UNIVERSITÀ DEGLI STUDI DI PADOVA

Dipartimento di Dipartimento di Psicologia dello Sviluppo e della Socializzazione

Corso di laurea in SCIENZE E TECHNICHE PSICOLOGICHE L5

Elaborato finale

DAI NEURONI SPECCHIO ALL'EMPATIA

FROM MIRROR NEURONS TO EMPATHY

Relatrice/Relatore
Prof.ssa PAOLA SESSA

Laureanda: MAEDE RAHIMI

Matricola:1180279

Anno Accademico   2021-2022

ABSTRACT

In this research, in the first place, I tried to satisfy my curiosity and answer my questions about brain functions, particularly mirror neurons' functional properties during feeling and experiencing regular activities or a brand new one and answer this question that how we predict others' emotions and decisions while observing them. The most important intention of this research is to find a relation between mirror neurons activities in the brain and predict others' emotions and mind-reading of another person during the observation of his executing an action or sense some emotions like disgust, by face recognition of another person, empathizing with other's pain turns on areas in our own brain the same as when we ourselves experience that pain. By predicting another person's actions and mind-reading, we can sense their feelings by mirror neuron activation, and maybe it causes empathy.

ASTRATTO

In questa ricerca, in primo luogo, ho cercato di soddisfare la mia curiosità e rispondere alle mie domande sulle funzioni cerebrali, in particolare sulle proprietà funzionali dei neuroni specchio durante il sentire e sperimentare attività regolari o nuove di zecca e rispondere a questa domanda che come prevediamo gli altri emozioni e decisioni osservandole. L'intenzione più importante di questa ricerca è trovare una relazione tra le attività dei neuroni specchio nel cervello e prevedere le emozioni degli altri e la lettura della mente di un'altra persona durante l'osservazione della sua esecuzione di un'azione o percepire alcune emozioni come il disgusto, attraverso il riconoscimento facciale di un'altra persona, entrare in empatia con il dolore dell'altro accende aree del nostro cervello come quando noi stessi sperimentiamo quel dolore. Prevedendo le azioni di un'altra persona e la lettura della mente, possiamo percepire i suoi sentimenti tramite l'attivazione del neurone specchio e forse provoca empatia.

FIRST CHAPTER

MIRROR NEURONS

Mirror Neurons are a distinct class of neurons that discharge both when individuals perform a given motor act and when individuals observe others' actions.

A basic brain mechanism that transforms sensory representations of others' behavior into one's own motor or visceromotor representations concerning that behavior and depending on the location can fulfil a range of cognitive functions including action and emotion understanding.

Mirror neurons respond to actions that we tend to observe in others. The attention-grabbing half is that mirror neurons fire within the same manner after we recreate that action ourselves. Except for imitation, they are liable for a myriad of other subtle human behavior and thought processes.

In humans, brain activity in line with that of mirror neurons has been found within the premotor cortex, the supplementary motor cortex, the first somatosensory cortex, and the inferior parietal cortex.

Neurophysiological (EEG, MEG, and TMS), and brain-imaging (PET and fMRI) experiments provided robust proof that a fronto-parietal circuit with properties almost like the monkey's mirror neuron system is additionally present in humans. As within the monkey, the mirror neuron system is recognized in IPL and in a frontal lobe sector shaped by the ventral premotor cortex and the posterior part of the inferior frontal gyrus (IFG).

The brain acts, first and foremost, as a planning and control system for organisms whose main job is exploring their surrounding world and facing its challenges and that can catch positive opportunities and escape threats.

These neurons by selection responded not only to present actions but additionally to past or future actions, facilitating social coordination.

Observing others' actions and emotions recruits completely different brain networks, every of them transforms the sensory data regarding others' actions and emotions into one's own motor and visceromotor representations of these actions and emotions.

MIRRORING ACTIONS(ACTION AND OBSERVATION)

A network of cortical areas becomes active throughout action observation in monkeys and humans. Functional magnetic resonance imaging studies in monkeys show that observed action activates the dorsal and therefore the ventral bank of the superior temporal sulcus, that contains high-order visual areas that are usually concerned in the motion process.

More recently, pyramidal tract neurons (PTNs) originating from area F5 were found to reply to action observation. A subset of PTNs, that fired throughout action execution, showed suppression of their discharge throughout action observation, this repressive result might need a role in preventing the incidence of movement throughout action observation.

DO OR NOT TO DO WHAT I SEE?

Mukamel et al. (2010) confirmed this idea: they found eleven anti-mirror neurons that raised their firing rate once the patient was executing a specific action however diminished their firing rate below baseline once the patient discovered some other people perform this action. Given the connections of the SMA, such neurons during this area would be ideally equipped to open the gate to M1 throughout action execution and shut it throughout action observation. useful magnetic resonance imaging is blind to the distinction between the mirror and anti-mirror neurons as a result of it simply measures will increase in metabolism, that in each is the same quantity.

GOAL ENCODING

What do mirror neurons encode during action observation?

By comparison PMv and IPL activation throughout the observation of similar actions performed with totally different effectors, an MRI study showed that PMv goal encoding cared-for be in the main mapped in a very somatotopic manner, whereas IPL goal encoding cared-for be in the main clustered according to the positive or negative that means of the observed action. Because of their goal sensitivity, it is been claimed, from the earliest studies, that mirror neurons have a role in understanding others' actions, enable the observer to identify the goal of the action relying mainly on her or his own motor process and representations.

THREE DIFFERENT LINES OF EVIDENCE

A first line: how deeply executing and observing actions are interlinked

It has been shown that observant associate action will facilitate acting a congruent action interfere with acting associate incongruent action, observant action can have an effect on the observer's ability to judge what another individual is doing. Crucially the after-effect vanished after delivering TMS over participant's PMv; this implies a causative role for PMv in decision making other's action goals.

A second line: the crucial role of motor expertise in identifying others' action goals.

It has been shown that individuals will improve their ability to judge the goal of an uncommon action just by activating that action themselves; this improvement happens even after they practice while blind.

The third line: comes from studies on transient and permanent lesions of brain motor areas. Transient lesions of PMv are shown to considerably impair action-goal recognition have a casual role in understanding others' actions. Patients with parietal or frontal brain lesions might need selective deficits in each producing and recognizing actions. The mirror mechanism incorporates a role in action understanding doesn't imply that each motor deficit ought to lead to apraxia impairment of action understanding. The patient's impairments in understanding others' actions weren't associated with ideomotor apraxia itself, as shown by the existence of patients with ideomotor apraxia who don't have gesture-recognition deficits. Instead, patients' impairments were rather because of the extension of their lesions in parietal and frontal areas, that are invested with mirror properties.

MIRRORING EMOTIONS

A link between action and emotion is already recommended by the etymology.The mirror mechanism operates within the emotion domain and plays a key part in the process and understanding of the emotions of others. We focus in the main on one emotion: disgust. the most cortical node is found within the anterior part of the insula (AI). The insula is connected with varied cortical areas and sends degressive connections to emotional core structures like the hypothalamus, periaqueductal gray, and centromedial nuclei of the amygdala.

The human insula is formed by four distinct sub-regions: a sensorimotor, an olfactory-gustatory, a socio-emotional, and a cognitive field. Electrical stimulation of the AI elicits disgust in each human and monkey.

Is that my emotion or yours?

The AI seems to be involved not only in feeling disgust but also in observing a person else being disgusted. the electrical stimulation of the rostral pregenual ACC elicited a burst of laughter, regularly followed through a change within the emotional state, as indicated through an unexpected look of mirth. seeing someone else laughing and electrical stimulation inducted personal laughter and mirth activate the equal site inside the ACC.

«VITALITY AFFECTS» OR «VITALITY FORMS»

A grip can be «vigorous» or «sensitive» attention to the kinds of gestures and emotional reactions can offer information about an agent's affective states, moods, attitudes, and even character traits.

Stern coined the term «power forms « or vitality affects», to focus on that those forms underline our most fundamental social interactions, as a result deeply shaping our experience of ourselves and of others. Findings suggest that the DCI performs a key component within the production and control of different vitality forms, by way of modulating the cortical circuit controlling actions. It's far worth noting that this modulation differs significantly from that associated with the activation of the AI, which is commonly involved in driving emotionally laden behaviour.

EMBODYING EMOTIONS

The latest theories of embodied cognition suggest new ways to study how we process emotional data. The theories propose that perceiving and considering emotion contain perceptual, somatovisceral, and motoric reexperiencing (together referred to as "embodiment") of the relevant emotion in oneself. The embodiment of emotion, while caused in human individuals with the aid of manipulations of facial expression and posture in the laboratory, causally impacts how emotional data is processed. Congruence between the recipient's physical expression of emotion and the sender's emotional tone of language, for instance, helps comprehension of the communication, whereas incongruence can impair comprehension.

CONCLUDING REMARKS

Mirror-based processing is not enough to fully undesrtand others' actions, feelings, or vitality forms from the inside. Understanding can be considered a multilevel procedure. The primary level involves identifying which outcome is the goal of the observed action and which emotion or vitality from other people are showing. Similarly, levels may also contain representing other's mental states which provide motives explaining why the action, the emotion, or the vitality form came about and how those reasons are linked to other's minds and their behaviour.

SECOND CHAPTER

HEBBIAN LEARNING

The term Hebbian learning derives from the studies of Donald Hebb, who proposed a neurophysiological account of learning and memory based on a simple principle: ‘while an axon of cell A is near enough to excite a cell B and repeatedly or constantly takes part in firing it, a few increases process or metabolic alternate takes place in one or both cells such that a’s efficiency, as one of the cells firing B, is accelerated’. A careful analysis of Hebb’s precept well-known shows his knowledge of the significance of causality and consistency. He doesn’t write that neurons need to fire collectively to grow the performance of their connection however that one neuron desires to repeatedly (consistency) take part in firing (causality) the other. Carla Shatz (but no longer Hebb himself) has paraphrased his principle in a rhyme: ‘what fires together, wires together’. While mnemonic, this precis is the risk of obscuring the importance of causation in Hebb’s actual work: if two neurons fire together, i.e., on an equal time, the firing of 1 can't reason that of the other. Temporal priority, rather than simultaneity, is the signature of causality and could suggest that ‘one took element in firing the other’.

NEUROPSYCHOLOGICAL UNDERSTANDING

Within the Nineties, neurophysiologists laid the inspiration for our current, neurophysiological knowledge of Hebbian learning based on STDP. Experiments in which two related neurons were stimulated with numerous stimulus onset asynchronies evidenced an uneven window of STDP. when an excitatory synapse connects onto an excitatory neuron, if the presynaptic neuron is stimulated forty ms or much less before the postsynaptic neuron, the synapse is potentiated. by using comparison, if the presynaptic neuron is stimulated simply after the postsynaptic neuron the synapse is depressed. If the 2 neurons clearly fire collectively, the inevitable temporal jitter could make the presynaptic neuron often fire just earlier than and sometimes just after the postsynaptic neuron, and potentiation and depression could annul each differently over time, main to no substantial net STDP. As Hebb had anticipated, causation is for this reason the key to synaptic plasticity.

HEBBIAN LEARNING AND MIRROR NEURONS

Mirror neurons exist at least inside the monkey's ventral premotor (PM; region F5) and inferior posterior parietal (region PF/PFG) cortex. Neurons in these two regions are reciprocally related PF/PFG sends data to PM and PM is returned to PF/PFG. Neurons in region PF/PFG also are reciprocally related with those in the superior temporal sulcus (STS), an area recognized to reply to the sight of body moves, faces, and the sound of movements. other fundamental regions contain mirror neurons as well but to demonstrate how the Hebbian learning account of the emergence of mirror neurons ought to in precept provide an explanation for the emergence of mirror neurons a simple system encompassing only Brain regions, STS and PM, together with reciprocal connections from STS to PM and from PM to STS suffices. In this phase, we can adopt an enormously coarse temporal resolution of approximately 1 s for the primary approximation of the Hebbian account of ways mirror neurons could arise. At this degree of description, Hebbian learning makes predictions on the neural level that are like those that associative sequence learning—a cognitive version to start with advanced to explain the emergence of imitation makes on the functional level.

RE-AFFERENCE

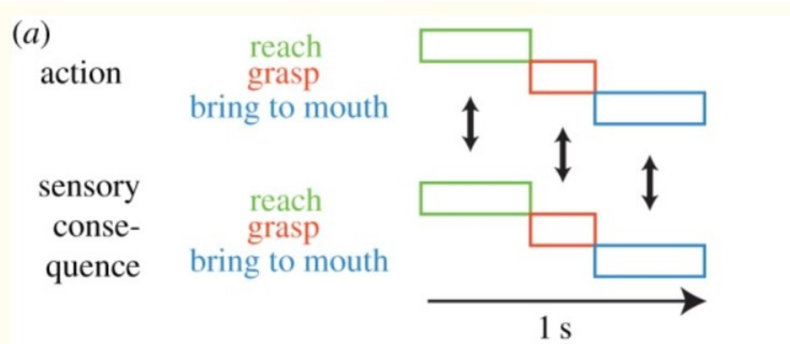
while a person executes a brand new hand movement, he sees and hears himself perform this movement. This sensory input as a consequence of one's own action is known as 're-afference'. The normal tendency of commonly growing babies to stare at their very own hands guarantees that such re-afference will happen often while the baby performs new actions. As a result, activity in PM neurons cause a particular action, and activity in neurons responding to the sound and vision of this particular action in the STS could, to the primary approximation, constantly and repeatedly overlap in time. as an example, a grasping neuron in STS can have firing in an effort to consistently overlap in time with the activity of PM grasping neurons while the person observes himself grasp.

THE MICRO-TEMPORAL HEBBIAN PERSPECTIVE AND PREDICTION

A key function of our current understanding of Hebbian learning is its super sensitivity to the exceptional temporal relations of pre-and postsynaptic activity.

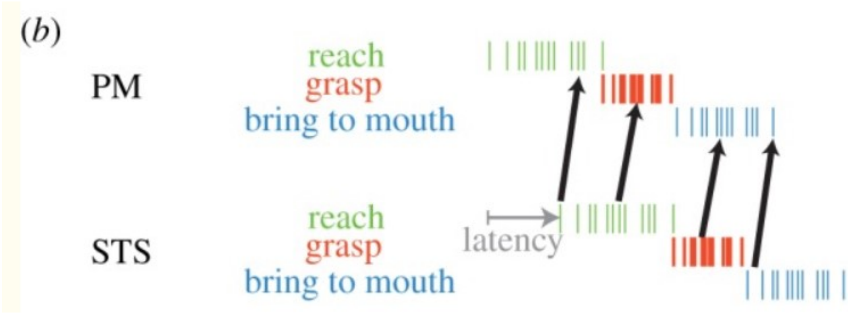
(a) Predictive forward connections

In the real world, the execution of an action and the sight and sound of each phase of an action occur at the same time, and one might therefore predict that corresponding phases inside the sensory and motor domain might come to be related.



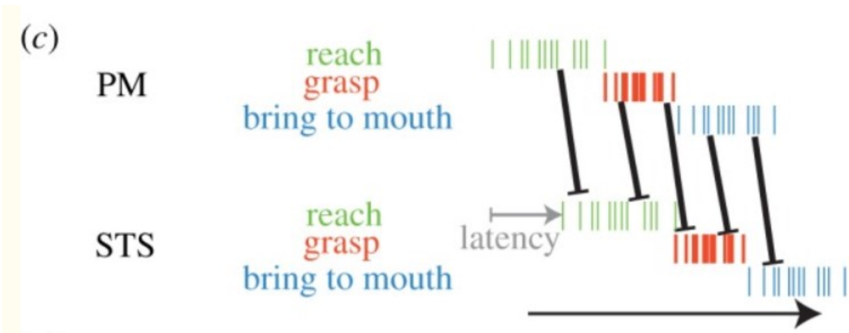
b) Inhibitory backward connections and prediction errors

as an alternative, latencies shift the responses within the STS relative to the premotor (PM) neurons, and Hebbian learning at a great temporal scale predicts associations between subsequent phases, i.e. predictions.



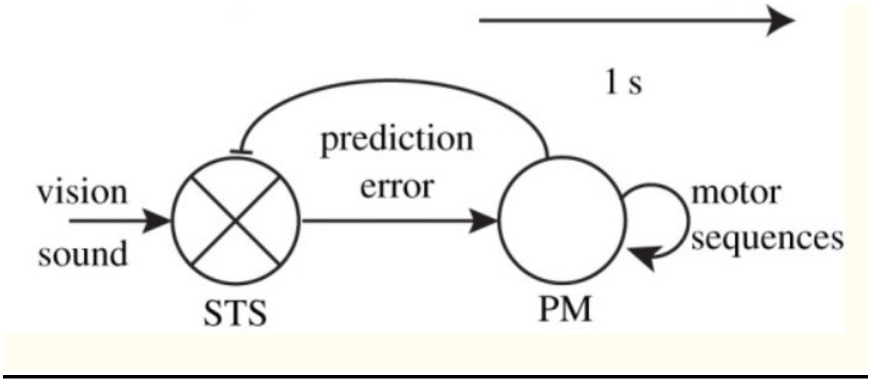
(c) regulating learning and contact points with other models

Inhibitory feedback from PM to STS is likewise subjected to Hebbian learning and generates prediction mistakes inside the emerging dynamic system, e.g., a person learns a brand-new talent like playing the piano, PM neurons fail to are expecting the auditory re-afference, and new learning occurs due to the fact new input from STS is sent to PM neurons with the capability for Hebbian learning.



(d) Hebbian learning and joint actions

individuals can act collectively with unexpected temporal precision. Pianists in a duet can synchronize their movements within 30 ms of a leader. Given about two hundred ms of sensorimotor delays we noted above, how is this possible? need to not it takes two hundred ms for a musician to hear what the leader performed and reply to it? one of the effective implications of a fine-grained analysis of Hebbian learning is that due to the fact the synaptic connections are trained through re-afference that consists of typical human sensorimotor delays, they train the connections from STS to PM, to perform predictions into the future with a time-shift in order to offset the sensorimotor delays which are encountered while performing with some other individual subject to similar delays. this is because it will take about the identical time (approx. two hundred ms) for your motor program to activate your STS neurons, as it would take on your motor program to activate my STS neurons while I am listening/looking at you. as a result, Hebbian learning reafference trains sensorimotor predictions that allow accurate joint actions regardless of long sensorimotor delays.



(e) Hebbian learning and projection

A crucial consequence of the notion that the mirror neuron system is wired up based on re-afference is that the brain relates to the inner states that have been present while we produced a certain action with the sound and vision of that action. for this reason, while we witness the movements of others, the pattern of motor activity that could be predictively activated within the witness is not a lot a reflection of what occurs inside the brain of the actor, however instead of the projection of what took place in our own brain when we executed such actions. due to the fact, individuals share about 99% of their genes with different humans, and likely over 90% of genes with macaques, if hidden motor states that happened in the course of our own movements are a decent version for those that appear in the brain of some other human or monkey isn't always unreasonable. It constitutes an informative ‘prior’ that can be updated through opposite evidence if available. however, the more different the observer is from the observed agent, the more the projective nature of this process needs to emerge as evident.

MOTOR SYSTEM

due to the fact mirror neurons have been first observed in PM and inside the posterior parietal areas, which control actions, motor aspects of mind-reading had been within the limelight. but proof from numerous resources now indicates that the highest levels of the primary somatosensory cortex also are vicariously activated while we see the movements of others and the secondary somatosensory cortex when we see others be touched. further, areas involved in experiencing emotions also emerge as vicariously activated when we witness others experience the same feelings, which include the insula for disgust, pain, and satisfaction, the rostral cingulate for pain, and the striatum for reward. We still lack single-cell recordings that show that vicarious somatosensory and emotional activations in fMRI are resulting from single cells responding to both the experience and observation of somatosensation and emotions. but, from a Hebbian learning point of view, mirror-like neurons for somatosensation or emotions are not unexpected. every time something touches our skin, we see our body touched, and we sense the somatosensory stimulation. in contrast to in the sensorimotor system, in which the motor activity precedes the visual/auditory re-afference, inside the case of feeling touched, both the tactile and visual/auditory signal could be affected by similar latencies relative to the outside experience.

CONCLUSION REMARKS

Decades ago, the mirror neurons had been first mentioned, they generated a vision in which the motor systems play a privileged role in analyzing the mind of others via embodied cognition. studies recommend that what we recognize about spike-timing-dependent synaptic plasticity shapes our current knowledge of Hebbian learning and gives a framework to explain not only how mirror neurons ought to emerge, however additionally how they emerge as endowed with predictive properties that could allow quasi-synchronous joint actions. studies show that this can create a system that could offer an approximate method to the inverse problem of inferring hidden internal states of others from observable adjustments inside the world, however, this answer is a projection plagued by egocentric cases. studies additionally prove those mirror neurons are likely a special case of vicarious activations that Hebbian learning and fMRI data shows also apply to how we share the emotions and sensations of others.

THIRD CHAPTER

EMPATHY

One of our species' best assets is imperative to connect to others, exercised frequently via our ability for empathy. Empathy – the ability of one individual (a perceiver) to share and understand the inner states of someone else (a goal) – impels us to take care of our young, to cultivate and transmit understanding, and coordinate collective action in the direction of shared targets. Given its essential role in social functioning, it is no wonder that empathy is related to adaptive consequences including increased emotional well-being, more social connectedness, and better health. Empathy also facilitates supporting behavior, cooperation, and altruism Empathy, by definition, needs to be preceded by using some level of perceived information or familiarity. to soften the edges of our divisive world and open our society's narrative to the viewpoints of others to advantage a greater valid, inclusive, and just knowledge of our world it is crucial to start from the ground up. step one is to apprehend the characteristic of empathy in our lives and attempt for increasing the empathy and compassion that we carry throughout every day.

As a society, our propensity to have interaction face to face with others has seemed to decrease as time and technology advances. it's far natural to shy away from discomfort and stay complacent while in a place of comfort, and empathy at times may be notably uncomfortable. It pains us to be involved inside the pain of others, even though we are playing a passive observer position. The pain of others is automatically processed within us as we apprehend the pain relative to our own neuronal firing. This automatic empathetic processing is unwavering and unyielding, so alternatively, we select, both consciously and secondarily, to keep away from situations that might especially cause this automatic processing in uncomfortable and poignant ways.

THE EMPATHY UMBRELL: THREE RELATED BUT DISTINCT COMPONENTS

Empathy is a multicomponent phenomenon regarding processes that permit individuals to share, understand and respond to others' feelings. despite the fact that researchers do not usually agree on the exact definition of empathy, many contend that it includes at least three components. First, empathy requires an affective component, known sometimes as affective empathy, emotion contagion, or experience sharing, wherein humans vicariously sense others' emotional states. second, empathy involves a cognitive component, known as the theory of mind, mentalizing, cognitive empathy, or perspective-taking, whereby humans consider others' thoughts and stories. ultimately, empathy includes a motivational component, which has been known as compassion, prosocial concern, or empathic concern, which refers to the preference to promote others' well-being or alleviate their suffering.

EMPATHY IN CONTEXT: DIFFERENT SITUATIONS REQUIRE DIFFERENT COMPONENTS

A massive part of research on empathy-associated consequences investigates empathy as a whole. But, there are at least 4 domains wherein researchers have tested how person components of empathy – in place of empathy as a whole – yield distinctive consequences. these domains consist of helping, occupational burnout, relationship satisfaction, and negotiation.

EMOTION REGULATION

Emotion regulation additionally performs an essential role in figuring out key effects associated with empathy, mainly those that relate to experience sharing. for example, experience sharing may not be detrimental in caregiving-related occupational settings if people can regulate their emotions. consistent with this prediction, among social workers, emotion regulation becomes negatively related to occupational burnout, possibly because of a progressed sense of efficacy. while unbridled experience sharing is probably a liability in this context, the potential to sense with a patient while additionally regulating one's vicarious emotions might be an asset. Emotion regulation abilities seem relevant to different effects, including relational consequences and helping. vicarious responses to others' suffering can be overwhelming among people who've low regulatory management over their feelings. his experience can culminate in excessive rates of personal distress, that may motivate people to take care of their very own vicarious pain rather than alleviate a goal's suffering. Conversely, people who are better capable of regulating their feelings experience much less personal distress and might consequently be greater willing to assist targets in need. because empathy-related components depend on separable neural systems, the field of social neuroscience has already made considerable development in the direction of the goal of characterizing instances while components do (or do no longer) track collectively. as an example, despite the fact that effective and cognitive channels can independently contribute to judgments of others' emotional states psychological and social phenomena, including empathy, are absolutely integral in our experience as a human. even as there is still a massive amount of research to be executed, we are beginning to see that as a minimum one portion of our innate nature of empathy lies in those mirror neurons. Scientifically, we are still at the cusp of composing a cohesive and indisputable explanation of the idea of empathy and the entire explanation within the brain. however, this knowledge of the mirror neuron system and how it could relate to empathy offers extra meaning to the Jesuit value of living not only for others but with others and can similarly inform the presiding Jesuit question of ways we need to live.

NEUROSCIENCE OF EMPATHY

HUMAN BRAIN REGIONS WITH MIRRORING CAPABILITIES AND EMPATHY

As we progress the discussion into the abilities of human beings to experience vicariously, it is critical to apprehend the transition from acknowledging the presence of individual mirror neurons in monkeys to the greater expansive assumption of a similar mirror neuron system in humans without direct proof of mirror neurons themselves. In each case, it is concluded that these structures are functionally analogous to their mirroring capabilities. consequently, in our exploration into neural mirroring and empathy, the self-assurance in a human mirroring system inside the brain is enough because of the information of individual mirror neurons inside the human brain in the context of empathy.

In 2012 a meta-analysis of the research on motor mirror neurons was performed via Molenberghs, Cunnington, and Mattingley. This analysis quantitatively predicts the probability that motor mirroring abilities are found in diverse human brain systems and pathways based on the cumulative information and fMRI images of preceding mirror neuron research. it can be concluded that mirroring activation is significant inside the brain, as Keysers and Gazzola (2009) and Heyes (2010) hypothesized. The outcomes of this careful inspection of the evidence of visuo-motor, emotional and auditory pathways strengthened the speculation that mirror neurons may extend beyond simple motor abilities. within the case of emotional mirroring, the importance of inactivation of associated structures became discovered, including in the amygdala, insula, and cingulate gyrus. All three of that are related to the limbic system—a grouping of structures operating together to process and alter emotion (Molenberghs, Cunnington & Mattingley, 2012). As defined by the meta-analysis above, the ability of mirror neurons as a primary mechanism for empathy turned into increased in addition to the discovery of diffusion of modalities of mirror neurons with particular functions that expand beyond motor mirroring. This shows that the overarching quality of self-other mirroring happens throughout many distinctive complicated systems inside the brain, a number of that are explicitly tied to emotion and empathetic response, while others are tangentially tied to an empathetic understanding of others.

CONCLUSION

at the same time as it still can be too early to definitively declare the great presence of individual mirror neurons throughout the human brain, there is powerful proof to indicate that a mirroring system exists and consists of out analogous mirroring functions which could, in turn, serve as a neural basis for empathy. analyzing mirror neuron correlate systems in human beings, including the mirroring system concerned with emotional facial recognition, can inform the argument that empathy is rooted in mirror neurons. human beings are amazingly gifted at reading minor modifications in facial expression to properly interpret emotion (Schmidt & Cohn, 2001). This trait of facial recognition is theorized to be selected evolutionarily due to the fact early humans, who should apprehend, work with and understand others were more likely to survive. It carefully follows that facial recognition and expression understanding are intently associated with empathy; in the end, it is much less complicated to sense empathy for someone while you could see their face, in comparison to when you do not have to witness their facial expressions. further, it is hard to experience empathy for things that do not have facial expressions that we will without difficulty perceive. We sense no empathy for a desk bearing a heavy weight on its back, while we are empathetic toward people who carry notable weight on their shoulders, literally or metaphorically. we are able to apprehend other people because we inherently understand ourselves, whereas we've got little sense or comparison for understanding things without facial expression as a physically represented indicator of emotion.

In 2003, one of the first research to examine mirror neurons in direct relation to human empathy was conducted. whilst in a functional MRI machine, the members have proven images of others, and either they just appeared, or the members attempted to imitate the facial expression. They observed that a few of the same brain regions were activated both for observation and imitation of expression. The reputation of a mirror neuron system that is particularly associated with empathy via facial processing holds wide support), connecting these studies even further to social cognition.

CONCLUSIONE

nello stesso momento in cui può essere ancora troppo presto per dichiarare definitivamente la grande presenza di singoli neuroni specchio in tutto il cervello umano, vi è una potente prova per indicare che un sistema di rispecchiamento esiste e consiste in analoghe funzioni di rispecchiamento che potrebbero, a loro volta, servono come base neurale per l'empatia. l'analisi dei sistemi correlati ai neuroni specchio negli esseri umani, incluso il sistema di mirroring interessato al riconoscimento facciale emotivo, può informare l'argomento secondo cui l'empatia è radicata nei neuroni specchio. gli esseri umani sono straordinariamente dotati nel leggere modifiche minori nell'espressione facciale per interpretare correttamente le emozioni (Schmidt & Cohn, 2001). Si teorizza che questo tratto del riconoscimento facciale sia selezionato evolutivamente a causa del fatto che i primi umani, che avrebbero dovuto apprendere, lavorare con e capire gli altri, avevano maggiori probabilità di sopravvivere. Ne consegue attentamente che il riconoscimento facciale e la comprensione dell'espressione sono strettamente associati all'empatia; alla fine, è molto meno complicato provare empatia per qualcuno mentre potresti vedere il suo viso, rispetto a quando non devi assistere alle sue espressioni facciali. inoltre, è difficile provare empatia per cose che non hanno espressioni facciali che percepiremo senza difficoltà. Non proviamo empatia per una scrivania che porta un peso pesante sulla schiena, mentre siamo empatici verso le persone che portano un peso notevole sulle spalle, letteralmente o metaforicamente. siamo in grado di apprendere le altre persone perché comprendiamo intrinsecamente noi stessi, mentre abbiamo poco senso o paragone per comprendere le cose senza l'espressione facciale come indicatore di emozione rappresentato fisicamente.

Nel 2003 è stata condotta una delle prime ricerche per esaminare i neuroni specchio in relazione diretta con l'empatia umana. mentre in una macchina per risonanza magnetica funzionale, i membri hanno provato immagini di altri e o sono appena apparsi, oppure i membri hanno tentato di imitare l'espressione facciale. Hanno osservato che alcune delle stesse regioni del cervello sono state attivate sia per l'osservazione che per l'imitazione dell'espressione. La reputazione di un sistema di neuroni specchio che è particolarmente associato all'empatia attraverso l'elaborazione facciale ha un ampio supporto), collegando questi studi ancora di più alla cognizione sociale.

REFERENCES

1. R. Mukamel, A.D. Ekstrom, J. Kaplan, M. Iacoboni, I. Fried Single-neuron responses in humans during execution and observation of actions Curr. Biol., 20 (2010), pp. 750-756
2. Rizzolatti, G., & Sinigaglia, C. (2016). The mirror mechanism: a basic principle of brain function. Nature Reviews Neuroscience, 17(12), 757-765.
3. Keysers, C. & Gazzola, V. Expanding the mirror: vicarious activity for action, emotion and sensation.Curr. Opin. Neurobiol. 19, 666–671 (2009).
4. Keysers, C., & Gazzola, V. (2010). Social neuroscience: mirror neurons recorded in humans. Current biology, 20(8), R353-R354.
5. Keysers, C., Paracampo, R., & Gazzola, V. (2018). What neuromodulation and lesion studies tell us about the function of the mirror neuron system and embodied cognition. Current opinion in psychology, 24, 35-40.
6. Keysers, C., & Gazzola, V. (2014). Hebbian learning and predictive mirror neurons for actions, sensations and emotions. Philosophical Transactions of the Royal Society B: Biological Sciences, 369(1644), 20130175.
7. Weisz, E., & Cikara, M. (2021). Strategic regulation of empathy. Trends in Cognitive Sciences, 25(3), 213-227.
8. Zaki, J., & Ochsner, K. N. (2012). The neuroscience of empathy: progress, pitfalls and promise. Nature neuroscience, 15(5), 675-680.
9. Bekkali, S., Youssef, G. J., Donaldson, P. H., Albein-Urios, N., Hyde, C., & Enticott, P. G. (2021). Is the putative mirror neuron system associated with empathy? A systematic review and meta-analysis. Neuropsychology review, 31(1), 14-57.
10. Steward, M. (2017). Empathy and the Role of Mirror Neurons.
11. Molenberghs, P., Cunnington, R., & Mattingley, J. B. (2012). Brain regions with mirror properties: a meta-analysis of 125 human fMRI studies. Neuroscience & Biobehavioral

Reviews, 36(1), 341-349.

12. Schmidt, K. L., & Cohn, J. F. (2001). Human facial expressions as adaptations: Evolutionary questions in facial expression research. American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists, 116(S33), 3-24.
13. Carr, L., Iacoboni, M., Dubeau, M. C., Mazziotta, J. C., & Lenzi, G. L. (2003). Neural mechanisms of empathy in humans: a relay from neural systems for imitation to limbic areas. *Proceedings of the national Academy of Sciences*, *100*(9), 5497-5502.