Embodiment and Language Acquisition in Humanoid Robots

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COGNITIVE ROBOTICS WITH PLYMOUTH UNIVERSITY

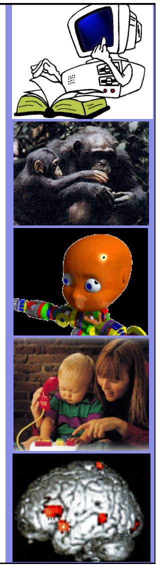
MARIE CURIE ACTIONS

SEVENTH FRAMEWORK PROGRAMME

Overview

1. Embodied developmental learning
   - Embodiment and language
   - The Chinese Room Experiment
   - Developmental robotics and the iCub
2. Experiments with the iCub
   - Language and category learning
   - Action and syntax learning
   - Space and numbers
3. Conclusions

Language and Cognition



There are two opposing theoretical approaches to the study of language and cognition (in humans and robots)

1. SYMBOLIC: Cognition is autonomous and amodal (e.g. Fodor, Chomsky, Landauer & Dumais)

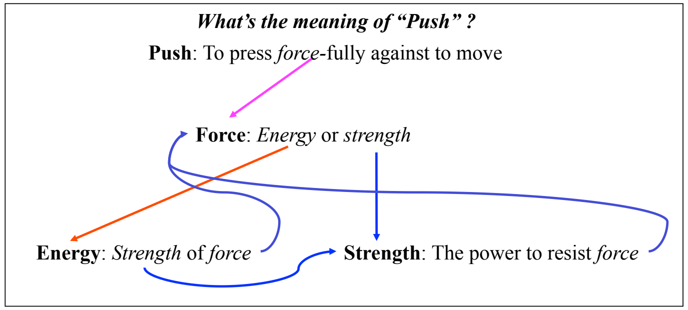
2. GROUNDING: Language and cognition is grounded in the world/body (eg. Cangelosi & Harnad, Gallese & Lakoff, Pulvermuller, Glenberg, Roy, Rohlfing et al.)

Language and Machines

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

Siri. Beta
Your wish is its command.

"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)

Language and Machines

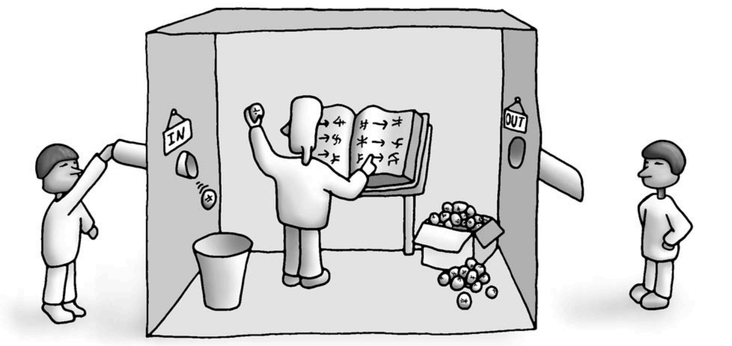
Do Eliza and Siri

understand

the language they are using?

Chinese Room Thought Experiment

(Searle 1980)



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 in Palma

Question: ❑◆♋■⧫♓ ♋■■♓ ♒♋❖♓ ●♋ ✠ ?

Dictionary

- ◻♓♍♍♓□⧫⧫♋💻 ⬧♏⧫⧫♓ ♋■■♓📪 ◻♓♍♍♋ ◻♓⧫♓⧫⧫◆📪 ❍♋♍♓♋❒♓ ♒□❖◆
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Reply Rule Book

- ❑◆♋■⧫♓ ♋■■♓ ♒♋❖♓ ●♋ ✠ ✍ ➔ ●♋ ✠ ♒♋❖♓ ✌ ♋■■♓
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Chinese Room Experiment in Palma

Question: *quanti anni havi la X ?*

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

Chinese Room Experiment

Questions	Answers
• *quanti anni havi la picciotta ?*	la picciotta havi setti anni
• *quanti anni havi la za'nzina ?*	la za'nzina havi settanta anni
• *quanti anni havi la haddina ?*	la haddina havi dui anni
• *quantu pitittu havi la picciotta ?*	la picciotta havi picca pituittu
• *quantu pitittu havi la za'nzina?*	la za'nzina havi assai pitittu
• *quantu pitittu havi la haddina?*	*la haddina havi assai pitittu*
• *soccu voli manciari la picciotta ?*	la picciotta voli manciari hovu
• *soccu voli manciari la za'nzina?*	la za'nzina voli mancirai haddina
• *soccu voli manciari la haddina?*	la haddina voli manciari simenza

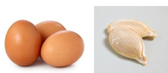
Sicilian Room Experiment

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 / **girl** — **za'nzina** / **aunt** — **haddina** / **chicken** — **hovu** / **egg** — **simenza** / **seeds**

assai
much



picca
little

The Symbol Grounding Problem

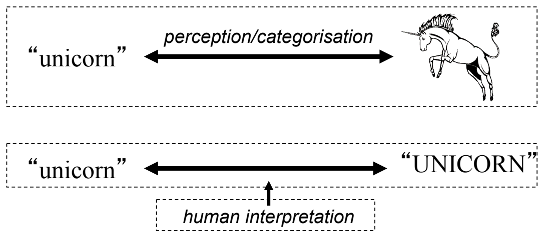
(Harnad 1990)

How can the meanings of the symbols (words)
in a cognitive symbol system be *grounded*
in something other than just further ungrounded symbols?

To embody thought, a cognitive system must be autonomous, i.e. have direct and intrinsic symbol-meaning links

grounded symbols

amodal symbols



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)

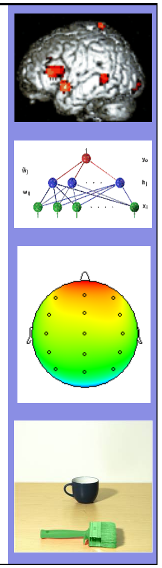
✓ Children are **slow**, but efficient at learning a language

Action and Language

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

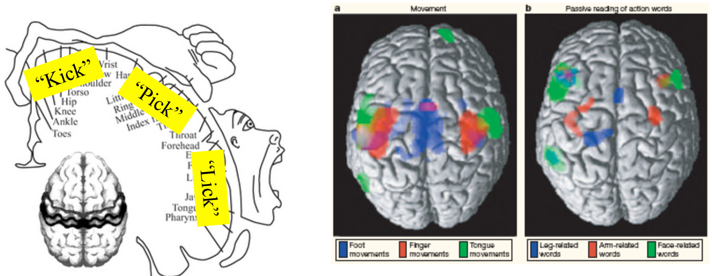
✓ The **brain integrates** language and sensorimotor knowledge (Pulvermuller 2003)

✓ Action and perception are **intrinsically linked** – microaffordances (Ellis et al. 2004)

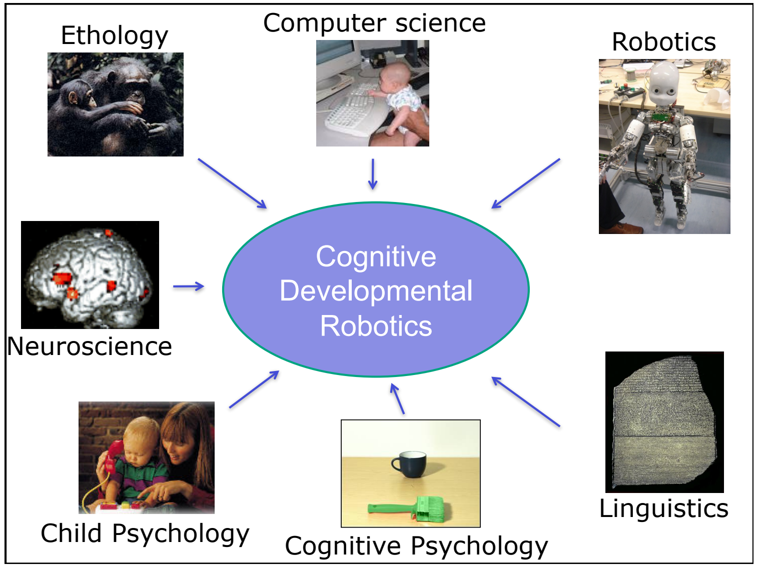


Words and Actions in the Brain

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

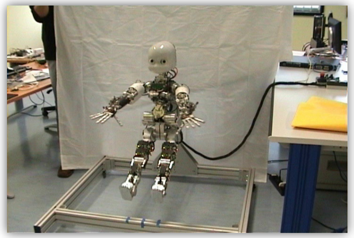


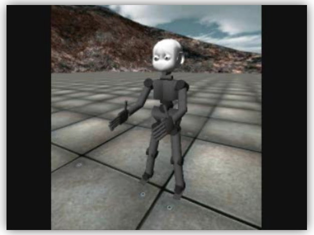
"Kick", "Pick", "Lick"



Simulated and Physical iCub

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

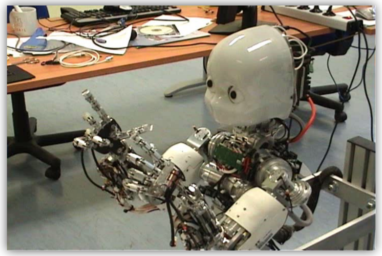




www.robotcub.org

iCub: Degrees of freedom

- Head: vergence, common tilt + 3 dof neck
- Arms: 7 dof each
  - Shoulder (3), elbow (1), wrist (3)
- Hands: 9 dof each ▶ 19 joints
  - 5 fingers ▶ underactuated
- Legs: 6 dof each
  - Hip (3), knee (1), ankle (2)
- Waist: 3 dof



Σ = 53 dof (not counting the facial expressions)

open source

Benchmark Robotics Platform (21+ iCubs in 2012)

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   - Space and numbers
3. Conclusions

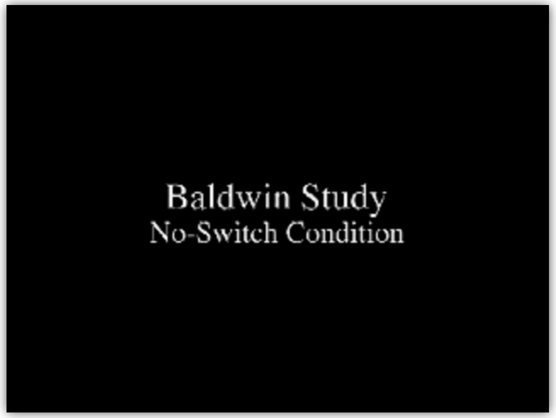
Body Posture and Cognition

- Challenges to the idea that names are only associated to the object being attended to when the name is heard (Smith & Samuelson 2010)
- The cognitive system uses the body's orientation in space to select remembered objects

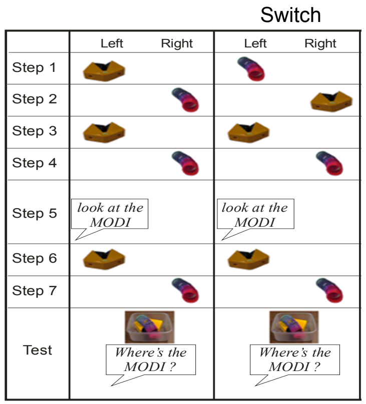
"Body as cognitive hub" Hypothesis
(Smith 2005; Morse et al. 2010)

Embodied representations (body map) cross-link various modalities (e.g. visual, tactile, sound maps)

Baldwin 'Modi' Experiment



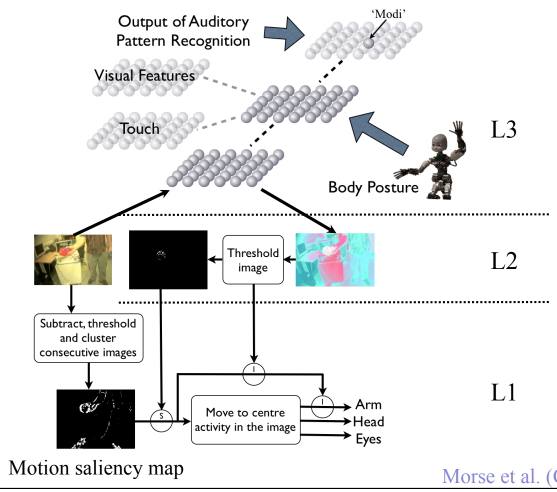
D. Baldwin (1993); Smith & Samuelson (2010)



Consistent spatial cue **73%**

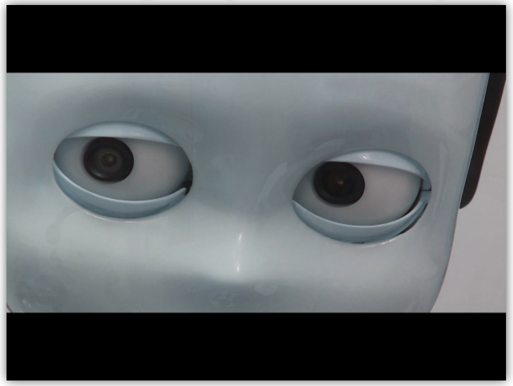
No consistecy **46%**

Epigenetic Robotics Architecture



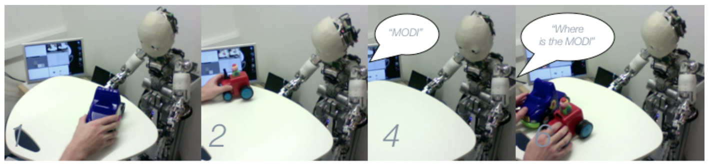
Morse et al. (CogSci-2010)

iCub's First Words: Naming objects in sight

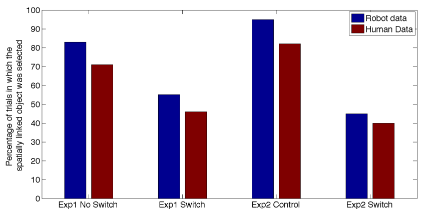


Morse et al. (CogSci-2010)

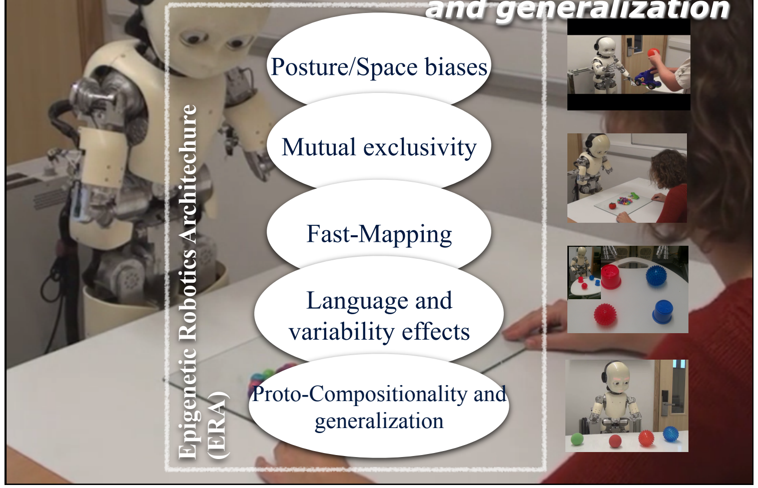
iCub 'Modi' : Predictions



- 4 Experiments
  - S&S Exp1: No switch
  - S&S Exp1: Switch
  - S&S Exp2: Control
  - S&S Exp2: Switch
- Model prediction
  - Changes in body posture are predictors of sensory change
  - *Changing position from sitting to standing should remove the effect, and sitting again should reinstate it*

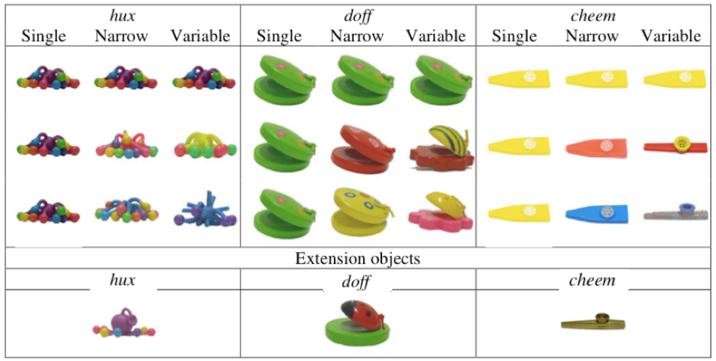


Psychological modelling & Developmental learning for action-language integration and generalization

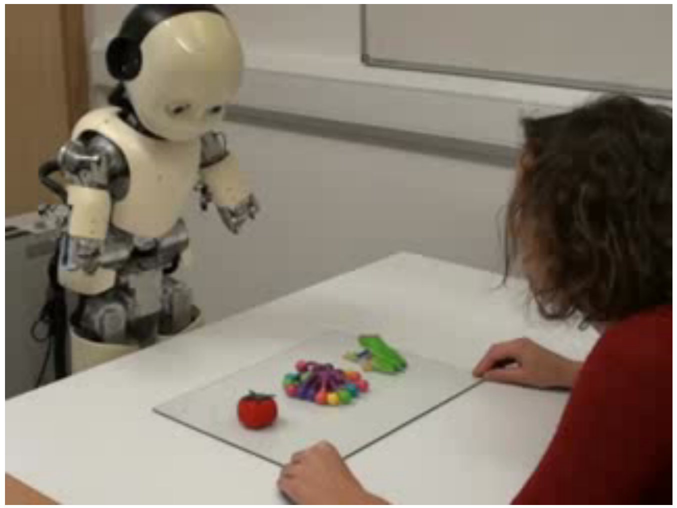


Embodied Category Learning

Mutual Exclusivity And Category Variability



With K. Twomey (Sussex Babylab)



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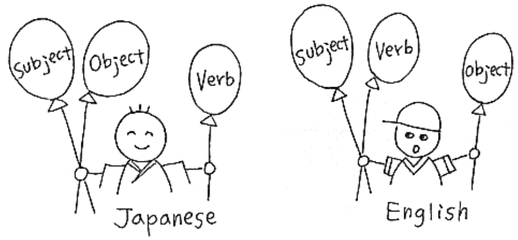


Learning from Word Order

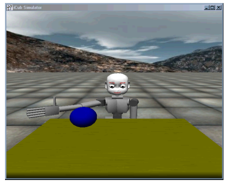
- Language development: Meaning from a **structural cue** like word order:
  - category information, e.g. *the N*, *look at the N*
  - semantic roles, e.g. *John kisses Mary*
  - children use such cues (Gomez 2007; StClair et al. 2010)
- iCub modelling of word order for information on
  - grammatical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

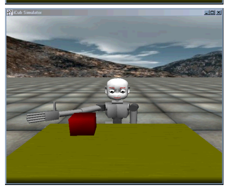
with Kerstin Fischer

Learning from Word Order Cues:

Language training:

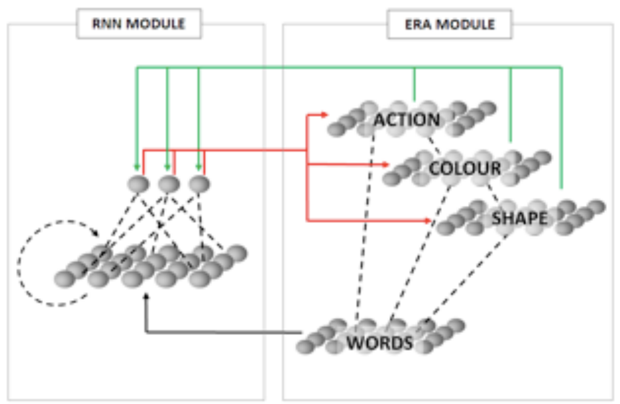
- *touch ball* [V-N]
- *touch cube* [V-N]
- *touch red* [V-A]
- *touch green* [V-A]
- *touch green ball* [V-A-N]
- *touch green cube* [V-A-N]
- *touch red ball* [V-A-N]
- *touch red cube* [V-A-N]





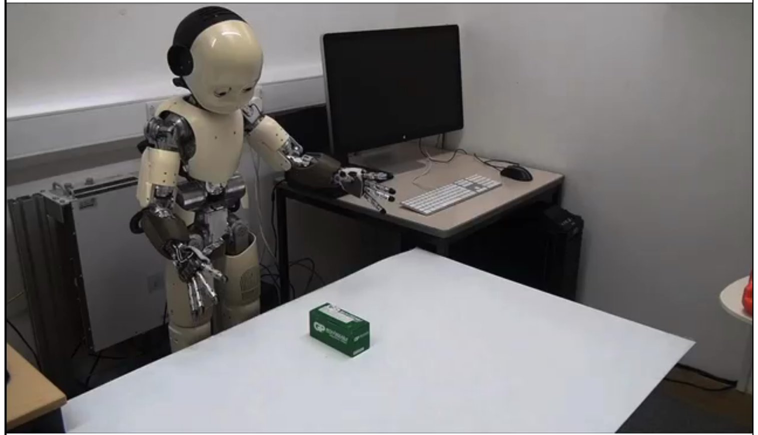
Positive + negative sentences

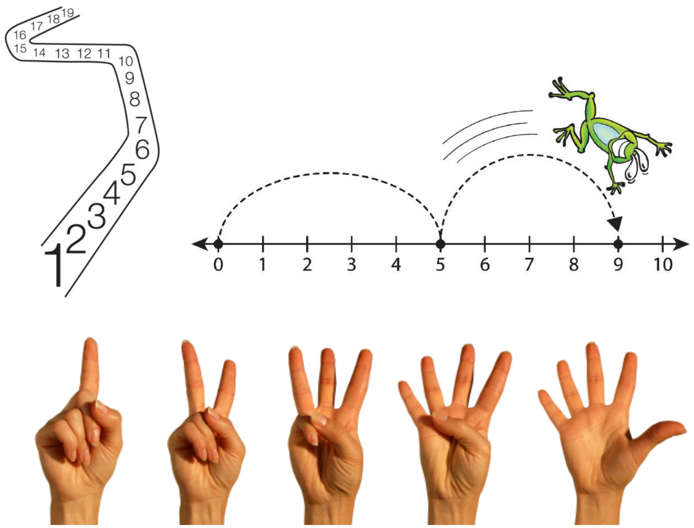
Environment	Language input	Action
RED CUBE	*"touch red cube"*	Touch the box
GREEN CUBE	*"touch green ball"*	Do not touch



Example Grammar
- Action Colour Shape
- Action Shape
- Action
- Colour
- Shape

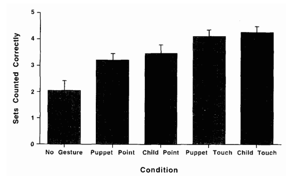
poeticon++





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

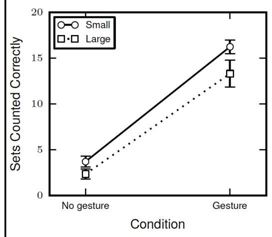


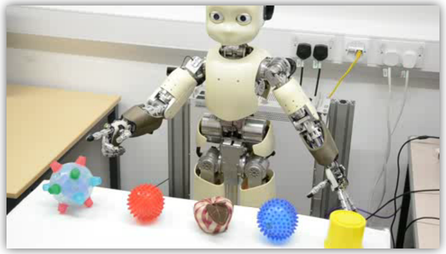
Alibali & DiRusso (1999)

Photo: JewelAnnclaudius, youtube.com

Space and Gestures

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





Rucinski et al. (ICDL-EpiRob-2012)

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Take Home Message

- Embodied Language Learning
  - Embodiment cues in development
  - “Body as Cognitive Hub” hypothesis
  - Embodied Words and Numbers
  - 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

Acknowledgments

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SEVENTH FRAMEWORK PROGRAMME
MARIE CURIE ACTIONS
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AIR FORCE RESEARCH LABORATORY
E·S·R·C
esa

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