International Journal of Research in Medical Sciences
Shete AN et al. Int J Res Med Sci. 2016 Aug;4(8):3097-3101
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20162265

Review Article

Mirror neurons and their role in communication

Anjali N. Shete[1]*, K. D. Garkal[2]

[1]Department of Physiology, Government medical college, Aurangabad, Maharashtra, India
[2]Maharashtra University of Health Sciences, Nasik, Maharashtra, India

Received: 12 June 2016
Accepted: 02 July 2016

***Correspondence:**
Dr. Anjali N. Shete,
E-mail: dranju01@yahoo.com

ABSTRACT

Actions done by others are probably the most important stimuli of our lives. Most of others' actions do not convey intentional information to the observer. From them, however, we understand what others are doing and we can infer why they are doing it. This involuntary communication is fundamental for interpersonal relations, and is at the basis of social life. What is the mechanism underlying our capacity to understand others' actions? The traditional view is that actions done by others are understood in the same way as other visual stimuli. Thus, action understanding is based on the visual analysis of the different elements that form an action. For example, when we observe a girl picking up a flower, the analyzed elements would be her hand, the flower, and the movement of the hand towards the flower. The association of these elements and inferences about their interaction enables the observer to understand the witnessed action. The discovery of neurons that code selectively biological motion has better specified the neural basis of this recognition mechanism. These theoretical considerations received strong support from the discovery that in the motor cortex of the macaque monkey there is a particular set of neurons that discharge both when the monkey observes a given motor act and when it does the same act. These neurons called "mirror neurons," represent a system that directly matches observed and executed actions.

Keywords: Mirror neurons, Communication, Language

INTRODUCTION

Actions done by others are probably the most important stimuli of our lives. Most of others' actions do not convey intentional information to the observer. From them, however, we understand what others are doing and we can infer why they are doing it. This involuntary communication is fundamental for interpersonal relations, and is at the basis of social life. What is the mechanism underlying our capacity to understand others' actions? The traditional view is that actions done by others are understood in the same way as other visual stimuli.

Thus, action understanding is based on the visual analysis of the different elements that form an action. For example, when we observe a girl picking up a flower, the analyzed elements would be her hand, the flower, and the movement of the hand towards the flower. The association of these elements and inferences about their interaction enables the observer to understand the witnessed action. The discovery of neurons that code selectively biological motion has better specified the neural basis of this recognition mechanism according to Perrett et al.[1] These theoretical considerations received strong support from the discovery that in the motor cortex of the macaque monkey there is a particular set of neurons that discharge both when the monkey observes a given motor act and when it does the same act. These neurons called "mirror neurons," represent a system that directly matches observed and executed actions.

DISCUSSION

Mirror neurons

In the mid-1990s a new class of premotor neurons was discovered in the rostral sector of the macaque monkey's ventral premotor cortex, known as area F5. These neurons discharge not only when the monkey executes goal-related hand actions like grasping objects, but also when observing other individuals (monkeys or humans) executing similar actions. These neurons were called mirror neurons according to Gallese et al.[2] Neurons with similar properties were later discovered in a sector of the posterior parietal cortex reciprocally connected with area F5.

Action observation causes in the observer the automatic activation of the same neural mechanism triggered by action execution. The novelty of these findings is the fact that, for the first time, a neural mechanism that allows a direct matching between the visual description of an action and its execution has been identified. Such a matching system constitutes a parsimonious solution to the problem of translating the results of the visual analysis of an observed action-devoid of meaning for the observer-into an account that the individual is able to understand. It was proposed that this mechanism could be at the basis of a direct form of action understanding. If mirror neurons really mediate action understanding, their activity should reflect the meaning of the observed action, not its visual features.

- Mirror neurons in monkeys
- Mirror neuron systems in humans

Mirror neurons in monkeys

Typically, mirror neurons in monkeys do not respond to the sight of a hand mimicking an action in the absence of the target. Similarly, they do not respond to the observation of an object alone, even when it is of interest to the monkey according to Rizzolatti et al.[3] Prompted by these considerations, two series of experiments were carried out in which the monkey had no access to the visual features that normally activate mirror neurons.

The first experiments tested whether the mental representation of an action triggers F5 mirror neurons, the second whether the monkeys are able to recognize actions from their sound. The results of these experiments provided positive answers to both questions, by showing that what drives the discharge of mirror neuron is not the pictorial description of an action, but rather the goal of the action, or to use a more mentalistic term, the motor idea of that action according to Rizzolatti et al.[3]

In the most lateral part of area F5 a population of mirror neurons related to the execution/observation of mouth actions was described according to Rizzolatti et al.[3] Most of these neurons discharge when the monkey executes and observes transitive, object-related ingestive actions, such as grasping, biting, or licking. However, a small percentage of mouth-related mirror neurons discharge during the observation of intransitive, communicative facial actions performed by the experimenter in front of the monkey (communicative mirror neurons). Macaque monkeys seem to have an initial capacity to control and emit 'voluntarily' social signals mediated by the frontal lobe. Most interestingly, this capacity develops in a cortical area—area F5—that in humans became Brodmann's area 44, a key area for verbal communication. More recently the role of parietal mirror neurons in intention understanding has been unveiled. Fogassi et al described a class of parietal mirror neurons whose discharge during the observation of an act (e.g. grasping an object), is conditioned by the type of not yet observed subsequent act (e.g. bringing the object to the mouth) specifying the overall action intention.[4] This study shows that parietal mirror neurons, in addition to recognizing the goal of the observed motor act, allow the observing monkey to predict the agent's next action, henceforth its overall intention. This neural mechanism could scaffold more sophisticated mind reading abilities, as those characterizing our species according to Gallese et al.[5,6]

Mirror neuron systems in humans

Several studies using different experimental methodologies and techniques have demonstrated that a mirror neuron system matching action perception and execution also exists in the human brain according to Rizzolatti et al.[3] During action observation there is a strong activation of premotor and posterior parietal areas, the likely human homologue of the monkey areas in which mirror neurons were originally described.

The mirror neuron system for actions in humans is somatotopically organized, with distinct cortical regions within the premotor and posterior parietal cortices being activated by the observation/execution of mouth-, hand-, and foot-related actions. The mirror neuron system for actions in humans is directly involved in imitation, in the perception of communicative actions, and in the detection of action intentions according to Gallese et al.[5]

Furthermore, the premotor cortex containing the mirror system for action is involved in processing action-related sentences according to Gallese et al suggesting that mirror neurons together with other parts of the sensorimotor system could play a relevant role in language semantics according to Gallese et al.[7]

Mirror neuron systems also underpin our capacity to empathize. When we perceive others expressing a given emotion such as disgust, the same brain areas are activated as when we subjectively experience the same emotion. Similar direct matching mechanisms have been described for the perception of pain according to Gallese et al.[5] These results taken together suggest that our capacity to empathize with others is mediated by embodied simulation mechanisms; that is, by the activation of the same neural circuits underpinning our own emotional and sensory experiences according to Gallese et al.[5] Recent studies suggest that these mechanisms could be deficient in individuals affected by autistic spectrum disorders according to Gallese et al.[5]

The discovery of mirror neurons opens new exciting perspectives in a variety of different fields in social cognitive neuroscience, like our understanding of language, ethics and aesthetics according to Freedberg et al.[7]

Role of mirror neurons in communication

Communication is a process of exchanging information via a common system. There are many natural ways in which individuals may communicate. Besides linguistic communication, which is at the core of human communication, humans communicate using arm gestures, body postures, facial expressions, eye contact, and head and body movements.

Communication may be intentional and non-intentional. In both cases, the sender and the receiver of the messages must have a common code. The difference is that in the case of intentional communication the sender plays the leading role and imposes the communication on the receiver, while in the case of non-intentional communication, the sender sends the message without having any intention to do so.

The message is just there. If sender and receiver have a common code, the message reaches the receiver, regardless of the will of the sender. Of these two types of communication, the non-intentional one is the most basic and primitive. It is evolutionarily necessary because, in social life, individuals have to understand what others are doing, whether or not those others intend to be understood. It is very plausible that intentional communication is an evolutionarily late development of non-intentional communication.

Mirror neurons and language

Humans mostly communicate by sounds. Sound-based languages, however, do not represent the only natural way for communicating. Languages based on gestures (signed languages) represent another form of complex, fully structured communication system. By using sign language, people express abstract concepts, learn mathematics, physics, philosophy, and even create poetry according to Corballis et al.[7]

Nonetheless, the fact that signed languages represent a fully structured communication system has not changed the view, which many share, that speech is the only *natural* human communication system, and that the evolutionary precursor of human speech consists of animal calls. Humans emit sound to communicate; animals emit sounds to communicate, therefore human speech evolved from animal calls. The logic of this syllogism is rather shaky. Its weakness becomes apparent when one examines animal calls and human speech more closely. First, the anatomical structures underlying primate calls and human speech are different. Primate calls are mostly mediated by the cingulate cortex and by deep, diencephalic and brain stem structures according to Jürgens.[8] In contrast, the circuits underlying human speech are formed by areas located around the Sylvian fissure, including the posterior part of IFG. It is hard to imagine how in primate evolution, the call system shifted from its deep position found in non-human primates to the lateral convexity of the cortex where human speech is housed.

Second, speech in humans is not, or is not necessarily, linked to emotional behavior, whereas animal calls are. Third, speech is mostly a dyadic, person-to-person communication system. In contrast, animal calls are typically emitted without a well-identified receiver. Fourth, speech is endowed with combinatorial properties that are absent in animal communication.

As Chomsky et al rightly stressed, human language is “based on an entirely different principle” from all other forms of animal communication.[9] finally, humans do possess a “call” communication system like that of nonhuman primates and its anatomical location is similar. This system mediates the utterances that humans emit when in particular emotional states (cries, yelling, etc.).

These utterances, which are preserved in patients with global aphasia, lack the referential character and the combinatorial properties that characterize human speech. The advocates of the sound-based theory of language origin consider a strong argument in favour of this theory to be the presence of referential information in some animal calls according to Pinker et al.[10] The famous study of the alarm calls of vervet monkeys according to Cheney et al, as well as other studies that extended these observations to other species and other communicative contexts (social relationship, food, inter-group aggression), showed that evolution tried this pathway.[11]

The reason why this attempt did not succeed is the lack of flexibility inherent in any communicative system based on emotions. In a non-emotional communication system the same word, for example the word *fire*, which is basically an alarm message (“escape”), may assume a completely different meaning. It may indicate, for example, that the fire is ready and we can start to cook our meal (“approach message”), as well as conveying other positive messages.

This flexibility cannot occur in an emotional communicative system because a referential meaning cannot indicate a behavior that is in contrast with the emotion that generated it. Thus the same utterance or call cannot convey, in different contexts, an escape and an approach message. If not animal calls, what could be the origin of human speech? An alternative hypothesis is that the path leading to speech started with gestural communication. This hypothesis, first proposed by the French philosopher Condillac, has recently found several defenders according to Armstrong et al; Corballis.[12,13] According to this theory, the initial communicative system in precursors of modern humans was based on very simple, elementary gesturing. Sounds were then associated with the gestures and became progressively the dominant way of communication.

The discovery of mirror neurons provided strong support for the gestural theory of speech origin. Mirror neurons create a direct link between the sender of a message and its receiver. Thanks to the mirror mechanism, actions had done by one individual become messages that are understood by an observer without any cognitive mediation. The observation of an individual grasping an apple is immediately understood because it evokes the same motor representation in the parieto-frontal mirror system of the observer. Similarly, the observation of a facial expression of disgust is immediately understood because it evokes the same representation in the amygdala of the individual observing it according to Gallese et al.[3]

On the basis of this fundamental property of mirror neurons, and the fact that the observation of actions like hand grasping activates the caudal part of IFG (Broca's area), Rizzolatti et al proposed that the mirror mechanism is the basic mechanism from which language evolved.[14] In fact, the mirror mechanism solved, at an initial stage of language evolution, two fundamental communication problems: parity and direct comprehension.

Thanks to the mirror neurons, what counted for the sender of the message also counted for the receiver. No arbitrary symbols were required. The comprehension was inherent in the neural organization of the two individuals. A criticism of this view is based on the fact that the monkey mirror neuron system is constituted of neurons coding object-directed actions. Thus, the monkey mirror neuron system forms a closed system, which by definition does not appear to be particularly suitable for intentional communication.

Yet, if this is true for the monkey, it is not the case for the human mirror system. As reviewed above, TMS and brain imaging studies have shown that activation of the human mirror system is achieved by presentation of intransitive actions according to Fadiga et al, Maeda et al, as well as during pantomime observation according to (Buccino et al, Grèzes et al.[15-18] It is difficult to specify how the shift from a closed system of monkeys to an open, intentionally communicative system, in humans might have occurred.

The view, however, that communicative actions derived from a more ancient system of non-communicative gestures is not new. Van Hoof for example, proposed that many of the most common communicative gestures of the monkey, such as lip smacking, are ritualizations of ingestive actions that monkeys use for affiliative purposes.[19] The fact that mouth mirror neurons respond both to the observation of communicative actions and during the execution of ingestive actions appears to give a neurophysiological basis to this idea according to Ferrari et al.[20] Similarly, Vygotsky suggested that intransitive actions derive in children from object-directed transitive actions.[21] For example, when objects are located close to a child, the child grasps them. When they are located far from the child, the child extends his or her hands towards the objects. Because the mother understands this gesture, the child uses it again and again and, eventually, attempts to reach objects become communicative gestures. Thus, the transition from object-directed to intentional communicative gesture can be accommodated by the mirror neuron hypothesis of language evolution.

The discovery of mirror neurons opens new exciting perspectives in a variety of different fields in social cognitive neuroscience, like our understanding of language, ethics and aesthetics.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Perrett DI, Harries MH, Bevan R, Thomas S, Benson PJ, Mistlin AJ, et al. Frameworks of analysis for the neural representation of animate objects and actions. Journal of Experimental Biology. 1980;147:87-113.
2. Gallese V, Fadiga L, Fogassi L, Rizzolatti G. Action recognition in the premotor cortex. Brain. 1996;119:593-609.
3. Rizzolatti G, Craighero L. 'The mirror neuron system'. Annu Rev Neurosci. 2004;27:169-92.
4. Fogassi L, Ferrari PF, Gesierich B, Rozzi S, Chersi, F, Rizzolatti G. 'Parietal lobe: from action organization to intention understanding'. Science. 2005;308(5722):662-7.
5. Gallese, V. 'Intentional attunement: a neurophysiological perspective on social cognition and its disruption in autism'. Brain Res. 2006;1079(1):15-24.
6. Freedberg D, Gallese V. 'Motion, emotion and empathy in esthetic experience'. Trends Cogn Sci. 2007;(5):197-203.
7. Corballis MC. From Hand to Mouth: The Origins of Language. Princeton University Press, Princeton, NJ. 2000.
8. Jürgens U. Neural pathways underlying vocal control. Neurosci Biobehav Rev. 2002;26(2):235-58.
9. Chomsky, N. Cartesian Linguistics. Harper & Row, New York. 1969;5(01):165-87.
10. Pinker S. The Language Instinct: How the Mind Creates Language. Morrow, NewYork. 1994.
11. Cheney DL, Seyfarth RM. How Monkeys See The World: Inside The Mind Of Another Species. University of Chicago Press, Chicago. 1990.

12. Armstrong AC, Stokoe WC, Wilcox SE. Gesture and the Nature of Language. Cambridge University Press, Cambridge. 1995.
13. Corballis MC. From Hand to Mouth: The Origins of Language. Princeton University Press, Princeton, NJ. 2002
14. Rizzolatti G, Arbib MA. Language within our grasp. Trends in Neurosciences. 1998;21:188-94.
15. Fadiga L, Fogassi L, Pavesi G, Rizzolatti G. Motor facilitation during action observation: a magnetic stimulation study. Journal of Neurophysiology. 1995;73: 2608-11.
16. Maeda F, Kleiner-Fisman G, Pascual-Leone A. Motor facilitation while observing hand actions: specificity of the effect and role of observer's orientation. Journal of Neurophysiology. 2002;87:1329-5.
17. Buccino G, Lui F, Vanessa N, Patteri I, Lagravinese G, Benuzzi F, et al. Neural circuits involved in the recognition of actions performed by nonconspecifics: and FMRI study. Journal of Cognitive Neuroscience. 2004;16:114-26.
18. Grèzes J, Armony JL, Rowe J, Passingham RE. Activations related to "mirror" and "canonical" neurones in the human brain: an fMRI study. NeuroImage. 2003;18:928-37.
19. Van Hoof J. The facial displays of the catarrhine monkeys and apes. In D.Morris (ed.), Primate Ethology. Weidenfield & Nicolson, London.1967;7-68.
20. Ferrari PF, Gallese V, Rizzolatti G, Fogassi L. Mirror neurons responding to the observation of ingestive and communicative mouth actions in the monkey ventral premotor cortex. European Journal of Neuroscience. 2003;17: 1703-14.
21. Vygotsky LS. Thought and Language. MIT Press, Cambridge. Mass. 1934.

Cite this article as: Shete AN, Garkal KD. Mirror neurons and their role in communication. Int J Res Med Sci 2016;4:3097-101.