Critical Appraisal

The intention underneath: Can the motor system ascribe intentions?

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Abstract

Many researchers have tried to answer if the motor system can ascribe intentions. Previous research by Iacoboni *et al.* (2005) suggests that mirror neurons (MNs) code motor actions are most likely to follow what is observed in a specific context. Therefore, they could ascribe intentions automatically. Evidence is for and against the statement that this system acts immediately and solely. However, according to the findings from studies by Iacoboni *et al.* (2005) and Fogassi *et al.* (2005), the subject needs to know the basic outcome to activate the correct stimulation (Hickok and Sinigaglia, 2013). In other words, participants' motor system evoked potentials that quickly shifted from imitative to complementary actions to respond to social cues. Furthermore, it is consistently argued that mirror neurons are linked to developmental and cultural contingencies regarding understanding some actions rather than being the cause of perceiving the intention underneath. This critical appraisal argues against the statement that mirror neurons provide action understanding. There is solid evidence that this process is not solely due to the mirror system, which only identifies actions – to ascribe intentions involves a chain of events and associative learning.

Keywords: action understanding, mirror neurons, motor learning

Date of Submission: 14.11.2023 **Date of Acceptance:** 27.11.2024

Actions are ambiguous: only context can provide understanding. Recently, the role of mirror neurons in contextual understanding of ambiguous actions have gained increasing attention among researchers. The mirror neuron system is a network composed of several neuronal systems around the premotor and sensorimotor cortices, related to execution and observation of some movements.

DOI: https://doi.org/10.5526/esj.306

Regarding the intention behind observed movements, Iacoboni *et al.* (2005), experimented grasping a cup considering context, action, and intention, conditions to prove the “direct matching hypothesis” (Rizzolatti, Fogassi and Gallese, 2001). This hypothesis holds that motor behaviour matches with previous motor knowledge. They used two scenarios: to grasp the cup to clean or to grasp likewise to drink. The fMRI showed significant signal increase in the parieto-frontal cortical circuit for grasping when the participants observed the intention and action clips (Iacoboni *et al.*, 2005). In addition, the differential signal increase found for the two intention condition clips would indicate neural activity specifically coding the intention of the agent (Iacoboni *et al.*, 2005). Therefore, mirror neurons were more activated in the intention condition than in the action condition, revealing that this system codes more than mere movements.

However, these findings do not prove that the motor system and the observer resonate in a manner that this system is the only responsible to understand it. This does not prove the “direct matching hypothesis” due to various reasons. For instance, Iacoboni *et al.* (2005), when presenting their results, stated that context always indicated the intention behind the action. There was greater activation of mirror neuron areas, but it is not certain which function the network was developing, since those neurons can fire differently for different goals. It is probable, also, that this system does encode goals, but not based on stimulation. The inference of possible outcomes is derived from general knowledge of the situation (Hickok and Sinigaglia, 2013). Afterwards, the motor system is engaged by allowing joint action and social responding, thus facilitating the prediction of actions. Additionally, Hickok and Sinigaglia (2013) point out that motor goal and motor intentions are distinct concepts. Overall, the mentioned findings suggest that some motor representations produce a consecution of outcomes to which an action is directed. Nevertheless, these differ from intentions in format, since motor representations are still only motor representations.

Action understanding is not a function of motor systems. It is perceptual—it focuses on the consequences and involves representation of goals that require something more than action executions. Studies by Fogassi et. al (2005) and Bonini et. al. (2010) both worked with animal subjects and concluded that mirror neurons allow the observer to understand the intention of different actions, since their results showed coding for grasping according to the specific goals. In Fogassi *et al.*'s study, inferior parietal lobule cells were recorded when the monkey was executing and observing motor actions (grasping a piece of food either to bring it into the mouth or to put it

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into a container). Neural activity showed that many grasping neurons selectively discharged according to the whole action, notably during the reaching phase (Hickok and Sinigaglia, 2013). As for Bonini *et al.*'s (2010) findings, ventral premotor cortex (PMv) neurons were accessed and considered as part of the MN circuit because this cluster also "endows individuals with predictive representations of the next motor acts belonging to an action" (Bonini *et al.*, 2010, p.12). Their experiment also included motor and visual grasping tasks, and neuronal activity was accessed through action potentials.

Furthermore, since some F5 motor neurons coded the same grasping act differently depending on the context, the authors concluded that PMv neurons are part of a functional circuit underlying others' intention understanding. The above-mentioned findings suggest that some motor representations constitute a chain of outcomes to which an action is directed (Hickok and Sinigaglia, 2013). The parietofrontal mirror mechanism is indeed fundamental for evoking motor potentials. This means that when the motor chain is simulated, this simulation is compared with what is observed and deviations from predicted understandings are noted (Hickok and Sinigaglia, 2013). For instance, this process does not involve only the action itself, which is not capable of predicting what someone is going to do afterwards. It is quite different from the claim in which motor simulation leads to understanding rather than merely facilitating analysis of predicted outcomes (Hickok and Sinigaglia, 2013). The perception of biological motion does not rely on motor networks; it is separate from the action execution function (Thompson, Bird and Catmur, 2019). In summary, neurons fire when an intention is understood but the motor system is not responsible for ascribing those intentions.

Hickok and Sinigaglia (2013) came up with an interesting example to negate the statement that an action is understood because the motor representation of that action is being activated in the brain. Mary is interacting with a cup, and the reason she is doing it is understood according to how she is grasping it. This statement would also negate the "direct-matching hypothesis" when the motor system of the observer "resonates". The parieto-frontal mirror mechanism may mediate Mary's interaction, due to its motor chain organisation. Nevertheless, mirror neurons cannot provide reasons that underlie Mary's actual intentions. Action understanding is, in essence, a perceptual functionality because it is an inferential process that the motor system cannot ascribe alone (Hickok and Sinigaglia, 2013).

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Moreover, recent research also supports the evidence that the motor system does not work alone. In one of Thompson, Bird and Catmur's (2022) experiments, a key mirror neuron region (left inferior frontal gyrus – lIFG) did not find independent responses during intention identification. This indicates that while mirror neuron brain regions may contribute to action identification, there is neither an added nor a separate contribution of these brain regions to intention identification (Thompson, Bird and Catmur, 2022). Heyes and Catmur (2022) found evidence that mirror neurons are forged by sensorimotor experience since young human infants develop imitation relying on general, unrestricted associative learning. This opens the possibility that, according to Heyes (2018), other neurocognitive mechanisms are shaped by cultural learning (cited in Heyes and Catmur, 2022). Huang and collaborators (2024) revised ERP and fMRI research in which action intention understanding is not a single psychological process but consists of several different social cognitive processes. In their review, they also found that the ability to comprehend the motive underlying actions involves both context and kinematic information – a wide range of sequences of social-visual computations (Huang, *et al.* 2024). Finally, those three recent articles highlight that mirror neurons do not ascribe intentions. They only identify actions. Thus, action understanding involves a chain of events linked to developmental factors and social stimuli.

In sum, a goal is different from an intention and motor representations can provide an understanding of another's action but in a manner that does not involve ascriptions of intentions or desires (Hickok and Sinigaglia, 2013). The real "outcome understanding" requires the knowledge of the target of the action to activate correct simulations. In the final analysis, mirror neurons may develop through associative learning; newborn babies do not have this network, but when they copy the behaviour of others, those neurons generate the human capacity to imitate behaviour (Heyes and Catmur, 2022). That way, visual representation starts to match motor representation and children are reinforced by their parents to behave like this. Through the developmental and learning importance of mirror neurons, a person can know the implications of his or her actions, as well as other people's actions. Motor knowledge is possible because of societal reading and evaluation – it prepares the motor system to interact with others. Finally, mirror neurons and similar areas are activated only when the intention behind the action is known (PsychAlive, 2011) – it demands meaning, provided by previous experience. Thus, in this matter, the motor system cannot work alone.

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