Development of Social Cognition: Functional Neuroimaging Approach .

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Workshop on Linguistics of 'Ba'
July 4-5, 2015
Future University Hakodate
Hakodate, Japan

16:00 – 17:00 (50 min talk + 10 min discussion)

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Key question

How do we become social beings?

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Functional neuroimaging
(ACTIVATION STUDY)

The method to detect and localize
fast change in neuronal activity
related to specific tasks

regional cerebral blood flow (rCBF) changes

measured by

PET/fMRI
with
psychological experimental design

Neural activity measured by CBF
Physiological background

- **1881 Mosso** — **pulsation of the brain**
- **1890 Roy & Sherrington** — **CBF // brain function**
- **1928 Fulton** — **bruit and visual process**

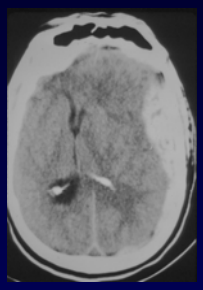
What is **ACTIVATION STUDY**?

The method to detect and localize
fast change in neuronal activity
related to specific tasks

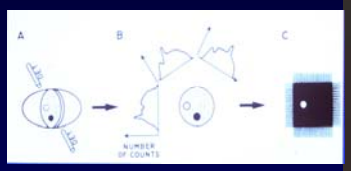
regional cerebral blood flow changes
as a measure

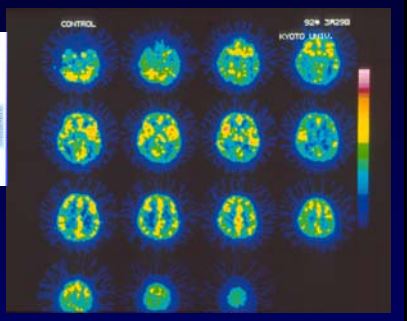
PET('80s) / fMRI('90s)
with
psychological experimental design

1975 PET (positron emission tomography) @Wash. U



Coincidence detection





X ray CT

Filtered backprojection

Imaging tissue
attenuation of
tranmitted X ray

PET
Tomography of quantified rCBF
Imaging the distribution of positron-labeled water which accumulates in proportion to rCBF (radio-tracer technique)

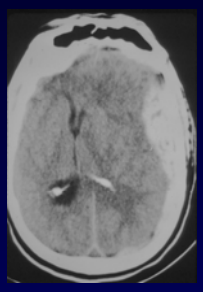
What is ACTIVATION STUDY?

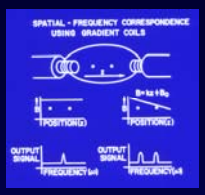
The method to detect and localize
fast change in neuronal activity
related to specific tasks

regional cerebral blood flow changes
as a measure

PET/**fMRI**
with
psychological experimental design

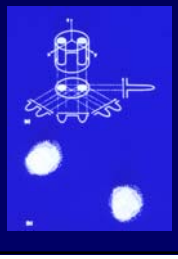
1973 Lauterbur cross-sectional imaging with MR signa

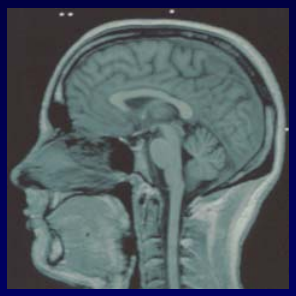




Linear gradient system

Filtered backprojection
(=2D Fourier transform)





X ray CT

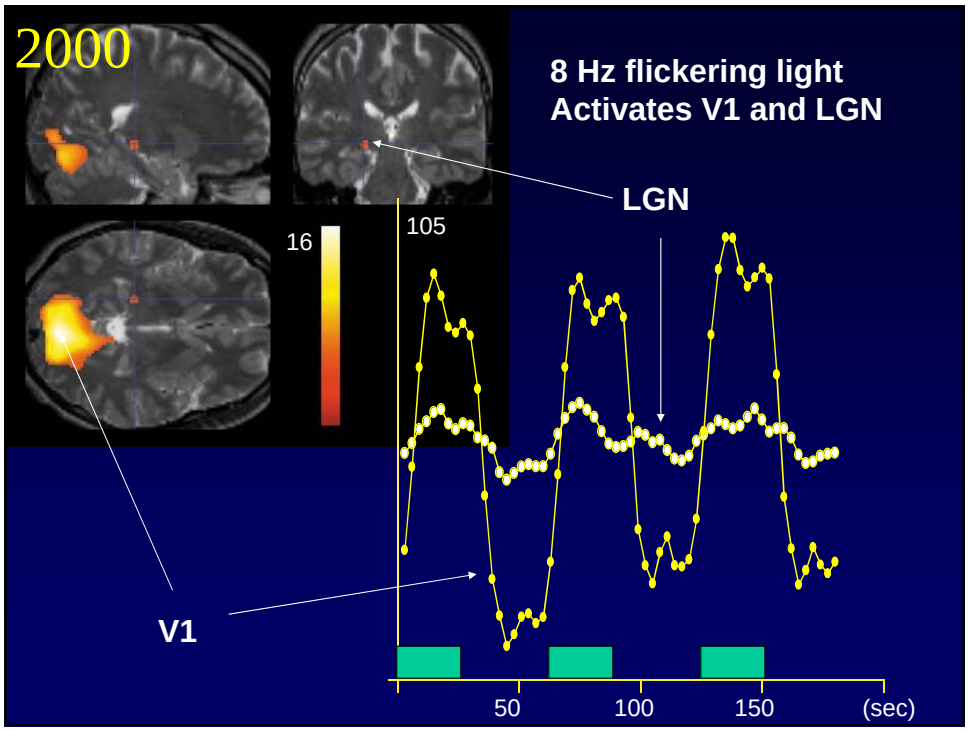
Imaging tissue
attenuation of
transmitted X ray

MRI
visualizes
distribution of proton
~detailed anatomy

1990 Ogawa **principle of functional MRI**

MRI can measure
change in rCBF

Utilizes oxygen (+ Hemoglobin)
as a marker of blood flow



Definition

Social cognition

The processing of information which culminates in the accurate perception of the dispositions and intentions of other individual.

(Brothers, 1990)

→ implies prediction of action

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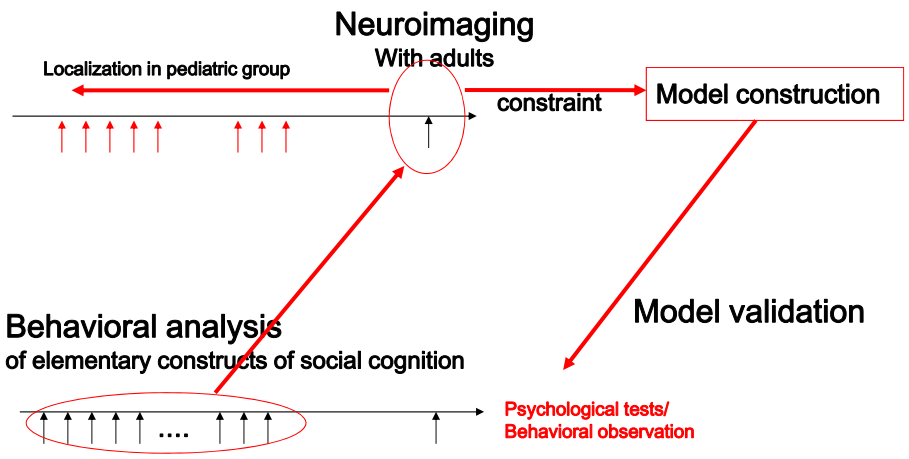
Approaches to Social Cognitive Development with Neuroimaging technique



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Development of social cognition

age	milestone behavior
0 m	neonatal imitation
4 m	social contingency
9 m	joint attention
1.5 y	self recognition
4.5 y	theory of mind
school	metaphor / sarcasm
	white lie
	moral
	empathy
	prosocial behavior

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Phylosophical consideration

Intention and action

(Searle, 1983)

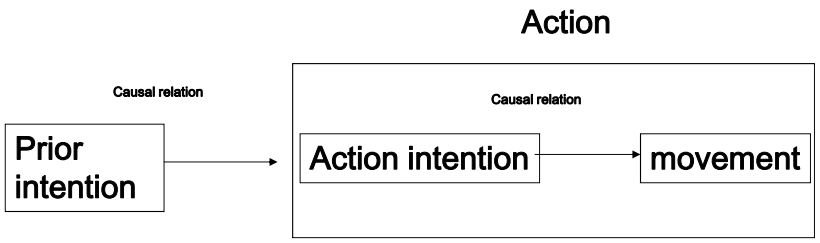
- "When I raise my arm, my arm goes up. And the problem arises: what is left over if I subtract the fact that my arm goes up from the fact that I raise my arm?" (Wittgenstein 1953)

- = Action intention

Phylosophical consideration

Intention and Action

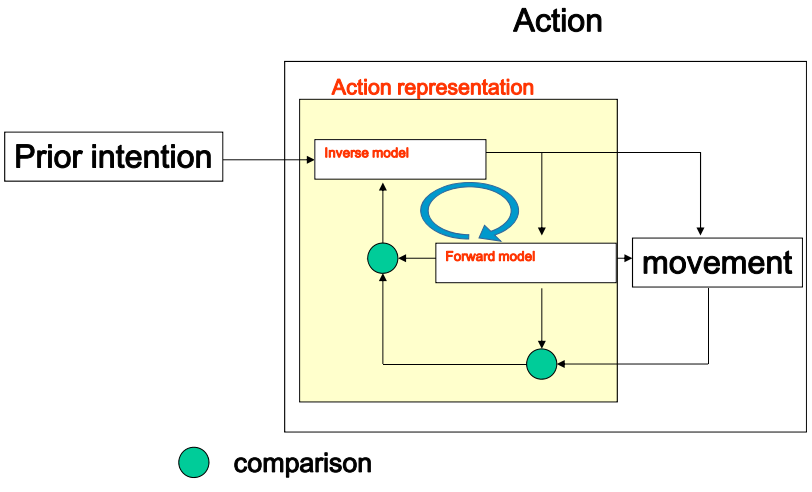
Searle (1983)



Neuroscientific extension

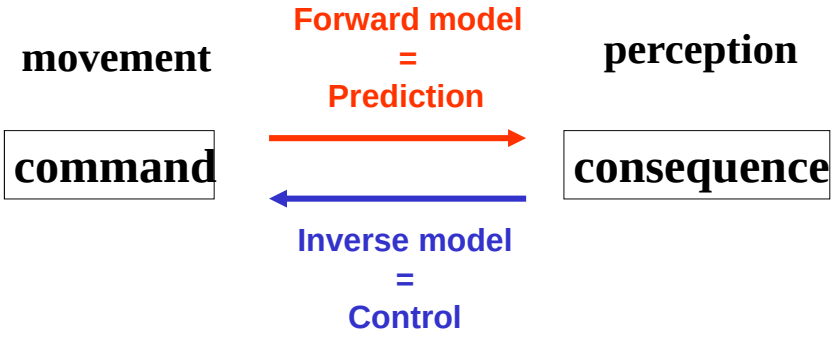
Intention and Action

Jeannerod (2006)



Model of motor control

(Wolpert et al. 2003)



Action representation

(Jeannerod 2006)

- Describes how actions are imagined, planned, intended, organized, understood, learned, and imitated
- Motoric and perceptual components tightly linked
- Perceiving another person's action activates the same representations as performing the action.

- Common coding allows to embody the behaviors of others and to infer the internal states driving them (Barsalou et al. 2003).

Action representation is important for social cognition

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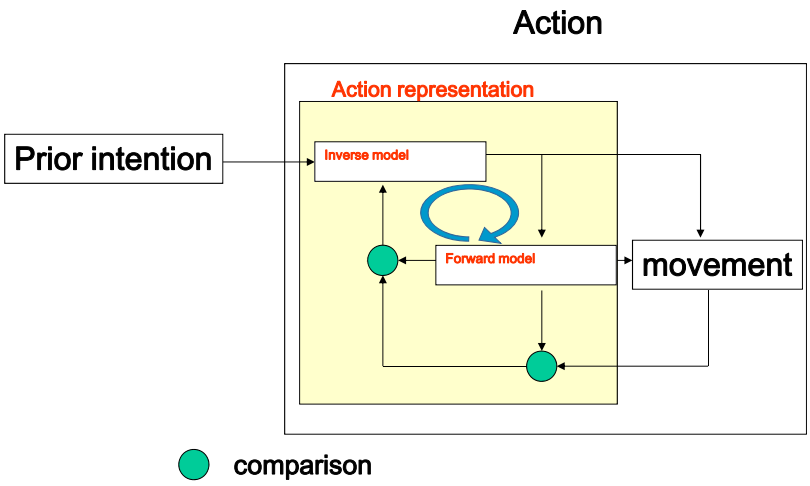
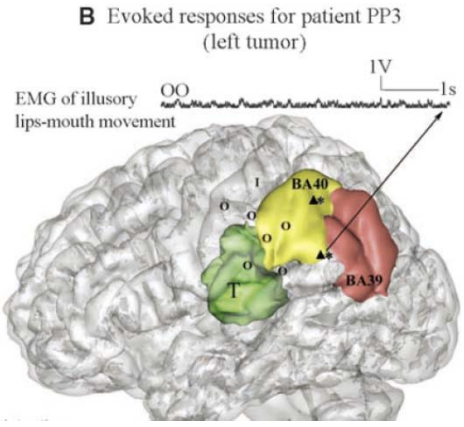
Intention and Action

Jeannerod (2006)



Electrical stimulation of the inferior parietal cortex provoked intention to move
= neural substrates of action intention

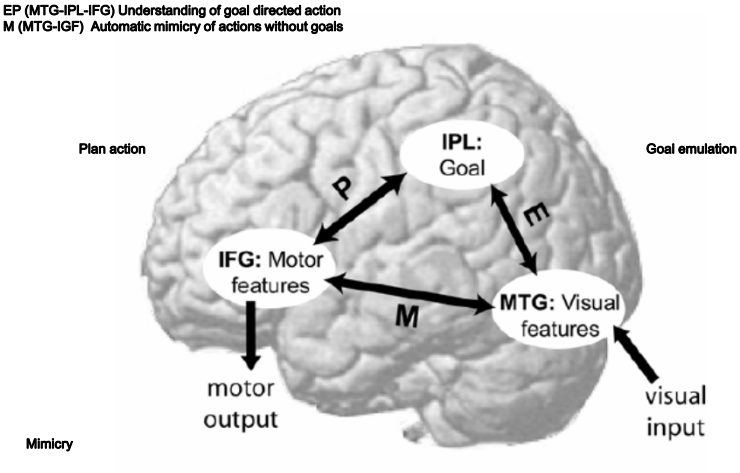


When stimulation intensity increased, motor intention was replaced by illusory movement awareness.
"The signal we are aware of when making a movement … emerge from the predictions we make about the movement in advance of action"

(Desmurget et al. 2003) *20/89*

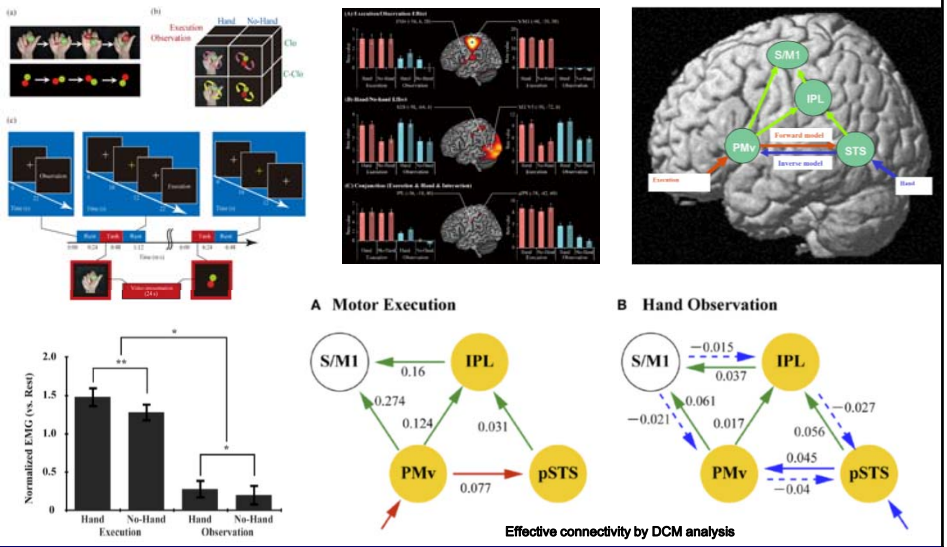
Dual pathway hypothesis of putative Mirror Neuron System EP-M model (Hamilton, 2008)

EP (MTG-IPL-IFG) Understanding of goal directed action
M (MTG-IGF) Automatic mimicry of actions without goals



Neural Networks of automatic mimicry

Constituting 2 x 2 (Execution x Hand observation) factorial design



Action representation implemented as the dynamic interaction of putative mirror neuron system and the primary sensori-motor cortex (Sasaki et al. 2012)

Development of social cognition

age	milestone behavior
0 m	neonatal imitation
4 m	social contingency
9 m	joint attention
1.5 y	self recognition
4.5 y	theory of mind
school	metaphor / sarcasm
	white lie
	moral
	empathy
	prosocial behavior

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Joint attention

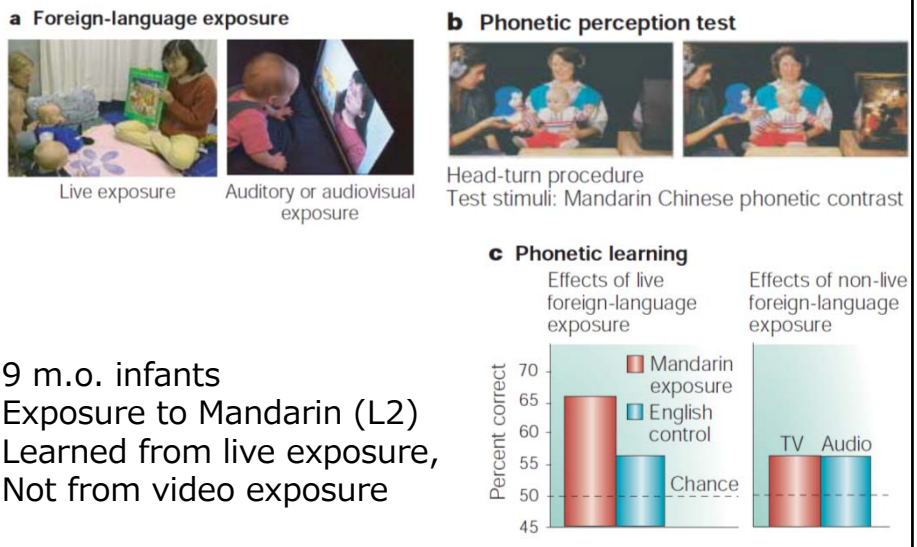
- To coordinate attention
- between interactive social partners
- with respect to objects
- to share an awareness of the objects

Joint attention

- Emerges around 6 to 12 months of age
- Through eye gaze
- Precursor of Theory of Mind
- Essential for language acquisition
- Lack of JA is an early sign of autism
- Eye-contact is prerequisite for JA

Eye-contact and JA play an important role for typical development of social behavior

Live interaction is critical for language acquisition



- 9 m.o. infants
- Exposure to Mandarin (L2)
- Learned from live exposure,
- Not from video exposure

(Kuhl, 2004)

Eye-contact

- Sharing psychological states (Travarthen, 1979)
  - intention (I am looking at you)
  - attention (I am paying attention to you)
  - emotion (proto-conversation)

Making inter-subjectivity possible

How to depict the neural substrates of "sharing"

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Synchronization as the result of interaction of multiple systems

C. Huygens (1629-1695)

✣ホイヘンスの2つの柱時計の同期実験（イメージ図）

池口研究室

メトロノーム同期 (2個，大)
Synchronization of two metronomes (Large)

2010年10月11日，池口研究室にて撮影
Filmed at Ikeguchi Laboratory, on October 11, 2010.

How to depict the neural substrates of “sharing”

- Perspect of individual brain function
  （Llinas, 2001)
  - Input-output system
    - Driven by interaction with the external world
    - External factors determine the system operation
    - Similar inputs produce similar output
    - Regular task-related functional MRI
  - Operating-on-its-own system
    - Intrinsically driven
    - External factors modulate system operation
    - Studies of spontaneous activity for the evaluation of functional connectivity (inter-regional correlation)

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How to depict the neural substrates of “sharing”

- Perspect of paired brain function
  （Llinas, 2001)
  - Input-output system
    - Driven by interaction with the external world
    - External factors determine the system operation
    - Similar inputs produce similar output
    - Regular task-related functional MRI: difficult to depict pair specific findings (because tasks are common)
  - Operating-on-its-own system
    - Intrinsically driven
    - External factors modulate system operation
    - Studies of spontaneous activity for the evaluation of functional connectivity (inter-**subject** correlation)

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Our approach to the neural substrates of joint attention & eye contact

- Joint attention
  - Eye-cue based input-output system
- Eye contact
  - Synchronization of two “Operating-on-its-own” system
    - Sharing psychological states
    - Inter-subjective synchronization of the residual time series after model-out of the task-related activity

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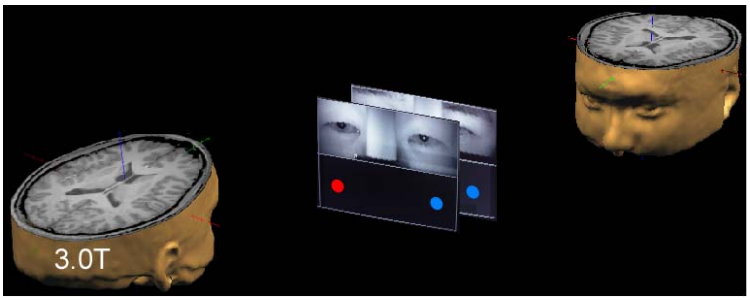
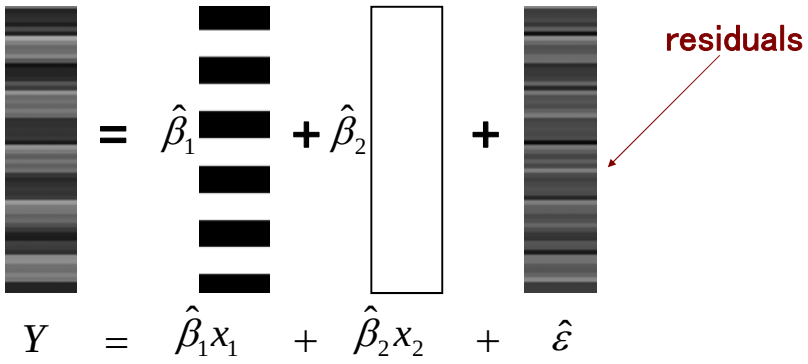
Hyperscanning fMRI during joint attention task



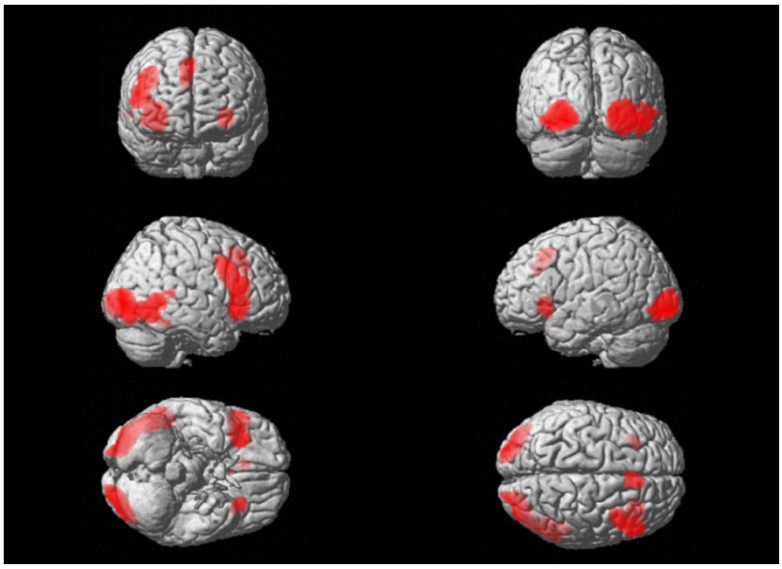
Using Dual fMRI system (prototype: 3.0T – 1.5T @Fukui Med School) 33

How to obtain *state-related* activities



The residual time series after model-out of the task-related

Eye Cue effect (Eye – Object)



P<0.05 FWE corrected

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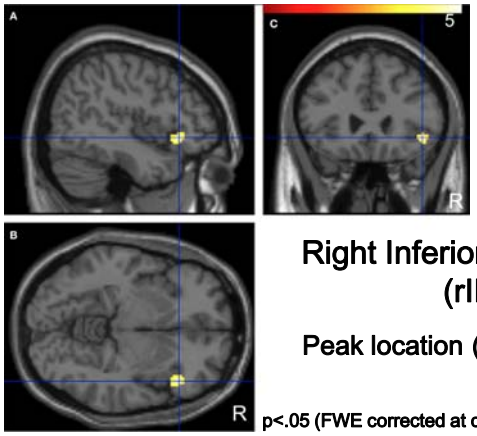
Inter-subject correlation in the rIFG

High correlation in pair (Pair – NonPair)



Right Inferior frontal gyrus (rIFG)

Peak location (46,26,-6)

p<.05 (FWE corrected at cluster level)

Saito & Tanabe et al (2010)

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Questions

- What does the synchronization represent?
- Could the synchronization be learned?
- What is the role of the right IFG?

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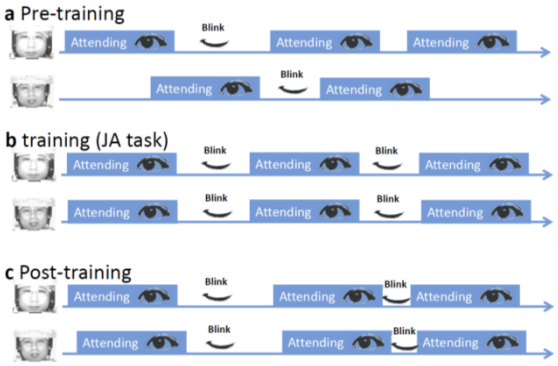
Blink

- Blink of the speaker and listener are entrained at the pause of the conversation
  （Nakano and Kitazawa, 2010）
- → Synchronization of blink may represent the shared attention

Hypothesis

- Joint attention synchronizes the attentional window
- Joint attetntion task enhances shared attention through Hebbian learning
- Right IFG is where Hebbian learning occurs



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Serial hyperscanning fMRI (mutual gaze –JA mutual gaze)
To evaluate the inter-subject connectivity *per se*

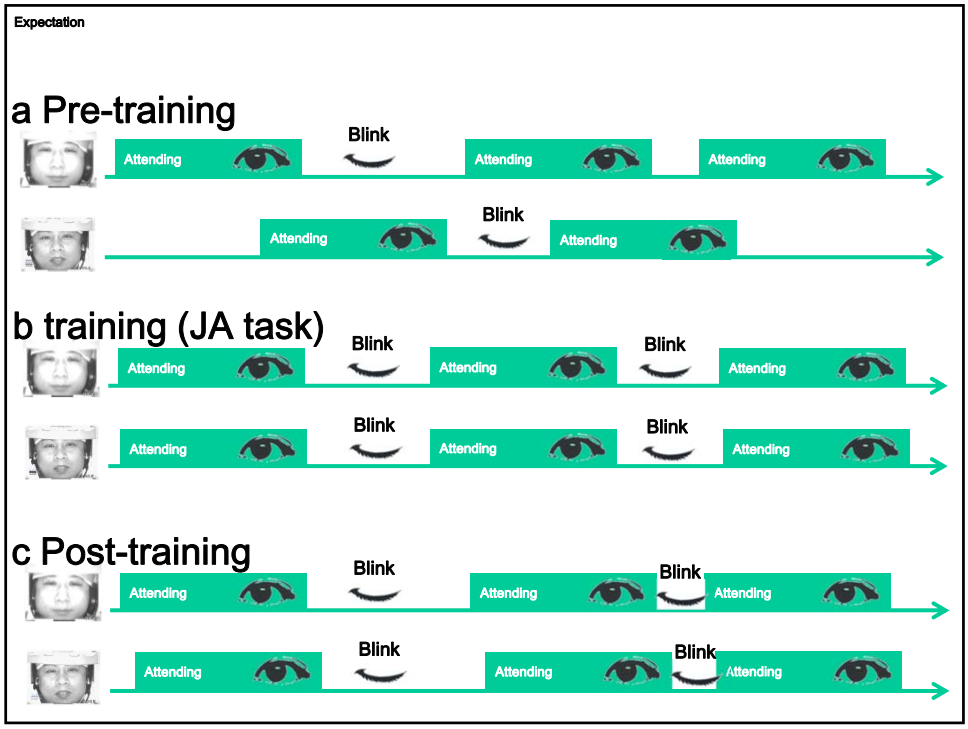
Day 1 | **Day 2**

Live mutual gaze

JA tasks

Live mutual gaze + Control condition (video)

Using Hyperscanning fMRI system (3T-3T) @ Okazaki


Expectation
a Pre-training
Attending
Blink
Attending
Attending
Attending
Blink
Attending
b training (JA task)
Attending
Blink
Attending
Blink
Attending
Attending
Blink
Attending
Blink
Attending
c Post-training
Attending
Blink
Attending
Blink
Attending
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Blink
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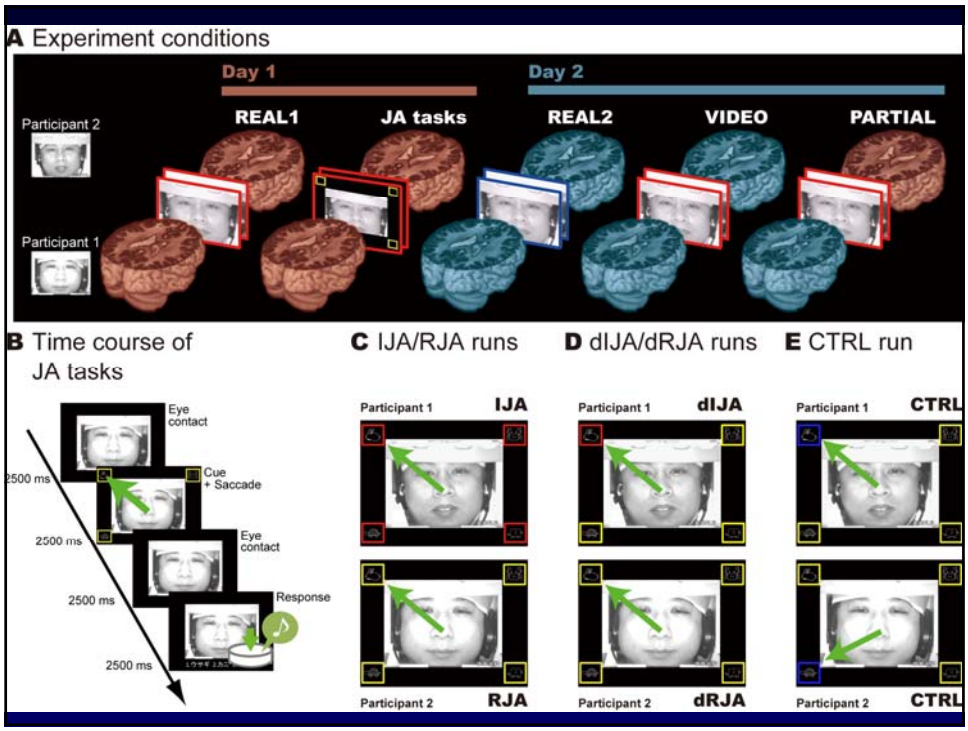
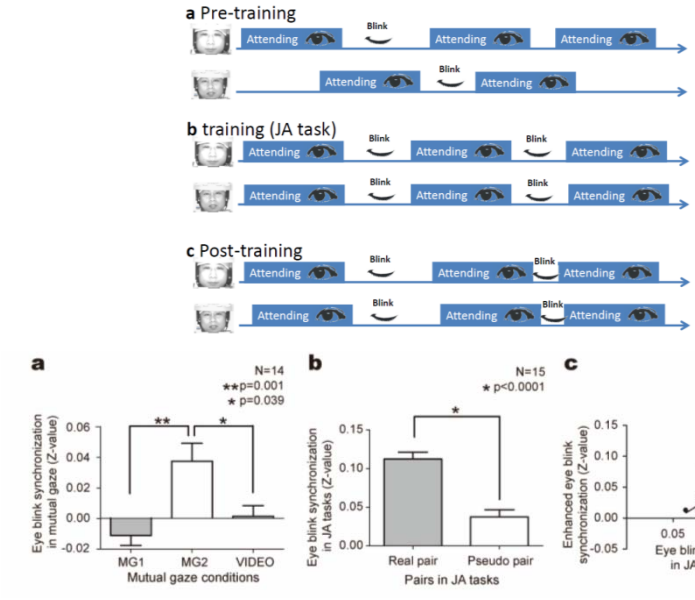
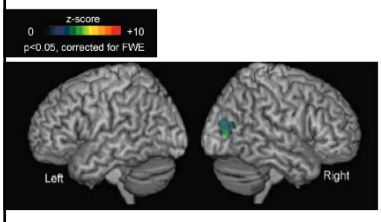
Blink
Attending


A Experiment conditions
Day 1
Day 2
Participant 2
Participant 1
REAL1
JA tasks
REAL2
VIDEO
PARTIAL
B Time course of JA tasks
Eye contact
Cue + Saccade
Eye contact
Response
2500 ms
2500 ms
2500 ms
2500 ms
C IJA/RJA runs
D dIJA/dRJA runs
E CTRL run
Participant 1
IJA
Participant 2
RJA
Participant 1
dIJA
Participant 2
dRJA
Participant 1
CTRL
Participant 2
CTRL

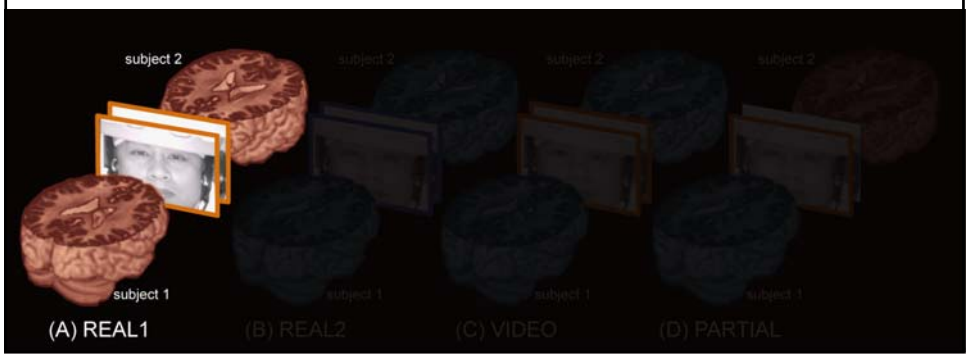
Enhanced blink synchronization during JA
Persisted at post-training mutual gaze



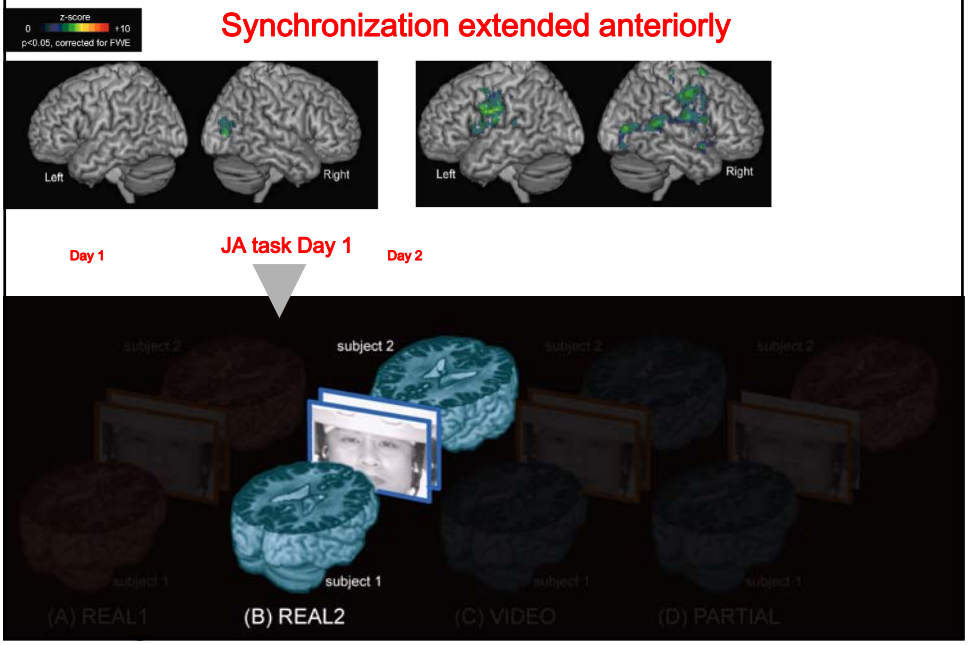
Real mutual gaze condition day 1 (REAL1)



Synchronization confined to the right MTG



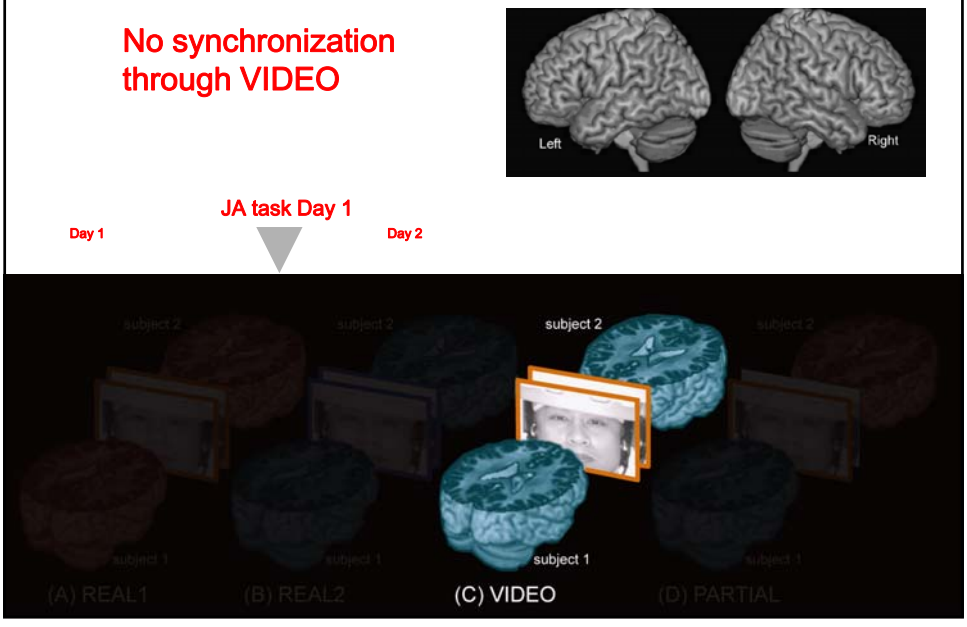
Real mutual gaze condition day 2 (REAL2)



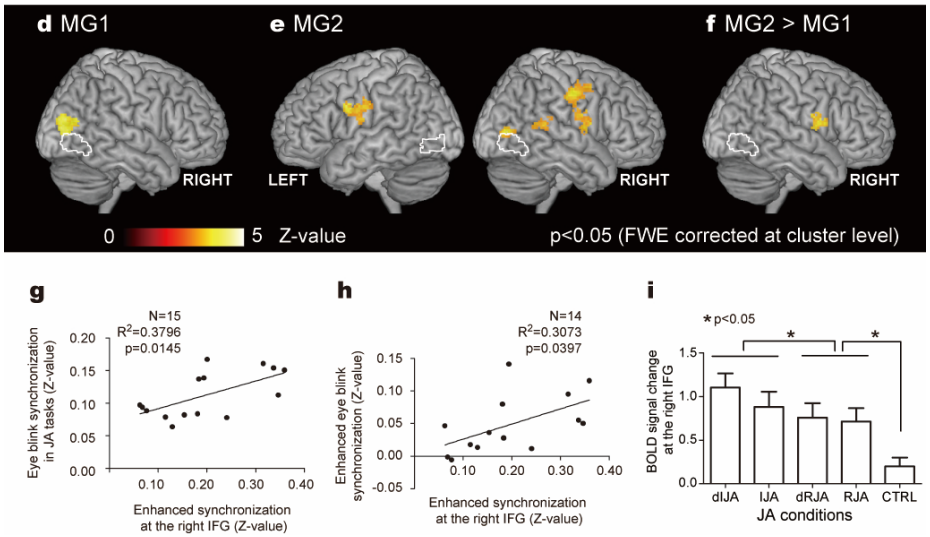
Synchronization extended anteriorly

Fake mutual gaze condition day 2 (VIDEO)

No synchronization through VIDEO



Neural synchronization of the right IFG represents enhanced sharing attention



Koike & Tanabe et al. (submitted)

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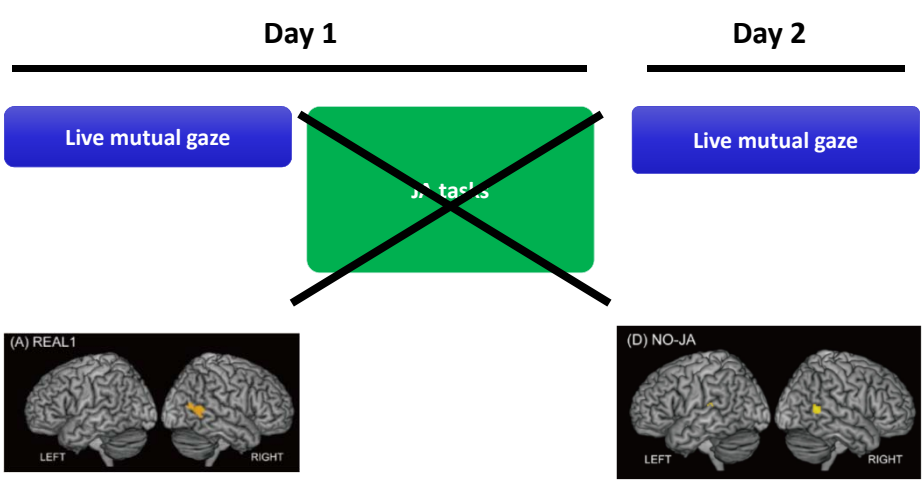
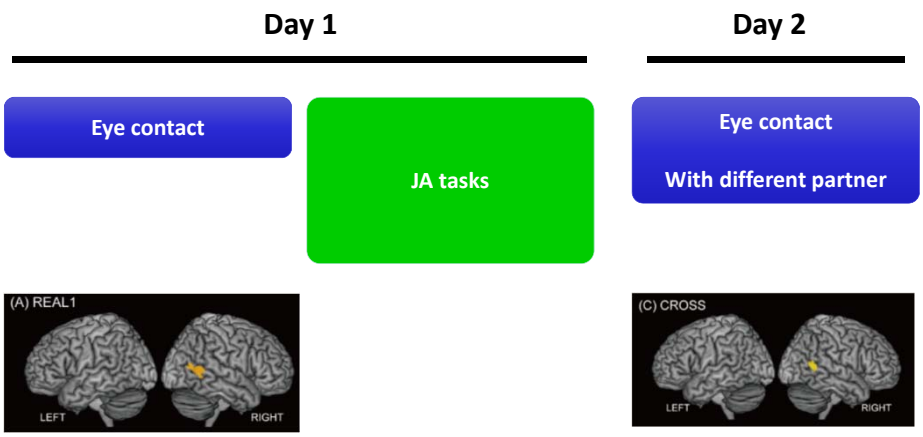
No JA, no change in synchronization



Anteriorly extended synchronization is JA specific

With different partner, no change in synchronization



Anteriorly extended synchronization is partner specific

Summary

Hyperscanning functional MRI showed the inter-brain effect of enhanced sharing attention emerged from the joint attention that cannot be reduced to the individual.

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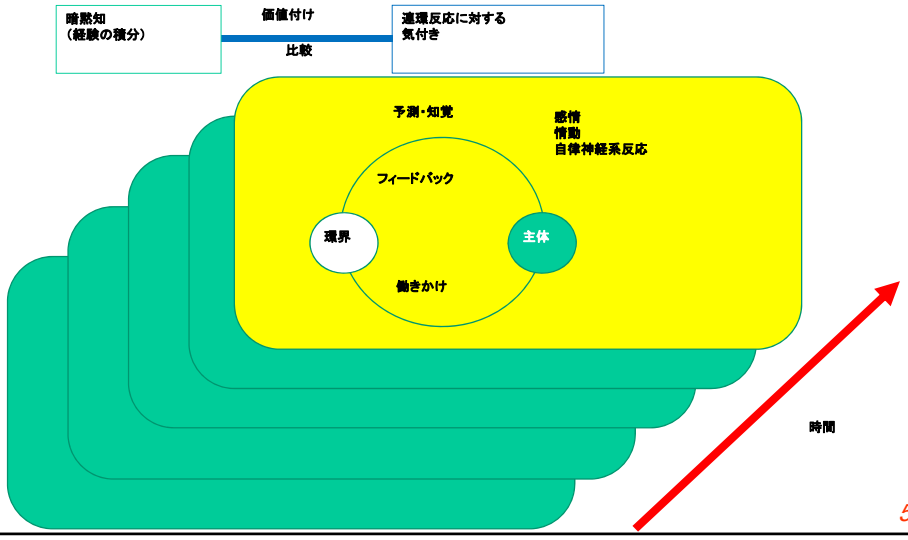
感性（KANSEI)

環界への働きかけとその結果の予測・知覚に至る一連の連環反応を俯瞰し（気付き）、暗黙的知識と比較することによって価値付ける（意味付ける）高次脳機能。Evoked metaphor (誘発された隠喩　山中（筑波大））。



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感性（KANSEI)

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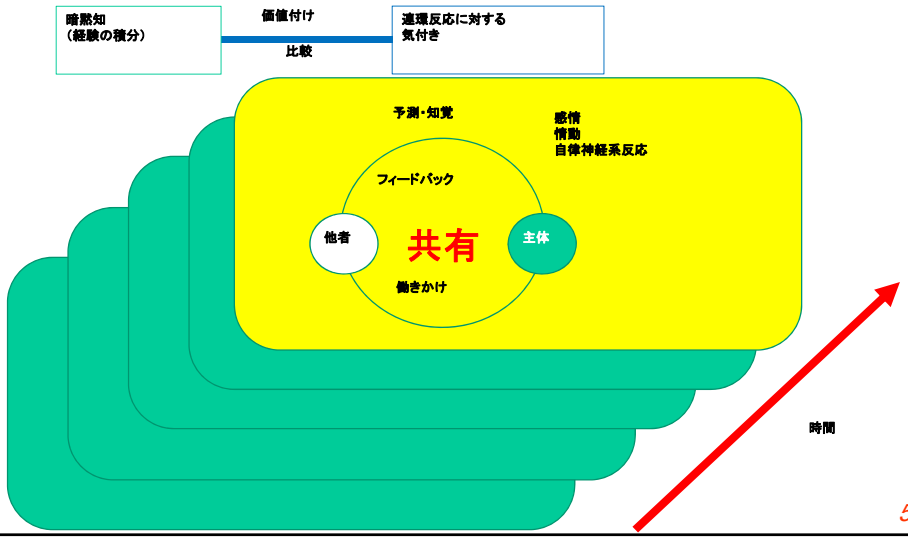

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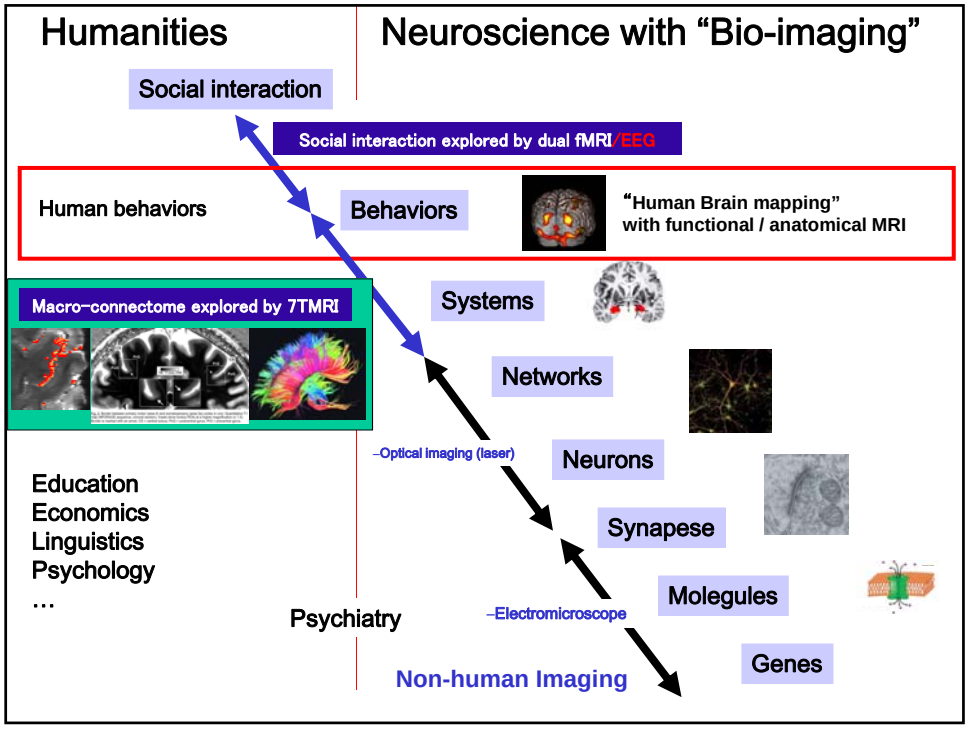

Thank you for your attention!

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