

“Creating connections II”

International Conference on Attachment, Neuroscience, Mentalization
based treatment and Emotionally focused therapy,
18-20 April 2013

How social cognition emerges from motor organization: the mirror neuron system



Leonardo Fogassi

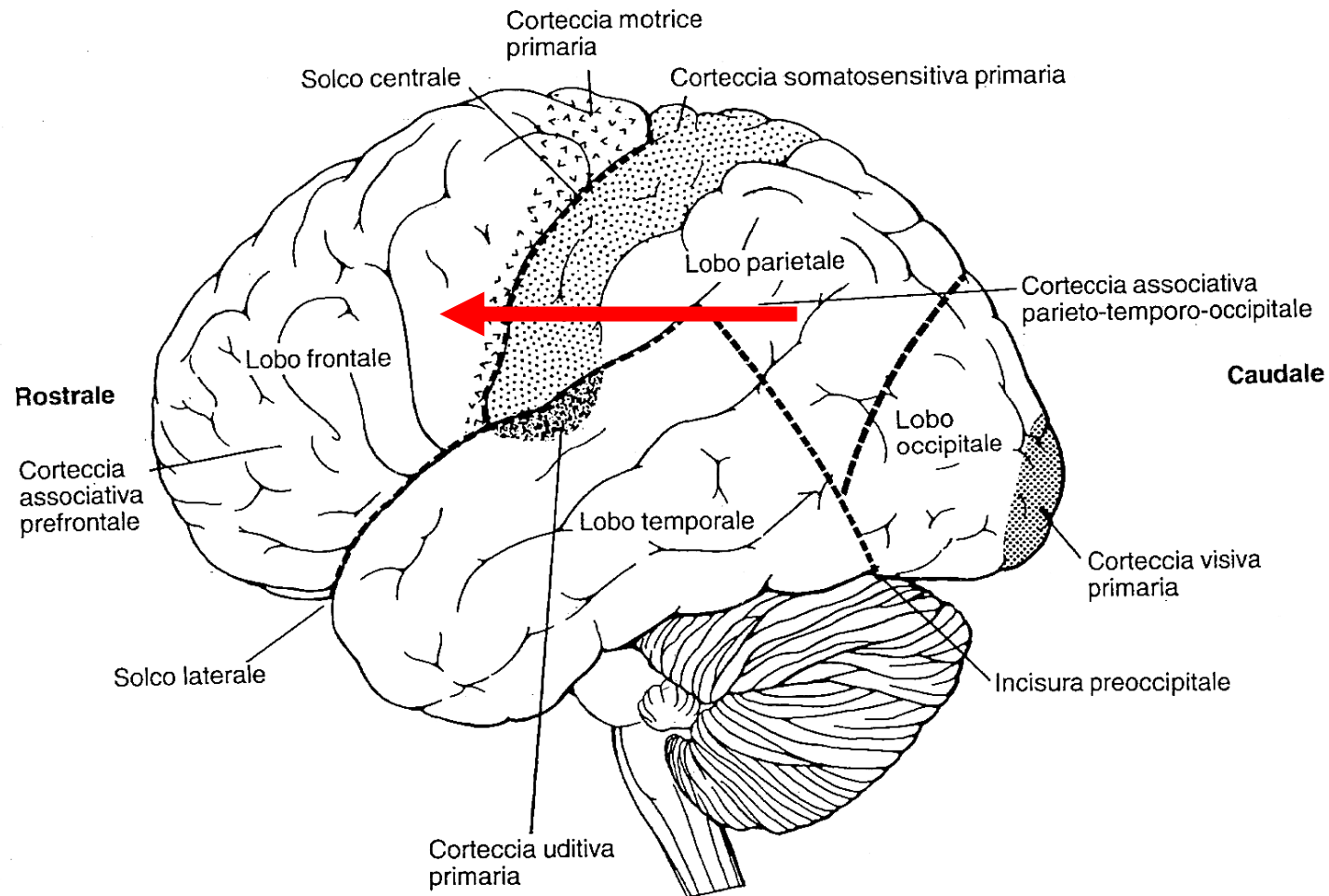
Department of Neuroscience

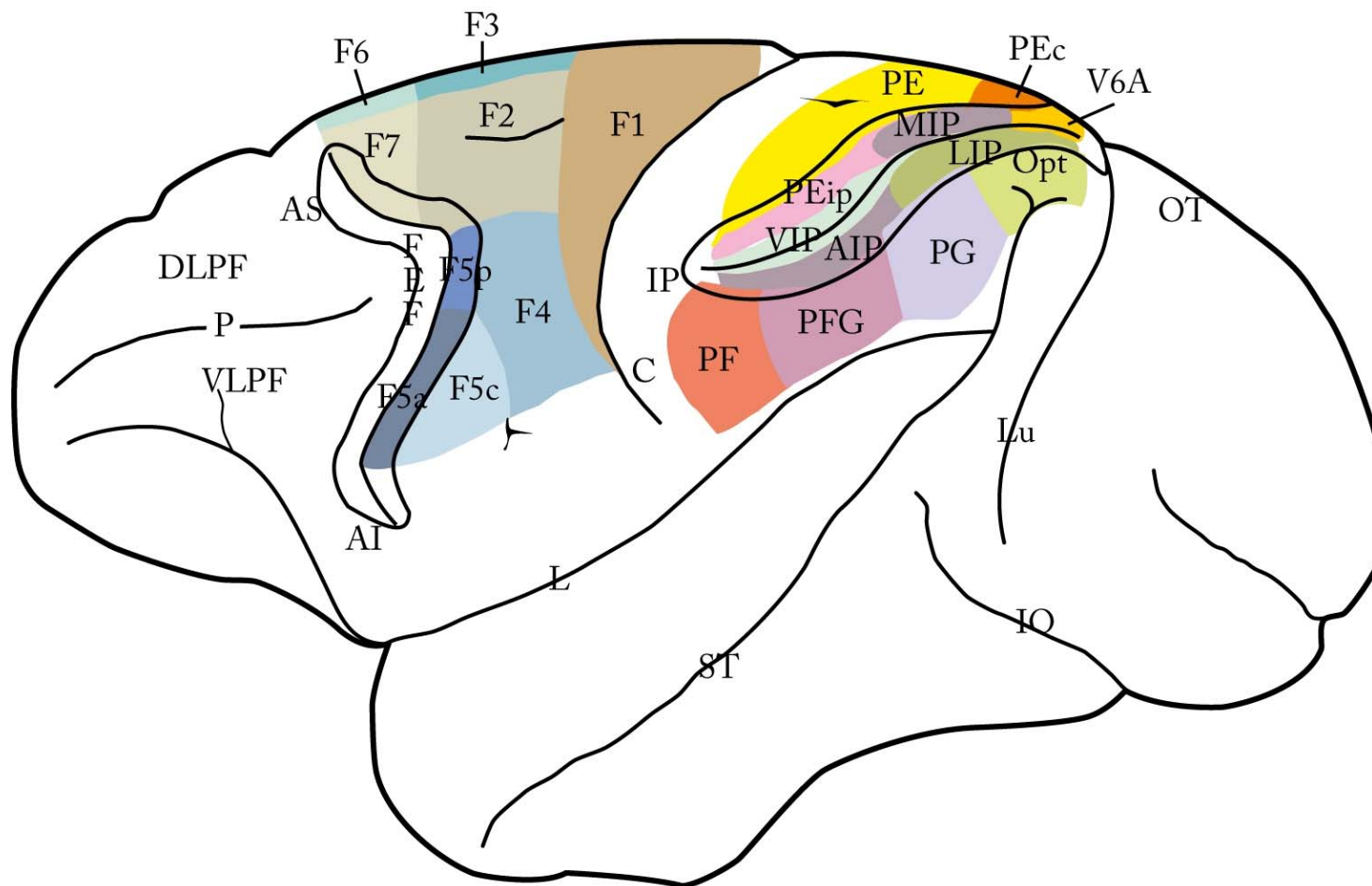
University of Parma

1. New concepts on the organization of the motor system
2. Emergence of cognitive functions from motor organization: Mirror neurons
3. The mirror system in humans and its involvement in social cognition
4. Involvement of the mirror neuron system in intention coding

1. New concepts on the organization of the motor system

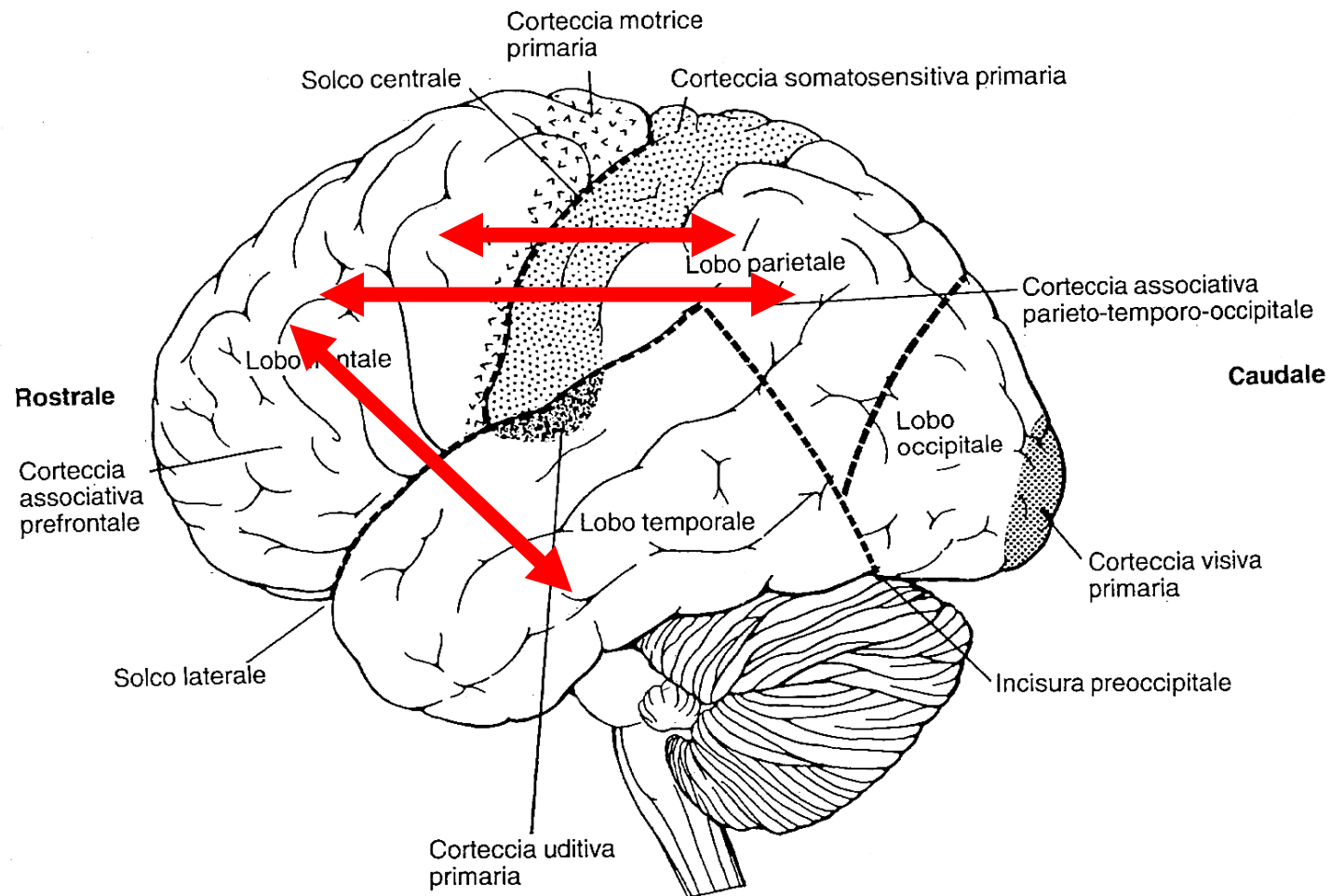
The flow of information in the cerebral cortex



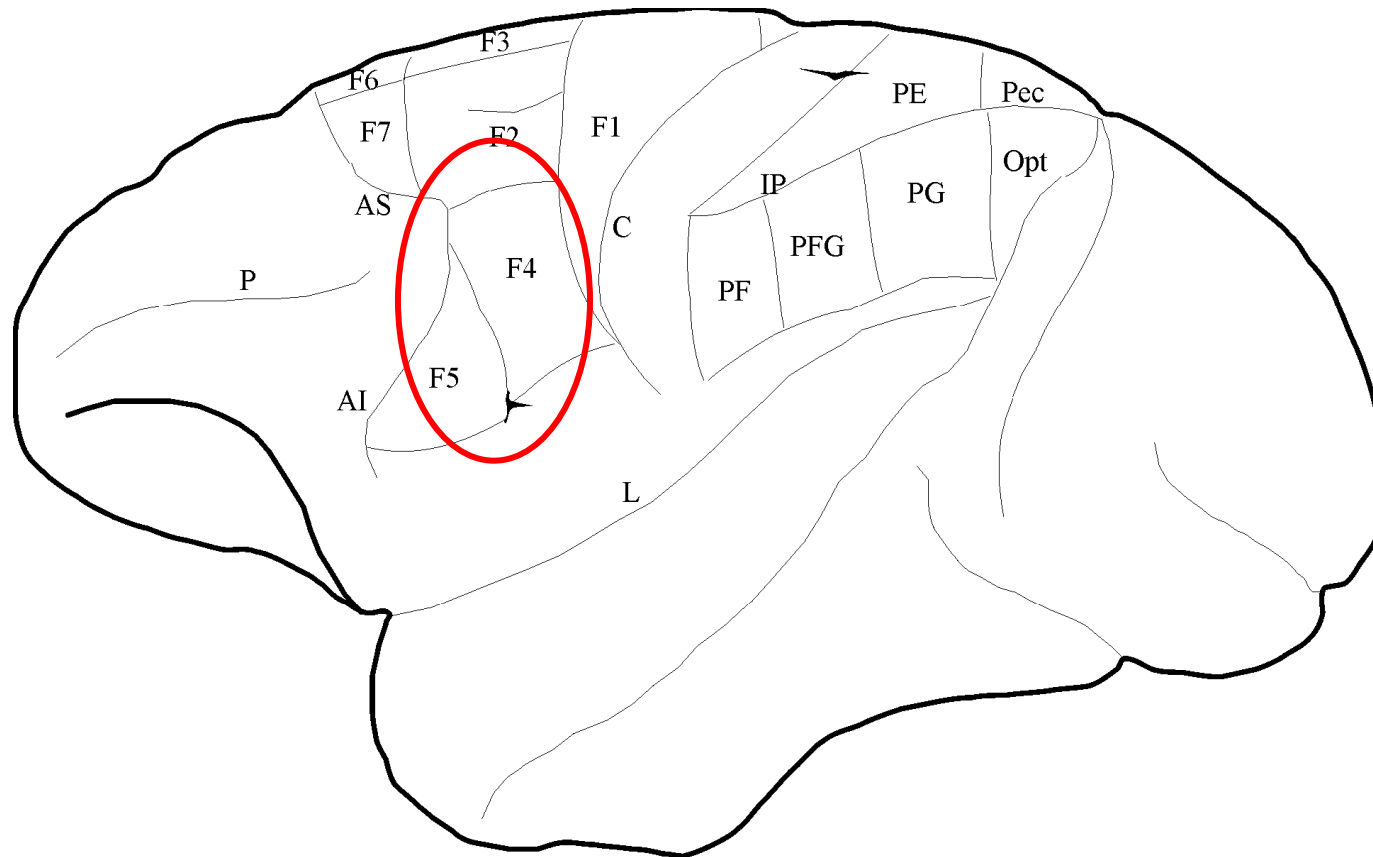


Anatomical parcellation of posterior parietal and agranular frontal cortex

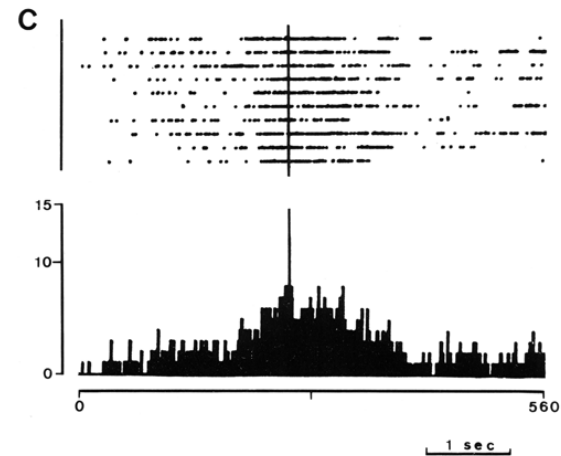
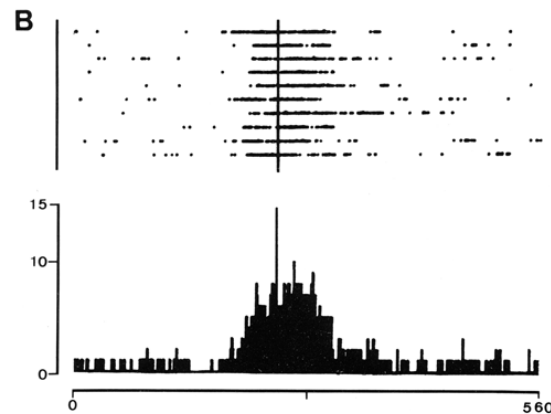
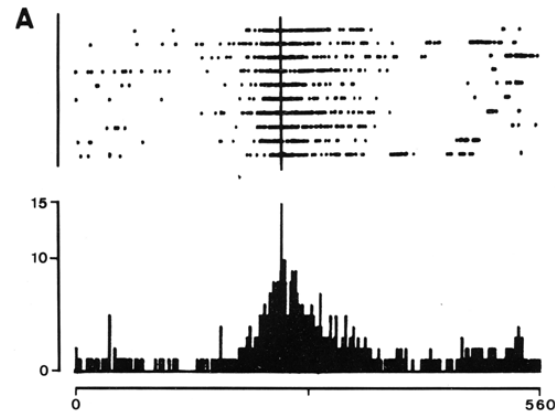
Posterior and anterior cortical areas are reciprocally connected



Representation of the goal of motor acts



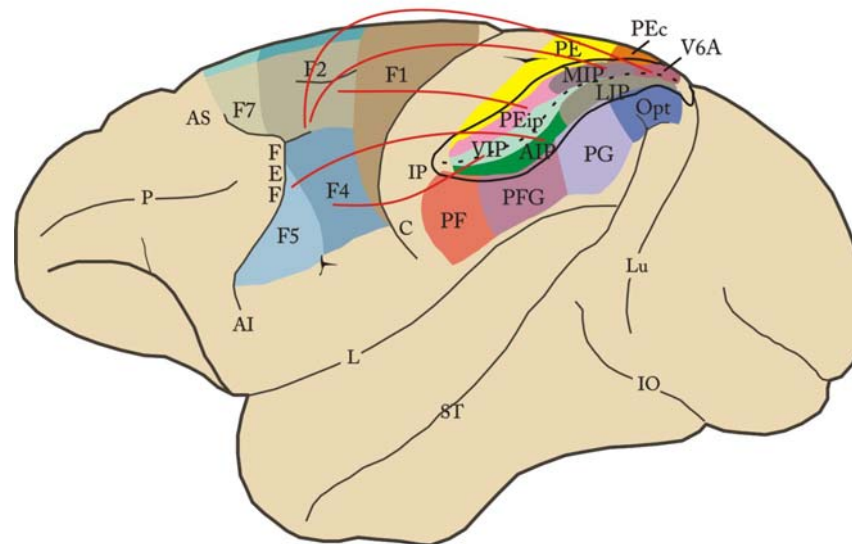
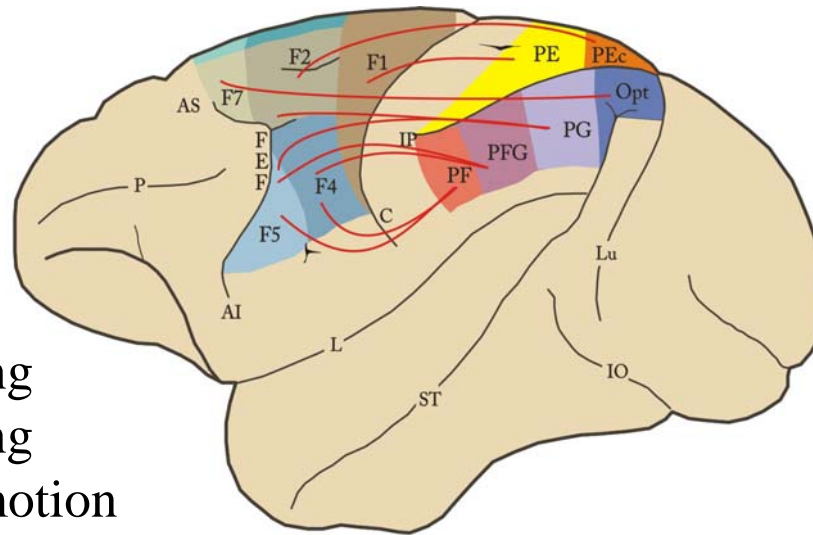
Coding of grasping



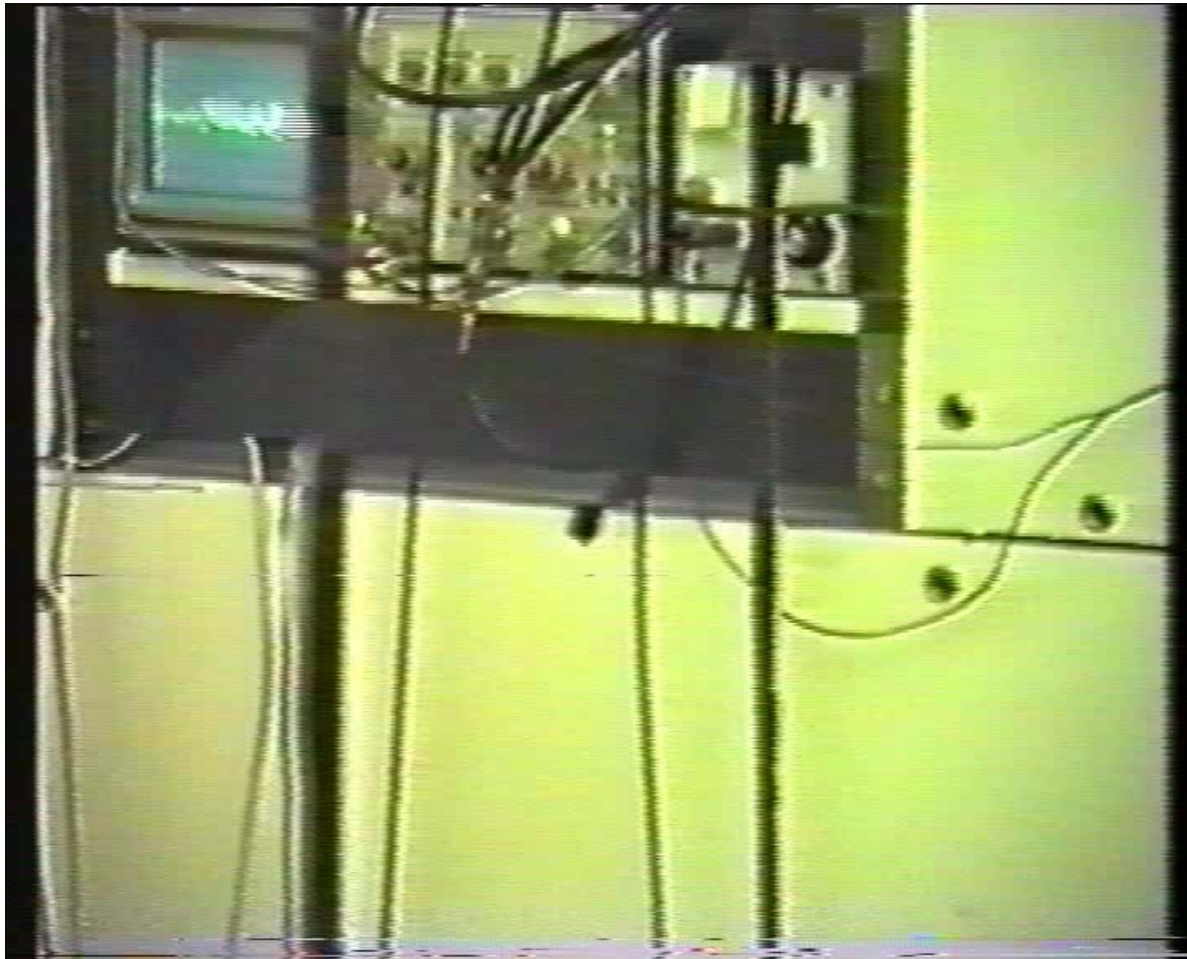
Rizzolatti et al. 1988

Goal coding is a property of a circuit, not of a restricted cortical sector

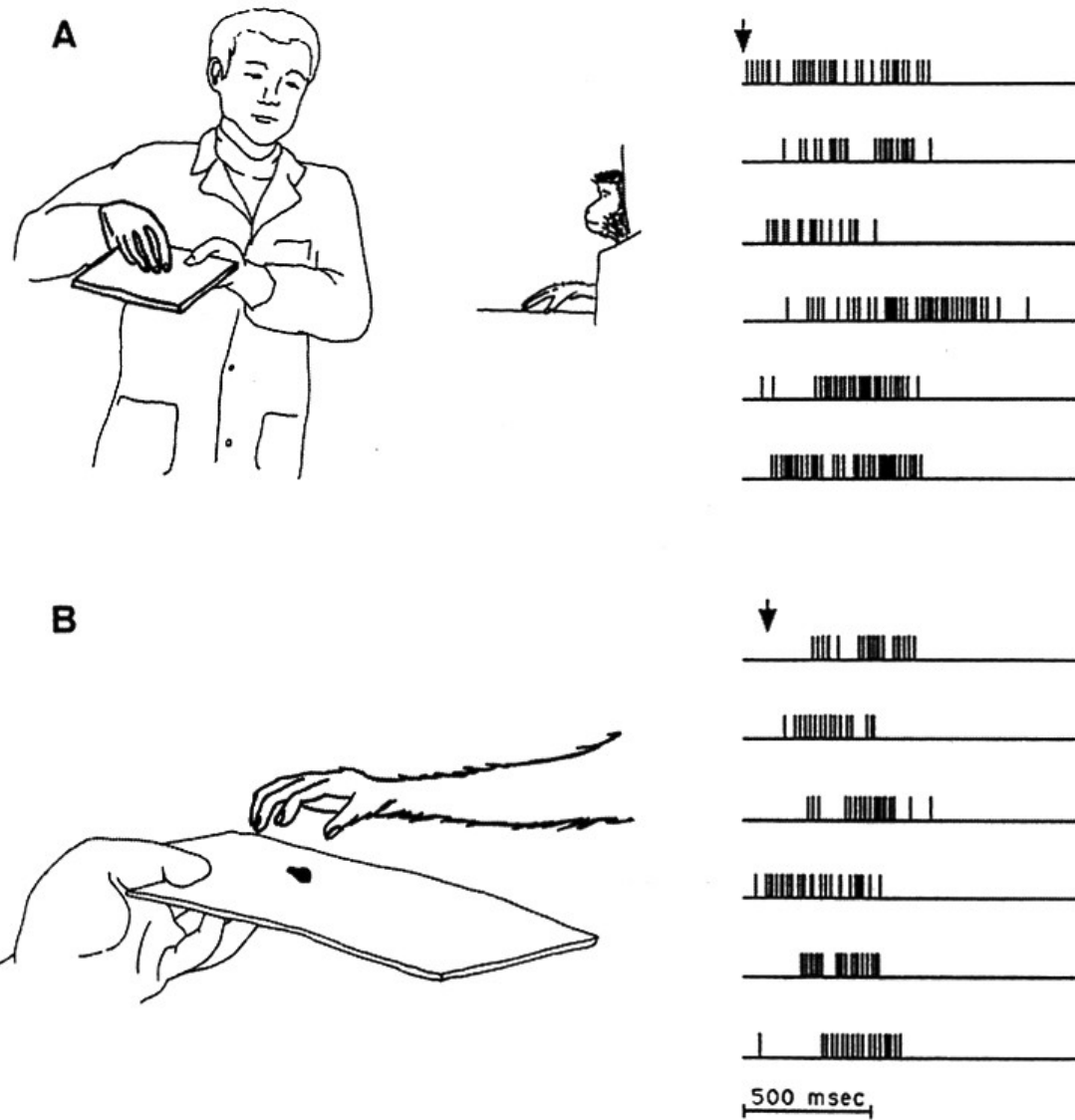
AIP-F5: circuit for grasping
VIP-F4: circuit for reaching
LIP-FEF: circuit for eye motion
MIP/V6A-F2: circuit for on-line
control of reaching-grasping



2. Emergence of cognitive functions from motor organization: Mirror neurons



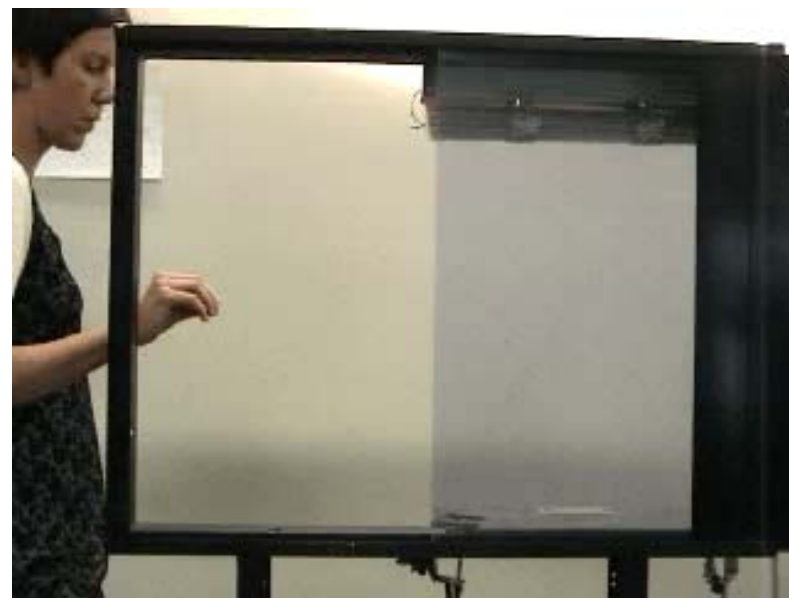
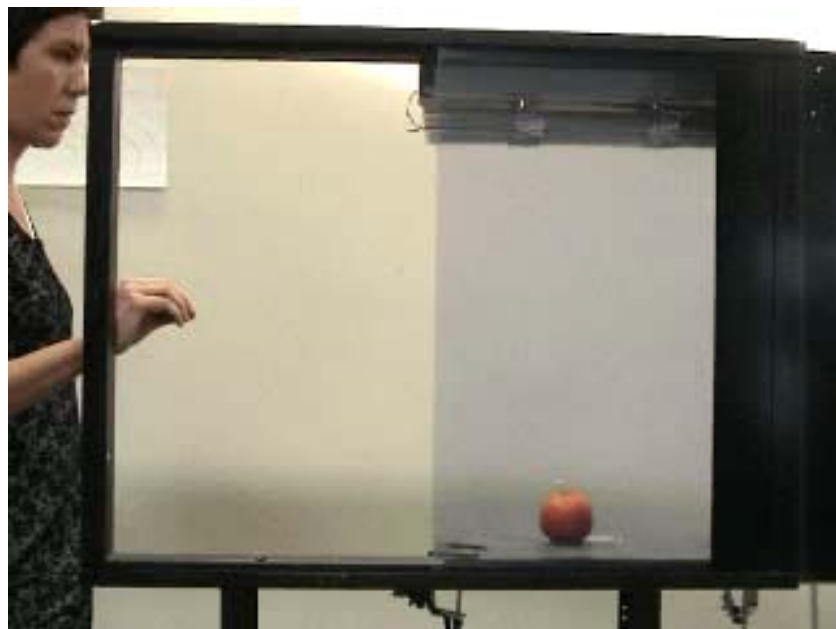
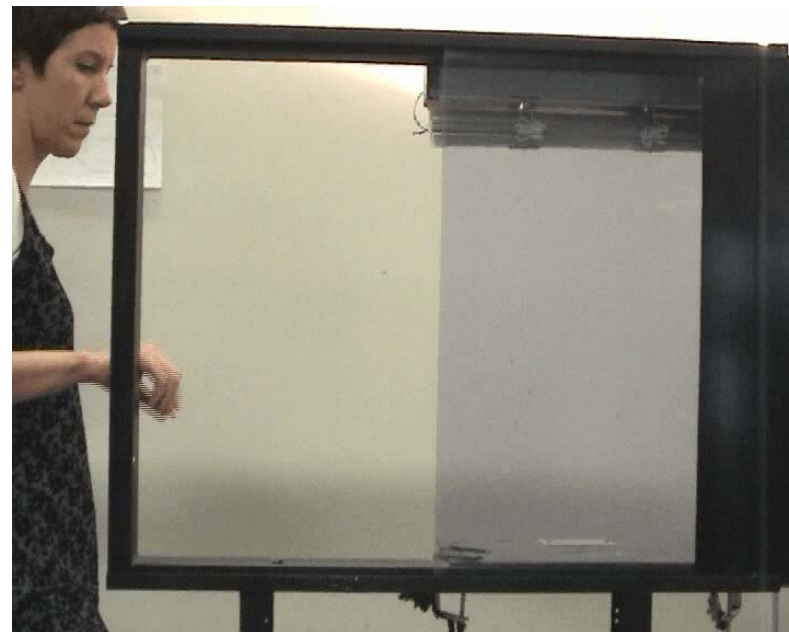
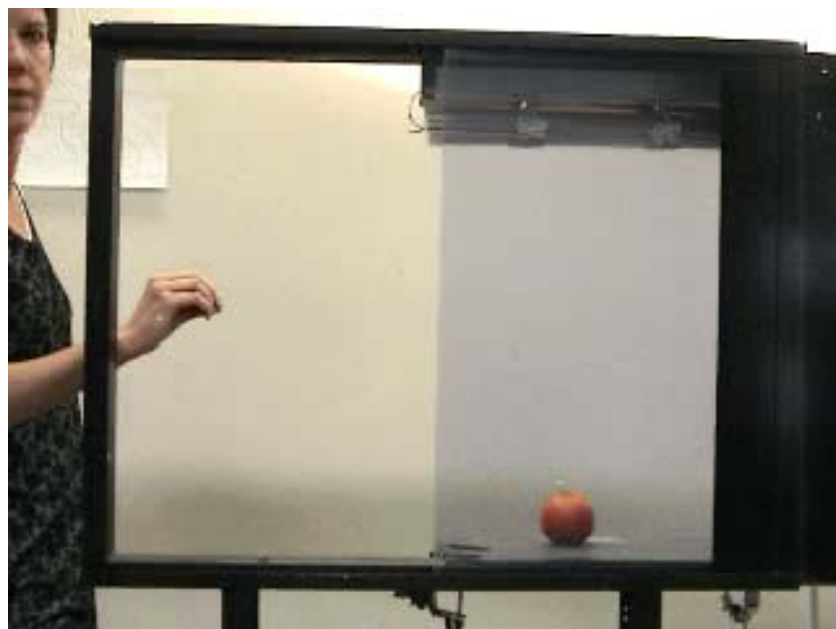
Example of mirror neuron

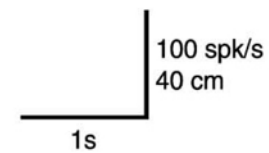
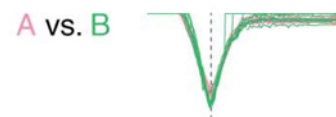
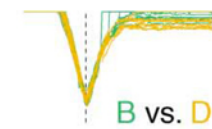
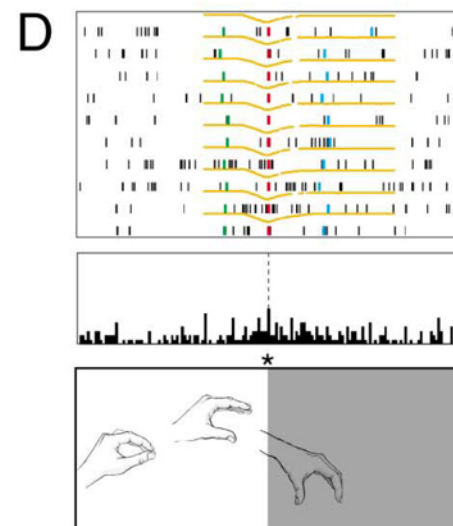
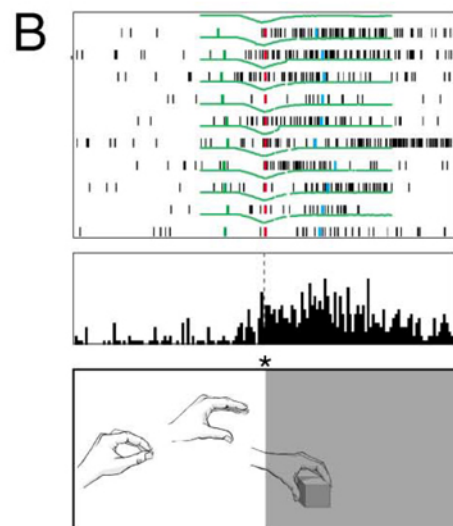
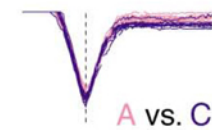
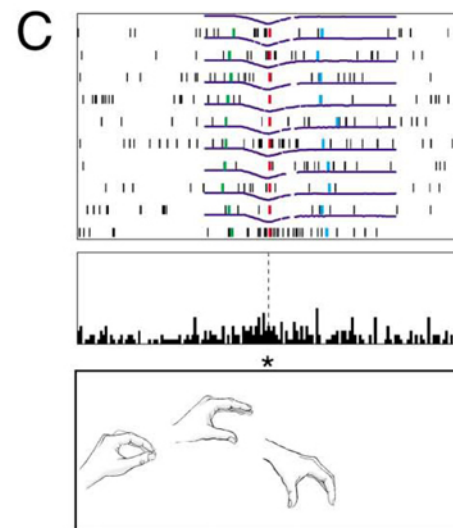
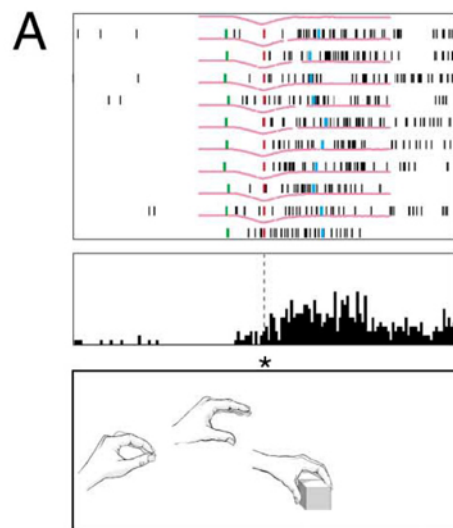


Di Pellegrino et al. 1992; Gallese et al. 1996;
Rizzolatti et al. 1996

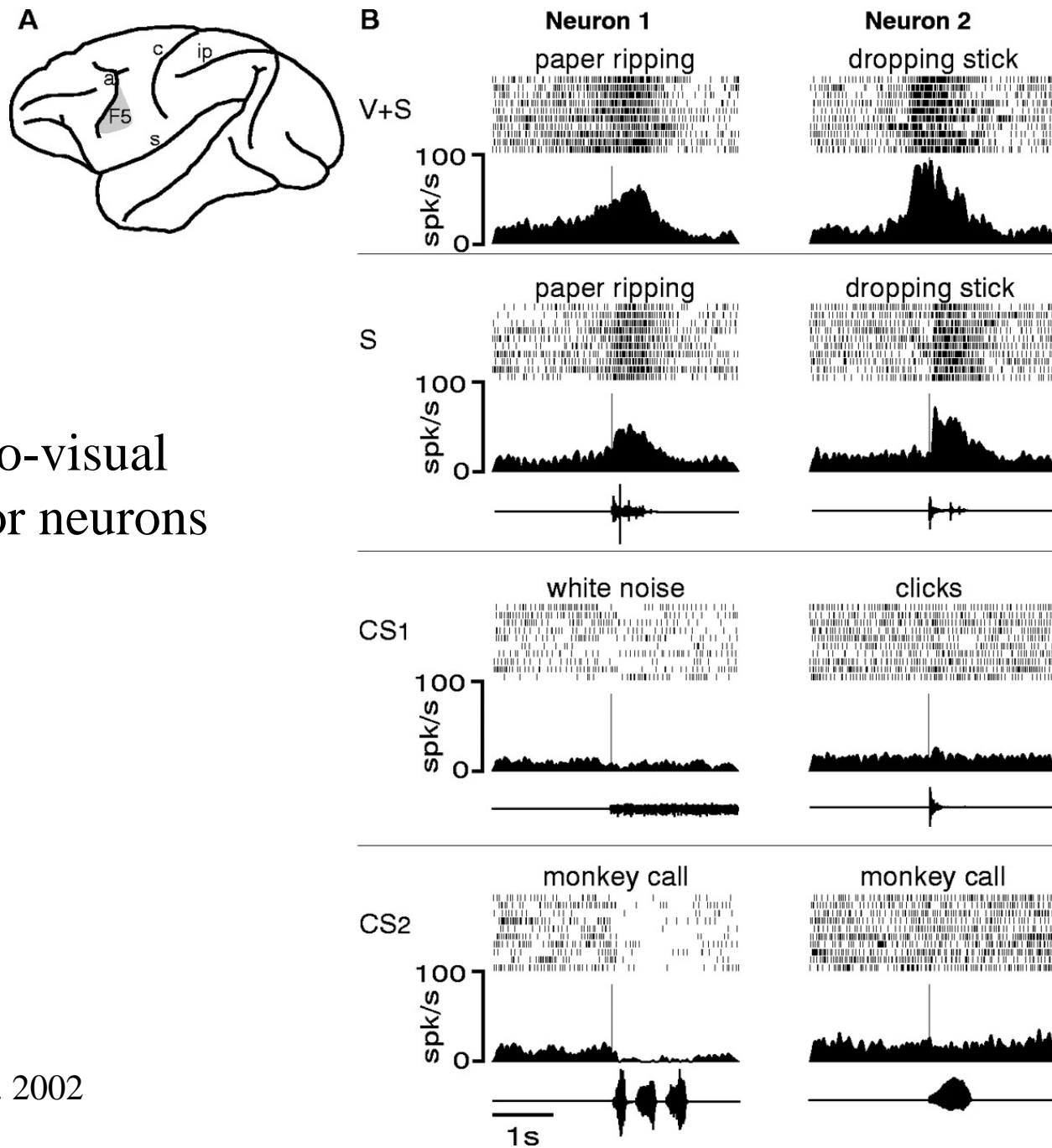
Observed motor acts effective in evoking mirror neurons response

<i>Observed actions</i>	<i>No. of neurons</i>
Grasping	30
Placing	7
Manipulating	7
Hands interaction	5
Holding	2
Grasping/placing	20
Grasping/manipulating	3
Grasping/hands interaction	3
Grasping/holding	5
Grasping/grasping with the mouth	3
Placing/holding	1
Hands interaction/holding	1
Grasping/placing/manipulating	1
Grasping/placing/holding	4
Total	92





Audio-visual mirror neurons



Kohler et al. 2002

Ingestive



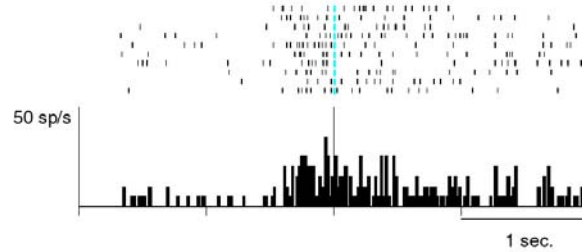
Communicative



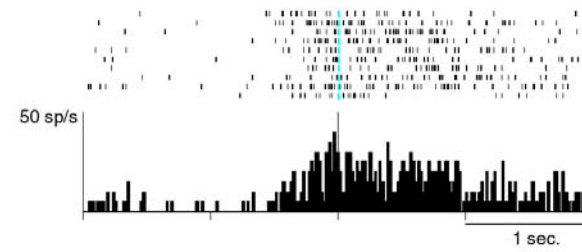
Mouth “ingestive” mirror neurons

U087

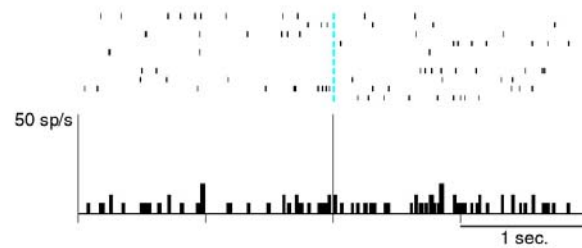
Experimenter grasps food with the mouth



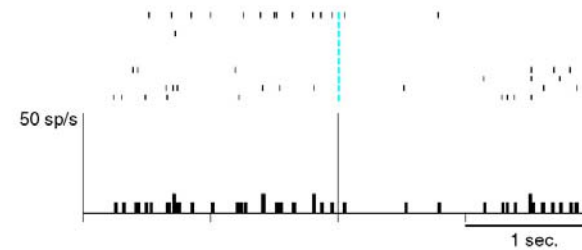
Monkey grasps food with the mouth



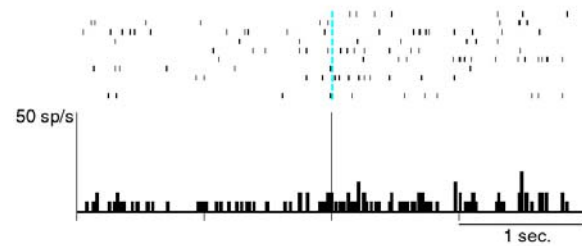
Experimenter sucks from a syringe



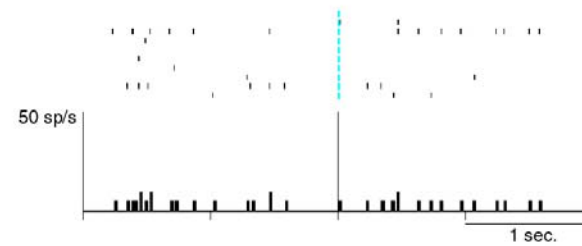
Monkey sucks from a syringe



Experimenter mimes grasping food with the mouth

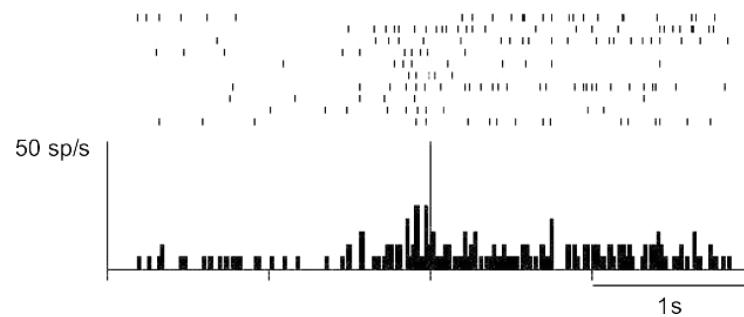


Food presentation

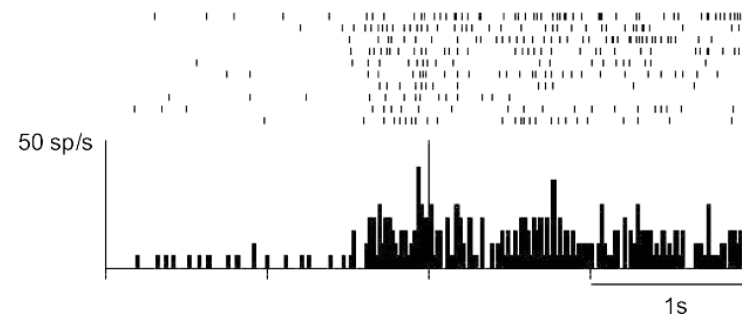


Mouth “communicative” mirror neurons

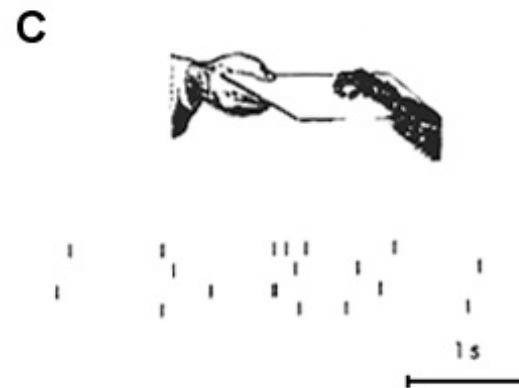
A) Experimenter protrudes his lips



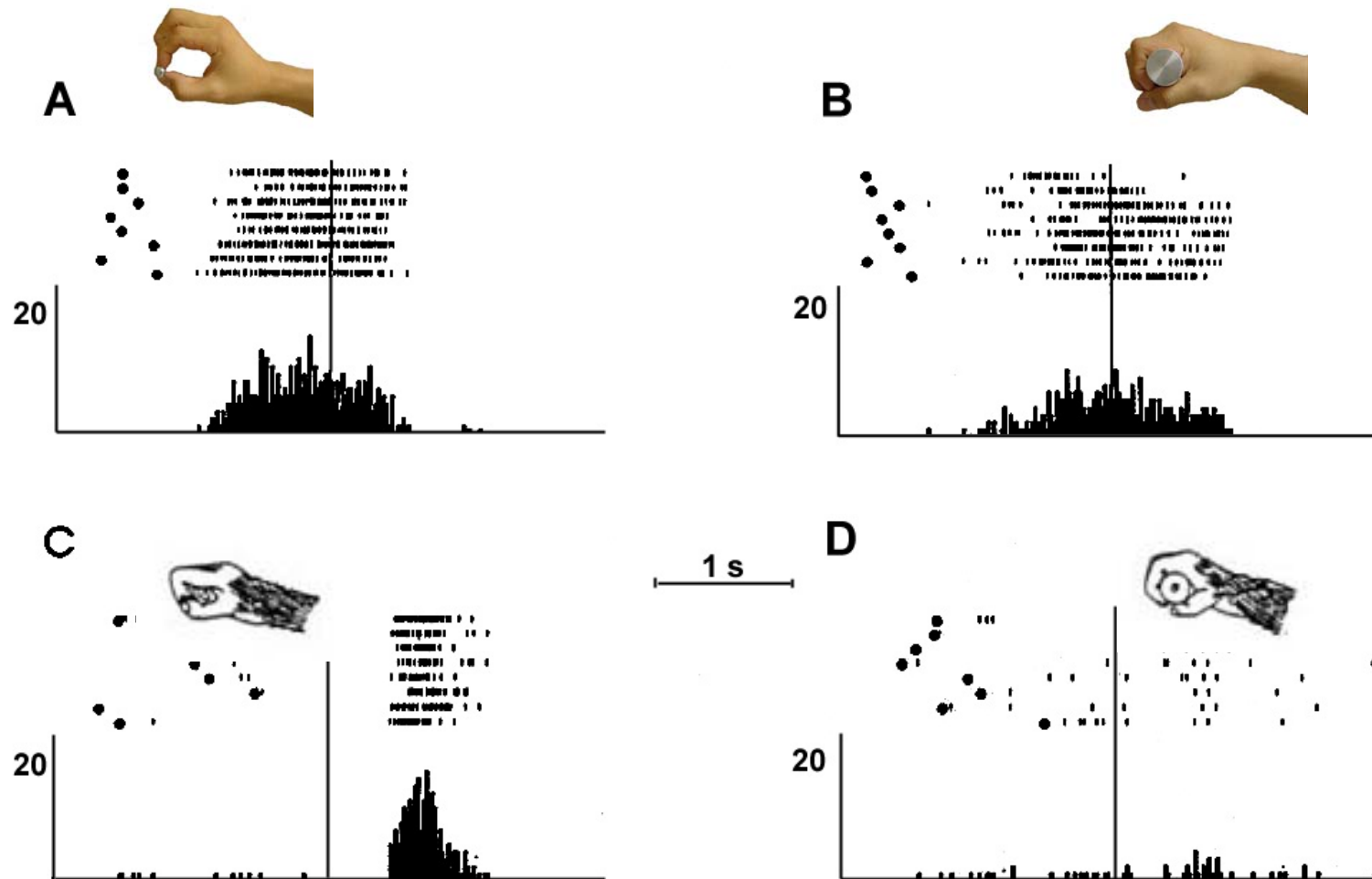
B) Monkey lip-smacking



Strictly congruent mirror neurons

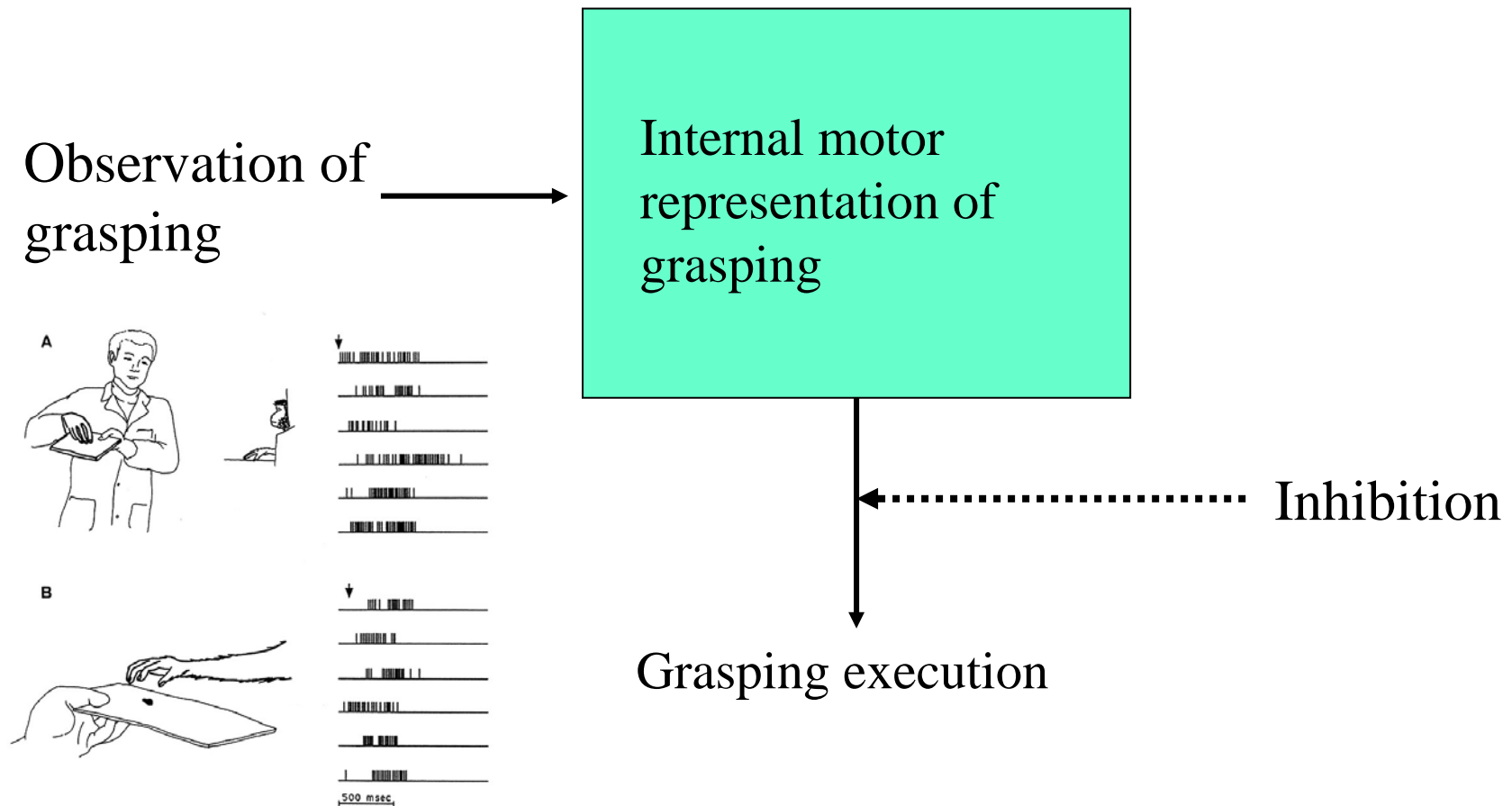


Broadly congruent mirror neurons

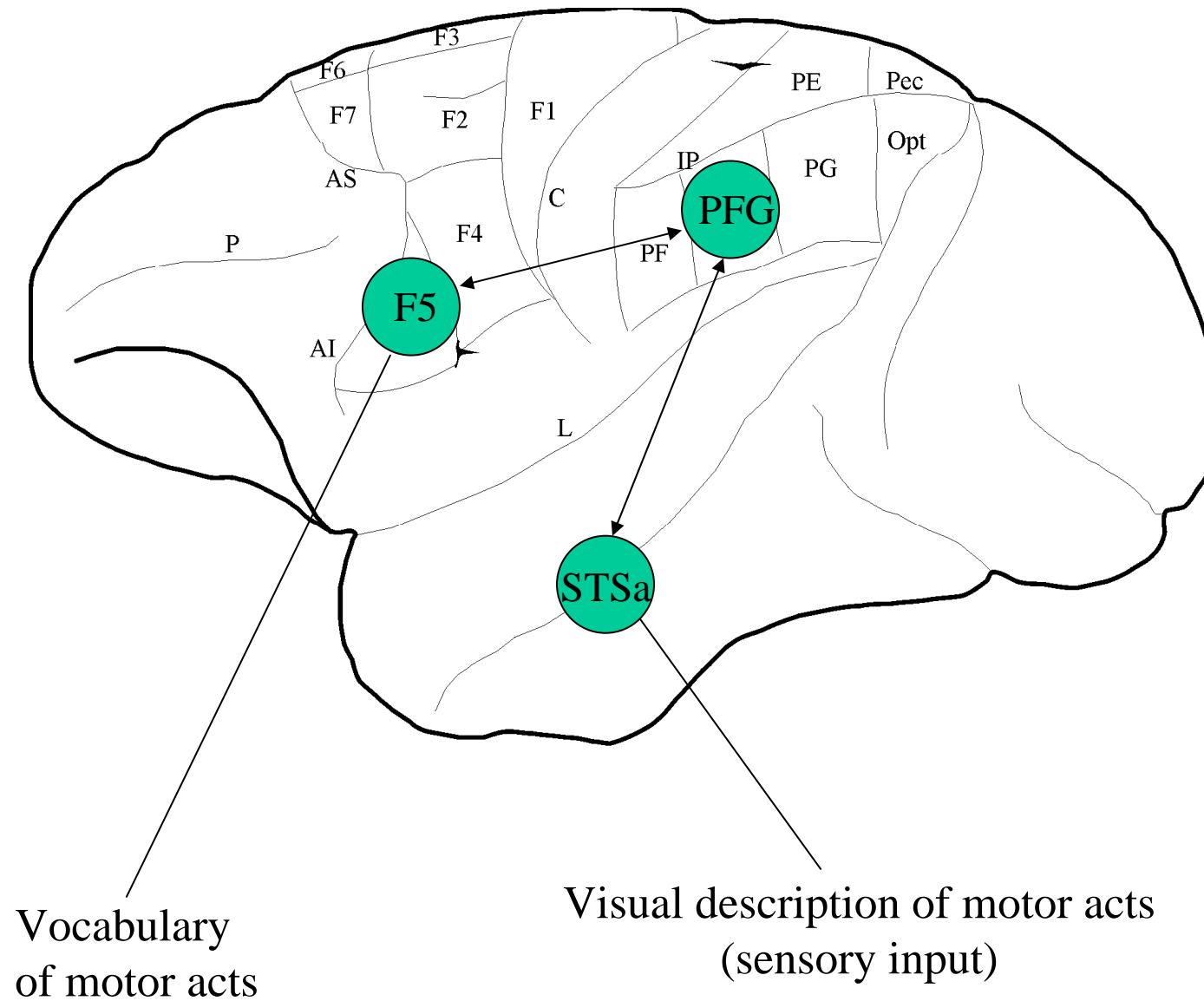


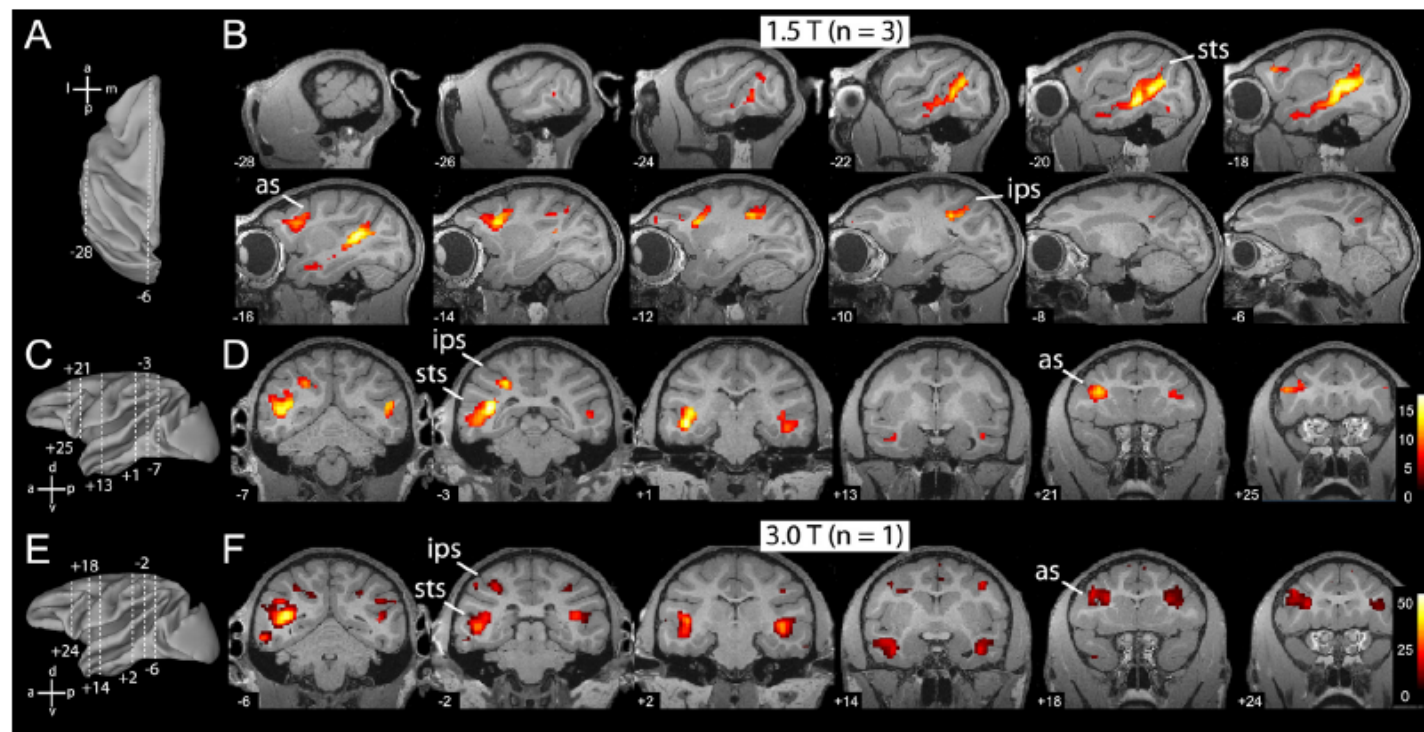
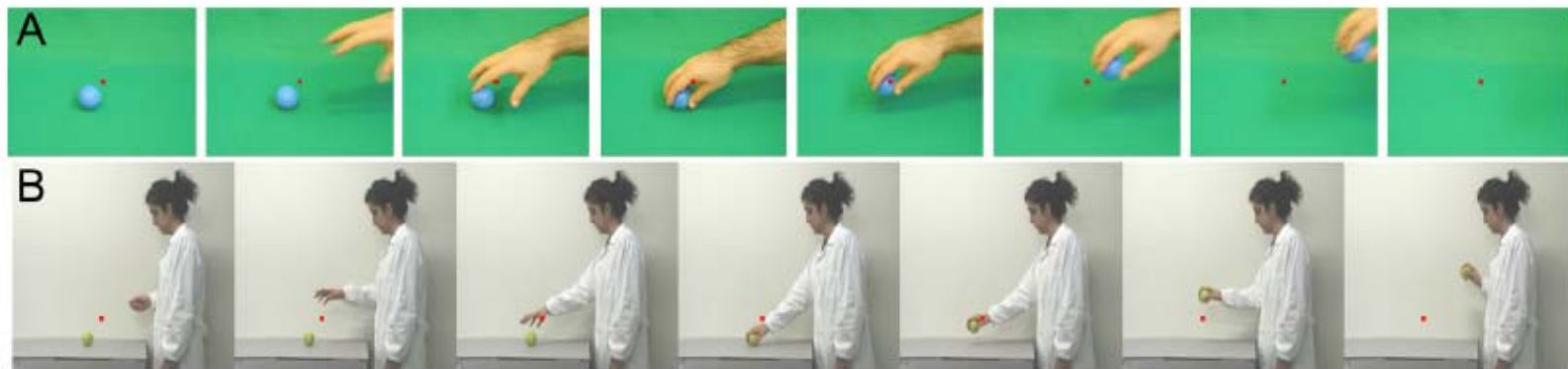
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Mirror neurons allow a direct matching between observed goal-directed motor acts and the internal representation of the same acts in the observer. This matching system underpins understanding of goal-directed motor acts



The parieto-frontal mirror neuron matching system

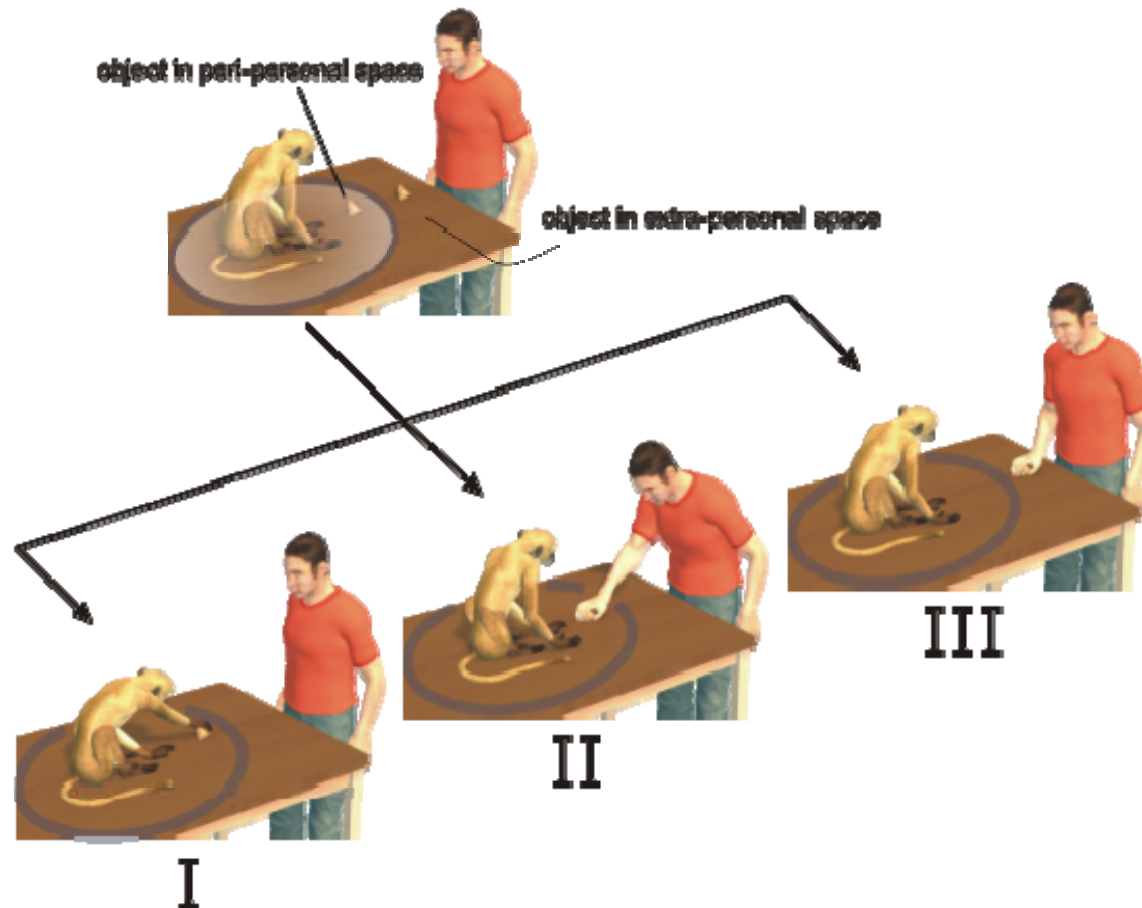




Nelissen et al. 2011

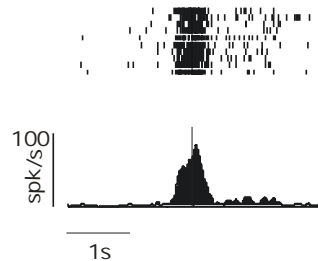
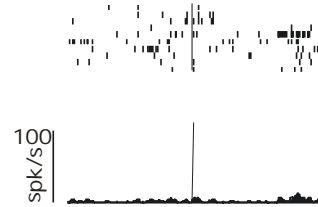
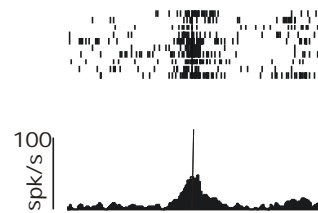
Are mirror neurons sensitive to the distance at which an observed motor act is performed?

Goal-directed motor acts executed in the peri- and extra-personal space of the monkey



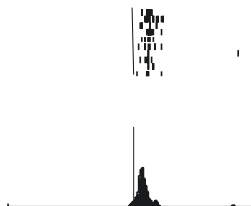
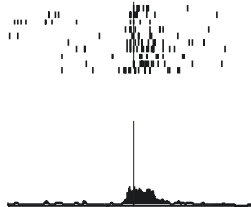
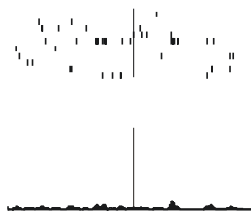


neuron 1



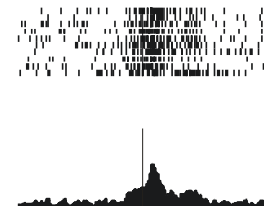
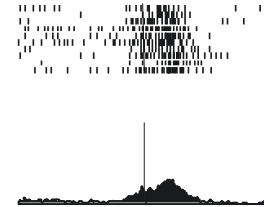
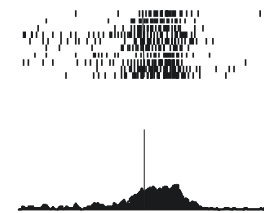
Mirror neuron
selective for the
extra-personal
space

neuron 2



Mirror neuron
selective for the
peri-personal
space

neuron 3



„*classic*“
mirror neuron

105 recorded mirror neurons

53% showed space-dependent response, 47% were space-independent

Is space-dependent modulation related to the monkey working space?



metric	extra-personal	peri-personal	peri-personal
operational	extra-personal	peri-personal	extra-personal

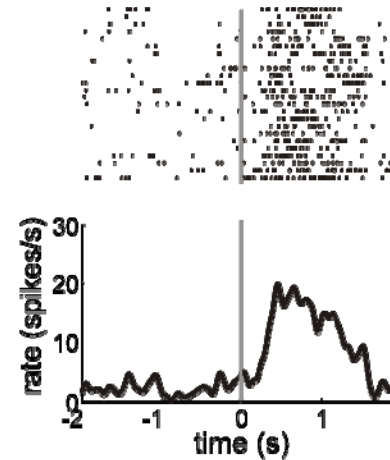
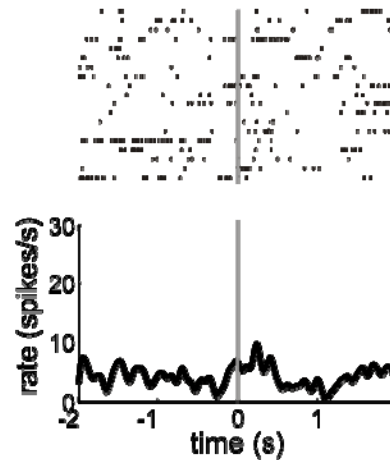
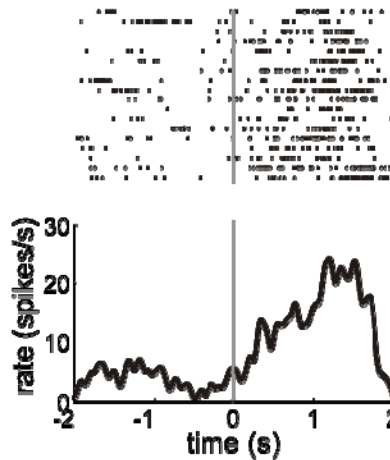
extra-personal space



peri-personal space
*object inside
workspace*



peri-personal space
*object outside
workspace*

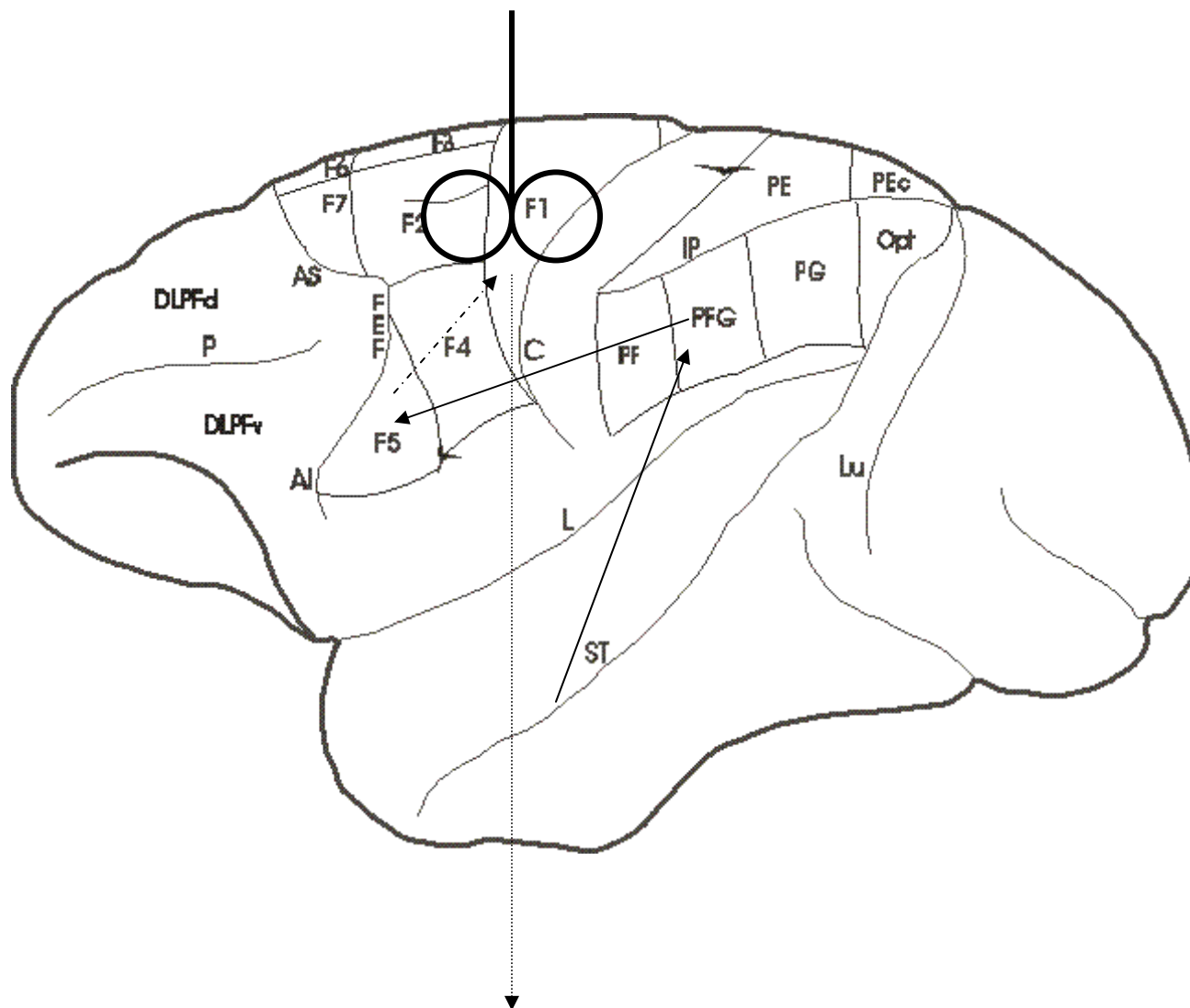


The space near the monkey body, with respect to action observation, is encoded both in metric and operational terms

3. The mirror system in humans and its involvement in social cognition



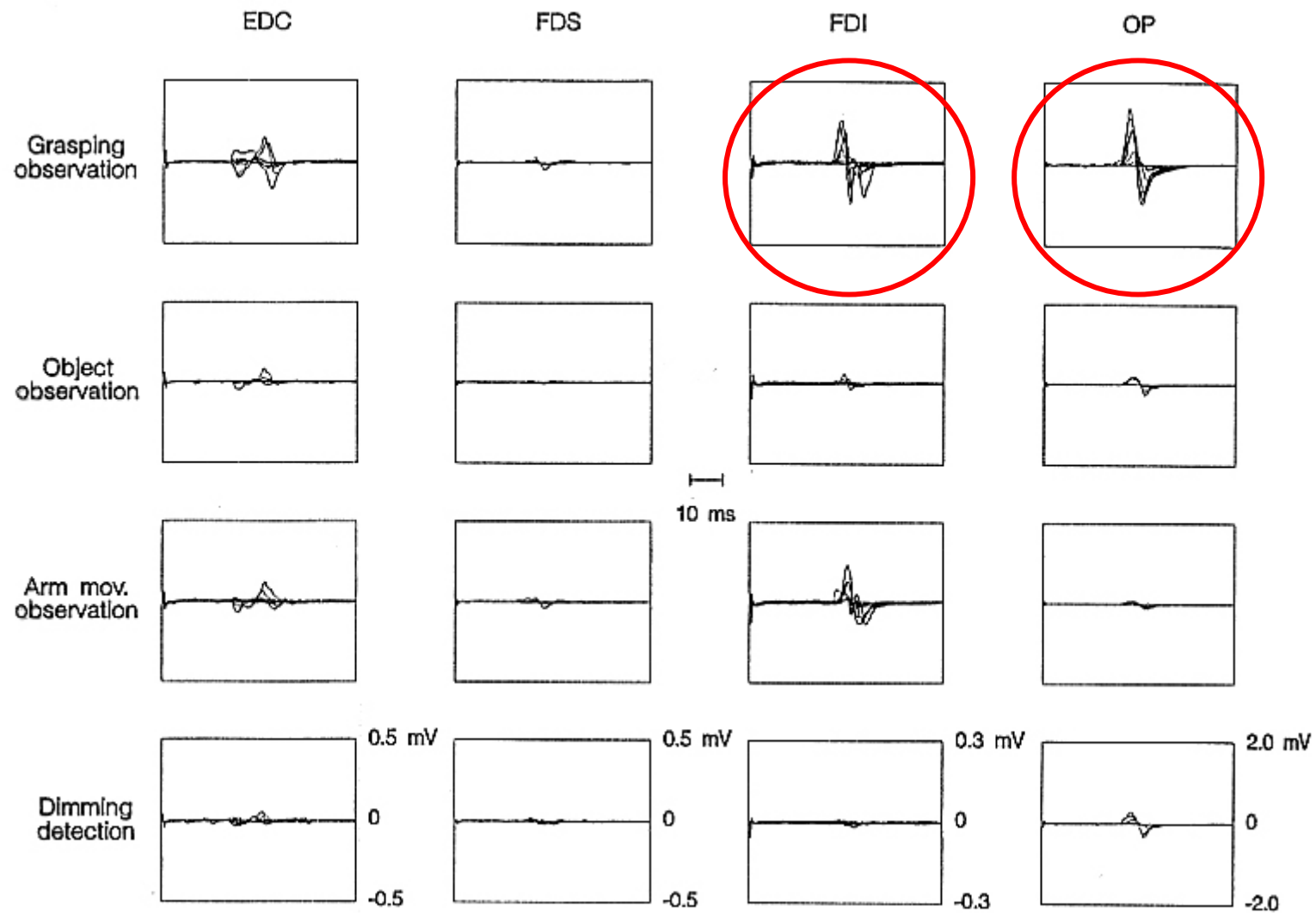
Transcranial magnetic stimulation



Spinal cord

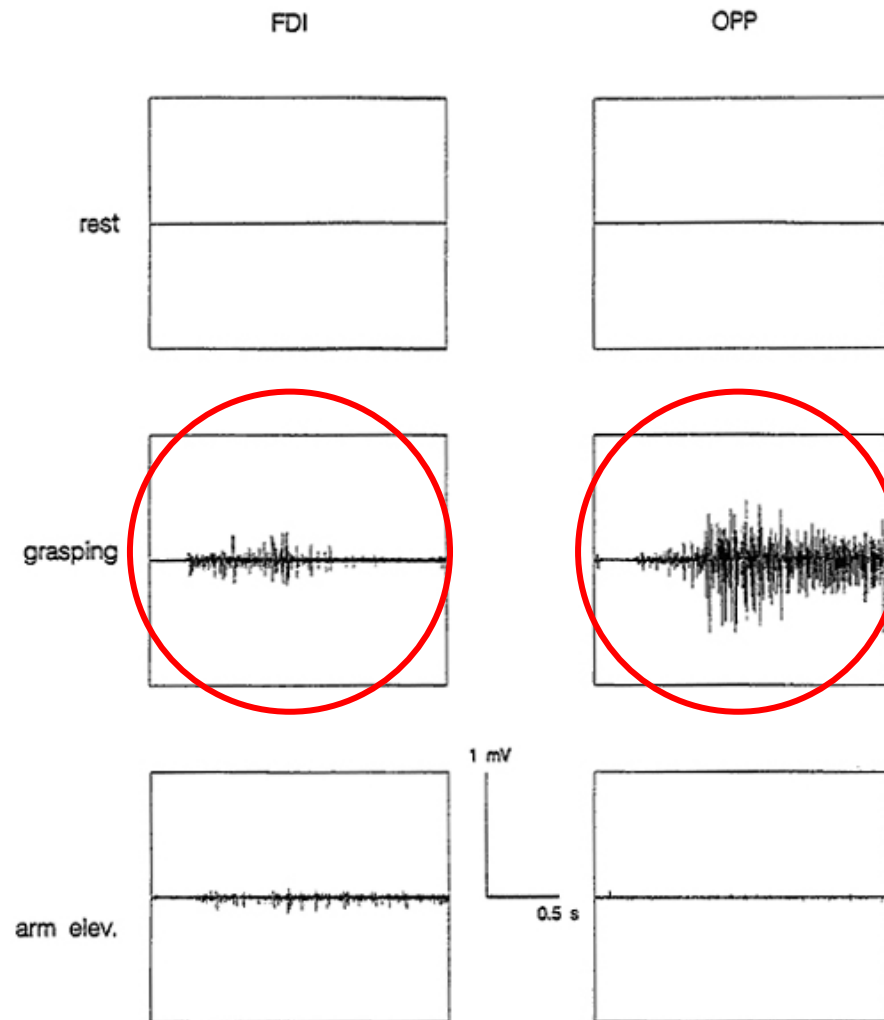
—————→ EMG activation
(MEPs)

Elettromyographic activation during motor acts observation

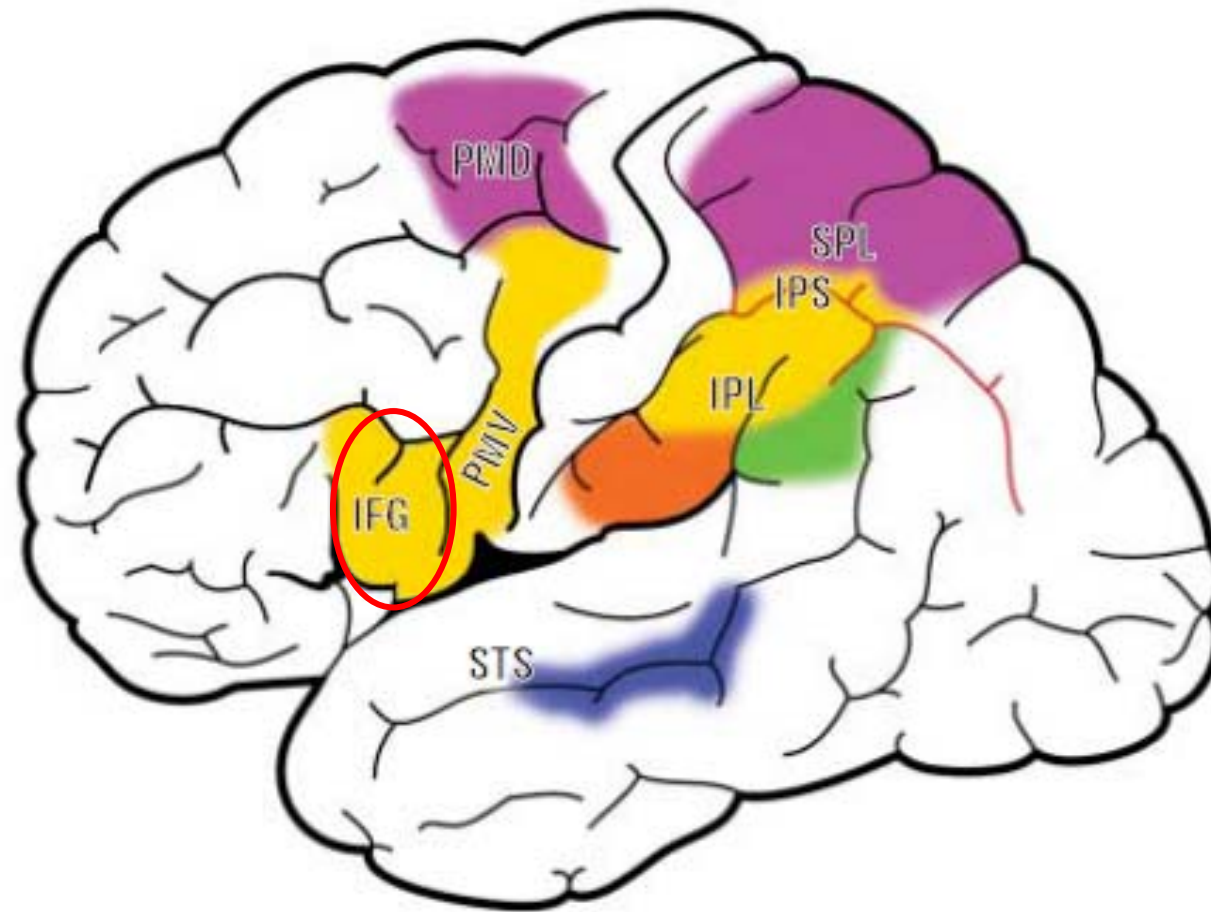


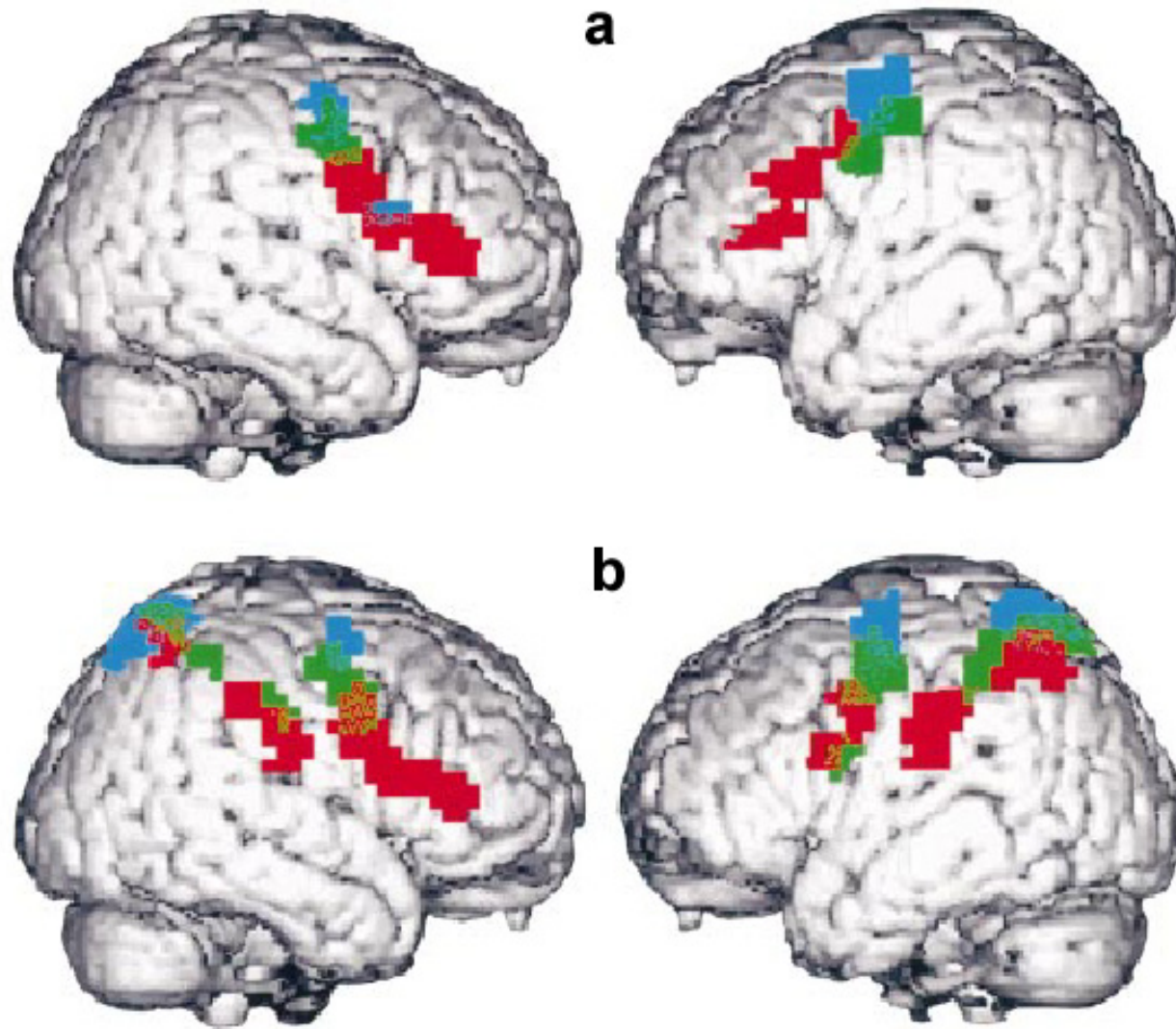
Fadiga et al. 1995

EMG activation during execution of the observed motor acts



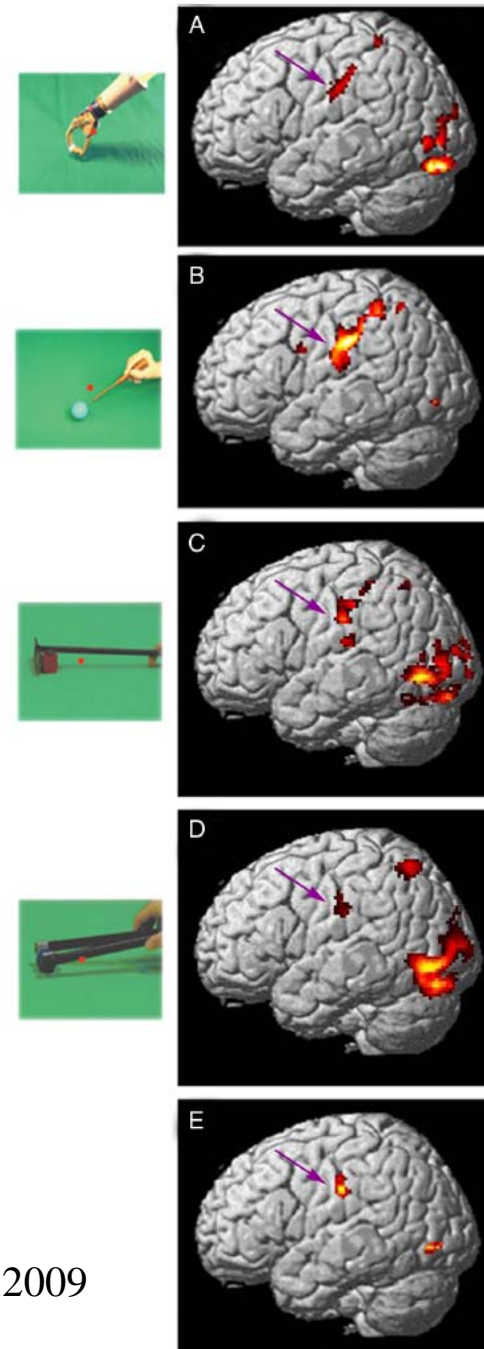
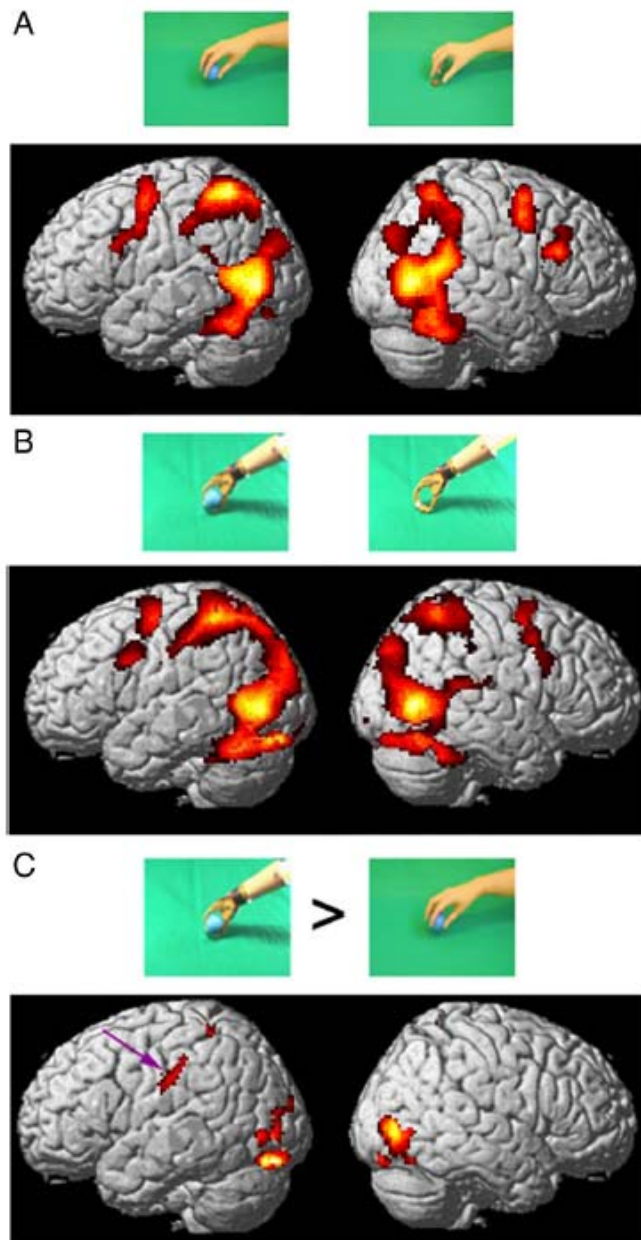
Action observation circuit in humans



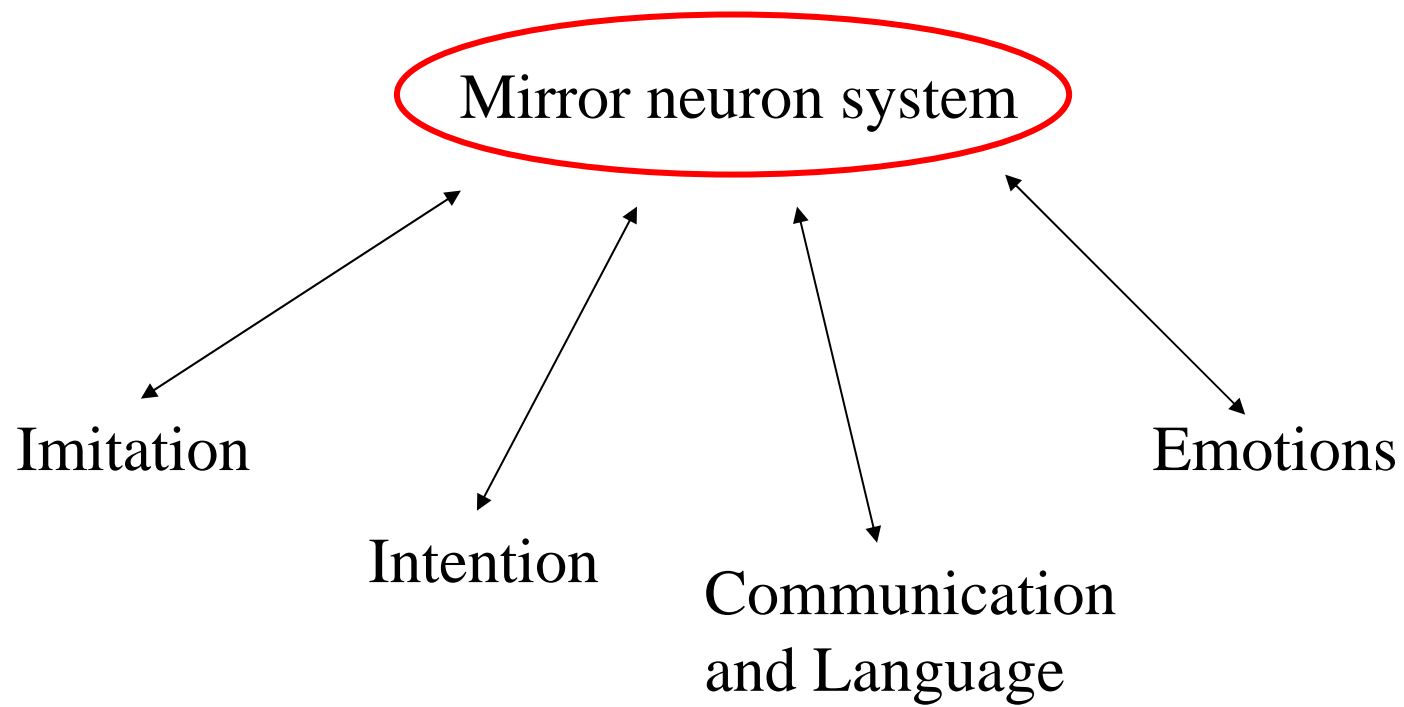


a = observation of mimed motor acts
b = observation of goal-directed motor acts

Observation of motor acts performed with tools



Peeters et al. 2009



Neonatal imitation



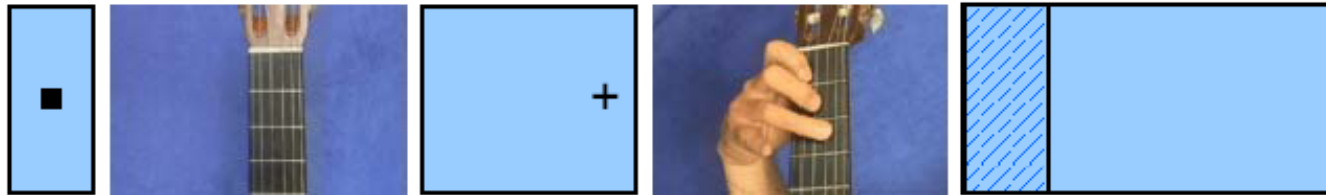
Meltzoff & Moore 1977



Ferrari et al. 2006

Imitation learning

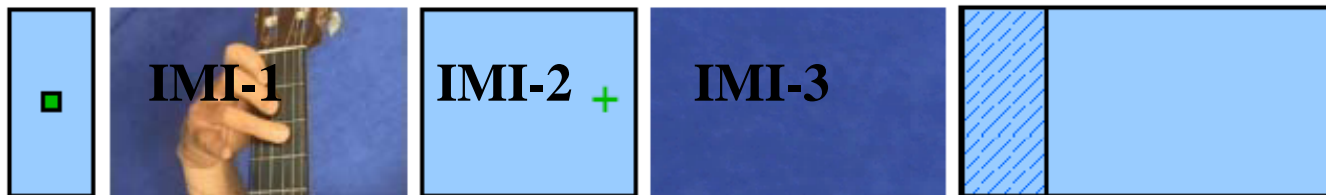
OBS: "just watch"



EXE: "play a chord of your choice"



IMI: "observe the model, then imitate"



NON-IMI: "observe the model, then perform a hand action"



Cue
(2 s)

Event 1
(4, 6, 8 or 10 s)

Event 2: pause
(2, 4, 6 or 8 s)

Event 3
(7 s)

Event 4: baseline
(6, 8, 10 or 12 s)

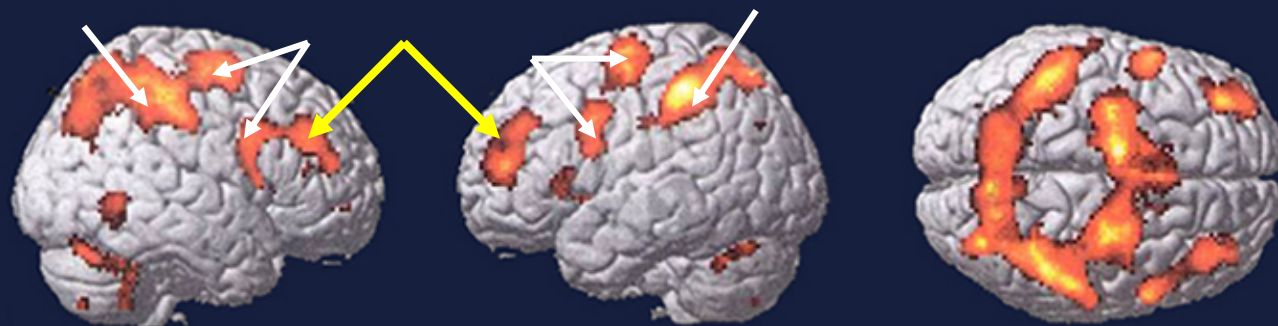
Buccino et al. 2004

Cortical activation during the Condition “Imitation”

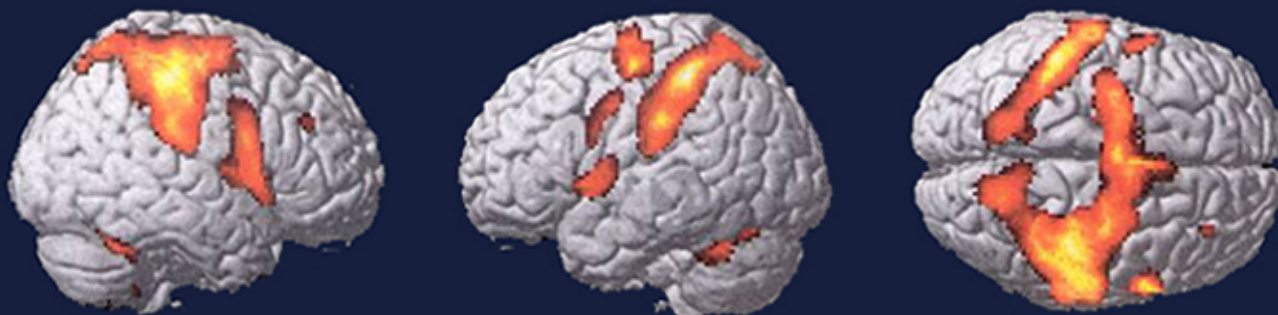
IMI-1



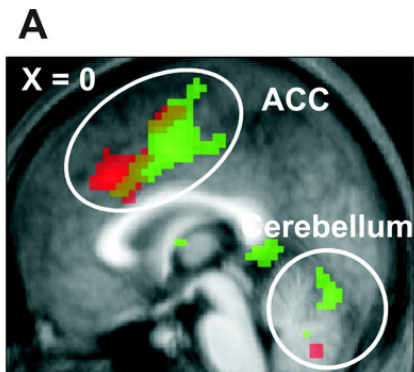
IMI-2



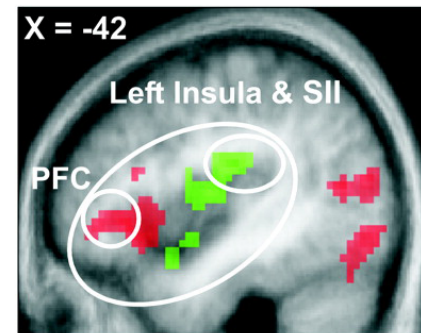
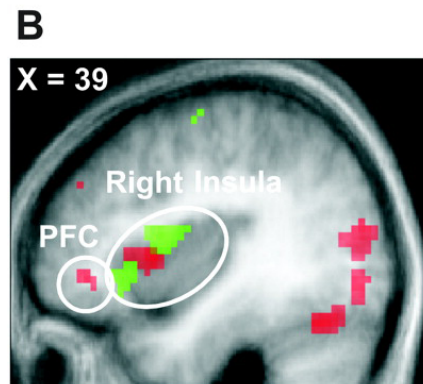
IMI-3



Understanding emotions

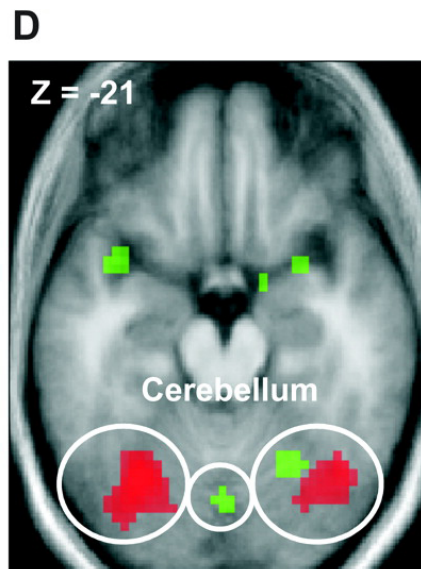
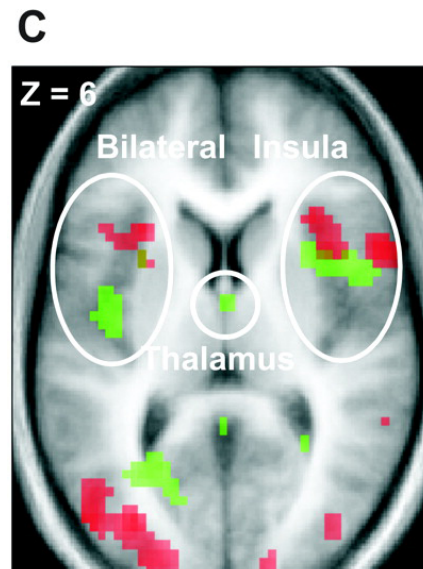


Empathy for pain



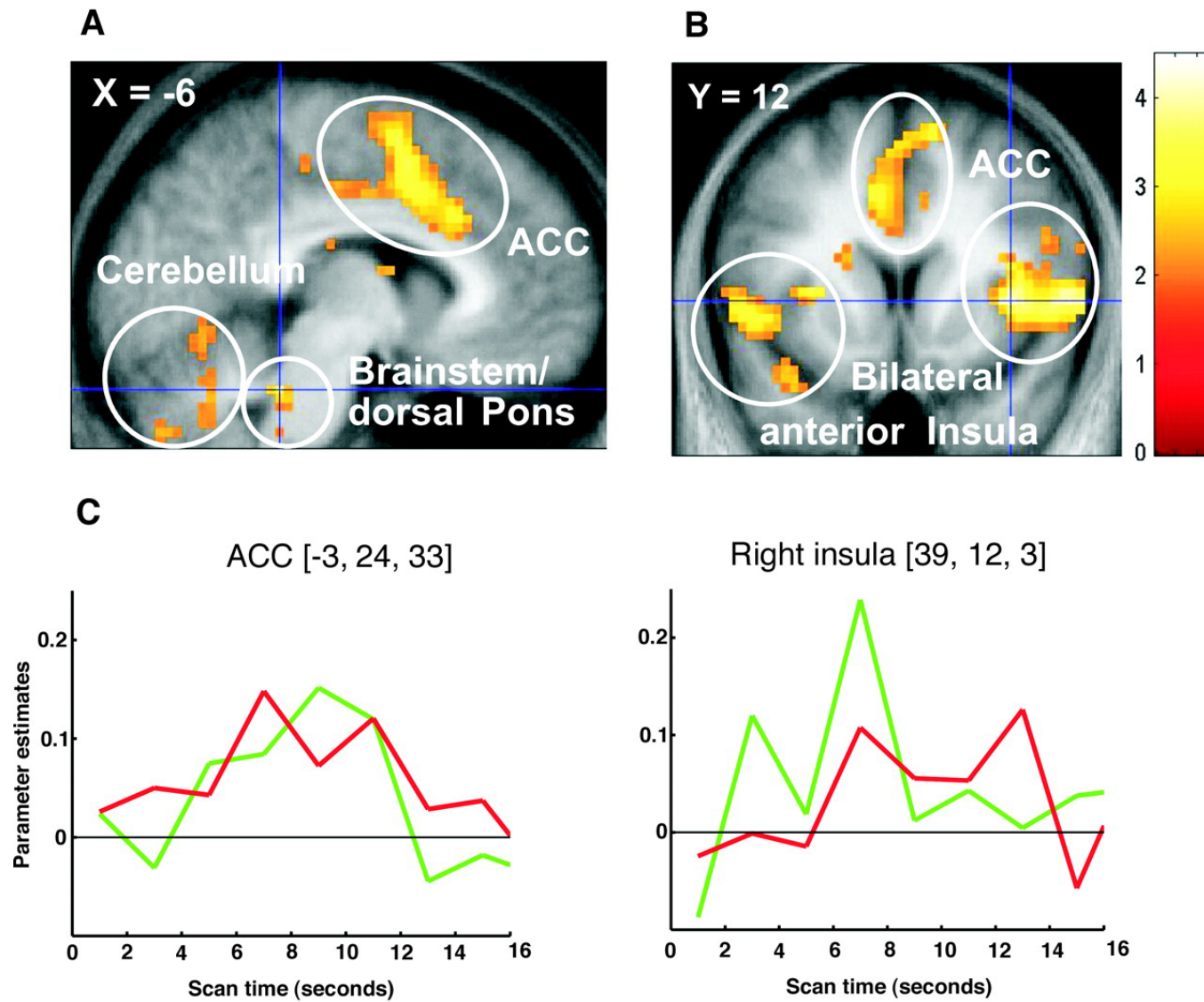
Green = “Self” Condition

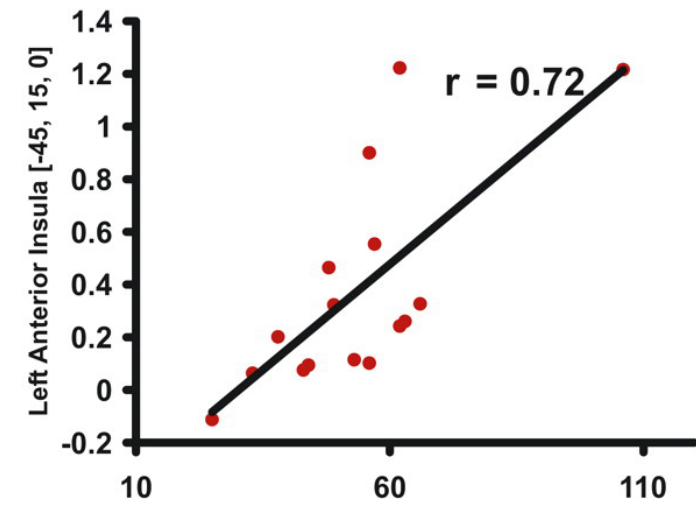
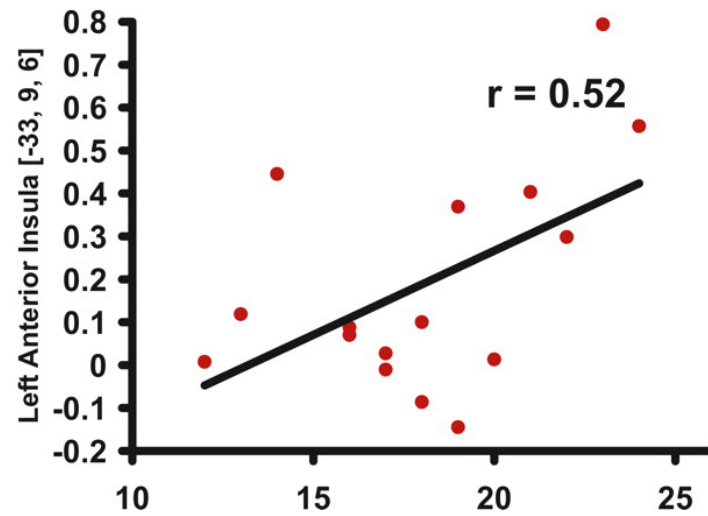
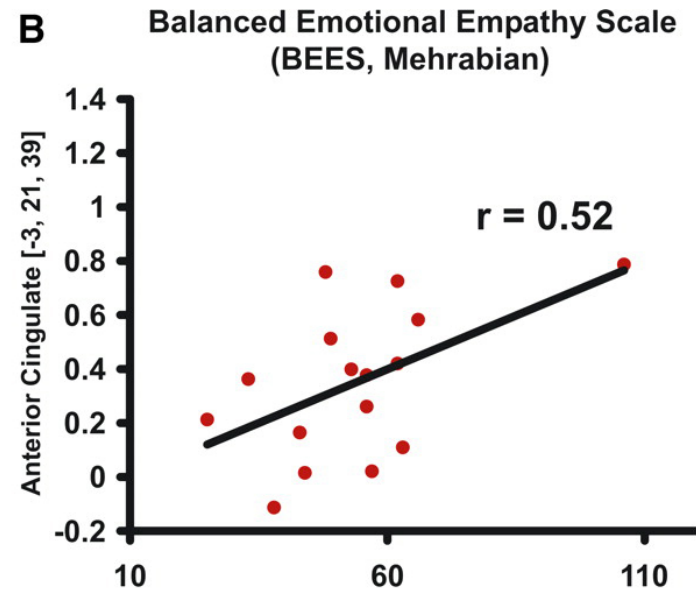
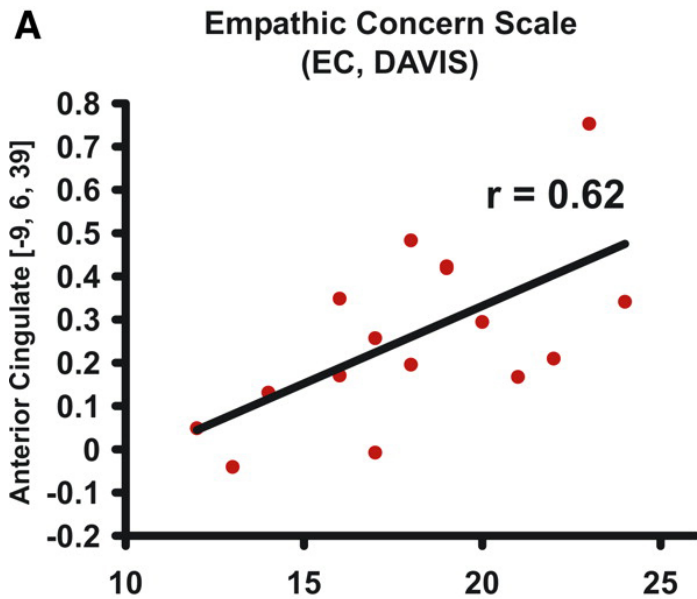
Red = “Other” Condition



Singer et al. 2004

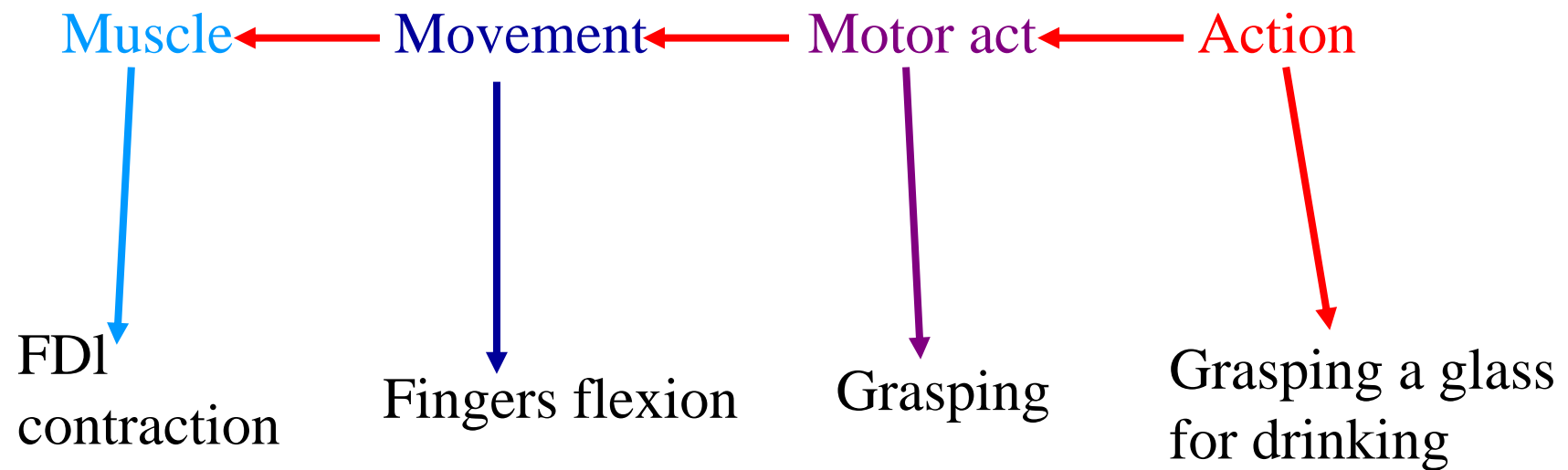
Common regions activate by perception of own and other's pain

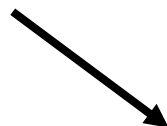
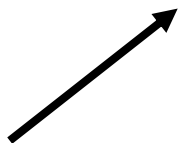




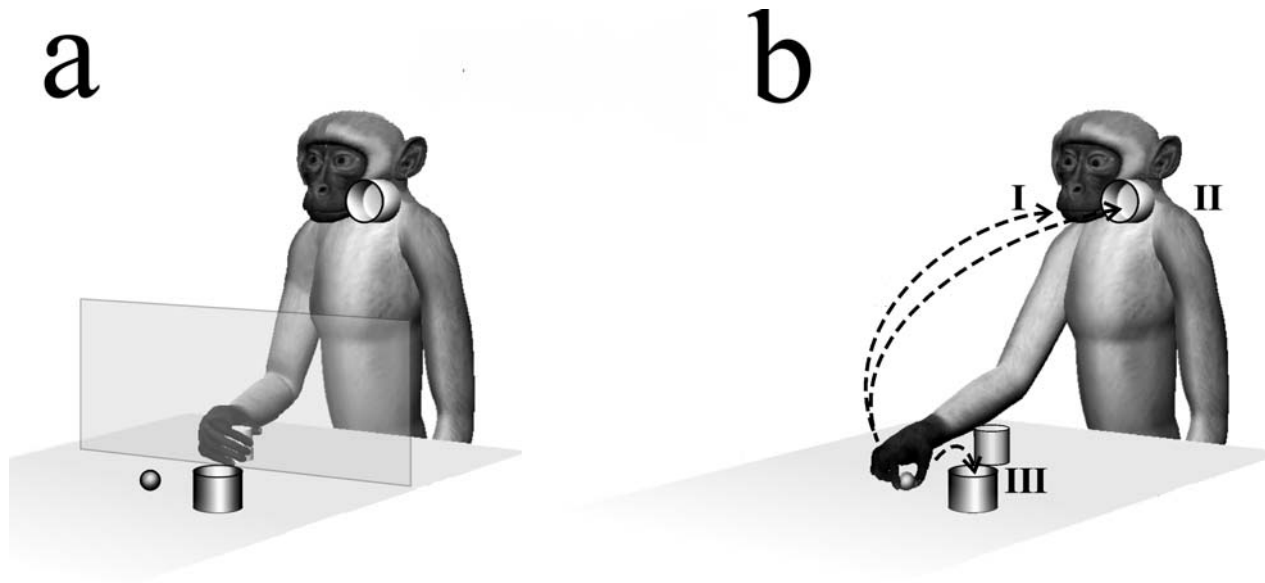
4. Involvement of the mirror neuron system in intention coding

Action organization

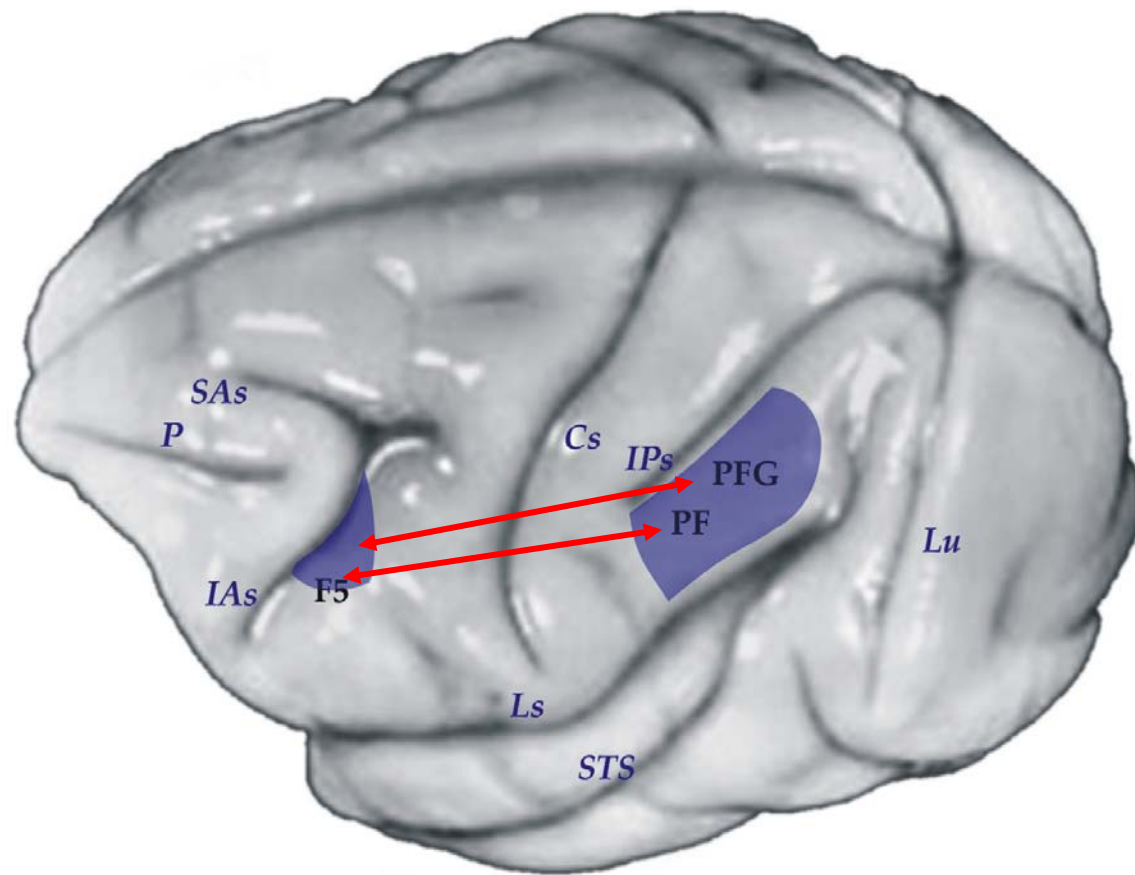




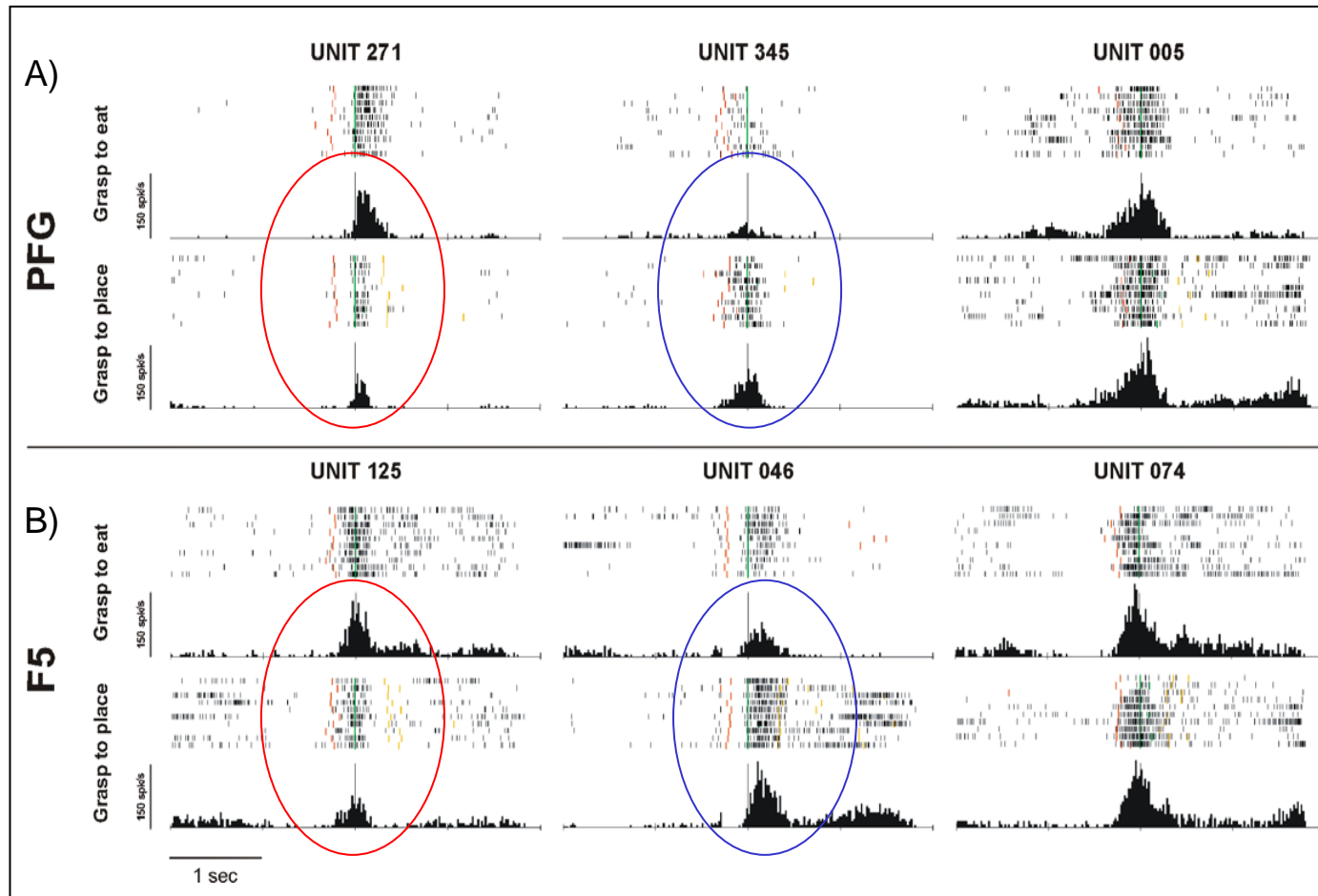
Action sequence motor task



Fogassi et al. 2005; Bonini et al. 2010



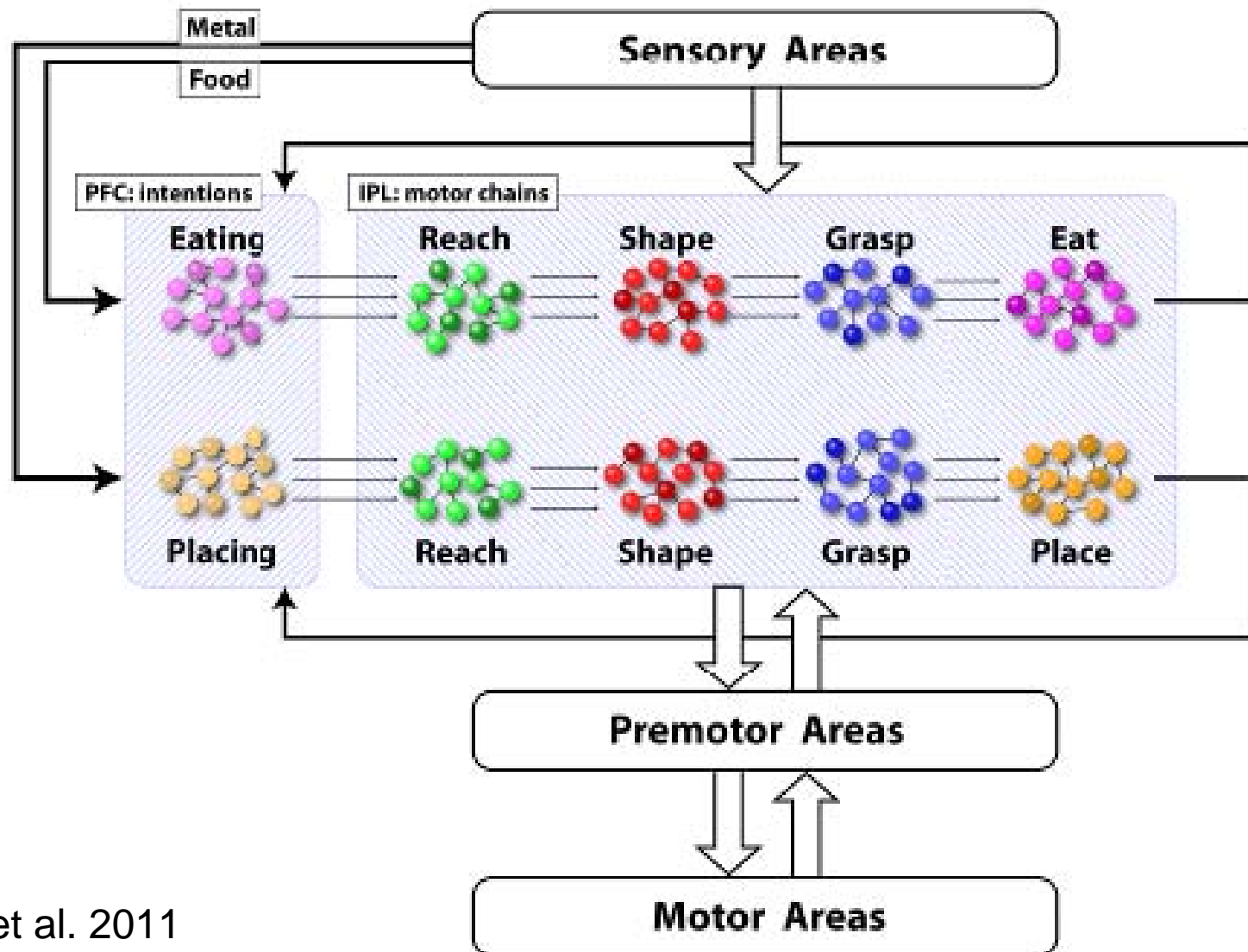
Activity of PFG and F5 grasping neurons during the execution of the motor task in the two conditions



PFG and F5 neurons reflect the agent's intention

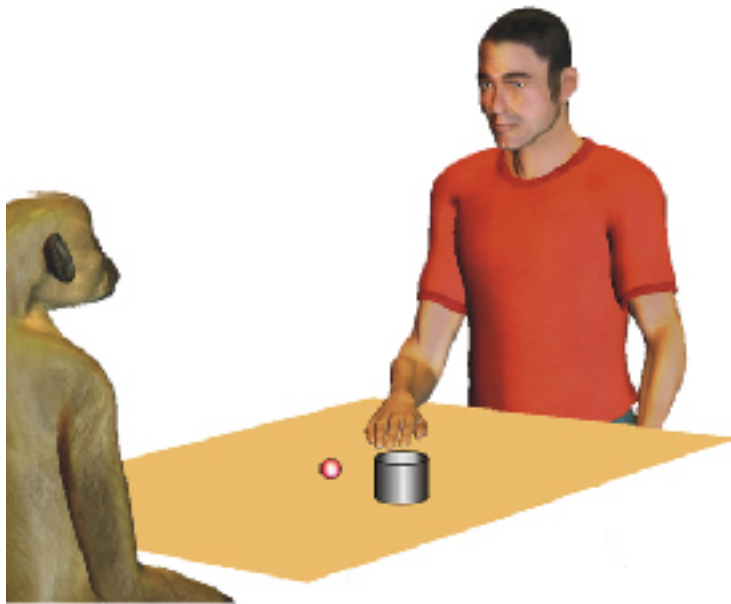
Intentional chains in the parietal cortex

Motor task

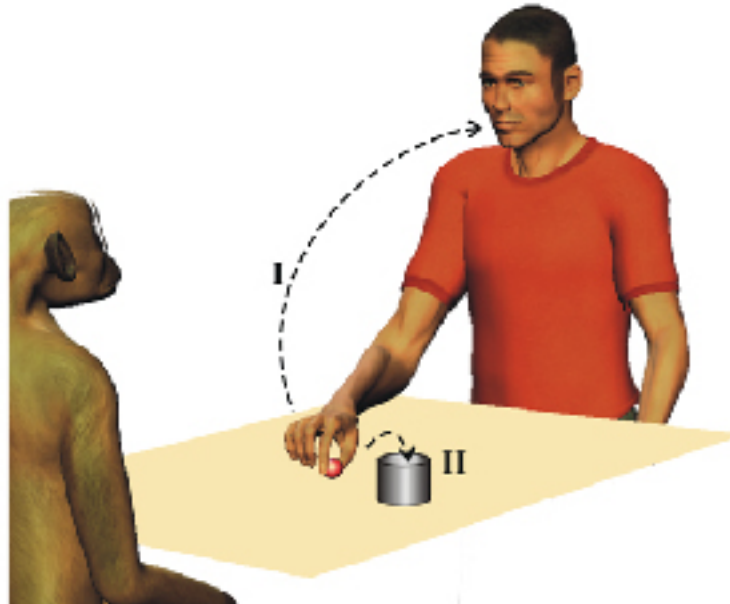


Action sequence visual task

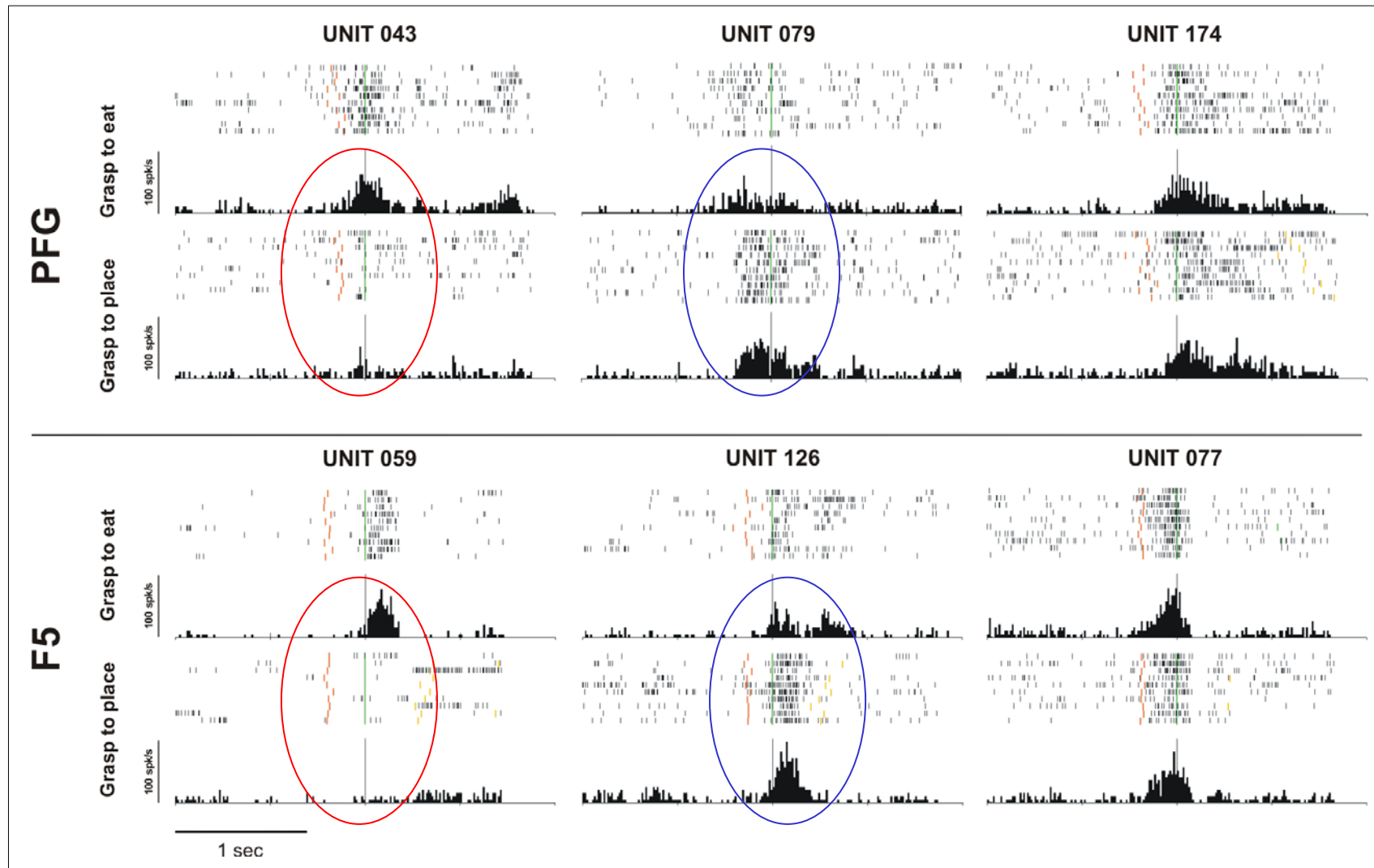
A



B

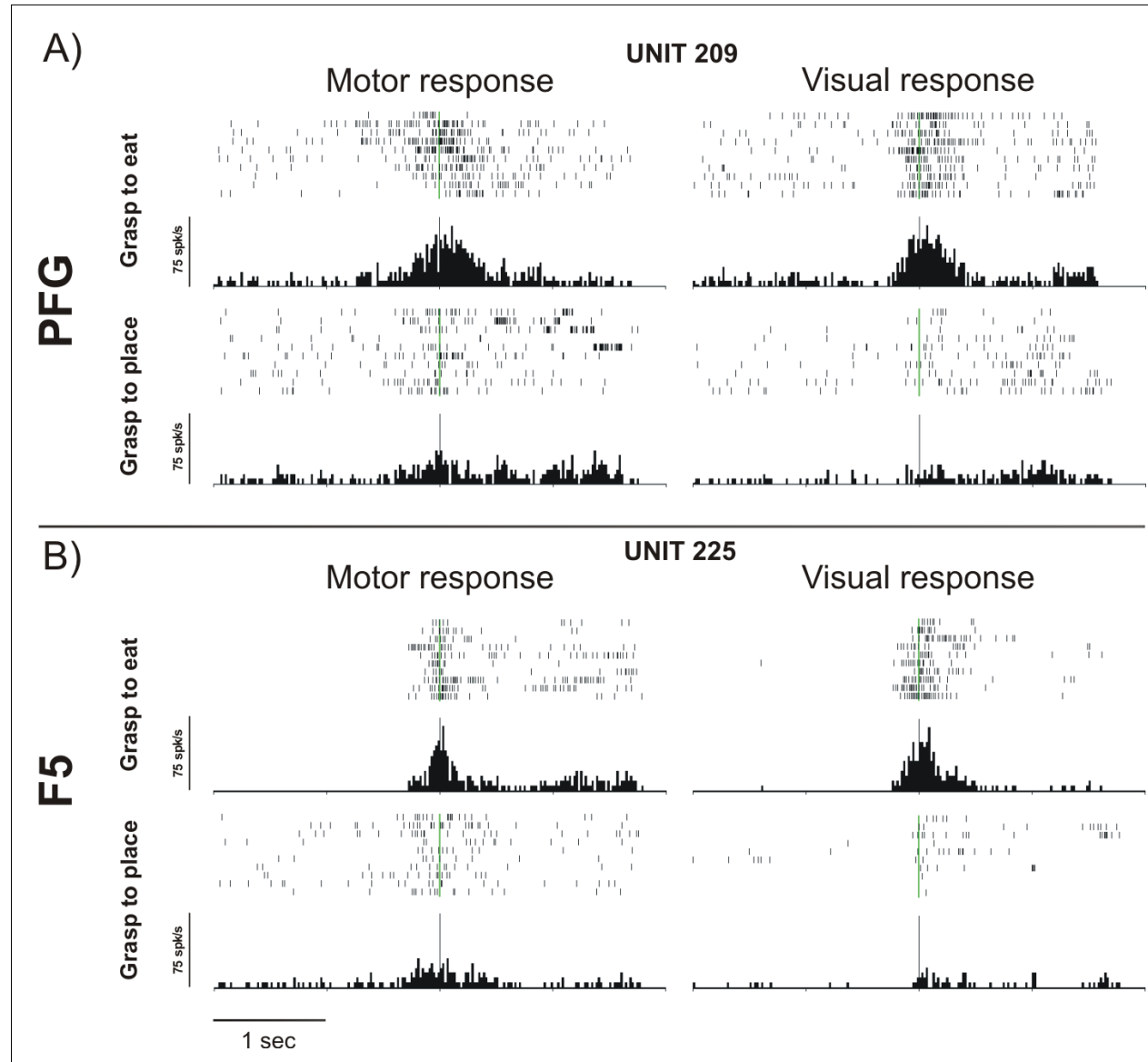


Responses of PFG and F5 mirror neurons during the visual task

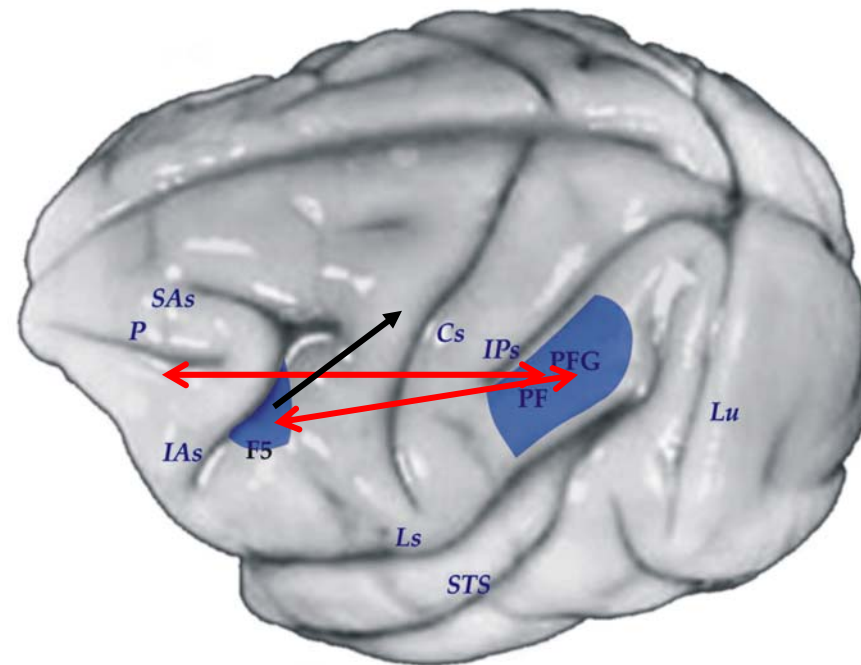


PFG and F5 mirror neurons predict the intention of the observed agent

Visuomotor congruence of parietal and premotor mirror neurons



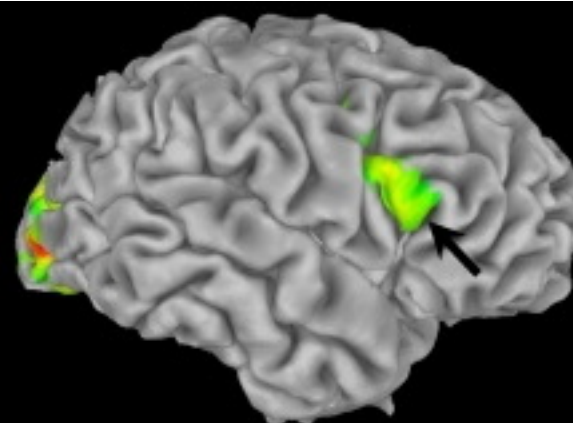
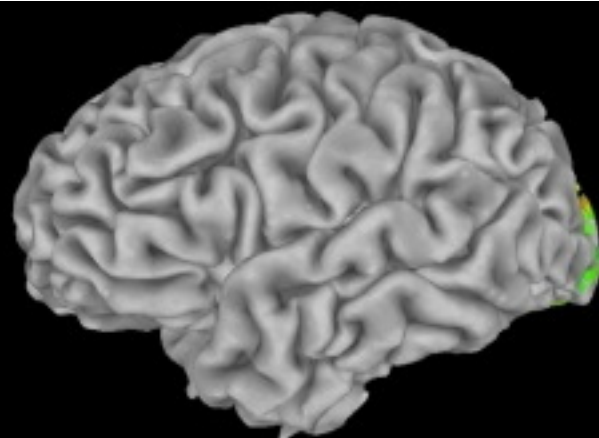
The parieto-premotor circuit appears to be involved in the organization of intentional actions. Prefrontal cortex could have the role of choosing and keeping active specific intentional motor chains, based on contextual information, memory and motivation.



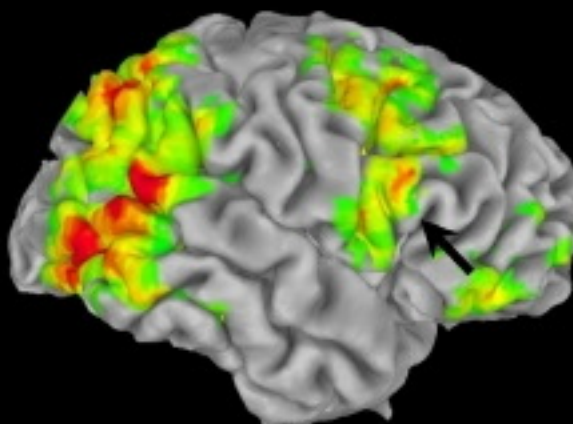
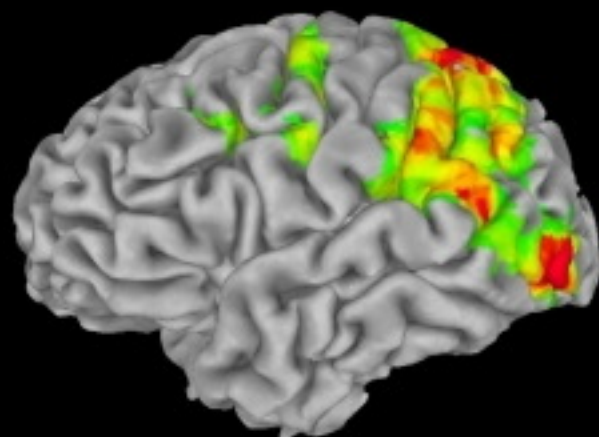


Iacoboni et al. 2005

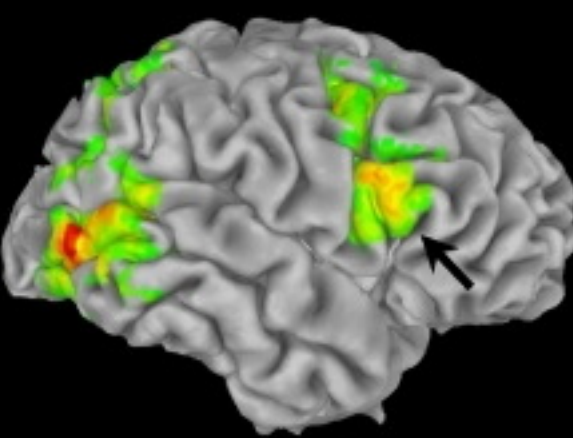
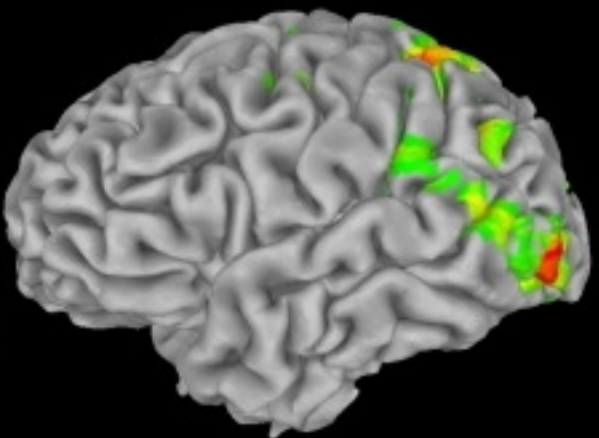
Intention
minus
Action



Intention
minus
Context

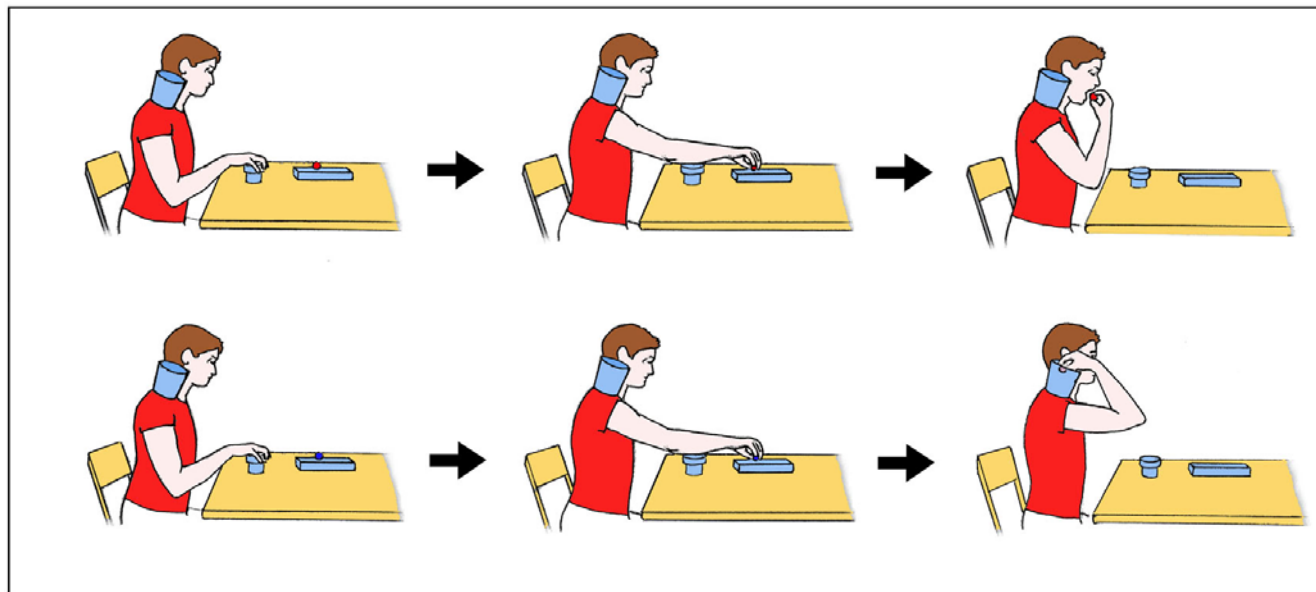


Intention
minus
(Action+Context)



Mirror system and autism

Motor task

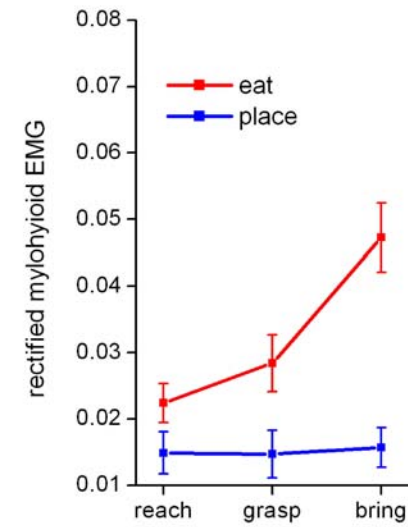
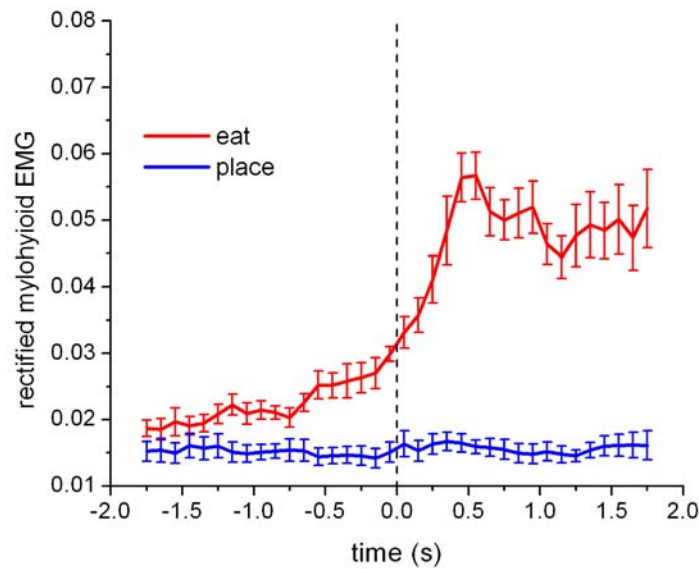


Cattaneo et al. 2008

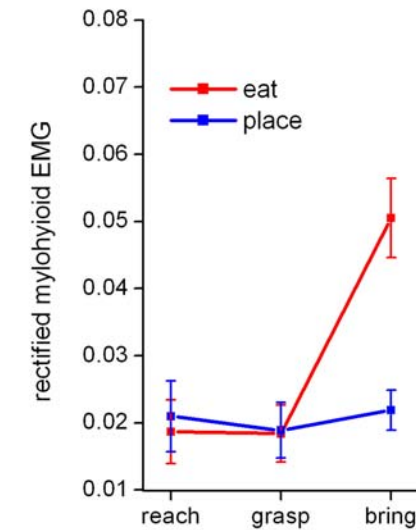
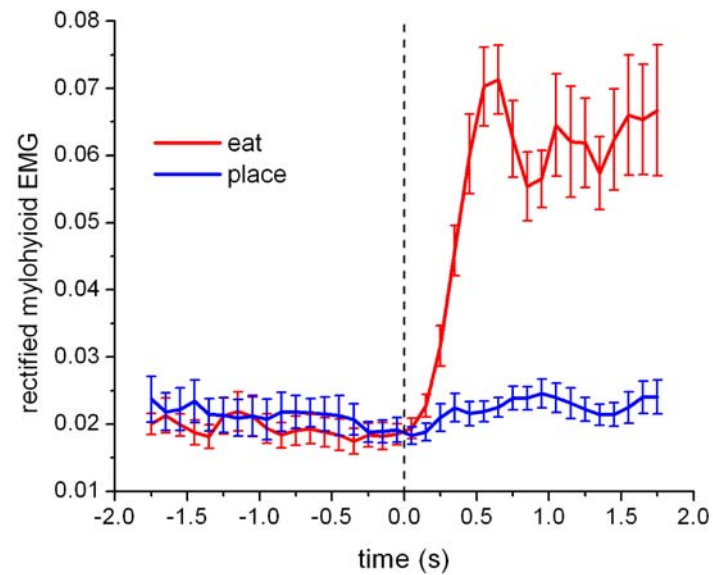
TD (n=8)
Age 5.2-11.9
Mean 6.5

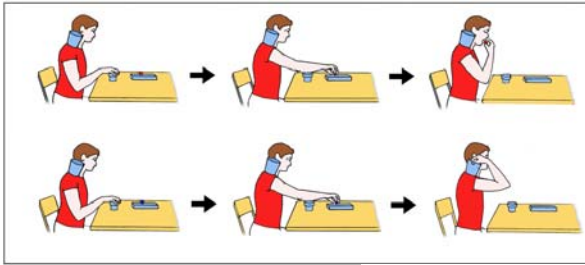
A (n=8)
Age 5.1-9.0
Mean 6.1

typically-developing children



autistic children



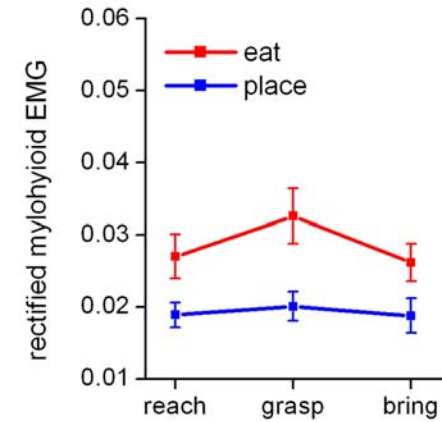
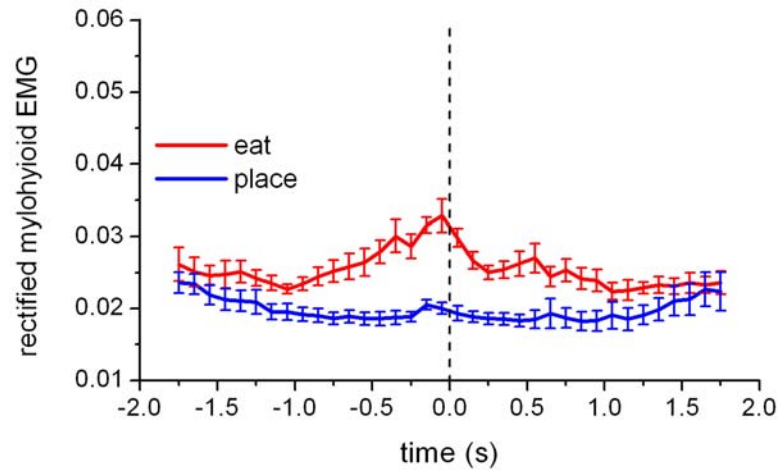


Observation task

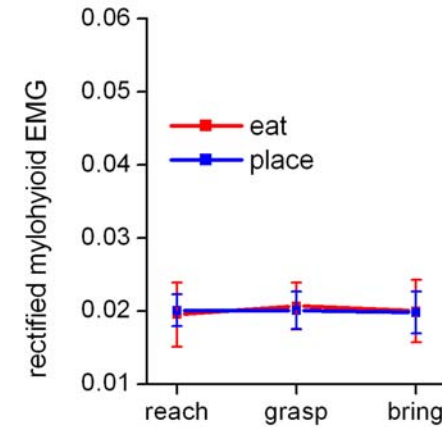
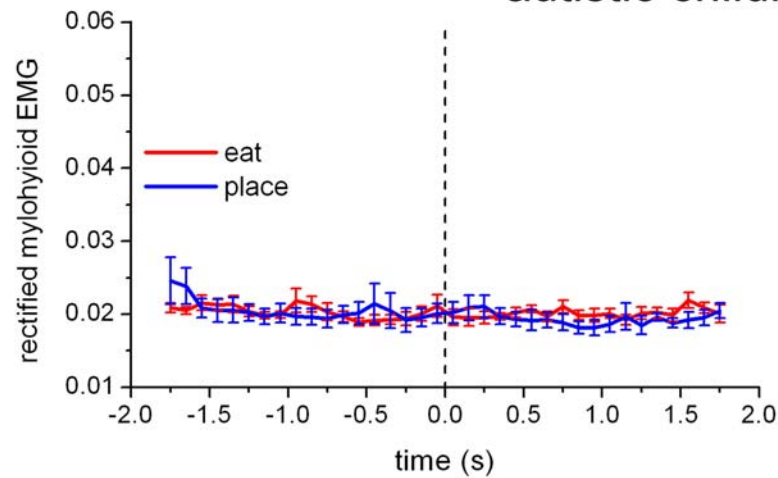
typically-developing children

TD (n=8)
Age 5.1-9.1
Mean 6.5

A (n=7)
Age 5.1-9.0
Mean 6.2



autistic children



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Thanks for attention!