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# **Mirror Neurons & the Sensory-Motor Framework**

In the 1980s and 1990s, neurophysiologists in Italy, studying neurons in the ventral premotor cortex of macaque monkeys, discovered that certain neurons fired both when the monkey picked up pieces of food as well as when the monkey observed a person picking up food (Di Pellegrino et al., 1992). The term 'mirror neurons' came about because the firing of neurons in the macaques' brains made it seem as though the monkey was observing its own actions in a mirror (Iacobini, 2009). These "mirroring" neurons have become an important point of research for neuroscience. Later studies confirmed that neurons with mirroring properties are also found in the inferior frontal and inferior parietal areas of the brain (Gallese et al., 1996).

Some key points about mirror neurons have been made since their discovery. First, although the term "mirror" might imply an exact replication of movements between the observer and observed, a minority of mirror neurons – one third of them -actually fire for the same observed and executed action (Iacobini, 2009). These mirror neurons are called 'strictly congruent mirror neurons' (Iacobini, 2009). The remaining majority of mirror neurons called 'broadly congruent mirror neurons' do not necessarily fire for the same executed and observed actions, but for ones that lead to the same result or are somehow related (Iacobini, 2009). Another important aspect of mirror neurons is that they are considered multimodal: activation can occur due to various forms of sensory input such as auditory, visual or somatosensory (Gallese et al., 1996).

Evidence of mirror neurons has only yet been found in studies of macaque brains. This is due to the fact that it is not possible to study single neurons in humans using currently available technology such as fMRI, because fMRI measures pooled responses of many neurons (Dinstein et al., 2008). Neuroscience researchers are therefore using functional neuroimaging techniques such as fMRI to confirm that similar mirror neuron *systems* exist in humans, rather than mirror neurons themselves (Iacobini et al., 1999). It must be emphasized that mirror neurons are not necessarily points of study in themselves, but are more points of analysis of intricate networks that connect massive numbers of neurons (Cozolino, 2002).

To extend findings from primate brains to humans, some studies are examining human brain regions that are analogous to the brain regions in macaque monkeys where mirror neurons have been found (Iacobini et al., 1999). The area of focus in studies of macaques' brains is an area called F5, which has a similar cellular make-up to Broca's area in humans, suggesting that the two areas are homologous (Wolf et al., 2001). PET scans have also suggested that these two areas are interrelated (Cozolino, 2002). The evidence of homologous properties in these areas of primate and human brains is an important starting point for other types of experiments and investigations into the existence of mirror neurons in humans and the role they play.

The first clue in observing mirror neurons in action is to see a movement or gesture in one person (or animal) being imitated by another. Therefore, in order to explore the mechanisms of mirror neurons, it is important to examine both theories actions and of imitation.

One of the main cognitive models of action is the sensory-motor framework, which assumes that external stimuli trigger actions (Iacobini, 2009). As Iacobini (2009) states, however, this model lacks a satisfactory explanation for how another person's motor action gets translated into sensory input that can trigger a replication of that movement by the imitator – the so-called "correspondence problem"(p. 655). He asserts that the ideomotor framework of action does not have this problem and naturally explains imitation because it proposes that both the *perception* of an action and the *actual action* share the same "representational format", making translation redundant (Iacobini, 2009, p. 659).

The starting point of the imitation process, according to this theory, was first proposed by Martin Lotze and William James (Iacobini, p. 655). Lotze and James believed that imitation is not triggered in response to sensory stimulation, but to what goal the action is supposed to achieve and what motor actions are required to achieve it (Iacobini, p. 655). This means that previous experience plays a role: people who have performed certain actions experienced a certain outcome as a result, which then leads to the expectation of the same outcome if that action is performed again. Observing a certain outcome, leads us to think about that outcome and automatically triggers the required movements that are known to achieve that same outcome (Iacobini, p. 655). In fact, several behavioral experiments with children suggest that when it comes to imitation, the goal of an action has more importance than the actual movements (Iacobini, p. 655).

One of these experiments consisted of the child being instructed to copy the experimenter's movement of either putting his hand to the right or left of the desk (Iacobini, 2009). In the next section of the experiment, the child was instructed to do the same thing, but this time the end result of the hand movement was to cover a big red dot on one corner of the desk. When the 'goal' of their hand movement went from simply moving it to copy the experimenter to moving it to cover the big red dot, the children made more mistakes of using the wrong hand or wrong movement: when it came to covering the red dot, they ended up using the simplest way to achieve that *goal,* which made certain motions of the experimenter unnecessary (Iacobini, p. 656). In this case, the child's perceptual and motor experiences activated the movements that they already knew would allow them to achieve the goal of covering the dot.

Another framework of imitation that also assumes the importance of experience in shaping the mechanisms of imitation is the associative sequence learning model

(Iacobini, p. 656). The associative sequence learning model posits that most imitative abilities are shaped by experience and are based on associations between representations of executed actions and observed actions (Iacobini, p. 657). Iacobini (2009) also notes that these associations can be brought about by certain environments, such as those in which a person sees their own extremities or is able to see themselves in reflective surfaces. The role of the environment in imitative abilities rather than specific neural mechanisms that are dedicated to these skills is demonstrated by the fact that imitation abilities vary substantially between species (Boysen & Himes, 1999 –from Iacbonin). The best explanation to account for these differences is variations in environment. Environment alone does not fully explain infants' abilities to mimic behavior: the associative sequence learning model, however, asserts that some imitative abilities are innate (Iacobini, 2009).

Other studies have also called into question whether the activity that occurs in areas of the brain that supposedly house mirror neurons is in fact due to the firing of mirror neurons, or other processes (Dinstein et al., 2008). In a study published by Dinstein et al. in 2009, it was found that the area aIPS did not exhibit cross-modal (meaning visual to motor or motor to visual) adaptation that would be expected from multi-modal neurons, namely, mirror neurons (2008). Response patterns in aIPS related to observation were explicitly different from the response patterns to execution (Dinstein et al., 2008). This suggests that observed and executed actions are in fact represented in different formats in the brain, arguing that the process of mirror neurons does not explain imitative abilities in humans (Dinstein et al., 2008).

Since there are still no studies that can physiologically prove or disprove the existence of mirror neurons in humans, but only studies that can demonstrate traits of a mirror neuron system, it would be ignorant to discount the possibility of mirror neurons in humans altogether. Regardless, whether there are distinct neurons or simply vast networks or interrelated neurons that are responsible for human imitative abilities, it cannot be denied that a certain process exists in human brains that allows for the mere observation of another person's action to activate a type of motor or even emotional imitation of that action.

Perhaps just as important as how that process works or what that process consists of, is how imitation - and therefore the potential of mirror neurons – has implications in real world settings. As Rizzolatti and Arbib postulate, mirror neurons may "represent the link between sender and receiver" (p. 188) that allows for the receiver to "understand" the action, utilizing this "understanding" to formulate an appropriate response to the performed action. (Wolf et al., 2001, p. 97). Mirror neurons appear to code facial action and gestures, particularly with the mouth, suggesting that they are important for emotional attunement of other people (Iacobini, p. 662, Cozolino, p. 186*)*. As Rizzolatti and Arbib state, "Our emotional understanding of these gestures allows us to distinguish various social cues and may have links to primitive communiction, allowing one person to detect, for example when another person is feeling peaceful or agitated"(1998).

It is logical to assume that the facial expressions, gestures, and posture of another will activate similar sensory-motor circuits in the observer. These motor systems, in turn, activate networks of emotion associated with such actions. Seeing someone cry, for example, can evoke a response such as an “aww” sound and tilting the head sideways, or seeing someone bow their head in shame can activate a memory of that same feeling within the observer (Cozolino, 2002, p. 186). Mirror neurons are activated by the visual cue of another person outwardly expressing their emotions which then leads to our own internal emotional state that acts as an “intuitive theory” of the inner emotions of the observed person (Cozolino, 2002, p. 186).

This type of internal understanding of another’s emotions is an important aspect of successful social interaction, particularly when seen from an evolutionary perspective: before humans had words, it was important for their survival to have some sense of what was going on with another person’s inner state (Meltzoff & Decety, 2003). Although in today’s modern society, there may be less use of this type of emotional resonance in terms of survival, empathy plays an important role in social relations, particularly in parenting as well as in helping others overcome distress. As Iacobini asserts, there is a strong correlation between the ability to imitate movements and empathic responses (2009, p. 659). Understanding how empathy occurs and perhaps even the neurological or biological mechanisms behind it may help us find ways to foster and cultivate it. This deeper understanding would be valuable in giving people skills to improve social and emotional interactions.