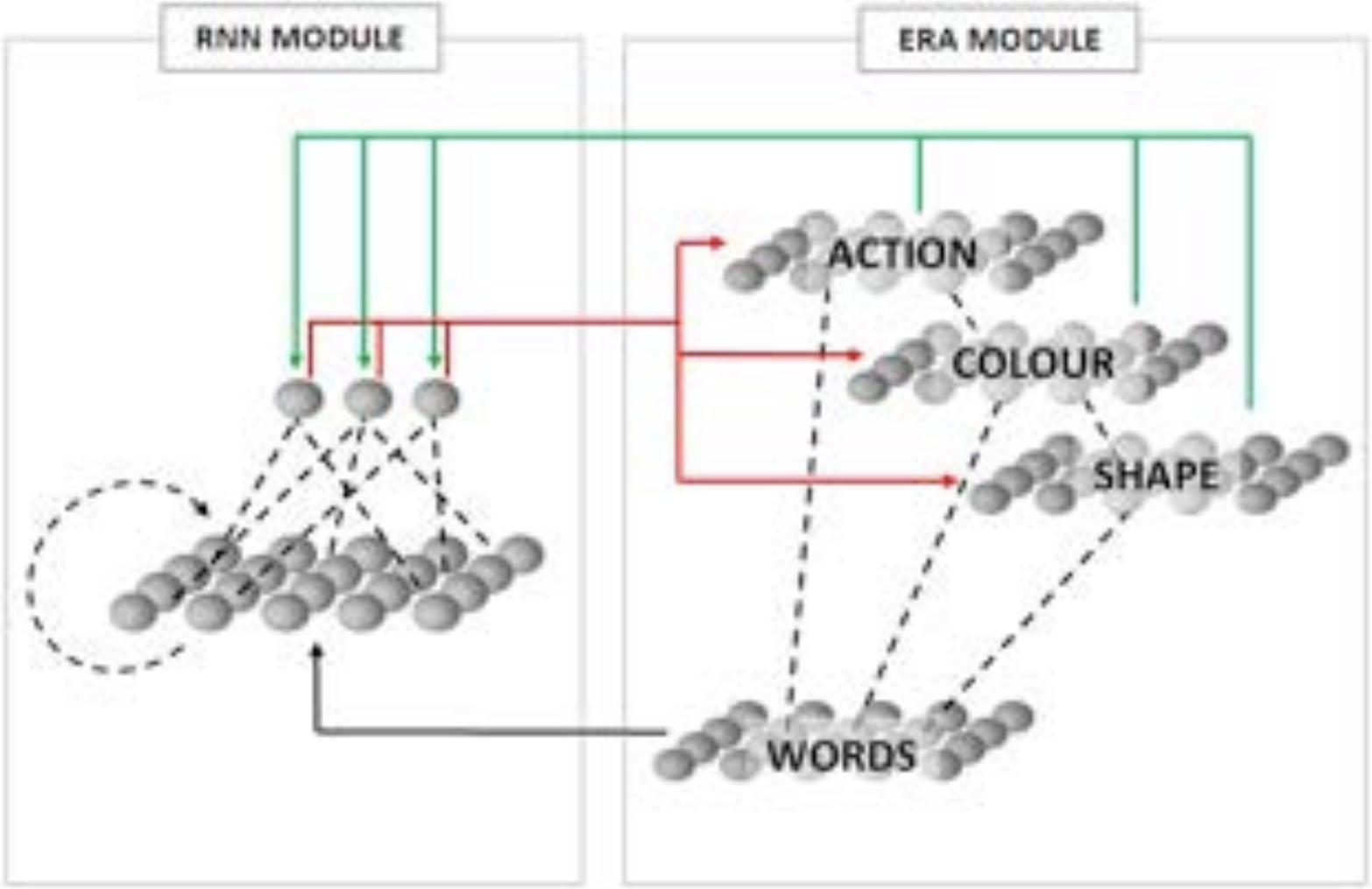


Language training:

- *touch ball* [V-N]
- *touch cube* [V-N]
- *touch red* [V-A]
- *touch green* [V-A]
- *touch green ball* [V-A-N]
- *touch green cube [V-A-N]*
- *touch red ball [V-A-N]*
- *touch red cube [V-A-N]*

Positive + negative sentences

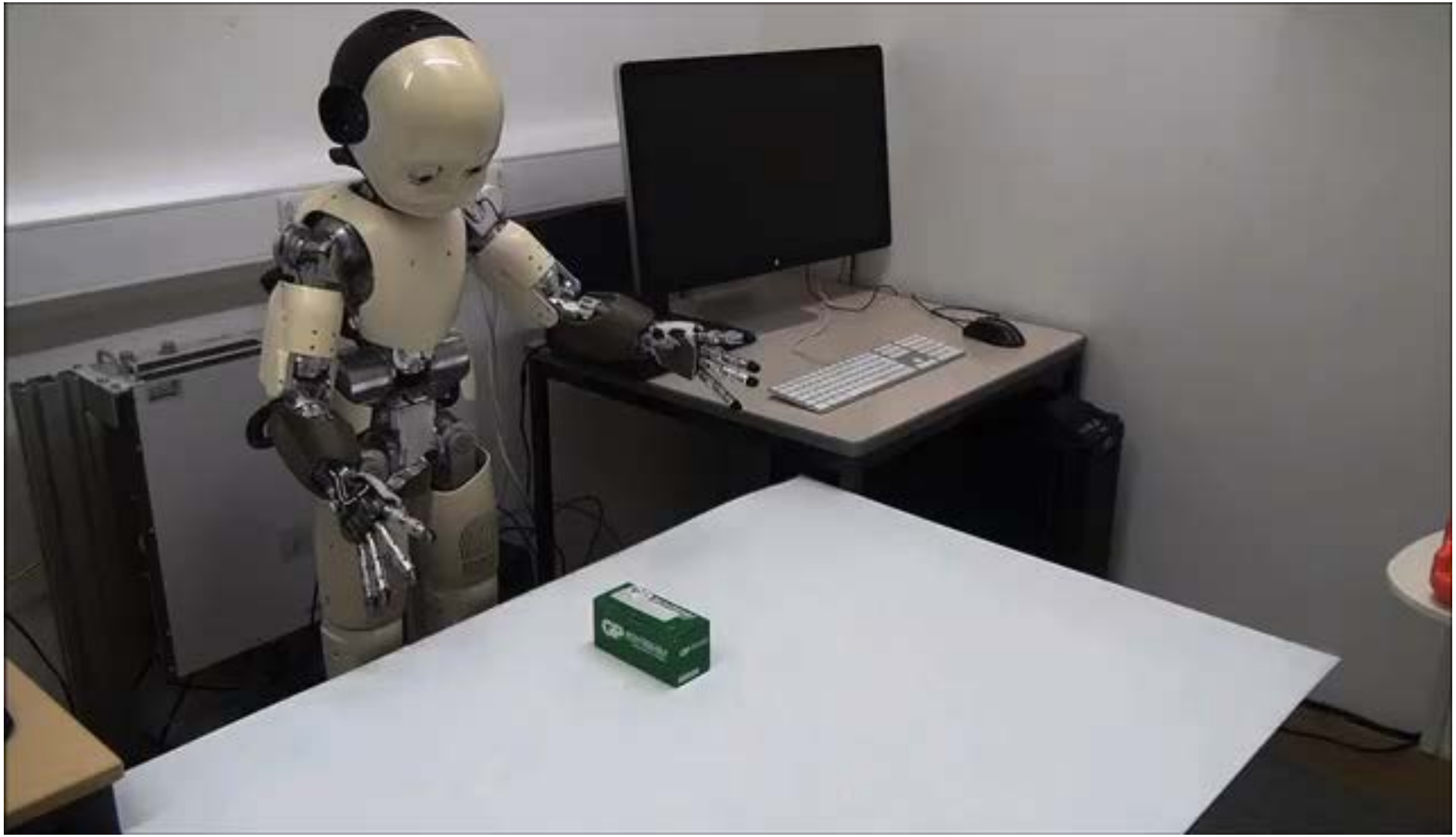
Environment	Language input	Action
RED CUBE	*"touch red cube"*	Touch the box
GREEN CUBE	*"touch green ball"*	Do not touch

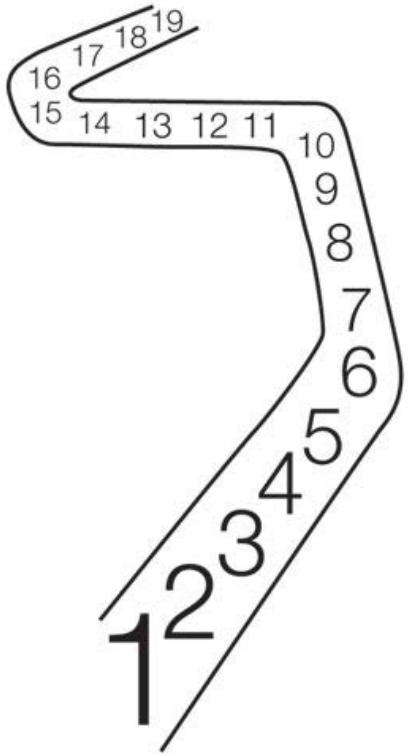


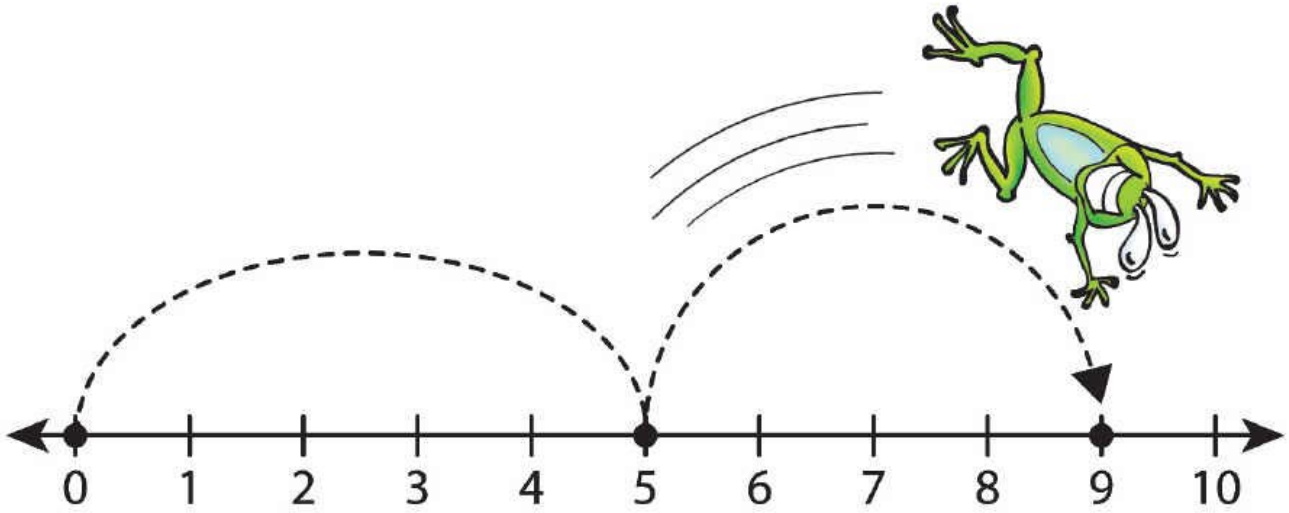
Example Grammar

Action Colour Shape
Action Shape
Action
Colour
Shape

poeticon++

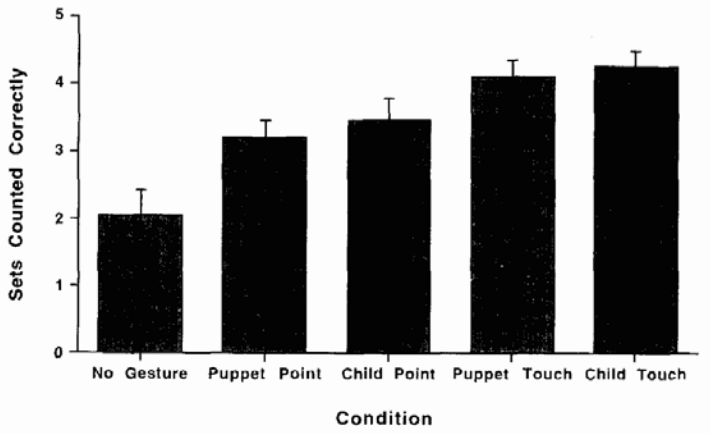



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19


0 1 2 3 4 5 6 7 8 9 10

Space and Gestures

- Gestures in counting: Pointing, touching, moving:
  - integral part of the development of number knowledge
  - spontaneous and omnipresent
  - prevention disrupts counting procedure
  - physical contact matters
  - development: 2-4-6 year-olds
  - active vs passive gesture

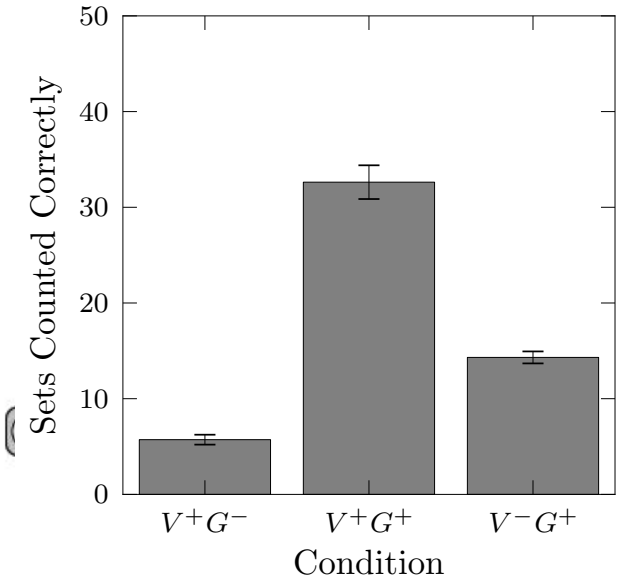


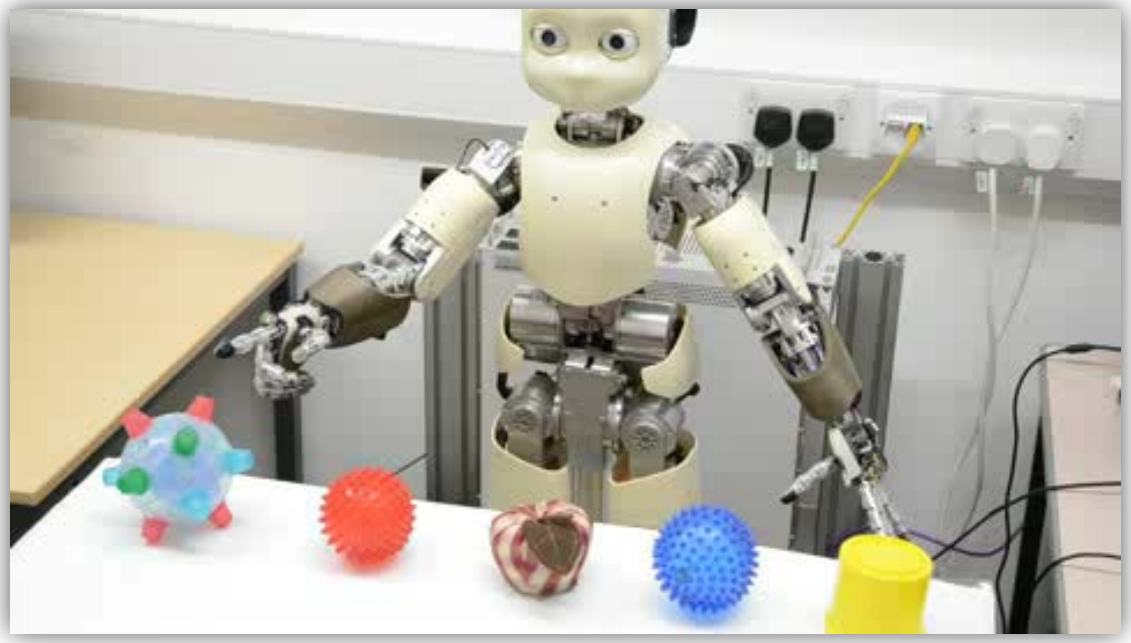
Alibali & DiRusso (1999)

Photo: JewelAnnclaudius, youtube.com

Space and Gestures

- Extended iCub gesture model (Rucinski et al. 2012)

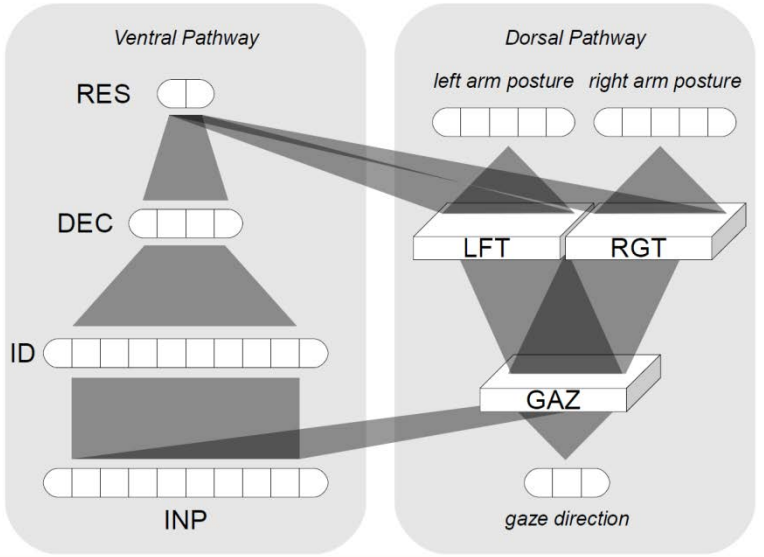


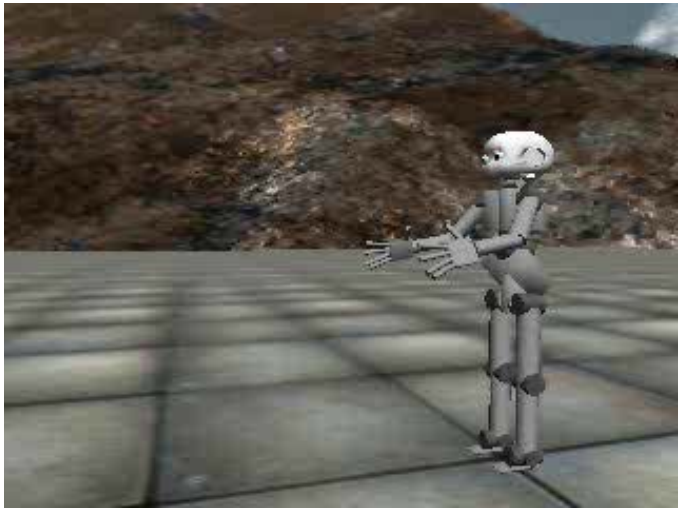


Rucinski et al. (ICDL-EpiRob-2012)

Space and Number: iCub

- Cognitive robotics model (Rucinski et al. 2011)
  - Add embodiment component to SNARC connectionist models (Chen & Verguts 2010)
  - Model developmental interaction space/number



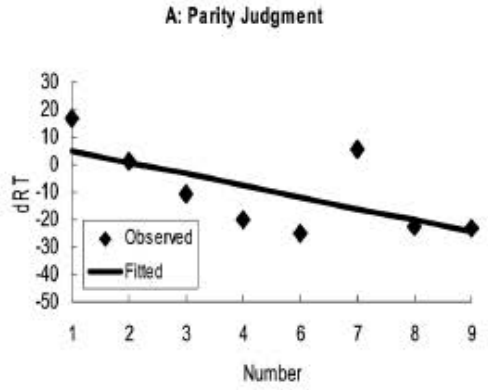


Rucinski et al. (CogSci-2011)

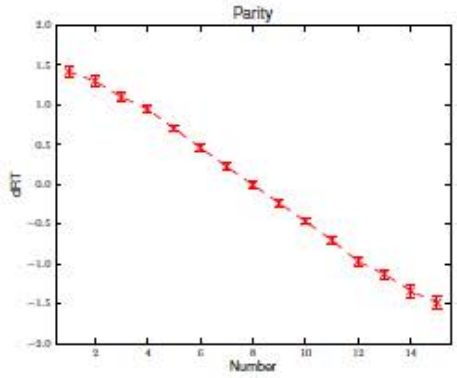
Space and Number: iCub

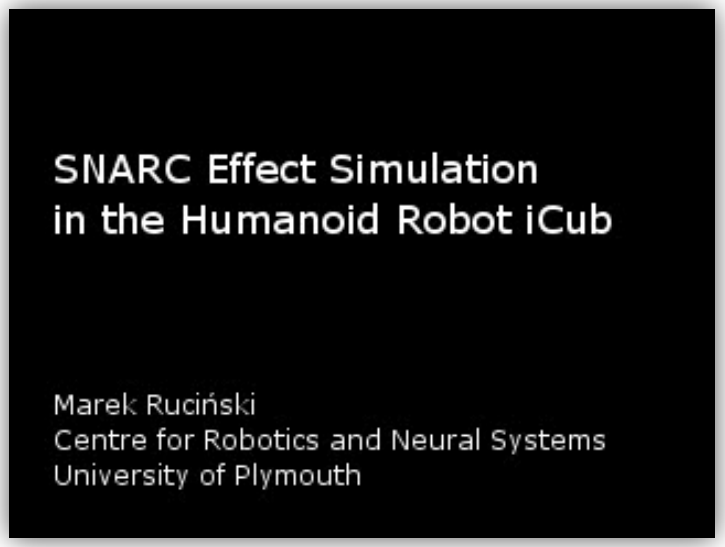
- Cognitive robotics model (Rucinski et al. 2011)
  - Add embodiment component to SNARC connectionist models (Chen & Verguts 2010)
  - Model developmental interaction space/number
  - Results: Replication of Size, Distance, SNARC effects

Experimental data (Gevers et al., 2006)



Modeling Results

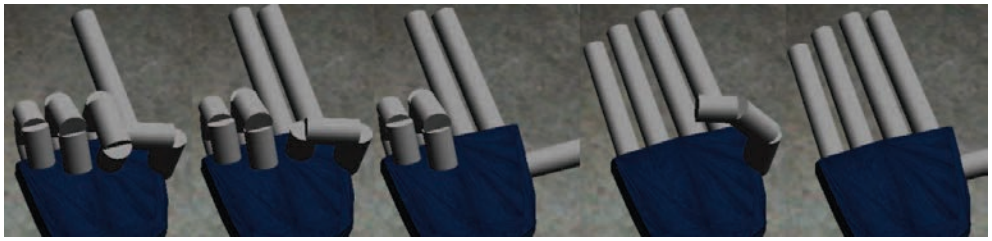


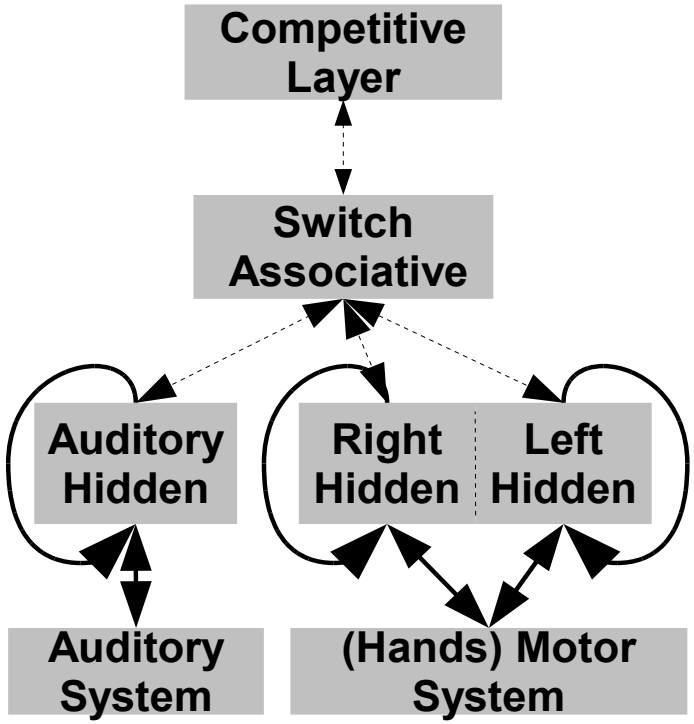


Rucinski et al. (CogSci-2011)

Finger Counting: Model

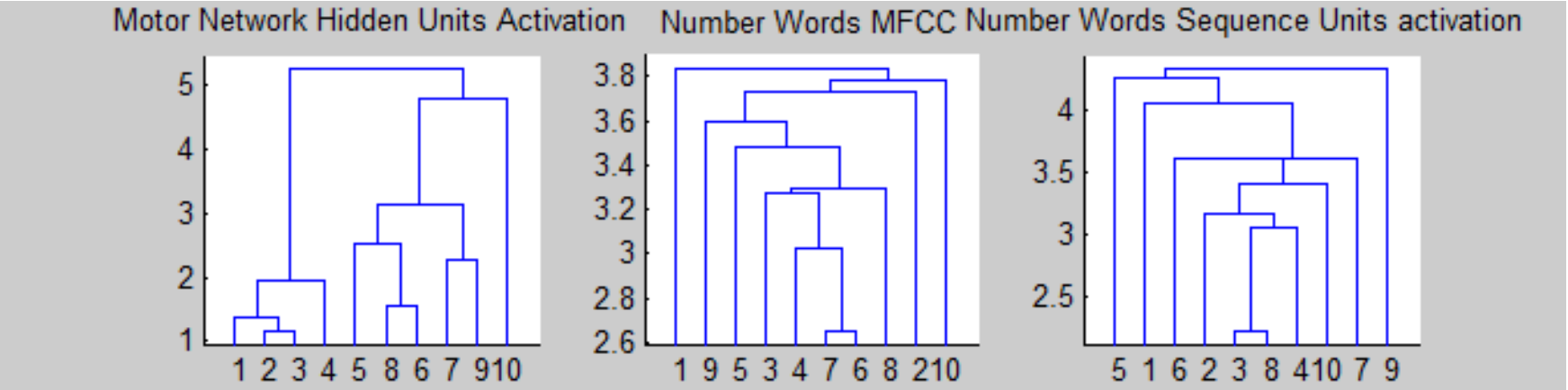
- Learning architecture
  - Motor system learns the finger sequences
  - Auditory system learns number word sequence (from speech/MFCCs)
  - Competitive layer for finger/number associations
- Training competitive layer
  - Motor finger sequence
  - Number words (not sequence)
  - Number word sequences
  - Motor sequence + number words
  - Motor and word sequences

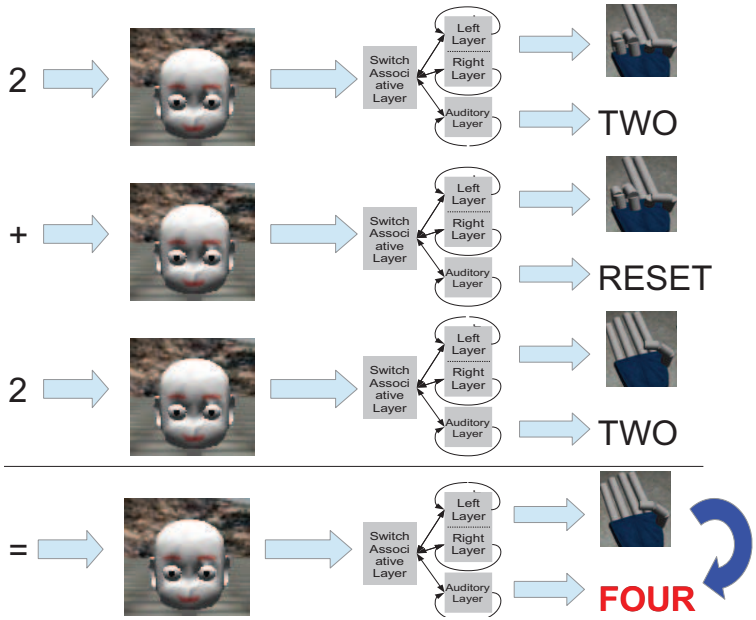




V. De La Cruz, A. Di Nuovo et al. (2014), Frontiers Behavioral Neuroscience

Finger Counting: Results





Addition

V. De La Cruz, A. Di Nuovo et al. (2014), Frontiers Behavioral Neuroscience

Take Home Message

- ERA architecture for embodied robots
  - Embodiment cues in development
  - “Body as Cognitive Hub” hypothesis
  - Multiple developmental phenomena
  - Close match with empirical data
- Open challenges
  - Open-ended, cumulative learning, larger lexicons and cognitive repertoires
  - Brain and language
  - Generalisation and creativity
  - Robot companion applications

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Ricardo Azambuja, Alex Smith,
Federico Da Rol, Daniela Conti

New Book: Cangelosi & Schlesinger (to appear, 2015).
Developmental Robotics: From Babies to Robots.
MIT Press / Bradford Books