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The role of mirror neurons in empathy, with a focus on their relevance in autism spectrum disorder and other clinical implications

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Abstract

Introduction

Mirror neurons are brain cells that engage when an individual performs an action and then observes another person completing the same action. These neurons are supposed to help us grasp others' emotions and intentions by mimicking their experiences. This has led to the theory that mirror neurons influence empathy, or the ability to share and understand the experiences of others. The article investigates the role of mirror neurons in empathy, specifically their potential contribution to emotional resonance, perspective-taking, their relevance in autism spectrum disorder and other clinical implications.

Aim of the study

The aim of this comprehensive review is to provide an overview of how mirror neurones contribute to the development and expression of empathy in humans, with a focus on their role in autism spectrum disorder. The objective of this research is to clarify the role of mirror neurons in social cognition and gain a better understanding of the neurological foundation for empathy.

Materials and methods

Scientific articles from the Pubmed, Google Scholar, and Web of Science databases were analysed. The goal of this study was to choose recent articles that most adequately

encompassed the problems under consideration. The search was conducted out using the following keylords: mirror neurones, empathy and autism spectrum disorder.

Summary

Mirror neurones appear to play an important part in empathy, as evidenced by neural activity patterns during emotion identification. While they are not the single source of empathy or the only trigger, they are definitely present. Conflicting evidence limits our understanding of their exact impact, and more credible studies need to be conducted. However, current research reveals that mirror neurones have a measurable, although limited, impact on empathy.

Key words: mirror neurons, autism spectrum disorder, empathy, social cognition, emotional recognition, neurobiology of empathy.

Introduction

Why are we getting moved by someone else's story? Why our heartbeat speeds up when watching a horror movie, even though we know that we are safe? The emotions of those around us can become part of us, became our emotions. Their cases seem to overflow ourselves. This sort of confrontation involves little physical or mental commitment. We respond politely, and the implementation ordeal is intuitive. In the majority of the cases, it operates outside of our control. It's indeed our minds, specifically, that is to blame. Emotions, it is said, are what makes us human. Empathy, according to Hodges and Myers (2007) [19], enhances prosocial behavior, leading to a more compassionate response. A neurological mechanism known as mirror neurons is one of the processes believed to play a role in empathy. Understanding what determines empathy might have a range of benefits and services, such as the power to enhance empathy levels, that will aid people with empathy-related disabilities in their treatment and rehabilitation. Many psychologists have dedicated their careers toward discovering more about the nature of empathy and how mirror neurons play a part in it.

Giacomo Rizzolatti and his colleagues in Parma became the first to explain the concept of mirror neurons. They analyzed macaque monkeys (Pellegrino et al, 1992) [20] and later demonstrated the role of mirror neurons in humans (Pellegrino et al, 1993) [21]. Their results revealed that when the participant in the study committed a particular action and when the subject witnessed the same action, similar regions of the brain were stimulated. This find has

intrigued people's attention. Many researchers feel compelled to delve further into the idea of mirror neurons to determine which functions they affect.

The case of mirror neurons appeared relatively recently. Their role in empathy and its significance is still in argue amongst psychologists. Singer (2004) [5], Wicker et al. (2003) [17], and Lacoboni (2009) [7] in their studies and theories concluded that mirror neurons do play a significant role in empathy. However, the studies by Danziger et al. (2009) [9], Hamilton et al. (2007) [31], and Singer et al. (2006) [6] have put forward conclusions opposing Singer (2004) [5], Wicker et al. (2003) [17], and Lacoboni (2009) [7]' claims. By putting into discussion results and claims made by studies above, the question "To what extent do mirror neurons influence empathy?" will be examined.

This paper will argue that **mirror neurons are partially responsible for empathy and its proper function, however, further research is needed in that area.**

History

The discovery of mirror neurons

As previously said, Giacomo Rizzolatti and his colleagues in Parma are credited with the discovery of mirror neurons, especially for their work with macaque monkeys (Pellegrino et al, 1992) [20]. The study aimed to investigate neuron activation in monkeys since their brain's structure was similar to humans. The single-unit recording system was used in the research, according to Hickok (2014) [34], in which microelectrodes implanted in the brain monitored the electrical activity of single neurons when the monkeys performed a task. Microelectrodes work by registering action potentials, which are the electrical signals that a neuron generates to interact with other neurons. When macaque monkeys performed actions like reaching for orbiting a peanut, several neurons in the F5 region of their premotor cortex were triggered, according to researchers in Parma. Rizzolatti's group [20], on the other hand, the flaw in the previous analysis was detected. It was difficult to distinguish the neuronal reaction when seeing the object from the responsibilities associated with the subsequent grabbing action when the two movements essentially overlapped in time. As a response, a new experiment was performed in which monkeys viewed an object inside a box and used a switch to light it

up to see it, then opened the box and grasped the object after a pause. This technique, along with a proper time interval between the acts, helped to minimize the overlapping recently identified. Something fascinating was discovered by the researchers. Some of the monkey's motor neurons were triggered when they picked up an item, such as peanut, to hand it to the monkey under examination. What's more shocking is that the stimulated neurons were discovered to be the same ones that fired when the monkey grabbed the peanut. According to the results of this experiment, individual neurons can only respond to very particular behaviors. The mirror neuron that fired when the monkey grasped a peanut, for example, would only fire when the experimenter grasped a peanut. A neuron that fired when the monkey began eating a peanut, on the other side, would only fire if the experimenter began eating a peanut. Nevertheless, it was the evidence collected during the research and observations that led to the identification of mirror neurons, not the study and observations themselves. The neurons that exhibited action potentials when the experimenters grasped the stimuli were remarkably similar to those that displayed action potentials when monkeys grasped the object on their own. Previous research has shown that neurons respond to perceived behavior, but these neurons were only in the sensory region, never in the motor area (Perrett et al, 1985) [22]

Rizzolatti findings that were published by the team (Rizzolatti et al, 1992) [20] had their limitations since they couldn’t be generalized into humans since there is no assurance that those processes work in the same way as in monkeys’. For this reason, the Parma team focused and moved on to human research. However, it was impossible to repeat the same procedure on humans like on monkeys, since it required attaching electrodes directly to the brain. Instead, the first human mirror neuron study examined hand-muscle twitching. Rizzolatti and neuroscientist Luciano Fadiga, MD, Ph.D., now at the University of Ferrara, recorded motor-evoked potentials, which is a signal that a muscle is ready to move, from participants' hand muscles as the participants observed the object being grasped by the experimenter. They found that these potentials matched the potentials recorded when the objects were grasped by the participants themselves (Rizzolatti et. Al, 1995) [23]. After that discovery, most studies on the human mirror-neuron system have used some sort of neuroimaging, generally functional magnetic resonance imaging (fMRI). This is essential to know to be able to discuss any further claims. This research serves as a solid basis to further investigate other areas to which mirror neurons are related.

Description of the state of knowledge

The Role of Mirror Neurons in Empathy

Insights from Neural Activation Studies

Empathy is a concept that is used to describe a broad variety of interactions. It's commonly described as the ability to detect other people's emotions as well as the ability to imagine what they're thinking or feeling. Since it is such a complex trait, it has been the subject of several studies, with the aim of determining the basic processes and causes that affect empathy. Psychologists have used a variety of methods to investigate the impact of mirror neurons on empathy. However, the emphasis of this review would be on determining whether or not this effect is important. Imaging studies in the past few years have started to investigate brain activity associated with different empathetic responses. The study conducted by Wicker et al.'s thesis from 2003 [17] provided a foundation for assumptions and arguments in this area. It was an fMRI study composed of four functional runs. In the first and second ("visual runs") 14 participants passively viewed movies of individuals smelling the contents of glass (disgusting, pleasant, or neutral) and expressing the facial expressions of the respective emotions. The same participants inhaled disgusting or enjoyable odorants through a mask positioned over their nose and mouth in the third and fourth ("olfactory runs"). According to Wehrle et al. (2000) [18], emotions are understood more from videos than from static displays, so this research has a big benefit in that it uses movies to show emotions instead of static pictures. According to the findings of this research, the anterior insula is triggered both during the detection of disgusted facial expressions and during the emotion of disgust evoked by offensive odorants. This finding suggests that there is a shared substrate for experiencing disgust and perceiving the same emotion in others. The left anterior insula and right anterior cingulate cortex were shown to be activated during the procedure, which is almost similar to the regions that were activated in Singer's experiment from 2004 [5] that was discussed above. As a result, this analysis supports the mentioned research question.

Role in Shared Emotional Experiences

In addition to the ability to understand the mental states (propositional attitudes) of others, humans can also empathize with others, that is, share their feelings and emotions in the absence of any direct emotional stimulation to themselves. Humans can feel empathy for other people in a wide variety of contexts: for basic emotions and sensations such as anger,

fear, sadness, pain. Neuro-scientific research on empathy has been strongly influenced by action–perception models outlined earlier. Thus, the idea that there are neural mechanisms enabling the sharing of other people's states has been expanded to include the ability to share their feelings and sensations as well. A similar conclusion to the study conducted by Wicker et al. In 2003 [17] was found in the study conducted by Singers in 2004 [5]. The study looked at pain-related empathy in 16 couples using fMRI (functional magnetic resonance imaging). In this study, couples were recruited allowing the assessment of empathy ‘‘in vivo’’ by bringing both partners into the same scanner environment. Brain activity was then measured in the female partner while painful stimulation was applied either to her own or to her partner's right hand via electrodes attached to the back of the hand. The male partner sat next to the MRI scanner, and a mirror in front of her allowed her to see both her and her partner's hands on a tilted board. Flashes of multiple colors on a large monitor behind the board demonstrated which of her hands or her partner would receive the stimulation and whether it would be painful or non-painful. As the pain was administered to the scanned subject or her partner, this technique allowed for the calculation of pain-related brain activity (the so-called "pain matrix"). It was discovered that similar regions of the brain were stimulated both when the person was in pain and when the person's partner was in pain. The findings show that when empathizing with the suffering of others, certain sections of the ‘‘pain matrix" were triggered, but not the whole ‘‘pain matrix." According to Gu et al., the regions that displayed activation were mostly parts of the anterior cingulate cortex and the anterior insular cortex, which are brain areas associated with empathetic pain reception (2012) [16]. The results of this research specifically demonstrated that a community of neurons is linked to an empathic response to pain. This indicates that there is a connection between mirror neurons and empathy, and therefore this study backs up the previous research question.

Neural Connections Between Mothers and Infants

“If mirroring is such a powerful mechanism for understanding the emotional states of other people and empathizing with them, one would expect lots of mirroring between parents and their children.”, says Marco Lacoboni (as cited in Lacoboni, 2009, p.126) [7]. He conducts a study to investigate the suggestion he made, that newborn babies have an innate mechanism of imitating movements of people around them, from the first few moments that they were born. Italian psychologists have studied the responses of mothers while looking at pictures imitating the expressions of their own and of an unfamiliar baby. The research has shown strong responses in the mirror neuron area of the brain – the insular cortex and the limbic

areas. The insular cortex represents the connection between the mirror neuron system and the limbic areas, which are responsible for emotions.

When comparing a mother's reaction to her own baby against an unfamiliar baby, the results revealed activations in a separate area not seen before. The pre-SMA (supplementary motor area) region is associated with complex motor planning. The significance of this finding is based on the similarities between the pre-SMA and the F6 region in macaques. The F6 area has strong anatomical connections with the F5 area, where mirror neurons were initially discovered. Further data also suggests that F6 may control and influence the activity in the F5 region (Rizzolatti et al, 2001) [15]. In the research in the area of maternal empathy, mothers and their babies have a unique mechanism of communication involving mirroring expressions and imitating movements, which is seen in the research examples above. When observing mothers' brain activity, neural activations in the pre-SMA are of great importance, as they give an indirect link to the F5 region of macaques, where mirror neurons were initially discovered, thus creating a correlation between macaque and human mirror neurons. Furthermore, this is another study that supports the research question.

Challenging the Mirror Neuron Theory

Empathy in the Absence of Pain Sensation

However, the occurred examples where emphatic responses were elicited without observing an action or a person. That challenges the idea of mirror neurons and their role in empathy. Previous studies clearly showed that empathetic response is triggered whenever observing other people's actions or expressions. In 2009 Danziger et al. [9] conducted an experiment, which aim was to investigate whether patients that suffer from congenital insensitivity to pain (CIP) where this condition makes them incapable of feeling any kind of pain are still capable of experiencing empathy responses when seeing people undergoing painful actions. The participants in this study were composed of 13 patients with diagnosed CIP and 13 healthy subjects. The stated hypothesis was as followed, that patients with congenital insensitivity to pain would show a significantly decreased activity in the anterior insula and the anterior mid-cingulate cortex. The study's procedure involved undergoing an fMRI scan of the participants, while at the same time they were shown pictures in two conditions. The first condition included pictures of different body parts in painful situations and the second condition was with the use of pictures showing a facial expression that is displaying pain. After the

presentation of pictures, they were told to think about how the people presented on them could have felt. The results showed that in the first condition there were no differences in brain activity between the healthy participants and the ones that suffered from CIP. However, in the second condition, the CIP group showed significant activity only present in the anterior insula, while no in the anterior mid-cingulate cortex. Those findings suggest that even if a person never felt pain, they can still empathize with others that are experiencing pain. Those results really challenge the idea of mirroring theory and show a possibility that empathy can be controlled by other mechanisms and factors.

The Role of Social Context in Shaping Empathetic Responses

There are also studies that suggest other feelings and circumstances which influence empathy, therefore decreasing the significance of the direct role of mirror neurons. In 2006 Singer et al.[6] conducted a study with the aim to investigate under what circumstances individuals feel empathy for other person's pain. For this purpose, participants were divided into two types: research subjects, which were composed of 16 men and 16 women, and confederates, which were composed of associates to the researchers. Before the actual experiment, both groups played a game in order to create trust relationships. The subjects were playing first and were supposed to give a certain amount of money to the confederates. Afterward, the confederates were supposed to do the same thing, either by sending lower amounts (it was named as unfair confederate) or higher amounts (called fair confederate) of money compared to the amount they received. This led to the situation where subjects liked or disliked certain confederates. In the actual experiment, the researchers used fMRI to observe the subject's brain activity while the subjects observed confederates who received electric shocks applied to the back of the hand. The results supported the initial hypothesis suggesting that subjects show higher activation of pain-related brain areas when they witness a fair confederate than when seeing an unfair confederate. Those findings show us that people experience higher levels of empathy towards people they are fond of. This shows how there are additional factors influencing empathy, besides mirror neurons, providing refuting arguments to the research question. This also indicates that probably in other similar research that investigated pain-related empathy there were subjective factors, which biased the results. This could potentially apply to the study previously mentioned in the essay – Singer (2004) [5].

Clinical Implications of Mirror Neuron research

Mirror neurons research has important clinical implications, especially for understanding and treating a variety of psychological and neurological problems. For example, research suggests that dysfunctions in the mirror neuron system may lead to diseases like autism spectrum disorder (ASD), in which people frequently struggle with social interactions and sympathetic reactions (Dapretto et al., 2006) [24]. Interventions that target mirror neurone activity, such as imitation-based therapy, may assist children with ASD improve their social skills. Furthermore, Iacoboni's (2009) [7] research reveals the potential of mirror neurone activity as a biomarker for empathy-related illnesses, creating possibilities for targeted treatments that might improve empathetic qualities between people with conditions such as psychopathy or schizophrenia.

Stroke Rehabilitation

Identifying how mirror neurons allow emotional resonance can additionally direct stroke patients' rehabilitation techniques, since creating empathetic connections may benefit in emotional and social recovery (Decety & Meyer, 2008) [25]. According to Fadiga et al. (2005) [26], motor resonance, which is a component of mirror neuron function, can be applied to rehabilitation activities that enhance action observation and imitation. These strategies can help patients restore their motor abilities by enabling them to watch and internalize movements, encouraging brain reorganization and improving functional results.

Empathy Training in Parkinson's Disease

In the context of neurological conditions such as Parkinson’s disease, research by Iani et al. (2015) [27] found that engaging patients in empathy-focused interventions could improve both their emotional well-being and cognitive functioning, implying that mirror neurons play a role in both emotional and social recovery processes. This study examined the influence of empathy training on patients with Parkinson’s disease, a condition characterized by motor impairment, emotional dysregulation, and frequent social withdrawal. The researchers developed a program that included exercises designed to enhance empathetic understanding, such as role-playing and group discussions about emotions.

The findings showed that individuals who received empathy-focused training showed significant improvements in both self-reported emotional well-being and cognitive efficiency

on tasks involving perspective-taking and social reasoning. This indicates that engaging the mirror neurone system through empathetic interaction may promote neuroplastic changes, improving patients' emotional connections with others. The researchers hypothesized that these improvements were a consequence of increased activity in brain areas that are related with empathy and emotional processing, particularly the anterior insula and anterior cingulate cortex.

Moreover, the study emphasizes the efficacy of empathy training as a non-pharmacological intervention to regulate some of Parkinson's disease's non-motor symptoms, such as depression and anxiety, which can considerably reduce quality of life. These types of treatments, which create social ties and increase emotional awareness, may help alleviate the feelings of isolation and powerlessness that many patients experience.

The implications extend beyond Parkinson's disease; empathy-focused therapy could assist people with other neurological conditions that result in deprived social functioning, such as multiple sclerosis or traumatic brain injury. Overall, this line of study emphasizes the mirror neuron system's role in aiding emotional recovery and social participation in clinical populations, paving the way for alternative treatment techniques that use empathy to promote holistic recovery.

Autism spectrum disorder and Mirror Neuron System.

Autistic children are often described as having poor empathy, being unable to form meaningful social bonds, having difficulty understanding others' intentions, emotions, and sensations, and being unable to imitate others. The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders describes Autism Spectrum Disorder (ASD) as lacking in communication and interaction within a social group, as well as a display of behavioral patterns that are limited and recurrent in nature (American Psychiatric Association, 2013) [14]. “Mirror neurons support language, imitation, the theory of mind, empathy, intention or goal understanding, and the ability to read others’ emotions. All of these are impaired in autism, therefore autism can be traced back to a deficit in the mirror neuron system.”, Gallese explained (Hickok, 2014, p. 593) [34]. Previously mentioned study of Dapretto et al.

(2006)[24] has indicated that people with ASD display abnormal MNS activity when viewing others' behaviors and emotions, implying a connection between MNS dysfunction and limited empathetic abilities commonly seen in these individuals. This study applied functional magnetic resonance imaging (fMRI) to evaluate brain activity between children with ASD and neurotypical children while observing emotional facial expressions. The results revealed decreased activity in critical regions involved with the MNS, such as the inferior frontal gyrus and inferior parietal lobule, which are essential for mirroring others' emotions and actions.

Further studies, such as that conducted by Schilbach et al. (2010) [28], support these findings by demonstrating that people with ASD struggle with both action observation and imitation tasks, which are necessary for social comprehension and the development of empathetic responses.

In a more recent study, Wang et al. (2021) [29] combined fMRI and electrophysiological methods to examine the neurological mechanisms that underlie social cognition in adolescents with ASD. Their findings suggested that disrupted connectivity within the MNS was associated with difficulties in social understanding and emotional identification, giving more evidence of the MNS's significant involvement in social functioning in individuals with ASD.

However, some studies challenge the significance of the MNS in ASD, claiming that atypical social behavior may not only originate from mirror neuron dysfunction, suggesting that those people actually are able to effectively imitate other's actions when they are related to a specific meaning, such as goal or object (Hamilton et al, 2007) [31]. In one of Hamilton's study participants, which were composed of children with diagnosed autism, were instructed to pair up various pictures with different hand postures on them to drawings of specific actions, however without showing the hand in this action. The evaluation showed that children with autism performed higher on this task than children who had not been diagnosed with autism in the control group. The study suggests that broader cognitive factors, such as executive function and theory of mind, may play more critical roles in social interactions.

Additionally, Orefice et al. (2020) [32] stated that while there is some evidence for altered MNS activity in individuals with ASD, research findings are inconsistent and fail to demonstrate a definitive causal connection between MNS dysfunction and autism's core symptoms.

Furthermore, Bird et al. (2007) [33] hypothesized people with ASD may possess intact mirror neuron systems but struggle to use them accurately in social circumstances due to differences in motivation or attention rather than outright malfunction. This viewpoint emphasises that

understanding the social difficulties in ASD may require a more complex approach that incorporates many cognitive and neurological factors beyond the MNS.

Overall, while the majority of evidence emphasizes the importance of the mirror neuron system in facilitating social interactions and emotional resonance in ASD, these opposing perspectives highlight the disorder's complexity and suggest that programs aimed at improving social and emotional outcomes should take into consideration a broader range of factors.

Discussion

Most psychological studies conducted with an aim of finding out to what extent are mirror neurons responsible for empathy responses suggest that the mirror neurons play a significant role in determining the ability for empathy responses. Lacoboni [7], [8] has focused on how the newborn babies have an innate mechanism of imitating movements of people around them, from the first few, and thus how strong are the responses in the mirror neuron area of the brain. Other studies focused on empathy and mechanisms responsible for it came up with similar findings to those of Lacoboni, including Singer who concluded from his study in 2004 [5] that there is a connection between a certain group of neurons and an empathetic response to pain, indicating a significant relationship between mirror neurons and empathy. Wicker et al. [17] also came to similar conclusions in his study from 2003, where his findings showed the link between empathizing and a neutral network that enables empathizing, which we know as mirror neurons. Overall many studies suggest that mirror neurons play a significant role in empathy. However, few researchers, like Hamilton et al [30], [31] or Danziger et al. [9] suggest in their studies that there is a possibility that empathy can be controlled by other mechanisms and factors, more specifically they showed how people with disabled mirror neuron area of the brain are still capable of empathetic responses. An experiment conducted by Singer et al. From 2006 [5] examines how other feelings and circumstances influence empathy and therefore, it also challenges the idea of mirroring theory. Moreover, there are several factors to consider. The studies display only correlational results. If the same activity is found in two conditions, it just indicates that the activation and the condition have a correlation, not a cause-and-effect relationship. Furthermore, many of the research used as

examples, as well as general studies in the field of empathy, concentrate on the negative effects (pain, disgust, etc.), since the brain responds differently to good and negative stimuli, this may be a restriction.

When considering the macaque analysis, as well as all other experiments that compare brain function using fMRI, identical fMRI activations in two situations (where an operation is done and where the action is observed) do not actually mean that the same mechanism is at work (Grill-Spector et al, 2001) [13]. This suggests that when identical brain regions are stimulated in two different situations, a mirror machine response is triggered. The low spatial resolution of fMRI, as well as the hemodynamic reaction, contribute to this restriction (delivery of blood to neural tissues). This means that when identical brain regions are stimulated in two different situations, a mirror system response is triggered. However, there is a solution, which requires the use of multivariate pattern analysis (MVPA). MVPA is dependent on knowledge levels rather than activation levels, which eliminates the hemodynamic reaction limitation.

Empathy is a broad and complicated psychological concept that refers to a person's cognitive and emotional reactions to the experiences of others. It's important to remember that the suffering experienced as a result of emotional empathy isn't quite the same as the other person's emotions. According to Hodges and Myers [19], while empathetic people are upset when someone falls, they are not in the same physical pain as the person who has fallen. When it comes to discussions of compassionate human nature, this form of empathy is particularly important. There is a connection between feeling empathetic concern and being willing to assist others. According to Hodges and Myers [19], “many of the most admirable manifestations of human conduct, such as assisting strangers and stigmatized individuals, are believed to have empathetic roots.”. Many different behaviors are included in the definition of empathy, therefore, and each of them can be studied separately, therefore, it is difficult to generalize the results of an experiment involving only one element of empathy, while talking about the importance of the role of mirror neurons in empathy.

Final Conclusions

As mentioned at the beginning of the essay, the detection and observation of mirror neurons in macaque monkeys in 1992 by Rizzolatti [20] and his team in Parma, piqued the interest of

many psychologists, leading to new experiments and speculation about the role of mirror neurons in empathy. Mirror neurons and their role in empathy have been the subject of numerous studies for years. The evidence is supported by combining multiple psychological studies that provide both supporting and contradictory data. Some of the given research showed that mirror neurons play a role in empathy, specifically regarding emotions like pain and disgust, and also in maternal empathy. On the other hand, findings that came to the opposite conclusion were presented, such as the fact that one's level of empathy for another human is influenced by one's subjective perception, the unfounded broken mirror theory, and case studies of CIP patients. However, the limitations and difficulties that most of these studies face, pose a problem, as they prevent the possibility of reaching a credible assumption.

The neural activations scanned when observing emotions displayed patterns suggest the significant importance of mirror neurons in empathy. It is certain that mirror neurons are not the only basis of empathy, as well as that they do not automatically engage an empathetic response, but they certainly do play a role. In conclusion, we can argue that mirror neurons influence empathy to a limited extent, considering that there is a lot of contradicting research. However, to draw a strong conclusion, more reliable research is required, along with more dependable theories and techniques, but for now, the role of mirror neurons in empathy is certainly undeniable.

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