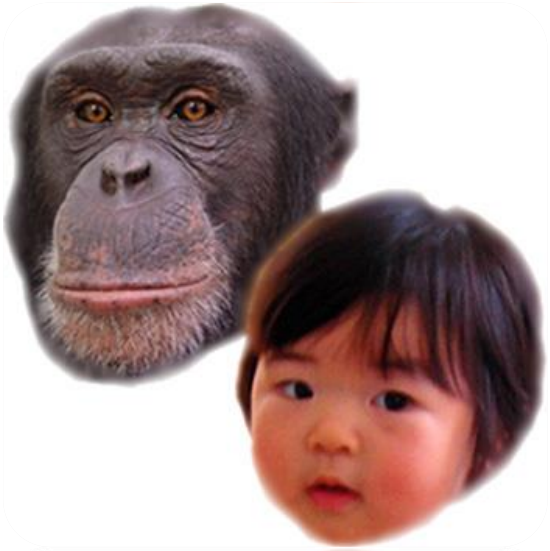
devsci
Constructive Developmental Science

Ontogeny and its Evolutionary Foundation of Human Mind



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KYOTO UNIVERSITY
KYOTO JAPAN
FOUNDED 1897

Smart Chimpanzees !

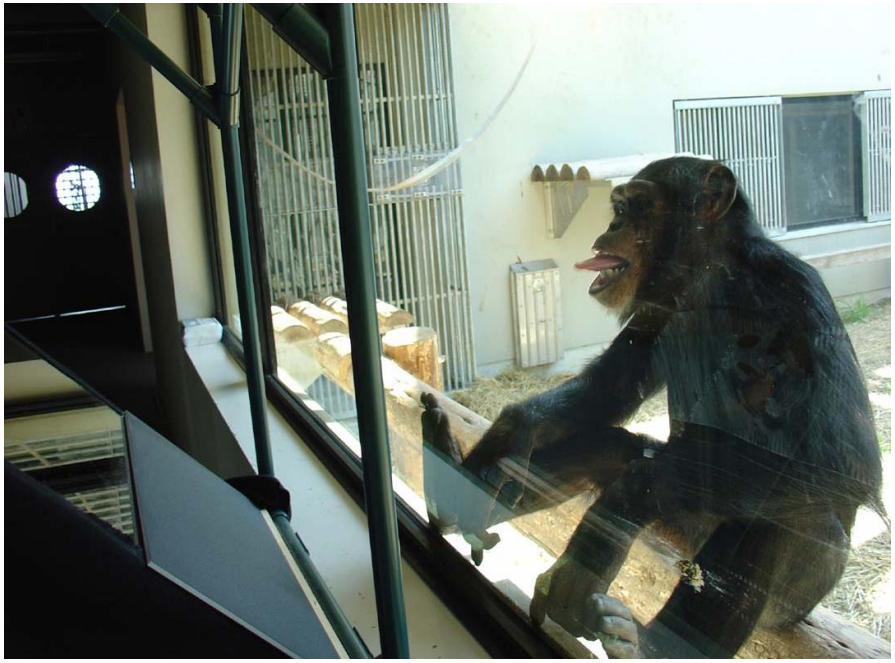
- Captive： Learning symbols (language, numbers…)
- Wild: Tool use and making

Tool use and making in wild chimpanzees

- ✓ Ant fishing by sticks
- ✓ leaves use as sponge to drink water
- ✓ Nut cracking by using stones as hummer and anvil

etc…

Mirror self-recognition



Self-exploratory behaviors while watching own mirror or live images

e.g., Gallup, 1968, 1970, Savage-Rumbaugh, 1984, Eddy et al., 1996

Beyond “here and now”
Recognition of 2 sec delayed self-image

Hirata, Fuwa, & Myowa-Yamakoshi, in prep.

Why have humans evolved "imitation" ?

- ***Social learning*** *by imitation*
  - Acquiring adaptive "non-genetic" skills in the human environment
  - Transmitting knowledge and skills to next generations
  - Foundation of human "***Culture***"

- *Foundation for* ***development of social cognition***
  - Awareness of self/others
  - Capacity to represent symbols
  - Understanding mental states of others "*Theory of mind*"

Newborns imitate facial gestures

Neonatal imitation

Humans' innate system:
Active intermodal matching
(AIM mechanism)

Fig. 1. Sample photographs from videotape recordings of 2- to 3-week-old infants imitating (a) tongue protrusion, (b) mouth opening, and (c) lip protrusion demonstrated by an adult experimenter.

--- Meltzoff & Moore, 1977, *Science*

Visual-Motor matching behavior in newborns

Auditory–oral motor matching in newborns

Mouth opening to /a/a/a/

Mouth clutching to /m/m/m/

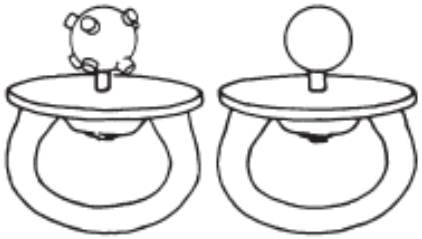
Auditory–Motor matching behavior in newborns

Chen, Striano, & Rakoczy, 2004, *Dev.Sci.*

“Synesthetic” at birth ?

- **Visual-Motor** matching (Meltzoff & Moore, 1977)

  facial imitation in the neonatal period



- **Auditory-Motor** matching (Chen et al., 2004)

- **Visual-Tactual** matching

  (Meltzoff & Borton, 1979, Streri et al., 2000)

  shape information in tactual modality transform it in visual modality

Neonatal Synesthesia hypothesis ?

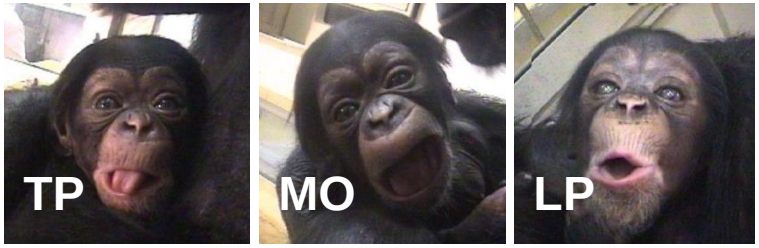
- Primary sensory cortex is not so specialized in the young infants
- Extra functional connections among cortical areas?

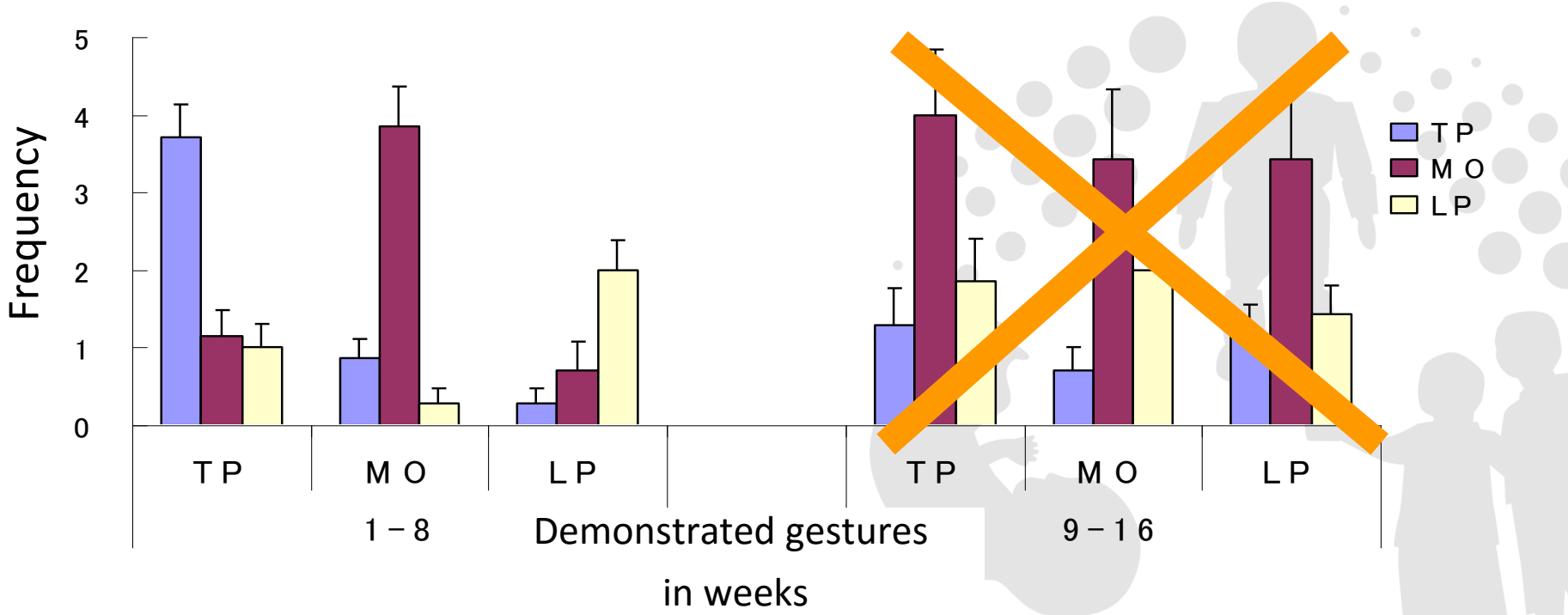
e.g., Baron-Cohen 1996, Maurer et al., 2009

Chimpanzee also show neonatal imitation

Myowa-Yamakoshi et al., 2004, *Dev Sci.*

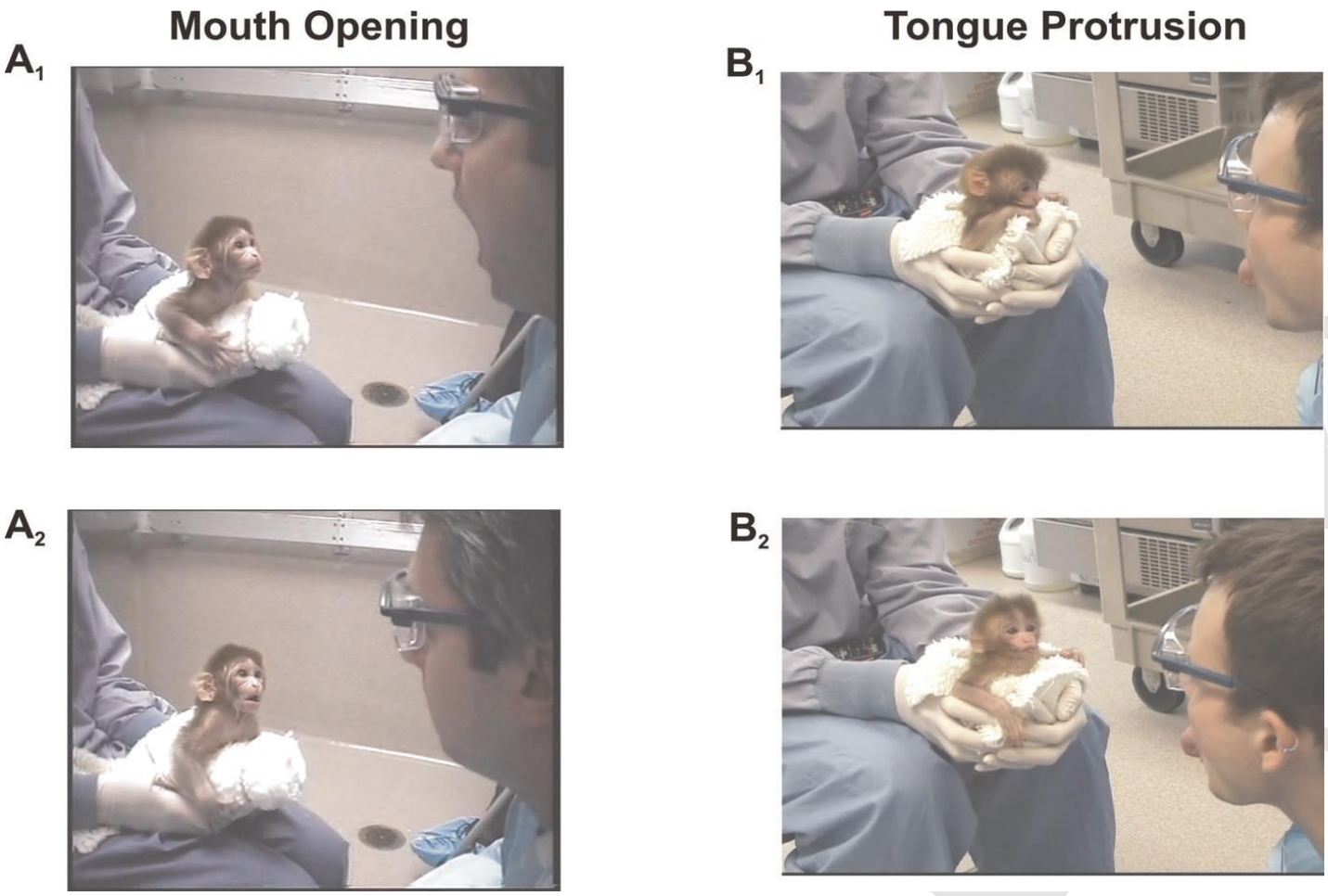
Neonatal imitation in chimpanzees





Myowa-Yamakoshi et al., 2004, *Dev Sci.*

Monkeys also show neonatal imitation



Ferrari et al., 2006, *PLoS Biology*

Is there evidence of a mirror system from birth?

- Mirror Neuron System is **innate** in humans ?
- MNS **developmentally changes ?**
- MNS and **goal-directed actions**

Neonatal imitation is goal-directed action ?

TARGET ARTICLE WITH COMMENTARIES

The mirror neuron system: grasping others' actions from birth?

Jean-François Lepage and Hugo Théoret

Abstract

Introduction

The mirror neuron system

No convincing evidence of mirror system in infancy

Developmental Science, 2007, Target article

Chimpanzee also show neonatal imitation

--- Myowa-Yamakoshi et al., 2004, *Dev Sci.*

Development of bodily imitation

	Humans	Chimpanzees
Neonatal imitation	at birth	at birth
Disappear of neonatal imitation	2-3 months	2 months
Whole body (later) imitation	**9-12 months**	

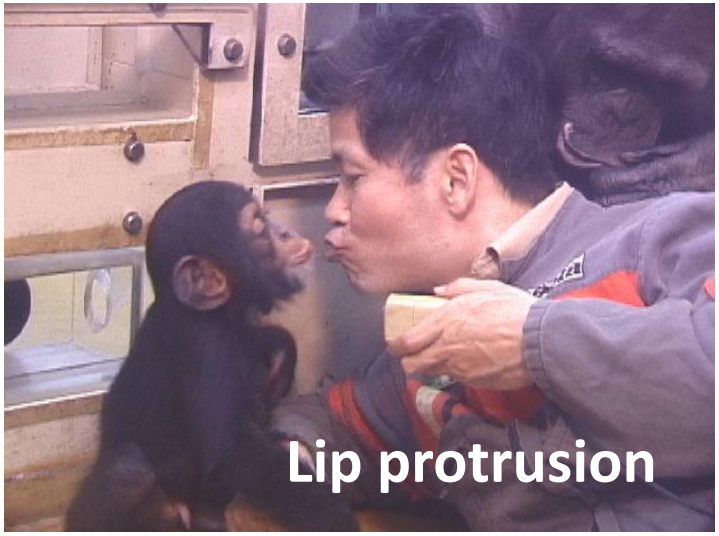
Later imitation in social-communicative context

Development of bodily imitation

	Humans	Chimpanzees
Neonatal imitation	at birth	at birth
Disappear of neonatal imitation	2-3 months	2 months
Whole body (later) imitation	**9-12 months**	?

Development of facial imitation in chimpanzees

- At 9 months of age, the chimpanzee's imitative responses "re-appeared"
- However ・ ・ ・



Myowa-Yamakoshi, 2009,
Handbook of Soc. Cog. Neurosci.

Do chimpanzees imitate ?

- Tomasello, Savage-Rumbaugh, & Kruger (1993)

  Three “encultulated” chimpanzees could imitate 16 novel actions on objects as much as human children did

- Custance, Whiten, & Bard (1995)

  Of 48 novel gestures, two captive chimpanzees could imitate 13 and 20 arbitrary gestures

- Whiten et al. (2009)

  Recent their experiments (chimpanzee model) suggest a significant capacity for copying of other’s action (goal-directed manipulations only)

Factors influencing whole-body imitation in chimpanzees

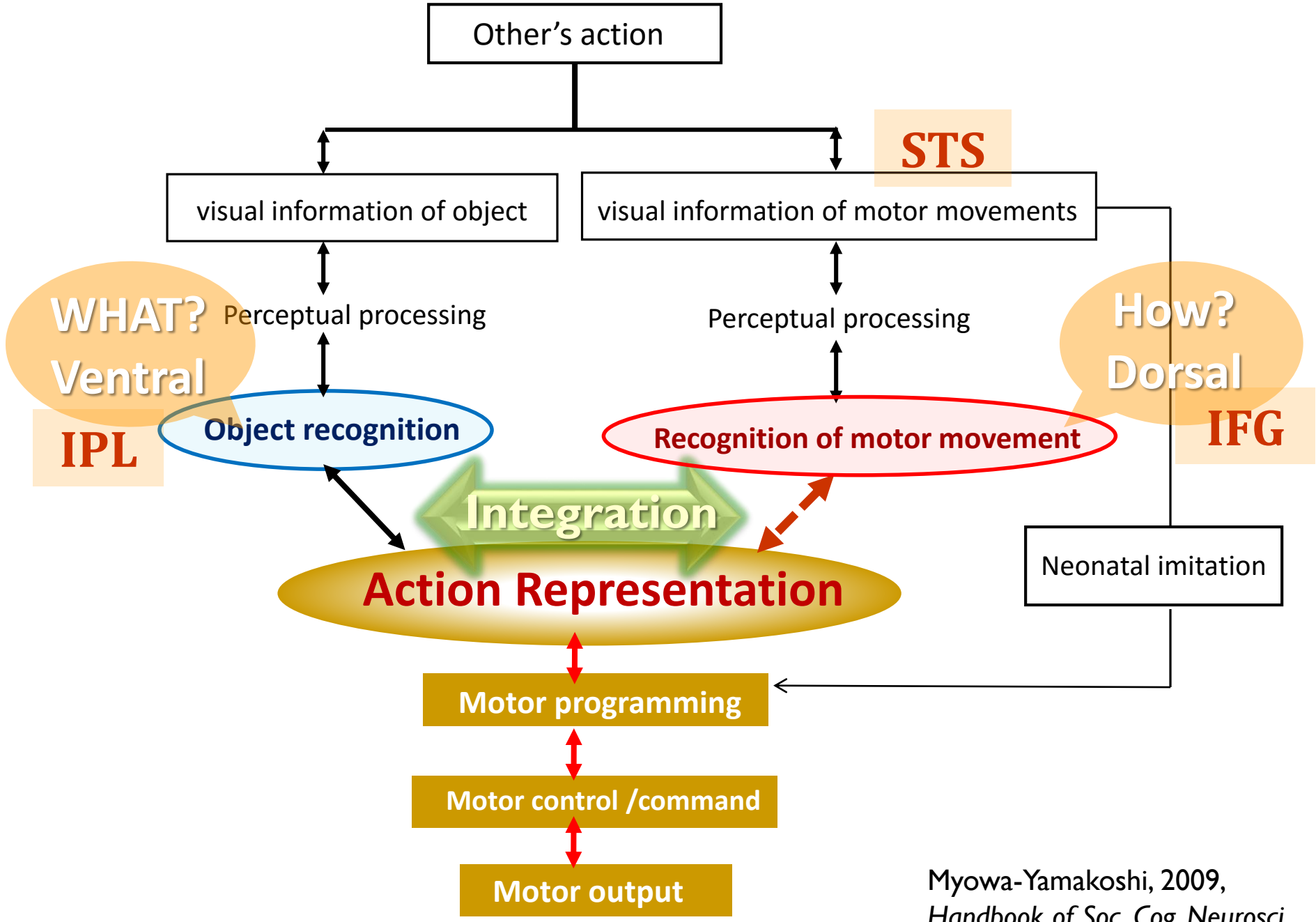
Myowa-Yamakoshi & Matsuzawa , 1999, 2000, *J. Comp. Psychol.*

Factors influencing imitation in chimps

- The chimpanzees rarely reproduced demonstrated actions at the first attempt
- It was easier for the chimpanzees to perform an action in which an object was directed toward some external location (***transitive*** action) than to manipulate a single object alone (***intransitive*** action)

- Chimpanzees seem to pay much attention to where the manipulated object was being directed than the motor movement of others performing the manipulation

Myowa-Yamakoshi & Matsuzawa , 1999, 2000, *J. Comp. Psychol.*



Myowa-Yamakoshi, 2009,
Handbook of Soc. Cog. Neurosci.

How do humans and chimpanzees see other's action?

- difference of visual information processing between humans and chimpanzees ??

- **Goal-directed action**
  e.g., "pouring juice into a cup"

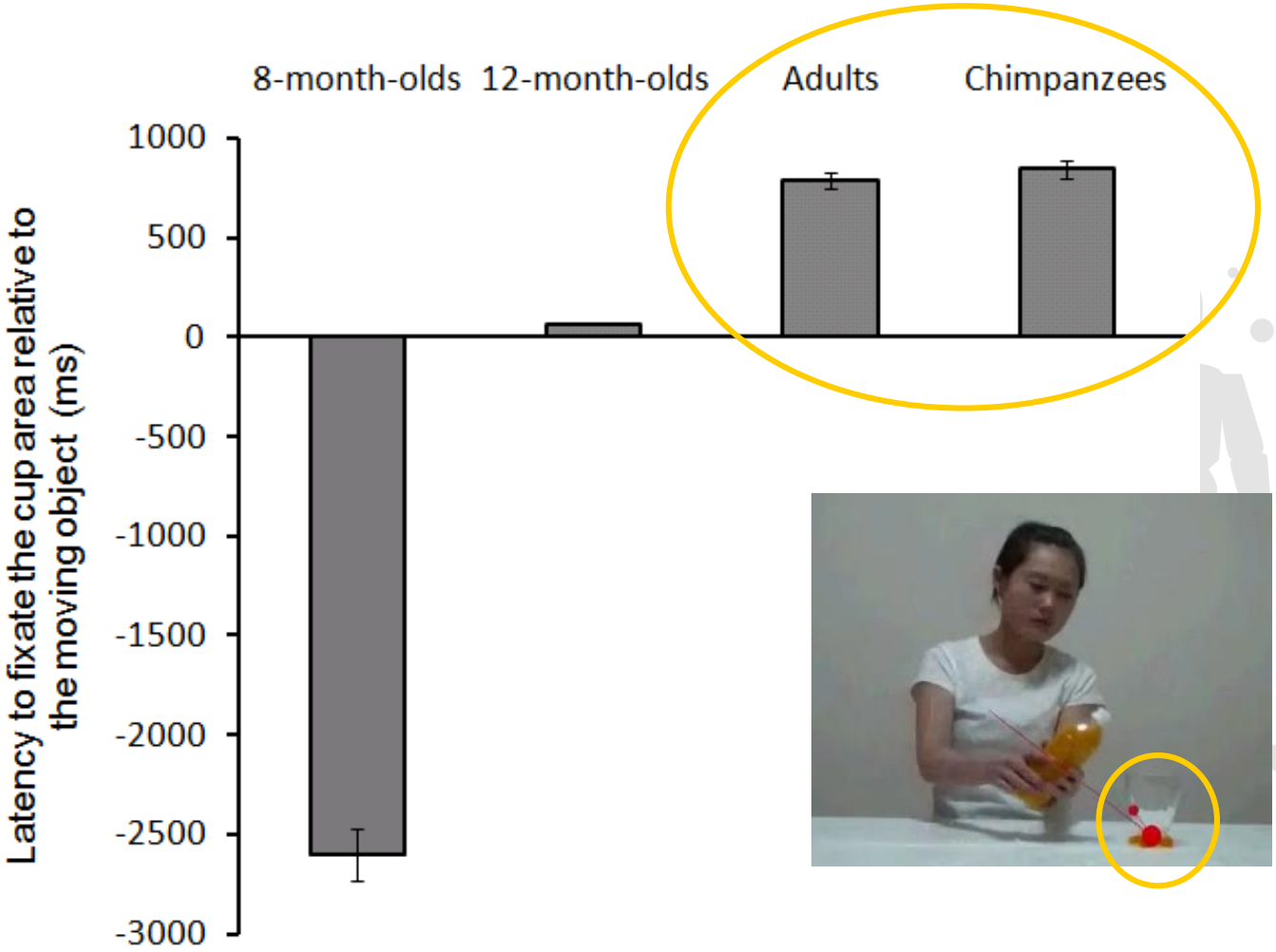
- Chimpanzees (5-14 years ; n=6)
- 8- and 12-month-old infants (n =16, each)
- Adults (n = 15)

Myowa-Yamakoshi, Scola, & Hirata, 2012, *Nature Commun.*

How do humans and chimpanzees see other's action?

Participants	pouring juice into a cup
Human 8 months	×
Human 12 months	△
Human adults （22.4 years）	○
Chimpanzees （5～15 years）	○

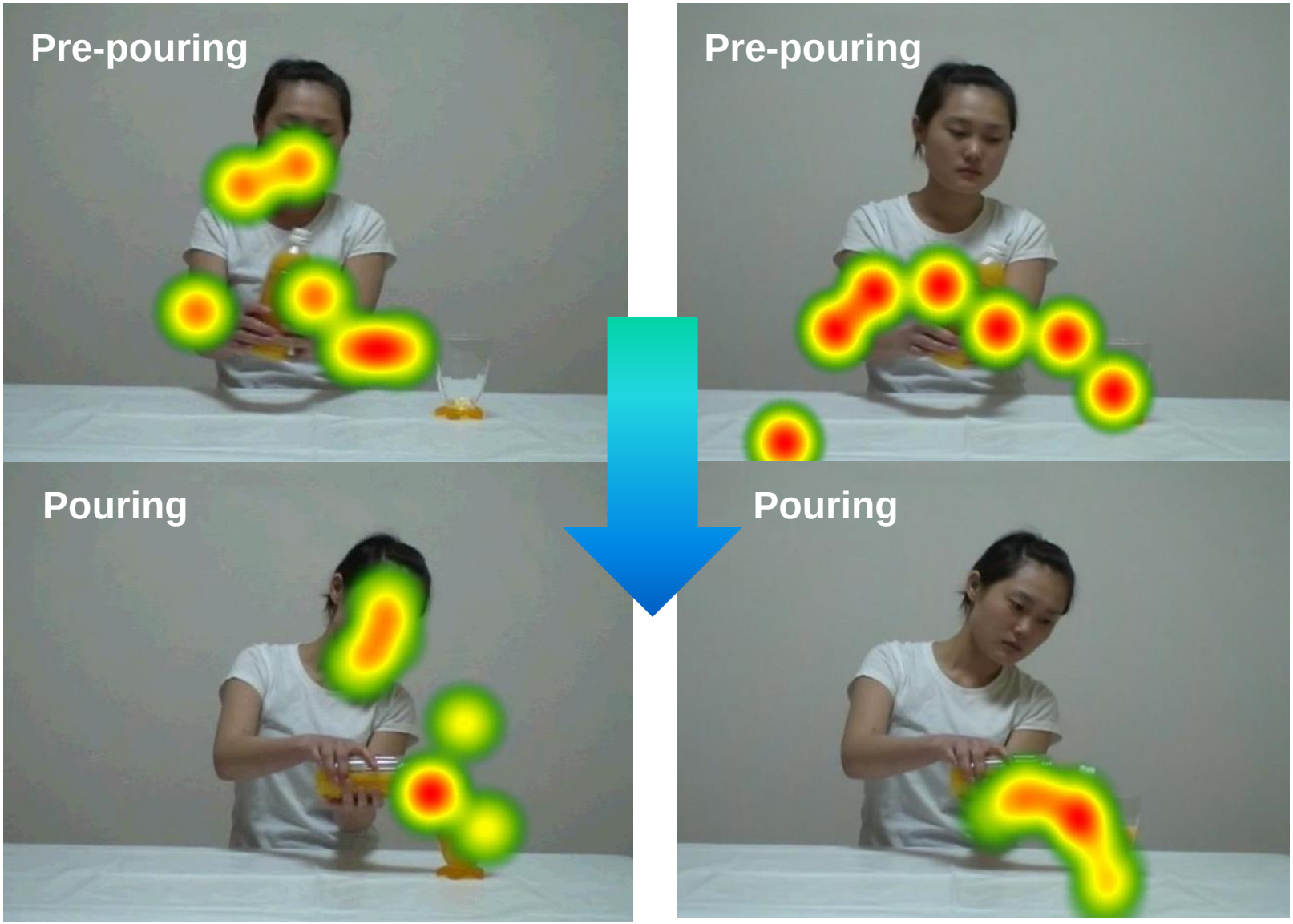
Anticipatory look of action goal



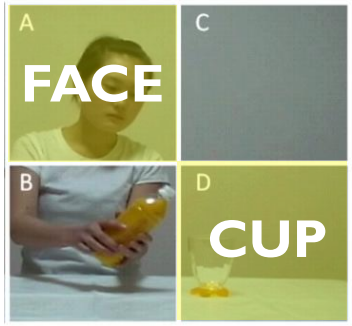
Myowa-Yamakoshi et al. 2012, *Nature Commun.*

12 months

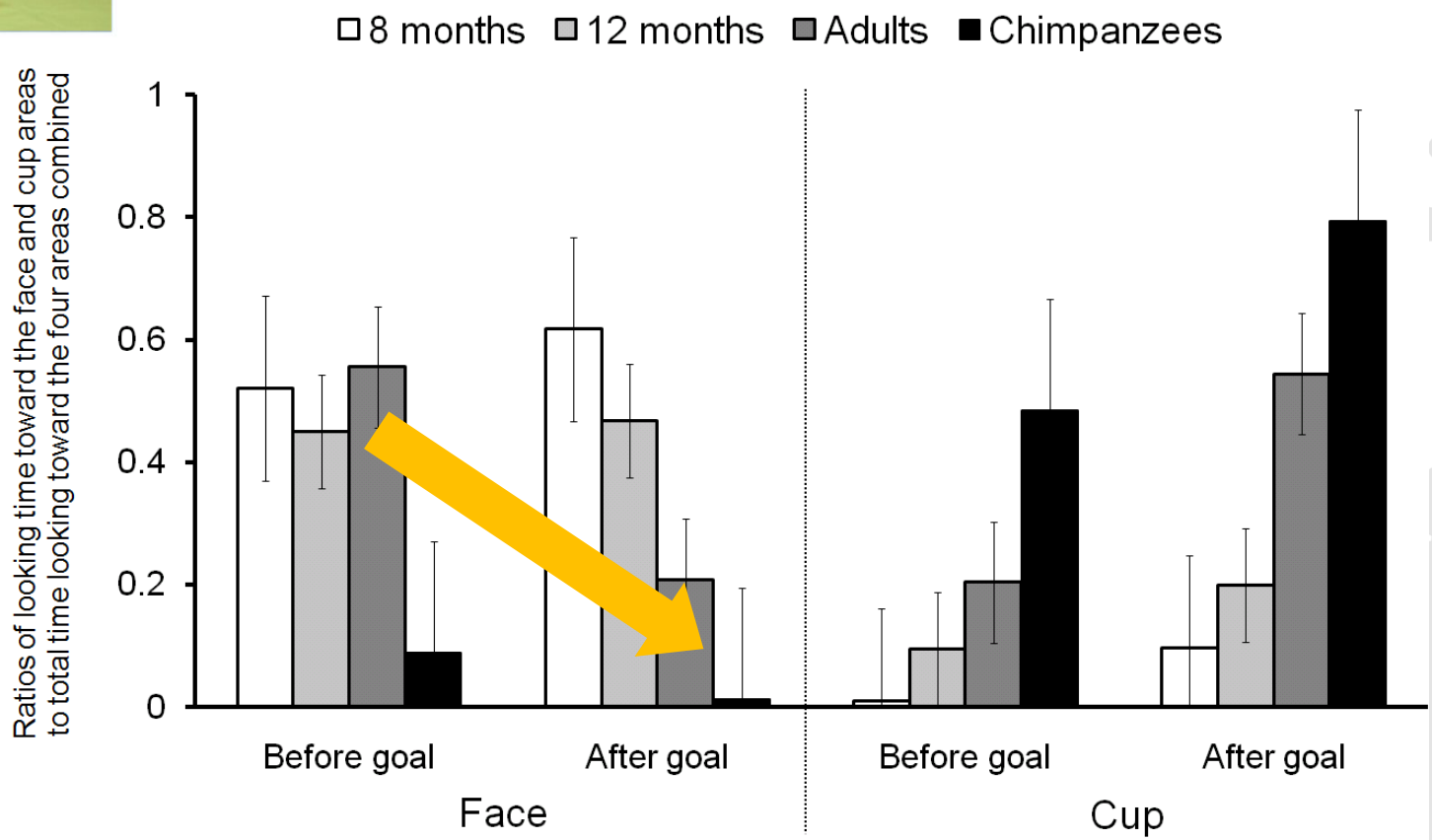
Chimpanzees



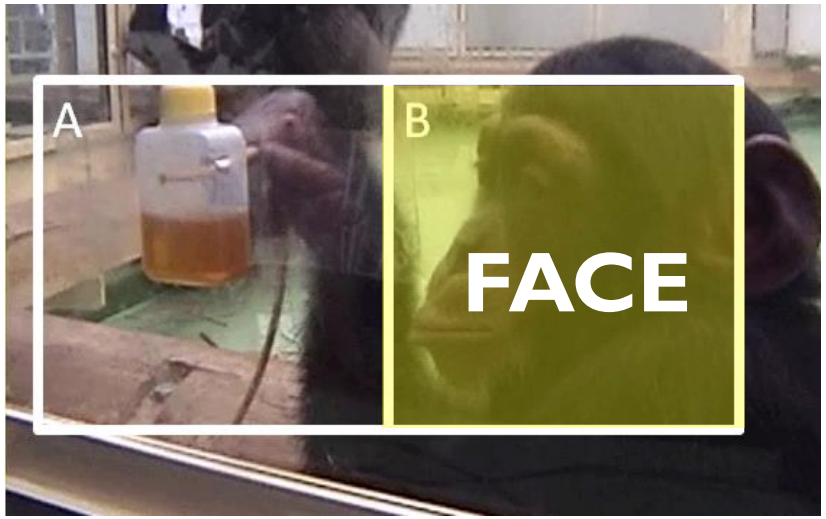
Spatial distribution of fixations

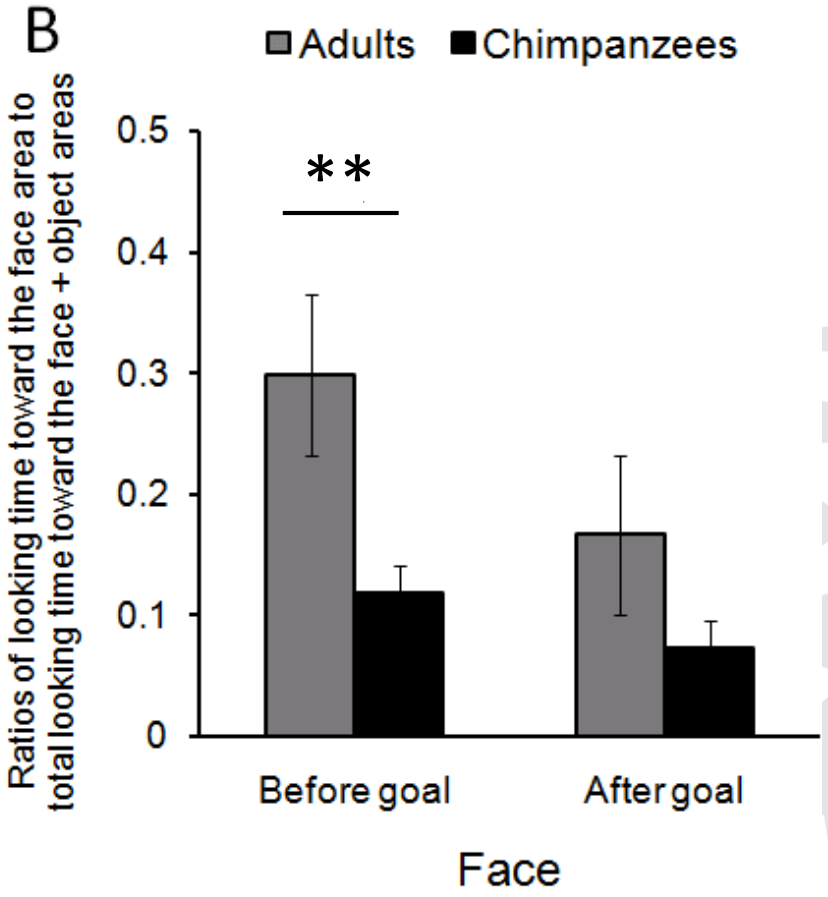


Myowa-Yamakoshi et al. 2012, *Nature Commun.*



Spatial distribution of fixations for chimpanzee action



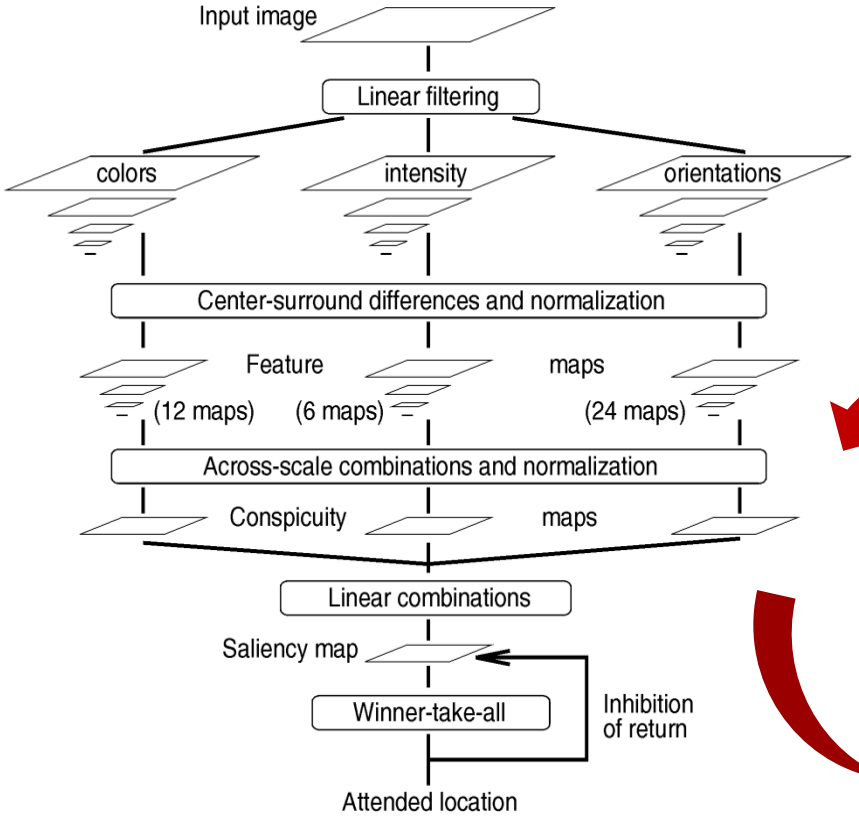


Myowa-Yamakoshi et al. 2012, *Nature Commun.*

Why do humans look at face?

Saliency-Based Visual Attention model

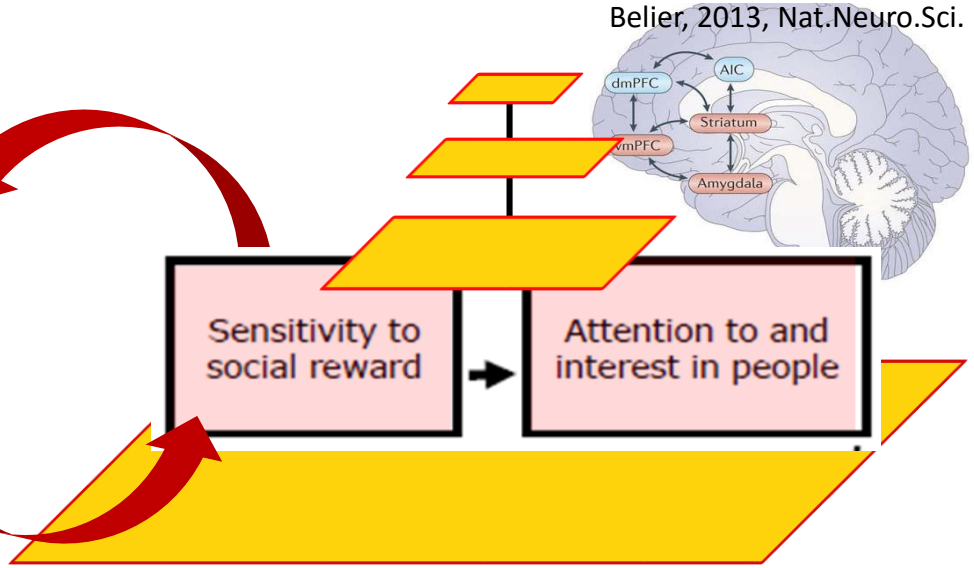
Itti et al. 1998



Disengagement, Preference

Intrinsic motivation (reward system)

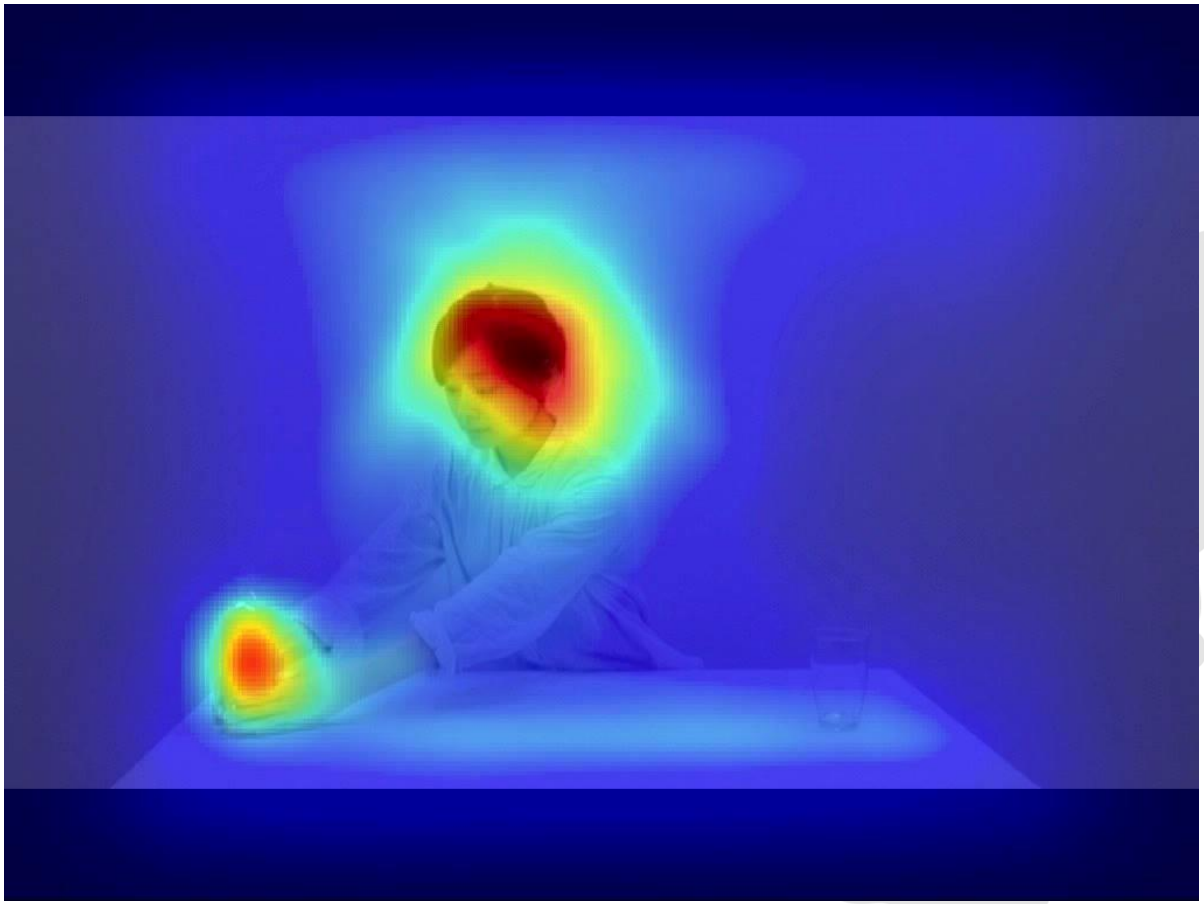
Belier, 2013, Nat.Neuro.Sci.



higher-order emotional/cognitive control system

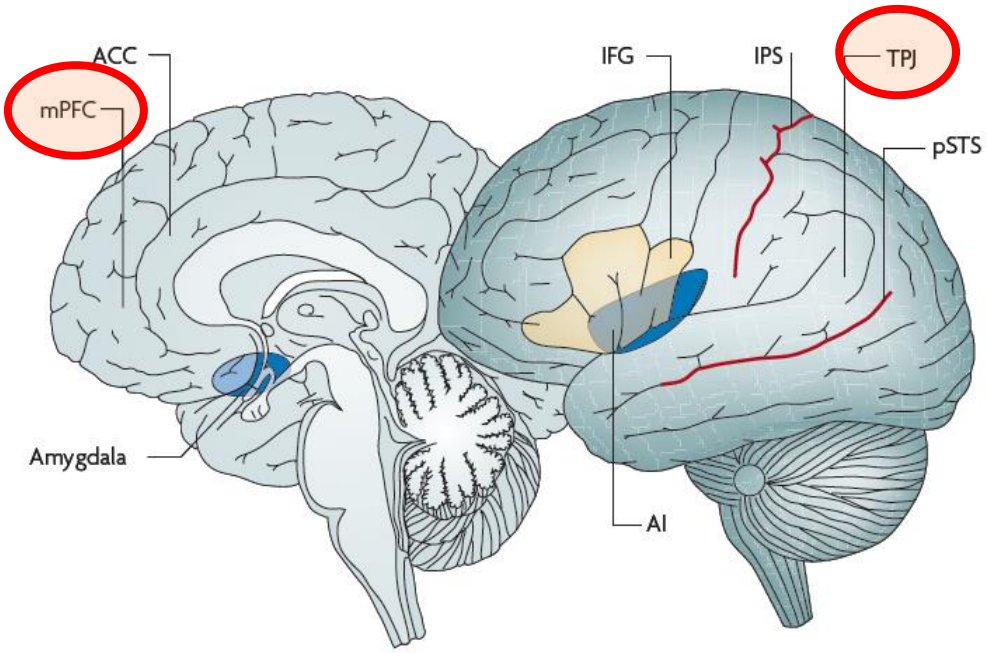
Probabilities by LL Saliency Model

Harel et al. , 2006



Myowa-Yamakoshi, Yoshida, Kawai, & Hirata, in prep.

Beyond mirror neuron system
"Mentalizing" Cognitive Process of Inferences



Blakemore, S-J., 2008, *Nat. Rev. Neurosci.*

Brain imaging in human adults

＊ Mirror neuron system

STS (Superior Temporal Sulcus)
BM perception

IPL (Inferior Parietal Lobule)
encode kinesthetic information

IFG (inferior frontal gyrus)
encode goal-orientation aspects of action,
connected with anterior insula (AI) & Amygdala

＊ Menalizing (inhibition/reasoning)

TPJ (temporo-parietal junction)
perspective taking
left＝egocentric, right ＝allocentric

mPFC (medial prefrontal cortex)
working memory, long-term memory
decision making, inhibitory control
Top-down control of IFG and STS

I think …

(1) **Familiar goal-directed actions**

- MNS (encode action goal based on own experience)
- no need to discriminate the perspectives of self and others

(2) **Unfamiliar/ambiguous actions**

- need to inhibit MNS (topdown-control)
- need to activate **the inference cognitive process** outside MNS areas
  (e.g., TPJ, mPFC…, the mentalizing circuit)

(3) Ontogenetic and evolutionary origins of latter types of action understanding?

How humans/chimpanzees see *unfamiliar/ambiguous* actions ?

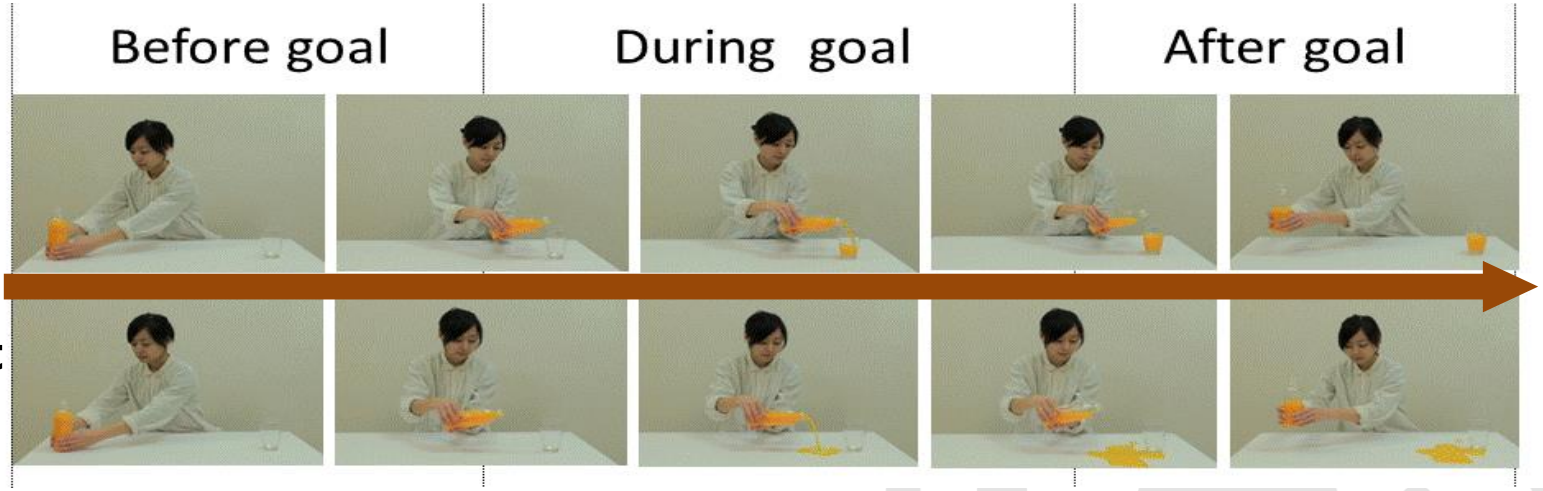
When the predicted action goal is **NOT** achieved…?

Congruent action

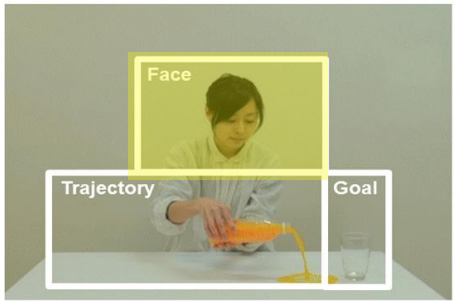
Incongruent action

Myowa-Yamakoshi, Yoshida, & Hirata, under revision

Face AOI and three phases



Congruent action

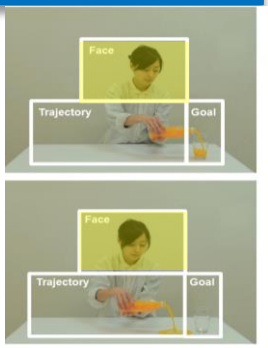


Incongruent action

Ratio of looking time at **FACE** area to total looking time in the 3 (Face+ Trajectory + Goal) areas combined

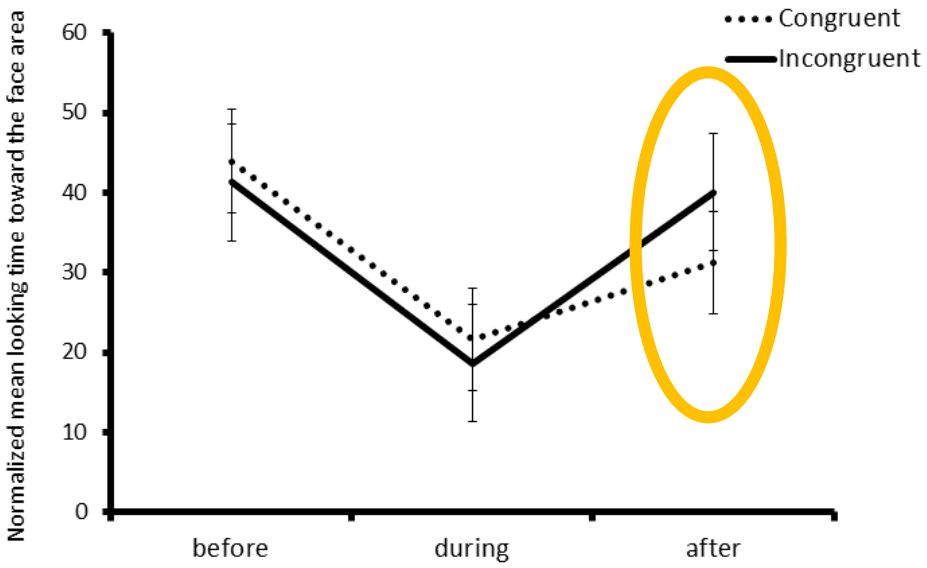
Myowa-Yamakoshi, Yoshida, & Hirata, under revision

Face AOI: Humans vs. Chimpanzees adults

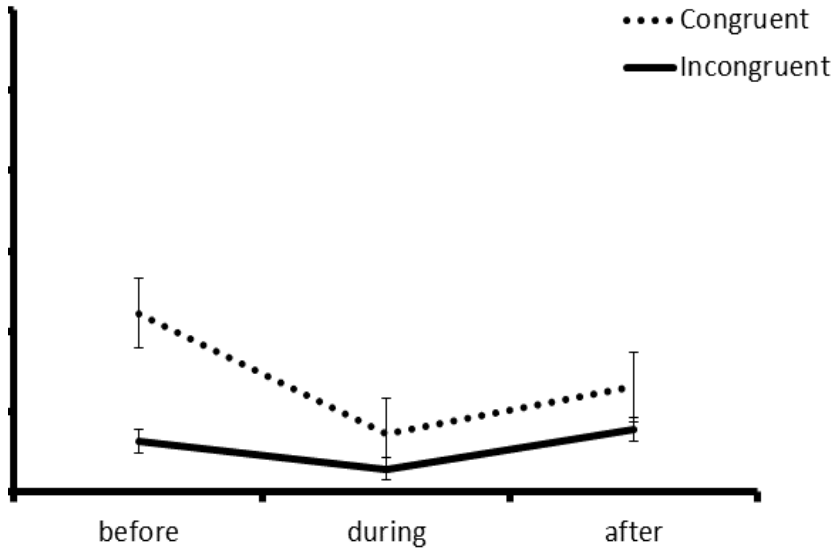


Congruent vs. Incongruent

Human adults (n=15)

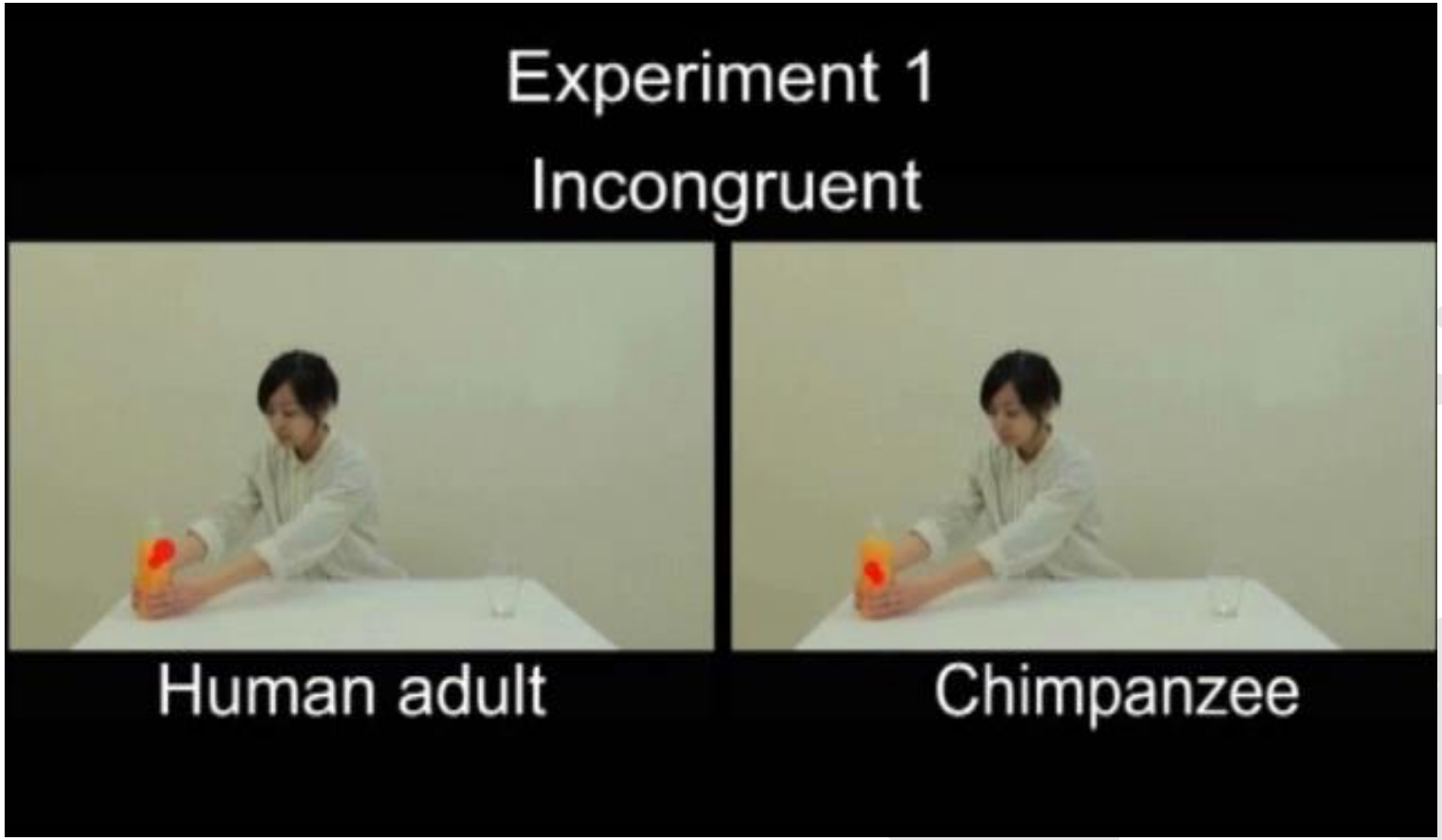


Chimpanzee adults (n=6)



Myowa-Yamakoshi, Yoshida, & Hirata, under revision

Humans vs. Chimpanzees

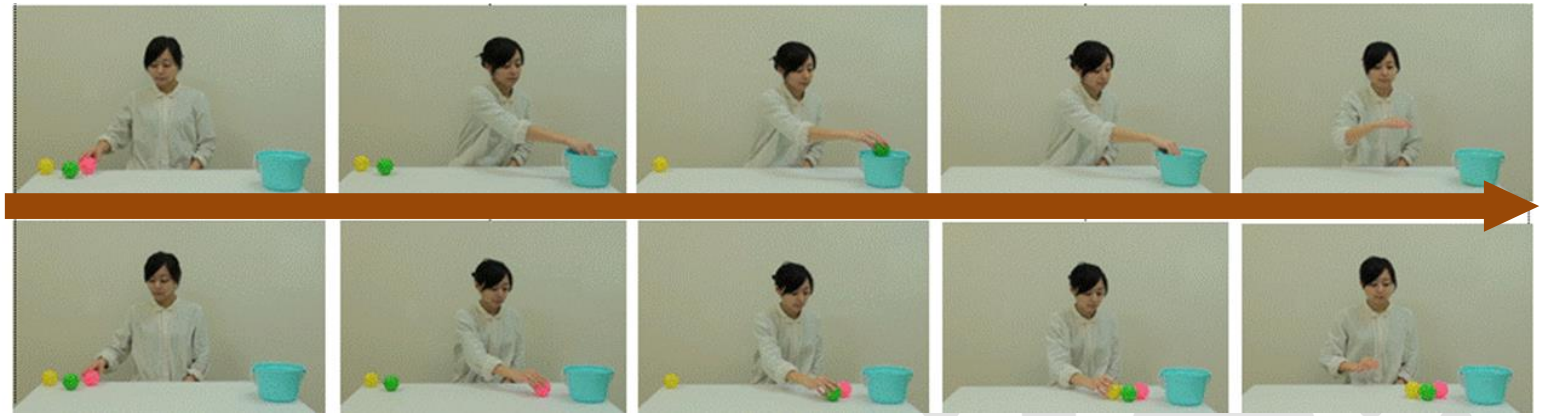


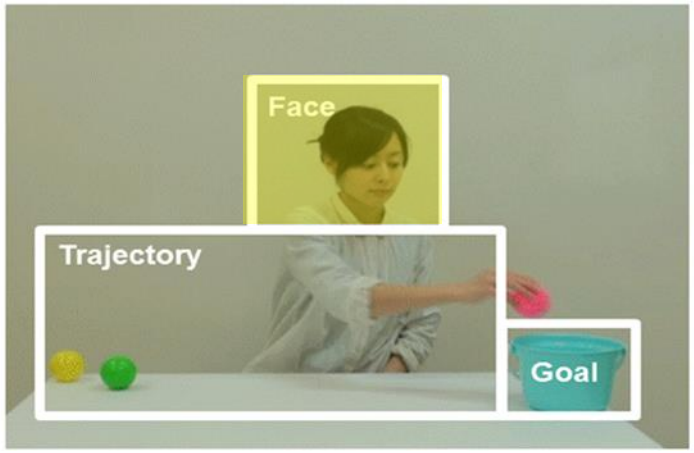
Myowa-Yamakoshi, Yoshida, & Hirata, under revision

Spatial distribution of fixations for "non-food-related" action

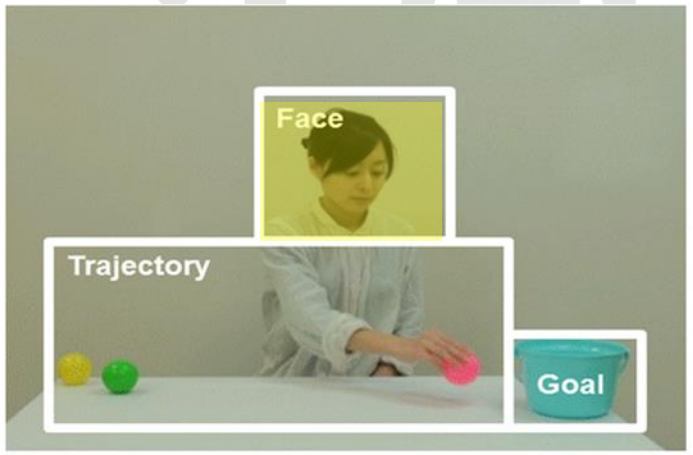
Congruent action

Incongruent action



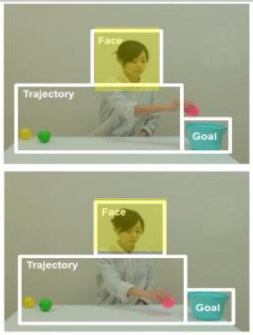


Congruent action



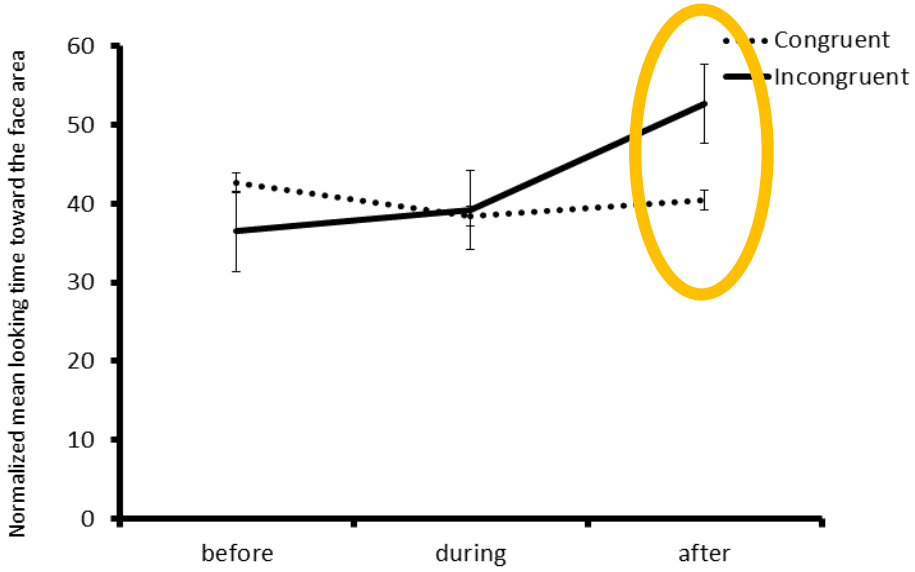
Incongruent action

Visual patterns for a "non-food-related" action

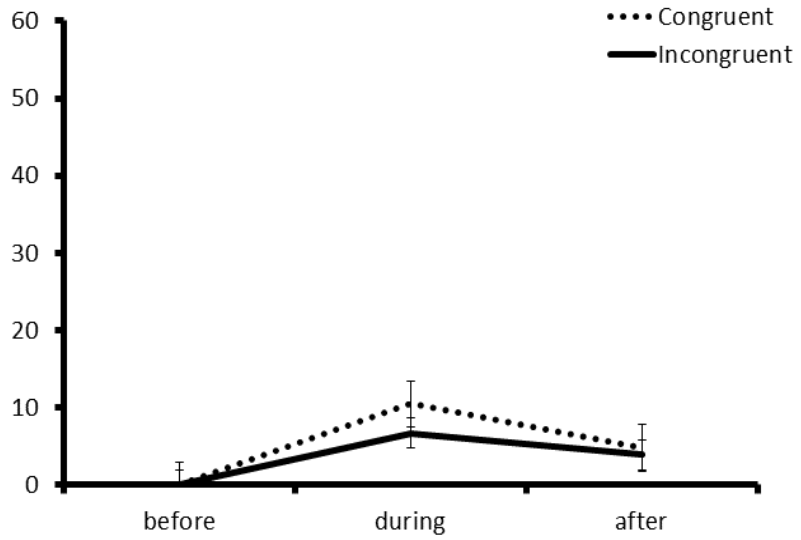


Congruent vs. Incongruent

Human adults (n=15)

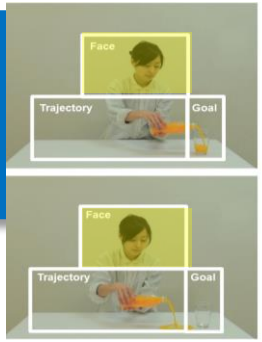


Chimpanzee adults (n=6)



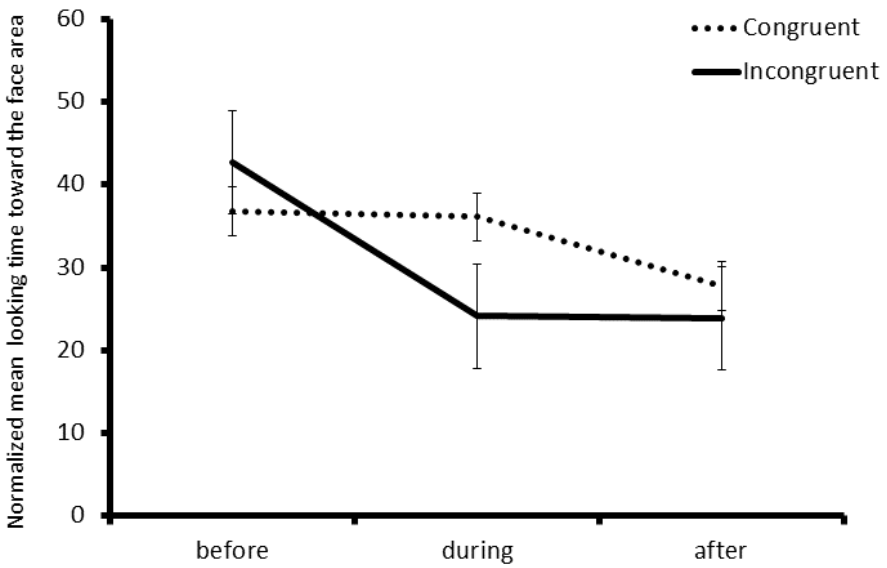
Myowa-Yamakoshi, Yoshida, & Hirata, under revision

Developmental change

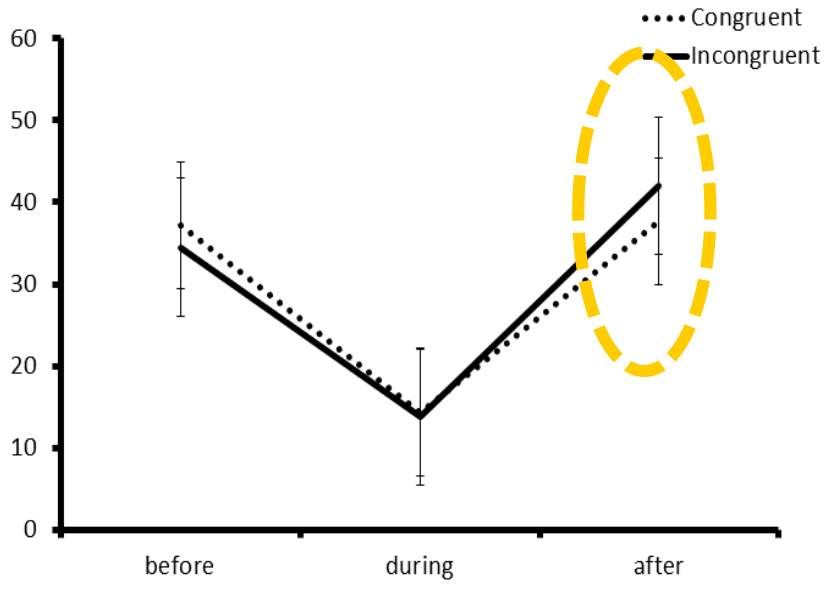


Congruent vs. Incongruent

12-month-old Human Infants (n=16)



3.5-year-old Human Children (n=16)



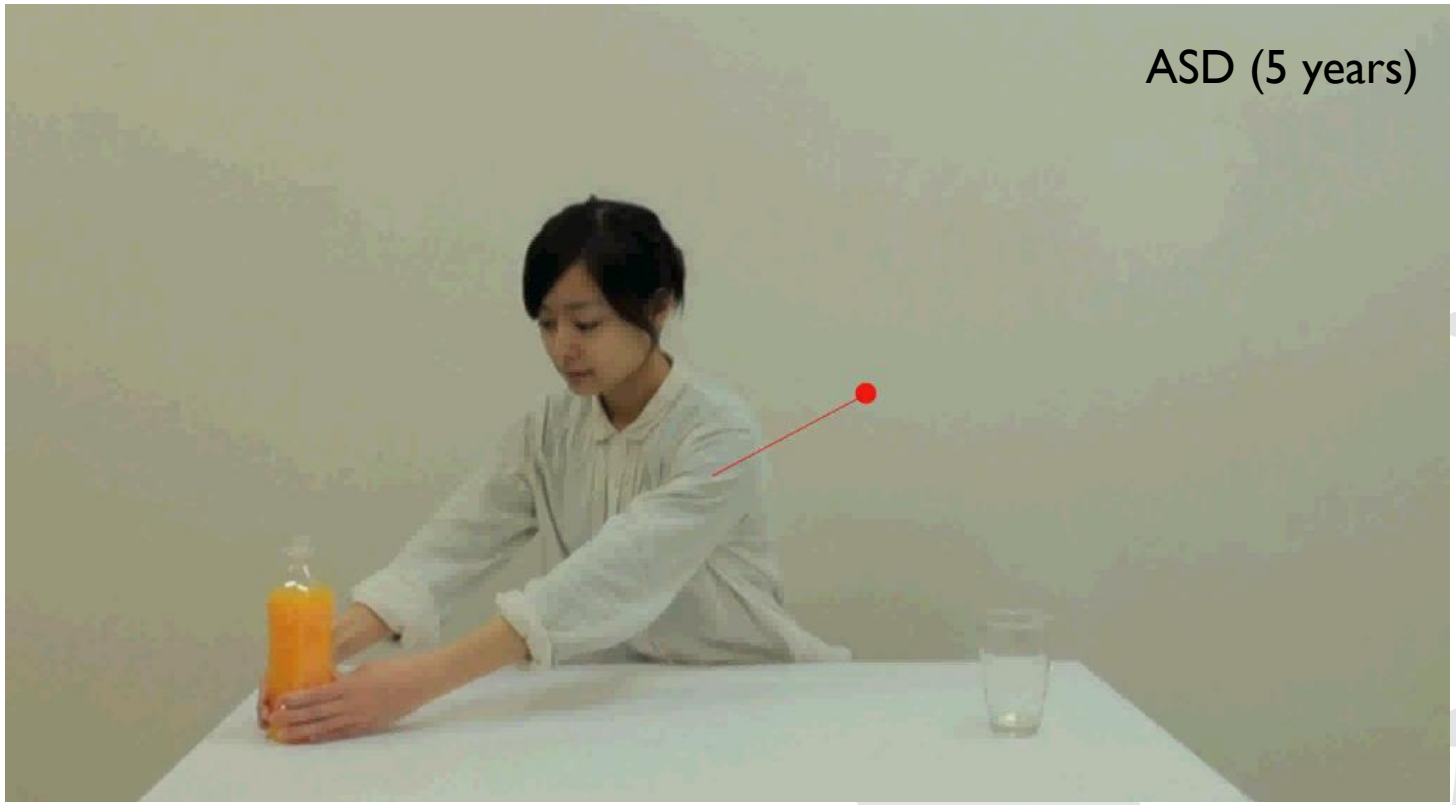
Myowa-Yamakoshi, Yoshida, & Hirata, under revision

Humans and chimpanzees differently attend to action

- Chimpanzees anticipate action goals in the same way as human adults
- Humans refer to other's face, **depending on context**
  Chimpanzees rarely pay attention to other's face
  - mainly focusing on object-related information
- Humans view goal-directed actions by integrating information of other's mental states and the manipulated objects
  - adaptive significance in human evolution?

Different attentional patterns is reflected in difference of action understanding of others

When children with ASD look at face ?



Joint research with Umino, M.D. (Aoyama Clinic, Tokyo)

Beyond automatic imitation

Humans “intentionally” imitate failed action of others

Humans show “active teaching” from early stage of life

Chimpanzees never show “active teaching”

NHK, Japan Broadcasting Corp.

Social Learning in chimpanzees

NHK, Japan Broadcasting Corp.

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