

Concepts and Discussions

Why the Mirror Neurons Cannot Support Action Understanding

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After the discovery of the “mirror” neurons in primates, some researchers tended to explain action understanding as a result of functioning of these units. The proponents of the traditional view on the nature of this cognitive and social phenomenon assume that the mirror neurons do not provide action understanding or provide it only partly. There exist empirical data that cannot be explained through the mirror neuron model of understanding others’ actions. Analyzing the mirror neuron data, I revise their function and propose an alternative role of this type of neurons. At first, goals and intentions of the executor’s action are coded *outside* the mirror neuron system. If the action is important for the observer and can be useful in his own motor repertoire, his/her mirror neuron system implicitly reproduces the action, retrieving the kinematics and sensory consequences the observer experienced in the past while executing the same action. Thus, the implicit reproduction facilitates the observer to execute this action either immediately or in the future. More likely, precisely this, but not action understanding, is the function of the mirror neurons.

Keywords: mirror neurons, action understanding.

After the discovery of the “mirror” neurons in primates in the 1990s [1], many investigators speculated that this finding can help shed light upon such phenomena as action understanding, imitation, language acquisition, autism spectrum disorders, and some other issues of social behavior of humans and other animals. In fact, this discovery is really surprising. In the frontal and parietal lobes of some species of primates, there are neurons activated both when an individual performs an action and when he/she perceives others performing the same action [1, 2]. Action understanding was one of the first phenomena that neuroscientists, psychologists, and philosophers attempted to explain using the data on mirror neurons. Thus, the mirror neuron system theory of action understanding was developed [3-5].

When we perceive an action, our mirror neurons, which are both sensory and motor units, become active as if we acted ourselves. The proponents of the mirror neuron system theory assumed that this mechanism supports action understanding. In this theory, action understanding means that sensory and motor aspects, goal, and intention of some action performed by another individual and perceived by the observing individual can be recognized and

understood by this observer through the mirror neuron system, and the respective neuronal activity can be reproduced by this system in a similar situation. So, as observers, we are “in the mental shoes” of the executor: We understand his/her goals and intentions because we internally simulate this action via our mirror neurons [6]. The system whereby we understand the goals and intentions of others’ actions is quite simple and parsimonious. We do it because our mirror areas code goals and intentions of the actions that we perform and perceive in others.

However, after the mirror neuron model of action understanding was accepted by many scientists, contradictory facts appeared that could refute this model (for a broad review of such dissociations, see [7]). The critics of the mirror neuron theory of action understanding support inference theories. They represent the traditional standpoint on the nature of this process. According to these theories, action understanding is more complex and meticulous. It requires costly stimulus processing and occurs outside the mirror neuron system [8-11].

As was mentioned above, the mirror neuron theory proponents use the term “action understanding” to emphasize that not only the sensory and motor aspects of an action, but also its goal and intention

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can be recognized by an observer through the mirror neuron system. The observer understands the “why?” of the action [5].

My criticism is based on the apparent internal logical inconsistency of the mirror neuron theory of action understanding. Its proponents postulate that the mirror neurons code the goals of others’ actions because they are activated if the observed action is goal-directed or is a pantomime of a goal-directed action [12]. However, the mirror neurons are activated *only* when the observed action is goal-directed (object-directed action or a communicative gesture, which certainly has a goal too) or is a pantomime of a goal-directed action. How do they “know” that the definite action is goal-directed or is a pantomime of the goal-directed action? In what stage of their activation do they detect a goal of the movement or its absence? In my opinion, the mirror neuron system can be activated only after the goal of the observed action is recognized by some other brain structures. In other words, the brain must “understand” that the movements it perceives form a complex action, and this action has a goal. Only if the action is goal-directed or is a pantomime of the goal-directed action, can the mirror neurons be activated. If the action is not goal-directed, they are not activated. I come to the conclusion that the mirror neurons cannot detect (or recognize, or attribute) the goals of others’ actions.

We all know that when an individual grasps a cup of tea, very often he/she drinks it; this is a simple association. Likewise, we expect that thunder always (or frequently) follows lightning. Calculating probabilities, we predict the sequence of events in our environment. We expect an event to happen under certain conditions just because we have faced it many times under similar conditions. Grasping the cup filled with tea is simply often followed by drinking.

We say that an executor has goals and intentions when we know or can imagine the potential consequences of his/her action. When we see new actions with new objects, it is hard to attribute goals and intentions because we do not know the consequences of each specific movement. A philosophical question arises as to whether or not we are capable of knowing that others’ actions have goals. We only attribute some goals to others’ actions because we believe that our actions have goals. So, I define action understanding as an ability to attribute prerequisites (reasons) and consequences (goals) of actions we perceive in others.

Imagine a bee flying towards a flower. We (non-experts on bee studies) do not know the biomechanics and neurodynamics of its movements; we cannot imagine ourselves “in the mental shoes” of a flying insect. We cannot internally simulate its actions. But we do understand the goal of its action; it is to collect nectar and pollen. We understand the goal because we saw and were told many times that bees collect nectar and pollen. We attribute this goal to a bee flying towards a flower from force of habit. We need experiments on the speed of understanding of actions that can be simulated and actions that cannot be simulated.

If we assume that the mirror neurons cannot support action understanding, we can answer one more question. It was shown that the human mirror neuron system responds during observation of a pantomime [13-15], whereas the monkey mirror neuron system does not [16]. Why do the human mirror neuron system and the macaque one differ from each other in the case of a pantomime? The human mirror system can be activated when a person watches the pantomime because, despite the absence of an object, the observer can guess that the goal of the pantomime is fun, training, art, transmission of information, etc. In any case, the pantomime “cracking of a peanut” can induce in us recollections of a peanut and the cracking of it. Humans understand the goal of such pantomime, and then their mirror neurons can be activated. Monkeys do not understand this pantomime; so, their mirror neurons cannot be activated by watching these actions. I think that monkeys do not understand the pantomime because they cannot recollect peanuts and the cracking while watching the pantomime. The limits of their high-order cognitive organization do not permit them to understand the goal of this pantomime. This is why their mirror neurons are not activated during observation of such pantomimes. However, this needs be examined experimentally.

Assuming that the mirror neurons do not code the goals and intentions of others’ actions, I would like to put forward the hypothesis that the mirror neurons play an alternative role in action understanding.

At first, the goal of a perceived action is attributed by inference processes outside the mirror neuron system; then, the higher-order brain structures (perhaps, within the prefrontal cortex) evaluate the goal.

If the whole action and its goal (expected consequences) might be important for the observer, the activation is transmitted to the mirror neurons.

The mirror neurons code the concrete representation of the action, i.e., the representation that would be activated if the observer acted. This would allow us to simulate (to repeat internally) the observed action implicitly (in the brain) to collect our own motor programs of observed actions and to get ourselves ready to reproduce the actions later. It is implicit training. Due to this, the observer will produce the action explicitly (in his/her behavior) with agility and finesse. This happens due to associative learning processes [17]. The more frequently a synaptic connection is activated, the stronger it becomes.

There are data confirming that observation of another individual learning a new action can improve the observer's performance of this action in the future [18]. On the other hand, a number of studies have shown that action execution was impaired when a person perceived others' actions [19-20]. The mirror neurons implicitly reproduced the perceived actions, and it impaired the performance of the motor tasks. Brass et al. [21] reported that the inferior frontal gyrus (the mirror area) was not activated when an observer watched an action that was very inconvenient and ridiculous (e.g., pushing by the knee a switch that was situated one meter high, the hands being free). When he/she watched a common (expectable) action (pushing by the knee a switch that was also situated one meter high, but the hands being busy), the region was active. According to my model, after the inferential understanding in the former case, it was useless to repeat internally the action because it could be performed by a hand. In the latter case, the mirror activity replicated the useful action.

Clinicians can use the mirror neurons data in their practice. Neuropsychological studies showed that observation of actions and mental imagery treatment might improve motor impairment after neurological traumas [22-26].

Due to activation of the mirror neurons, we can imitate others. We can express our attitude to the situation, and we can empathize because we can express similar emotions and perform similar actions while talking with an interlocutor. A perceived action is, however, primarily understood cognitively, and then the mirror neurons can facilitate social behavior, if there is need to.

This model tries to touch on the issue of delayed imitation. We understand the goal of an action and its kinematics, but there is no compulsory imitation because the higher-order brain structures "take decisions" when we should reproduce this action.

If there is no need to imitate the latter immediately, we do not imitate, but we can perform the observed action later under the appropriate circumstances. It is parsimonious because we have repeated the action implicitly via the mirror neurons.

Also, we often display the other type of behavior. We understand the goal of an observed action and reach the goal in our own way, in many cases using other kinematics. This process is called goal emulation [27]. Many goals can be achieved in a number of ways; hence, it is possible to assume that the activation from the regions that interpret others' goals is transmitted to several groups of the mirror neurons, which describe the action. We know that there are broadly congruent and strictly congruent mirror neurons. The broadly congruent mirror neurons (two-thirds of the monkey F5 mirror neurons) are activated during observation and execution of many types of actions. The strictly congruent mirror neurons (one-third of the monkey mirror neurons in this region) are activated during observation and execution of only one type or a few types of actions [1]. This flexible structure allows restoration of the action in the most habitual forms for the observer.

To conclude, our model eliminates the above-mentioned logical problem in the mirror neuron theory of action understanding and proposes an alternative role for this class of neurons. The mirror neurons *do not support action understanding*. After the goal of the perceived action has been understood *outside* the mirror neurons, they repeat the action internally (simulate) to improve the performance in an appropriate situation in the future.

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