CHAPTER 22

# MIRROR NEURONS AND ART

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### THE MIRROR NEURON SYSTEM

In the past 30 years there has been a remarkable increase in our knowledge of the physiology and function of the brain in the appreciation of art. Several scientists believe that the most intriguing discovery in this field is that of the mirror neuron system (MNS). To understand this enthusiasm and assert the possible implications of this discovery for the appreciation and creation of art, we should firstly establish the basic facts. About 16 years ago we discovered in the premotor area F5 of the macaque monkey brain a class of motor neurons that discharge not only when the monkey executes goal-related hand motor acts like grasping objects, but also when observing other individuals (monkeys or humans) executing similar acts (Gallese et al. 1996; Rizzolatti et al. 1996). We called them 'mirror neurons' because, in a sense, their visual properties—the stimuli that excite them when observed—'mirror' their motor properties—the motor acts that excite the neurons when actively performed by the monkey. Neurons with similar properties were later discovered in a sector of the posterior parietal cortex reciprocally connected with area F5 (Gallese et al. 2002). Mirror neurons provide the neurophysiological basis for the capacity of primates to recognize different actions made by other individuals: the same neural motor pattern that characterizes the action when actively executed is evoked in the observer. This matching mechanism, which can be framed within the motor theories of perception, offers the great advantage of using a repertoire of coded actions in two ways at the same time: at the output side

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[1] This essay originates from an interview of Prof. Gallese by the editors.

to act, and at the input side, to directly understand the actions of others. What is remarkable is that this matching system has also been demonstrated in humans (see Gallese et al. 2004; Rizzolatti and Craighero 2004). Furthermore, new empirical evidence suggests that the same neural structures that are involved in processing felt sensations and emotions are also active when the same sensations and emotions are to be detected in others (Gallese 2006). It appears therefore that a whole range of different 'mirror matching mechanisms' may be present in the human brain.

When the discovery of mirror neurons occurred, theories regarding embodied cognition and multisensory perception were being explored. Although the discovery seemed to fit in this research context, one should keep in mind that we did not look for mirror neurons. In other words, the discovery was not guided by a preconceived thesis about social cognition. However, we were ready to see mirror neurons, because we were looking for visual properties within the motor system, something that back then was extremely unorthodox. The mainstream view in cognitive science was, and to a certain extent even today is, that action, perception, and cognition are to be seen as separate domains. The discovery of the MNS challenges this view as it shows that such domains are intimately intertwined.

The sharp distinction, classically drawn between the first- and third-person experience of acting and experiencing emotions and sensations, appears to be much more blurred at the level of the neural mechanisms mapping it. The gap between the two perspectives is bridged by the way intentional relations are functionally mapped at the neural-body level. The mirror matching systems in our brains map the different intentional relations in a fashion that is neutral about the specific quality or identity of the agentive/subjective parameter. By means of a shared functional state realized in two different bodies that nevertheless obey to the same functional rules, the 'objectual other' becomes 'another self'. Our seemingly effortless capacity to conceive of the acting bodies inhabiting our social world as *goal-oriented selves* like us depends on the constitution of a shared meaningful *we-centric* space. I propose that this shared manifold space can be characterized at the functional level as *embodied simulation*, a basic functional mechanism by means of which our brain/body system models its interactions with the world. Embodied simulation constitutes a crucial functional mechanism in social cognition, and it can be neurobiologically characterized. The mirror neuron matching systems so far discovered in the human brain represent subpersonal instantiations of embodied simulation.

While one could think that the input to the MNS needs to be visual, we actually showed that a particular class of F5 mirror neurons, 'audiovisual mirror neurons', discharge not only when the monkey executes or observes a particular type of noisy action (e.g. breaking a peanut), but also when it just listen to the sound produced by the same action (Kohler et al. 2002). These 'audiovisual mirror neurons' not only respond to the sound of actions, but also discriminate between the sounds of different actions. The actions, whose sounds maximally trigger the neurons' discharge when heard, are those also producing the strongest response when observed or executed.

Among their several possible functions, it has been hypothesized that mirror neurons may be involved in the processing of *meaning* (Gallese and Lakoff 2005;

Gallese 2007, 2008). The multimodally driven simulation of action goals instantiated by 'audiovisual mirror neurons' situated in the ventral premotor cortex of the monkey, instantiates properties that are strikingly similar to the symbolic properties so characteristic of human thought. The similarity with conceptual content is quite appealing: the same conceptual content ('the goal of action A') results from a multiplicity of states subsuming it, sounds, observed and executed actions. The *action simulation* embodied by audiovisual mirror neurons is indeed reminiscent of the use of predicates. The verb 'to break' is used to convey a meaning that can be used in different contexts: 'Seeing someone breaking a peanut', 'Hearing someone breaking a peanut', 'Breaking a peanut'. The predicate, similarly to the responses in audiovisual mirror neurons, does not change depending on the context to which it applies, nor depending on the subject/agent performing the action. All that changes is the context the predicate refers to.

This is particularly interesting also because these results paved the road to a new empirical approach to the study of human language. Several brain imaging studies have shown that processing action-related linguistic material in order to retrieve its meaning activates regions of the motor system congruent with the processed semantic content. Silent reading of words referring to face, arm, or leg actions, or listening to sentences expressing actions performed with the mouth, the hand, and the foot, both produce activation of different sectors of the premotor cortex, depending on the effector used in the action-related linguistic expression read or listened to by participants. These activated premotor sectors coarsely correspond to those active during the execution/observation of hand, mouth, and foot actions. Thus, it appears that the MNS is involved not only in understanding visually presented actions, but also in mapping acoustically or visually presented action-related linguistic expressions (Gallese 2007, 2008).

Such evidence suggests that key aspects of human social cognition are produced by neural exploitation, that is, by the exaptation of neural mechanisms originally evolved for sensory–motor integration, later on also employed to contribute to the neurofunctional architecture of thought and language, while retaining their original functions as well (see Gallese 2008). Within the premotor system there is 'structuring' architecture that can function according to two modes of operation. In the first mode of operation, the circuit structures action execution and action perception, imitation, and imagination, with neural connections to motor effectors and/or other sensory cortical areas. When the action is executed or imitated, the corticospinal pathway is activated, leading to the excitation of muscles and the ensuing movements. When the action is observed or imagined, its actual execution is inhibited. The cortical motor network is activated (though, not in all of its components and, likely, not with the same intensity), but action is not produced, it is only simulated.

In the second mode of operation, the same system is decupled from its action execution/perception functions and can offer its structuring output to non-sensory–motor parts of the brain, among which the dorsal prefrontal cortex most likely plays a pivotal role. When engaged in the second mode of operation, the neurofunctional architecture of the premotor system might contribute to the mastering of the hierarchical structure of language and thought.

# Mirror neurons and art

The significance of the discovery of mirror neurons for the understanding of responses to art has not yet been fully assessed. In a paper I recently coauthored with the art historian David Freedberg, we argued against the primacy of cognition in our responses to art (Gallese and Freedberg 2007). We proposed that a crucial fundamental element of aesthetic response to works of art consists of the activation of embodied mechanisms encompassing simulation of actions, emotions, and corporeal feeling sensations; and that these mechanisms are universal. It is true that over the years theorists of art have commented on a variety of forms of felt bodily engagement with works of art, but the mechanisms by which this happens have remained unspecified or entirely speculative. While the evidence we deal with allows for modulation by contextual factors of a wide variety (e.g. temporal, social, cultural, and even personal factors), David Freedberg and I are concerned with the basic mechanisms brought to light by recent research on mirror neurons, empathy and embodiment. While most of the research in these areas has concentrated on responses to living actors, we proposed its relevance not just for realistic representation but also for the understanding of the effectiveness of images and works of art.

Given the variety of forms and techniques employed in contemporary art (video and performance art, digital, painting, and photography), it is interesting to address the difference between representation and object or, more specifically, between watching a video of an action, watching the action being performed for real, and watching a static image portraying the same action. The very few experiments that specifically addressed the issue of the relationship between the degree of activation of the MNS and the real or virtual nature of the agent being observed showed that real action performed in front of the observer elicits stronger responses with respect to videos portraying those same actions. That said, it might be argued that since the activation of the MNS is typically induced by the observation of ongoing actions, the relevance of such mechanism for the aesthetic experience while contemplating static art works could be negligible. However, recent research carried out on the MNS in humans with a variety of techniques has shown that even the observation of static images of actions lead to action simulation in the brain of the observer, through the activation of the same brain regions normally activated by execution of the observed actions. The observation of pictures of a hand reaching to grasp an object, or firmly holding it activates the motor representation of grasping in the observer's brain. On the basis of these results it is highly plausible to hypothesize that a similar motor simulation process can be induced by the observation of still images of actions carried out by other effectors. In any still image, the 'decisive moment' of the action portrayed, to use an expression of Cartier-Bresson, is captured by an embodied simulation of the contemplator.

There are situations that lead to greater activation than others, which support the view that MNS response can be increased through learning. Recent neurophysiological studies carried out on macaque monkeys have shown that a particular class of ventral premotor mirror neurons starts to respond to the observation of unfamiliar actions

after extensive visual exposure to them, or after motor training. Both results seem to suggest that when an action performed by others becomes familiar, independently from the perceptual or motor source of its familiarization, it is nevertheless always mapped onto a motor representation belonging to the observing individual. Even more strikingly, several brain-imaging studies carried out on humans have shown that the intensity of the MNS activation during action observation depends on the similarity between the observed actions and the participants' action repertoire. In particular, one functional magnetic resonance imaging (fMRI) study by Calvo-Merino and co-workers focused on the distinction between the relative contribution of visual and motor experience in processing an observed action (Calvo-Merino et al. 2005, 2006; see Chapter 27 by Calvo-Merino and Haggard, this volume). The results revealed greater activation of the MNS when the observed actions were frequently performed with respect to those that were only perceptually familiar but never practised. In this sense, one can say that the MNS actually learns through experience. It is, nonetheless, an open question to be empirically investigated, to which extent the professional expertise and/or personal and cultural background of the beholder do play a role in modulating these simulations when contemplating art works.

In the case of mirror neurons, what seems to matter most is that the action must be goal oriented, rather than performed by a human, or at least biological, actor. A recent fMRI paper by Gazzola and co-workers specifically addressed this issue (Gazzola et al. 2007). The results showed that the mirror system was activated strongly by the sight of both human and robotic hand actions, with no significant differences between these two agents. This seems to suggest that the MNS could contribute to the understanding of a wider range of actions than previously assumed, and that the goal of an action might be more important for mirror activations than the way in which the action is performed.

The relationship between art appreciation and empathy is certainly not a new idea. As David Freedberg and I recently pointed out, the notion of empathy (*Einfühlung*) was originally introduced in aesthetics by Robert Vischer in 1873, thus well before its use in psychology. By *Einfühlung*, literally 'feeling-in', Vischer meant the physical responses generated by the observation of forms within paintings. He described how particular forms aroused particular responsive feelings, depending on their conformity to the design and function of the muscles of the body, from those of the eyes to our limbs and to our bodily posture as a whole. Developing Vischer's ideas, Wölfflin (1886) speculated on the ways in which observation of specific architectural forms engage the beholder's bodily responses. Just before the end of the nineteenth century, Aby Warburg, adapting Vischer's notions of *Einfühlung*, developed his own theory of the *Pathosformel*, whereby the outward forms of movement in a work of Renaissance art (e.g. the hair or flowing draperies of a painting by Botticelli) revealed the inner emotions of the figure concerned. Very shortly afterwards, Theodor Lipps wrote at length about the relationship between space and geometry on the one hand, and aesthetic enjoyment on the other (1897, 1903). All these scholars believed that the feeling of physical involvement in a piece of painting, sculpture, or architecture, not only provoked a sense of imitating the motion or action seen or implied in the work, but also enhanced

our emotional responses to such a work. The relationship between embodiment and aesthetic experience was further highlighted by phenomenologists like Merleau-Ponty. Merleau-Ponty not only suggested the possibilities of felt bodily imitation of what is seen in a painting, but also of the implied actions of the producer of the work itself as in the case of the paintings of Cézanne

Thus, what is new in our approach? Perhaps the revitalization of this tradition of thought in light of what the empirical research in neuroscience has recently taught us about the enormous importance of the body in a variety of aspects of the human condition, aesthetic experience included. David Freedberg and I are proposing a theory of empathic responses to works of art that is not purely introspective, intuitive, or metaphysical, but that has a precise and definable material basis in the brain. Our theory is articulated in two complementary aspects: 1) the relationship between embodied simulation-driven empathic feelings in the observer and the *content* of art works, in terms of the actions, intentions, objects, emotions, and sensations portrayed in a given painting or sculpture. This aspect can be viewed as the 'what' of aesthetic experience; 2) the relationship between embodied simulation-driven empathic feelings in the observer and the quality of the art work in terms of the visible traces of the artist's creative gestures, like brush work, chisel marks, and signs of the movement of the hand more generally. We can refer to this component as the 'how' of aesthetic experience. Of course, both aspects require now an empirical validation by means of specifically designed experiments, which we will be busy designing and carrying out in the coming years.

Regarding the question of whether the MNS can be activated by abstract art, according to the earlier-mentioned second aspect of our theory, the answer would be affirmative. Our proposal posits that even the artist's gestures producing the art work can induce an empathic engagement of the observer, by activating the simulation of the corresponding motor programme. The marks on the painting/sculpture are the visible traces of goal-directed movements, hence in principle capable of activating the somatotopically relevant motor areas in the observer's brain, as suggested by the mirror neuron research. While at present there are no published experiments tackling this issue, there is empirical evidence indirectly suggesting that this could be indeed the case. Several studies show that motor simulation can be induced in the observer's brain also when what is observed is not someone else's action, but the static graphic artefact produced by the action, such as a letter or a graphic stroke (Longcamp et al. 2005, 2006, 2008). This shows that our brain is able to reconstruct actions 'a posteriori' by merely observing the static graphic outcome of the agent's past action. This reconstruction process during observation is an embodied simulation mechanism, relying on the activation of the same motor centres required to produce the observed graphic sign. We predict that similar results could be obtained using as stimuli art works characterized by peculiar gestural signs of the artist, as in the case Fontana's or Pollock's works.

As far as a supposed link between the MNS and creativity, often suggested by the media, it is my opinion that such a relationship at the present stage of the research is too

far-fetched. Creativity is a distinguished feature of the human condition that I am afraid can hardly be reduced to the functional properties of specific populations of neurons, mirror neurons included.

On the other hand, though, I would like to say that creativity cannot either be reduced to the mere product of a disembodied cognitive apparatus. In *L'Œil et l'esprit* Merleau-Ponty writes that we could not possibly imagine how a *mind* could paint. Commenting the statement by Cézanne that 'nature is on the inside', Merleau-Ponty argues that things arouse in us a carnal formula of their presence. Pushing forward this line of thought, I'd suggest that the artist expresses her/his creativity precisely by being able to retrieve such carnal formula and make it available to others. This shouldn't imply that such expression is the outcome of a deliberate conscious effort. Actually, I think that most of the time it is totally unconscious. As Gilles Deleuze has beautifully emphasized (2005), Bacon is a perfect exemplification of that. Bacon's work epitomizes as the artist's creativity can be so effective in making visible the invisible forces buried inside material objects as well as inside the human psyche.

Many scholars are worried that the idea of mirror neurons has filtered down to a popular level in an inaccurate way, thus often being pushed too far. Some news reports have used it in contexts where it does not apply. Naturally, one should distinguish scientific research from its trivialization by the media. Scientists are responsible for their empirical work and the theories they put forward on the basis of what the evidence suggests to them. How media communicate, or even distort scientific discoveries is totally beyond our control.

If we ask ourselves what are the aspects of human social cognition we can shed new light upon on the basis of our discovery of the MNS, the answer would be imitation and mimetic behaviours, action and intention understanding, empathy and its relatedness to aesthetic experience, and language. I'd like to emphasize, though, that the relevance of the MNS in so many different aspects of social cognition does not stem from a specific endowment of these neural cells, as if mirror neurons were 'magic neurons', so to speak. Mirror neurons derive their functional properties from the specific input–output connections they entertain with other populations of neurons in the brain.

The MNS and the functional mechanism describing their activity, embodied simulation, are involved in so many aspects of social cognition because the activation of the multiple and parallel cortico-cortical circuits instantiating mirror properties underpins a fundamental aspect of social cognition, that is, *the multi-level connectedness and reciprocity among individuals within a social group*. Such connectedness finds its phylogenetic and ontogenetic roots in the social sharing of situated experiences of action and affect. The MNS provides the neural basis of such sharing. Embodied simulation and the MNS certainly cannot provide a full and thorough account of our sophisticated social cognitive skills. However, I believe that the evidence accumulated during the last 15 years indicates that embodied mechanisms involving the activation of the sensory–motor system, of which the MNS is part, do play a major role in social cognition, language included. A second merit of our discovery consists in the fact that

it enables the grounding of social cognition into the experiential domain of existence, something that classic cognitivism has totally neglected.

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