

# Brain mechanisms of tool-use that advance our knowledge/world beyond the border

IRIKI Atsushi

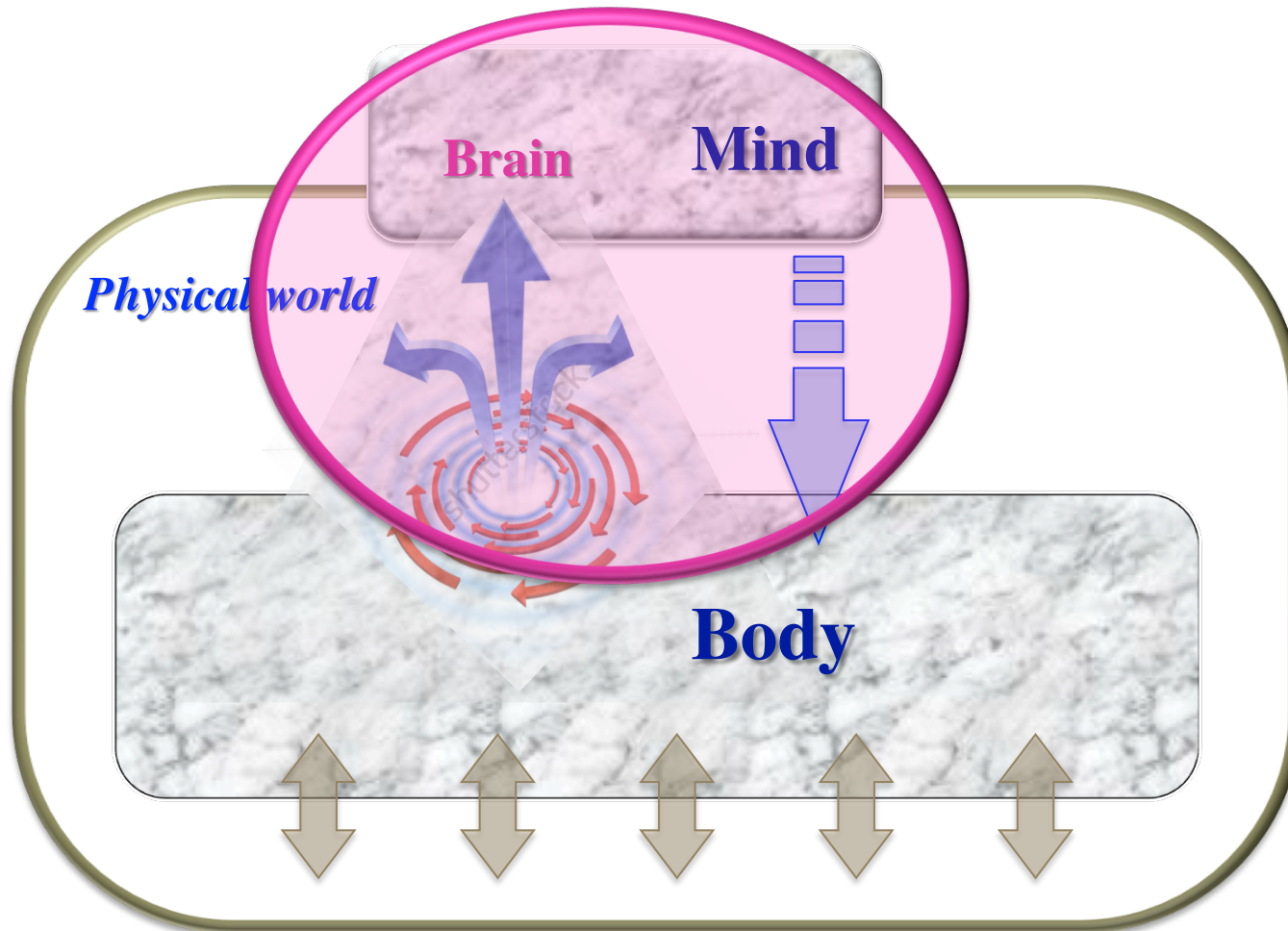
入 来 篤 史

*RIKEN Brain Science Institute  
Nanyang Technological University*

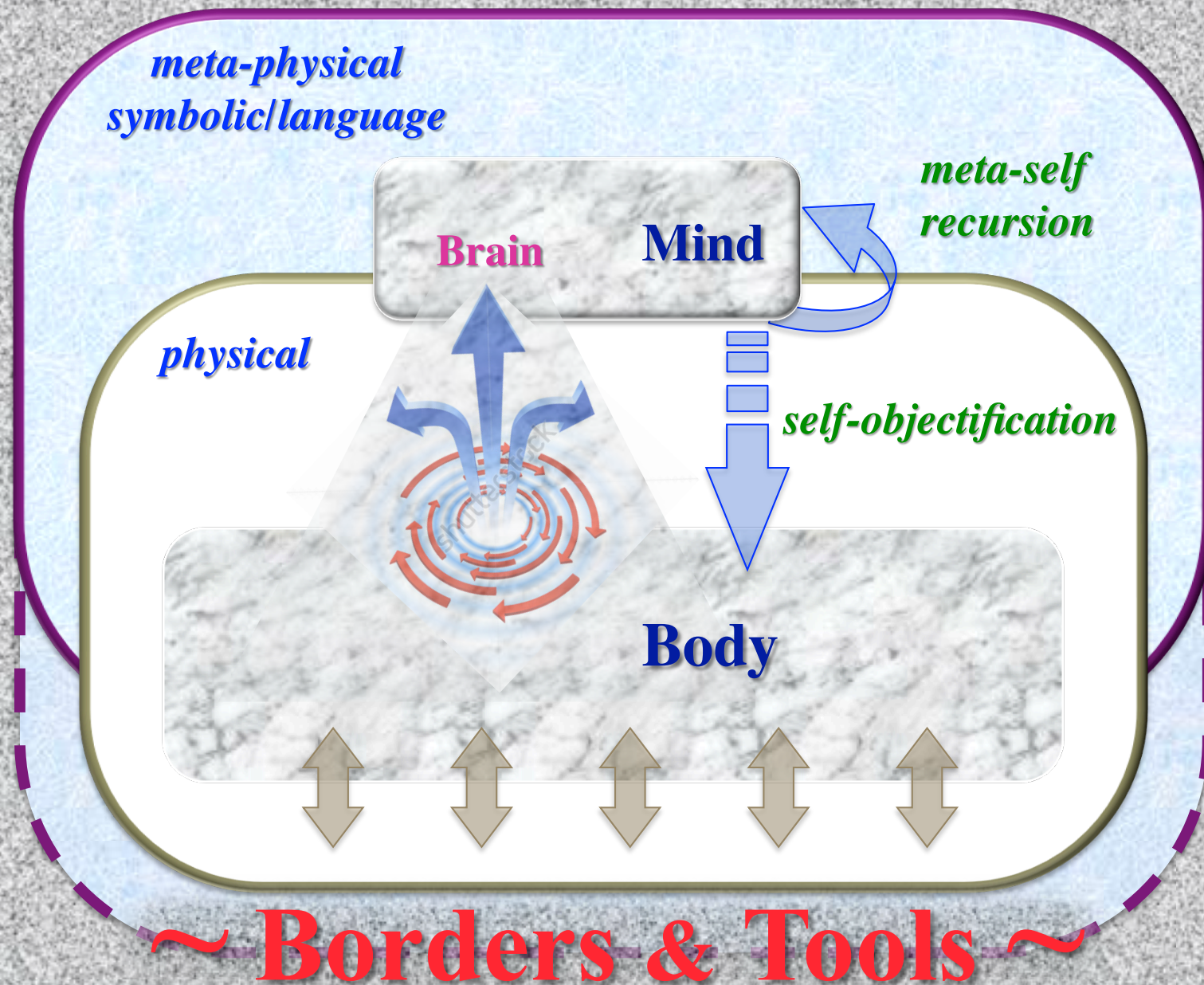


*Meta-physical world  
(symbolic / language)*

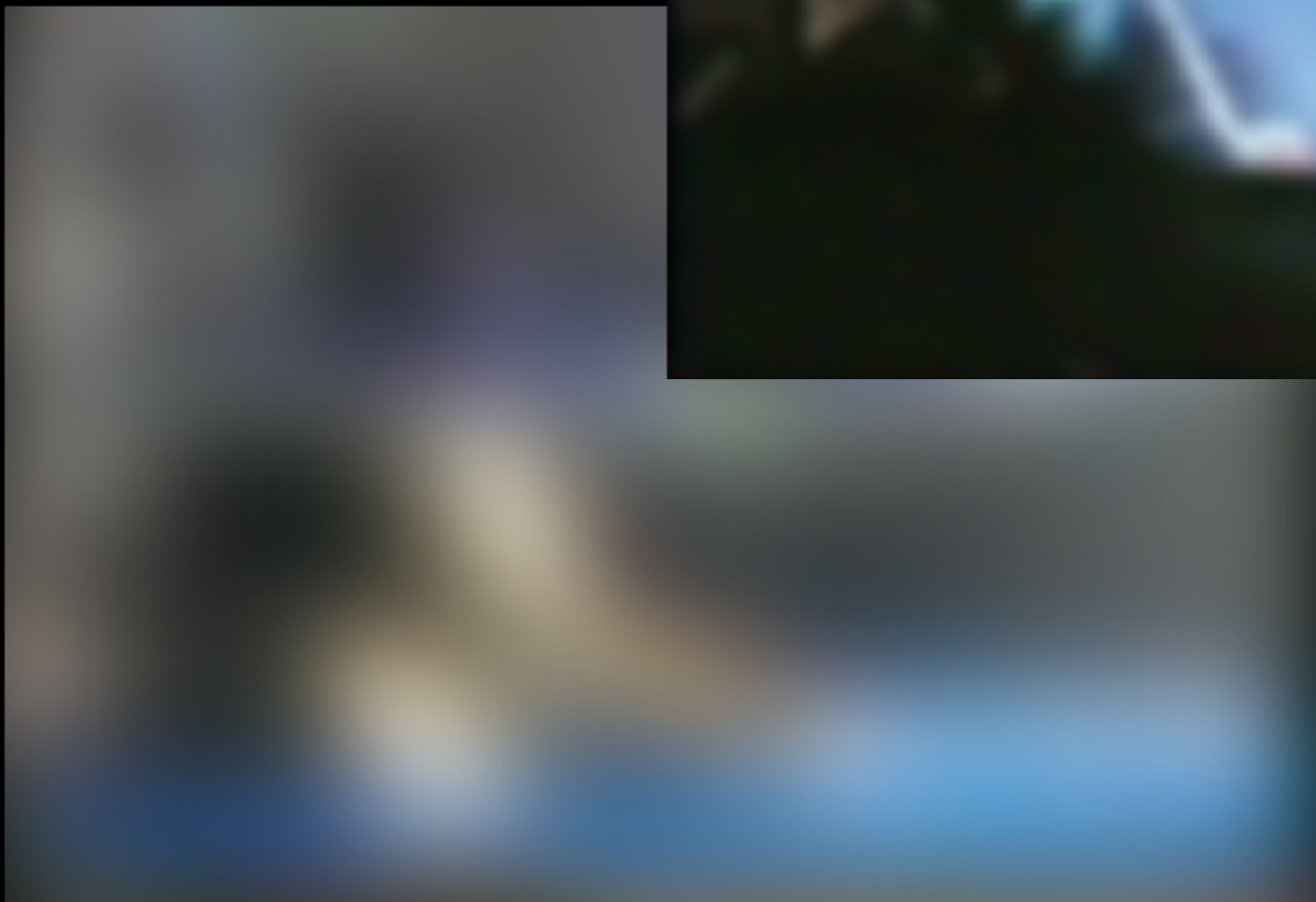
## **Triadic Niche-Construction**



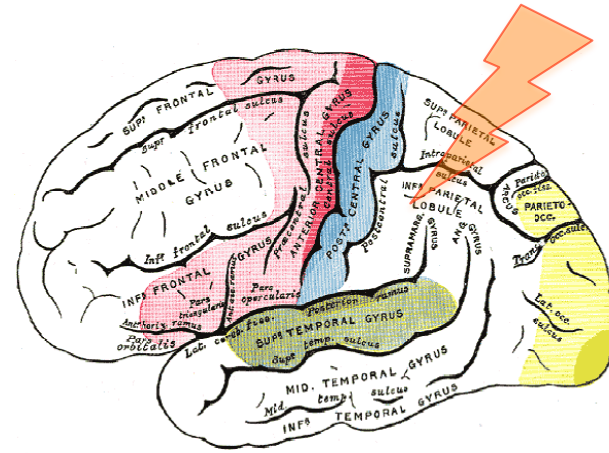








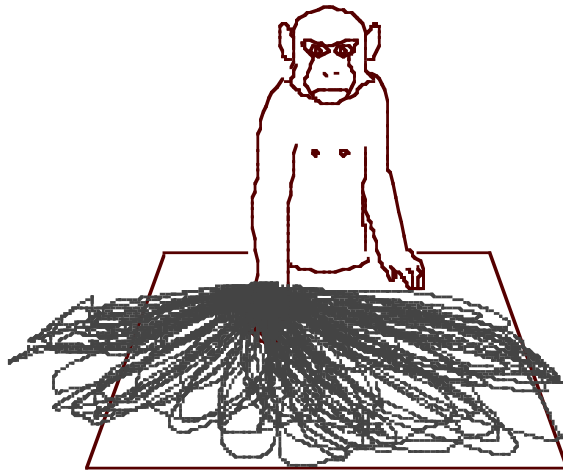




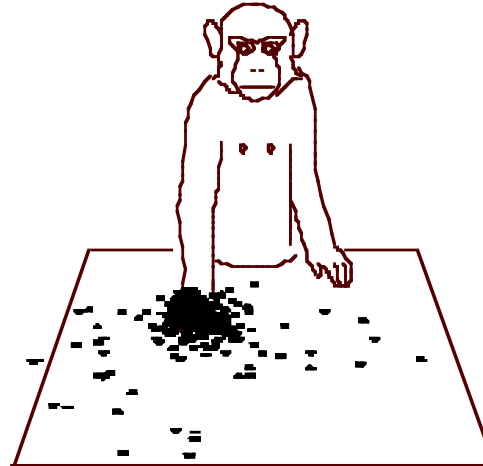
A



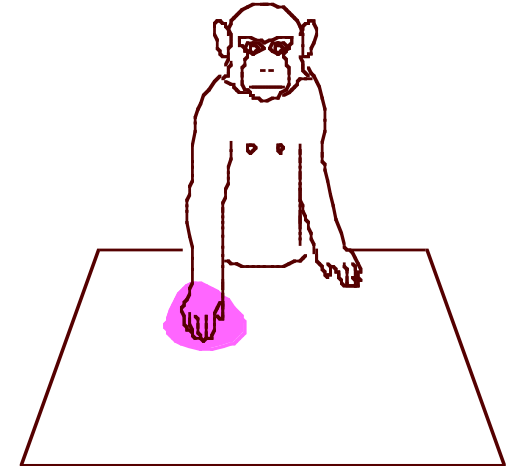
Ba



b

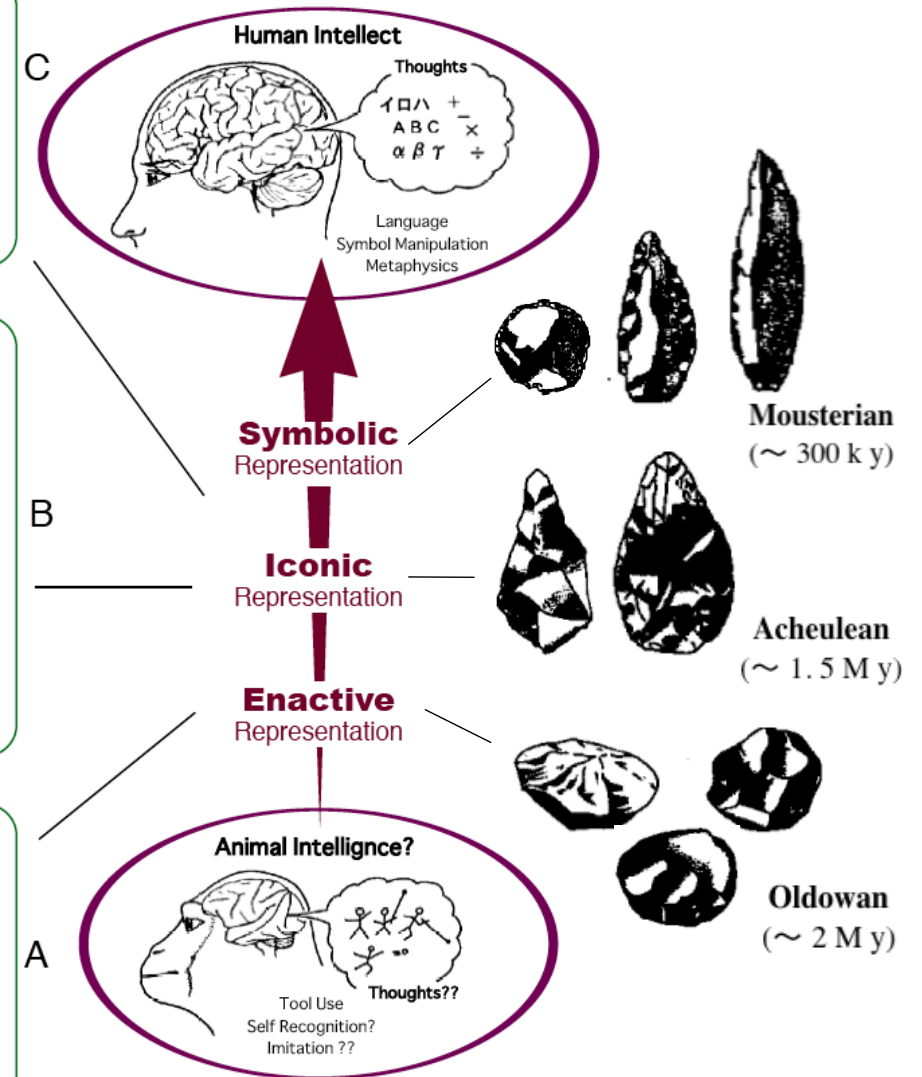
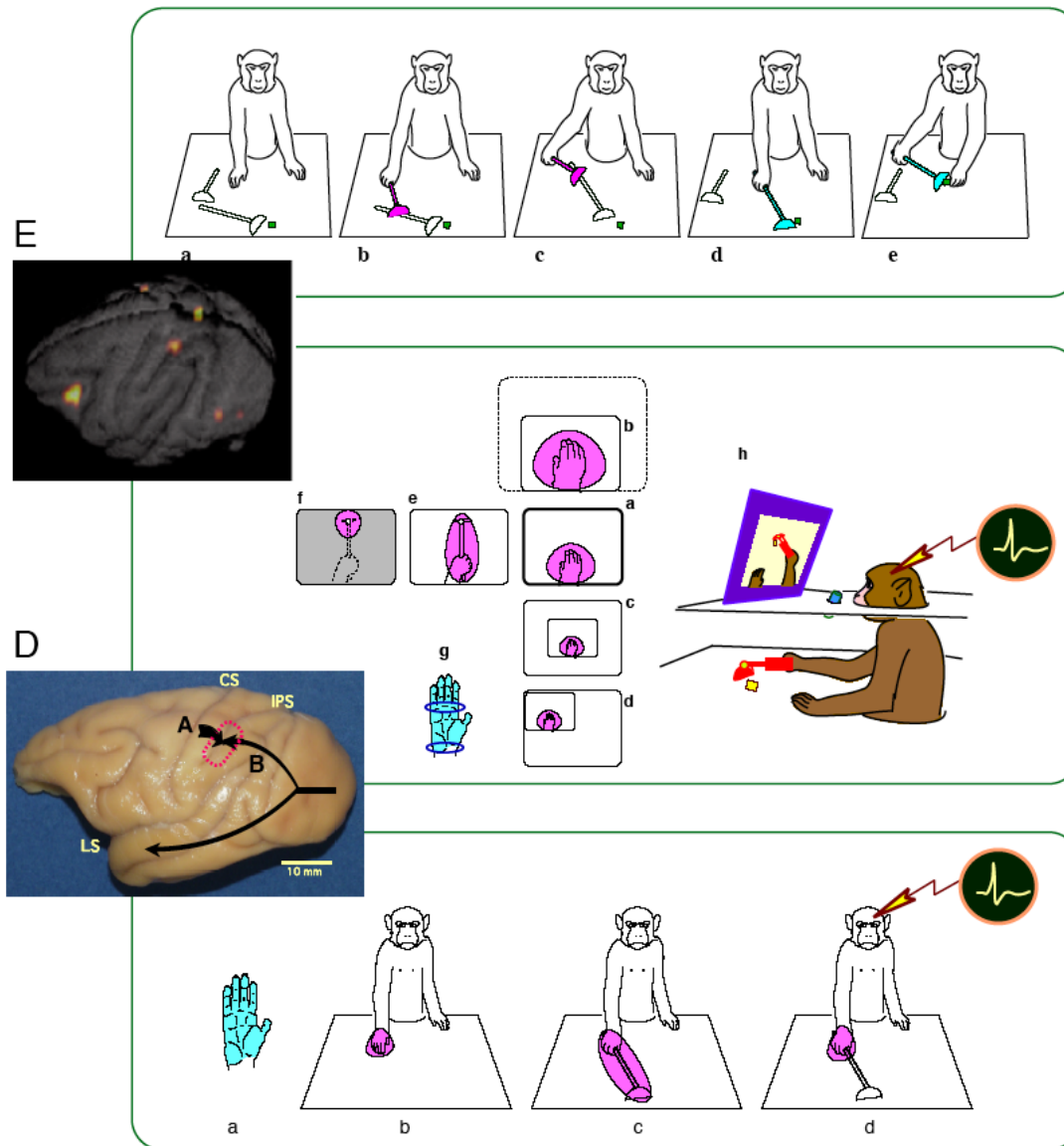


c

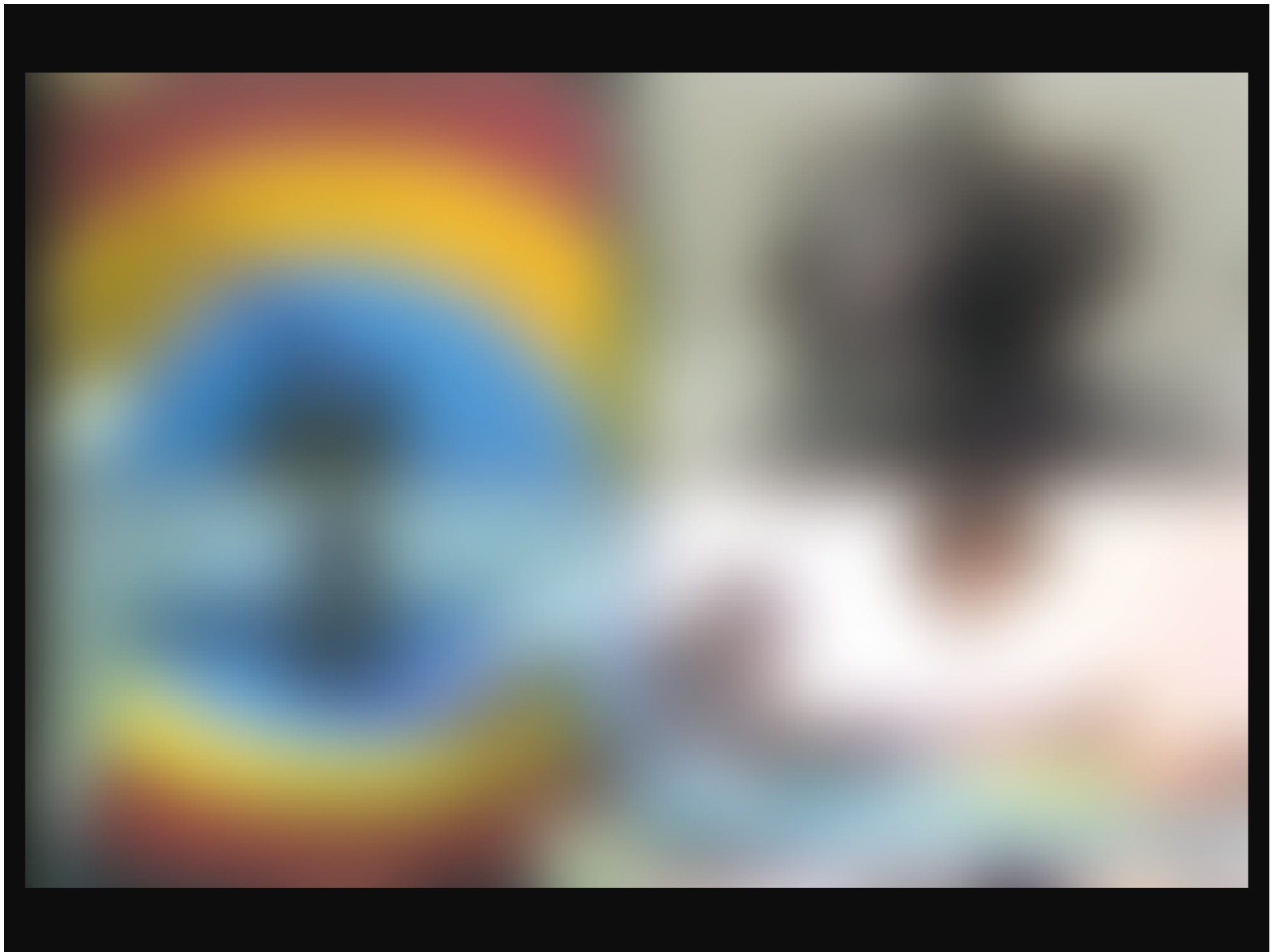




# Syntax of Action

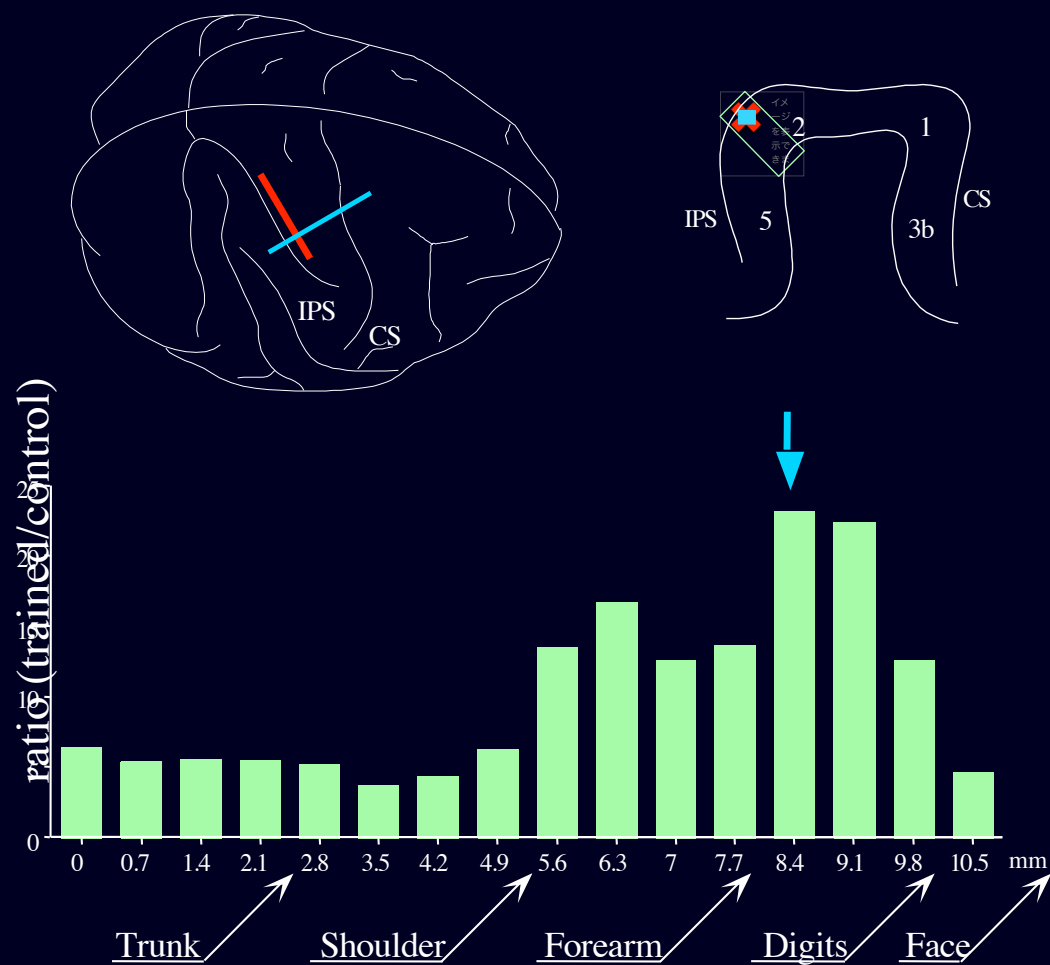


# Equivalence (tool – body)

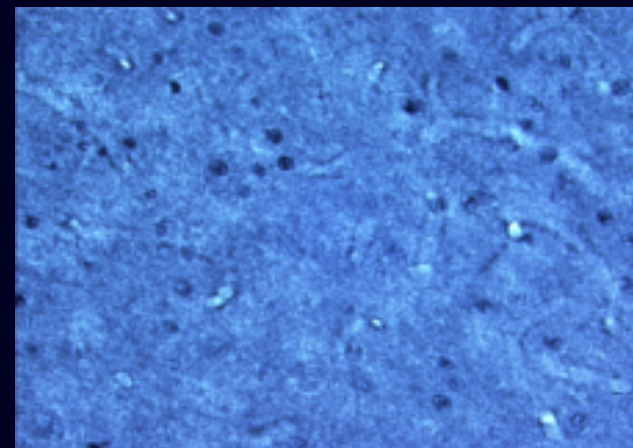




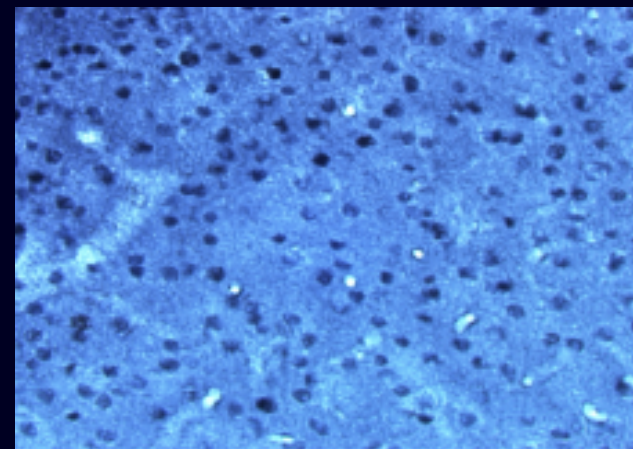
# Zif 268 expression



Control



Trained



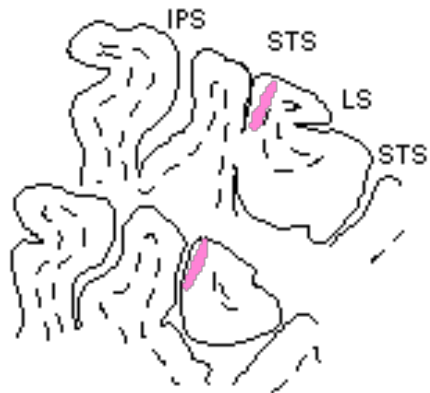
## Before Training

## After Training

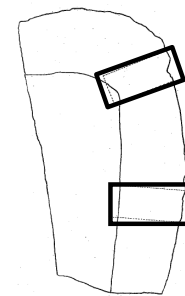
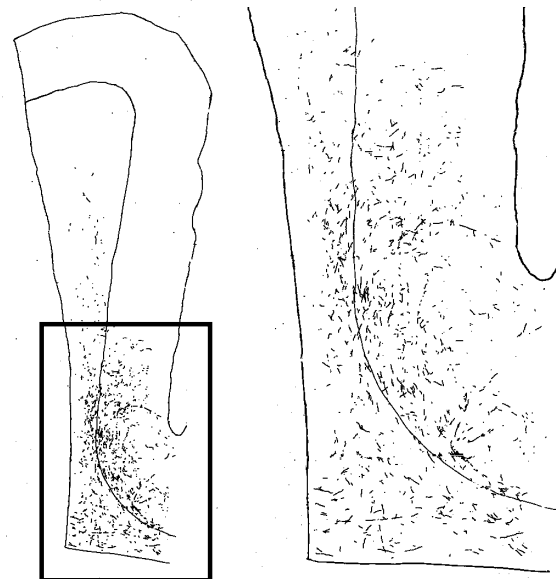
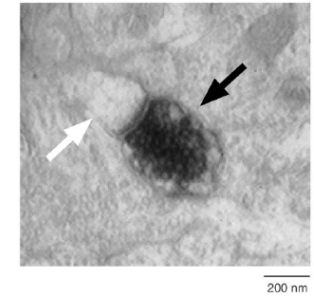
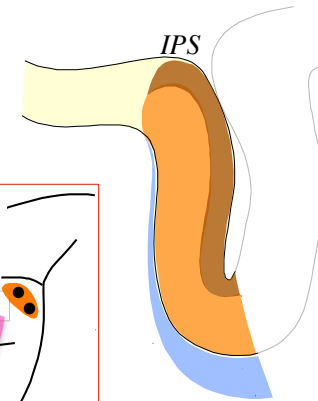
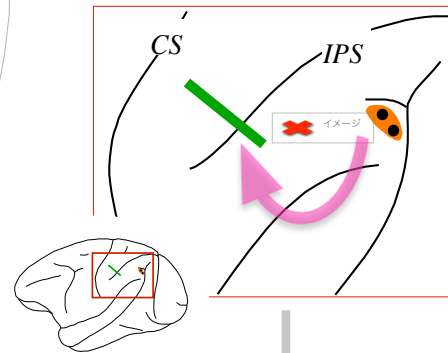
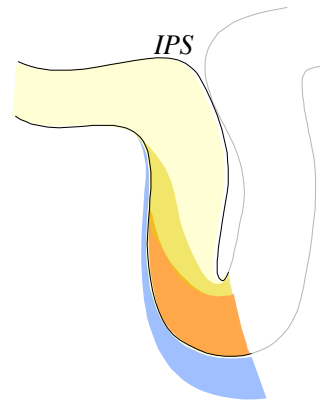


<CM2>

5 mm



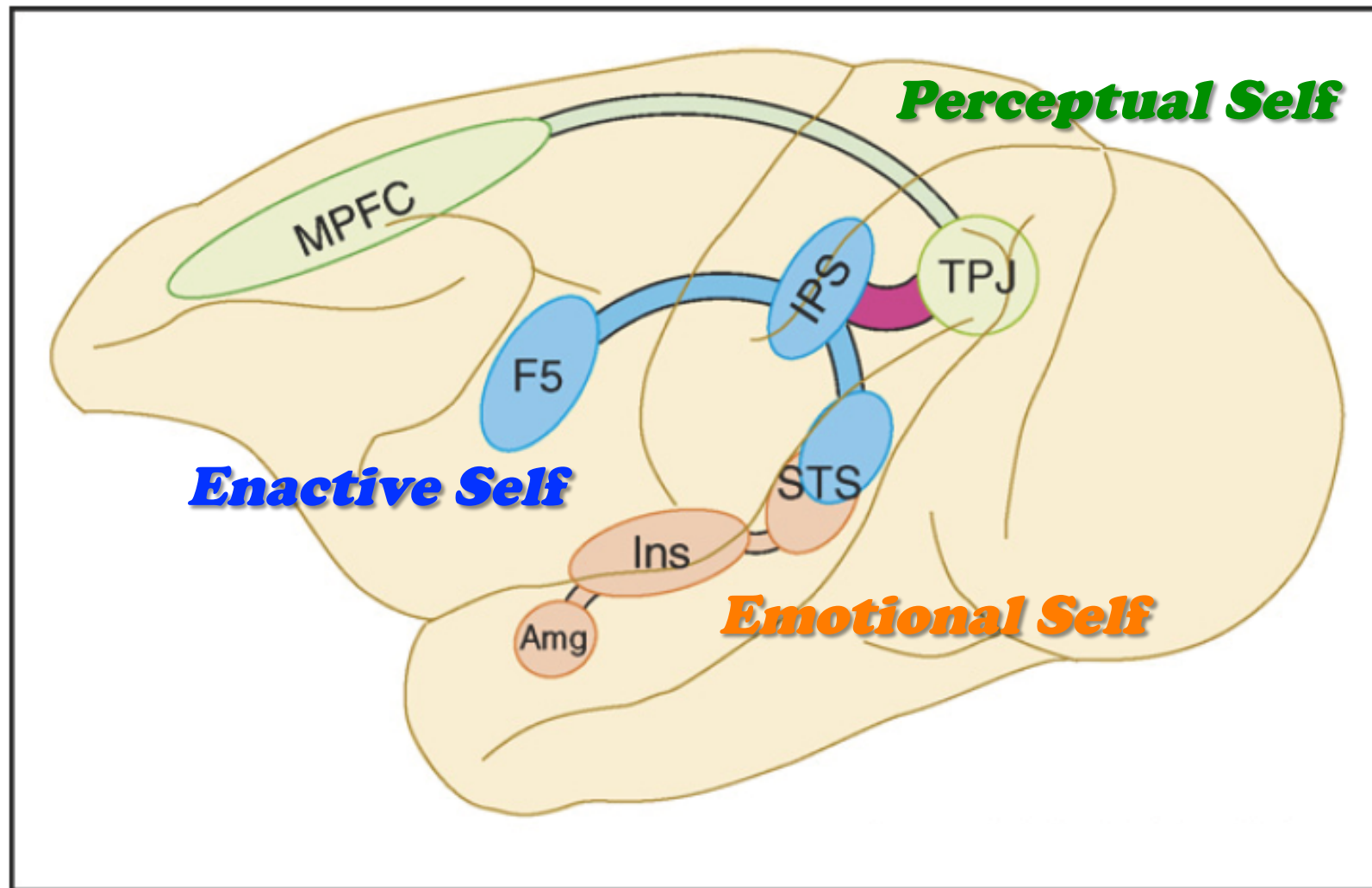
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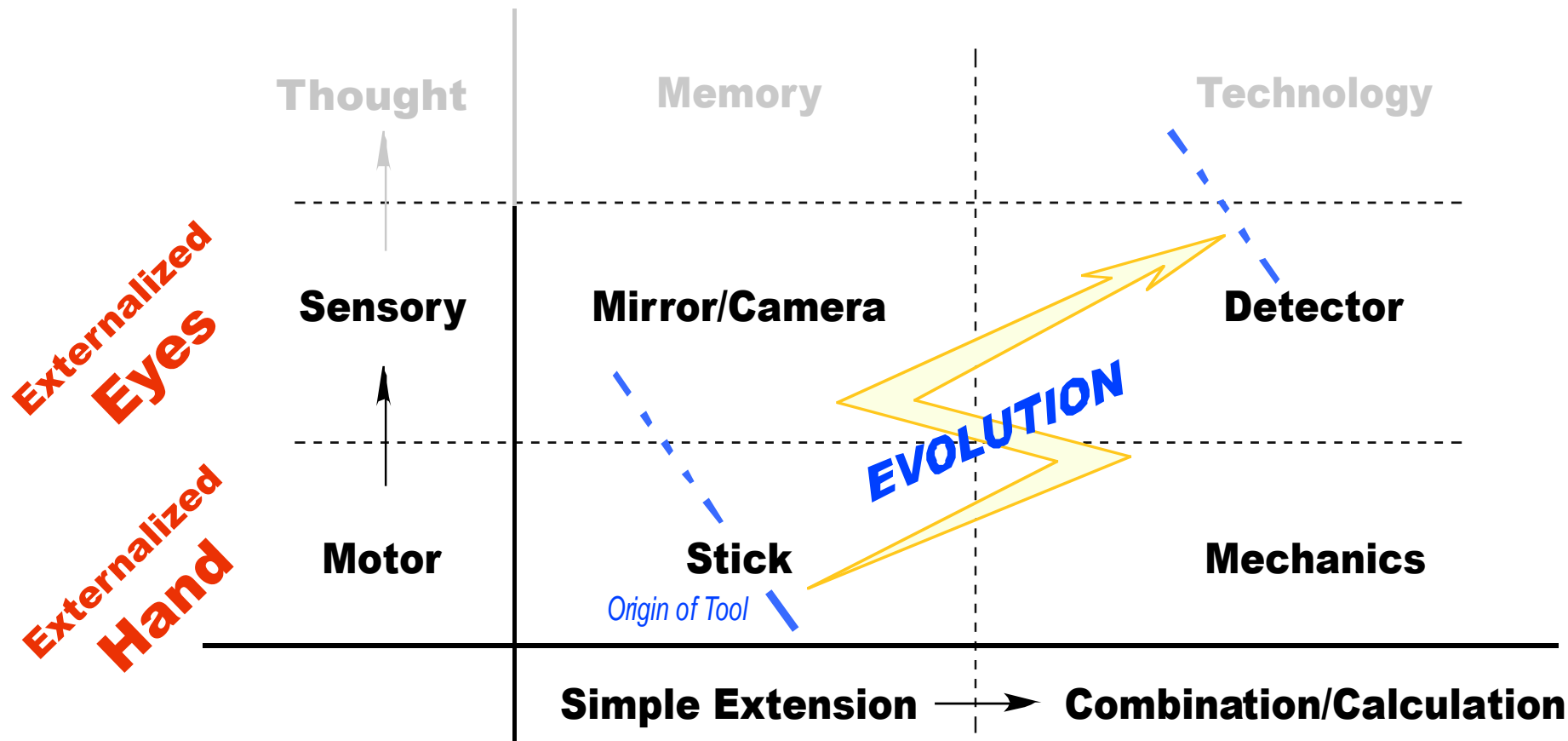




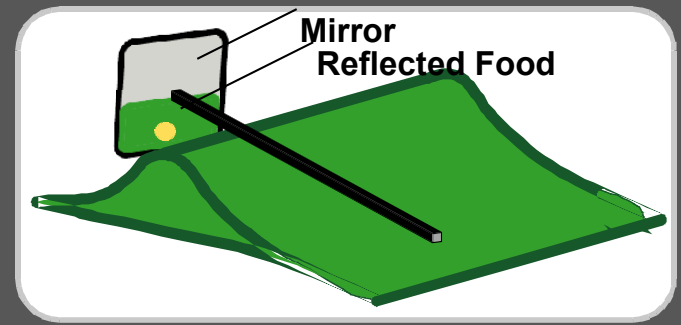
## Mirror Neuron System

## Equivalence (self – other)





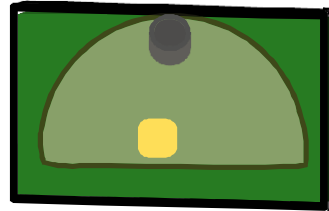
# Attached Sensory Information



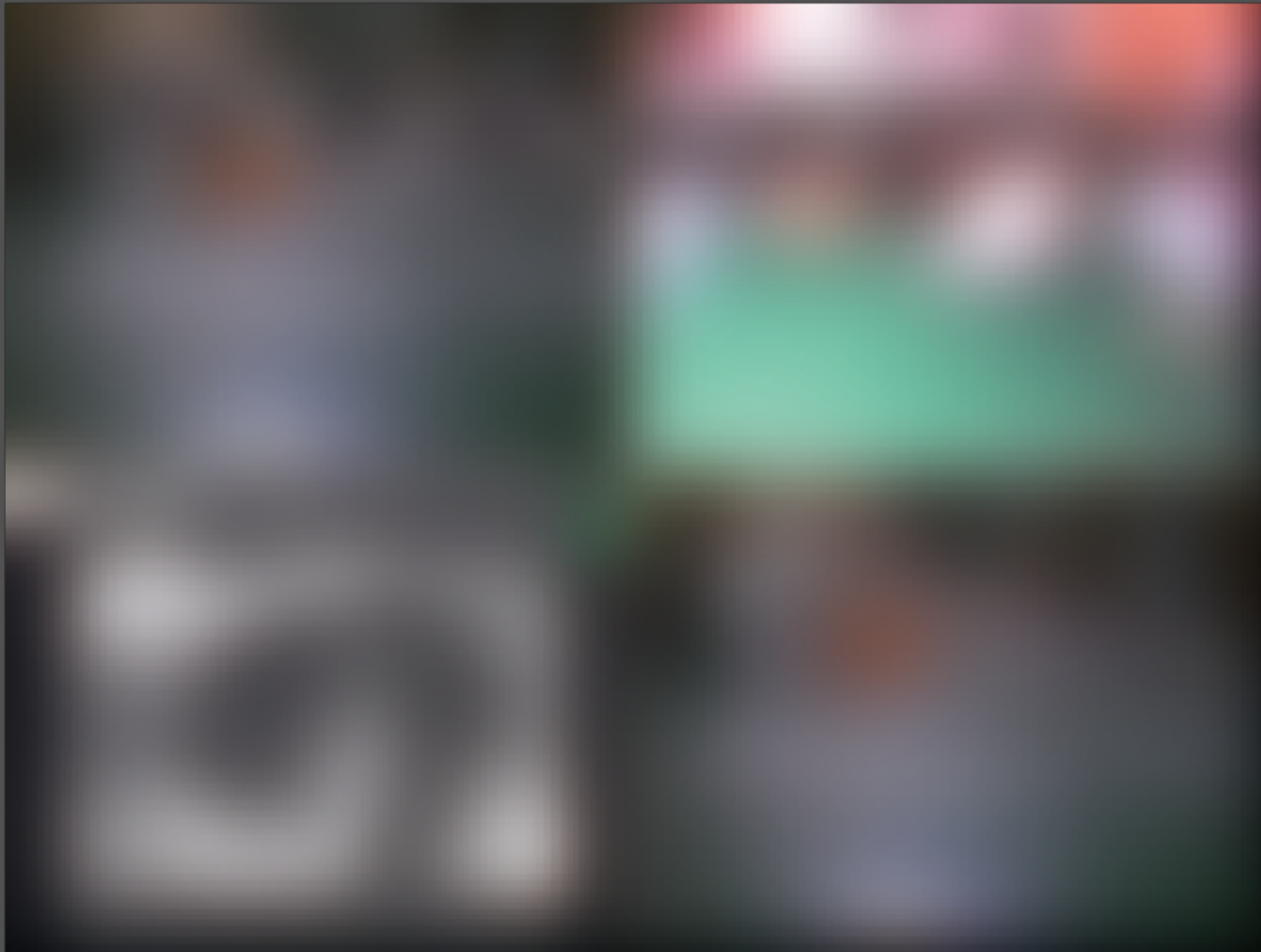
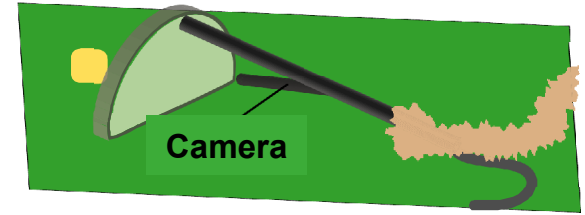


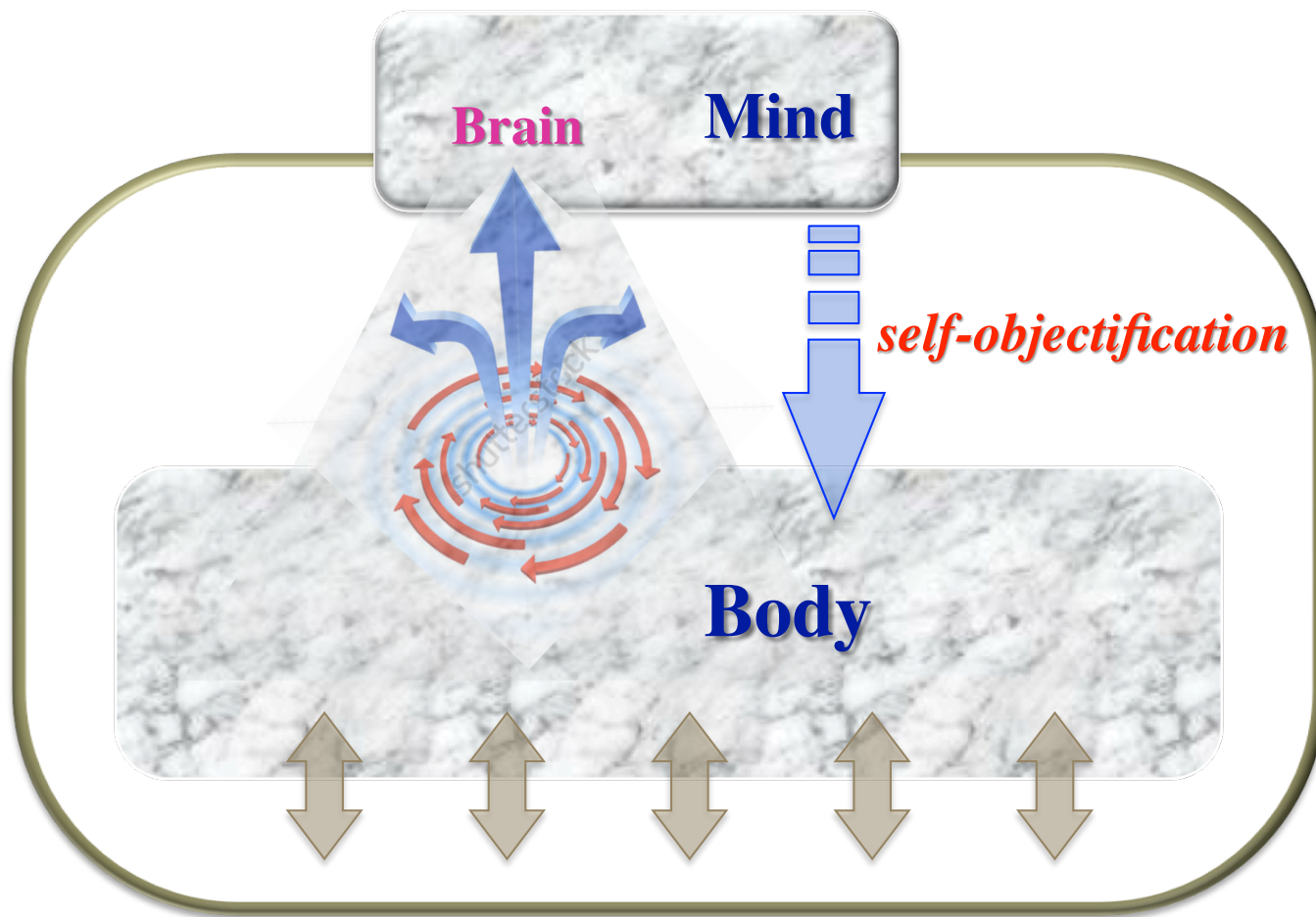
# Externalized Eye

Monitor



Camera



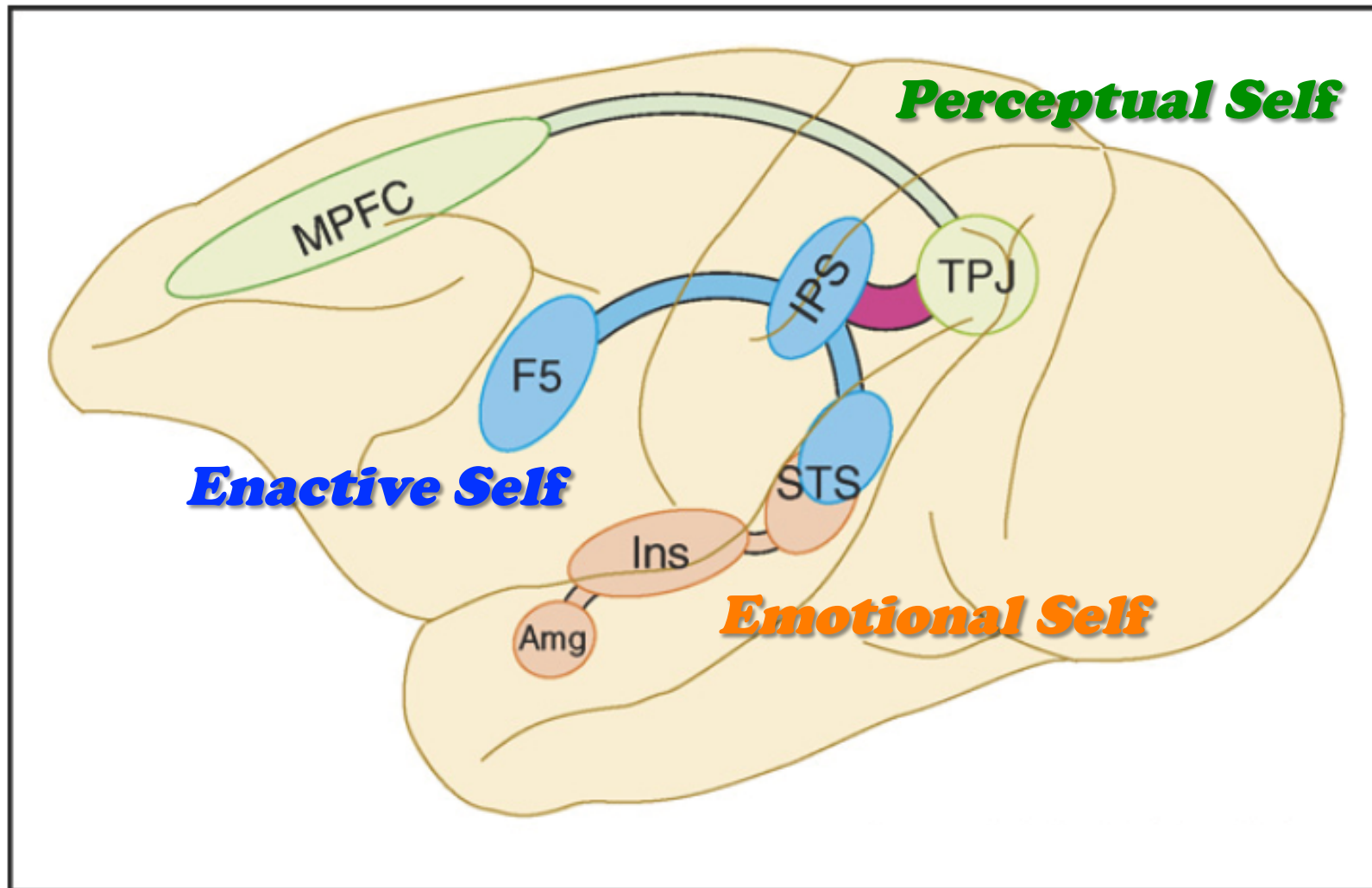


# Mirror Neuron System

Equivalence (self – other)



Self-Objectification

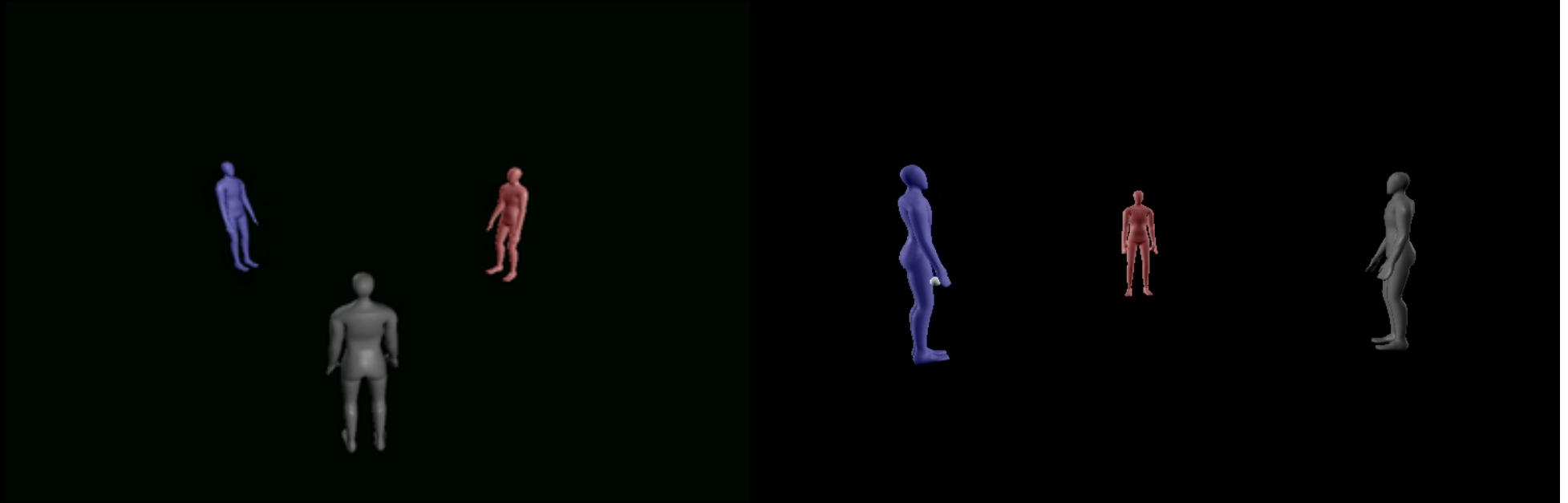




# Shifting Perspectives of the Self

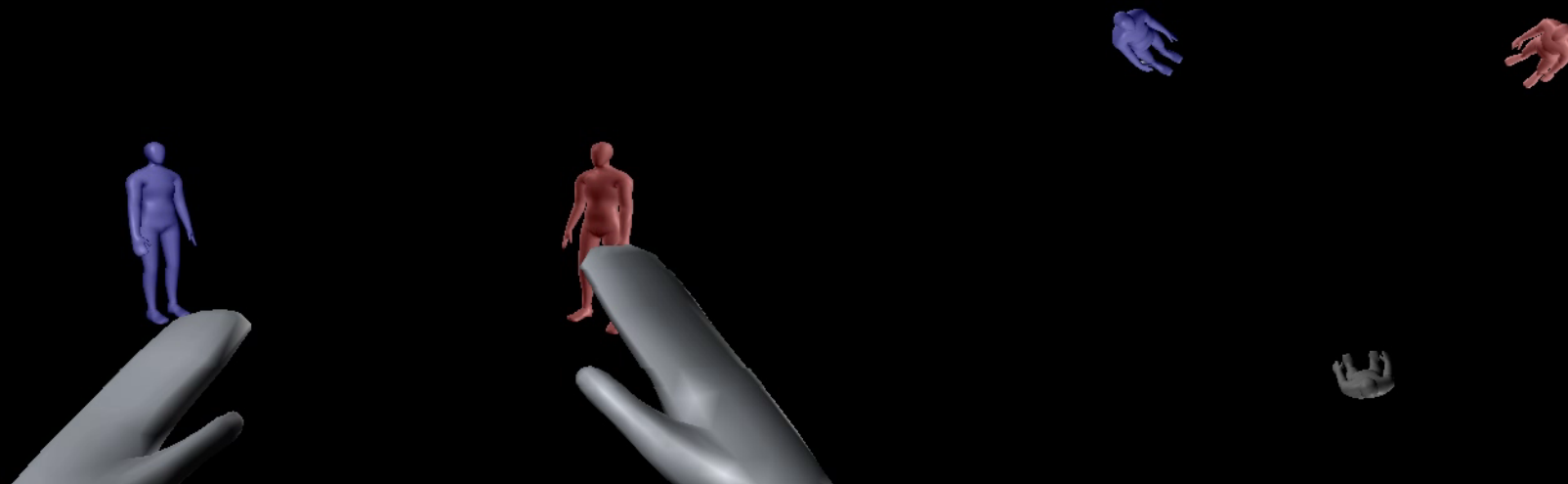
**Hinder View**

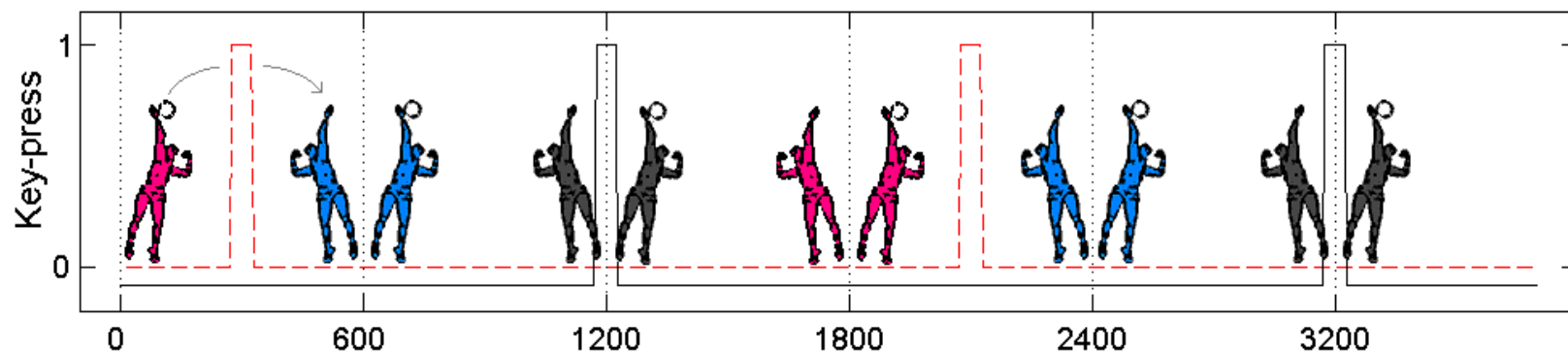
**Lateral View**



**Eye-ball View**

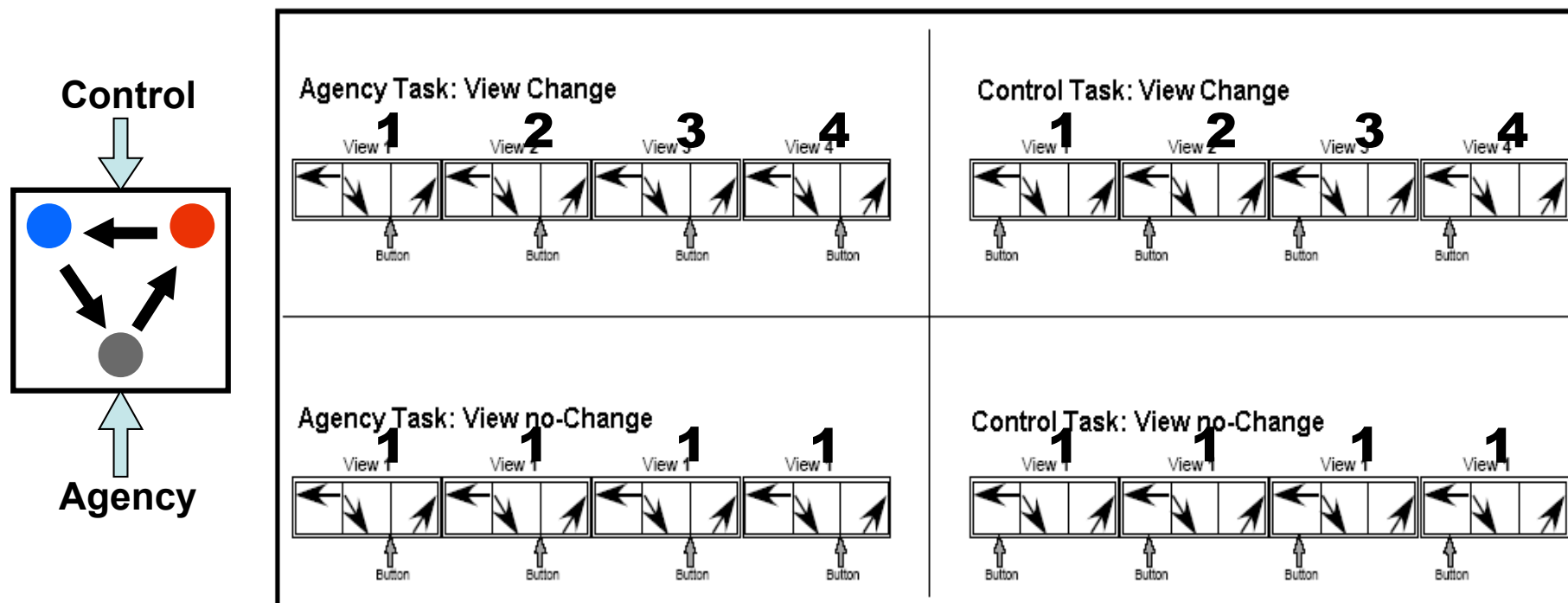
**Over View**



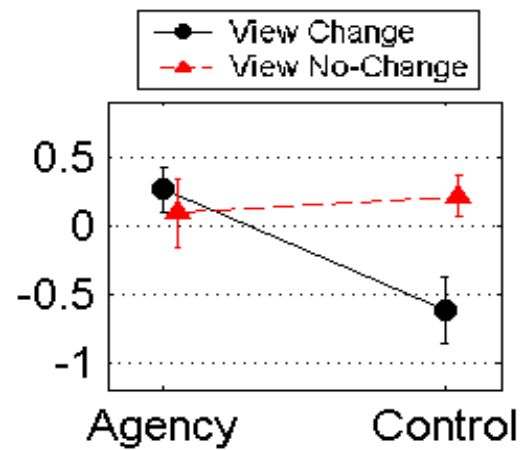
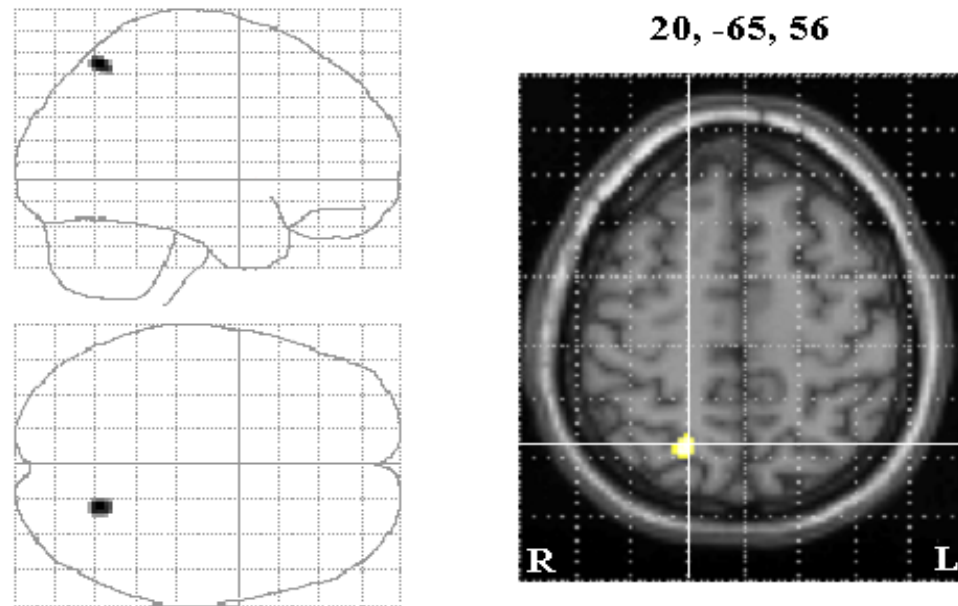


**Agency Task :** Press the key when the black player received the ball, in order to trigger his subsequent action.

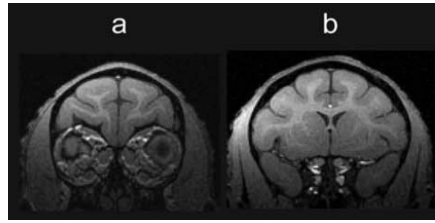
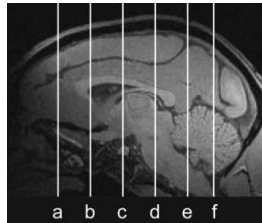
**Control Task :** Press the key when the ball is in between the red and the blue player.



# TPJ



**(Agency VC - Control VC) - (Agency NVC - Control NVC)**



## Single-neuron and genetic correlates of autistic behavior in macaque

Kyoko Yoshida, Yasuhiro Go, Itaru Kushima, Atsushi Toyoda, Asao Fujiyama, Hiroo Imai, Nobuhito Saito, Atsushi Iriki, Norio Ozaki and Masaki Isoda (September 21, 2016)

### RESEARCH ARTICLE

#### PSYCHOLOGY

# Single-neuron and genetic correlates of autistic behavior in macaque

Atypical neurodevelopment in autism spectrum disorder is a mystery, defying explanation despite increasing attention. We report on a Japanese macaque that spontaneously exhibited autistic traits, namely, impaired social ability as well as restricted and repetitive behaviors, along with our single-neuron and genomic analyses. Its social ability was measured in a turn-taking task, where two monkeys monitor each other's actions for adaptive behavioral planning. In its brain, the medial frontal neurons responding to others' actions, abundant in the controls, were almost nonexistent. In its genes, whole-exome sequencing and copy number variation analyses identified rare coding variants linked to human neuropsychiatric disorders in 5-hydroxytryptamine (serotonin) receptor 2C (*HTR2C*) and adenosine triphosphate (ATP)-binding cassette subfamily A13 (*ABCA13*). This combination of systems neuroscience and cognitive genomics in macaques suggests a new, phenotype-to-genotype approach to studying mental disorders.

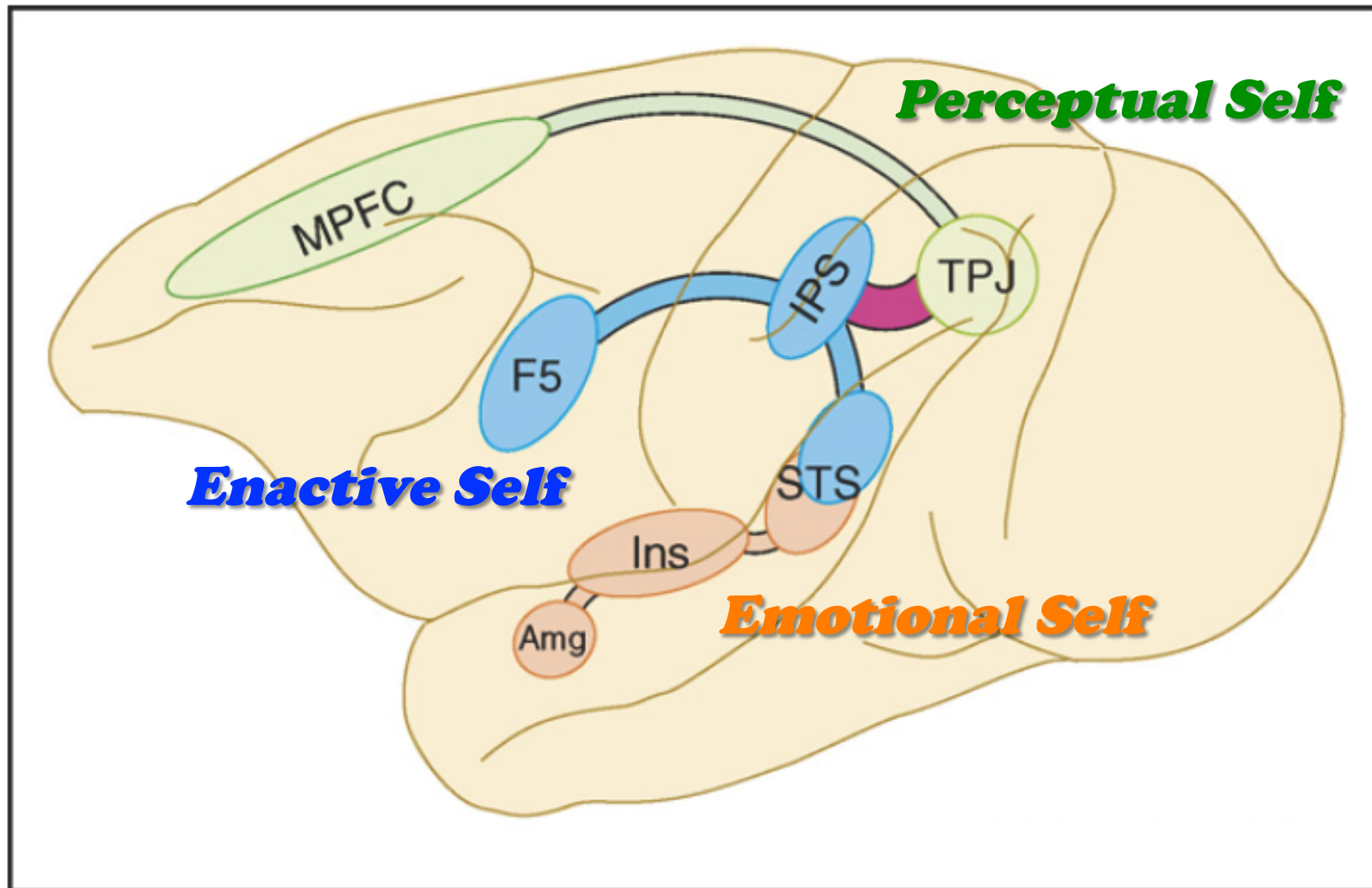


# Mirror Neuron System

Equivalence (self – other)



Self-Objectification

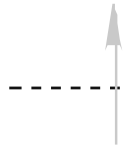


**Externalized  
Brain**

**Externalized  
Eyes**

**Externalized  
Hand**

**Thought**



**Sensory**



**Motor**

**Memory**

**Mirror/Camera**

**Stick**  
*Origin of Tool*

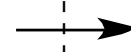
**Technology**

**Detector**

**Mechanics**

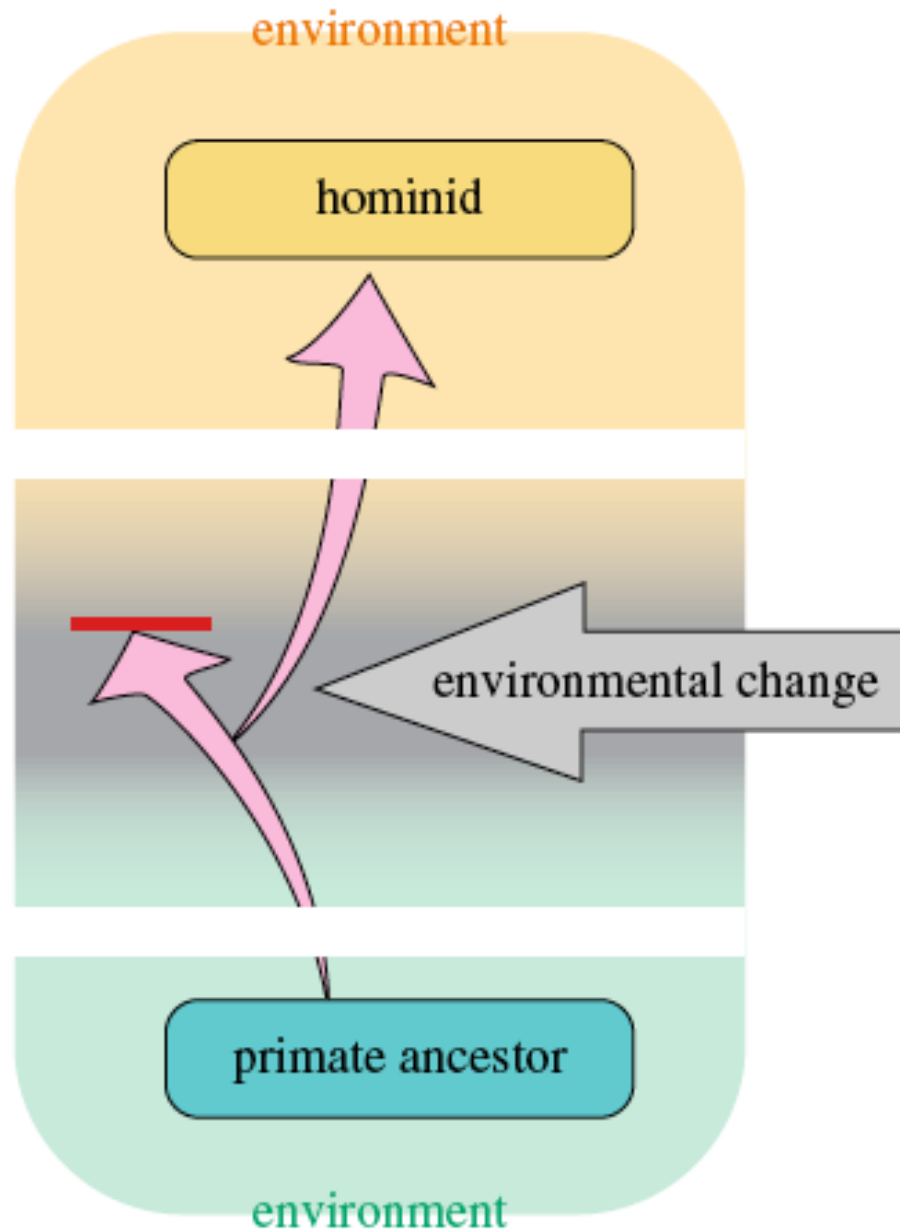
**EVOLUTION**

**Simple Extension**

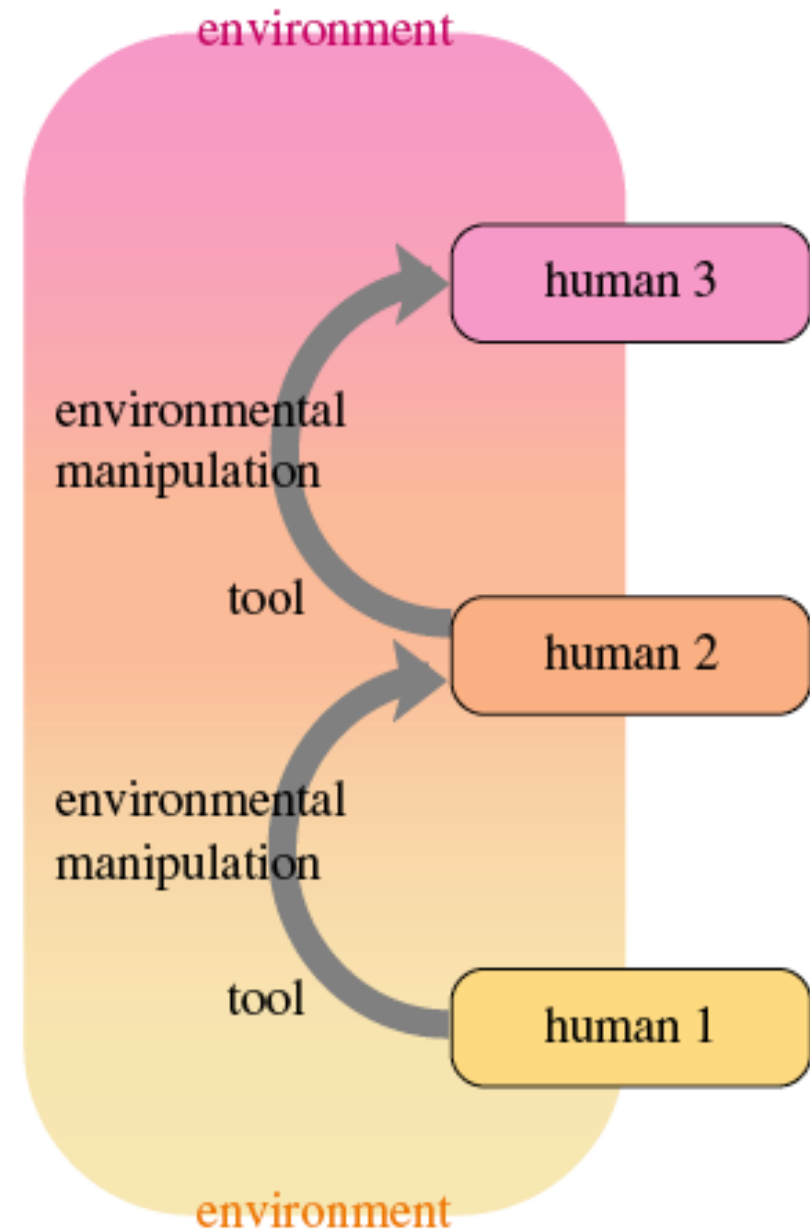


**Combination/Calculation**

## *Natural Selection*



## **1. Ecological Niche Construction**

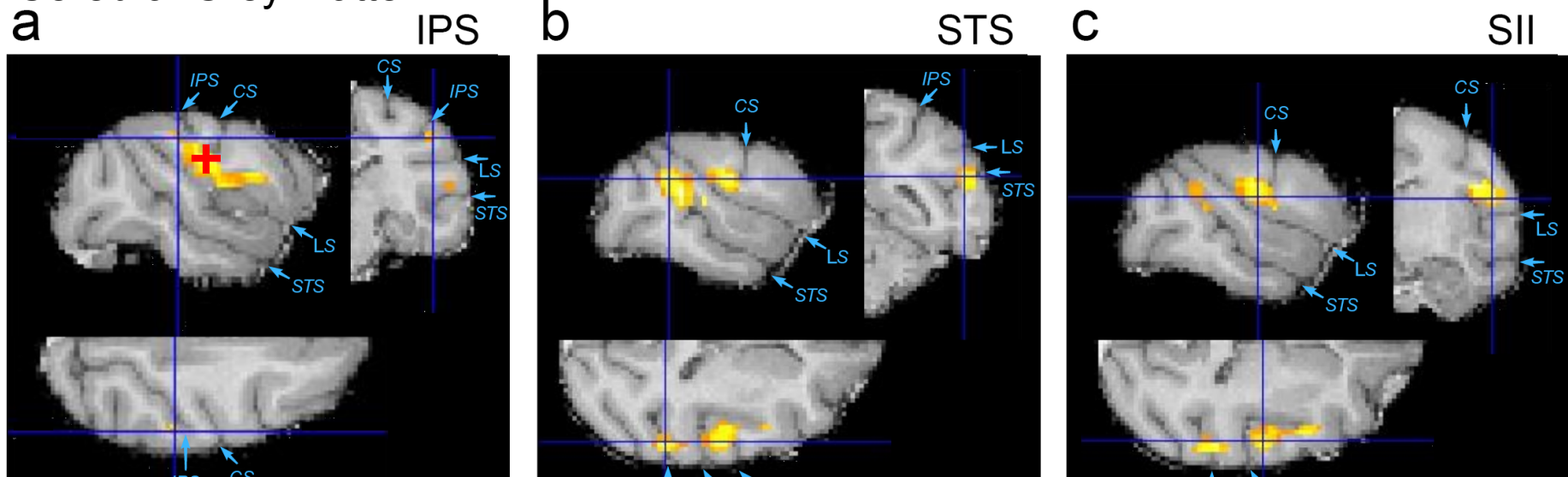


# Expansion of Cortical Gray Matter

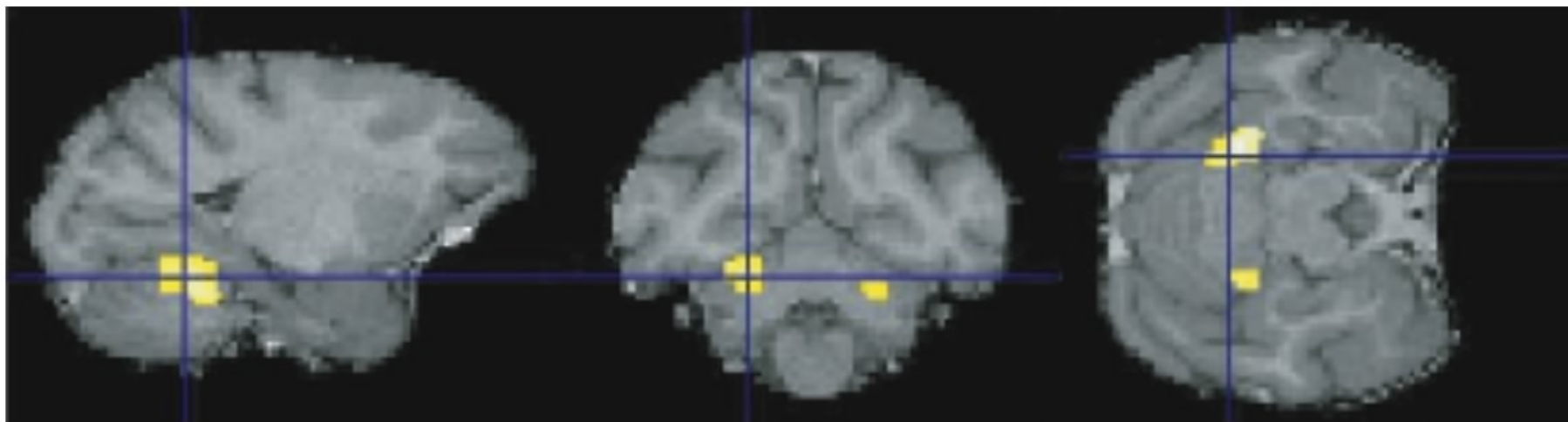
## **2. Neural Niche Construction**

## **VBM study**

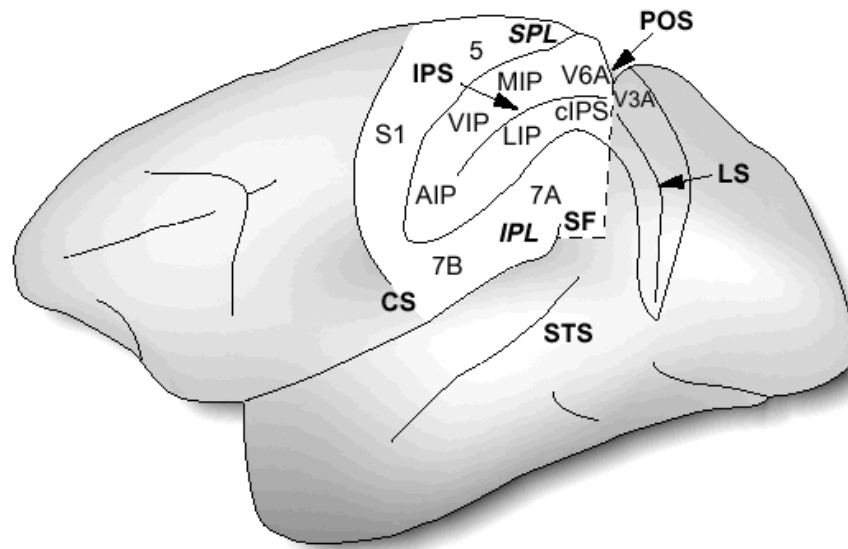
Cerebral Grey Matter



Cerebellar White Matter







Visual signals

Auditory signals

Somatosensory signals  
(Head, Hand, Limb, Eye)



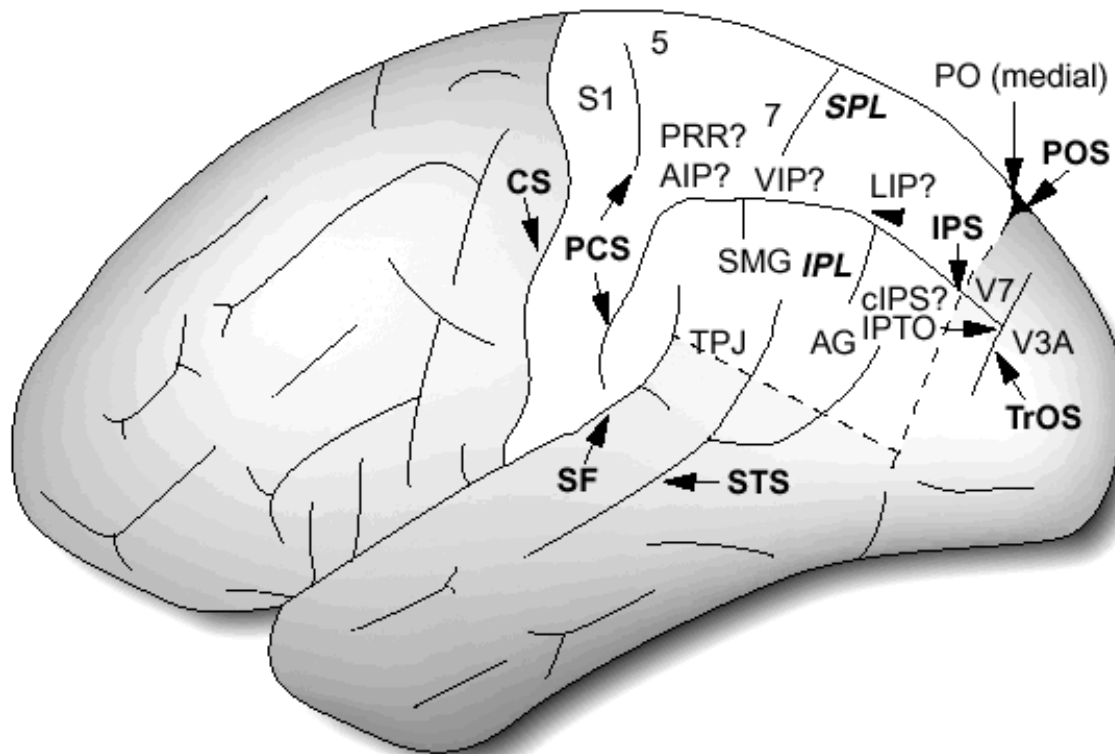
*Posterior Parietal Cortex*

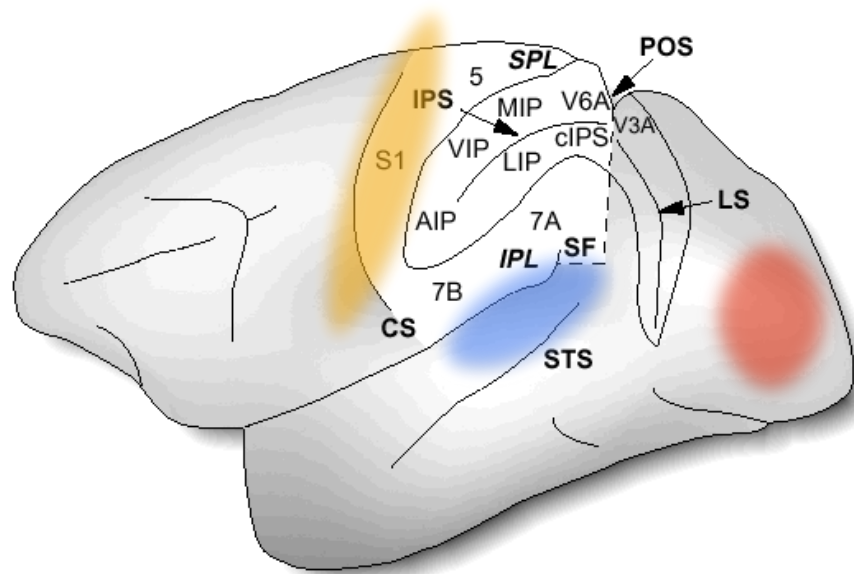


Eye movement

Hand movement

Head movement





Visual signals

Auditory signals

Somatosensory signals  
(Head, Hand, Limb, Eye)



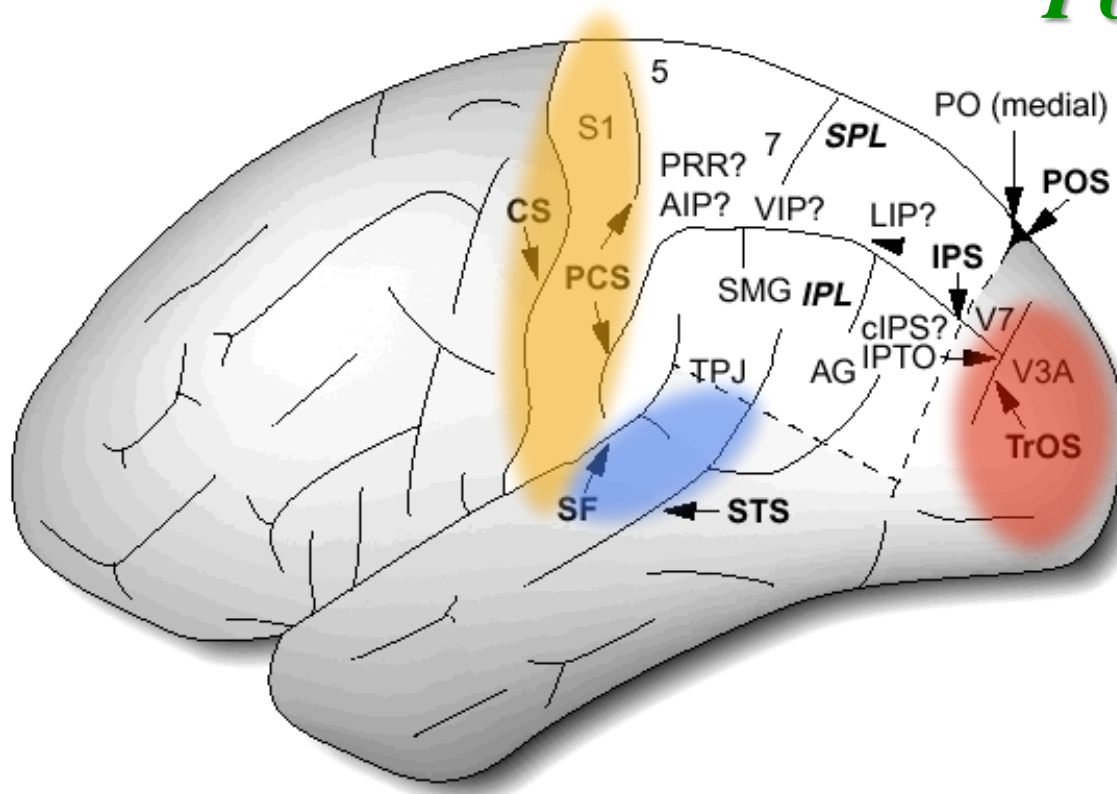
*Posterior Parietal Cortex*

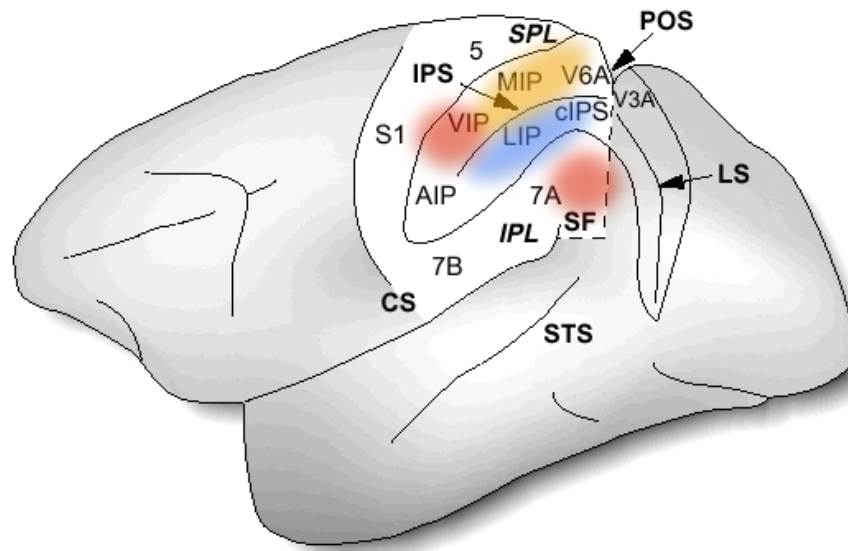


Eye movement

Hand movement

Head movement





Visual signals

Auditory signals

Somatosensory signals  
(Head, Hand, Limb, Eye)



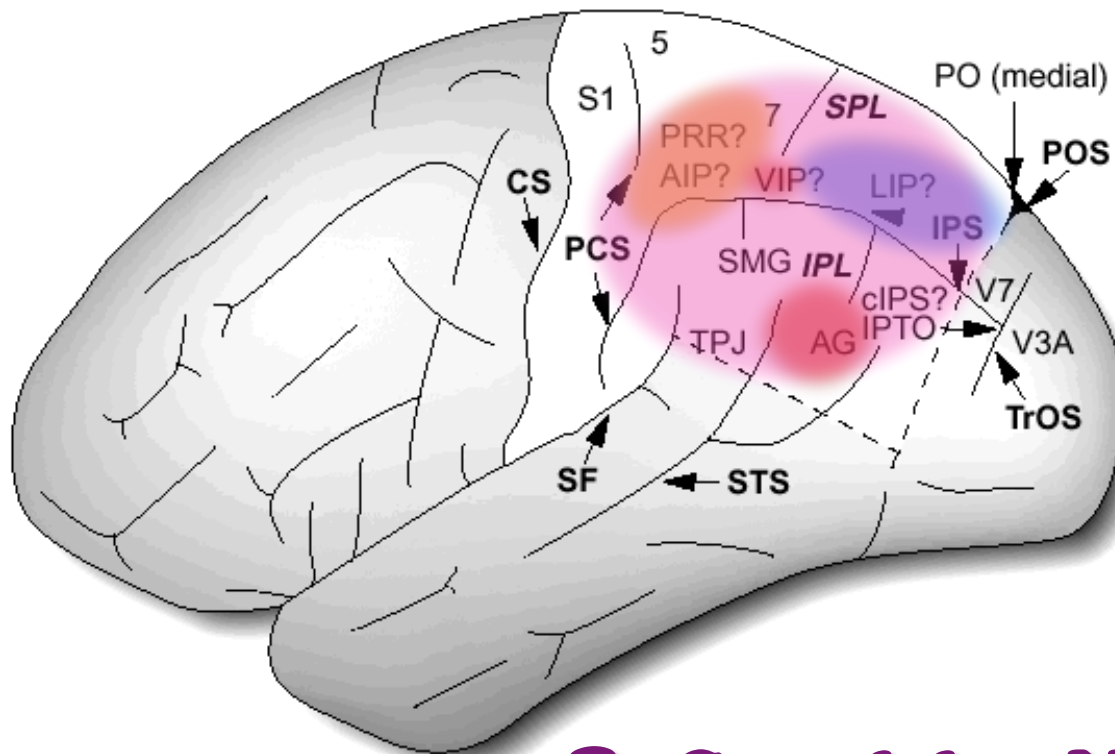
*Posterior Parietal Cortex*



Eye movement

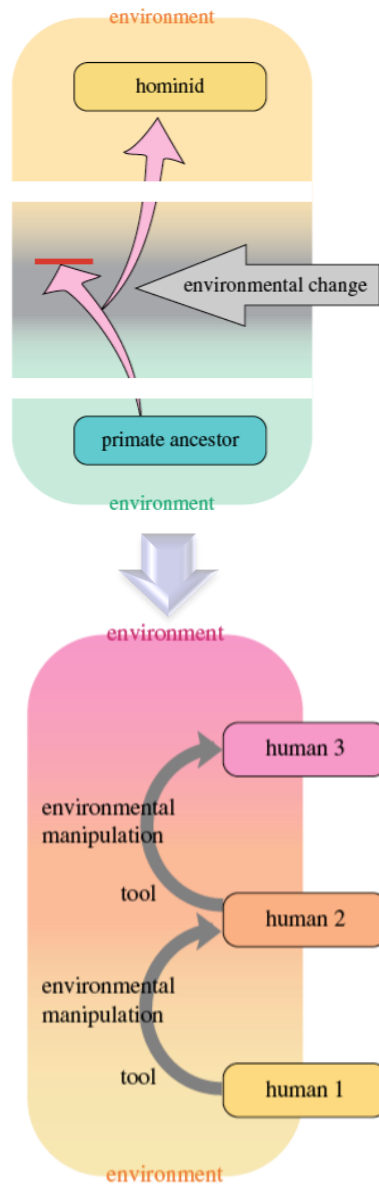
Hand movement

Head movement



**3. Cognitive Niche Construction**

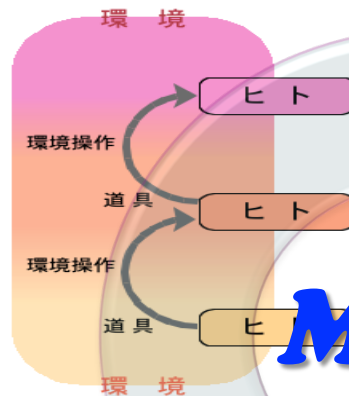
## Natural Selection



## Intentional Niche-Construction

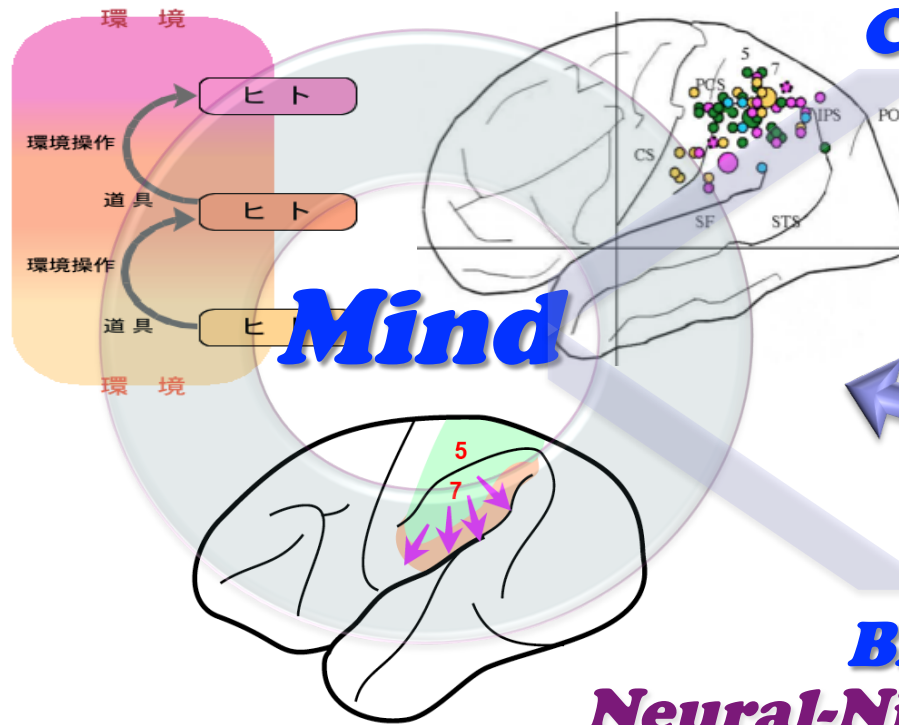
# Triadic Niche-Construction

## *Ecological-Niche*



## *Cognitive-Niche*

### **Cultural**



*Conceptual  
Biological*

## **Biological Neural-Niche**

**w/ extra-genomic  
epi-genetic  
evo-devo**

**mechanisms**



*meta-physical  
symbolic/language*

**Brain**

**Mind**

*recursion*

**Triadic Niche-Construction**

**Ecological-Niche**

**Cognitive-Niche**

**Cultural**

*self-objectification*

**Mind**

**Biological**

**Neural-Niche**

**Body**



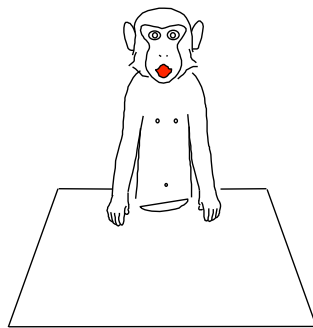


# Naming

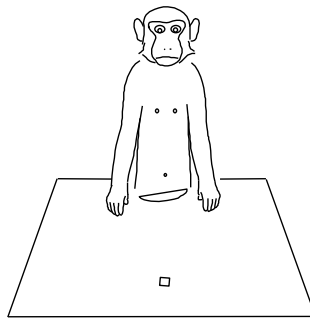
# Syntax



【 I 】



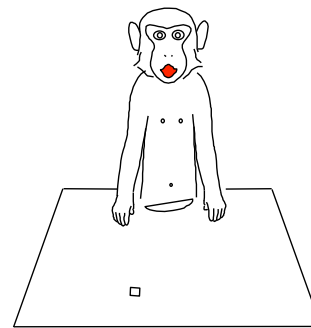
Call A



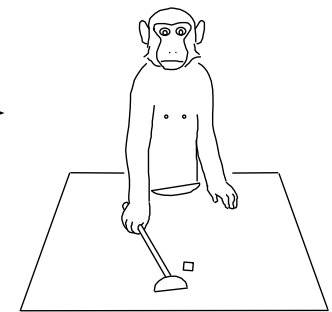
Food



【 II 】

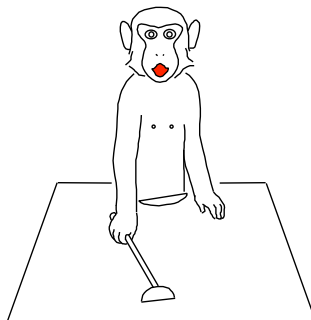


Call B

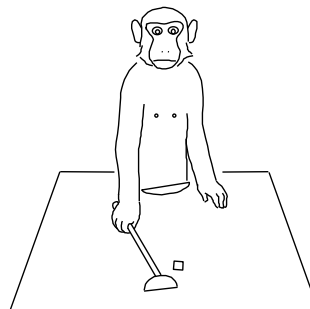


Tool

【 III 】

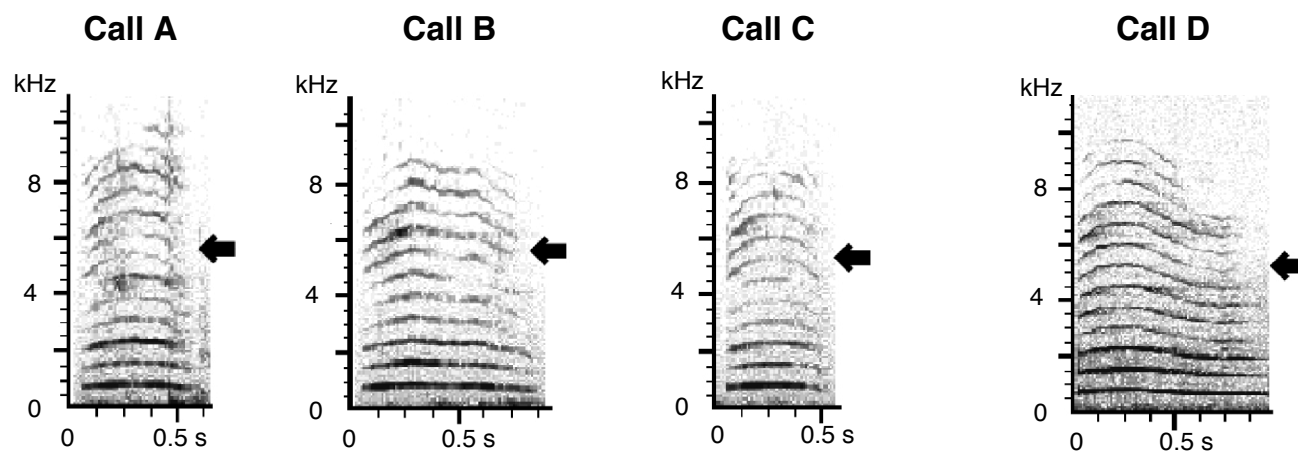
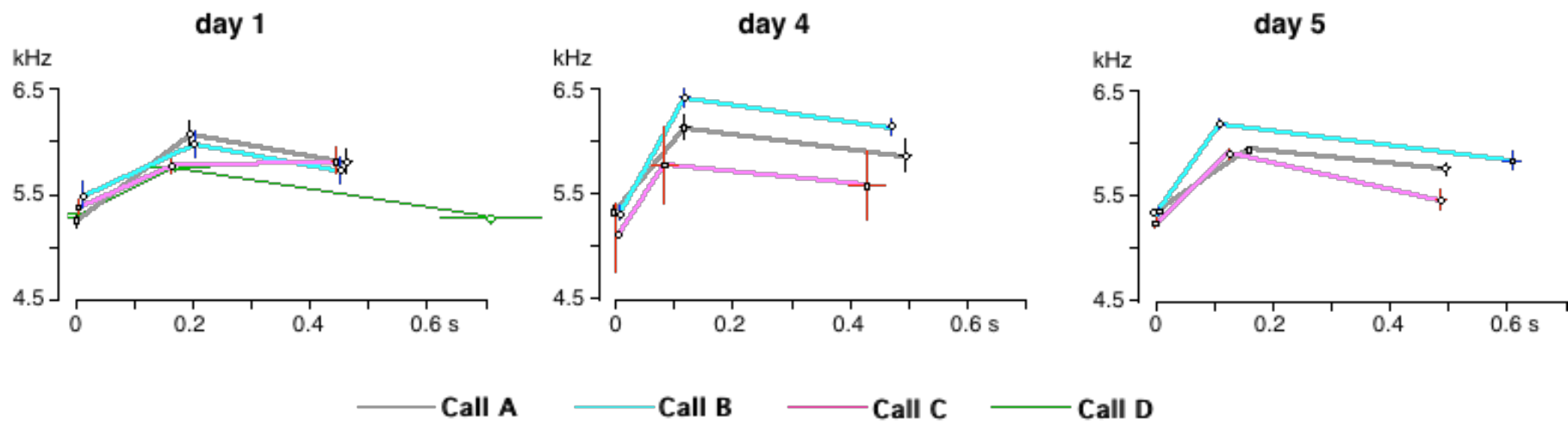


Call C



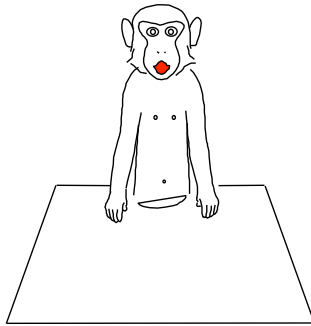
Food



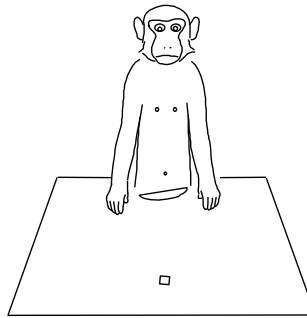




【 I 】



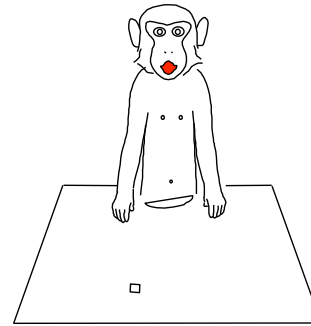
Call A



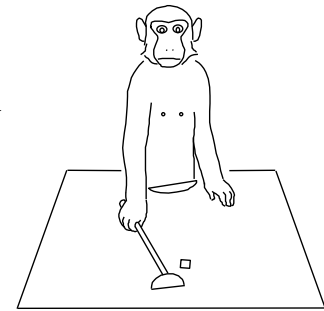
Food



【 II 】

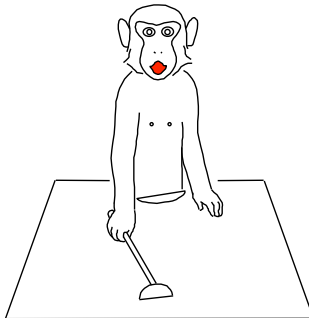


Call B

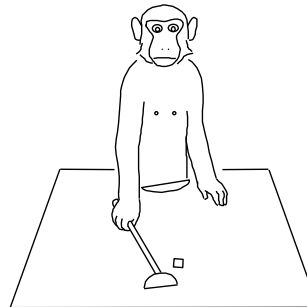


Tool

【 III 】



Call C

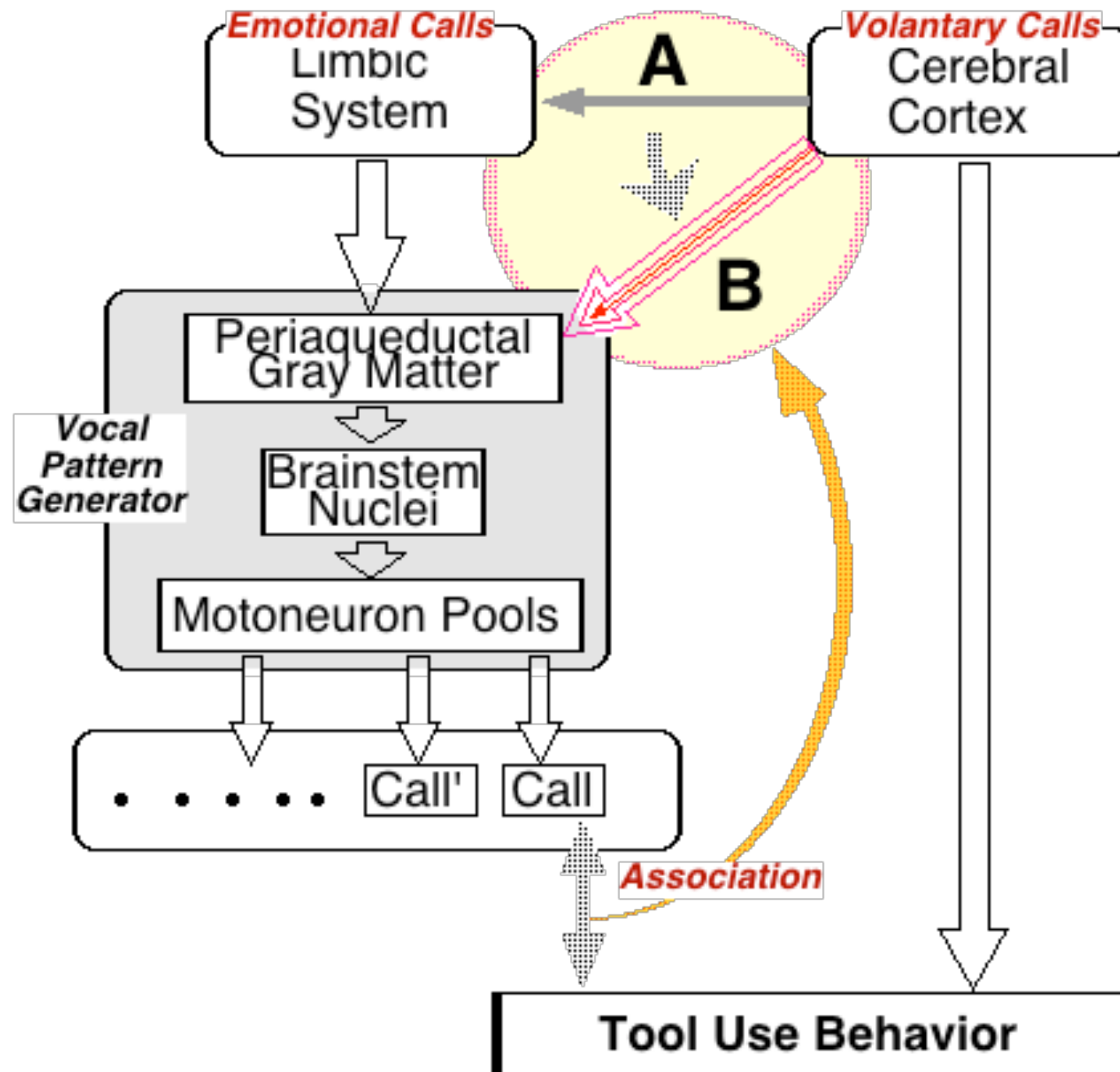


Food



*Analysis (tool – food)*

## < Hypothesis >





# Naming

# Syntax



# Mirror Neuron System

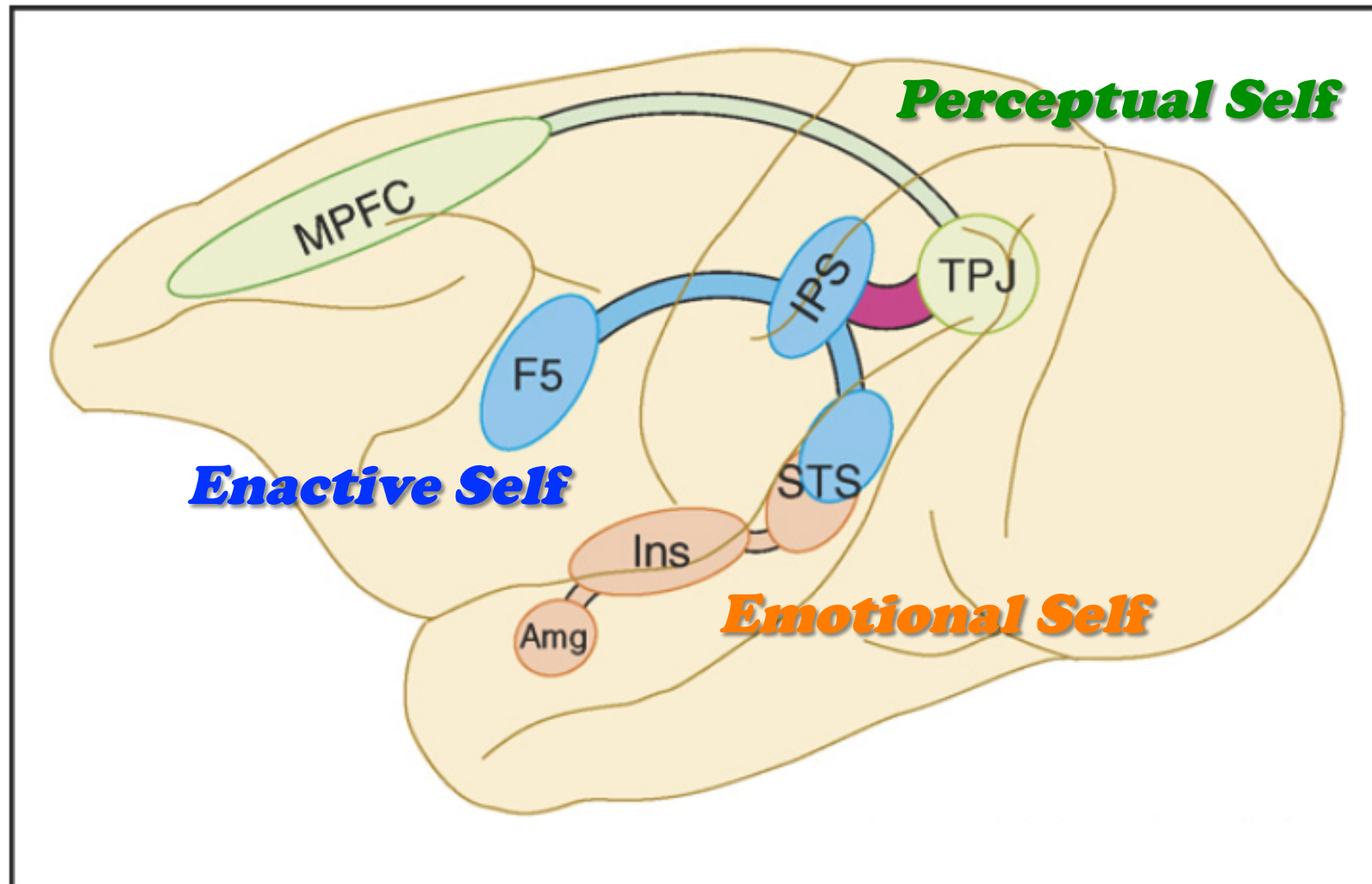
*Equivalence (self – other)*



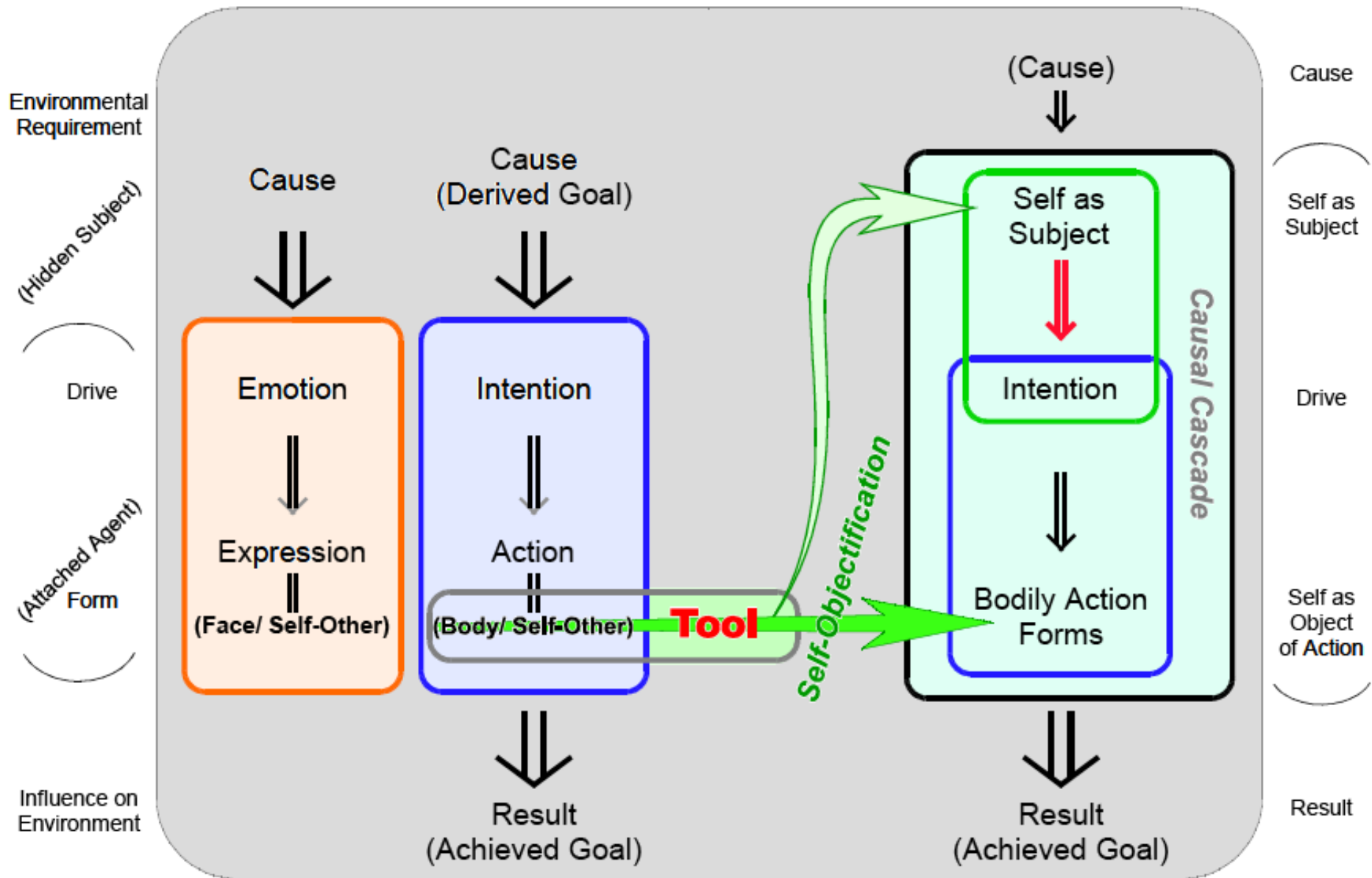
*Self-Objectification*

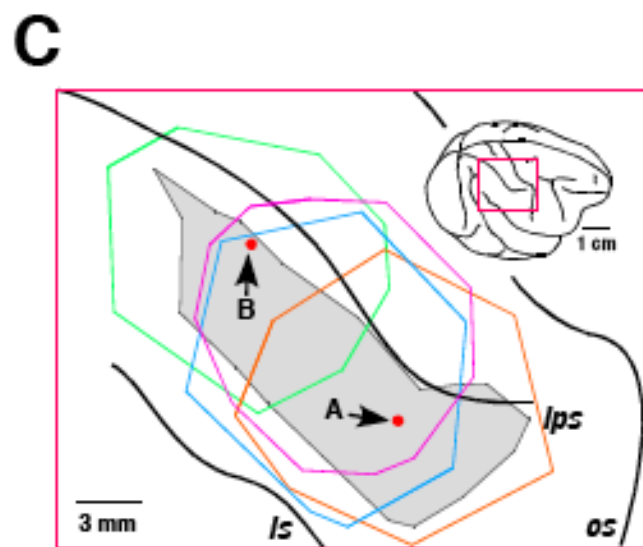
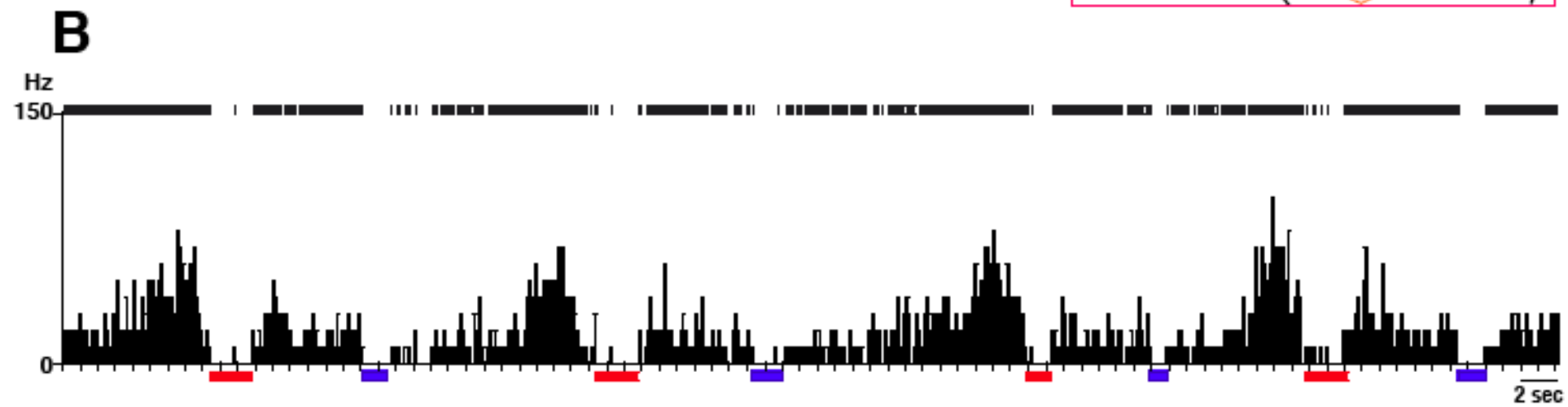
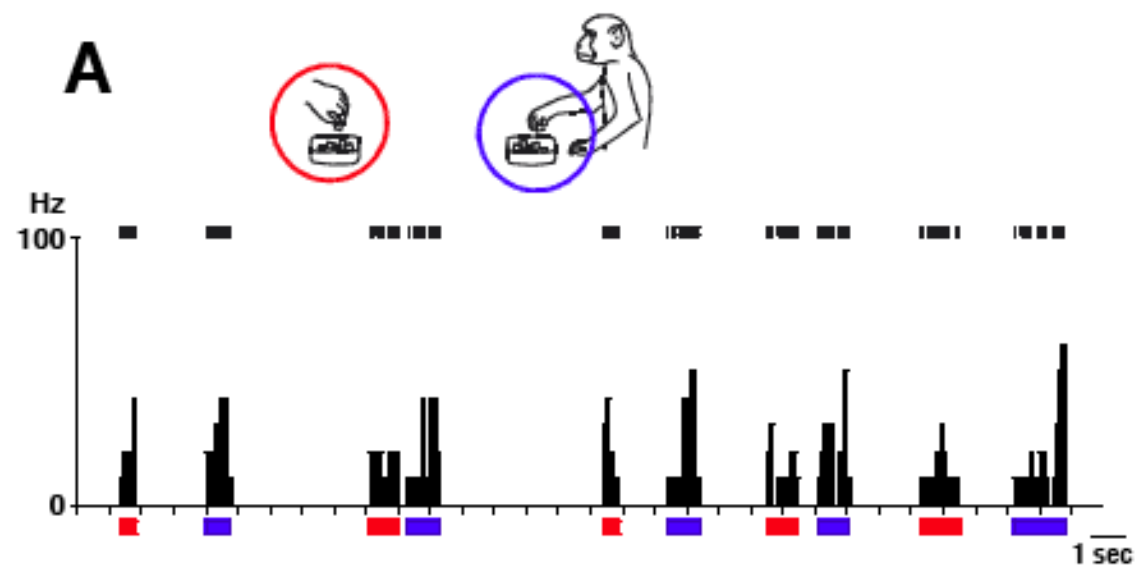


*Syntax of Action*





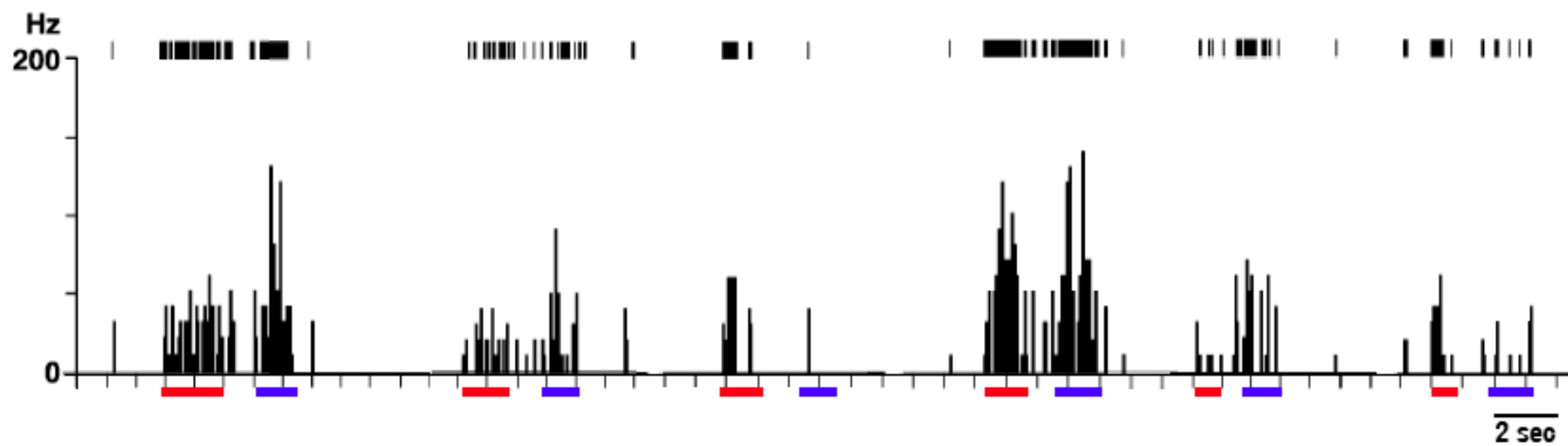
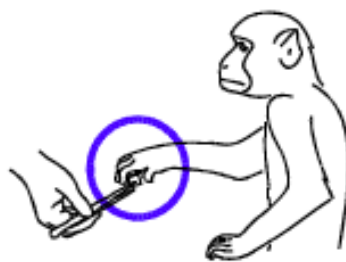
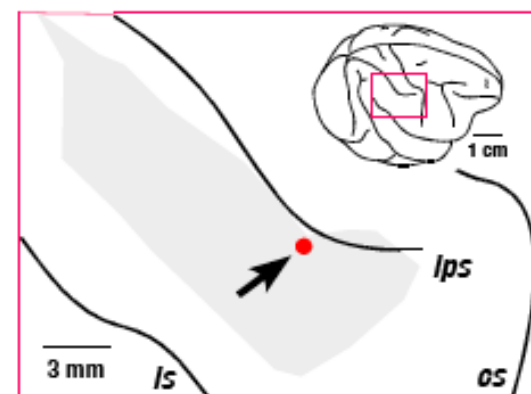


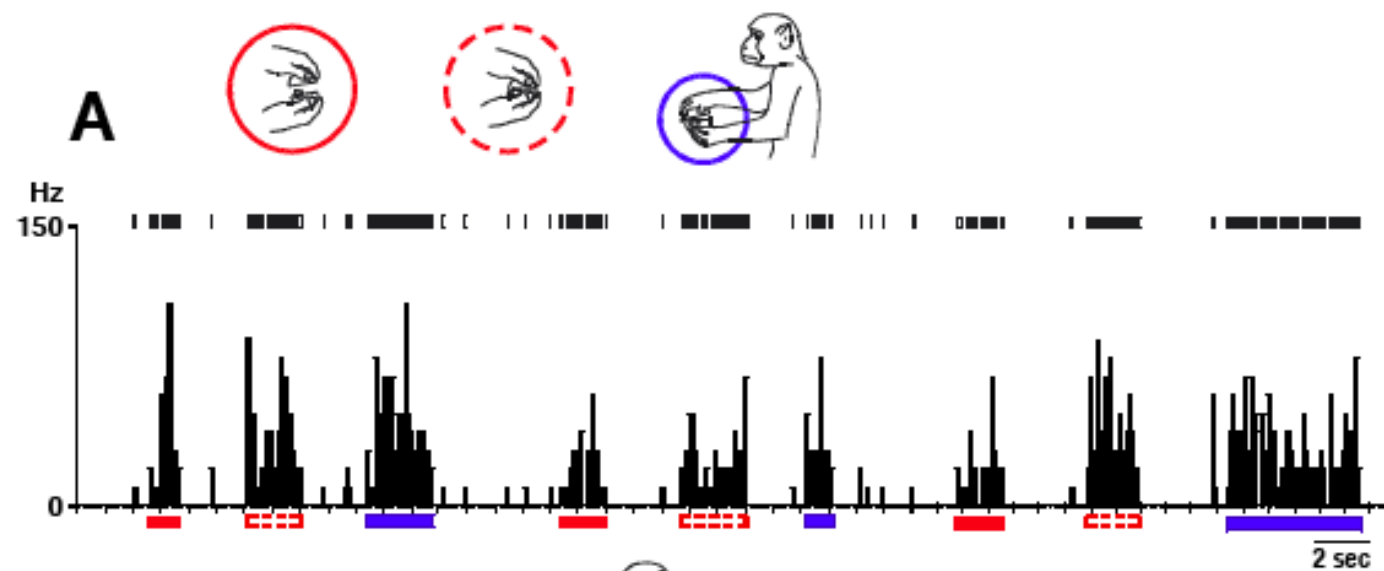


## *Equivalence (self – other)*

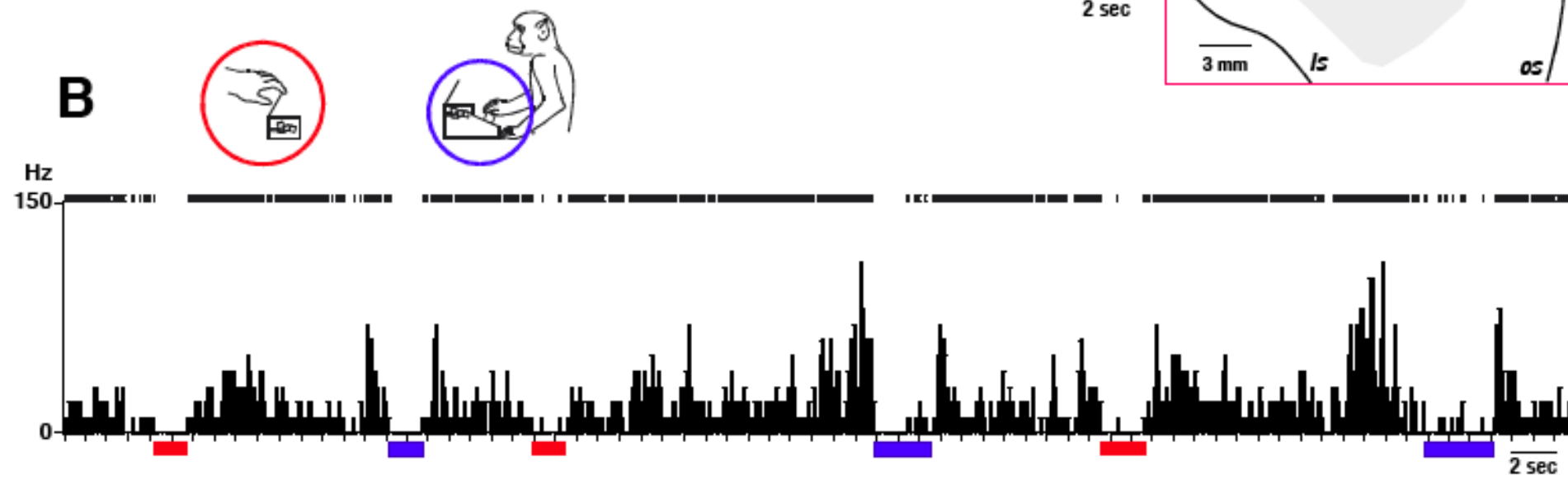
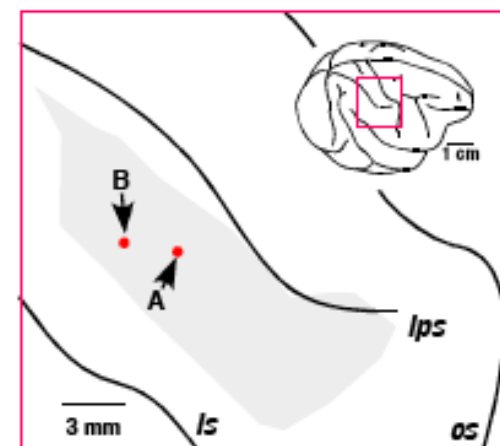
| Mirror Properties and Studies                              | Recording site | Agents     | Action forms | Goal of action                                                     | Others(Ot)                                 | Coding           | Neuro-cognitive Processes         |
|------------------------------------------------------------|----------------|------------|--------------|--------------------------------------------------------------------|--------------------------------------------|------------------|-----------------------------------|
|                                                            |                | Subject(S) | Verb(V)      | Object(O)                                                          |                                            |                  |                                   |
| <b>Classical mirror neuron</b><br>Rizzolatti et al. (1996) | F5             | X or Y     | grasp stick  | food                                                               |                                            | * - (V - O)      | Generalization of Agents          |
| Present study [Fig.2]                                      |                | X or Y     | grasp        | food                                                               |                                            |                  |                                   |
| <b>Contextual dependency</b><br>Fogassi et al. (2005)      | 7b             | X or Y     | bring        | food                                                               | <u>into the mouse</u><br><u>into a box</u> | * - V - O - (Ot) | Functional Equivalence of Actions |
| <b>Reward dependency</b>                                   |                | X          | pick         | <u>peanut</u><br><u>cookies</u><br><u>peanut</u><br><u>cookies</u> |                                            | * - V - (O)      |                                   |
| Present study [Fig.3]                                      |                | Y          |              |                                                                    |                                            |                  |                                   |
|                                                            |                |            |              |                                                                    |                                            |                  |                                   |
| <b>Contextual dependency</b><br>Present study [Fig.4, A]   |                | X or Y     | open         | box                                                                | * - * - (O)                                |                  |                                   |
|                                                            |                | Y          | close        |                                                                    |                                            |                  |                                   |
| <b>Functional equivalence</b><br>Present study [Fig.4, B]  | X or Y         | push pull  | button cover |                                                                    |                                            |                  |                                   |
| <b>Equivalence relations</b><br>(Prediction)               | ?              | X or Y     | any action   | any goal                                                           |                                            | (* - * - *)      | Stimulus Equivalence              |



**A****B**



**C**

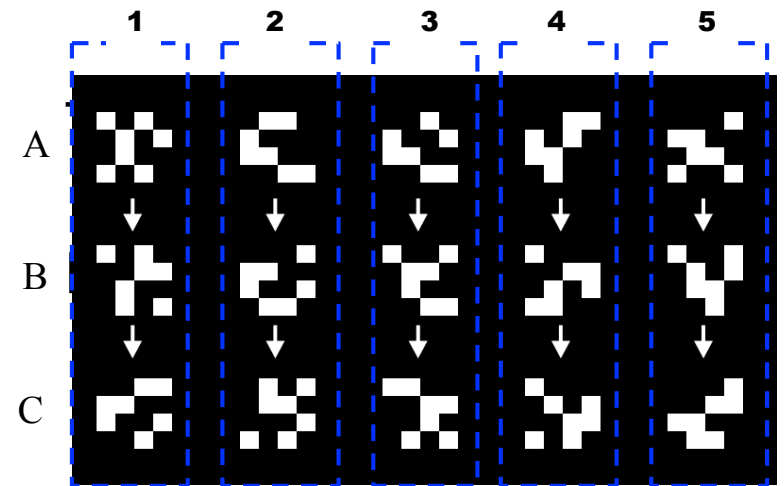
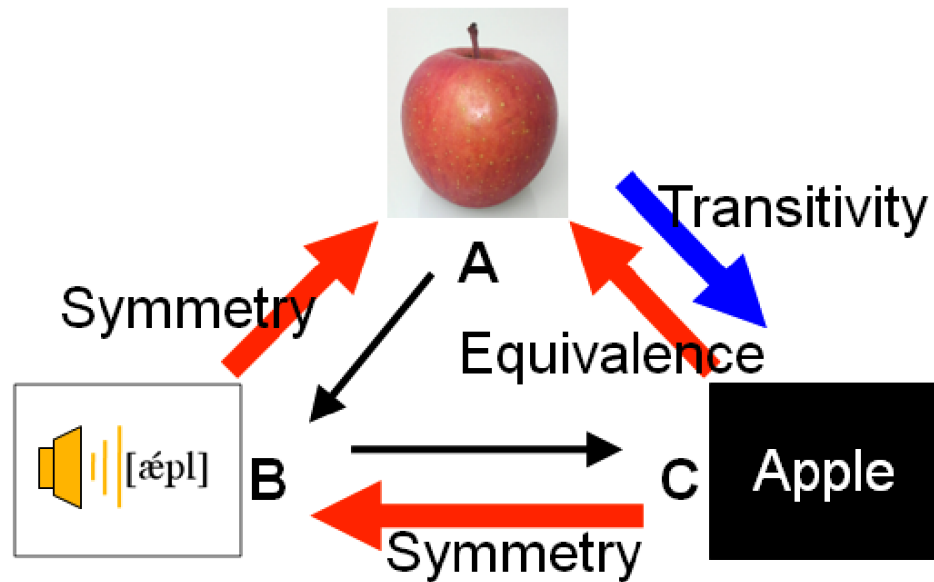


## Equivalence (self – other)

| Mirror Properties and Studies                              | Recording site               | Agents       | Action forms    |                          | Goal of action                      | Others(Ot)  | Coding               | Neuro-cognitive Processes                                                           |                                   |
|------------------------------------------------------------|------------------------------|--------------|-----------------|--------------------------|-------------------------------------|-------------|----------------------|-------------------------------------------------------------------------------------|-----------------------------------|
|                                                            |                              | Subject(S)   | Verb(V)         | Object(O)                |                                     |             |                      |                                                                                     |                                   |
| <b>Classical mirror neuron</b><br>Rizzolatti et al. (1996) | F5                           | X or Y       | grasp           | stick                    | food                                |             | * - (V - O)          | Generalization of Agents                                                            |                                   |
| Present study [Fig.2]                                      |                              | X or Y       | grasp           | food                     |                                     |             |                      |                                                                                     |                                   |
| <b>Contextual dependency</b><br>Fogassi et al. (2005)      |                              | X or Y       | bring           | food                     | <u>into the mouse</u><br>into a box |             | * - V - O - (Ot)     |  |                                   |
| <b>Reward dependency</b>                                   |                              | X            | pick            | <u>peanut</u><br>cookies |                                     |             | * - V - (O)          |                                                                                     | Functional Equivalence of Actions |
| Present study [Fig.3]                                      |                              | Y            |                 | <u>peanut</u><br>cookies |                                     |             |                      |                                                                                     |                                   |
|                                                            | <b>Contextual dependency</b> | X or Y       |                 | open                     | box                                 |             |                      |                                                                                     |                                   |
| Present study [Fig.4, A]                                   | Y                            | close        |                 |                          |                                     |             |                      |                                                                                     |                                   |
| <b>Functional equivalence</b><br>Present study [Fig.4, B]  | X or Y                       | push<br>pull | button<br>cover |                          |                                     |             | Stimulus Equivalence |                                                                                     |                                   |
| <b>Equivalence relations</b><br>(Prediction)               | ?                            | X or Y       | any action      | any goal                 |                                     | (* - * - *) |                      |                                                                                     |                                   |

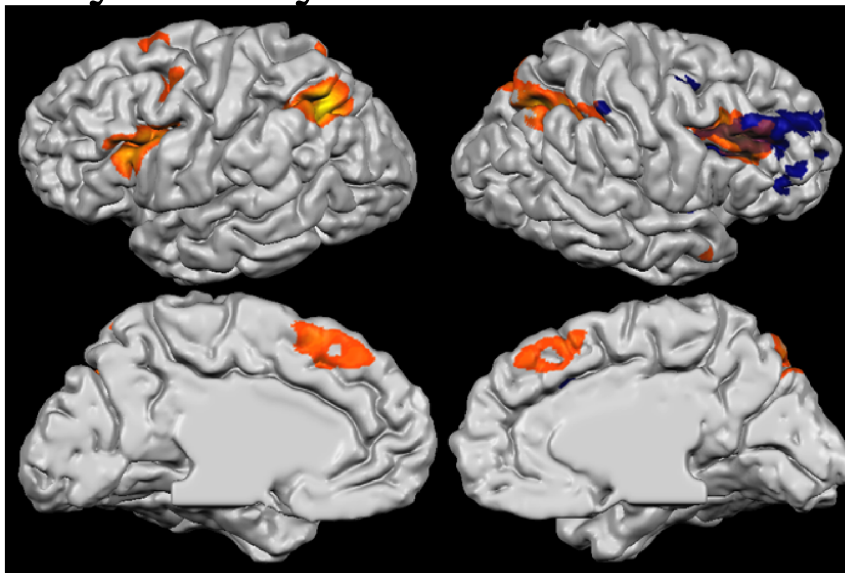
## Syntax (phenomena)

# Stimulus *Equivalence* (Illogical Inference)



Symmetry

Lateral

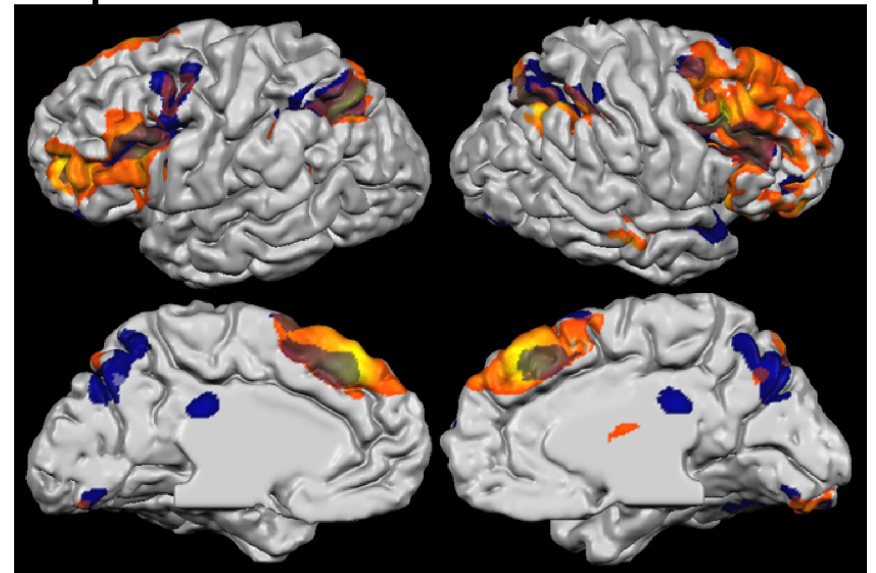


Left

Right

Equivalence

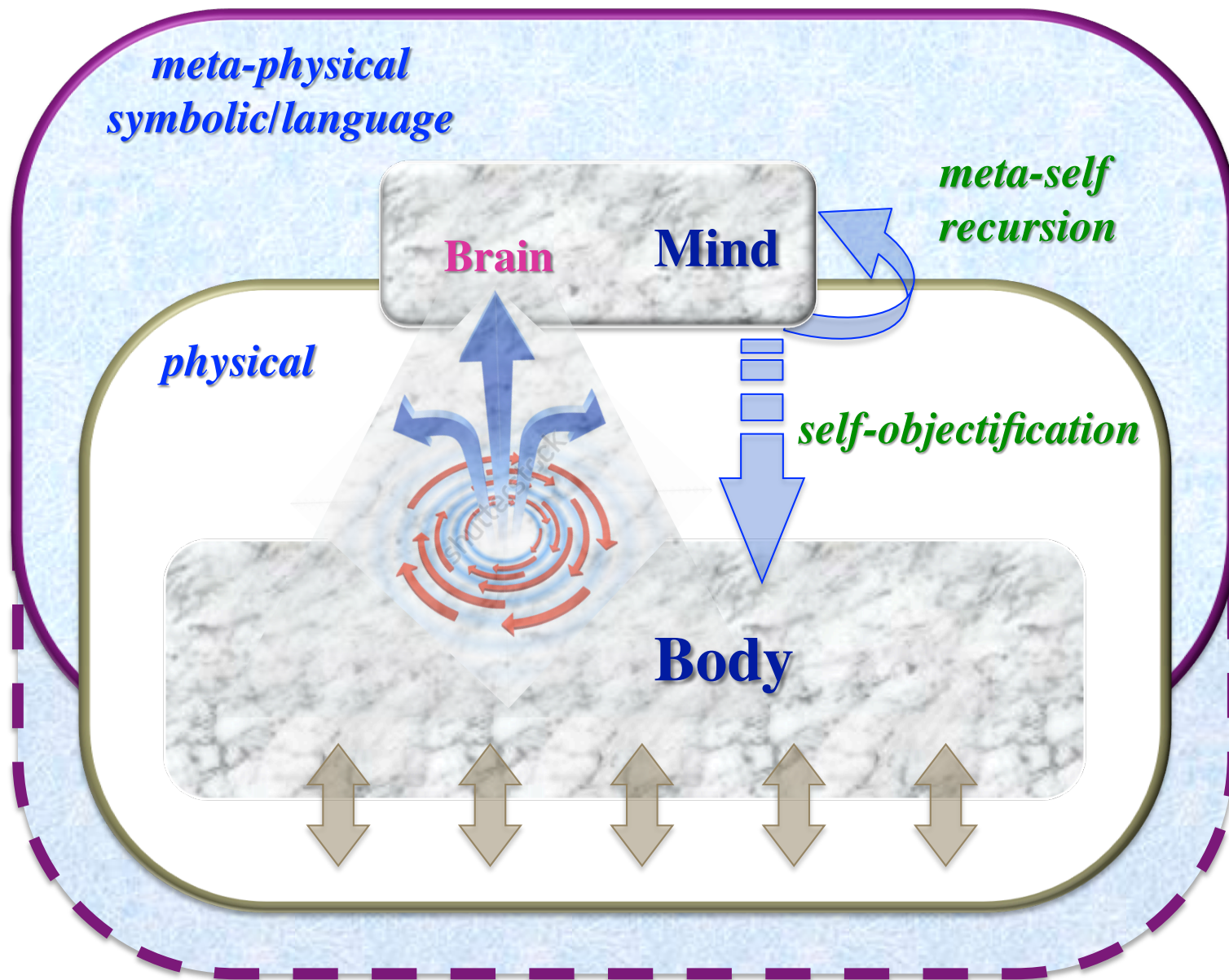
Lateral



Left

Right





*meta-physical  
symbolic/language*

**Brain**

**Mind**

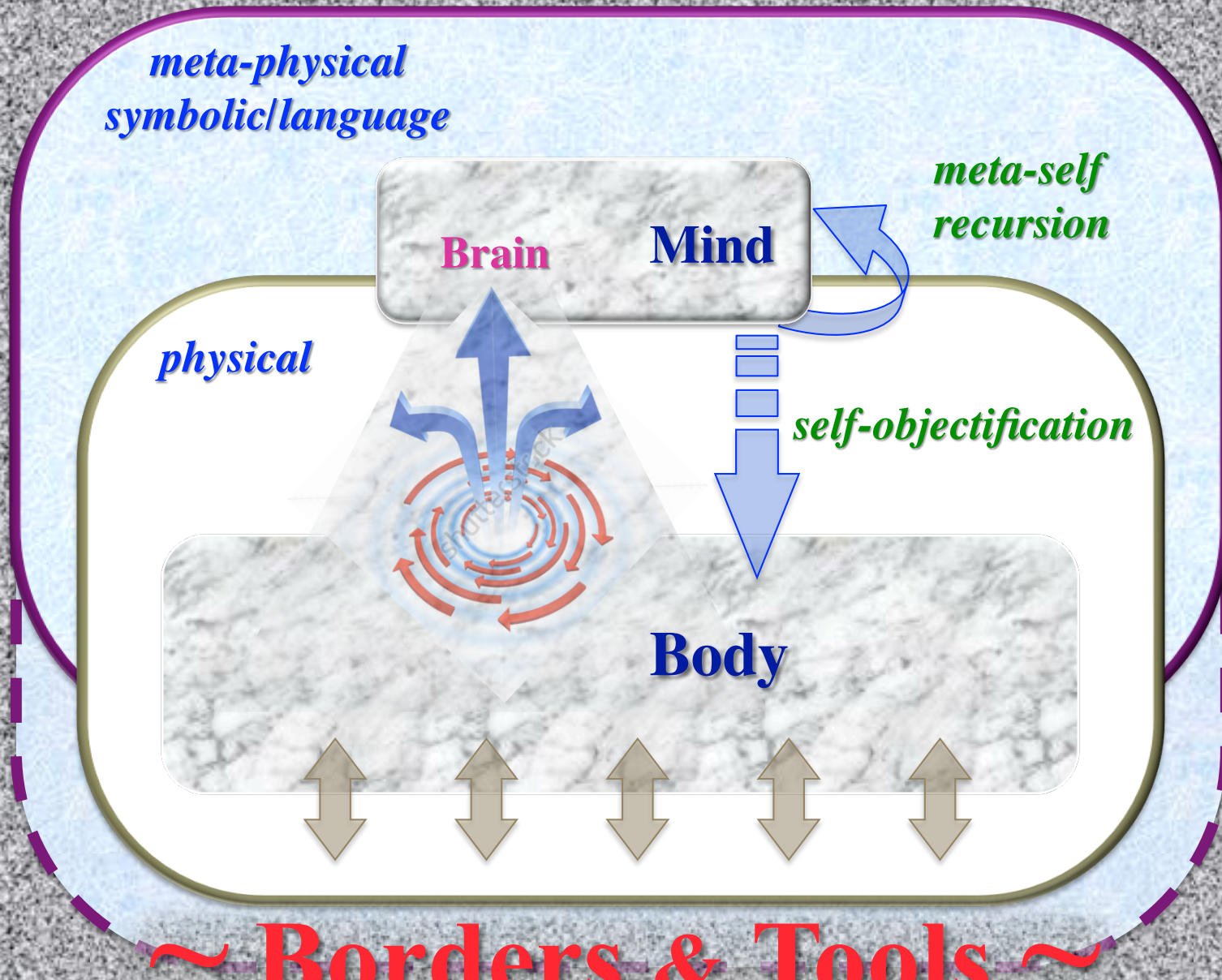
*meta-self  
recursion*

*physical*

*self-objectification*

**Body**

**~ Borders & Tools ~**





## Heartful Gratitude to ...

### Neural Recording

*Michio Tanaka*  
*Yoshiaki Iwamura*  
*Sayaka Hihara*  
*Hiroko Yokochi*

### PET imaging

*Shigeru Obayashi*  
*Tetsuya Suhara*

### Genetic Analyses

*Masaki Isoda*  
*Kyoko Yoshida*  
*Norio Ozaki*

### MRI-VBM

*Marsha Quallo*  
*Roger Lemon*  
*Cathy Price*  
*Keigo Hikishima*

### Tracer Labeling

*Sayaka Hihara*  
*Hisayuki Ojima*

### Sensory-Tool Use

*Yumiko Yamazaki*  
*Hiromi Namba*

### Human fMRI

*Corrado Corradi-Dell'Acqua*  
*Akitoshi Ogawa*  
*Yumiko Yamazaki*  
*Kang Cheng*  
*Raffaella Rumiati*

### Vocal Production

*Sayaka Hihara*  
*Kazuo Okanoya*