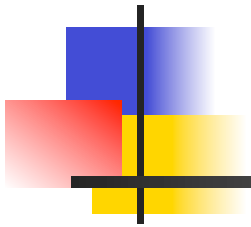


Mirroring and Social Cognition: In the beginning…

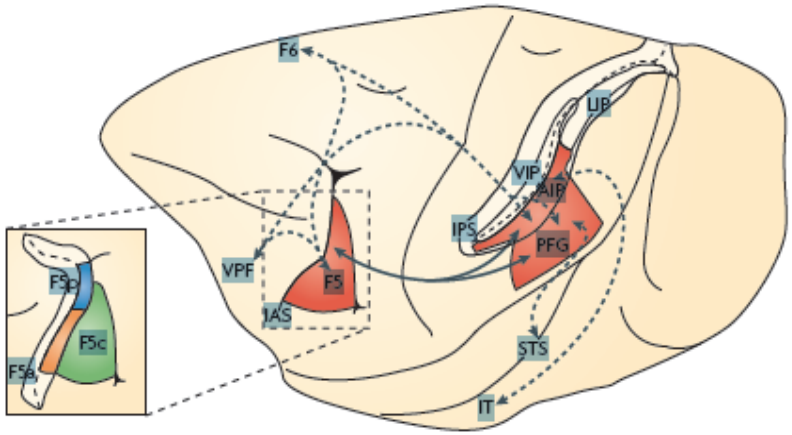
COGS171

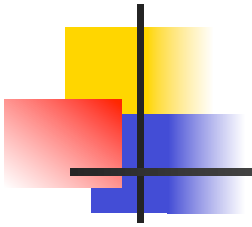
FALL Quarter 2011

J. A. Pineda

di Pellegrino study

- Studied the activity of F5 neurons
- Macaque monkeys were trained to retrieve objects of different sizes and shapes from a testing box.
- The monkey initiated trials by pressing a switch, which lit the box and made the object visible.
- After a delay of ~1.5 s, the door opened and the monkey was allowed to reach for the object.
- The animal was rewarded with a piece of food located under the object.

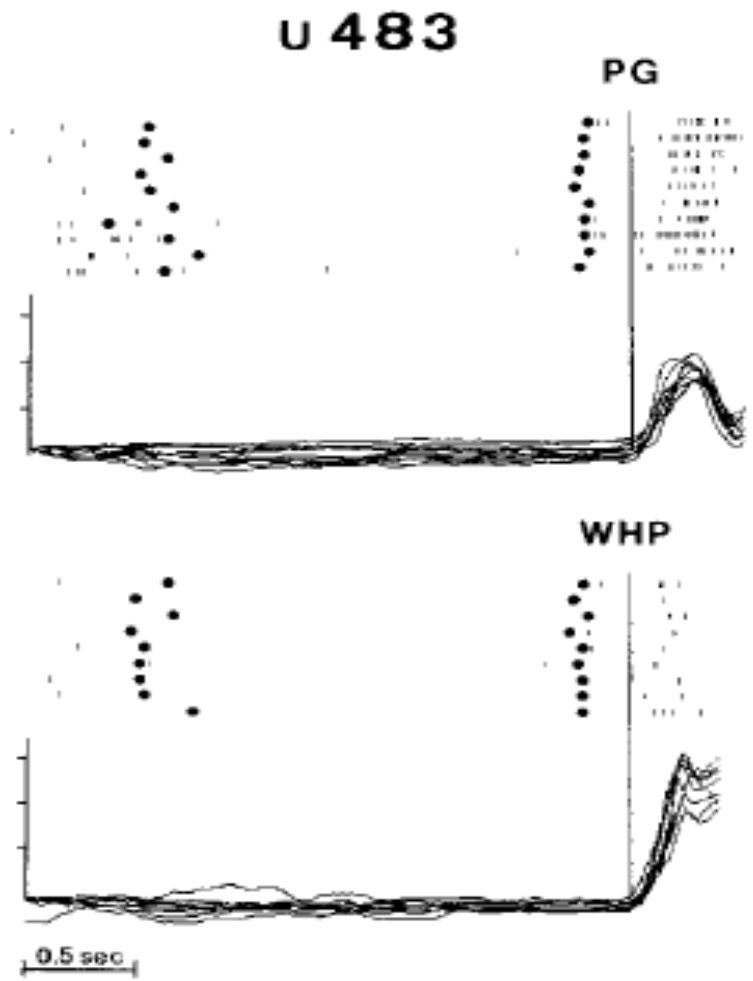


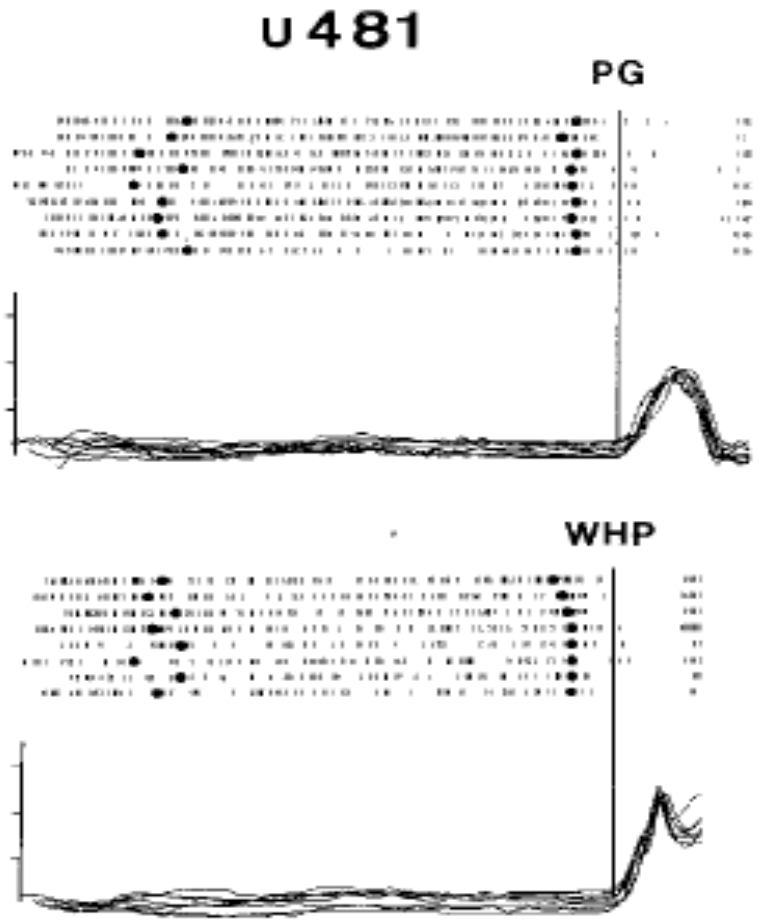


Expected Results

- Almost all neurons became active during different types of distal movements (grasping, holding, tearing).
- Stimulation of these neurons produced finger and hand movements
- These are clearly “motor” neurons

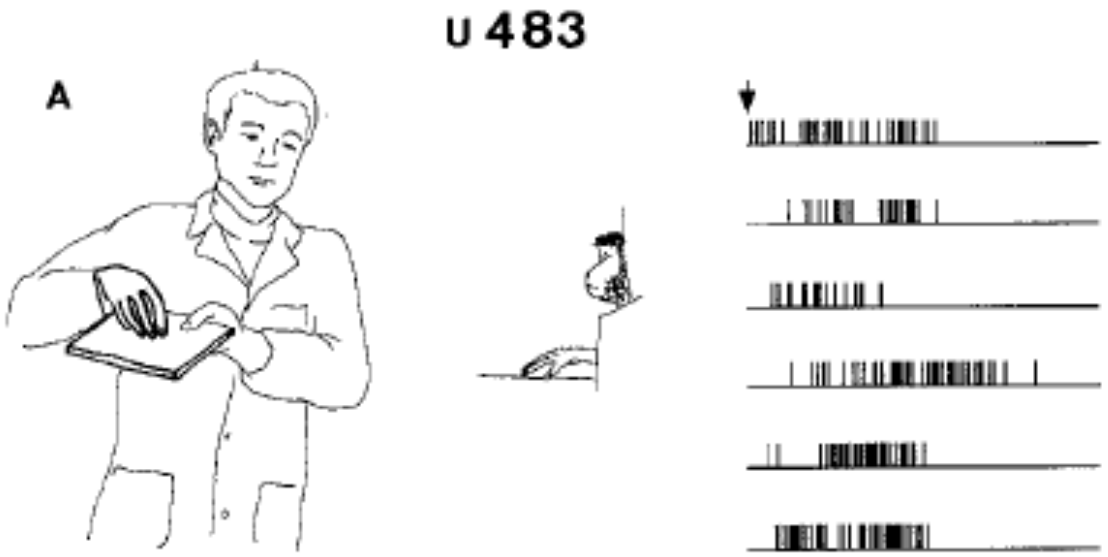
Expected Results

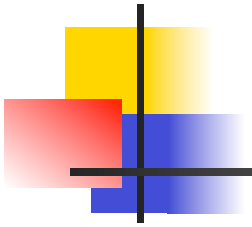




Unexpected Results

- Some experimenter's actions activated a large proportion of F5 neurons in the absence of any overt movement of the monkey.

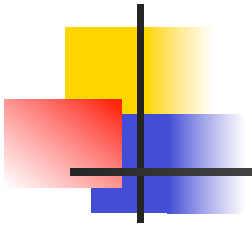




Which actions trigger such motor responses?

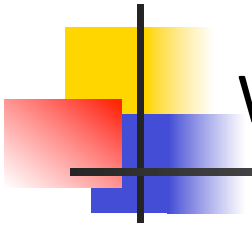
- On which side of visual space? How far from animal?
  - grasping food (e.g., presenting the food to the monkey),
  - putting it on a surface, retrieving it,
  - giving it to a second experimenter,
  - taking it away from him),
  - Manipulating food and other objects (breaking, tearing, folding),
  - gesturing with or without emotional content (threatening, lifting the arms, waving the hands).

A total of 184 neurons were studied



Unexpected Results

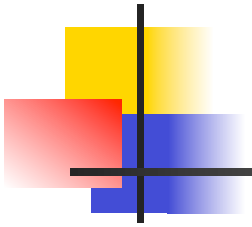
- 87/184 or ~47% of cells responded to visual stimulus
  - 48 responded to simple meaningful stimuli (food)
  - 39 had more complex properties
    - 12 showed corresponding executed and observed action
    - 6 showed corresponding actions PLUS response to visually similar actions
    - 11 showed logically-related executed and observed action
    - 10 responded to observed actions but no matching executed actions
- Appropriate movements of the experimenter triggered the neurons whether performed within the monkey's peripersonal space or outside it.



What actions didn’t trigger a response?

- Movements of the experimenter's hand alone
- The combined movements of hand and object spatially separated one from the other
- Grasping the food with forceps, pincers, or other tools
- Threatening movements

- Changes of electromyographic activity related to observed action were never found – i.e., monkey did not move

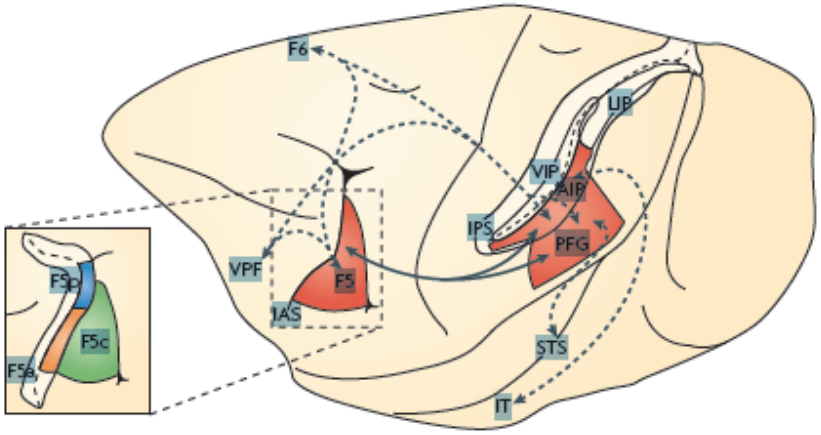


Discussion

- The present data indicate that in addition to these physical factors, retrieval can also occur in response to the meaning of the gestures made by other individuals.
- The discovery in the premotor cortex of neurons sensitive to the meaning of actions was unexpected.
- Hand-object interactions belong to those categories of complex stimuli which, like faces (Gross et al. 1972; Rolls 1984; Perrett et al. 1984, 1987; Desimone 1991), are explicitly coded by individual neurons.
- Findings consistent with motor theories of perception

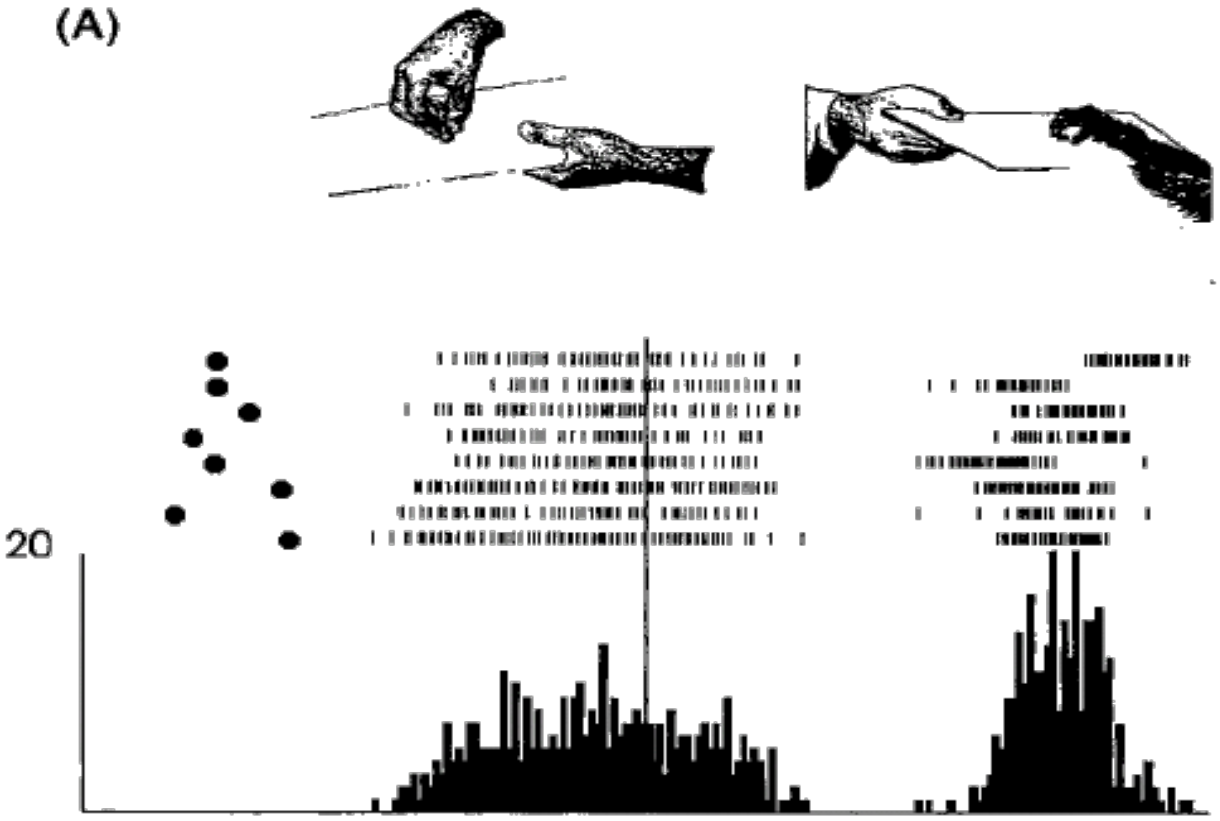
Mirror Neurons in Parietal-Frontal Circuit

- Discharge both when the monkey performs an action and when it observes a similar action done by another monkey or an experimenter
  - **Found in:**
    - area F5 (homolog of Broca's area); 10-20%
    - inferior parietal cortex (PF/7b)
  - **Activated by:**
    - Goal directed actions (reaching, grasping, holding, tearing)
    - Observation of similar actions performed by "biological" agents

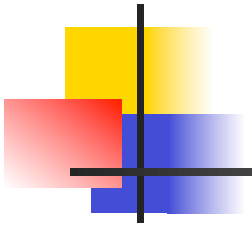


Di Pellegrino, Exp Brain Research, 1992

Mirror Neuron Activity



Rizzolatti et al., Cogn. Brain Res., 1996, 3:131-141



Neural Systems

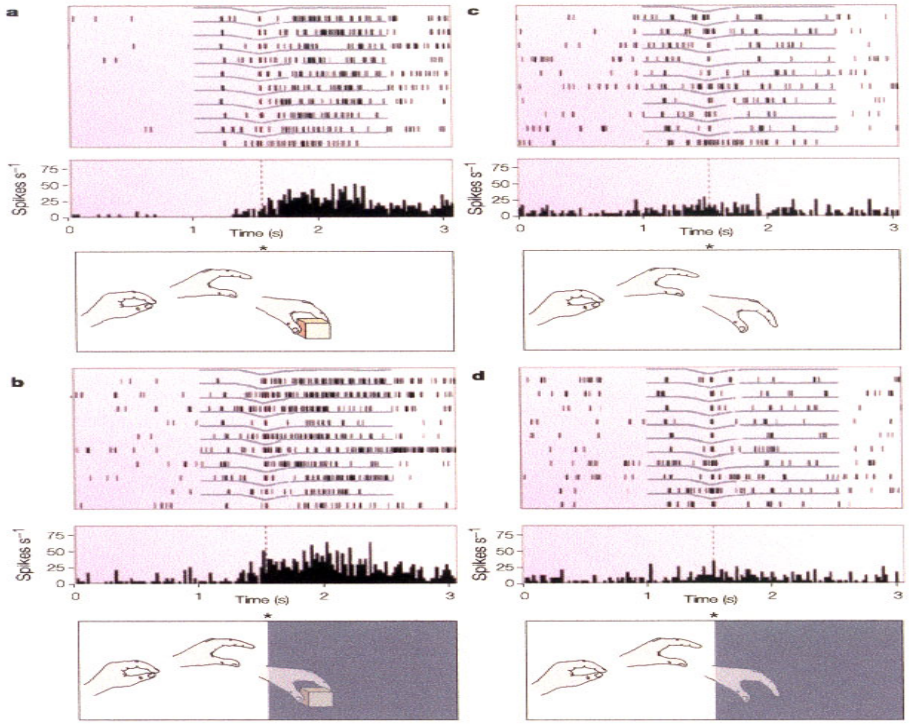
- At least two neural systems have been proposed to manage self/other distinction
  - **Classic motor system**: specialized for the preparation and execution of motor actions that are self realized and voluntary,
  - **Mirroring system**:
    - primarily involved in capturing and understanding the actions of non-self or others.
    - Evolved to share many of the same circuits involved in motor control.
    - Bridge between perception and action that allows for simulation

Mirroring System

- Mirroring or 'shared circuit systems' are assumed to be involved in
  - Resonating
  - Imitating
  - Simulating the actions of others
- Shared representations of motor actions may form a foundational cornerstone for higher order social processes
  - Each time an individual observes another individual performing an action, a set of neurons that encode that action is activated in the observer's cortical motor system.

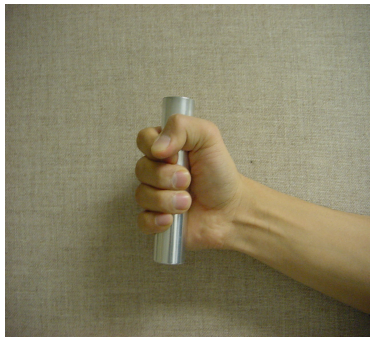
What do mirror neurons encode during observation?

Grasping Mimicking

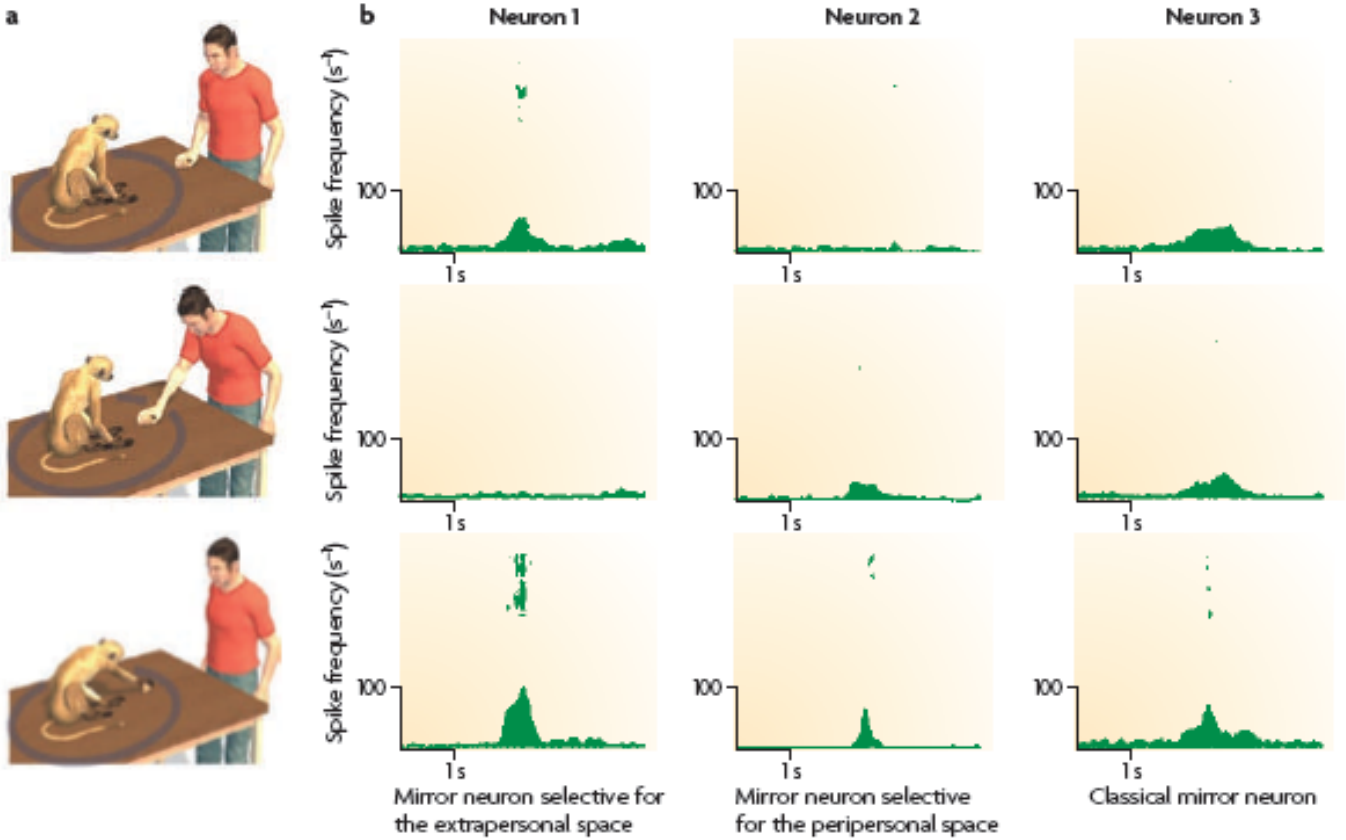


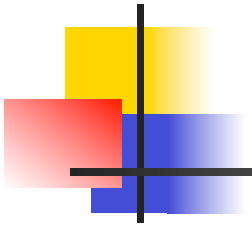
Umiltà et al. Neuron, 2001

Perception-to-Action Mapping Selectivity

	Congruent (effector dependent)	Logically-Related (effector independent; 2X)
Perception		
Action		

Encoding goal in an observer-centered spatial framework



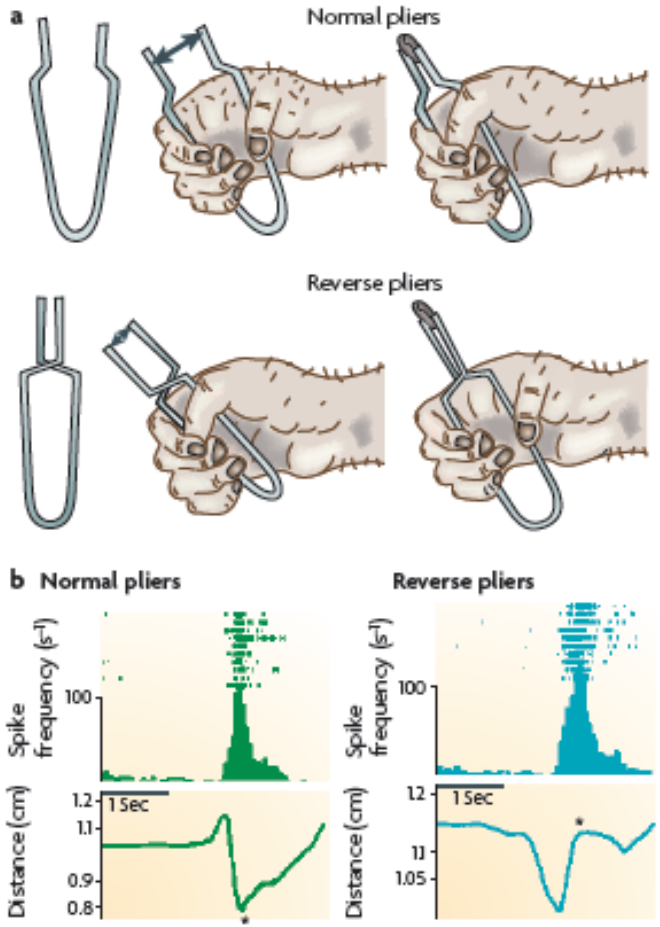


Differences Between Monkey/Humans

- Monkeys imitate the goal and not the individual movements;
- In humans, the mirroring system also becomes active during the observation of individual movements
- Mirror neurons seem tailor-made for imitation; yet monkeys (at least) are rotten imitators (monkeys aren't chimps)
  - maybe necessary element but not sufficient

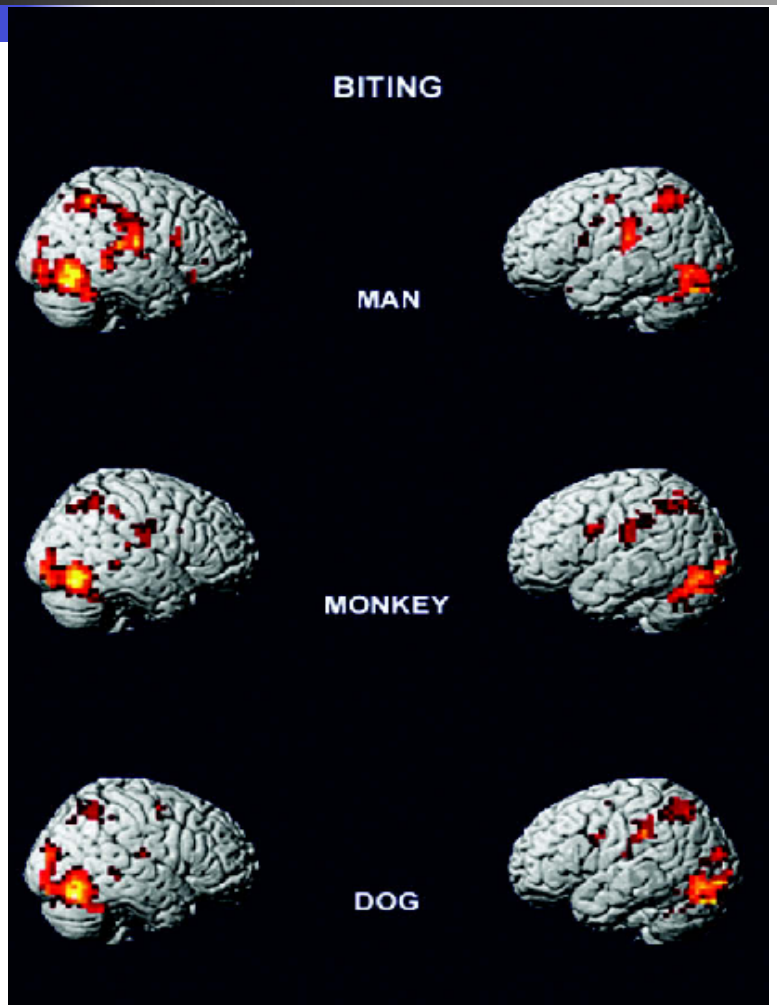
What do mirror neurons encode during movement?

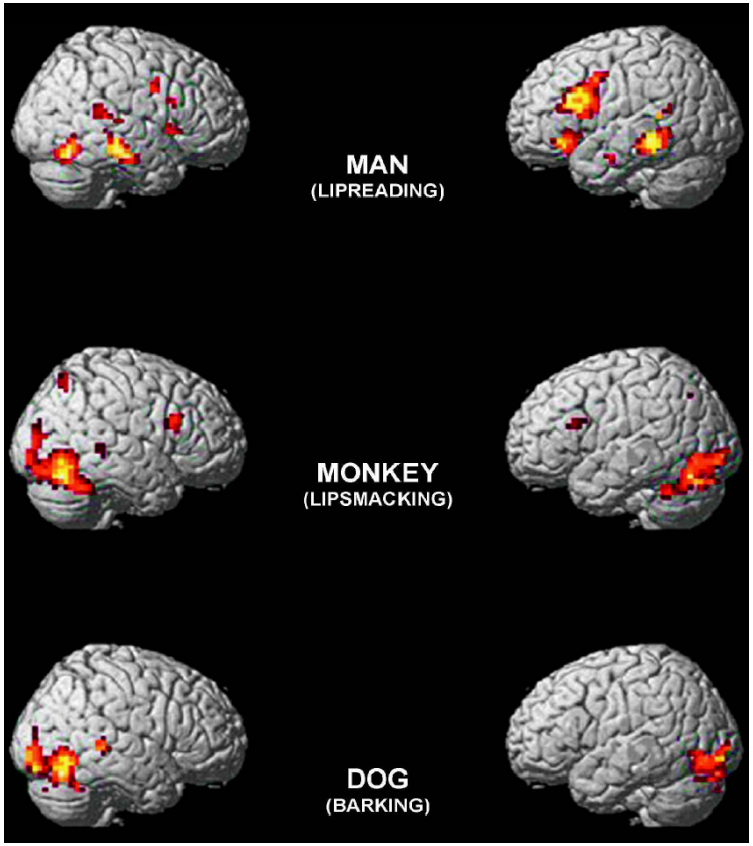
F5 neurons discharged during the same phase of grasping in both conditions, regardless of whether this involved opening or closing of the hand



Umiltà, M. A. *et al. Proc. Natl Acad. Sci. USA,* 2008.

Is there cross-species mirroring?





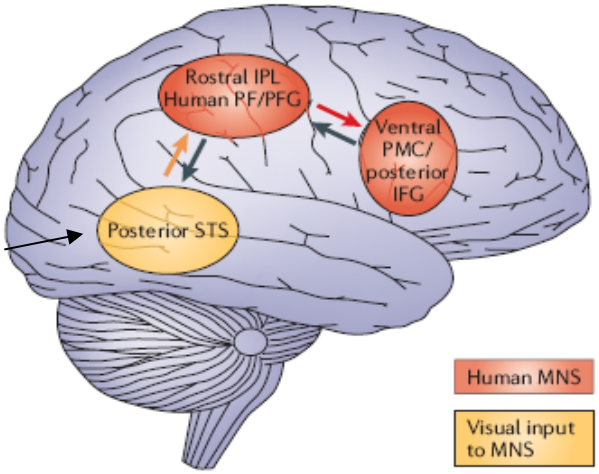
Buccino et al. J. Cogn. Neurosci., 2004, 16: 1-14

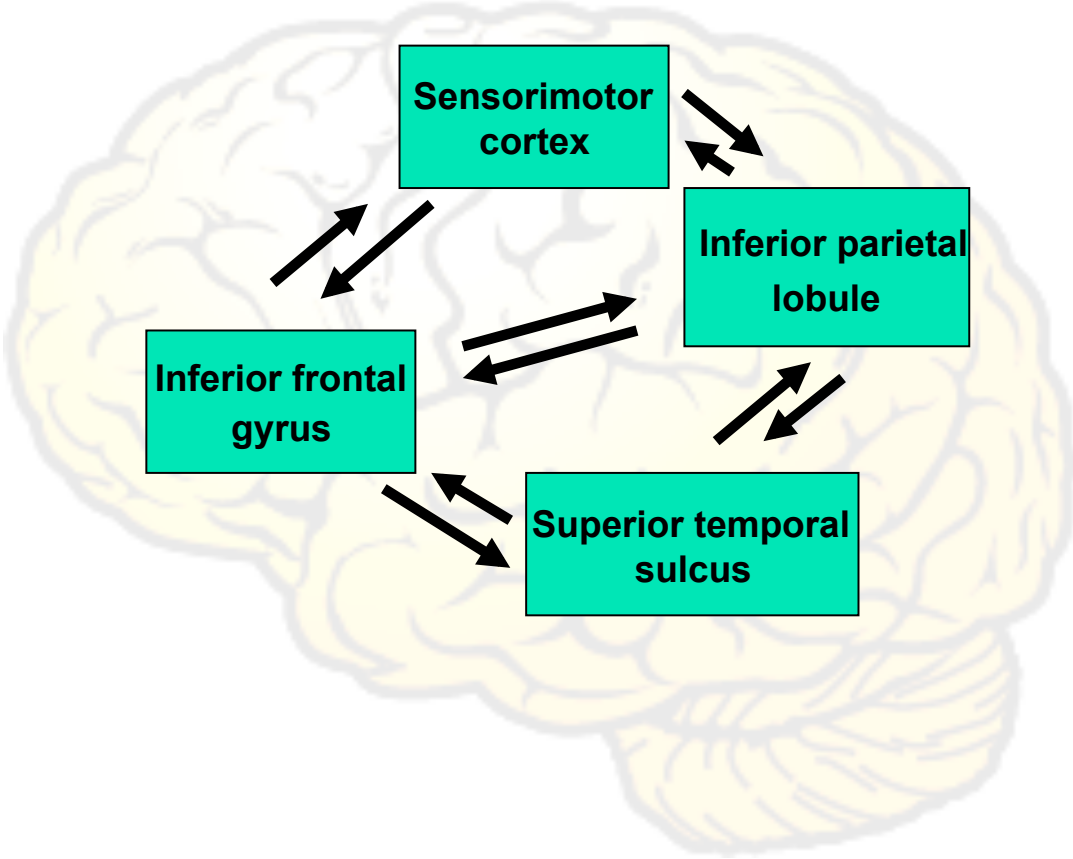
Why does the motor system encode the goal of actions performed by others?

- Allow the observer to understand directly the goal of the actions of others without needing inferential processing
- …although there are several mechanisms through which one can understand the behaviour of other individuals, the parieto-frontal mechanism is the only one that allows an individual to understand the action of others 'from the inside' and gives the observer a first-person grasp of the motor goals and intentions of other individuals.

Rizzolatti and Sinigaglia, 2010

The Human Mirror Neuron System





Iacoboni and Dapretto, Nature Reviews, 2006,7:942-951

Pineda, Beh & Brain Functions, 2008, 4, 47

Controversy: Do human MNs exist?

- Some have argued that the activation of the same areas during action observation and action execution via fMRI is not sufficient to prove the existence of the mirror mechanism in humans
- Motor areas have distinct, segregated populations of visual and motor neurons, the visual neurons discharging during action observation and the motor neurons during action execution.

Mukamel et al. study

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UCLA researchers make first direct recording of mirror neurons in human brain

Such cells appear to have wider distribution than previously thought

By Mark Wheeler | April 12, 2010

Mirror neurons, many say, are what make us human. They are the cells in the brain that fire not only when we perform a particular action but also when we watch someone else perform that same action.

Neuroscientists believe this "mirroring" is the mechanism by which we can "read" the minds of others and empathize with them. It's how we "feel" someone's pain, how we discern a grimace from a grin, a smirk from a smile.

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Media Contacts
Mark Wheeler,
310-794-2265
mwheeler@mednet.ucla.edu

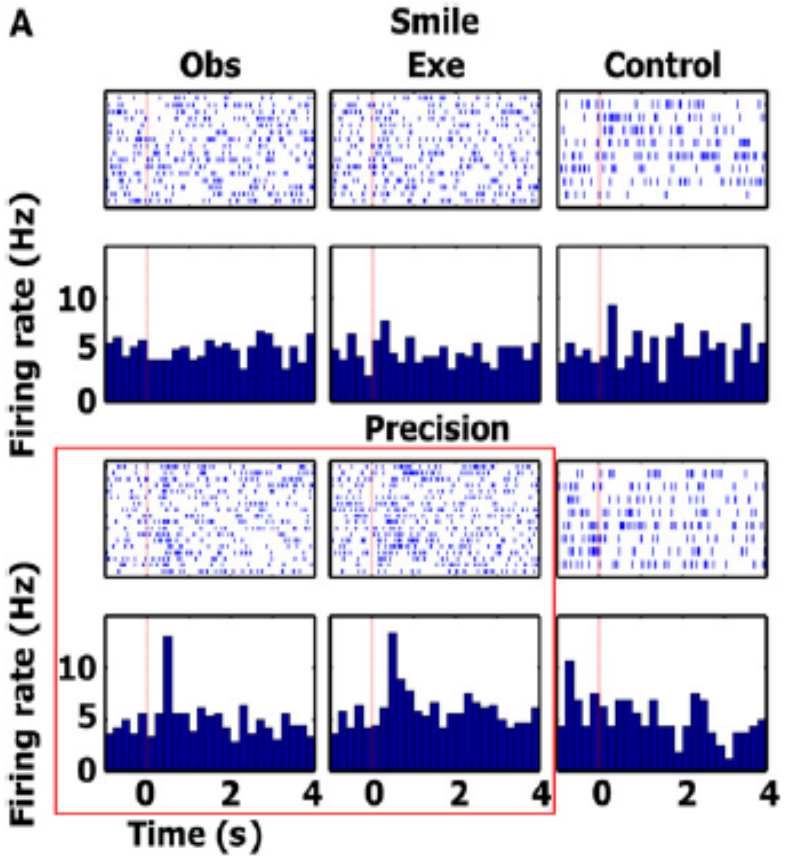
Related Images

Mukamel et al. Study

- Recorded from 1177 cells in 21 patients
  - 652-SMA/ACC
  - 525-medial temporal lobe
- Subjects observed and executed (via word cue) grasping actions and facial gestures
- Firing rate measured post-stimulus onset relative to a baseline

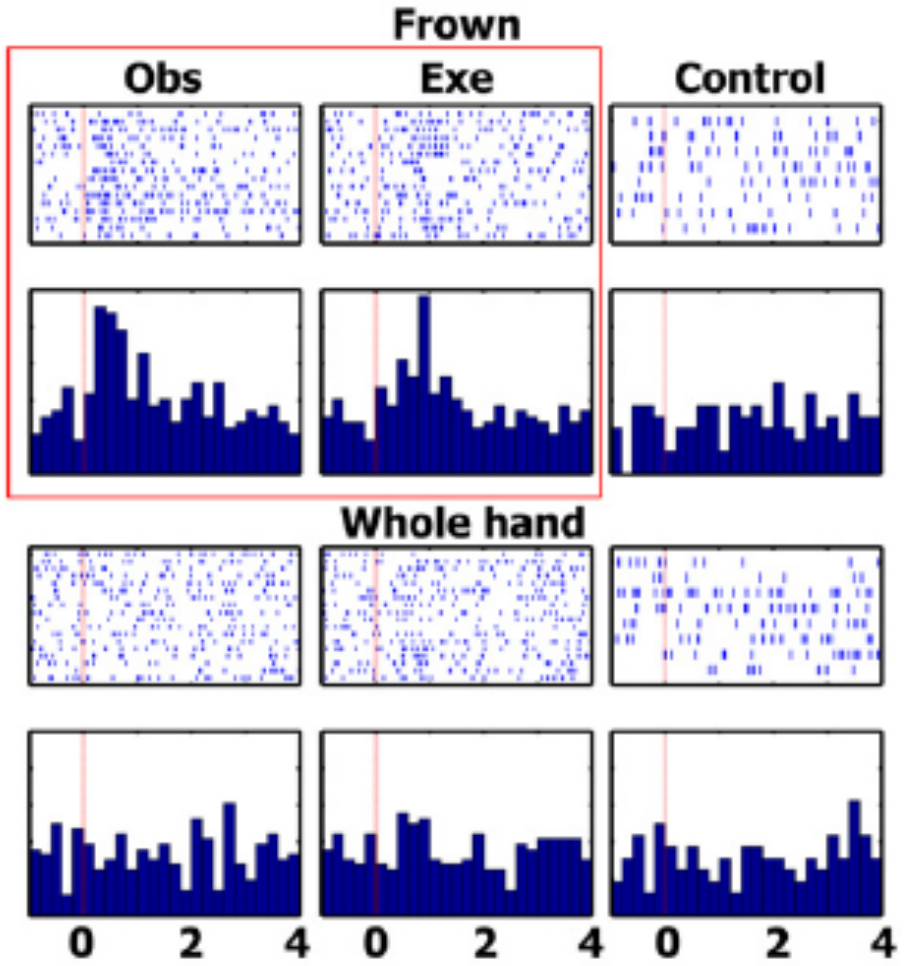
Cell Classification

- Action-execution (23%)
- Action-observation (17%)
- Action observation/ execution matching (8%)
- Action observation/ execution nonmatching (7%)



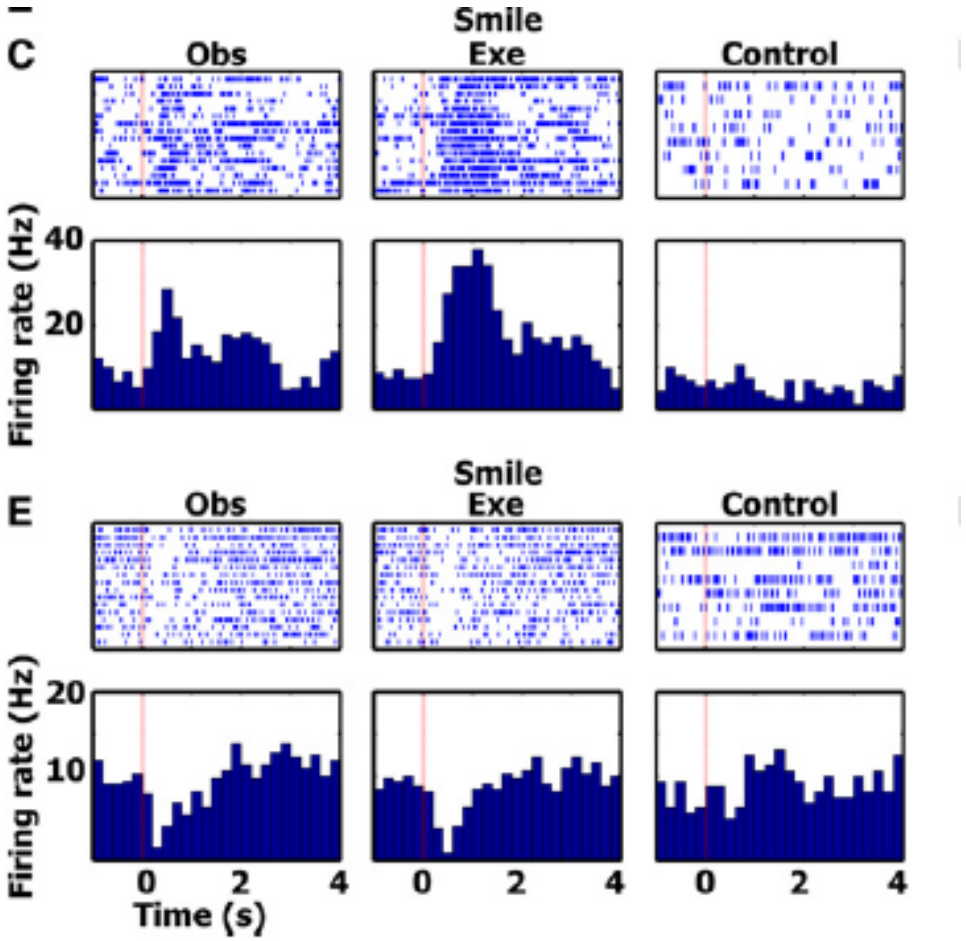
Cells responded selectively

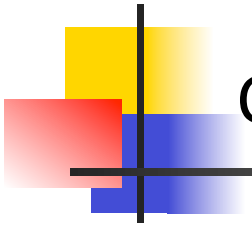
There were more responses to hand grasps (precision grip or wholehand prehension) in PHG relative to facial gestures **and more responses to observations of** facial gestures relative to hand grasps in ACC



Complementary actions

Among 68 action observation/execution matching cells, 33 increased their firing rate during both observation and execution of a particular action. In contrast, 21 other neurons decreased their firing rate during both conditions (anti-mirror neurons)





Conclusions

1. Significant proportion of mirror neuron-like cells were found in:
    - medial frontal lobe (SMA)
    - medial temporal lobe
        - hippocampus, parahippocampal gyrus, and entorhinal cortex.

"The action observation/execution matching neurons in the medial temporal lobe may match the sight of actions of others with the memory of those same actions performed by the observer."

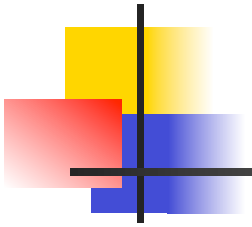
Conclusions

2. Some cells show anti-mirroring properties

3. Subpopulations of cells respond with excitation during action-execution and inhibition during action-observation.

4. Neurons responding with opposite patterns of excitation and inhibition during action-execution and action-observation seem ideally suited for a control function.

"The results demonstrate the presence of mirror mechanisms in humans at the single neuron level"



Problems with Mukamel et al study

1. Did not record from same areas as monkeys (i.e., F5 or Broca's area)
2. Found mirror neurons in areas not yet recorded in monkeys (medial temporal lobe)

Neurocritic

Mirror Neurons Join Marilyn Monroe Neurons and Halle Berry Neurons in the Human Hippocampus

Repetition–Suppression Technique

- If mirror neurons exist in humans, they should ‘adapt’ when the observation of a motor act is followed by the execution of that motor act, and *vice versa.*
- True only when information repeatedly reaches a neuron through the same or largely common pathways

Other Controversies/Questions

- Do MNs reflect understanding?
- Do they reflect intention?
- Are they born or made?
- Is the system broken in patients with social deficits?
- Are they the basis for theory of mind, empathy, language?

Watching actions you can do or can't do…
Do we only imitate what we know?

Dance videos

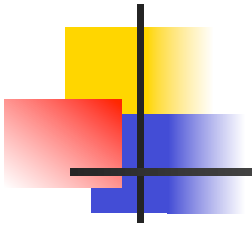
	Ballet	Capoeira
Subjects		
Ballet dancers	Expert	Non-expert
Capoeira dancers	Non-expert	Expert

Expert vs non-expert

Mirror neuron areas

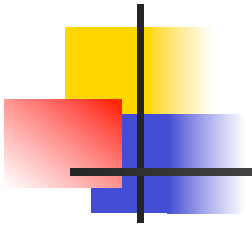
Experts show more mirror system brain activity than non-experts

Calvo-Merino et al., Cerebral Cortex (2005)



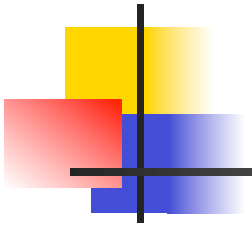
Other Problems

- Correspondence
  - How does the observer agent know what the observed agent's resonance activation pattern is?
  - How does the matching of motor activation patterns occur?



Problems (cont)

- Developmentally
  - How does a mirroring system arise?
  - How do humans acquire the ability to simulate through mapping observed onto executed actions?
  - Are mirror neurons innate and therefore genetically programmed?
  - To what extent is learning necessary?



Problems (cont)

- Control
  - How to efficiently control a mirroring system when it is turned on automatically through observation?
  - Or, as others have stated the problem more succinctly: “Why don’t we imitate all the time?”

EEG CHANGES DURING CINEMATOGRAPHIC PRESENTATION [1]

(Moving picture activation of the EEG)

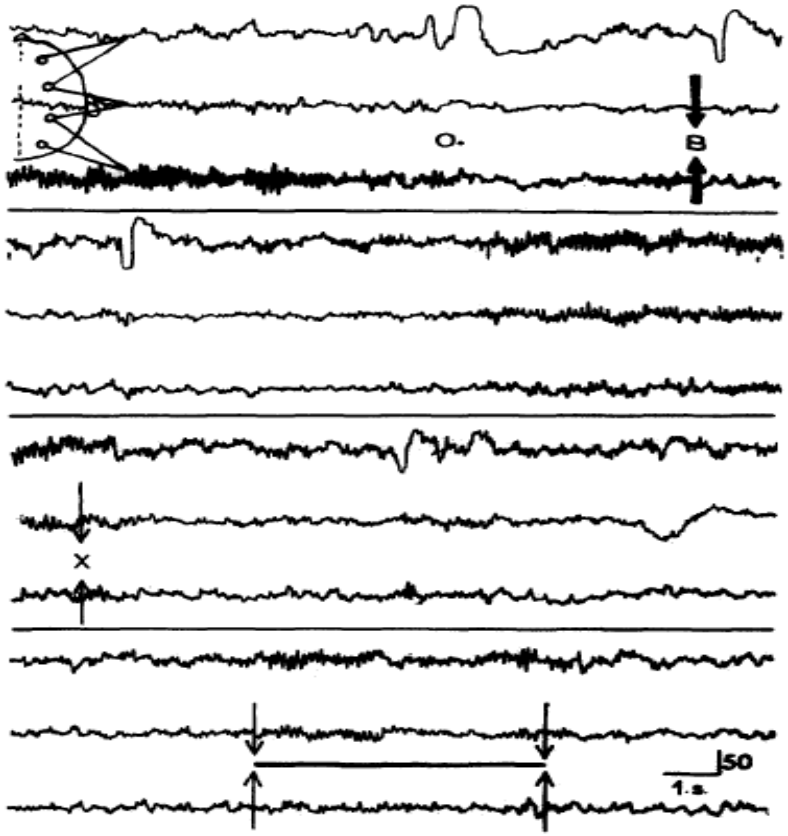
HENRI J. GASTAUT, M.D. and JACQUES BERT, M.D.
Laboratoire de Neurobiologie de la Faculté de Médecine de Marseille
and of the EEG Laboratory of the IX Military Region

(Received for publication: March 15, 1954)

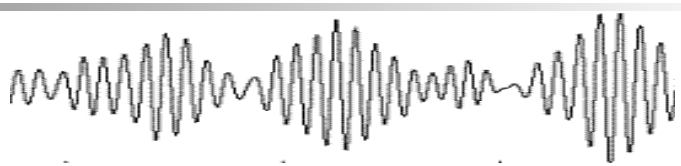
Rolandic "en arceau" rhythm
(7-11 Hz)

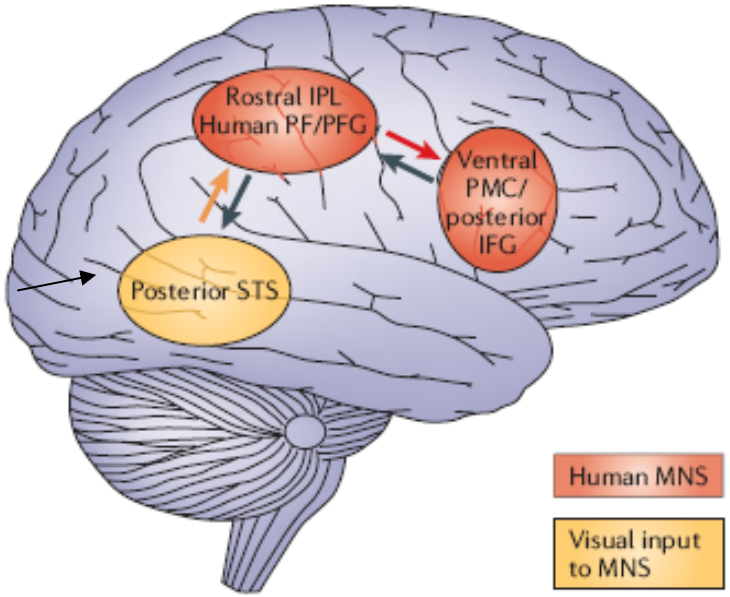
"…blocked when the subject performs a movement or simply when he changes his postural tone."

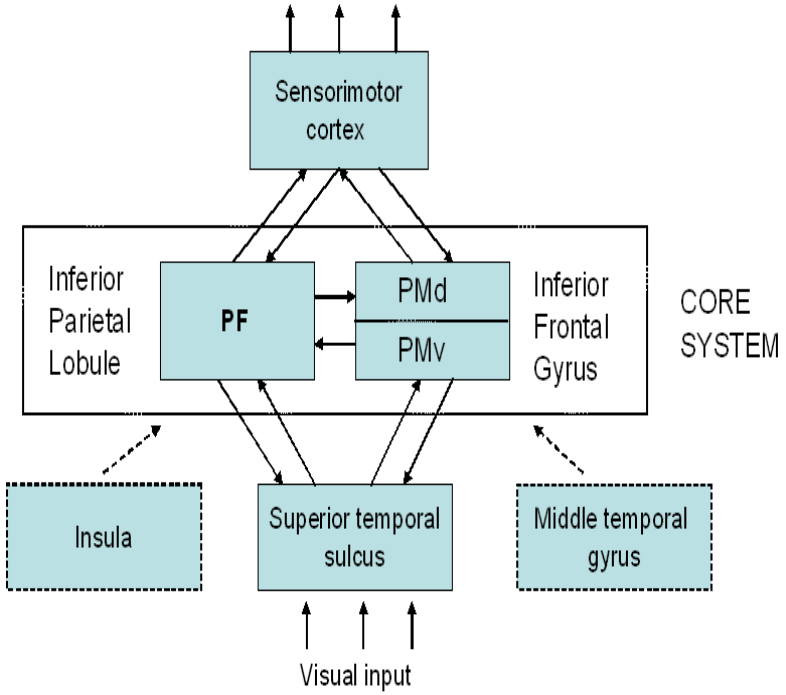
"…disappears when the subject identifies himself with an active person represented on the screen."



The Mirror Neuron System



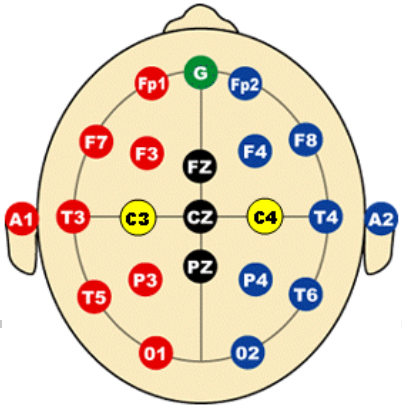




Iacoboni and Dapretto, Nature Reviews, 2006,7:942-951

EXTENDED MIRROR NEURON SYSTEM

Mu Rhythm

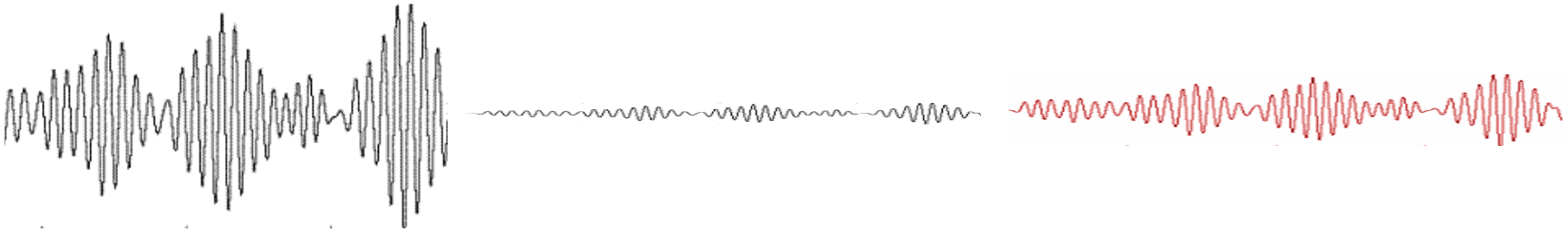


- 8-13 Hz oscillation over sensorimotor cortex

Normal Oscillation

Self Action

Observed Action



What Is It Like To Be…?

Can aspects of subjective experience be reduced to brain activity?

Thomas Nagel, The Philosophical Review 83 (1974).