Representing oneself and other's action, agency and space through sensorimotor coordination

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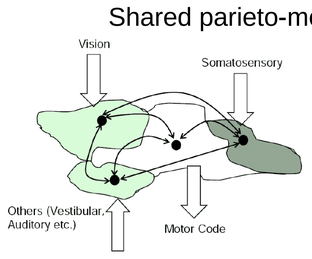
Abstract

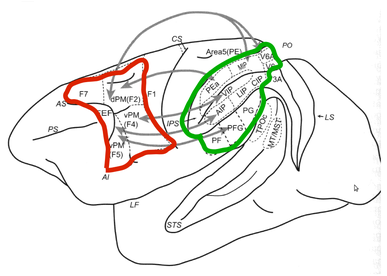
A large body of literature in neuroscience emphasizes the role of embodiment for intelligence, many important cognitive skills arise just from the simple structuring of the sensorimotor information flow; e.g., for representing actions performed by oneself and others (the mirror neurons system), for representing our own body image along with the peripersonal space (visual receptive fields), or to sense our own agency (the feeling that I am the cause or author of the movement) or the perceptual presence of others (in the parietal cortex). In three robotic experiments using proprioceptive, tactile or visual feedback information we simulate how low-level action representation, agency, spatial representation could arise in sensorimotor networks of spiking neurons [1-2]. We suggest a basic stage representing the self in relation to others at a very raw level in line with Gallese's Simulation Theory of shared circuits.

Shared circuits for cognition

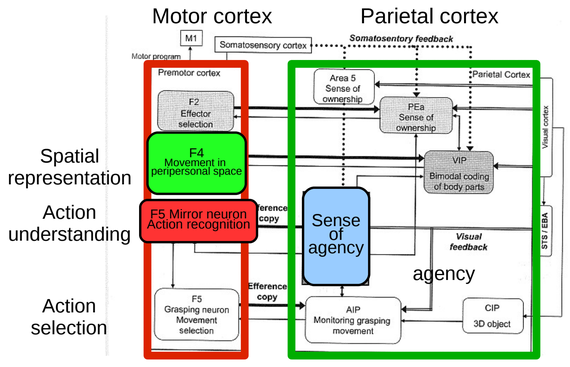
Shared parieto-motor circuits are involved in
- action representation
- spatial representation of the body
- agency and body ownership

to represent the self in relation to others.

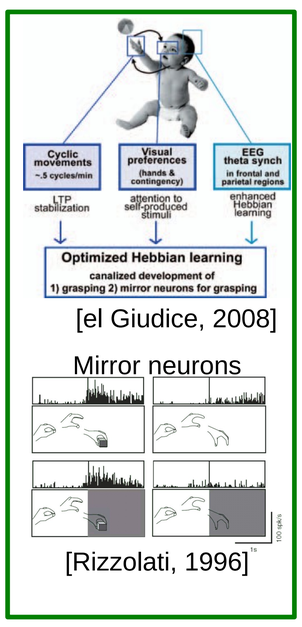




Parieto-premotor connection in the monkey cerebral cortex [Murata & Ishida, 2007]

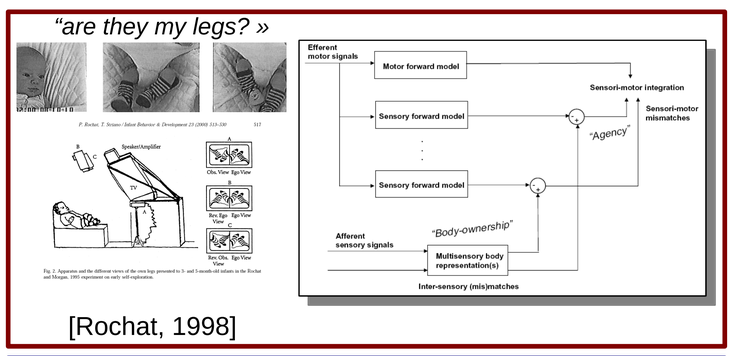


Conceptual framework for bodily self and sensory motor control in the parieto-premotor network. [Murata & Ishida, 2007]

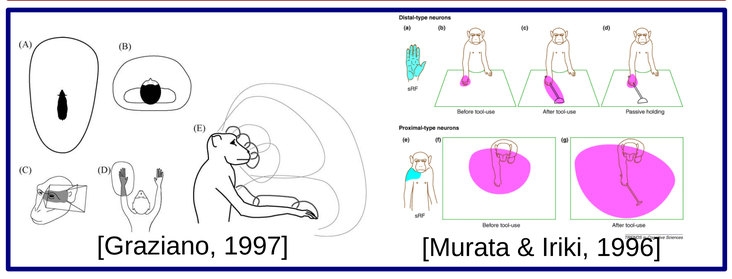


[el Giudice, 2008]

[Rizzolati, 1996]

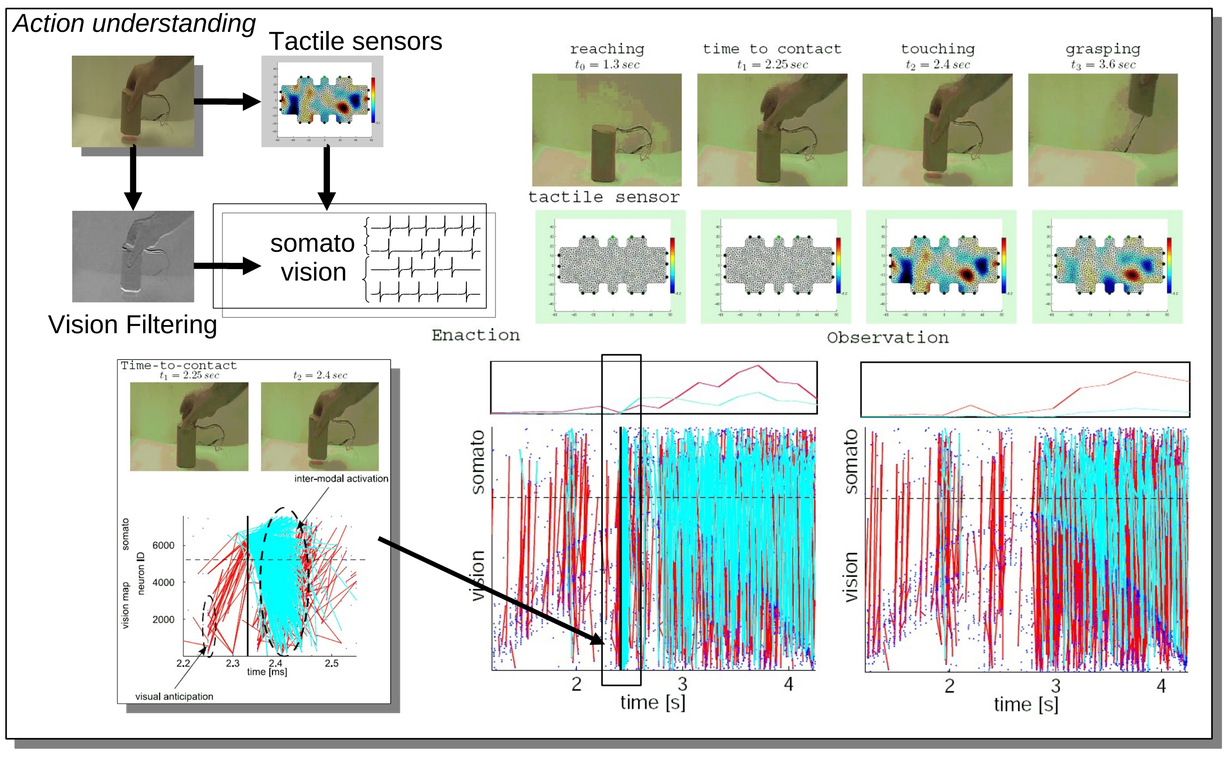


[Rochat, 1998]



[Graziano, 1997] [Murata & Iriki, 1996]

Experiments & Results



Importance of timing

Temporal information between sensorimotor signals (timing, contingency, synchrony, temporal delays) have been found critical in developmental psychology for these cognitive tasks. They create robust associative neural representations during physical interactions with the environment. We hypothesize that the neural mechanism of spike timing-dependent plasticity (STDP) that synchronizes the neurons to each others.

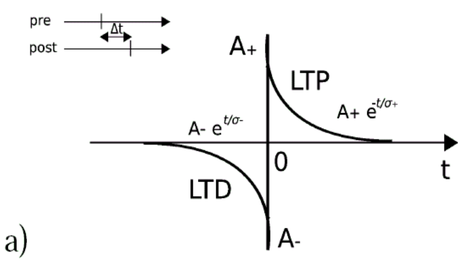


Fig1: STDP model

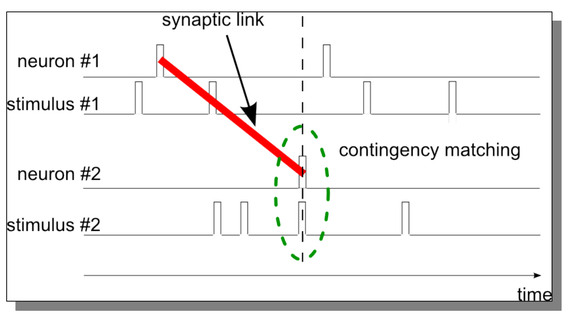


Fig2: Contingency detection & agency measure

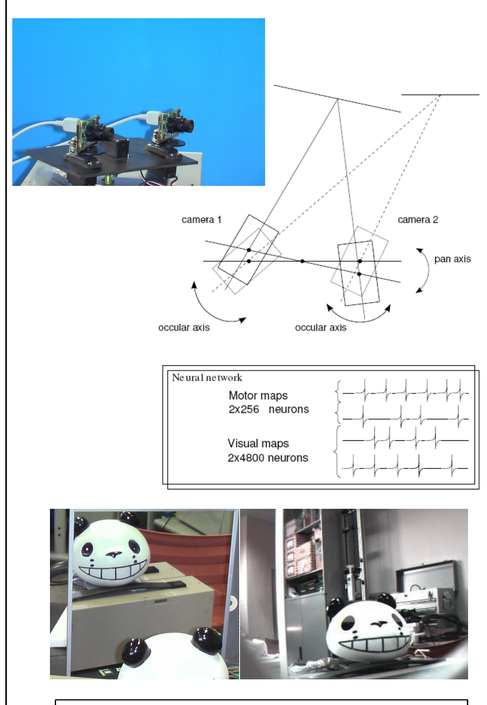
$$precision = \frac{nb\_correctly\_predicted}{nb\_predicted}$$
$$recall = \frac{nb\_correctly\_predicted}{size\_current\_input}$$
$$agency\_idx = \frac{2.precision.recall}{(precision + recall)}$$

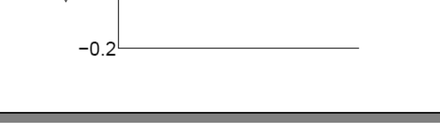
Imitation

Communication

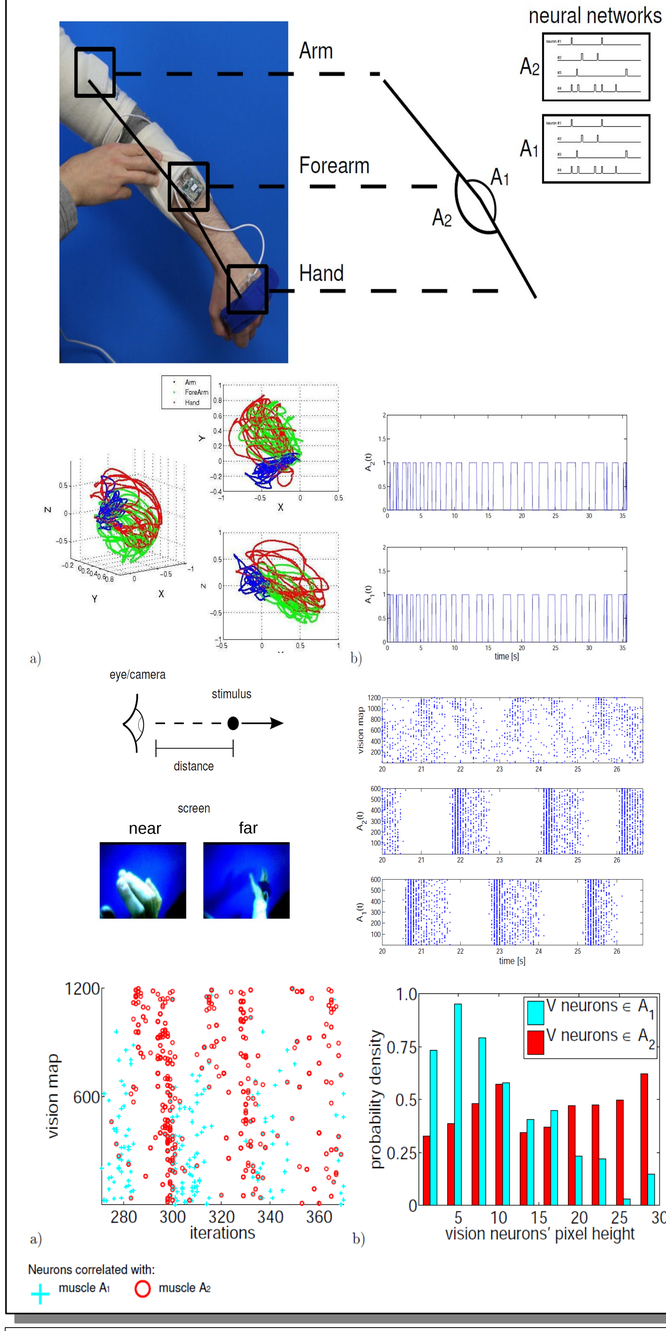
Coincident detection

Agency and self-other distinction





Spatial representation



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