Nicole Trappe
COGS 184

Commentaries Week 4

The mirror neuron system allowed primates to move from grasping for food or fiddling with objects to seeing how others interacted with objects. This may have given rise to imitation which allowed primates to mimic the actions of others (like grasping) simply by looking. Imitation may have developed further to include specific signs representing actions, objects, or concepts. This is pantomime which focuses less on the copying of actions but in the direct relation to praxis goals (i.e. focus on the observer).

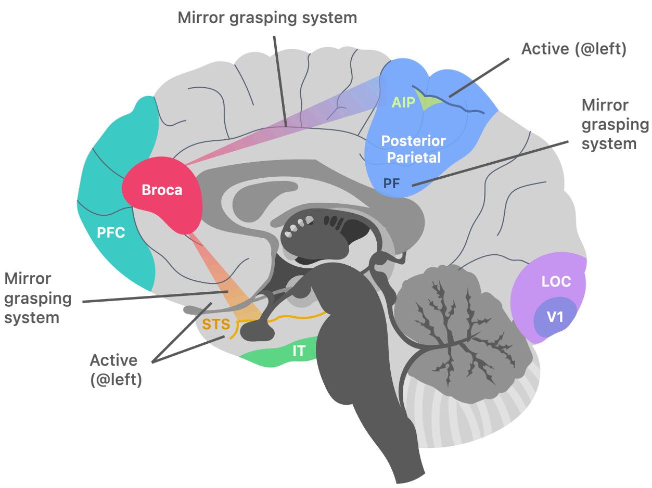
As we know from modern sign language, pantomime serves as a crutch to develop specific, learned signs. With the addition of context to pantomime, proto-sign may have emerged. By context we mean understanding which parts of the environment are relevant. This may abstract what used to be the imitation of an object to represent some attribute of that object. Dissociation may have enabled proto-sign to become a vocabulary of signs because a sign that may have delivered numerous detailed could be split into pieces which could be reused in a repertoire and applied to other things.

With proto-sign as a scaffold, proto-speech could emerge. It is important to emphasize that it was not the elaboration of vocalizations (e.g. alarm calls) that led to proto-speech. Because there is no direct mapping of sign to phonemes, we can also predict that proto-sign was the precursor to proto-language and proto-sign began the use of a set vocabulary a group of individuals could use rather than arbitrary, novel gestures.

Audiomotor neurons may have provided the extension from proto-sign to proto-speech. We believe this because mouth mirror neurons are most active not just in looking as mouth actions but when they are linked to audio like lip-smacking which has the most salient stimuli. To support more and more of these vocalizations, we would have needed an area like Broca's for the shift to predominantly vocal communication.

The classic mirror system hypothesis focuses on canonical cells of the premotor F5 (in non-human primates). Arbib agrees with the importance of the mirror neuron system, especially that of grasping, with the emergence of language. However, he finds fault in restricting grasping to the activation of F5 only. While we are often taught about Broca's area as the region of language production and Wernicke's for comprehension, it would be ludicrous to assume only two areas were responsible for something that only non-human primates have developed and not, like Arbib later says, a cumulative effect of different regions.

The premotor region F5 (homologous to Broca's in humans) contains mirror neurons, canonical neurons, orofacial cells, and manual cells. Mirror neurons are active when a monkey performs an action or sees an action performed. Canonical neurons are active for graspable objects. Orofacial cells and manual cells are to interpret the emotional state of the subject being observed.



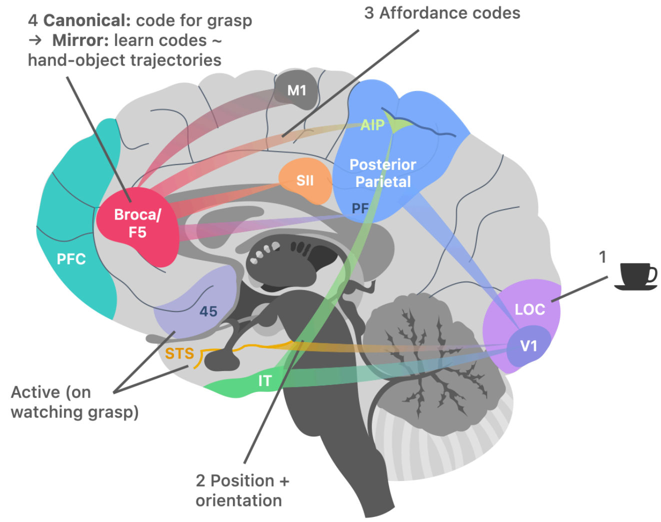


Figure 1 (left): Activation of Areas in Humans for Observed Grasp.
Figure 2 (right): Monkey MNS Model (*yes it is a human brain I was too lazy to change it*).
Note that regions may not be in the precise location and connections are not to scale.

In brain imaging studies of humans observing an object being grasped, Broca's area is not the only active area. Represented in **Figure 1**, we also see activation of the IT (in identifying the object being grasped), the prefrontal cortex (background, context), as well as the STS and AIP on the left hemisphere. It also seems likely that there are mirror neuron systems linking the STS (biological motion) to Broca's, the inferior parietal area (PF)(observations of actions like grasping), and linking AIP (parts of the object and whether their affordances) to Broca's.

From these studies alone, it seems clear that when one observes an object being grasped, STS notes that movement, IT defines the object, AIP and PF determine the affordances of the features of that object, and Broca's responds to the action as if one did it themself.

In the monkey mirror neuron system pictured in **Figure 2**, additional areas and white matter connections are seen in play. First, we see connections from somatosensory area II (SII) to F5. The primary somatosensory area focuses on peripheral sensory information while the second revolves around tactile object recognition and memory. The AIP which determines affordances sends affordance codes to F5 so that the mirror neurons can map codes to hand-object trajectories. SII may be essential in determining similar affordance codes by recalling tactile memories (though this is my own claim). Additionally, the primary motor cortex (M1) is active for the production of skilled movements which may arise from seeing a skilled movement like grasping. We also see the inferior frontal gyrus (area 45)—homologous to a portion of Broca's—active which may provide evidence for the growth of Broca's and the incorporation of cortical rhythms for sustained speech (my claim).

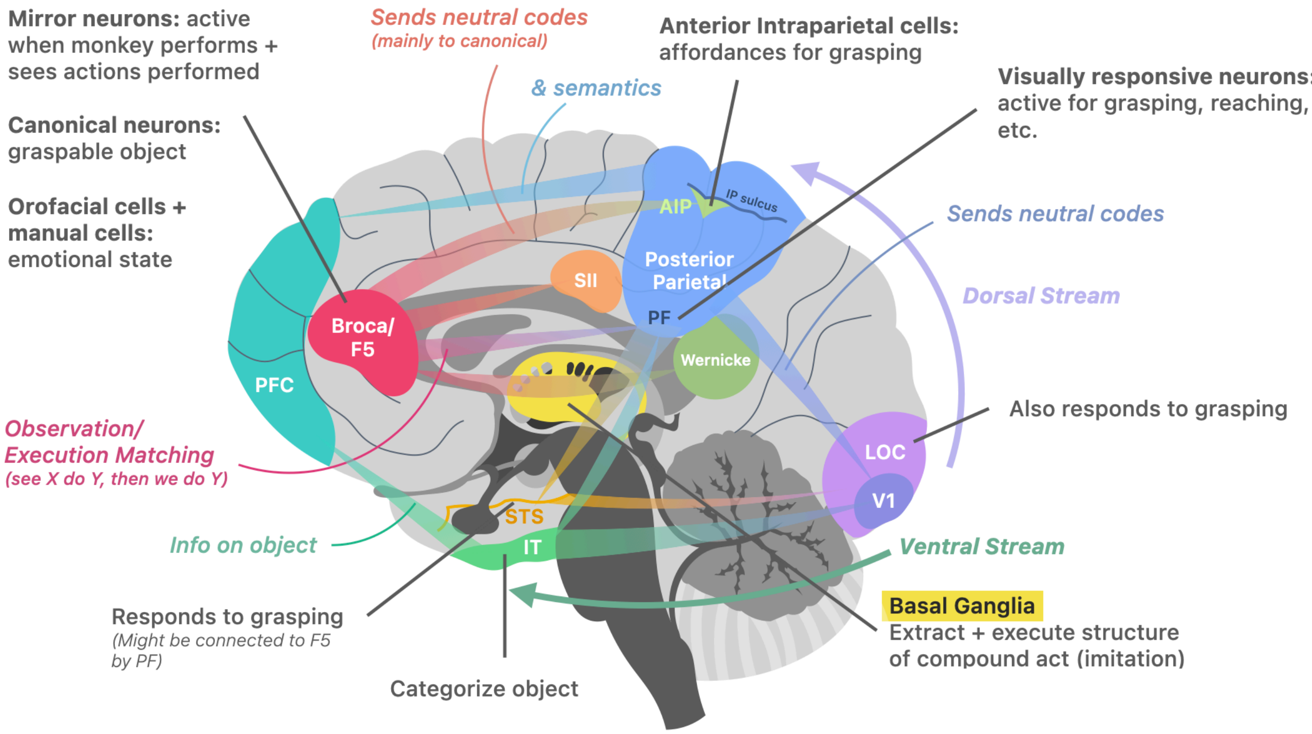


Figure 3: FARS Model in the human brain including additions to the model that later were mentioned (*basal ganglia & Wernicke's*). ***Note that regions may not be in the precise location and connections are not to scale.***

The FARS model (Figure 3) is both a critique of the MNS model but also an elaboration of it. In additional to mirror and canonical neurons in Broca's, orofacial and manual cells expose emotional states, and 40% of visually responsive neurons in PF are active for seeing grasping. More like the reality of the brain, the connections in this model are also "messier". IT connects to the posterior parietal (PP) lobe both directly and indirectly: it sends the identity of the object straight to the PF as well as information on the object to the prefrontal cortex (PFC) which relays it to the PP lobe in the form of semantics which eventually makes its way over to Broca's.

The basal ganglia is also responsible for extracting and executing structure of compound actions. In the case of imitation (and proto-sign, proto-language) the basal ganglia must break down what is happening into chunks. It isn't clear where this information is sent but it may be through the thalamus as it's the relay to higher cortical areas (my claim). Additionally, the STS may be connected to Broca's by PF, although, it could also be directly linked as area 45 is an expansion towards STS.

We also know that the posterior parietal is responsible for determining affordances that allow one to preshape their hand in a way that will allow them to grasp an object appropriately (Figure 4). In contrast, the IT allows us to pantomime or verbally describe the shape we would take.

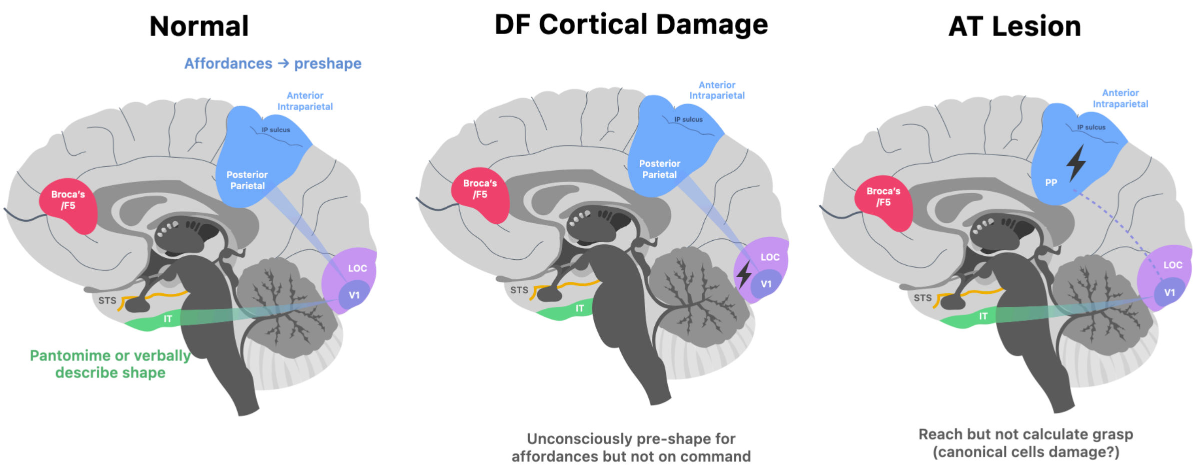


Figure 4: Normal human brain connections between occipital lobe and IT and PP as well as the impact of damage. ***Note that regions may not be in the precise location and connections are not to scale.***

Throughout the paper Arbib does a great job of clarifying his claims. For example, he states that "the claim is not that Broca's area, Wernicke's area, and STS are genetically pre-programmed for language…". I appreciate that he does not make claims that one region is language or that things specifically developed for language but rather that the developments of these regions (like support for grasping) gave way to the scaffolding language needed. Additionally, he makes similar remarks like "I would argue that there was no one distinctive speciation event … [language] was not a switch but was "cultural" and cumulative". This is an important distinction to remember that different areas may have morphed, grown, or specialized over time and that the joint network, connections, or activations of these areas culminate into something that can support an advanced social, cultural, vocal coordination.

One major issue I had with this paper was the continuous mention of "imitation". In COGS 13 and 144 we learned that non-human primates are *emulators* not true *imitators* like us. This means that non-human primates try to get to the same end goal but may not use the exact same means. If someone had a goal of getting to a door but did 10 jumping jacks first, a non-human primate would move to the door as swiftly as possible but the human would do the unnecessary steps of jumping jacks. I think it's important to note that we have such a developed mirror neuron system that it may be more relevant for us to be true imitators and commit to each individual step.

I was also confused by Arbib's limitations of the mirror neuron system. First he claims that the mirror system is not for concepts but only activations of the schema network. Second, he does not put much credit into the auditory mirror neuron system. I wish he would have been more thorough in why he believes the system is restricted.

I was hit by the claim “mirror neurons are not restricted to recognition of an innate set of actions but can be recruited to recognize and encode an expanding restore of novel actions” because it suggests that we rely on memory and similar-enough actions to adapt to novel actions. This is similar to the olfactory bulb in that we don’t have enough cells to map each scent but use a divergence of codes to give rise to billions more. The affordance codes, motor and somatosensory memory, and use of IT via the PFC may also enable this divergence and plasticity.
Alison Wray points out that Arbib’s model fails to encapsulate why languages appear to be unnecessarily complex considering the simple rule system. Especially since Broca’s is first associated with grasping and imitation (simple rules), how then does it proliferate into an unnecessarily complex system? For example, irregularity (*most of the English language*) is not explained by this model whatsoever.

Josef Rauschecker notes that the boundaries of Broca’s and Wernicke’s were already flawed thanks to limited imaging. Now, these areas are less of isolated individual systems and more sequential operations that give rise to a cumulative effect. Additionally, Wernicke’s and Broca’s are not limited in connection by just the arcuate fasiculus but a number of regions like the aST, STG, STS, and IF. So, some of the anatomical substrates for the decoding of vocalizations is similar to that of humans. Although Arbib eschewed this early on.