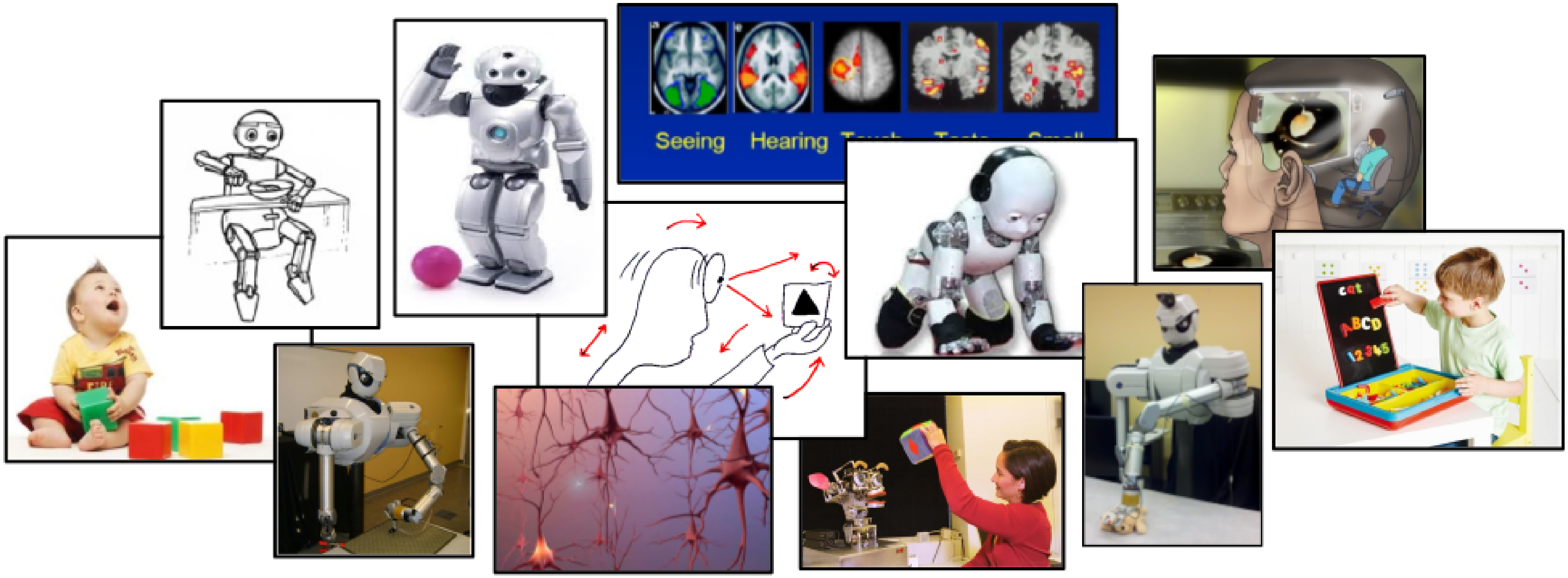

COMP 150: Developmental Robotics

Instructor: Jivko Sinapov
www.cs.tufts.edu/~jsinapov

Announcements

- Homework 2 is out
- Due date: Thursday Oct 12

Project Related Deadlines

- Team-up by the end of class, Thursday Oct 5
- “Preliminary” project ideas presentations: Tuesday Oct 10 and Thursday October 12
- Project Proposal is due October 26

Northeast Robotics Colloquium

- Held at Northeastern University on Saturday October 21st
- https://nerc2017.ccis.northeastern.edu/
- Deadline for registration: October 15
- $50 dollars for graduate students, $10 for undergrads

Overview of Related Conferences

Embodiment and Self-Recognition

How do we determine where an agent recognizes itself in the mirror?

Social Response

[https://www.youtube.com/watch?v=GaMylwohL14]

Self-Directed Response

[Barth, J., Povinelli, D.J., & Cant, J.G.H. (2004). "Bodily Origins of SELF"]

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Self-Directed Response

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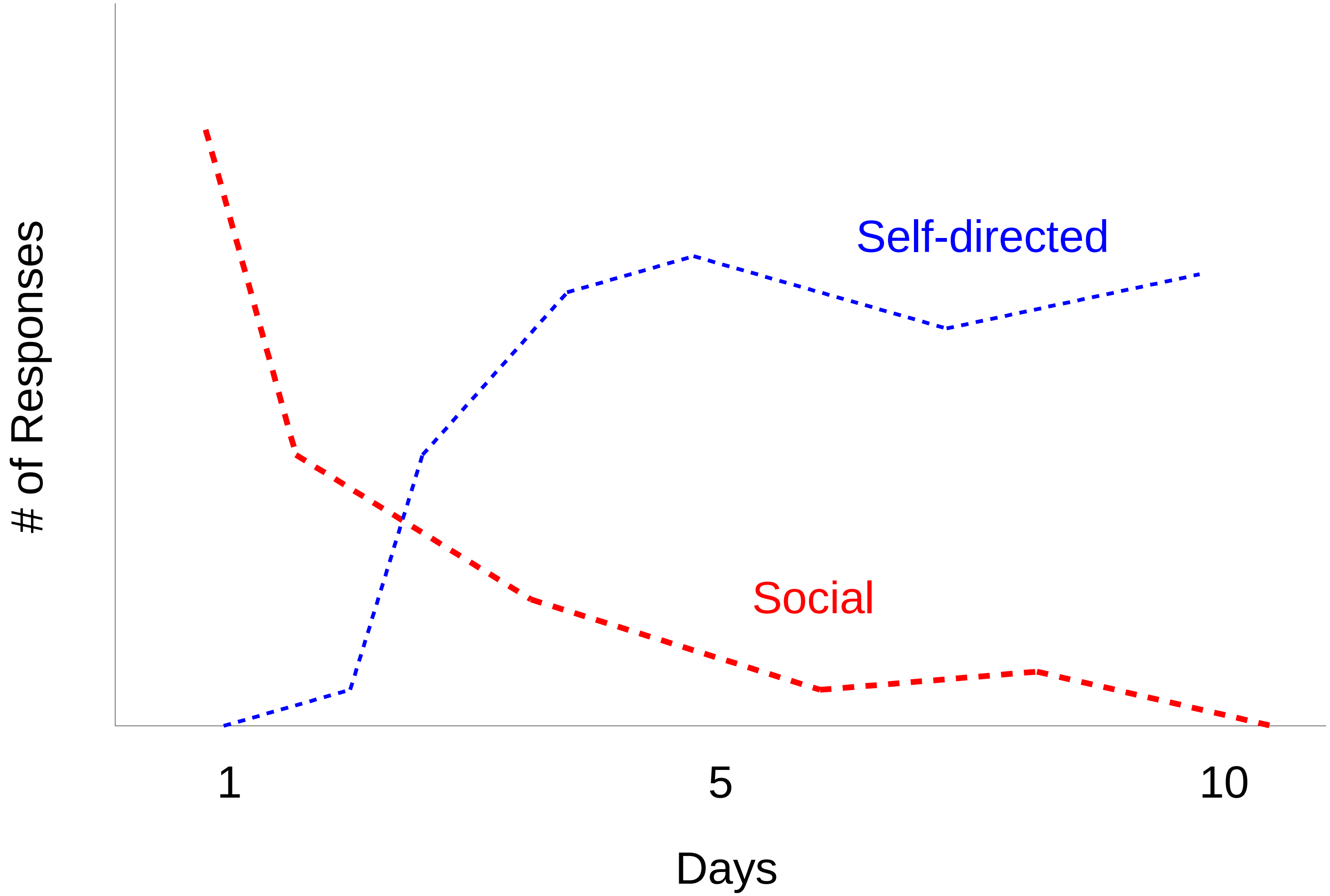
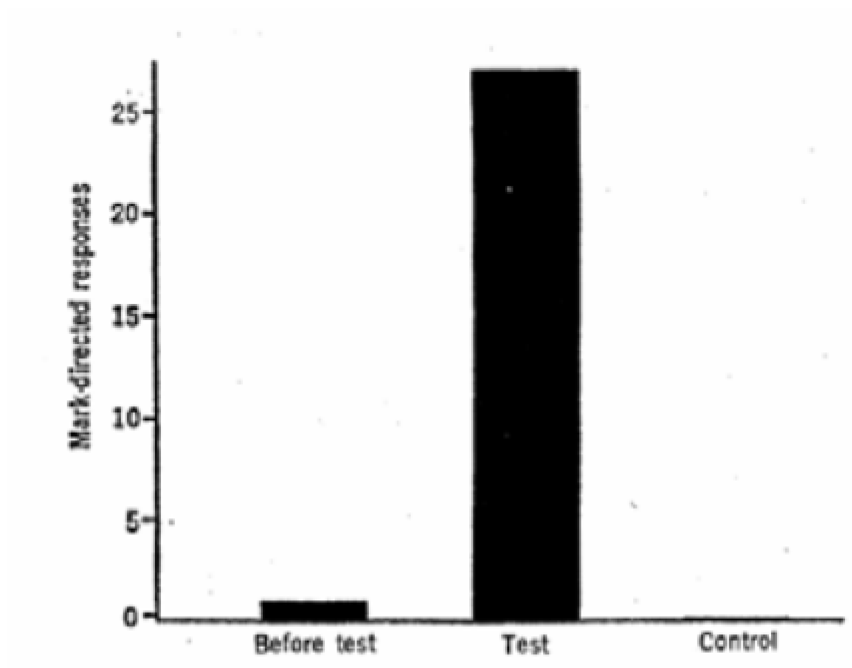
Social and Self-Directed Responses Over Time



[Gallup (1970)]

The Mark Test (Gallup, 1970)

Mark-related responses by experimental animals before being exposed to a mirror and by control and experimental animals during the test



[Gallup (1970)]

Analysis

“... self-directed and mark-directed behaviors would seem to require the ability to project, as it were, proprioceptive information and kinesthetic feedback onto the reflected visual image so as to coordinate the appropriate visually guided movements via the mirror.” (Gallup, 1970)

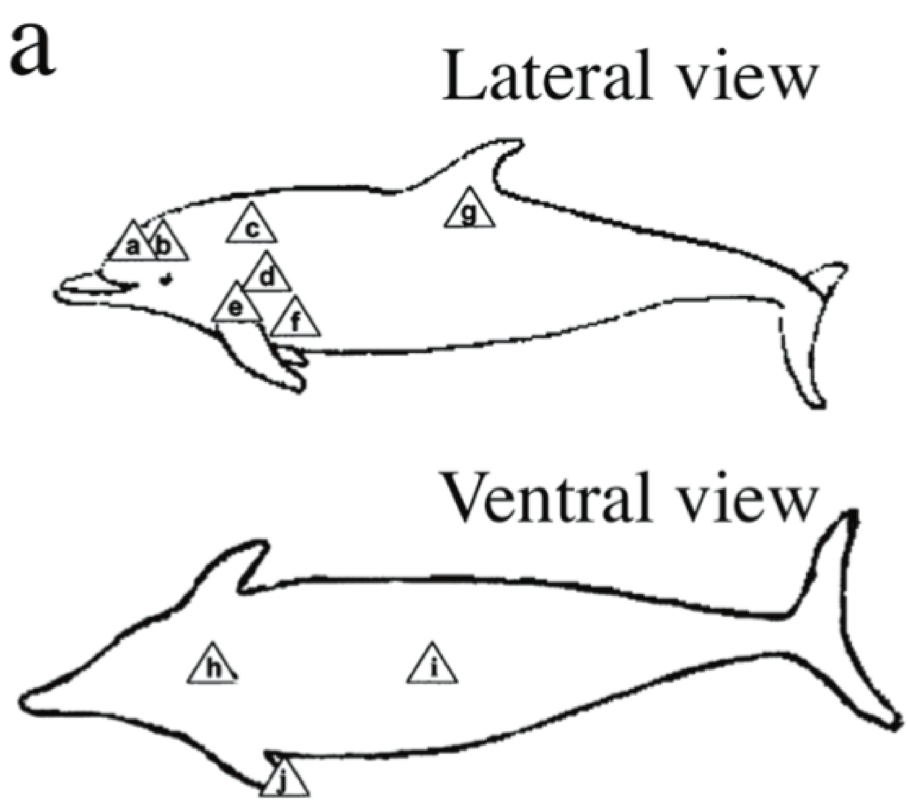
What about lesser primates?

- To see face markers you need to establish a direct eye contact with the image in the mirror, which in lesser monkeys is a threatening signal.
- The lesser monkeys are not as interested in exploring their bodies as chimpanzees and orangutans are.
- They will inspect markers on their abdomen and wrist (that could be seen without a mirror) but not facial markers (for which a mirror is required).

Self-Recognition in Dolphins

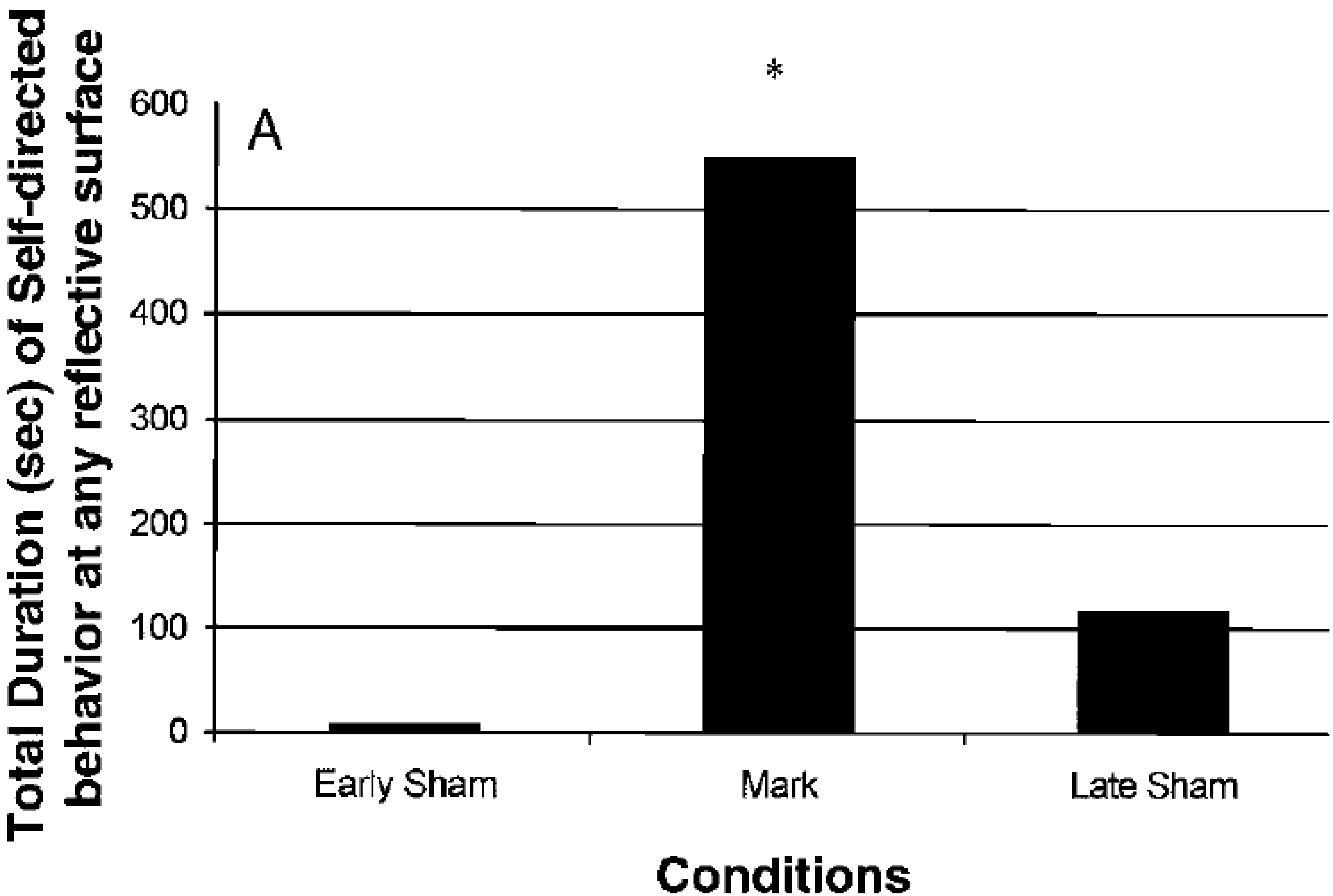
[From Reiss & Marino (2001)]

The mark test with dolphins



[From Reiss & Marino (2001)]

Results



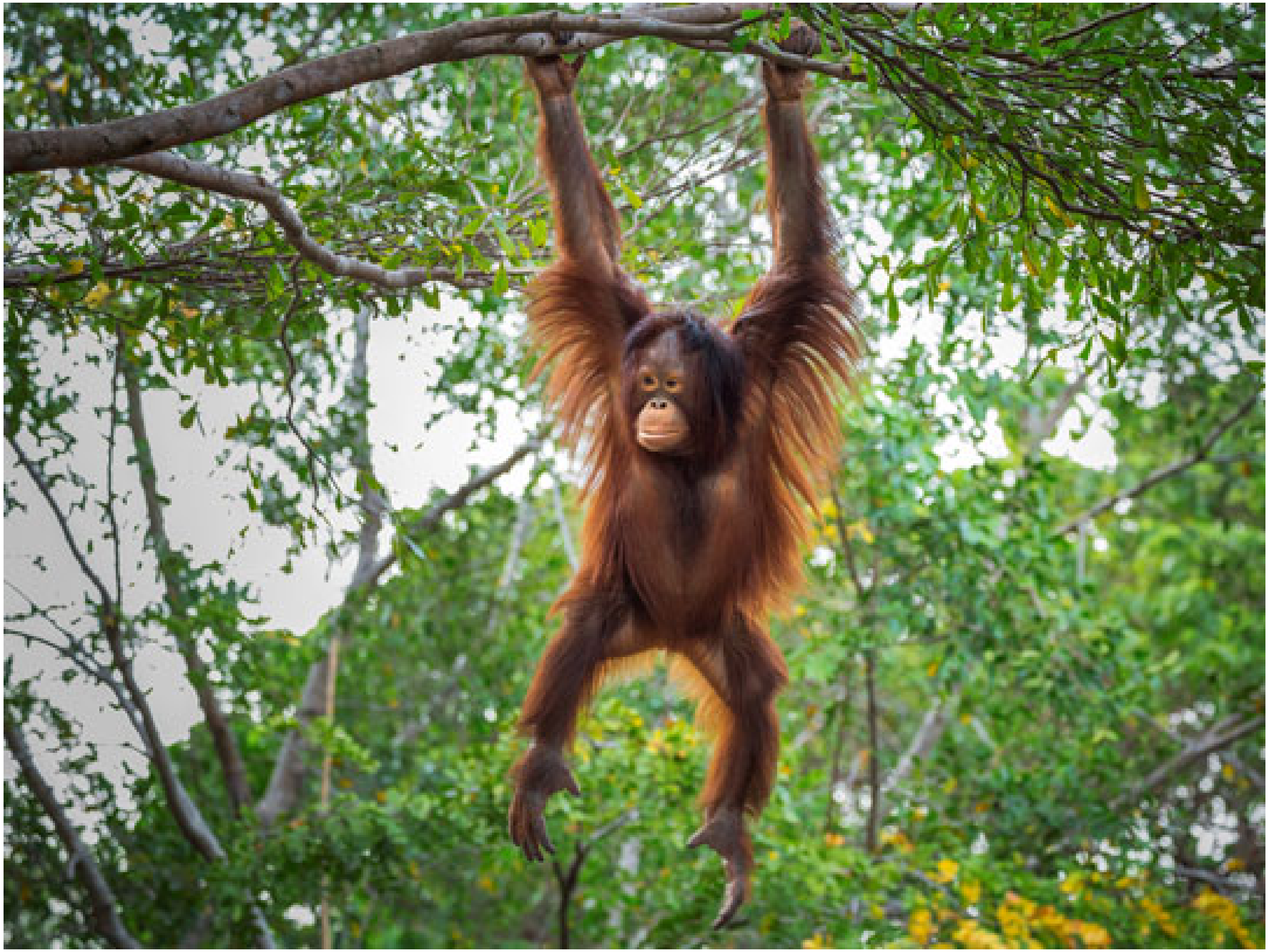
[From Reiss & Marino (2001)]

Video on Reiss' work

[from CNN]

What ecological pressures could have favored the ability to pass the marker test? (e.g., there are no mirrors in the wild)

The Clamebering Hypothesis



[http://www.dive-the-world.com/images/gallery/pages/medium/fc31ae490e-shutterstock-302571035-orangutan-on-the-tree.jpg]

The Great Apes

[http://wildpro.twycrosszoo.org/List_Vols/GreatApesViral/DCB_GreatApes4.jpg]

The Great Apes

[http://wildpro.twycrosszoo.org/List_Vols/GreatApesViral/DCB_GreatApes4.jpg]

Phylogeny of Primates

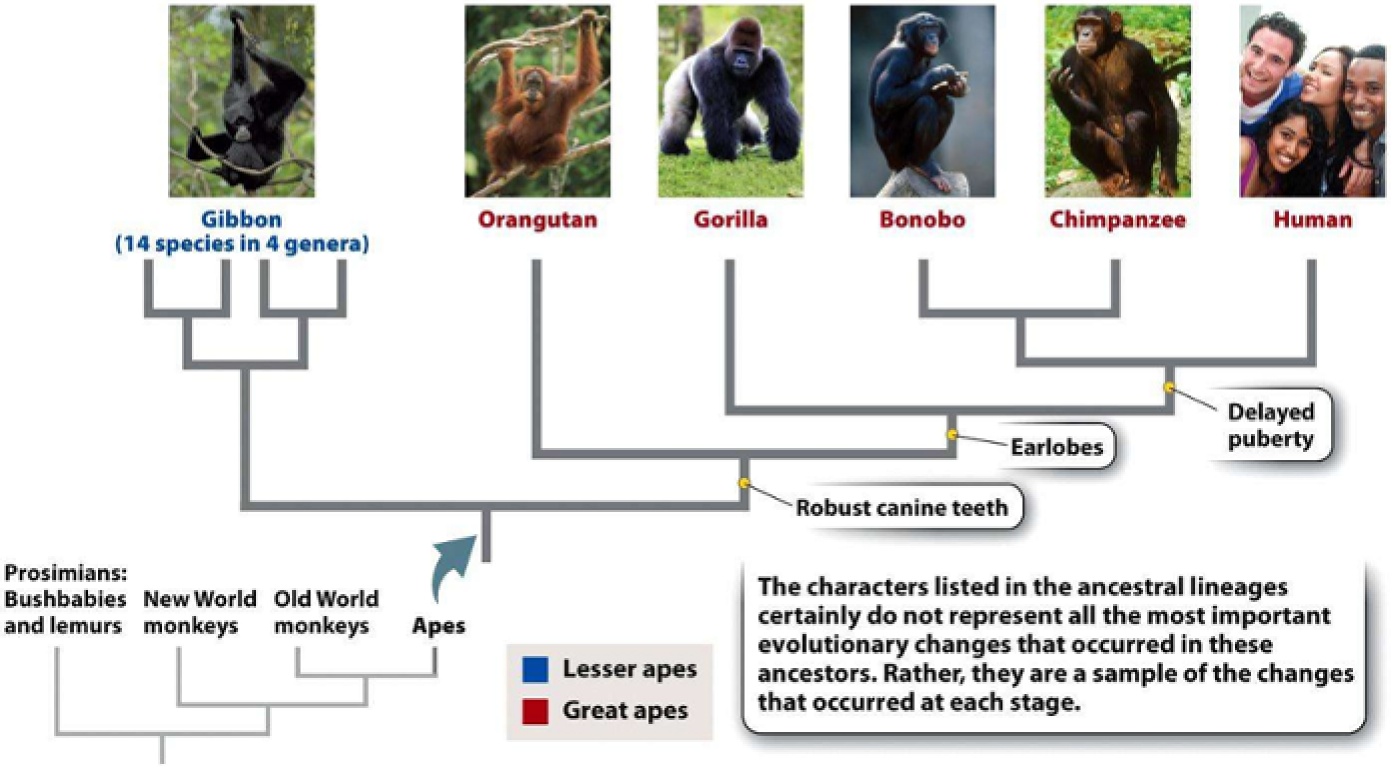


Figure 24.2
Biology: How Life Works

[https://www.easynotecards.com/uploads/1066/70/_6bdcb617_15405b7ae87__8000_00002484.png]

The Clambering Hypothesis

- “[...] evolutionary increase in body mass [of the common ancestor of the great apes and humans approximated by the capabilities of modern day orangutans] rendered the habitat increasingly difficult to traverse, primarily because of the severe deformation of supports (tree limbs) caused by this body mass.”
- “[...] the orangutan’s extreme body mass forces it to spend a non-trivial amount of time engaged in locomotor activities that appear to require a great deal of flexibility and planning in the translocation of the body through the arboreal habitat in which it travels. “
- “[...] this process of locomotion required the co-evolution of a more elaborated representation of the body and its actions to assist in planning and deploying their movements.“
- “[...] this capacity was subsequently lost in the gorilla lineage.”

[Barth, J., Povinelli, D.J., & Cant, J.G.H. (2004). "Bodily Origins of SELF"]

Unexpected Benefits

- Improved motor planning
- New ways of relating to the bodies of other (e.g., imitation learning)
- More flexible use of hand-based signals, e.g., body language, sign language
- More elaborate forms of tool use

Later on...tool use

Human Infants and the Marker Test

Would infants from cultures without mirrors pass the mark test?

Does exposure to mirrors matter?

“Human infants raised in cultures without mirrors pass the mark test at the same age as infants raised in cultures with mirrors, after only (5-minute) pre-rest exposure to their mirror image” (p. 15)”

[Barth, J., Povinelli, D.J., & Cant, J.G.H. (2004). "Bodily Origins of SELF"]

Does exposure to mirrors matter?

- “It is not necessary to understand how mirrors work in order to pass the marker test.” (p. 14)
- “Research with human infants, for example, has consistently shown that there is no connection between whether the infants pass the mark test and whether they can solve a simple task of turning around to look at a toy that is presented in a mirror.” (p. 15)

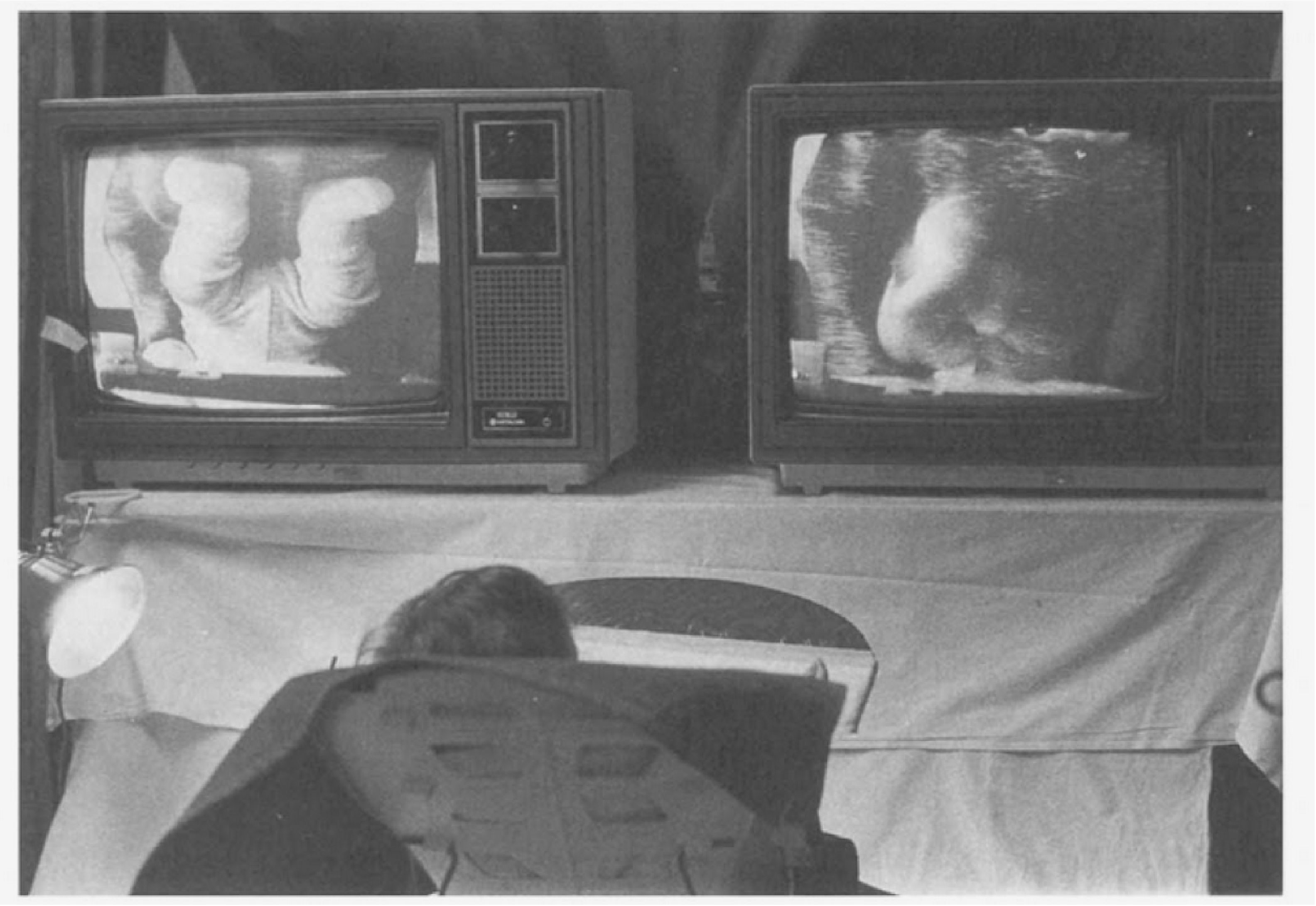
[Barth, J., Povinelli, D.J., & Cant, J.G.H. (2004). "Bodily Origins of SELF"]

Humans have slower maturation rates compared to other great apes

“Rather than accelerating physical development, humans evolved an extended period of physical immaturity and pushed aspects of general intellectual development considerably later, with all key life history parameters delayed relative to the great apes.” (p. 30)

[Barth, J., Povinelli, D.J., & Cant, J.G.H. (2004). "Bodily Origins of SELF"]

Watson's Experiment



[From Watson (1994), "Detection of Self: The Perfect Algorithm"]

Main Result

- At 3 months, infants split their attention equally between the 2 screens
- At 5 months, they are much more likely (nearly 100%) to focus on the screen showing the other infants’ movement

Contingency

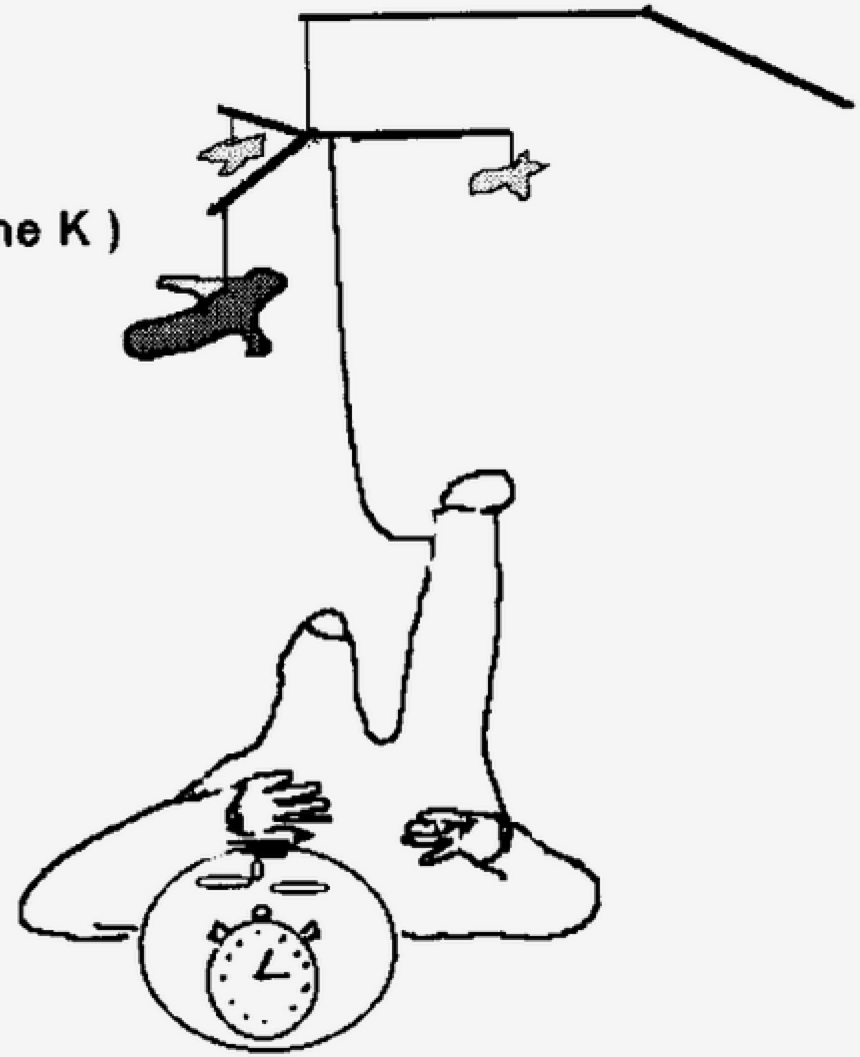


Figure 8.1. Depiction of contingency perception (*CP*) being computed by reference to temporal contiguity of mobile movement (*M*) and infant's kick (*K*).

Correlatioin

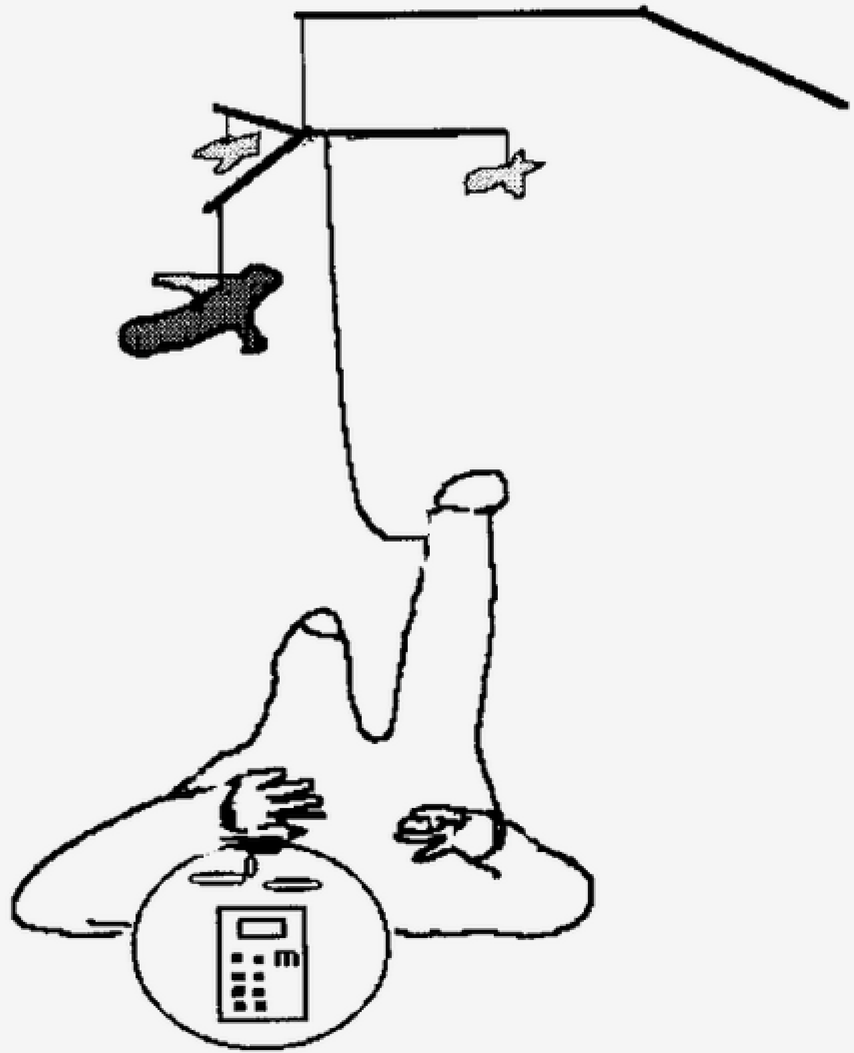


Figure 8.2. Depiction of contingency perception (*CP*) being computed by reference to correlation (*r*) of amount of mobile movement (*M*) and amount of infant's kicking (*K*) over time.

Conditional Probability

CONDITIONAL PROBABILITY?

$$CP = f\ P(M / K_t)$$

and

$$CP = f\ P(K / {}_tM)$$

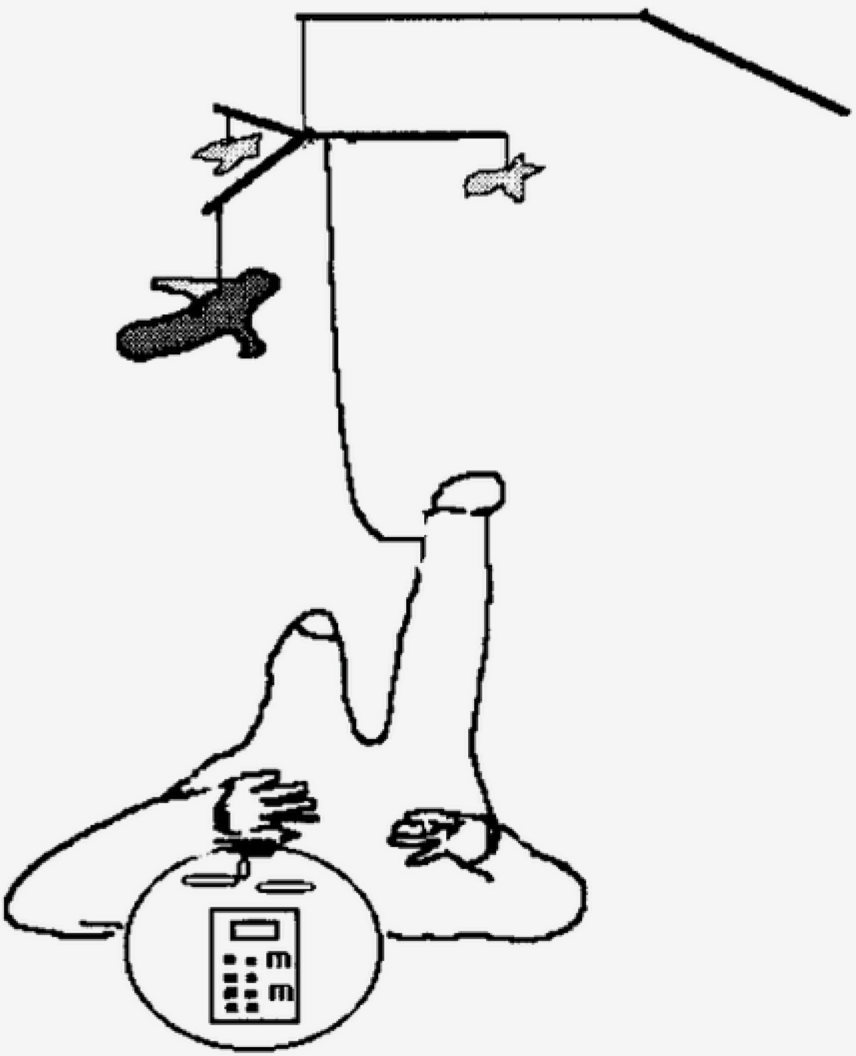


Figure 8.3. Depiction of contingency perception (*CP*) being computed by reference to the "sufficiency index" of conditional probability, $P(M / Kt)$, to be read as the probability of mobile movement (M) in a specified time span (t) following a kick (K) and by reference to the "necessity index" of conditional probability, $P(K / tM)$, to be read as the probability of a kick (K) in a specified time span (t) preceding a mobile movement (M).

Causal Implication

CAUSAL IMPLICATION?

CP = f (K implies M)
and
CP = f (not K implies M)
and
CP = f (K implies not M)
and
CP = f (not K implies not M)

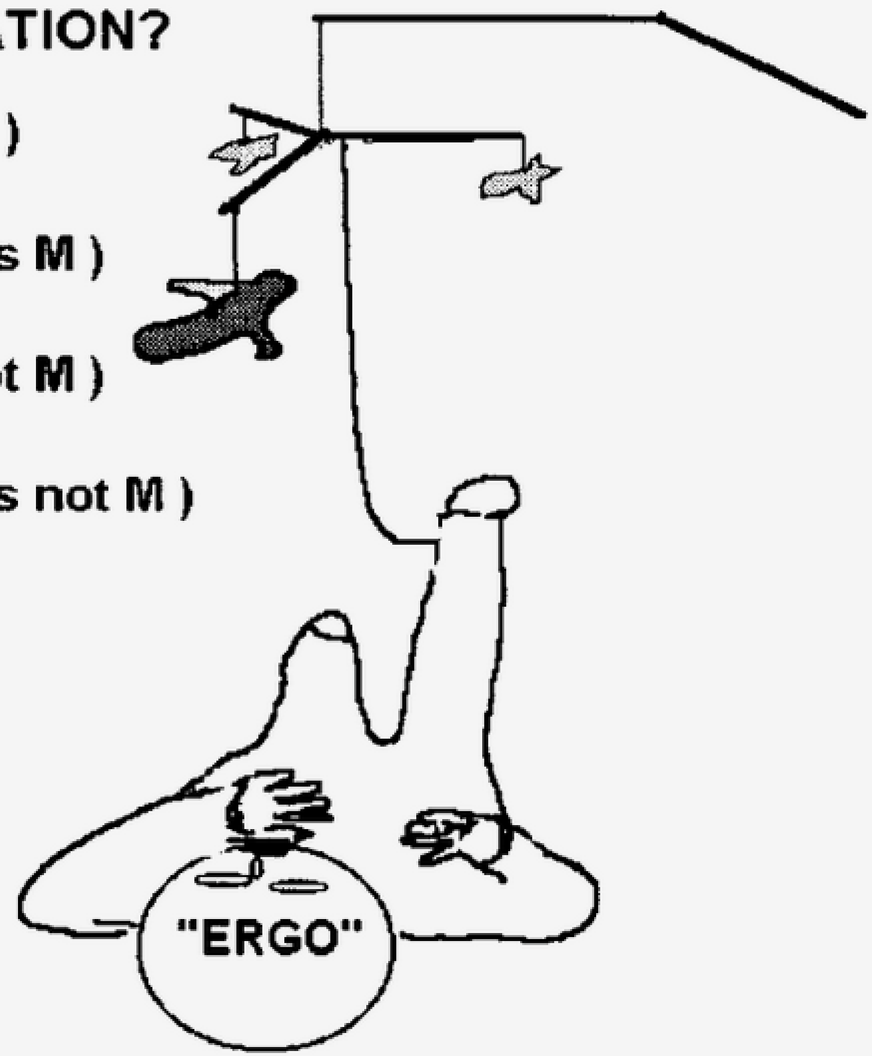
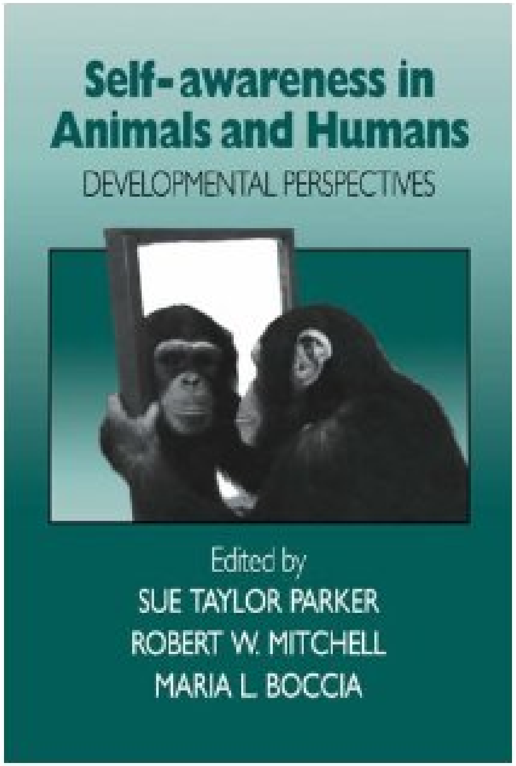


Figure 8.4. Depiction of contingency perception (*CP*) being deduced ("ERGO") by reference to the causal implication of observed relations between the four logical options for combining mobile movement (*M*) versus no movement (*not-M*) with kicking (*K*) versus no kicking (*not-K*) as represented in Table 8.1.

Detecting Contingency

- Contiguity
  - Does the mobile move with or as soon after my kick?
- Temporal correlation
  - Does the mobile movement vary over time in relation to the variation of my kicking?
- Conditional probability
  - Does the probability of a mobile movement given some time following a kick differ from the probability of mobile movement without consideration of kicking?
- Causal implication
  - Does my kicking versus not kicking have a logical implication for mobile movement versus no movement?

To find out more...



Prime

Self-Detection by Robots

The Vision

[from Honda]

Self-Detection by Robots

- How should the problem even be formalized?

Self-Detection as a Pixel-labeling Problem

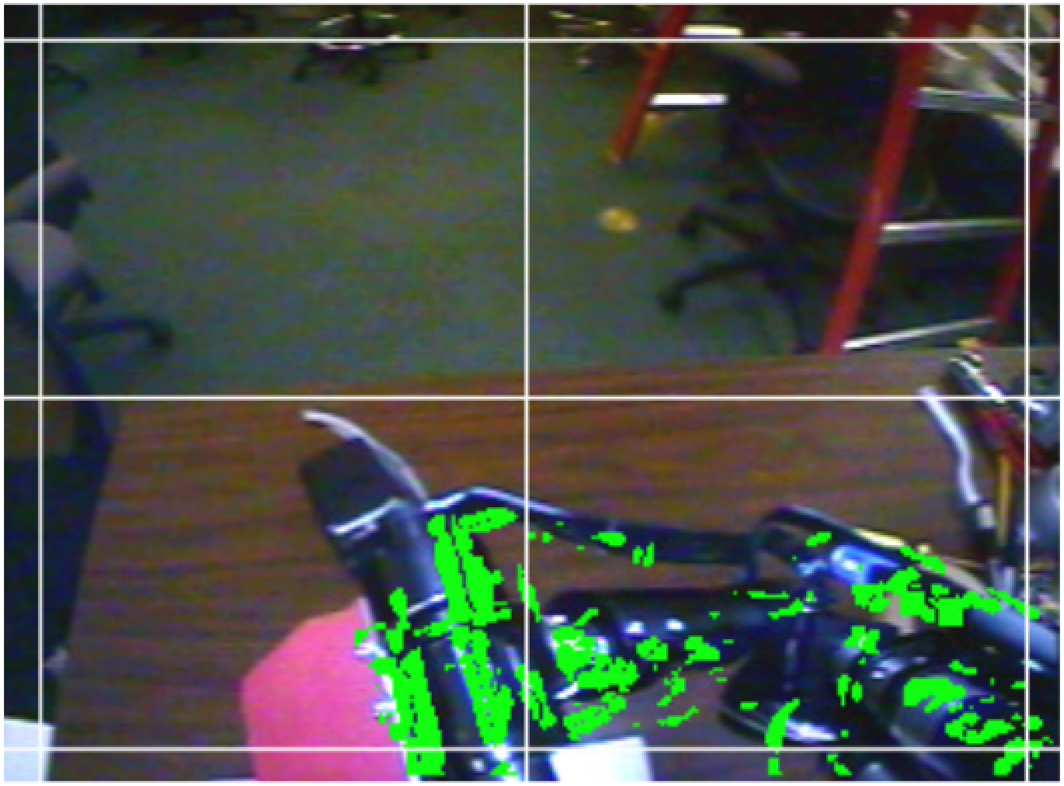
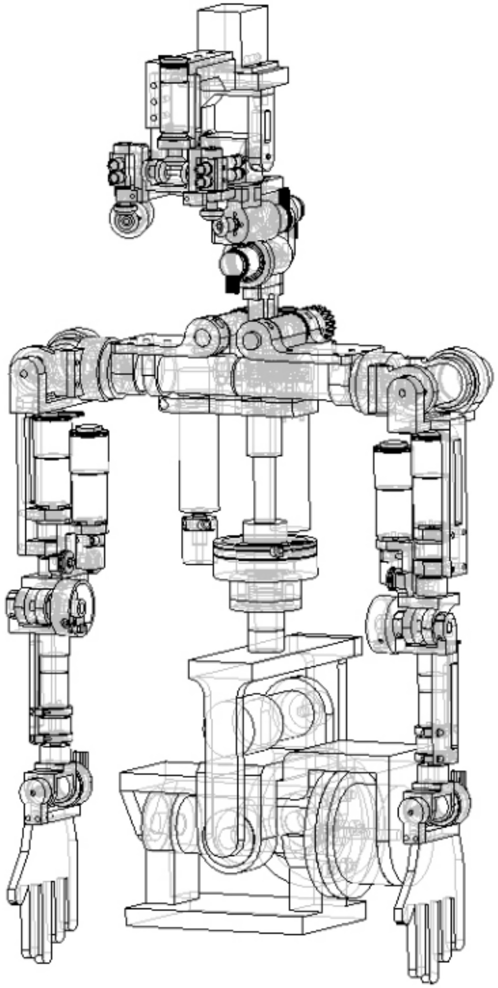


Fig. 5. Output from the self-motion classifier, overlaid onto the visual input from one eye. All salient pixels from a moving object identified as ‘self’ are highlighted (colored bright green).

Nico



[From Michel, Gold, Scassellati (2004)]

Pipeline

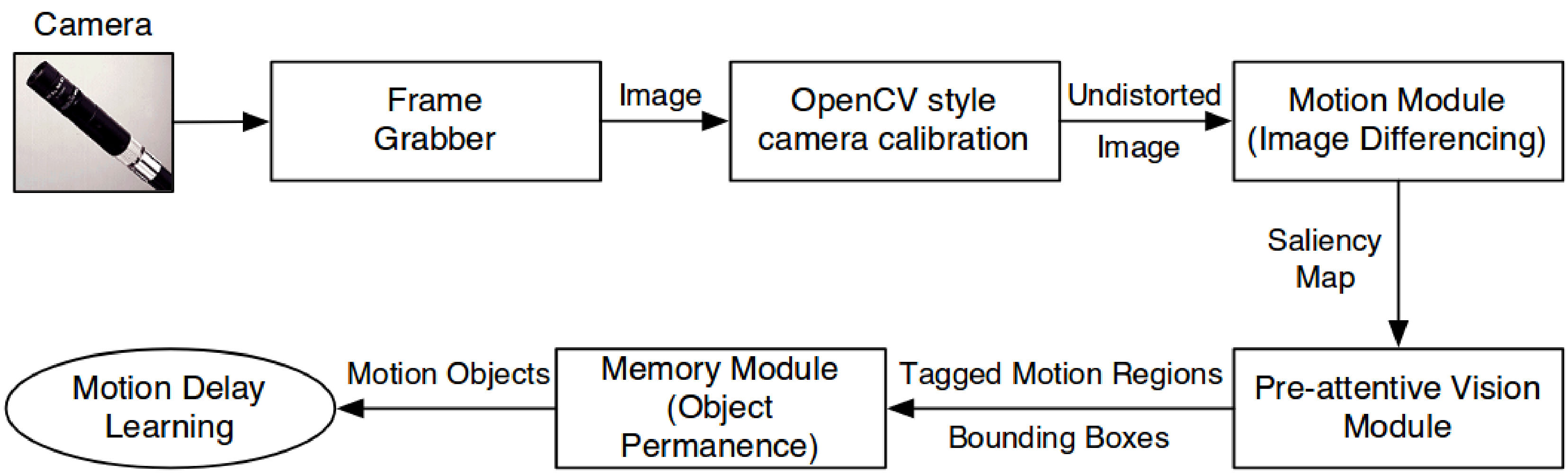


Fig. 3. Visual and attentive processing preceding the delay learning stage. A separate processing flow is associated with each eye.

Learning Temporal Delays

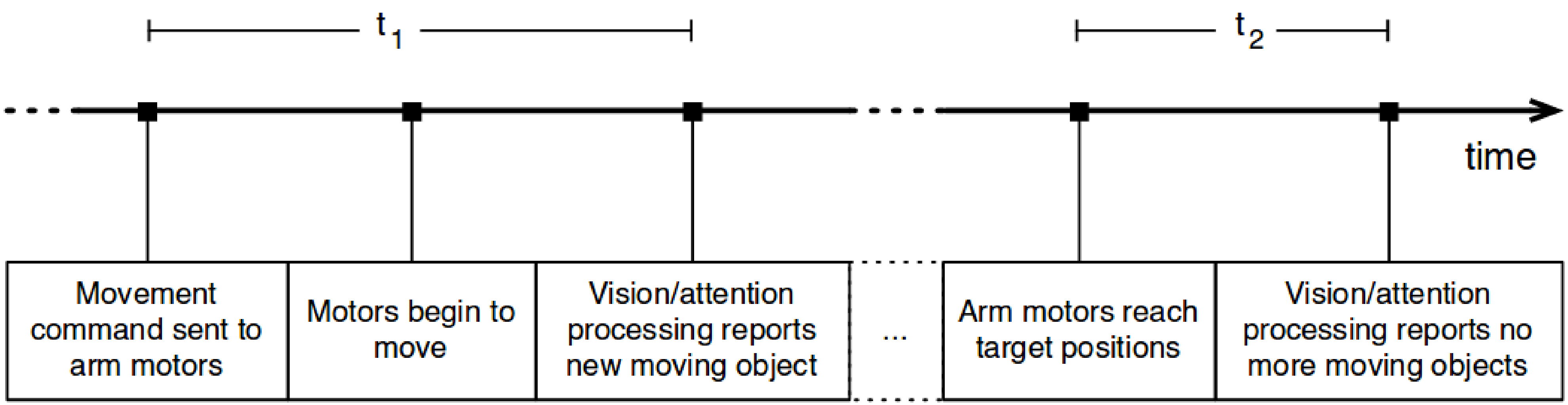
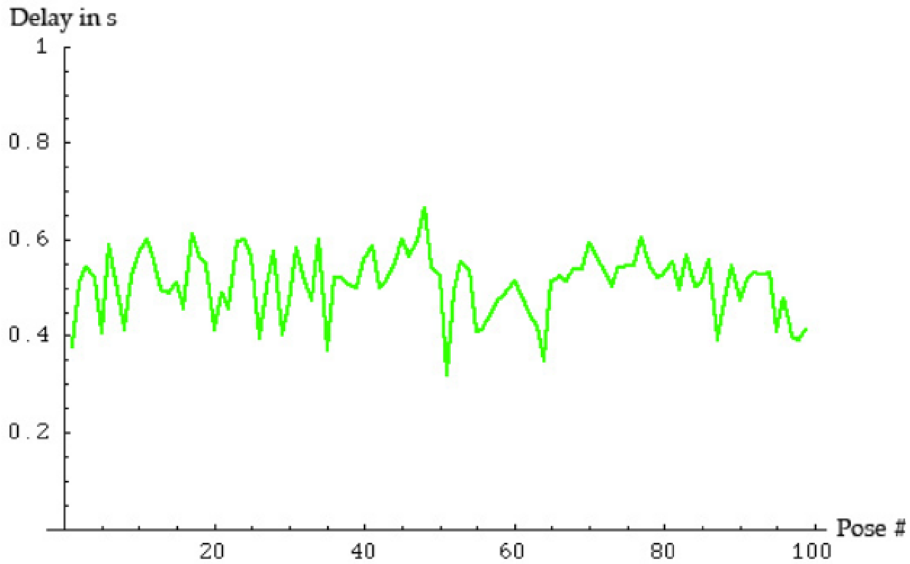
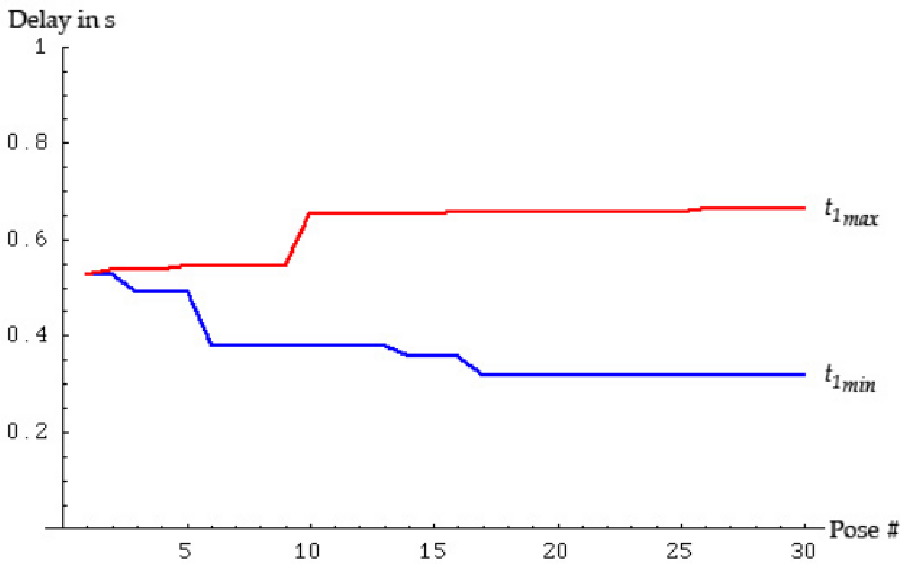


Fig. 4. Timeline showing relevant events for the measurement of t_1 and t_2.

Delay Measurements

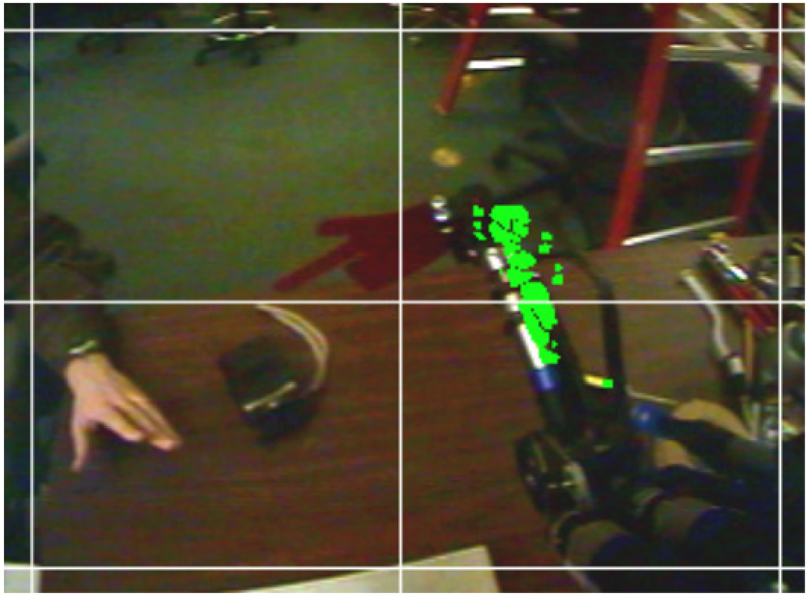


(a) Delay t_1 measured over a trial run of 100 arm movements. $\mu = 0.506599s$, $\sigma = 0.0660767s$.

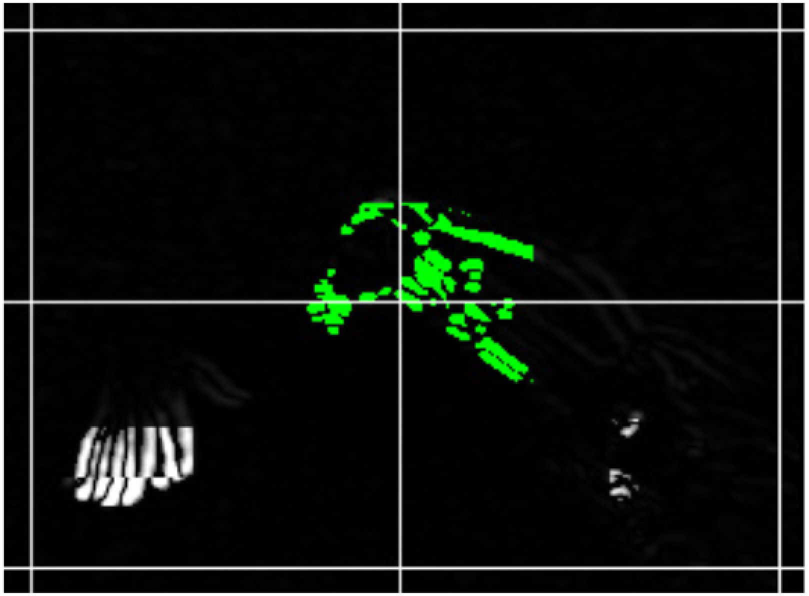


(b) Bounds on the delay over a trial run of 30 arm movements.

Distinguishing Self vs. Other



(a) First person view of the test condition with the distractor. Only the robot's motion is labeled as 'self'.



(b) Motion module output under the same conditions. Both the human hand and the robot arm are moving, but only the robot's motion satisfies the learned time delay (robot arm highlighted green, hand remains white).

Detecting a “gloved” hand

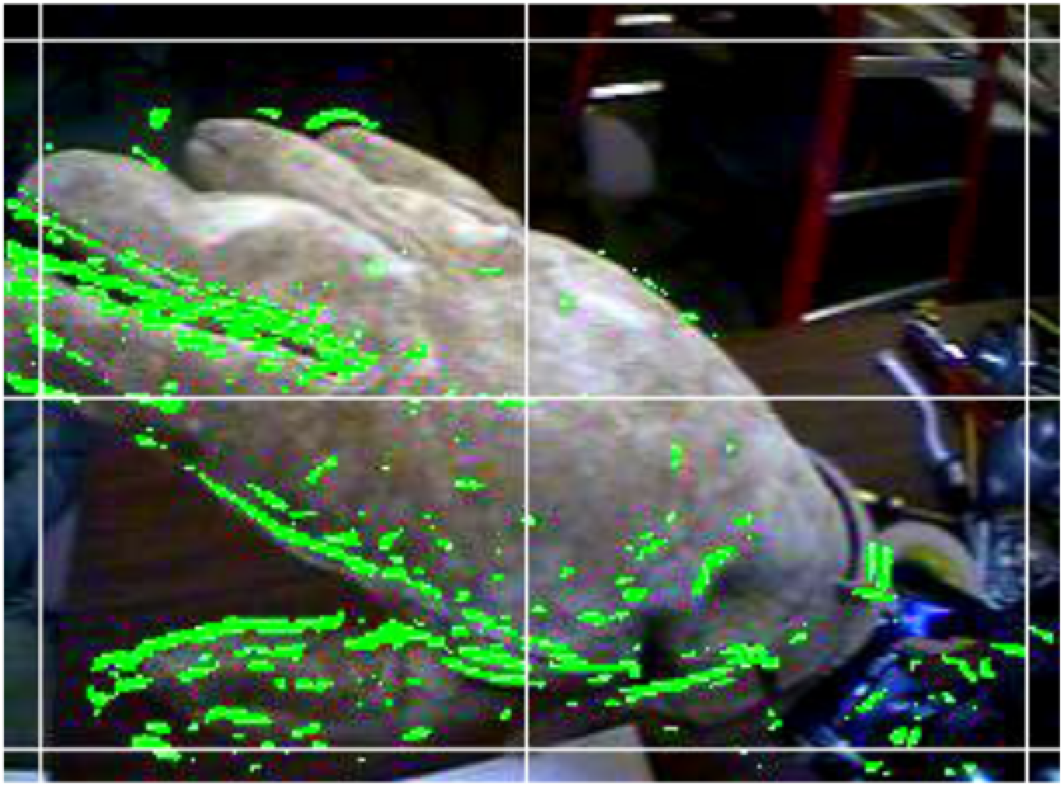


Fig. 8. Nico’s gloved hand correctly being labeled as ‘self’.

Detecting Self in the Mirror

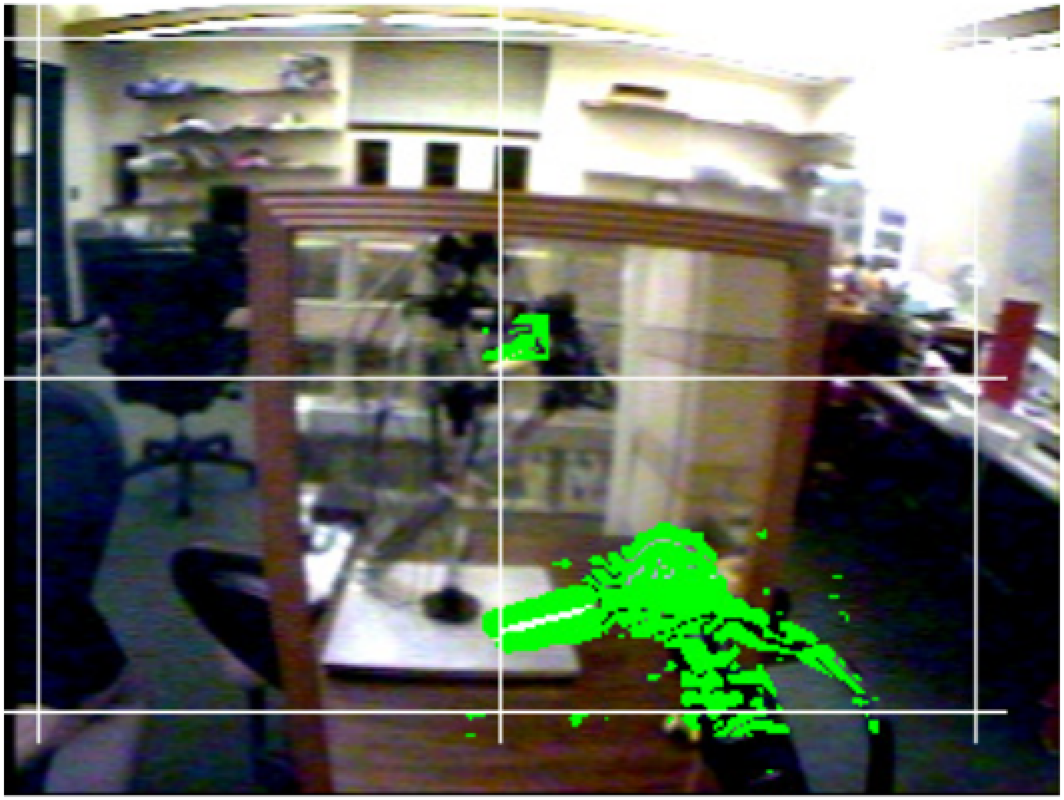
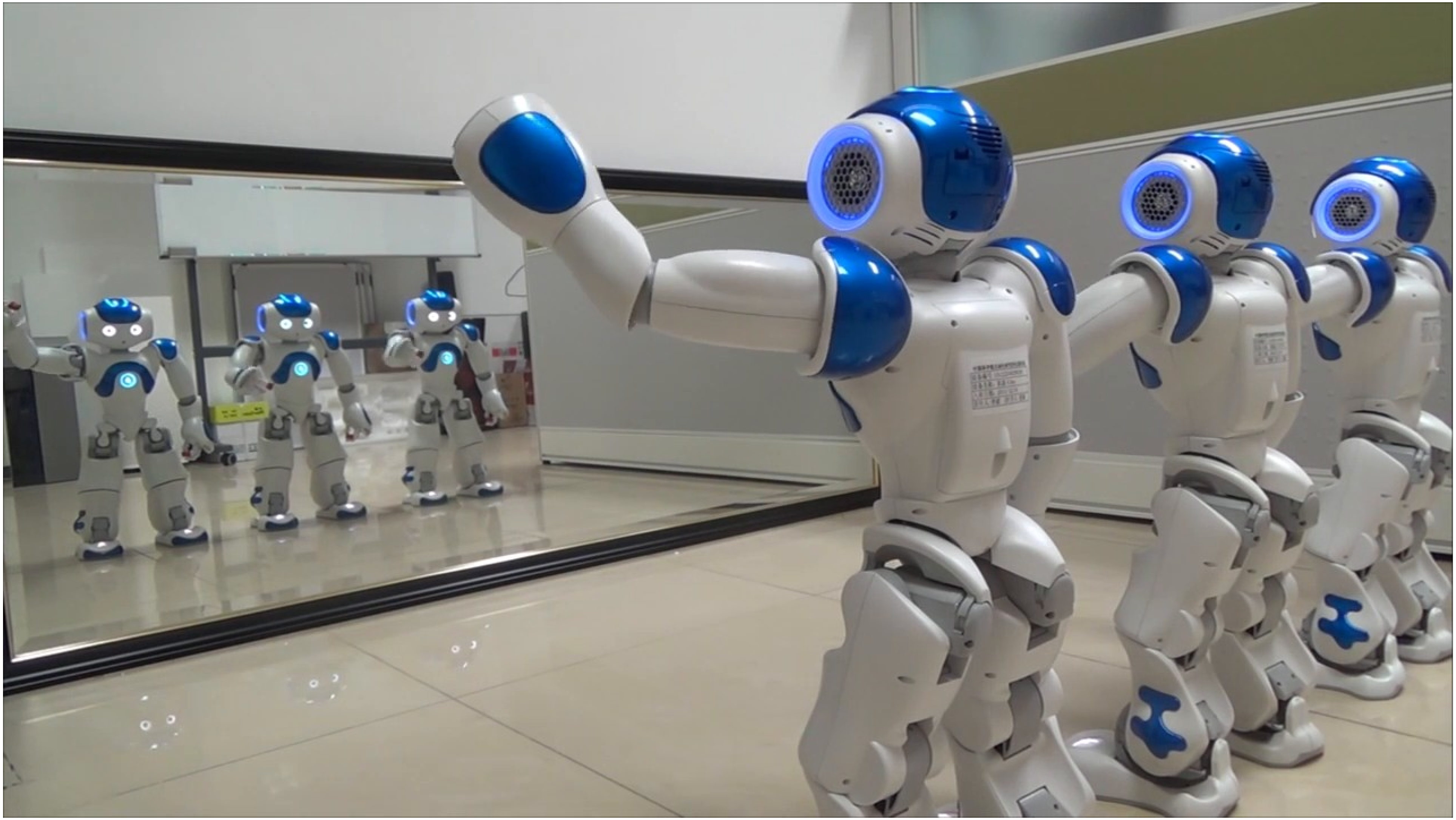


Fig. 9. Nico recognizes self-motion in a mirror.

Mirror Test with Robots



Zeng, Y., Zhao, Y., & Bai, J. (2016). Towards Robot Self-consciousness (I): Brain-Inspired Robot Mirror Neuron System Model and Its Application in Mirror Self-recognition. In Advances in Brain Inspired Cognitive Systems: 8th International Conference, BICS 2016, Beijing, China, November 28-30, 2016, Proceedings 8 (pp. 11-21). Springer International Publishing.

SELFCEPTION

http://www.ics.ei.tum.de/en/selfception/home/

THE END