The neural substrate of action observation.

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Support: ERC parietalaction
Restriction to the simple case of action observation: others’ actions, biological effectors, presentation of videos on a screen: no stereo

We have also studied tool action observation (Peeters et al 2009, 2013) and stereoscopic observation (Ferri et al 2016)
Processing of observed actions involves two aspects

- **Identity** (nature of the goal and ways to reach the goal): 3 levels
  - class: manipulation, locomotion
  - exemplar: grasping, squeeze, push
  - exemplar version: precision grip and part of object

- **Parameters**: effector, kinematics and dynamics

Several aspects are **extrinsic** to observed actions:
- **Actor**: gender, age, posture, intention, determination
- **Target**: object (size, shape, weight), point in space
- **Observer**: viewpoint, distance, visual field

In the present studies actor and object are manipulated to generate **variants** of actions
I Passive observation studies
Action observation activates a 3-level network
PrMC: action parameters: effector, kinematics

PPC level: perception of the action identity (ie where actions are coded)

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LOTC level: visual detail about actor (and relation to target)
Coding of observed action identity in PPC:

1) different *classes* are encoded in different parts of PPC
2) within each part *exemplars* are encoded by selective elements (neurons/voxels)
Evidence part 1:

Observation of different classes of actions activate specifically different parts of PPC: Manipulation in phAIP (all studies)  
Climbing in dorsal SPL (Abdollahi et al. 2013)  
Skin-displacing actions: in S2-PF (Ferri et al. 2015)  
Interpersonal interactions: dDIPSA  
Vocal communication: PFm and Spt (PFcm)  
Corbo and Orban under revision

Manipulation (grasp)  Skin displacing actions (rubbing)  Interpersonal interactions (hugging)  Climbing (climbing a rock)  Vocal communication (sing)  Indirect communication by trace in environment (write)
Observing vocal communication

• Does observing others speak or sing activate the Sylvian parieto-temporal (Spt) area involved in speech production according to Hickok et al 2003.

• Test the value of action observation as proxy for action execution
2x3 Factorial Design:

Classes: vocal com & oral mani
Presentation modes: video, Static, dynamic scramble.
Specific map or oral manipulation (yellow) and vocal communication (red)
New study (B Urgen & GA Orban)

Activation Maps

Indirect Communication (write draw Erase Sculpt)

Direct Communication (here No Wave Clap)

Specific Map

Indirect Communication

Manipulation (drop grasp push drag)
Interim conclusion (proxy theory)

• Observation of different action classes involves different PPC regions
• These regions match at least approximatively those involved in the planning (sensori-motor transformations) of the same actions.
Evidence part 2: single voxels and neurons in phAIP are specific for manipulative exemplars

Aflalo, Corbo, Ferri, Liu, Poultrain, Andersen & Orban
in preparation

Observed action selective Neurons in putative human AIP
Single voxel tuning:

Serences et al 2009: human V1-V3

Dubois et al 2015: monkey IT neurons and voxels
fMRI experiment:

- 7 manipulative actions each four versions (2 object, two actors), videos 2.6s
- 1 cycle= Drag1-4, drop 1-4, Squeeze 1-4, grasp 1-4, push 1-4, roll 1-4, rotate 1-4, fix1-4 (83.6s)
- 1 run=4 cycles; 10 runs per session
- 20 subjects
Grasping
II Discrimination experiments
Psychophysical study of action perception (Platonov & Orban in revision)

- 2AFC (roll/rotate)
- Fitted by diffusion model:

- Two steps: sensory evidence (OAS neurons) & accumulation of the evidence in a race
Compare with control conditions
View point and duration.
<table>
<thead>
<tr>
<th>Action</th>
<th>Gender</th>
</tr>
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<tbody>
<tr>
<td><strong>75%-Accuracy Threshold</strong></td>
<td>Action</td>
</tr>
<tr>
<td></td>
<td>20.05±2.62</td>
</tr>
<tr>
<td><strong>Threshold ratio</strong></td>
<td>3.49±0.04</td>
</tr>
<tr>
<td><strong>A’</strong></td>
<td>1.26±0.24</td>
</tr>
<tr>
<td><strong>k</strong></td>
<td>22.9±7.48</td>
</tr>
<tr>
<td><strong>t_R</strong></td>
<td>0.34±0.31</td>
</tr>
</tbody>
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*A’ – normalized bound
k – normalized drift rate
t_R – residual time*
Comparing tasks (Ferri, Platonov & Orban in prepar): Two specific networks: action vs color & gender; gender vs action& color
A priori ROIs

* = more than 57% of accuracy in MVPA range (65.5 - 85)
MVPA

Action vs Gender

Action vs Color

LH

RH

% Accuracy

\begin{center}
\text{OTS } \quad \text{MT+ } \quad \text{MTG } \quad \text{phAIP } \quad \text{preCS}
\end{center}

\begin{center}
\text{Change level } = 57 \%
\end{center}
General network: (action, gender, color discrimination vs active fixation)
PPI of all 3 Action specific sites & masking with the general network

Yields activation of posterior cingulate: clusters 5 (RCZp, involved in action selection) and 6 (CCZ) of Beckman et al (2009):
Conclusions

• 1) direct support for selectivity of single voxels of phAIP: neurons are selective and clustered.
• 2) new type of selectivity for a discontinuous variable: different kind of map with local ‘flower like’ arrangement modulated globally.
• 3) we have a complete scheme for coding of all observed actions of human repertoire
Conclusions II

• 4) PPC regions, specifically involved in action observation are recruited specifically in action discrimination

• 5) output of PPC regions (hosting sensory neurons) to posterior cingulate (action selection region): putative locations of decision processes

• 6) **meta conclusion selectivity for an unordered set of related items:** the coding scheme discovered for visual parameters (H&W 59) may apply to cognitive variables (similarity cortical anatomy)
Further studies

• 1) link with behavioral repertoire: which are the action classes
• 2) differences of PPC with other levels of AON
• 3) invariance of single phAIP neurons and voxels
• 4) relationship with mirror neurons:
  mirror neurons not needed for action observation
  mirror neurons (egocentric) attract visual afferences to appropriate PPC region
Match execution-observation at single neuron level
D-prime and degree of selectivity
Expected nb of voxels: 7x20x419x (.14)4= 23 observed=41 voxels

Expected nb of voxels: 7x20x323x(.14)4= 17 observed 60 voxels
phAIP: Overview PPC (flatmap)
Left PFcm
Metaconclusion: single voxels are worth more than expected

- In DIPSM single voxels ‘discriminate between actions when stereo is enabled.'