[illegible]

Daniele Caligiore[123], Domenico Parisi[12], Gianluca Baldassarre[1]

[1]Istituto di Scienze e Tecnologie della Cognizione, Consiglio Nazionale delle Ricerche, Roma
[2]Dipartimento di Psicologia, EMbodied COgnition group, Universita' di Bologna, Bologna
[3]Universita' Campus Bio-Medico, Roma
{daniele.caligiore, domenico.parisi, gianluca.baldassarre}@istc.cnr.it

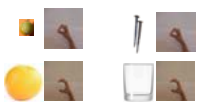
www.istc.cnr.it

www.rossiproject.eu

ABSTRACT

Affordances: a quality of an object, or the environment, that invites an individual to perform an action (Gibson, 1979)

Seeing objects tends to elicit the actions appropriate to interact with them, e.g. a precision or power grasp.



Compatibility effects: Tucker and Ellis (2001) found a compatibility effect between objects' size (large, small) and the kind of grip (power, precision) used to respond whether seen objects were "natural" or "artifacts".

Categorisation task	Incompatibility	Compatibility
Artifact: precision grasp	Slow reaction time	Fast reaction time
Natural: power grasp	Slow reaction time	Fast reaction time

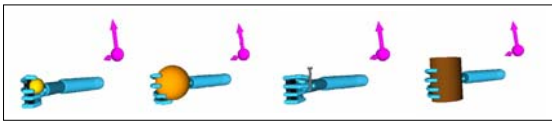
Working hypothesis: There is an *interaction* between the *action afforded* by the object and the *kind of motor response*

Goal of this work: a biomimetic neural-network model to study compatibility effects

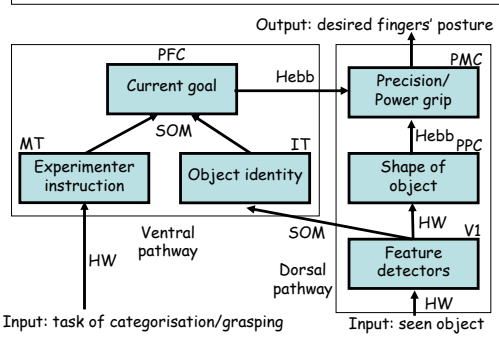
The model suggests an interpretation of the results by Tucker and Elllis (2001) in the light of the general theory on the functions of Prefrontal Cortex (PFC) (Miller and Cohen, 2001). This theory views *PFC as an important source of top-down biasing* which leads organisms to *select one among many neural pathways* which carry different information and *compete for expression in behaviour* (the winner is the pathway with the strongest sources of support).

THE MODEL

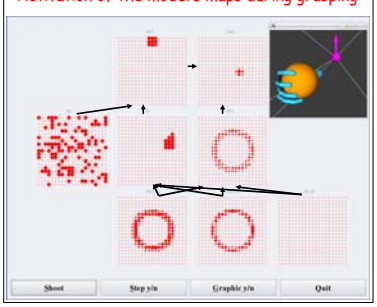
Architecture: Formed by various 2D neural maps which:
(1) Reproduce the key cortical areas involved in the Tucker and Ellis (2001)'s experiment, according to the brain-imaging data reported in Grezes et al. (2003);
(2) Are organised along the "ventral" and "dorsal" pathways encoding respectively the "what" and "how" information on objects (Goodale and Milner, 1992).



Simulated 3D physical robot: The neural-network model is tested in a simulated human-like 3-segment/4-degree-of-freedom arm and a 21-sement/19-degree-of-freedom hand; the robot has a visual system composed of an "eye" (a camera with 630x630 RGB pixels) looking frontally towards the objects.



Activation of the model's maps during grasping



Functions of the model's neural maps
- V1: Implements RGB edge detection on the basis of HW weights.
- PPC: Encodes objects' shape by performing an average of RGB edges (V1).
- PMC: Selects actions on the basis of a biased competition (see below).
- MT: Encodes the task (grasping/categorisation) with arbitrary patterns.
- IT: Encodes objects identity on the basis of a self-organising map.
- PFC: Encodes the current goal related to the current object and task.

Learning in the dorsal pathway and IT (during life)
The organism performs hand-closure actions on objects ("motor babbling") and associates the sight of big/small objects (V1 and PPC) with power/precision grips (PMC) on the basis of a Hebb rule. This mimics the acquisition of affordances taking place before the psychology experiment.
V1-IT: Connection weights developed with a Kohonen algorithm.

Learning in the ventral pathway (during the psychological experiment)
(MT-IT)-PFC: Connection weights developed with a Kohonen algorithm.
PFC-PMC: Connection weights developed with a Hebb rule: task response.

Legend: V1: Primary Visual Cortex; PPC: Posterior Parietal Cortex; PMC: Premotor Cortex; IT: Inferotemporal Cortex; MT: Medial Temporal Cortex; PFC: Prefrontal Cortex; HW: hardwired weights; Hebb: Hebb learning rule; SOM: Self-Organising Learning Rule (Kohonen).

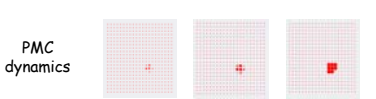
Reaction times: The PMC is a neural map of leaky neurons which triggers actions on the basis of a biased dynamic competition (Erlhagen and Schöner, 2002) ending when a cluster of neurons reaches a certain threshold (→reaction time).

RESULTS

The organism sees an object (e.g. a glass): the dorsal pathway evokes an action on the basis of the *affordance* elicited by the object (i.e. a power grasp), and the *task* (e.g. the categorisation task of the experiment) suggests a response which can be *compatible or incompatible with the affordance*.

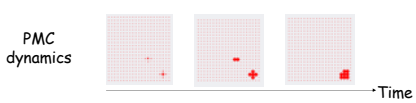
E.g., orange: affordance → power grasp; task: power grasp

The ventral pathway evokes the same action (e.g. a power grasp) as the one suggested by the dorsal pathway: no conflict in PMC → fast RT

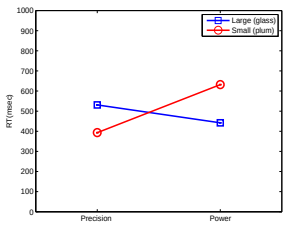


E.g., glass: affordance → power grasp; task: precision grasp

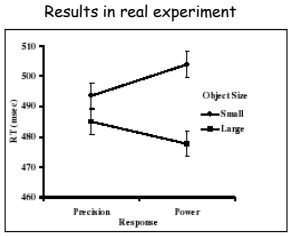
The ventral pathway evokes a different action (e.g. a precision grasp) with respect to the dorsal pathway: conflict in PMC → slow RT



Results with the model



Results in real experiment



Results (graphs on the left) show that:
(1) The model successfully reproduces the main experimental result of Tucker and Ellis (2001): when categorisation task requires responses *compatible* with the objects' affordances *reaction times are faster* than in the *incompatible* condition.
(2) The model does not reproduce the main effect showing that large objects are faster than smaller ones (see Ehrsson et al., 2000: a more complex, slower mechanism might be involved in precision vs. power grip).

Conclusion: The model allows interpreting the results of Tucker and Ellis (2001) on the basis of the general theory on PFC (Miller and Cohen, 2001): the PFC's bias allows organisms to perform actions different from those suggested by objects' affordances; however affordances still exert their influence on behaviour (interference), and this is reflected by longer reaction times.

- Ehrsson, HH, Fagergren, A, Jonsson, T, Westling, G, Johansson, RS, Forssberg, H (2000). Cortical activity in precision- versus power-grip tasks: an fMRI study. *J. Neurophys*, 83, 528-536
- Erlhagen, W, Schöner, G (2002). Dynamic field theory of movement preparation. *Psychol rev*, 109, 545-572.
- Gibson, JJ (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.
- Goodale, MA, Milner, AD (1992). Separate visual pathways for perception and action. *Trends Neurosci*, 15, 20-25.
- Grezes, J, Tucker, M, Armony, J, Ellis, R, Passingham, RE (2003). Objects automatically potentiate action: an fMRI study of implicit processing. *Eur J Neurosci*, 17, 2735-2740
- Miller, EK, Cohen, JD (2001). An integrative theory of premotor cortex function, *Annu Rev Neurosci*, 24, 167-202.
- Tucker, M, Ellis, R (2001). The potentiation of grasp types during visual object categorization, *Vis Cogn*, 8, 769-800.

This research was supported by the EU FP7 Project ROSSI, contract no.216125-STREP