In the Footsteps of Another:
The Mirror Neuron Network Behind Empathy and Imitation

Figure 1: Unsell, B. (n.d). *My Grandmother Maryse Norgret Göbel* [Image].

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Introduction

People often say that they would take a bullet for their loved ones. That they would throw themselves into danger to save those they care about. But what about a stranger - a person you hold no emotional ties to and know nothing about? Often, we see news articles about good Samaritans saving the lives of those in distress in life-threatening moments. They jump into action and become heroes who do what others cannot for no self-benefit. What drives them to put themselves in danger to save someone else? Morality? Justice? Sheer goodwill?

Maryse did not know how she had ended up in this situation. Full of feelings of complexity, she stared at the apartment door tightly closed at the end of the hall. Beyond that door would be the soldier she would be smuggling out of the country. Although she did not know his name or face, she knew his dire situation from what the officer had told her. Delivering a special knock on the door, the officer gave her a curt nod before turning and leaving. No one could know who or why he had been there. Maryse took a deep breath before slowly opening the door and coming face-to-face with the Legion soldier. Despite knowing the man she would help was wounded, a small gasp still involuntarily escaped. The man lay reclined on an armchair with his feet resting on a hassock. His face was contorted in pain as he attempted to sit up to give his greetings. Maryse took in the sight of bandages wrapped around the man's waist, peeking out through his shirt and dark purple bruises lining his legs and arms. She couldn't help but wince and felt a pang in her heart. Understanding that this soldier was being hunted down and seeing his pained state made Maryse even more determined to get him out of Algeria. She would be the one to get him home no matter the danger.

In the late 1950s, during the French-Algerian war, my grandmother did just that. She placed herself in danger to save a French Foreign Legion soldier. At the time, my French grandmother was a professional ballet dancer dancing in Algeria with her company. One fateful day, an officer approached her, asking for her help in smuggling a wounded soldier back to France. The man was being hunted down, and someone was needed to play the part of his nurse to avoid suspicion. Although I do not know why the officer chose my grandmother for the job, she did not refuse him. She went on to sneak the soldier out of Algeria back to her mother's house in France and went beyond her fake role as a nurse to help the man recover for the next six months. Ultimately, the soldier went on to make a full recovery, returning to his duties while my grandmother was a changed woman. She went on to retire from her professional ballet career and eventually became a certified cardiopulmonary technician, saving the lives of many more.

No matter how you look at it, my grandmother had no ties nor motive to help the soldier aside from perhaps a sense of kindness and duty. Although I do not know her

thoughts at that moment, what if we could examine this story from a scientific perspective? A reason that may have aroused empathy and a sense of morality?

In the past three decades, a new area of study within neuroscience has arisen referred to as “mirror neurons.” A class of neurons thought to be involved in motor mimicry and emotions, in particular, empathy. The question is, do we have enough evidence to suggest that mirror neurons are responsible for a stranger’s kindness? Something to consider, however, is that mirror neurons are not solely responsible for the sensation or activation of empathy, they are simply another method to experience those emotions.

In 1992 scientists published a paper first describing mirror neurons as a class of monkey premotor cells. They found that these cells would discharge “both when the animal performed a goal-directed action (e.g., grasping a food morsel) and when the animal observed an experimenter or another monkey performing the same or similar action” (Bonini, 2017). Unfortunately, unlike the directly observable activation method of mimicry, the relationship between the neurons and empathy is much more complex. This paper was the first recorded study of mirror neurons whose information proceeded to spark a massive wave of interest in the scientific community.

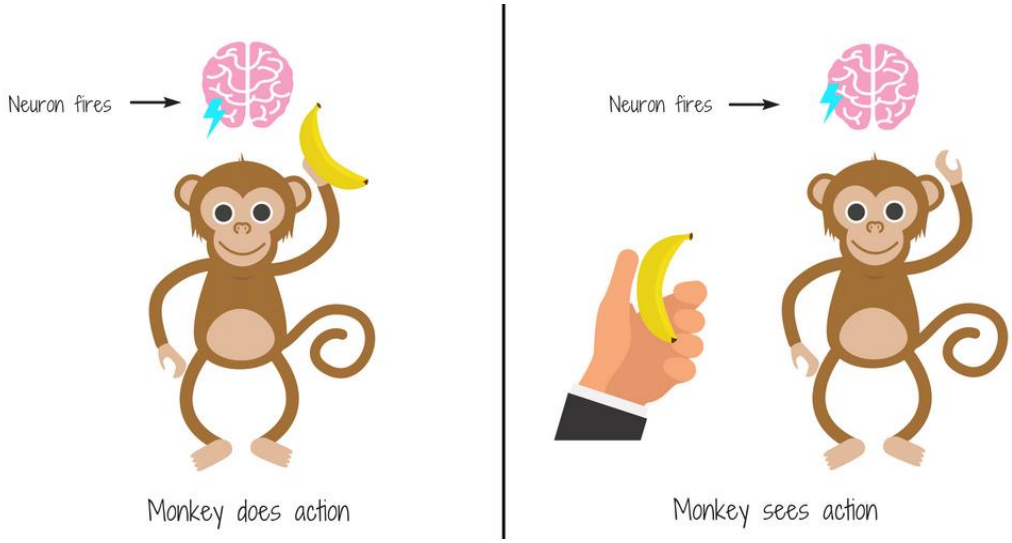

Figure 2: Badinsoft. (2023, February). *Mirror neurons in monkeys* [Image]. Badinsoft. https://www.badinsoft.com/wp-content/uploads/2023/02/mirror-neurons-monkeys-1.png

As within almost any field of study regarding emotions, the attempt to study the mirror neurons' linkage to emotion has been a lot more elusive and obscure. Although

one may think the mirror neurons' mimicry function and effects on emotion are two separate capabilities, in reality, research has placed the two together as interdependent. A clarifying example may be if the observer witnesses another person accidentally getting cut by a knife, their motor neurons activate from viewing the action and stimulate the emotional centers of the brain due to the action type being harmful. Thus, the observer experiences “empathy.”

Empathy is a word that has been thrown around a lot both inside and outside this article. The word is a “vicarious emotion, a feeling of what the other individual is feeling” (Alford, 2016). When an individual places themselves in another’s shoes, that is empathy. The emotion may encompass experiences including when you cry for a character dying in a movie to pity for a friend having a bad day. Many individuals forget the vast range of experiences empathy reflects, especially in their daily lives. Considering empathy from this perspective, one may better understand how empathy has been linked to mirror neurons and why there was a large buzz surrounding the neurons when they were first discovered. It sparked the thought that we could finally have an explanation for why we feel what we feel and how.

Unlike what was believed during its initial surge in popularity and excitement, mirror neurons fell off the trend bandwagon as research furthered. The excitement surrounding the discovery lay behind the theory that the neurons were the foundation behind emotion. There was an assumption that they were the answer to emotions and how emotions functioned. The enthusiasm was so great that “The neuroscientist V.S. Ramachandran (2000) stated that ‘I predict that mirror neurons will do for psychology what DNA did for biology’” (Alford, 2016). A truly bold statement as a majority of theories since the discovery of DNA rely on DNA’s principles. Truly, many thought mirror neurons would be the start of a new series of theories. Unfortunately, over time, it quickly became apparent that this was not the case and that many mechanisms still remained behind emotional responses aside from mirror neurons.

As aforementioned, the neurons were first described by a paper in 1992 using monkeys as its subjects. These monkeys were specifically the macaque monkey breed which continued to be used as the test subjects in mirror neuron research beyond the first paper. The primary reason is the methodology required would not have been ethically allowed in humans. This practice involved electrodes being implanted into neurons in their brains that were then used to manipulate and measure electrical impulses affecting brain activity (Alford, 2016). When the monkey observed or performed an action, this was how the data was accurately recorded. Macaque monkeys also worked as a good model and test subject as the brain regions they noticed mirror neurons in overlapped with a few suspected mirror neuron regions in humans. They were such a good model, in fact, that they made up all 25 of the studies

that actually researched the neurons versus the over 800 PubMed studies that used presumptive evidence (Alford, 2016). In short, we have monkeys to thank for the discovery of these magical neurons.

While a mirror neuron may be a cluster of brain cells, according to Bonini, a doctor of neuroscience, these neurons may work beyond themselves as “a variety of cell types distributed among multiple motor, sensory, and emotional brain areas forming a ‘mirror mechanism’ more complex and flexible than originally thought, which has an evolutionarily conserved role in social interaction” (2017). An image one may use to imagine this mechanism is a spider web strung out amongst certain regions of the brain made of mirror neurons. This web is especially concentrated in the left inferior frontal gyrus (LIFG), which is involved in language processing. Other regions of the brain that were found to have the neurons, and aligned with the monkey subjects we just discussed, were “F5 in the ventral premotor cortex and area PF/PFG in the rostral sector of the inferior parietal lobule” (Iacoboni). This emphasized that we can apply what we have observed in the macaque monkeys to ourselves. Despite LIFG’s role in language processing, the neurons located there were crucial for imitation, aligning with the main function of mirror neurons. Alford also noticed that mirror neurons respond to goals or intentions rather than specific movements despite their function in the brain’s motor system (2016). This further demonstrates the complexities that lay behind mirror neurons and the reason for their nickname as a “psychic” or “mind-reading” neuron.

As you may have noticed, the methodology behind how we activate certain emotions is not necessarily clear because of the complexity of the brain. As such, the research on mirror neurons thus far does not completely explain its connection to empathy. Therefore, a series of educated guesses have been released based on what is known from the limited research. Alford, a professor at the University of Maryland, provides an interesting alternative definition for mirror neuron function, “Mirror neurons work by assuming that you intend what I would intend in a similar situation... Mirror neurons work by assuming that you are the reflection of me” (Alford, 2016). In other words, mirror neurons are stimulated by the concept of intentionality. A sort of prediction-based system where a person may pick up a teacup and the mirror neurons are stimulated by the high likelihood of the other person drinking from the cup versus dropping it on the floor. With this in mind, it may be difficult to understand the link between “mind-reading” and empathic responses. However, it is because of this predictive ability that mirror neurons are highly attuned to other organisms. This attunement includes emotional experiences which are conveyed to the observer.

Looking to deep dive into the mechanisms beneath this emotional resonance, the general idea is that we partially process the emotions we perceive from others in our own emotion system. This allows us to share and understand or empathize with what

the other person is experiencing. The theory behind this concept stemmed from experimental results that, when seeing someone in pain, the anterior insular (AI) and the anterior midcingulate cortex (aMCC) also known as the anterior cingulate cortex (ACC) will activate (Lamm, 2015). Carillo performed this research on rats using controlled shocks on one side while the other side watched. The data concluded that when shocked, the observing rat's mirror neurons in the ACC would be stimulated (Carillo et al., 2019). This response provided supporting evidence that witnessing another in pain will activate the neurons. An additional detail of interest was that there was no response in the ACC to fear, as tested with a fear-conditioned sound, only pain. The AI and ACC are two regions of the brain that facilitate relevant stimuli that will guide behavior. The important implication behind the regions getting stimulated was that we have a response to someone else's experiences. Ultimately, these results implied that we can attune to another's emotions and process them as our own to feel empathy.

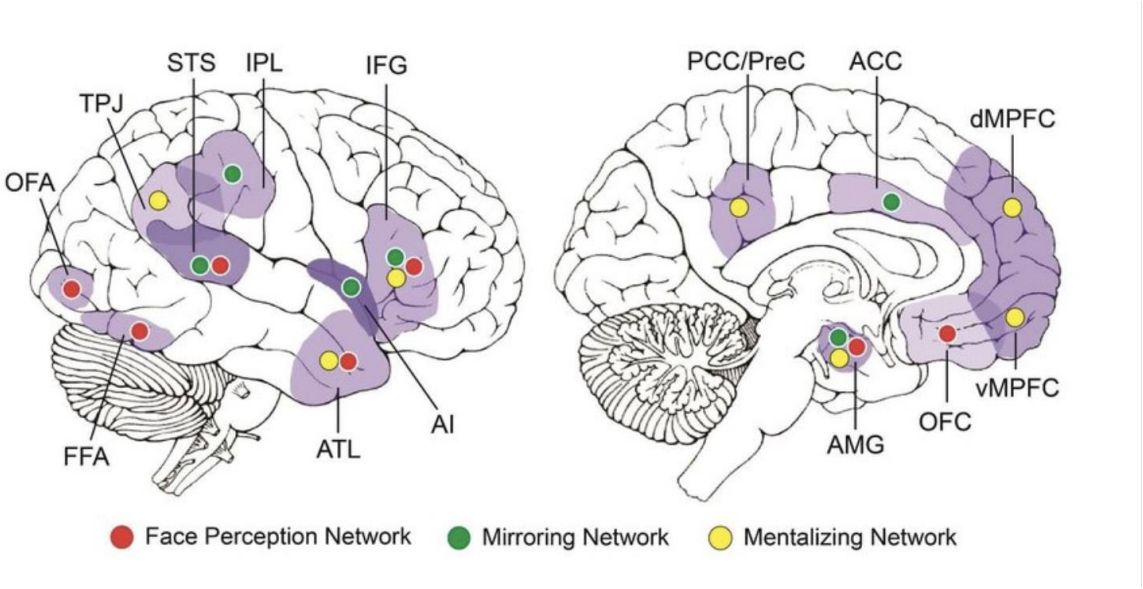

Figure 3: No author. (n.d.). *Highlighted regions of the brain* [Image]. ResearchGate. https://www.researchgate.net/figure/Three-major-networks-in-the-social-brain-ACC-anterior-cingulate-cortex-AI-anterior_fig1_345122660

The pain of the soldier my grandmother took in would have perfectly stimulated my grandmother's AI and ACC regions and mirror neurons. As a result, she would have felt empathy for the soldier's pain and a desire to help from a moral standpoint. But would she have felt enough empathy to overcome the fact that the soldier was a stranger she was risking her life for? According to Keestra, those who have a closer relationship with us such as a partner will elicit a greater activation response than a third party who performs an action (2012). To achieve this improved response, the mechanism that filters any information going through to the mirror neuron system ends up allowing "socially relevant" (e.g. boyfriend) people's actions through more easily.

This is why those who are close to you will receive your empathy while it is more easy to ignore the pain of outsiders (Alford, 2016).

Such research may explain why we are willing to take a bullet for a loved one but still does not quite explain how some can do the same for strangers. Especially if we can “screen” them out from our empathic responses. Interestingly enough, this quote-unquote filter can be influenced to be more porous to people who are less socially relevant through means such as education and mass media. Similarly, you can achieve the opposite effect on the filter through ideology and propaganda (Alford, 2016). I found this to be fascinating as you can build yourself a world where you can mentally control who will cause you distress and who you can ignore emotionally. Perhaps this can be used to explain why a bad breakup hurts for a long while afterward because you are allowing them through a filter that was used to letting their emotions in. You have no defense against them and no impermeable filter yet as they continue to influence you. For my grandmother, who was French, to save a soldier belonging to the same country was likely the correct moral combination to let the experience in through her mirror neuron filter.

Something else that was an unexpected find during my research of these neurons was their connection to my grandmother’s ballet skills. Let us recall that mirror neurons are a part of the motor system in the brain and that they play a major role in mimicry. But in the case of mirror neurons, what is mimicry? Because the neurons are stimulated when watching someone perform an action the observer relates to, the observer gains a deeper understanding of the action and improves their ability to replicate it. Similarly, one may consider how in dance you watch your instructor perform the choreography and then do it yourself. Scientists especially hold high hopes for dance to be a field that can provide a lot of insight into mirror neurons (Zardi et al, 2021). With this in mind, my grandmother had the secret help of mirror neurons on top of her hard work as she improved her dancing skills over time. When learning new choreography her neurons recognized actions that were similar to what she had done before and let her quickly replicate what she was seeing. She would later go on to be an instructor for others at her own ballet school, helping others learn and improve their ballet.

Upon the discovery that mirror neurons can improve skill learning through reflected actions, some inquisitive minds wondered if it could be applied to help accelerate learning. Rao et al. especially considered the development of surgical skills, a field that would require both careful observation and physical execution. “According to studies on the human mirror neuron system, specific regions of the motor cortex are very capable of picking up manual dexterity through observation” (Rao et al., 2023). They used the term “observational learning” to describe gaining a new skill using what

they are observing as a model. By watching an expert surgeon perform, the observer will form a mental blueprint of how they are performing their task to replicate it themselves. When using observational learning in tandem with physical practice, any extra complexities are revealed and the efficiency of learning the task improves. While other considerations such as the level of surgeon skill should be taken into consideration with the efficiency level, researchers should continue to explore how mirror neurons can improve skill attainment when used with observational learning.

Neuroscience is a field of study that has so much left to be unraveled. One such mystery is mirror neurons and their relationship with empathy and improved learning through mimicry. Through their initial discovery in macaque monkeys as premotor cells, scientists have come to understand just how much and how little they know about them and their mechanisms. What I have come to realize is how intertwined the neurons are in major and daily life stories. My grandmother once saved and cared for a French Foreign Legion soldier in Algeria and then France when they were nothing more than strangers. Her aid was given out of kindness and empathy that many reserve only for their loved ones. Now, we have a more scientific basis for why rather than just out of a sense of duty or goodwill. I can assume that some portion of her empathy stemmed from stimulated mirror neurons which may have influenced her decision to agree to help. Furthermore, the skills my grandmother honed over decades as a ballerina through her hard work had a boost from the side as the neurons deepened her movement comprehension to allow for reflection. There is still so much to learn about the tiny neurons in our brain that I hope researchers continue to uncover over time. For now, I hope any reader who is a good Samaritan may remember that there is some underlying logic in what others may deem a reckless yet selfless decision.

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Images:

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