



# *Can "Synthetic Methodology" cause a paradigm shift?*

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Adaptive Machine Systems

Osaka University (lecture from U. Tokyo)

*November 21<sup>st</sup>, 2013*



Constructive Developmental Science  
Based on Understanding the Process  
from Neuro-Dynamics to Social Interaction

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2012 - 2016  
JSPS Grant-in-Aid  
for Specially Promoted Research

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# *Introduction of myself: Minoru Asada*

- [www.er.ams.eng.osaka-u.ac.jp](http://www.er.ams.eng.osaka-u.ac.jp)
- Research director of JST ERATO (Exploratory Research for Advanced Technology) Asada Project (2005-11)  
[www.jeap.jp](http://www.jeap.jp)
- The former president of RoboCup Federation (2002-8) [www.robocup.org](http://www.robocup.org)
- Principal Investigator for JSPS Grand-in-Aid for Specially Promoted Research (2012-17)  
[www.er.ams.eng.osaka-u.ac.jp/asadalab/tokusui/index\\_en.html](http://www.er.ams.eng.osaka-u.ac.jp/asadalab/tokusui/index_en.html)
- Board member of Japanese Society of Baby Science [www.childresearch.net/BABY/index.html](http://www.childresearch.net/BABY/index.html)

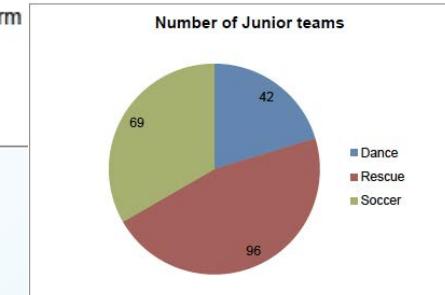
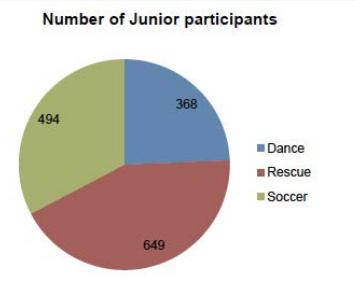
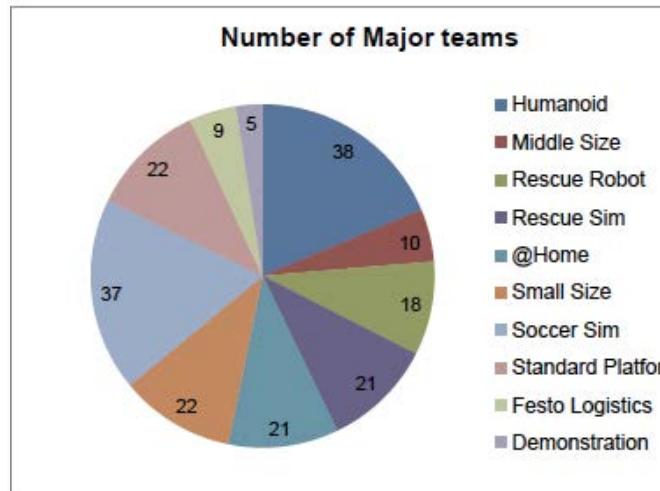
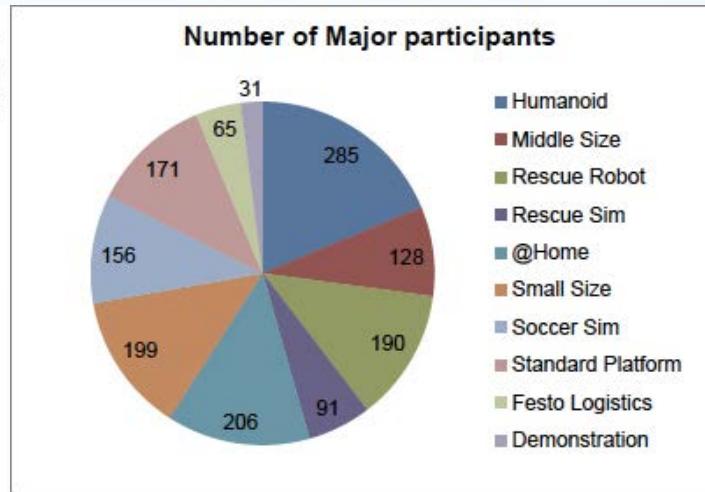




# RoboCup2013 Digest!

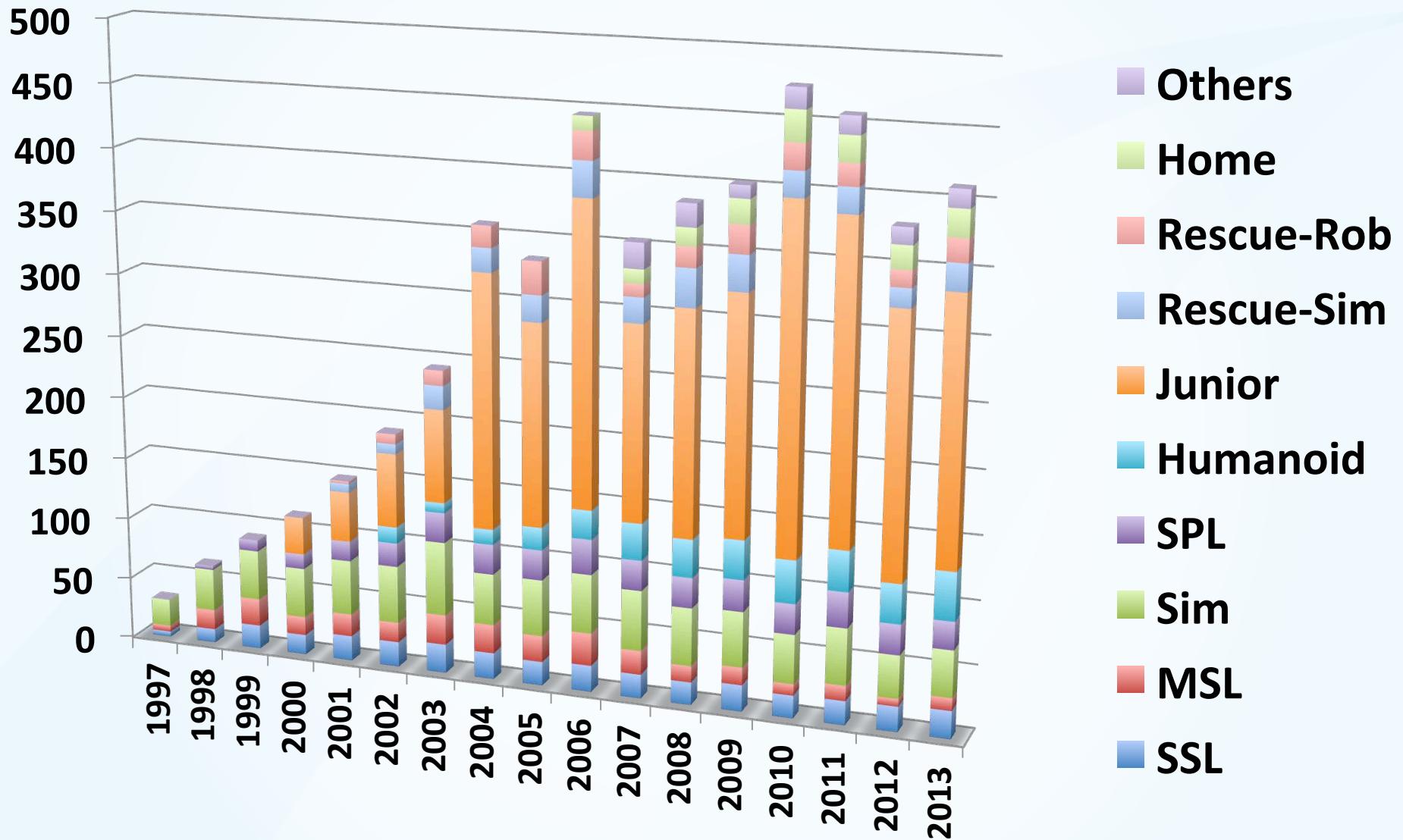


**410 teams**  
**3033 participants**  
**15770 visitors including Queen of Netherland**





# *Number of teams in RoboCups*



## ***JoiTech got the best humanoid award!***

- In RoboCup 2013, "*JoiTech*", a RoboCup joint team with Osaka University and Osaka Institute of Technology got a win, also the best humanoid award “LouisVuitton’s Cup”



<http://www.flickr.com/photos/robocup2013/9177211488/in/photostream/>

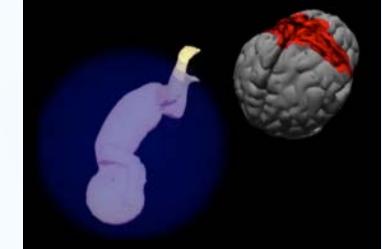


# *Outline of my talk*

1. Human development



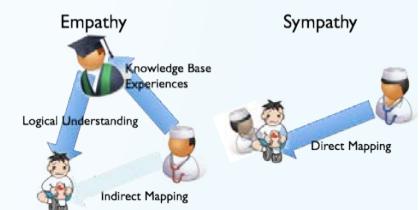
2. What are Synthetic Methodology and Paradigm Shift?



3. Cognitive Developmental Robotics



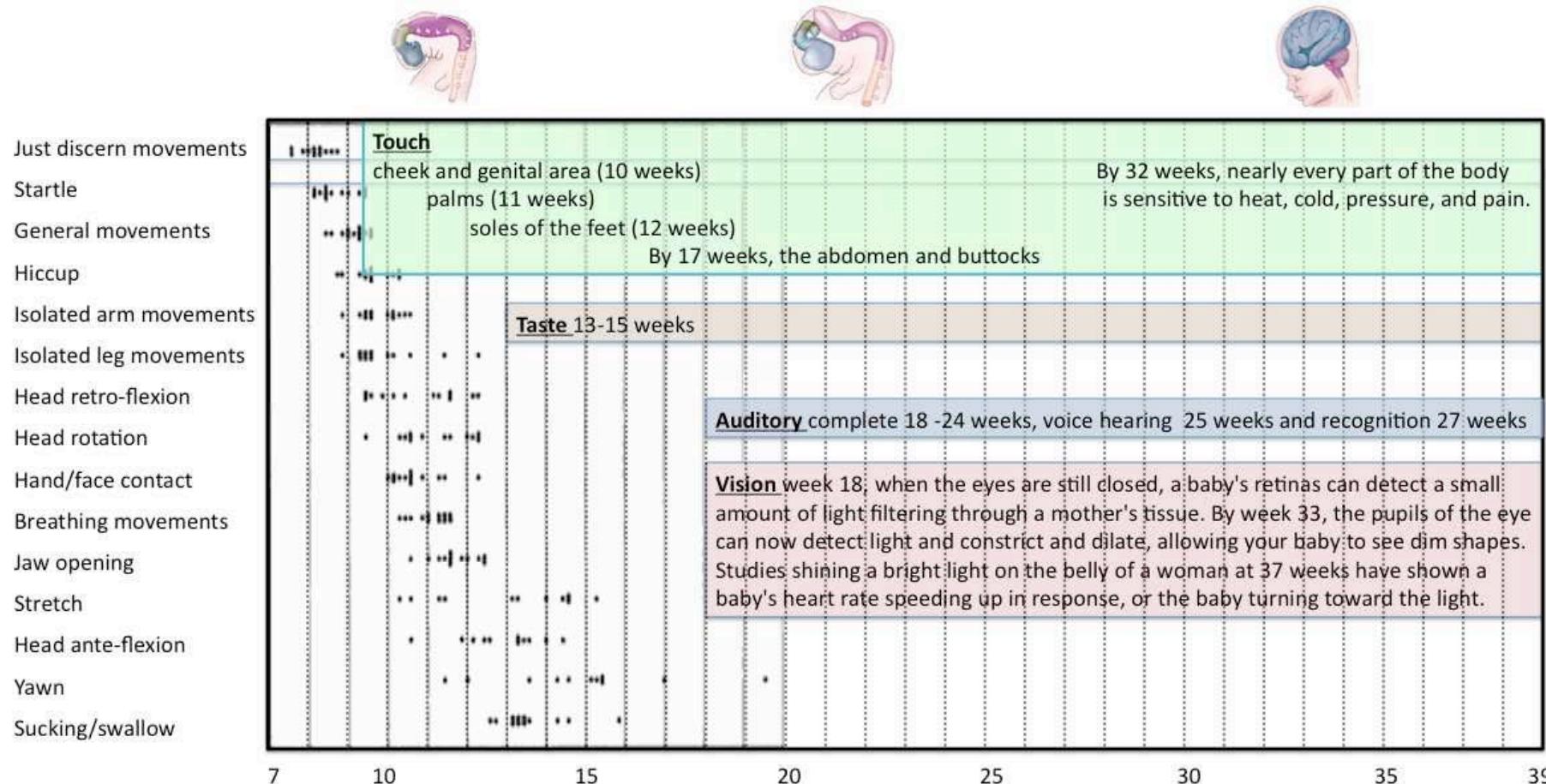
4. The Evolution of Empathy



5. Sad music induces pleasant emotion



# ■ What's going on in the womb? (1)



Emergence of fetal movements and sense (Brain figures on the top are from Figure 22.5 in [Purves et al., 08], emergence of movements is from Figure 1 in [Vries et al., 84], and fetal senses are from [<http://www.birthpsychology.com/lifebefore/fetalsense.html>]

# *Infant development and learning targets*

M	behaviors	learning targets	
5	hand regard	forward and inverse models of the hand	
6	finger the other's face	integration of visuo-tactile sensation of the face	
7	drop objects and observe the result	causality and permanency of objects	

# *Infant development and learning targets*

M	behaviors	learning targets
8	hit objects	dynamics model of objects
9	drum or bring a cup to mouth	tool use
10	imitate movements	imitation of unseen movements
11	grasp and carry objects to others	action recognition and generation, cooperation
12	pretend	mental simulation



# Nature v.s. Nurture ?

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Nature Via Nurture: Genes, Experience and What Makes Us Human Matt Ridley



*Ridley presents a history of the long debate over genes versus the environment as the dominant influence on human behavior. He asserts that "versus" is wrong. His point of departure is the recent identification of the full sequence of the human genome. "The discovery of how genes actually influence human behaviour, and how human behaviour influences genes, is about to recast the debate entirely. No longer is it nature-versus-nurture, but nature-via-nurture.*

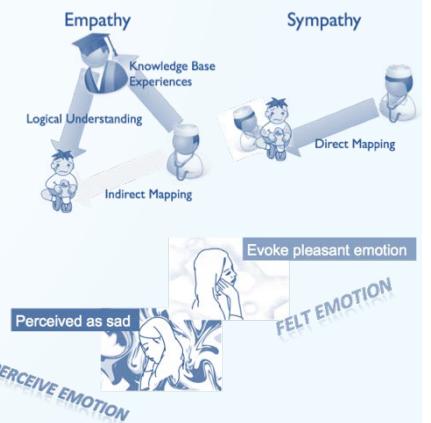
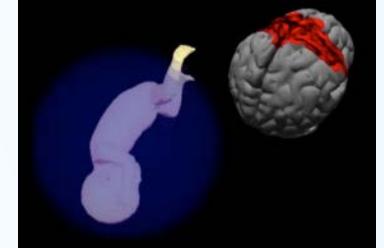
[From Scientific American]

- A balance between nature (embedded) and nurture (learning and development) sides is an issue in designing humanoids.



# *Outline of my talk*

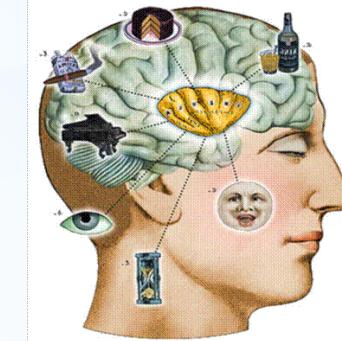
1. Human development
2. What are Synthetic Methodology and Paradigm Shift?
3. Cognitive Developmental Robotics
4. The Evolution of Empathy
5. Sad music induces pleasant emotion





# *What's Synthetic Methodology?*

- Existing disciplines → philosophy of explanations



- What are explanations? → Based on observation and analysis! → Limited to available data.



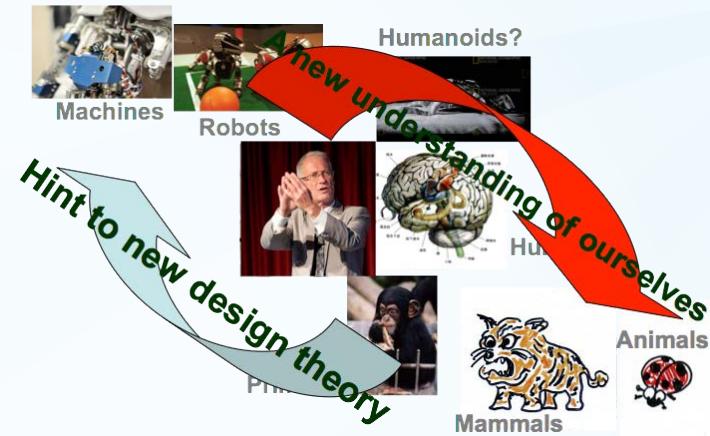
- How can we conquer this limitation?



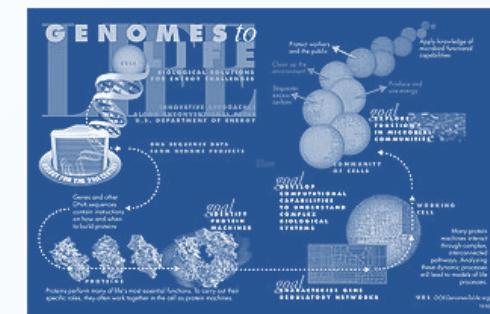


# What's Paradigm Shift?

- From the philosophy of explanations to the philosophy of synthesis (design)



- Are there any attempts? →  
Systems Biology, Synthetic  
Ethics, Systems Psychology, ...





# *Is a paradigm shift possible? (1)*

[Asada 2011]

Analysis based approach from a God's viewpoint → two-fold difficulties to understand what humans are.

1. How to understand living things. Biology → many sub-disciplines. Recent progress of the most advanced technologies → more and more microscopic such as molecular biology.
2. How to understand human beings as social agents, that involves psychology, cognitive science, and sociology.

*Interdisciplinary approach is a necessary condition!*



## *Is a paradigm shift possible? (II)*

[Asada 2011]

- Is it impossible by integrating the existing scientific disciplines?
- Is CDR completely independent from them?

→ → → → →    *Of course not!*

By involving them, CDR should give its significance by prospecting the limits of the existing scientific disciplines.



Photo by The Mainichi Newspapers



## *Is a paradigm shift possible? (III)*

[Asada 2011]

- 1) Integrate the knowledge, evidences, and findings (utilize the existing paradigms and synthesize them), → *not to deny the existing disciplines but to involve them. Therefore, CDR researchers should have the minimum amount of knowledge in these disciplines*
- 2) Build a model or a hypothesis that have no contra- diction with the existing disciplines or resolve the contradiction or controversial issues, → *a key point for the CDR researchers to hit on an idea that reflects the integrated knowledge in 1).*

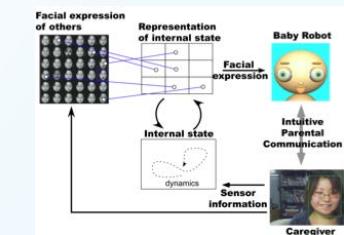
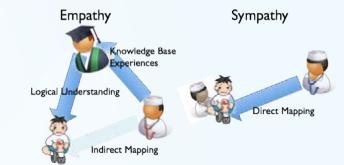
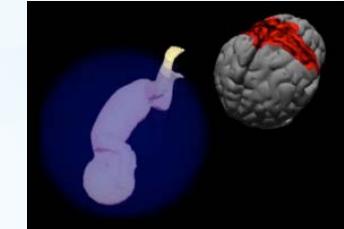


# *Is a paradigm shift possible? (IV)*

[Asada 2011]

- 3) Find a new factor that provides a solution to mystery through the verification process of the model or the hypothesis by simulations or real experiments.

The common issues are *body representation, rhythm and timing, multimodal input/output (vision, auditory, touch, somatosensory, motion, vocalization etc.), self-other separation, sociality acquisition*, and so on.





# *Is a paradigm shift possible? (V)*

[Asada 2011]



## ➤ *What's a sufficient condition?*

- If CDR can provide the *constructive and unified form of the representation* that can explain and simultaneously design the cognitive development of these issues → → → *a new value of the paradigm shift.*
- To enable this, the *studies of developmental disorders* may help the unified model construction of cognitive development.



# *Outline of my talk*

1. Human development



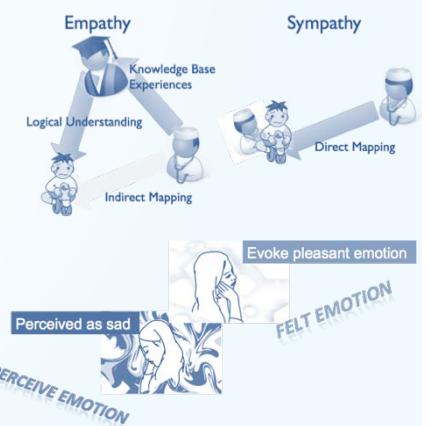
2. What are Synthetic Methodology and Paradigm Shift?



3. Cognitive Developmental Robotics



4. The Evolution of Empathy



5. Sad music induces pleasant emotion

## ■ *What is cognitive developmental robotics?*

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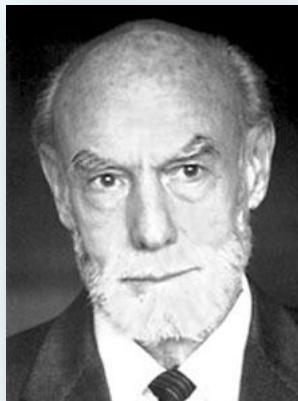
- Cognitive developmental robotics aims at understanding human cognitive developmental process by synthetic or constructive approaches.
- Its core idea is "***physical embodiment***" and "***social interaction***" that enable information structuring through interactions with the environment including other agents.



# Physical Embodiment

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- To understand the mind, begin with patterns of motor activities and derive the underlying mental structures from them. [Sperry, 1952]



## NEUROLOGY AND THE MIND-BRAIN PROBLEM

By R. W. SPERRY

Hull Anatomical Laboratory, University of Chicago

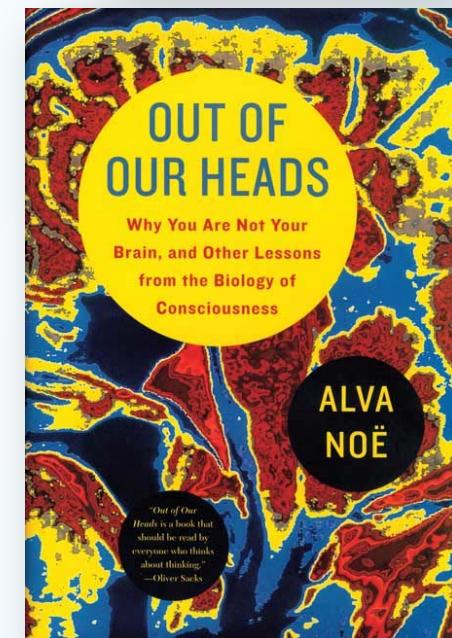
THE discrepancy between physiological processes in the brain and the correlated psychic experiences to which they give rise in consciousness has ever posed a baffling puzzle to students of psychology, neurology, and the related sciences. Despite steady advancement in our knowledge of the brain, the intrinsic nature of mind and its relation to cerebral excitation remains as much an enigma today as it was a hundred years ago.



# *Social Interaction*

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- The mind cannot be understood except in terms of the interaction of a whole organism with the external environment, especially the social environment [Noe, 2009].





# Cognitive Development

- Cognitive development seamlessly connects physical embodiment and social interaction.  
[Asada, 2009]



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IEEE TRANSACTIONS ON AUTONOMOUS MENTAL DEVELOPMENT, VOL. 1, NO. 1, MAY 2009

## Cognitive Developmental Robotics: A Survey

Minoru Asada, *Fellow, IEEE*, Koh Hosoda, *Member, IEEE*, Yasuo Kuniyoshi, *Member, IEEE*, Hiroshi Ishiguro, *Member, IEEE*, Toshio Inui, Yuichiro Yoshikawa, Masaki Ogino, and Chisato Yoshida

**Abstract**—Cognitive developmental robotics (CDR) aims to provide new understanding of how human's higher cognitive functions develop by means of a synthetic approach that developmentally constructs cognitive functions. The core idea of CDR is “physical embodiment” that enables information structuring through interactions with the environment, including other agents. The idea is shaped based on the hypothesized development model of human cognitive functions from body representation to social behavior. Along with the model, studies of CDR and related works are introduced, and discussion on the model and future issues are argued.

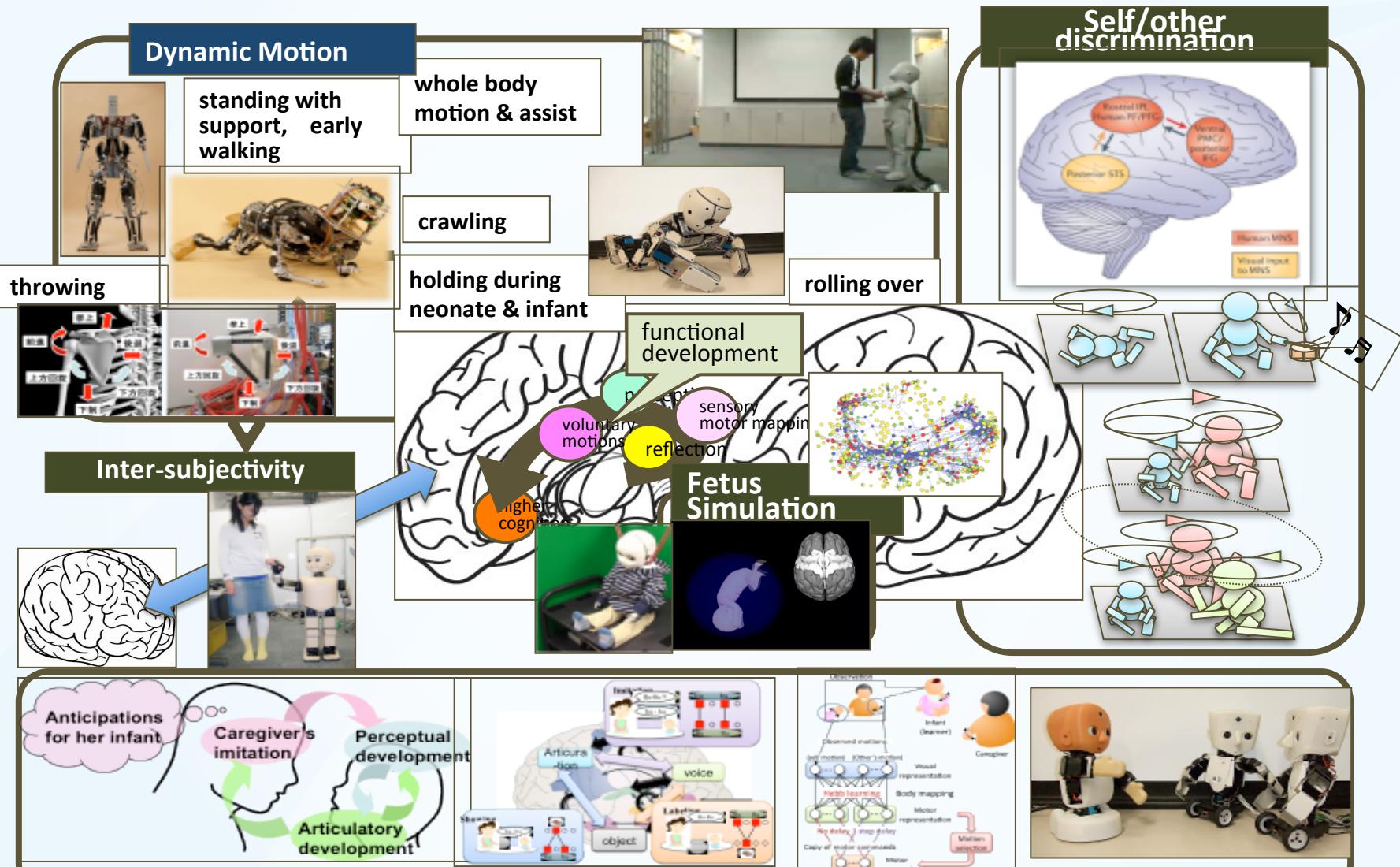
**Index Terms**—Cognitive developmental robotics (CDR), development model, synthetic approach.

### I. INTRODUCTION

MERGENCE of higher order cognitive functions through learning and development is one of the greatest challenges in trying to make artificial systems more intelligent since existing systems are of limited capability even in fixed environments. Related disciplines are not just artificial intelligence and robotics but also neuroscience, cognitive science, developmental psychology, sociology, and so on, and we share this challenge. An obvious fact is that we have insufficient knowledge and too superficial implementations based on such knowledge to declare that we have only one unique solution to the mystery. The main reasons are the following.

# From physical interaction to social one

[www.jeap.jp](http://www.jeap.jp)



From emergence of social behavior through interactions with caregiver to development of communication

# Platforms for Cognitive Developmental Approaches

15M walk alone

13M go up stairs

11M walk led by the hand

10M crawl

9M stand supported by furniture

8M stand with help

7M sit by itself

1M jaw up

0M fetal posture

(左から) M3-Neony, M3-Kindy, M3-Synchy (社会)

CB2 (社会)

↑ Pneumorn-7II (身体)  
Pneuborn-13 (身体)→

Pneuborn-7 (身体)

CB2 (社会)

Noby (対人)

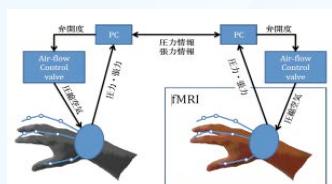
胎児・新生児シミュレーション (対人)

[www.jeap.jp](http://www.jeap.jp)



# *Our new project*

## *Towards Constructive Developmental Science: Understanding and designing the process from neural dynamics to social interaction*



- Synchronization with own body, and gradually with environment (objects), caregivers, and (de)synchronization with other persons.
- Neural dynamics → fundamental structure of synchronization
- The consequence of macro behavior → MNS: an important role of self/other discrimination and non-discrimination.

# **Basic idea for cognitive and affective development**

**(1) ecological self**

sprouting  
of self

Synchronization  
with environment



**(2) interpersonal self**

self/other identification  
(MNS infrastructure)

Synchronization  
from caregiver



**(3) social self**

Self/other  
separation

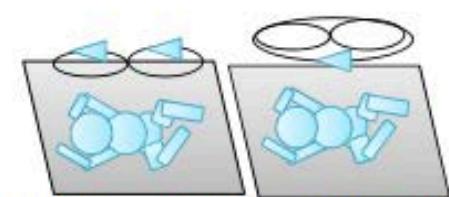
desynchronization  
from others



Physical body in synchronization → self/other identification

Desynchronization → self/other separation

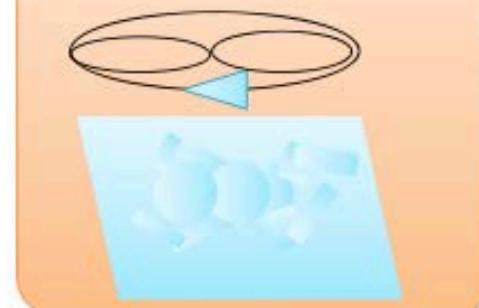
### I. Synchronizing body



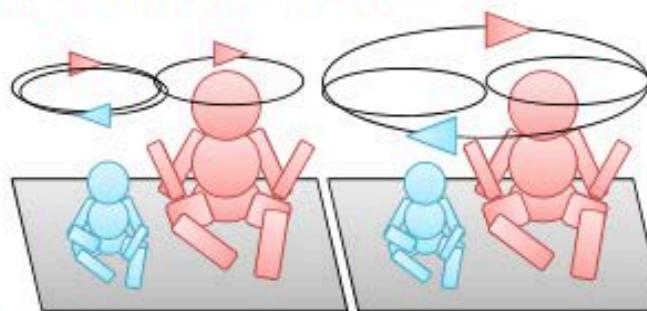
Synchronization with environment  
Rhythmic movement  
Reaching



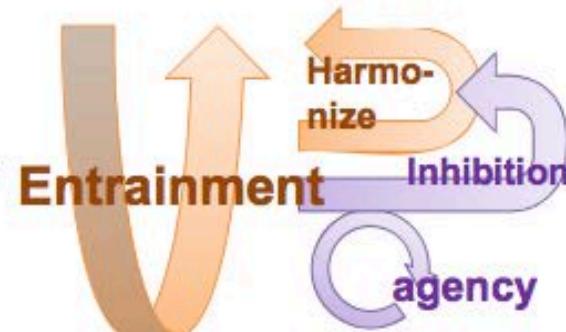
Ecological self  
(formation of phase)



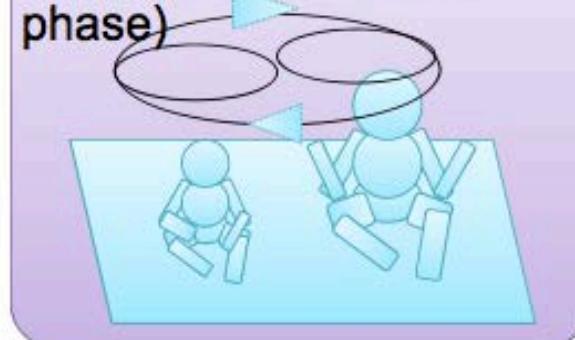
### II. Synchronization initiated by caregiver



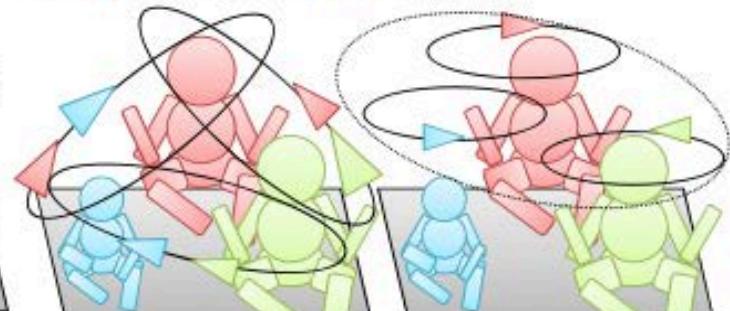
Synchronization from caregiver  
Response, Turn-taking  
imitation



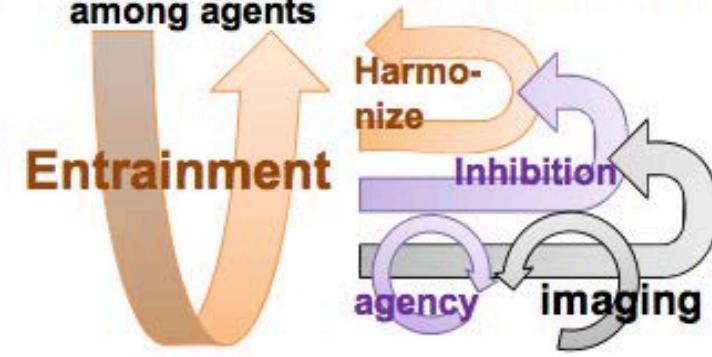
Interpersonal self  
(recognize/inhibition of phase)



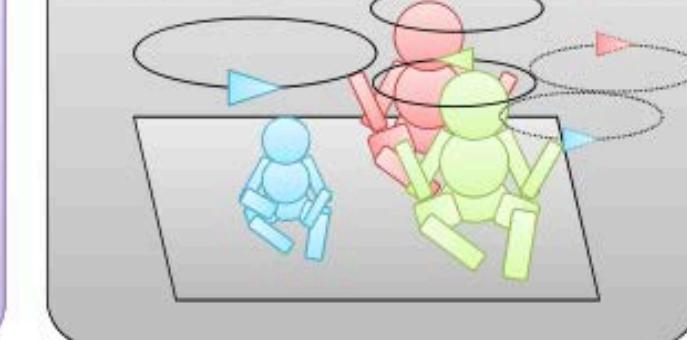
### III. Synchronizing and desynchronizing bodies



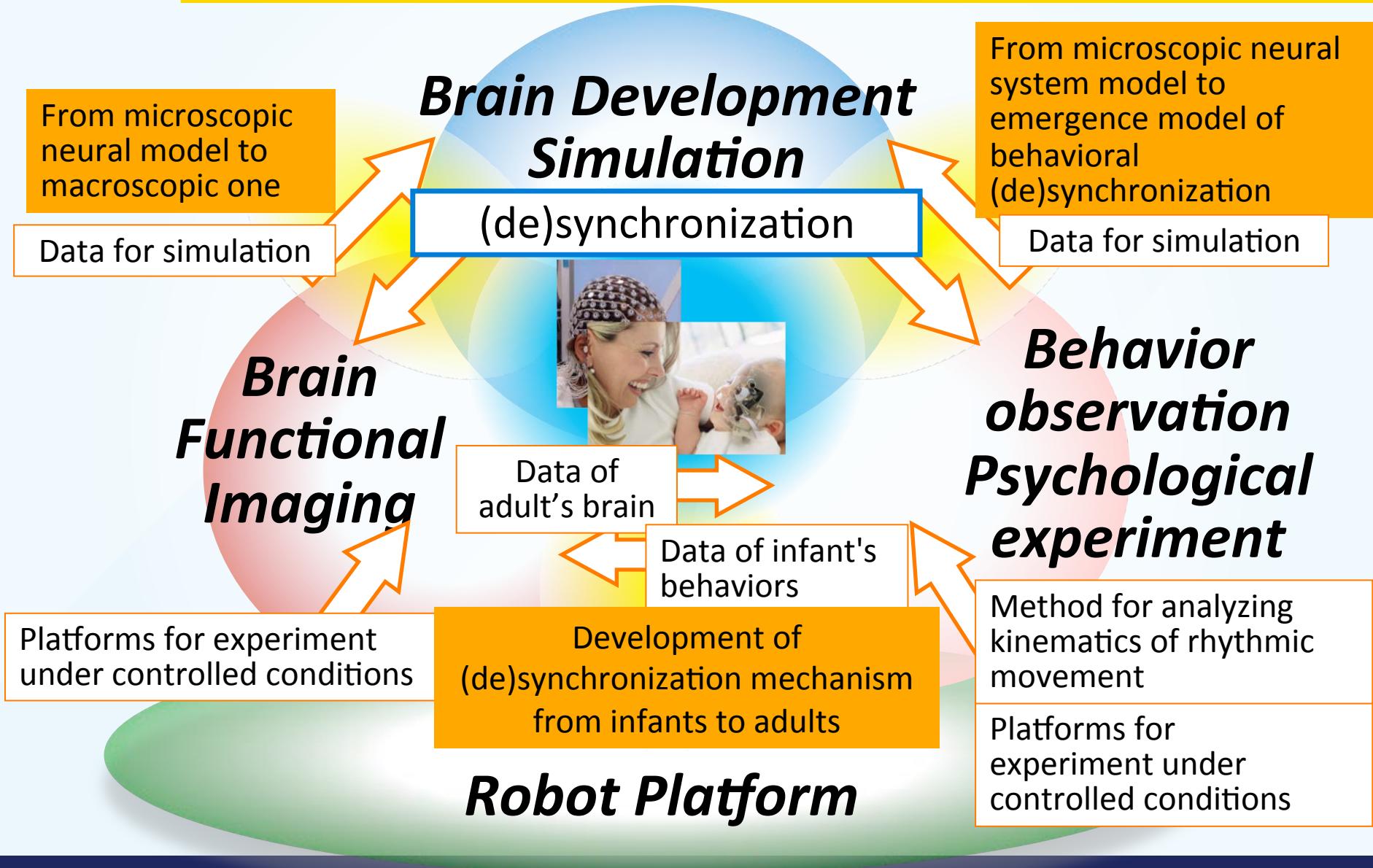
Synchronization/  
desynchronization among agents  
Prospective Synchronization



Social self (imaging and prospective control of phase)



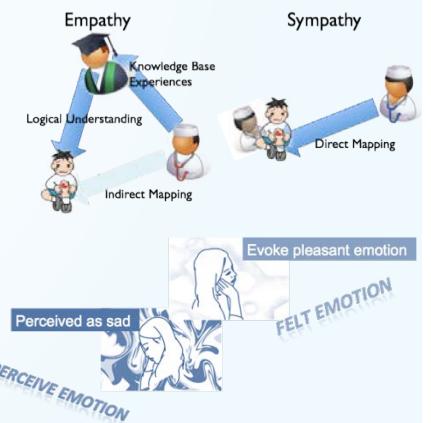
# *An overview of the whole project*





# *Outline of my talk*

1. Human development
2. What are Synthetic Methodology and Paradigm Shift?
3. Cognitive Developmental Robotics
4. The Evolution of Empathy
5. Sad music induces pleasant emotion





## *Empathy v.s. Sympathy?*

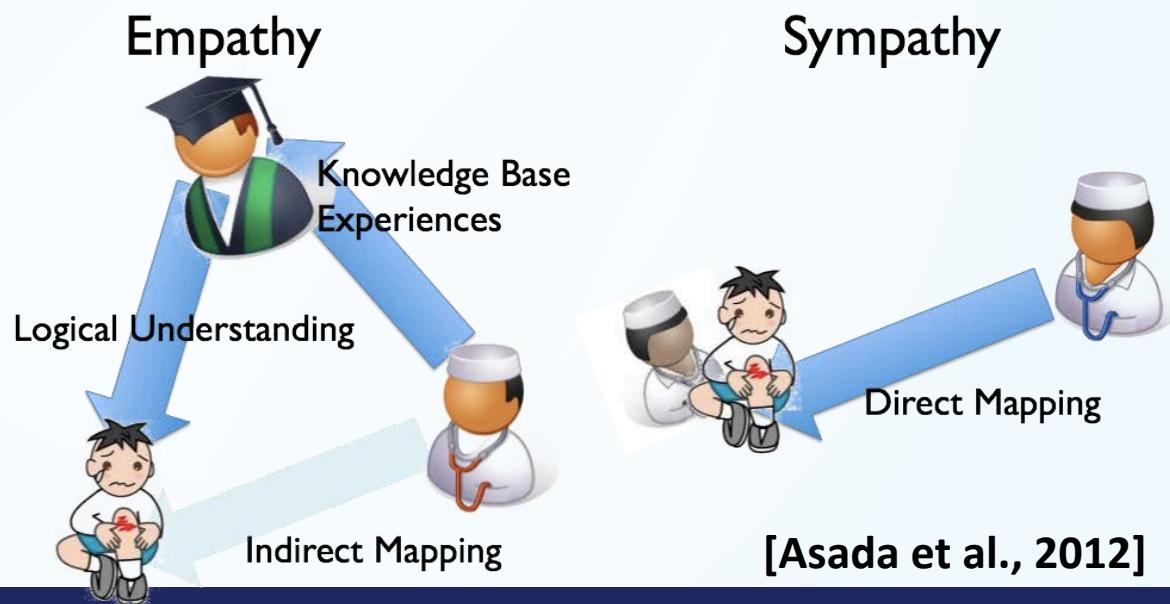
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- “Empathy” and “Sympathy” are often confusingly used.
- Beside the difference in their usage, the key component could be a sort of emotional state to be shared, and the way to represent or manipulate it might be different.
- This could be clearer when we attempt to design it for artificial agents.
- We start from a metaphor and an evolutionary study for non-human primate to approach to the artificial empathy.

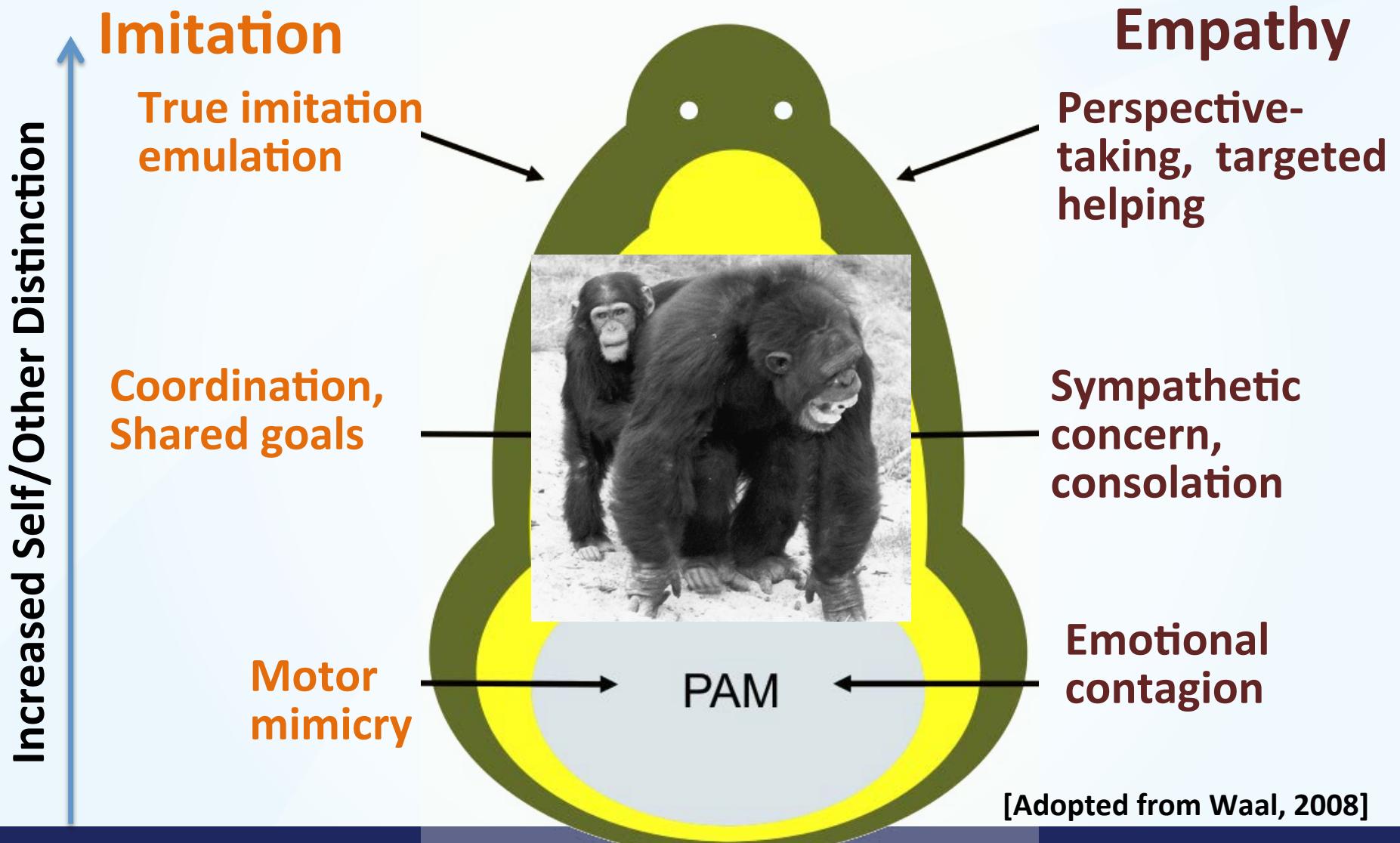
[Asada et al., 2012]

# A metaphor

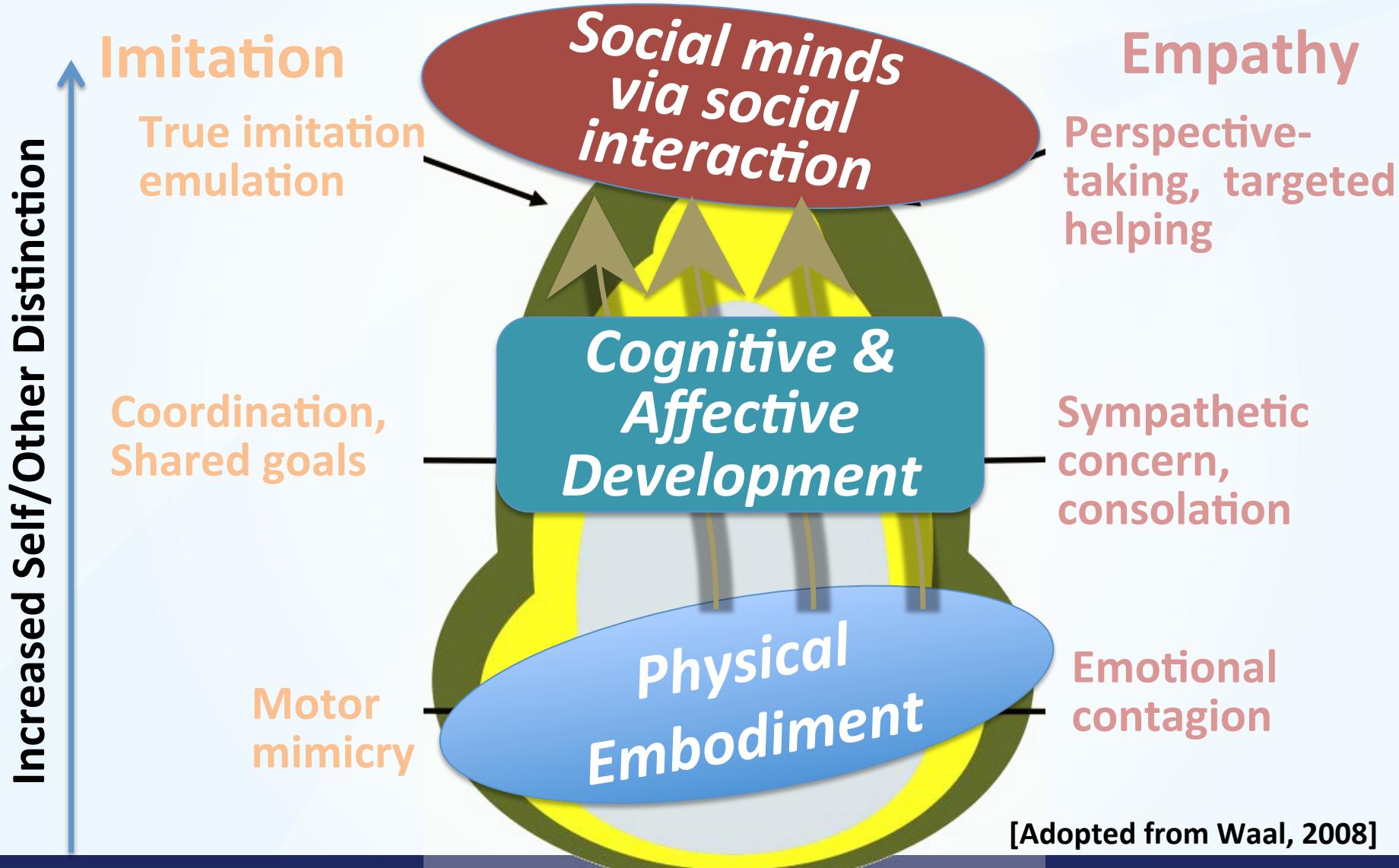
- Medical doctors can infer the distress of their patients (**empathy: perspective-taking**), and they can do adequate operations to reduce the distress of the patients (**targeted helping**). However, they often face difficulty to do any operations when the patients are their own sons or daughters (**sympathetic concern**).



# The Evolution of Empathy

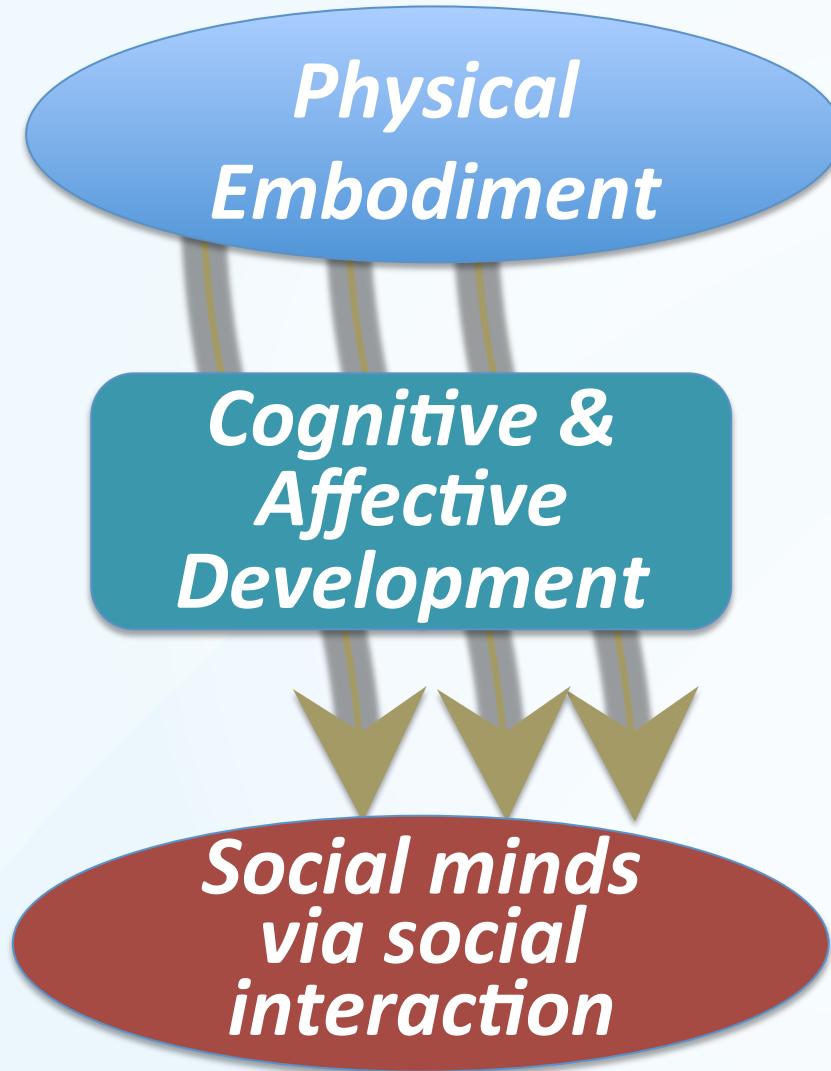


# **Constructive approaches toward social minds**





# *Towards Artificial Emotion*



- 1) Primary emotion  
(pleasant/unpleasant,  
sleep/arousal)
- 2) Differentiation of primary  
emotion to more social  
ones
- 3) Evolution of social and  
virtual emotion (human-  
specific)



# *Outline of my talk*

1. Human development



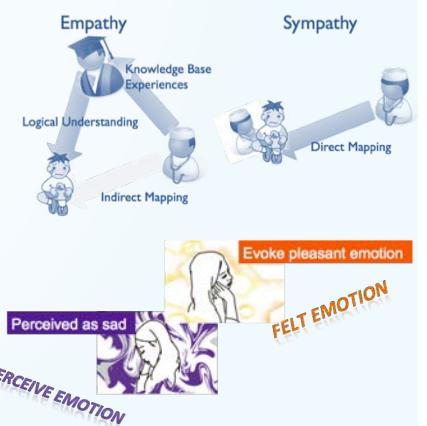
2. What are Synthetic Methodology and Paradigm Shift?



3. Cognitive Developmental Robotics



4. The Evolution of Empathy



5. Sad music induces pleasant emotion

# Sad music induces pleasant emotion

[Kawakami et al., 2013a]

frontiers in  
PSYCHOLOGY

## Sad music induces pleasant emotion

Ai Kawakami<sup>1,2,3</sup>, Kiyoshi Furukawa<sup>1,3</sup>, Kentaro Katahira<sup>2,3,4</sup> and Kazuo Okanoya<sup>2,3,5\*</sup>

<sup>1</sup> School of Fine Arts, Tokyo University of the Arts, Tokyo, Japan

<sup>2</sup> Emotional Information Joint Research Laboratory, RIKEN BSI, Wako-shi, Saitama, Japan

<sup>3</sup> OKANOYA Emotional Information Project, ERATO, JST, Tokyo, Japan

<sup>4</sup> OKANOYA Emotional Information Project, The University of Tokyo, Tokyo, Japan

<sup>5</sup> Center for Evolutionary Cognitive Sciences, Graduate School of Arts and Sciences, The University of Tokyo, Tokyo, Japan

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ORIGINAL RESEARCH ARTICLE

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In general, sad music is thought to cause us to experience sadness, which is considered an unpleasant emotion. As a result, the question arises as to why we listen to sad music if it evokes sadness. One possible answer to this question is that we may actually feel positive emotions when we listen to sad music. This suggestion may appear to be counterintuitive; however, in this study, by dividing musical emotion into perceived emotion and felt emotion, we investigated this potential emotional response to music. We hypothesized that felt and perceived emotion may not actually coincide in this respect: sad music would be perceived as sad, but the experience of listening to sad music would evoke positive emotions. A total of 44 participants listened to musical excerpts and provided data on perceived and felt emotions by rating 62 descriptive words or phrases related to emotions on a scale that ranged from 0 (not at all) to 4 (very much). The results revealed that the sad music was perceived to be more tragic, whereas the actual experiences of the participants listening to the sad music induced them to feel more romantic, more blithe,

June 2013 | Volume 4 | Article 311 | 3

# Sad music induces pleasant emotion.

- Sad music would be **perceived as sad**, but evoke pleasant emotion.

Perceived as sad



PERCEIVED EMOTION



Evoke pleasant emotion

FELT EMOTION

RELATIONS BETWEEN MUSICAL STRUCTURES AND PERCEIVED  
AND FELT EMOTIONS

AI KAWAKAMI & KIYOSHI FURUKAWA  
Tokyo University of the Arts, Tokyo, Japan  
KENTARO KATAHIRA, KEIKO KAMIYAMA, &  
KAZUO OKANOYA  
Emotional Information Joint Research Laboratory,  
RIKEN, BSI, Saitama, Japan

Musical Structures and Perceived and Felt Emotions 407

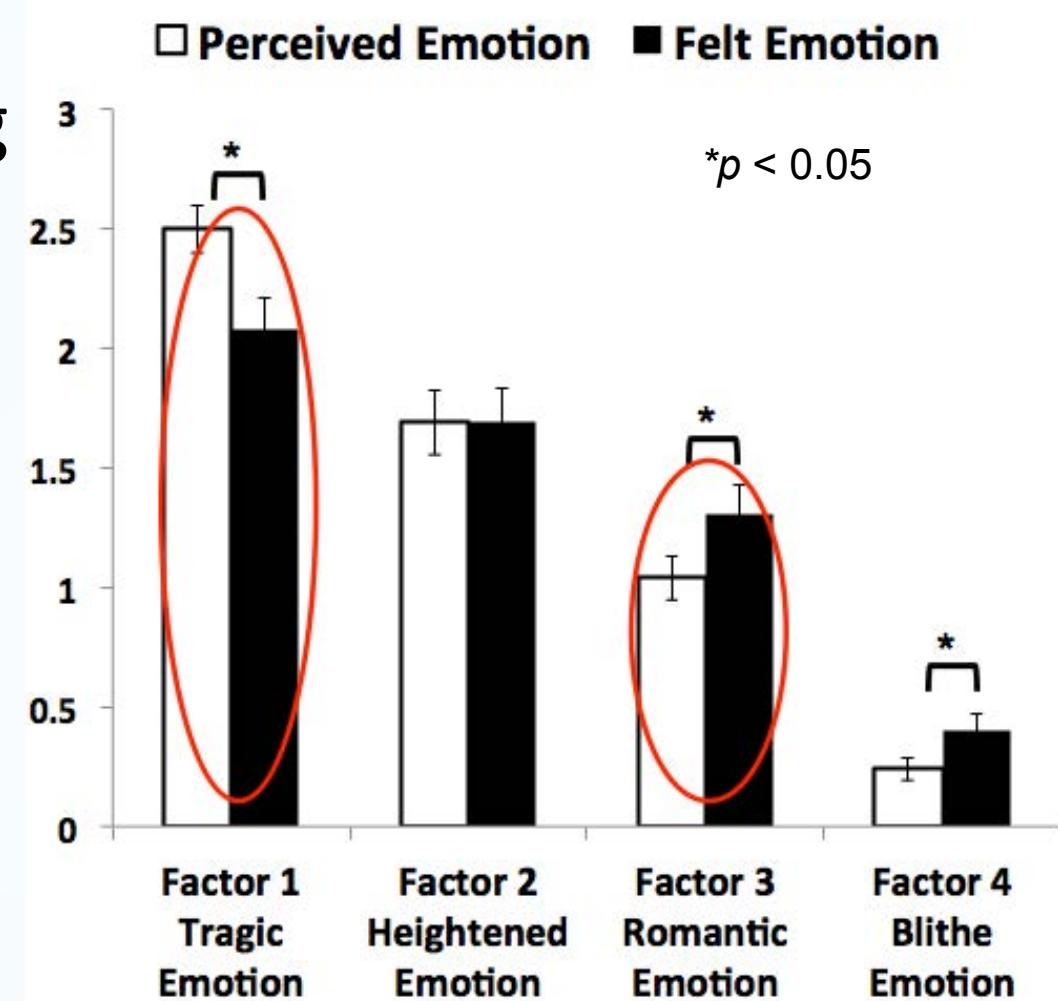
a cognitivist perspective in which music is regarded as simply representing emotions, and an emotivist perspective in which music is regarded as actually evoking emotions in listeners. Although Meyer (1956) and Krumhansl (1990) questioned the emotivist position, it is supported by the results of studies of the relations between musical structures and autonomic reactions (Krumhansl, 1990). Consequently, music is now thought to both represent

[Kawakami et al., 2013b]



## Results

- Although sad music was perceived to be more tragic, listening to sad music actually induced participants to feel more romantic, blither, and less tragic.





## *Media reacted!*

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***NYTimes***

[http://www.nytimes.com/2013/09/22/opinion/  
sunday/why-we-like-sad-music.html?\\_r=0](http://www.nytimes.com/2013/09/22/opinion/sunday/why-we-like-sad-music.html?_r=0)

***BBCradio***

[http://www.bbc.co.uk/iplayer/episode/p01gmhx6/  
The\\_Why\\_Factor\\_Sad\\_Music/](http://www.bbc.co.uk/iplayer/episode/p01gmhx6/The_Why_Factor_Sad_Music/)

***Oliver Sacks Facebook and twitter***

[https://www.facebook.com/oliversacks/posts/  
586998398022879](https://www.facebook.com/oliversacks/posts/586998398022879)

<https://twitter.com/OliverSacks>



## *Why this is interesting?*

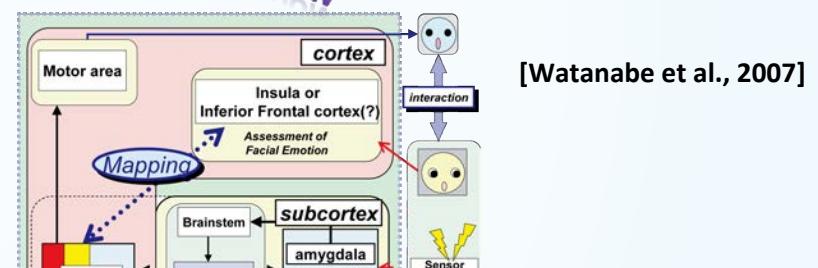
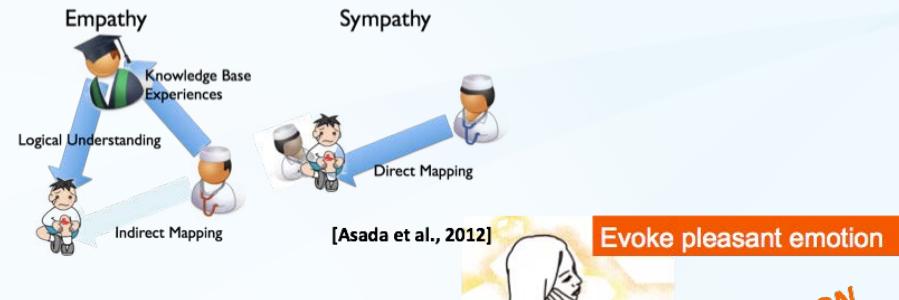
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### Empathy and Sympathy, again

- Sympathy → direct mapping of other's emotional state to self's one. Self/others non discrimination!
- Empathy → non-direct mapping of other's emotional state to self's one. Self/others discrimination!
- The above cases: same or similar emotional states, but in case of sad music, opposite emotional state happened! Self/others more discriminated!
- What's the developmental process of the above?

# Discussion

1. The relationship between empathy and sympathy can be projected to that of “perceived” and “felt” emotions.
2. This implies the underline mechanism of brain functions.
3. Development of emotion is development of self/others cognition?



[Watanabe et al., 2007]



[Communications of the ACM vol.55, no.11, 2012]



# Affetto: New Concept

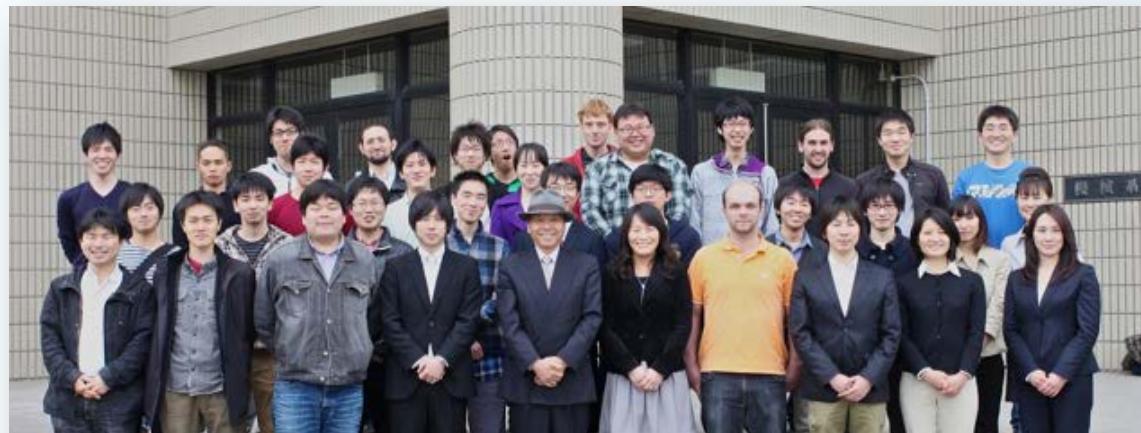
[Ishihara and Asada, 2013]

- Affetto = Android + Soft Robot + Child Robot
  - Android: Robot that has human appearance and behavior
  - Soft robot: Robot that has mechanical softness
  - Child robot: Robot that suggests a child



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Thank you  
for your  
attention!