International Journal of Innovative Studies in Medical Sciences (IJISMS)

ISSN 2457-063X (Online) **www.ijisms.com** *Volume: 4 Issue: 3 | 2020*

The Role of Mirror Neurons from the Emergence of Empathy to Criminal Behavior

Erich Kasten

Medical School Hamburg (MSH), Dep. Human Sciences, Am Kaiserkai 1, D-20457 Hamburg, Germany

Abstract: *Mirror neurons were initially examined primarily with regard to hand motor skills; later, studies on oral responses and non-verbal cumulative gestures were added. The system of mirror neurons consists of (at least) two different anatomical pathways: one pathway involves sensorimotor movements, especially hand gripping. This path runs in the known parietal-premotoric cycles. The second path refers to the control of the mouth and face motor skills. This trajectory is very closely related to the limbic system, which is involved in instinctive behavior as well as in the formation of emotions and is closely linked to the mesolimbic reward system. Mirror neurons are extremely useful in childhood because children can observe others' behaviors and incorporate these into their own behavioral repertoire. Humans are genetically conditioned with a set of mirror neurons, and soon after birth, children can imitate facial expressions of mother or father; they apparently correspond to the basic emotional need of the newborn. On the other hand, a damage of the mirror neurons can lead to criminal behavior. Already in 1894 Lombroso & Ferrero described in the book "The Woman as a criminal and prostitute" various criminals who had suffered brain damage and speculated that the penchant for crime has to do with a dysfunction of specific brain parts.*

Keywords: *mirror neurons, empathy, criminal brain, ego-centrism, theory-of-mind, Asperger's syndrome, schizophrenia, sociopathic personality disorder.*

The term "mirror neurons" was coined at the end of the 20th century by Giacomo Rizzolatti at the University of Parma. The team conducted animal studies on apes to examine how actions are planned and carried out. The scientists concentrated on the area F5 in the ape's brain. Using thin electrodes, the researchers were able to show that whenever the animals grabbed a nut by hand and brought it to the mouth, the neurons in area F5 of the brain (which is responsible for movement patterns of the hand) became active. Rather accidentally, the researchers observed that about 17% of the cells in the area were activated even when the monkeys were watching a human experimenter take a nut. The premotor cortex also responded when others performed the movement. Only by observation this part of the brain reacted as if the ape had carried out the activity itself; it was "mirrored" in the brain of the animal. Therefore, the researchers now called this group of neurons mirror neurons.

Initially, the concept developed by Rizolatti was only about mimicking observed movements, but then it quickly expanded to allow us to empathize with the world of thoughts and other people's emotional lives. In the addition of the imitation of motor actions is also the ability to understand the intentions of others. Mirror neurons thus also provide a neuro-anatomical explanation for phenomena such as empathy and compassion (Rizolatti et al., 1996, 1999).

The concept is not new. Already in 1894 Lombroso & Ferrero described in her book "*The Woman as a criminal and prostitute*" various criminal women who had suffered brain damage and speculated that the penchant for crime has to do with a dysfunction of specific brain parts. Among other things, these authors cited a work by Hotzen from 1889, in which an 18-year-old girl was described, who had killed her mother with 60 ax blows. She died of pulmonary consumption at a young age, her brain could be dissected, and one found inter alia a "*Durchbrechung der vorderen Centralwindung am unteren Drittel*" (quoted in Lombroso & Ferrero, 1894, p. 298). Another example from the book is about a criminal named Marianne Kürtschen, who sold seriously ill patients bizarre and overpriced medications. She also died of tuberculosis, and brain-defects were found in the lower parts of the upper frontal and anterior central convolutions (cited by Lombroso & Ferrero, 1894, p.299).

Another book dealing with the connection between crime and the inability to empathize with others is the textbook of the German memory researcher H.-J. Markowitsch. He describes, among other things, Jürgen Bartsch, who killed four boys between the ages of eight and twelve. Bartsch committed his first murder at the age of just 15 years. He later died during a surgery, his brain showed a lesion of unknown origin. The RAF terrorist Ulrike Meinhof was involved in bombings and kidnappings and represented one of the most radical ways of terrorism at that time. Ulrike Meinhof's brain showed brain damage as a result of a previous head surgery in the area of the emotional center of the brain, which was with great certainty the cause of the subsequent course of the terror. Gian Franco Stevanin, who was named as "Terrazzo's monster", raped and killed at least five young women in the early 1990s, whose bodies he later dismembered. His dream had been to fill a whole pillow with the pubic hair of women. Stevanin had suffered a serious motorcycle accident at the age of 16 with traumatic brain injury and coma. Here, much of the frontal cortex had been destroyed.

These case reports suggest that dysfunction of mirror neurons may be associated with psychopathological disorders. A typical mental disturbance is the antisocial personality disorder. Among other things, the DSM-V describes symptoms as: ego-centrism, goals are pursued only on the basis of own interests, not because of prosocial behavior (e.g. with violations of laws), lack of understanding for the feelings, needs and suffering of other people, lack of empathy, when others are hurt, problems with intimate partnerships that are exploited for one's own purposes without addressing the needs of the partner; and dominant behavior to control others.

Fig. 1: Shortly after birth, toddlers have a wide range of feelings.

The mirror neurons lying in the frontal lobe of the brain do not act in isolation. They are involved in a network. A simplified model was developed by Rajmohand & Mohandas (2007, see Fig. 1).

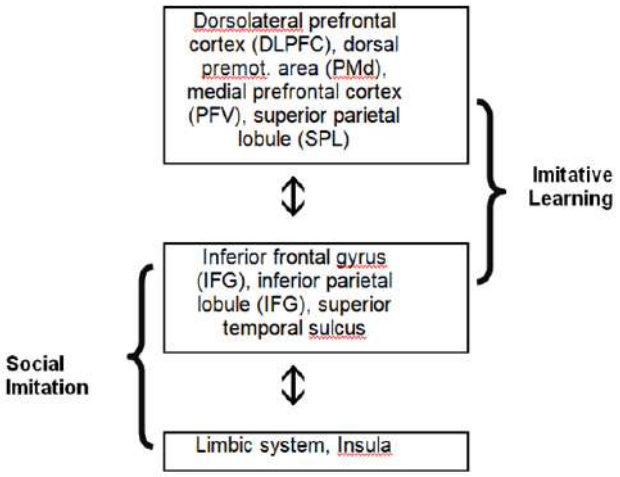

Fig. 2: Simplified model of the neural mirror system (based on: Rajmohand & Mohandas; 2007)

Since then other brain areas are found. Via EEG, MEG, PET and fMRI studies, it was possible to localize the areas of the brain that are involved in the system of mirror neurons. Monitoring of actions leads to an increase in blood sugar levels in the inferior lobule parietalis, in the ventral cortex and in the caudal part of the lower frontal gyrus. Most of these have motor tasks. The observation of motor actions activates the precentral gyrus and the pars opercularis of the inferior frontal gyrus. In an fMRI study, participants in video films should observe hand movements; activations were found in the dorsal premotor cortex and also in the upper parietal lobe, as far as the intraparietal sulcus. In further studies, these systems could even be detected if participants who observed only a robot arm whose complex movements people could not mimic (Rizolatti & Fogassi, 2014).

Mirror neurons (MNs) were initially examined primarily with regard to hand motor skills; later, studies on oral responses and non-verbal cumulative gestures were added. In 2017, Ferrari et al published a paper in which they demonstrated that the system of mirror neurons consists of (at least) two different anatomical pathways: one pathway involves sensorimotor movements, especially hand gripping. This path runs in the known parietal-premotoric cycles. The second path refers to the control of the mouth and face motor skills. This trajectory is very closely related to the limbic system, which is involved in instinctive behavior as well as in the formation of emotions and is closely linked to the mesolimbic reward system. The involved structures of this system are the anterior cingulate cortex, the anterior and medial dorsal insula, the orbitofrontal cortex, and the basolateral amygdala.

Mirror neurons are extremely useful in childhood because children can observe others' behaviors and incorporate these into their own behavioral repertoire. Humans are genetically conditioned with a set of mirror neurons, and soon after birth, children can imitate facial expressions of mother or father; they apparently correspond to the basic emotional need of the newborn. From about the age of 3 to 4 years, the mirror neurons are so developed that a child, for example, tries to comfort his mother, if she pretends to have pain. However, experience also plays an essential role. Humans who have had bad experiences in childhood, form in the field of mirror neurons other interconnections than people who have grown up with a lot of basic trust. The ability to reflect feelings of others does not develop on its own, it needs a partner. For the baby, it's mostly the mother. Endedijk and co-workers indicated in their article in 2017 that neuronal mirrors play a crucial role in childhood social interactions. Using EEG, it was demonstrated that 4-year-old children with a higher involvement of the musculoskeletal system were even more successful in peer communication. The authors saw this as an indication of a connection between the motor system

and interpersonal social interaction related on mirror neurons.

Fig. 3: *Siblings quarrel most of the time. To comfort the little sister requires empathy in another person's suffering.*

In the motor field, it was examined whether the mirror neurons can make quasi predictions for future events. In a study by Flanagan and Johansson (2003), the subjects were asked to watch video films that contained certain movements for objects. When subjects observe a block stacking task, the coordination between their gaze and the actor's hand is predictive, rather than reactive.

These experiments lead to the conclusion that mirror neurons are extremely useful in everyday life; taking into account the two different pathways of the mirror-neuron-system we can not only anticipate movements of others, but we can put ourselves in the emotional world of others, and anticipate what our counterpart will feel and do next. So one notices quickly that the interlocutor reacts sadly and can respond to it, but one also notices that the other is just angry and can then redraw from a risky situation.

Research with fMRI has shown that mirror neurons play an important role in sports as well as in learning how to play a musical instrument (see e.g. Wang & Agius, 2018). For piano playing, Hou et al. (2017) compared musicians and non-musicians. Subjects should either focus on whether the piece was played perfectly or simply enjoy the music. The musicians showed a stronger activation of the mirror neurons than the non-musicians in the correctness mode as well as in the enjoyment mode. The results of these authors suggest that mirror neurons are not simply initiated by movement, but are modulated by expertise. When listening to the music, the musicians play along with the played piece in their brain. For other activities this was not proven. Kok and co-authors investigated in 2018 if there was any evidence that the network of mirror neurons might even play a role in learning surgical techniques, but the authors found no evidence for their hypothesis.

Patients with hemiplegia can exercise compensatory brain areas by imagining movements, but they may also improve abilities of movement in the case of hemiparetic limbs due to only observe others. By pursuing the activities of others, patients become better at exercising this action themselves (Son & Kim, 2018). It is assumed that the mirror neurons also play an important role here. In a study by Hioka et al. (2018), five subacute stroke patients and nine healthy individuals were compared with fMRI to assess activation of the brain during walking. In the stroke patients, neuronal activity was higher in the lower left parietal lobe and in the lower right and left inferior gyrus than in the resting phase. The authors believe that treating stroke patients by observing walking of others may be a promising therapy.

One of the most important concepts that builds on the existence of mirror neurons is the "Theory of Mind" (ToM), which describes not only the understanding of how one's perceptions, feelings, thoughts and intentions affect one's behavior, but also one's acceptance of emotions and thought processes of other people. However, the theory of mind goes beyond empathy and mirror neurons, as it describes the complex ability to understand a state of mind or behavior.

It is believed that deficiencies in the network of the mirror neurons are closely related to various psychiatric disorders, such as autism, Asperger's syndrome, schizophrenia and the above mentioned sociopathic personality disorder. All of these mental illnesses include people who have problems understanding the feelings, thoughts and actions of others. On the other hand several studies show that in autism or the negative type of schizophrenia symptoms like echolalia or echopraxia occur (see e.g. Grossi et al, 2012); but these are based on the imitation of behavior. Other studies in this field reported that these patients had good imitation performance (Aldrige et al., 2000; Carpenter et al. 2001; Bird et al., 2007; Hamilton et al., 2007). Therefore, according to the book and an article of Hamilton (2013) "*the broken mirror theory of autism cannot be supported in its standard form*".

Ultimately, mirror neurons do not allow mere social learning to be learned through observation, but they are the basis for peaceful social coexistence. Only by means of mirror neurons can we translate ourselves into others and thus show moral behavior. The bestselling author Jeremy Rifkin already said that human beings would ultimately develop *"empathic, biosphere consciousness"* via the mirror neurons. (https://www.ted.com/talks/jeremy_rifkin_on_the_empathic_civilization).

However, there is now increasing criticism of the omnipotence of the mirror neurons. In summary, the significance of the mirror neurons has nowadays reduced significantly. For nearly 20 years, they were considered as an explanation of empathy and moral behavior. Today, one only accepts their task in perceiving and possibly imitating behavior (at least when other brain areas agree with it). To understand an action, it is not enough to observe it. Already in 2012, Carmo, Rumiato and Vallesi pointed out that the brain activity of mirror neurons is not sufficient to describe an imitation of actions outside of their own behavioral repertoire. In their view, the observation of actions does not mean that the meaning of the action is understood and even more so not that the act can be imitated. These authors conducted a study of event-related EEG potentials, in which subjects were presented (a) meaningful familiar acts and (b) meaningless unknown actions that they were supposed to discriminate as known / unknown and later mimic. The results of this study indicate that imitation and understanding of an action in the brain are two different things. During the imitation of unknown actions left-hemispheric frontal processes are activated, the understanding of action was rather in the right rear brain region home. Ultimately, one and the same action can have very different meanings here. The grip on a knife, for example, means that you want to cut off a piece of cheese or kill someone. The understanding of the meaning of an action is thus dependent on diverse context experiences.

Rather, it can be assumed that the mirror neurons are only part of a much more complex system. Presumably, the mirror neurons essentially have only the task of imitation learning, they alone cannot be held responsible for the entire prediction of human behaviors; that is a total output of the human brain in which mirror neurons are just a piece of the puzzle. For example, in 2005, Churchland pointed out in her neuro-philosophical studies about the question how the brain works and how it creates consciousness, that the distribution patterns in the brain are extremely complex and that it is difficult to explain data from specific areas. Greg Hickok from the University of California, Irvine, wrote in 2013: "*Mirror neurons were once widely believed to be supportive in understanding motor simulation of the observed actions.*" In the opinion of Hickok, the model of mirror neurons was rashly extended to the explanation of the understanding of actions, though these neural assemblies are actually seen only responsible for the imitation of actions. Hickok criticized in the mirror-theory that humans are not social because they can imitate thanks to mirror neurons. They imitate because they are social. And he says that humans can ape better behavior than the monkeys on which the original studies took place.

References

Aldridge MA, Stone KR, Sweeney MH & BowerPreverbal TGR (2000). Children with autism understand the intentions of others. Developmental Science, 3 (3), 294

American Psychiatric Association (APA) (2013). Diagnostic and Statistical Manual of Mental Disorders American Psychiatric Publishing; 5 edition. ISBN-13: 978-0890425558

Bird G, Leighton J, Press C & Heyes C (2007). Intact automatic imitation of human and robot actions in autism spectrum disorders. Proceedings of the Royal Society B: Biological Sciences, 274 (1628): 3027-3031. doi: B717X703LR287633 [pii] 10.1098/rspb.2007.1019

Carmo JC, Rumiati RI, Vallesi A (2012). Understanding and imitating unfamiliar actions: distinct underlying mechanisms. PLoS One;7(10):e46939. doi: 10.1371/journal.pone.0046939.

Churchland PS (2005). A neurophilosophical slant on consciousness research. Prog Brain Res. 2005;149:285-93.

Endedijk HM, Meyer M, Bekkering H, Cillessen AHN, Hunnius S (2017). Neural mirroring and social interaction: Motor system involvement during action observation relates to early peer cooperation. Dev Cogn Neurosci;24:33-41. doi: 10.1016/j.dcn.2017.01.001.

Ferrari PF & Rizzolatti G (2014). Mirror neuron research: the past and the future. Philos Trans R Soc Lond B Biol Sci. 2014 Jun 5; 369(1644): 20130169. doi: 10.1098/rstb.2013.0169

Ferrari PF, Gerbella M, Coudé G & Rozzi S. (2017). Two different mirror neuron networks: The sensorimotor (hand) and limbic (face) pathways. Neuroscience. ;358:300-315.

doi:10.1016/j.neuroscience.2017.06.052.

Flanagan J.R. & Johannson R.S. (2003) Action Plans Used in Action Observation. Nature. 424(6950): 769-771

Grossi D, Marcone R, Cinquegrana T & Gallucci M (2012). On the differential nature of induced and incidental echolalia in autism Journal of Intellectual Disability Research: JIDR, 1-10, 10.1111/j.1365-2788.2012.01579.x

Hamilton AF (2013). Reflecting on the mirror neuron system in autism: a systematic review of current theories. Dev Cogn Neurosci;3:91-105. doi: 10.1016/j.dcn.2012.09.008.

Hamilton AF de (2013). Reflecting on the mirror neuron system in autism: A systematic review of current theories. Developmental Cognitive Neuroscience. 3: 91-105

Hamilton AF de C & Grafton SS (2007). The motor hierarchy: from kinematics to goals and intentions. In: P. Haggard, Y. Rosetti, M. Kawato

(Eds.), Attention and Performance, vol. XXII, Oxford University Press, Oxford, UK (2007)

Hickok G (2013). Do mirror neurons subserve action understanding? Neurosci Lett;540:56-8. doi: 10.1016/j.neulet.2012.11.001

Hioka A, Tada Y, Kitazato K, Kanematsu Y, Mizobuchi Y, Mure H, Shimada K, Okazaki T, Korai M, Akazawa N, Matsumoto Y, Harada M, Takagi Y & Nagahiro S (2018). Activation of mirror neuron system during gait observation in sub-acute stroke patients and healthy persons. J Clin Neurosci. pii: S0967-5868(18)31498-X.

doi:10.1016/j.jocn.2018.09.035.

Hotzen, O. (1888). Befunde am Gehirne einer Muttermörderin. Vierteljahrsschrift für gerichtliche Medicin und öffentliches Sanitätswesen, 48, 381-404.

Hou J, Rajmohan R, Fang D, Kashfi K, Al-Khalil K, Yang J, Westney W, Grund CM & O'Boyle MW (2017).Mirror neuron activation of musicians and non-musicians in response to motion captured piano performances. Brain Cogn;115:47-55. doi: 10.1016/j.bandc.2017.04.001.

Kok E, De Bruin AB, van Geel K, Gegenfurtner A, Heyligers I & Sorger B. (2018). The Neural Implementation of Surgical Expertise Within the Mirror-Neuron System: An fMRI Study. Front Hum Neurosci. 20;12:291. doi: 10.3389/fnhum.2018.00291.

Lombroso, C. & Ferrero, G. (1894). Das Weib als Verbrecherin und Prostituierte. Translated by: H. Kurella. Hamburg: Verlagsanstalt und Druckerei A.-G..

Markowitsch HJ & Siefer W (2007). Tatort Gehirn: Auf der Suche nach dem Ursprung des Verbrechens. Campus-Verlag

Rajmohan V & Mohandas E (2007). Mirror neuron system. Indian J Psychiatry; 49(1): 66–69. doi: 10.4103/0019-5545.31522

Rizzolatti G, Fadiga L, Gallese V & Fogassi L. (1996). Premotor cortex and the recognition of motor actions. Brain Res. Cogn. Brain Res. 3, 131–141. doi:10.1016/0926-6410(95)00038-0)

Rizzolatti G. & Fogassi L (2014). The mirror mechanism: recent findings and perspectives. Philos Trans R Soc Lond B Biol Sci.; 369(1644): 20130420. doi: 10.1098/rstb.2013.0420

Rizzolatti G, Fadiga L, Fogassi L & Gallese V. (1999). Resonance behaviors and mirror neurons. Arch Ital. Biol. ;137(2-3):85-100.

Rizzolatti, G.; Maddalena Fabbri-Destro & Luigi Cattaneo (2009). Mirror Neurons and Their Clinical Relevance Nature Clinical Practice Neurology;5(1):24-34.

Son YL & Kim JW (2018).The effects of mirror neuron system-based self-observation training on lower limb muscle activity and dynamic balance in patients with chronic stroke. J Phys Ther Sci. ;30(10):1241-1244.

doi:10.1589/jpts.30.1241.

Wang S & Agius M (2018). The neuroscience of music; a review and summary. Psychiatr Danub;30(Suppl 7):588-594.