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Action Observation: Inferring Intentions without Mirror Neurons

A recent study has shown, using fMRI, that the mirror neuron system does not mediate action understanding when the observed action is novel or when it is hard to understand.

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Social interaction depends upon the ability to infer beliefs and intentions in the minds of others [1]. It has been suggested that humans can infer the intentions of others through observation of their actions [2]. This notion that actions are intrinsically linked to perception was proposed by William James, who suggested that "every mental representation of a movement awakens to some degree the actual movement which is its object" [3]. The implication is that observing, imagining, preparing or in any way representing an action excites the motor program used to execute that same action [4,5]. Interest in this idea has grown recently following the neurophysiological discovery of mirror neurons and, in turn, the mirror neuron system. Mirror neurons, first discovered in monkey premotor area F5 and subsequently in inferior parietal lobule, discharge not only during action execution but also during action observation [6]. This has led many to suggest that these neurons could be the neural substrate for automatic action understanding; however, the precise role of mirror neurons in action understanding is a matter of much debate [7–9].

Now Brass *et al.* [10] have reported in *Current Biology* that, in humans, action understanding in novel situations is not mediated by the mirror neuron network but rather by an inferential interpretive system. The authors used functional magnetic resonance imaging (fMRI) to measure brain activity from healthy human subjects whilst they watched a series of videos in which an actor made a very unusual action: switching on a light with their knee. The videos differed in the ease to which this unusual action could be understood. In the easy to understand videos, the actor was clearly unable to operate the switch with her hands as these were fully occupied holding some folders, whereas in the difficult to understand action, the actors hands were free and consequently the actor's decision to operate the switch with their knee and not their hand is hard to understand. The authors argue that this latter condition should activate any system involved in action understanding more than the easy to understand action.

Brass *et al.* [10] found that activity in brain areas that are considered part of the mirror neuron system is not modulated by the ease of action understanding. Instead, such modulations are seen in brain areas that have previously been associated with social perception and mentalizing, namely the superior temporal sulcus (STS), the posterior STS and the anterior fronto-median cortex (aFMC). This result demonstrates that the mirror neuron system is not sufficient for action understanding when the intention of the observed action is hard to understand. This would suggest that the mirror neuron system does not infer the high level intention of an observed action, in this example, why did the actor operate the switch with their knee?

Actions have to be understood at many different levels [11]: an intention level; a goal level that describes short-term goals necessary to realize the intention;

a motor signal level that describes the pattern of motor-unit (muscle) activity which enables the action to be executed; and the kinematic level that describes the movement of the action in space and time. For an observer to understand the intentions of an observed action, they must be able to describe the observed movement at either the goal level or the intention level having only access to a visual representation of the kinematic level. The results of Brass *et al.* [10] suggest that the description of the intention of an observed action is not encoded by the mirror neuron system. However, the mirror neuron system could be encoding the goal level, a level that describes the short-term goals necessary to realize the intention.

In support of this idea, Hamilton *et al.* [12] used an elegant repetition suppression paradigm in an event-related fMRI experiment to localize the neural representation of action goals. They demonstrated that in humans one of the areas of the mirror neuron system, the intraparietal sulcus, has a central role in representing and interpreting the goals of observed hand actions. This role for the mirror neuron system in encoding the goal, and not the intention, of an observed action is consistent with the results of Brass *et al.* [10]: here, the goal of the action, to operate the light switch with the knee, was the same in every video. If the mirror neuron system is encoding the goal of the action then one would not expect a modulation of activity in areas of the mirror neuron system across the different conditions. This is indeed what Brass *et al.* [10] report. These two studies by Hamilton *et al.* [12] and Brass *et al.* [10] would suggest that the goal of an observed action is encoded by the mirror neuron system whereas the intention of that goal is not.

The two processes of understanding the intention and the goal of any observed action are not independent. In order to be able to infer the most likely intention of an observed action, the observer must first infer the most likely goal of that observed action. For example, in Brass *et al.* [10] in order to address the question 'why is the actor operating the light switch with their knee?' the observer has to first infer that the goal of the observed action is to operate the light switch with their knee. Such a hierarchical organisation is consistent with the proposal that the process of inferring the intentions and goals of observed actions is best considered within a predictive coding framework [13,14]. Within this framework, signals encoding higher-level attributes of an observed action, such as intentions, are predicted to be expressed as activity in higher cortical levels whereas those encoding lower-level attributes, such as the goal and the kinematics of the movement, will be expressed in lower cortical levels.

The essence of the predictive coding account is that, given *a priori* expectation about the goal/intention of the person we are observing, we can predict their motor commands. Given their motor commands we can predict the kinematics on the basis of our own action system. The comparison of these predicted kinematics with the observed kinematics generates a prediction error. This prediction error is used to update our representation of the person's motor commands. Similarly, the inferred goals are updated by minimising the prediction error between the predicted and inferred motor commands. By minimizing the prediction error at all the levels of a cortical hierarchy engaged when observing actions, the most likely cause of the action will be inferred at all levels — intention, goal, motor and kinematic (see also [15,16]). This approach provides a mechanistic account of how responses in the visual and motor systems are organised and explains how the cause of an action can be inferred from its observation.

Social interaction depends upon our ability to infer beliefs and intentions in others. Recently, much of the research investigating how humans are able to infer the intentions of others has focussed on the mirror neuron system. However, the work by Brass *et al.* [10] suggests that the mirror neuron system is not sufficient to encode the intentions of observed actions, and that higher cortical levels encoding the intention of an observed action lie outside of the mirror neuron system.

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