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Mirror Neuron System and Social Cognition: Understanding Others by Embodiment

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The theory of embodied cognition states that embodied cognition is the process of the motor system and the body influencing the mind: playing a role in knowledge acquisition, understanding, and emotions, just as the mind influences the body. This paper provides an introduction to the theory of embodied cognition by examining the development of the theory, how concept formation may be enabled by embodied cognition, and introduce the neural mechanism suggested to be responsible for embodied cognition. This paper also explores the role of embodiment in emotions, how embodied cognition may enable first person perspective, and whether embodied cognition is inherent or acquired. Further on, this paper will showcase how embodied cognition may enable intention understanding, the influence of love on embodied understanding, and whether embodied cognition can be used to understand those strikingly different from self.

Embodied cognition is the cognition that is deeply rooted in the visceral body states and sensory experiences. Some researchers claim that embodied cognition is not our only cognition, but it is the only affective cognition and thus serves as our main cognition (Zajonc, 1980). Many researchers found that affects, judgment formation, and even social cognition may be based on bodily sensations. Damasio and Damasio (2006) proposed that understanding the physical states of our body enables understanding of ourselves and this understanding can even be extended to others. They suggested that this is extension is possible because we are all humans who share a similar body and a similar governing neural network, living in relatively similar environments.

Recently, various researchers focused on finding the neural mechanism that underlies embodiment. A network of neurons was discovered where the same neurons responded both when the subject executed a specific action and when the subject observed someone else performing the same action (Rizollati & Sinigaglia, 2010). This network was named the mirror neuron system (MNS). The mirror neuron system is the proposed neural mechanism that matches representations of observed actions with the observer's catalogue of actions, as the same neurons fire both when doing an action and when observing the same action performed by another person. Rizollati and Sinigaglia (2010) proposed that this matching process leads to understanding the actions and intentions of the actor.

In this review paper, we will look at what embodiment cognition is and explore in detail the most recent model, the mirror neuron system. We will also showcase embodiment at work in various social settings, observing how embodied cognition enables communication with others. We will first review evidence of social cognition in early childhood via embodiment and the importance of intentions. Then, we will examine the proposed theory is that embodied cognition is at work even when we interact with strangers, but the effect is strongest when we have a strong personal connection with the other, such as in a romantic relationship. That is, there are research findings that suggest that understanding of others through embodied cognition can only be fully utilized when we can mentally recognize them to be similar enough to ourselves. Thus we will also examine how we may sometimes opt out from using embodied cognition and employ a secondary cognition when we interact with those we judge to be significantly dissimilar from ourselves.

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Embodied Cognition and Concept Formation

Many modern psychologists believe there are two major types of cognition, each for a different purpose: one that is strictly information processing and another that is embodied. Embodied cognition is more rapid than the information processing cognition. On the other hand, information processing cognition, though slower in processing speed, may have developed later in evolution for situations that require more elaborate analysis and thus serve an important purpose (Damasio & Damasio, 2006). Miller and Johnson-Laird (1976) remarked that this more recent system can assemble information, process it and later recall it, but it is limited because it is dispassionate, with no emotional component. However, social interactions are ladled with emotions and require fast and continual responses, so we rely most heavily on embodied cognition as our main social cognition. Thus this is why information processing cognition was often referred to as “cold” cognition−because it was without affect−and in contrast, embodied cognition was often referred to as “hot” cognition−as it was a cognition with affect (Zajonc, 1980).

Zajonc (1980) suggested that prior to information processing and inference forming, our body already influenced us to form preferences in our minds on the stimulus we are interacting with. Along the same line, Keenan and Bailett (1979) argued that the crucial factor in our memory of a stimulus is not the wealth of information we have, but our affect towards it. Thus, embodied cognition, which is our cognition with imbedded emotions, may also be the foundation of our concept formation, which is the basis of how we judge others. A concept formation process, called scaffolding, is a process through which humans readily integrate incoming information with extant knowledge structures (Williams, Huang, and Bargh, 2009). Williams et al. (2009) argued that the primary foundation of knowledge is bodily sensation and thus concept formation must be primarily based on bodily sensations. They emphasized that scaffolding is a general practice in human cognition, but it is most significant during functional interactions with others and the environment (Williams et al., 2009). These researchers agree with Zajonc (1980) in that how we perceive the world is based on our body and what our body gives preference to usually has evolutionary survival value. Asch (1946) was able to provide experimental evidence of how concept formation and judgment formation may be based on bodily sensations. In his experiments, Asch found that participants’ judgment of a person changed dramatically depending on whether the person was described to be “warm” or “cold”, which are words describing bodily sensations. More specifically, when all the other details were the same and ambiguously described, participants instantaneously favoured a “warm” person over a “cold” person.

We may have associated warmth with good characteristics because as infants, we had the experience of being held by our mothers and caregivers who first gave us the sense of warmth in combination with characteristics such as caring and kindness that improve our well-being. So, we associate warmth with characteristics that are beneficial to us. We are able to form black or white judgements even in ambiguous circumstances due to embodied cognition. Embodied cognition enables such concept formation and judgment formation based on our sensory information without requiring the effort from our prefrontal cortex to manually assess different situations. What, then, is the neural mechanism that enables this process?

Mirror Neuron System: Encoding of Goals and Intentions

Through single-neuron recording, researchers found a group of neurons that fired both when the monkey performed a motor act and when the monkey only observed someone else performing the same motor act (Rizrolatti, Fogassi, & Gallese, 2001). The exact same neurons fired in both occasions. Since these neurons were activated by the observation of action, as if mirroring them, they were named “mirror neurons” the network of these neurons was called mirror neuron system (Rizzolatti &

Sinigaglia, 2010). Mirror neurons were first found in area F5 in the ventral pre-motor cortex of macaque monkeys (Rizrolatti, Fogassi, & Gallese, 2001). The findings with the primate subjects were soon replicated with human subjects. Prather et al. (2008) were the first to establish the evidence of mirror neurons in non-primates, providing empirical evidence of groups of neurons that responded in a strikingly similar way as the mirror neurons in the macaque money brain.

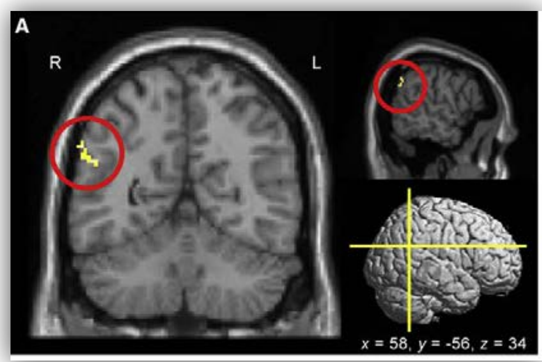

Figure 1. Mirror neuron activation in human inferior parietal cortex.

It is notable that mirror neurons were found in humans in the human inferior parietal cortex (Chong, Cunnington, Williams, Kanwisher, & Mattingley, 2008). The parietal cortex is actually known for constructing maps of physical space that are egocentric (Yamakawa, Kanai, Matsumura, & Naito, 2009). Neggers, Van der Lubbe, Ramsey, and Postma (2006) found that the parietal cortex was only activated when a subject made a spacial judgement of two stimuli relative to them. These evidences suggest that how we perceive the self and others is rooted in our concept of physical space. Using a more anecdotal example, physical distance is even linguistically used to describe relationships in terms of social distance, with terms such as “close friends” and “growing apart”. In addition to the parietal cortex, the human mirror neuron system (MNS) also includes the caudal sector (pars opercularis) of the inferior frontal gyrus (IFG), the premotor cortex, and other neural areas, but we currently have the most empirical data of mirror neurons in the parietal cortex (Gallese et al., 2004).

Research in the brains of macaque monkey subjects are done with single neuron recording – where a single neuron is stimulated and the effect is observed, or the effect of an observation is measured as the response or firing from the single neuron. However, single neuron recording requires open brain surgery, thus single neuron recording is usually not possible with human subjects due to ethical reasons. Instead, many researchers used fMRI in research with human subjects, measuring the blood oxygen level-dependent (BOLD) signals while they observed another person performing specific actions. Certain brain areas were activated during this action-observation process and these areas share significant overlaps with the MNS (Grafton, 2009).

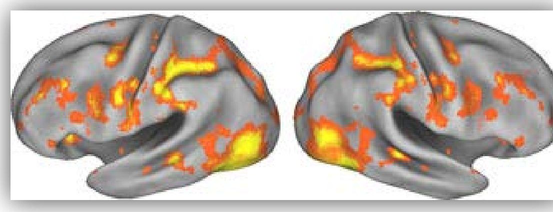

Figure 2. fMRI of BOLD activities in mirror neuron system area

These areas include the bilateral posterior superior temporal sulcus (STS), inferior parietal lobule (IPL), dorsal premotor cortex and ventral premotor cortex (Grafton, 2009). Many of these areas that were activated during observation are actually areas of motor execution. The inferior parietal lobule was where the mirror neurons were first found, responding both to action and observation of action. Also, the premotor cortex, which was previously thought to be solely for motor execution, was found to be involved in action observation as well (Grafton, 2009). The mirror mechanism, centrally located in the inferior parietal lobule, appeared to give the observer’s premotor cortex the sensation of actually performing the actions in a first person perspective.

Not only that, the mirror neurons were remarkable in that they only fired when the observed act was goal-oriented. A movement that is goal-oriented, such as grasping an object, is called a “motor act”, as opposed to an action without an intention, which is called a simple movement, even if the appearance of the movement may resemble a motor act such as closing the thumb and fingers around the air when there is no object to grasp. The mirror neurons in Figure 3 did not fire when the subject observed someone making a simple movement very similar in appearance to a motor act such as grasping, but without an actual object to grasp. This evidence supports the claim that monkey mirror neurons are able to distinguish between a motor act and a simple movement (Figure 3; Gallese, Keysers and Rizzolatti, 2004).

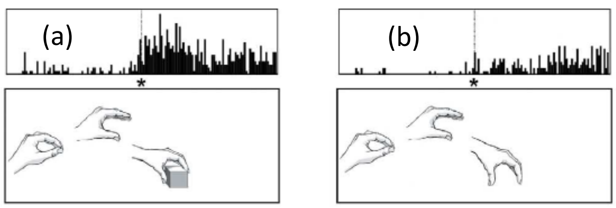

Figure 3. Compilation of 10 trials of monkey F5 neuron response during (a) action or (b) movement observation

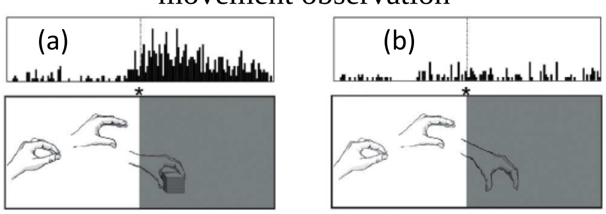

Figure 4. Monkey F5 neuron response across 10 trials during (a) action or (b) movement observation in hidden condition

The same experiment shown in Figure 3 was repeated with the final action or movement partially obscured from the monkey with a screen (Figure 4). Even when the visual stimulus of the end result was hidden in Figure 4, the mirror neurons in the monkey brain were able to distinguish from the sequences prior to the screen whether it was an action or a movement and responded only when the perceived motion was a goal-oriented action with intention.

Not surprisingly, the human mirror neuron system is even more sensitive than the monkey mirror neuron system at understanding the meaning of observed actions and deducing intentions. The presence of a partially obscured object seemed to be necessary for the monkey mirror neuron system to understand the intention of the actor. However, the human mirror neuron system was responsive even when observing intransitive actions and mimed actions without objects, provided that the mimed actions were not absent minded and were the result of intentions (Gallese et al., 2004). We can extrapolate from the empirical evidence that both human and monkey mirror neurons do not fire during observation of movements when there are no goals or intentions encoded in the movements that the mirror neurons could internalize. But embodiment is not limited only to motor actions. Researchers found evidence of embodiment in emotions and pain, which will be discussed in the following section.

Embodying Others’ Emotions: The Insular Cortex and Disgust

Researchers have found a system similar to the MNS in the insular cortex that enables embodying emotions. The insular cortex is more complex than the motor cortex. When motor areas of the brain are stimulated, movements are produced in specific body parts. However, when the anterior insula is stimulated, not only are movements evoked, but there is also a cascade of autonomic and viscera-motor responses (Gallese et al., 2004). The insula is a map of the body similar to the motor cortex’s homunculus and it is the centre of viscera-motor integration as well (Gallese et al., 2004). So, we feel and physically experience the information encoded by the insula. In many studies, the insular cortex−left anterior insula in particular−is associated with the emotion of disgust. Experiments were first conducted with monkey brains, but the findings were later confirmed by the renowned neurosurgeon Dr. Penfield in a few rare cases of human brain study with patients undergoing neurosurgery.

When Penfield and Faulk (1955) stimulated the patients’ anterior insula during neurosurgery, the patients reported that they felt nauseous, which is a visceral sensation of disgust. Subsequent studies found that the insula is linked to the cognitive processing of disgust and that it plays an important role in recognizing the facial expression of disgust. Calder, Keane, Manes, Antoun, and Young (2000) reported the case of patient NK who had damages in his left insula. NK was unable to fully experience disgust emotionally, could not read others' facial expressions of disgust, and could not even relate to sounds of disgust such as retching. Calder et al. (2000)'s research supports that the neural mechanism that relays the emotion of disgust is likely housed in the insula and that we use this neural mechanism to embody how others experience disgust, much like how we experience disgust ourselves. Similar to the insula, many brain areas directly connected from sensory input may also be involved in evaluating motor and emotional information without involving information processing cognition. It is reasonable to infer that we use these neural networks to rapidly embody and understand others' emotions in social interactions.

So far, there has been a lot of research focused on the embodiment of the emotion of disgust, but it is not the only emotion we can embody. The embodiment theory suggests that we can embody all the emotions of others as we, too, are capable of those emotions. In fact, the visual information that encoded the emotions of others was found to be stored directly in the same viscera-motor neural structures and pathways that allow the observer to experience the same emotions (Gallese et al., 2004). This process occurred even when participants were just imagining others' emotions and thus it was reasoned that imagination alone may be adequate to understand others' emotions in a first person perspective (Singer, Seymour, O'Doherty, Kaube, Dolan, & Frith, 2004). Further research is needed to investigate empirically how we embody various emotions and which other brain areas are involved.

Embodied Cognition: First-Person Perspective

We have a wealth of information about ourselves that our body continually maps and keeps as a template. For situations similar to ones previously experienced, the templates allow us to respond appropriately by recalling and simulating the stored states rapidly without processing new sensorimotor or emotional information every time (Damasio & Damasio, 2006). So, when we embody others, we can pull up our own templates to understand others with a first-person perspective. In this way, embodiment can bridge the gap between self and other to enable understanding. Gallese, Keysers and Rizzolatti (2004) linked action observation to emotion observation in social cognition. They proposed that we do not just perceive an action or an emotion, but we internalize representations of physical and neural states associated with it. That is, during social cognition, the mirror neurons cause the visual information we receive to be integrated into our own experiences so that we experience our observation as "first-person" and not as "third-person" (Gallese et al., 2004).

Experiencing other's actions in first-person was found to be crucial to embodiment because effects of embodiment diminished when we perceive something with a third-person perspective. Gianelli et al. (2011) recently gave evidence that when perspective was shifted from reading a sentence in first person to third person, motor embodied mechanisms were prevented. Interestingly, motor embodied mechanisms were reengaged when there a virtual body−in the form of a circle−was introduced so that the participants could imagine themselves to be the subject in the sentence, thereby taking a first-person perspective (Gianelli et al., 2011). Another recent study that used a dual electroencephalogram (EEG) setup may have found the neural rhythm underlying how we can understand others in first-person perspective. Evidence of two participants' brains synchronizing was found during simple interactions (Dumas, Nadel, Soussignan, Martinerie, & Garnero, 2010). Nine pairs of participants did turn-taking while copying each other's simple hand motions. EEG recordings of right centroparietal regions of the nine pairs showed alpha-mu signal synchronization (Dumas et al., 2010). Alpha waves brain oscillations originating predominantly from the occipital lobes, and thus related to vision, that can be detected during EEG recordings. Mu waves are a variant of alpha waves that appear over motor areas of the brain, thus related to motor movements, and can also be detected by EEG. The alpha-mu wave synchronization may be the explanation that bridges the gap in our brain between self and other. But how is embodied cognition activated in the first place? Many researchers have been focused on finding out the answer to this question, which will be explored in the subsequent section.

Activating Embodied Cognition

Is embodied cognition inherent or learned? There is an ongoing debate between researchers who support both sides. This paper will explore the arguments presented in both sides starting with the premises that embodied cognition–like language and many other abilities–may be an inherent capacity that was activated and improved with learning. The first learning takes place between a parent and a child. A mother and her child share a fundamental physiological connection through the cradle of life: the womb. This physiological connection then expands into the first ever mental connection for the fetus. As such, it is essential to have high quality interaction between the parent and their child in the early stages of the child's life.

Shai and Belsky (2011) introduced the concept of parent embodied mentalizing (PEM). PEM is the ability of a parent to use embodiment to implicitly understand the preverbal child's mental states from their whole-body movement and the ability to use this understanding to adjust parent's own kinematics to dynamically respond to the child's needs. Sahi and Belsky (2011) stressed that relying only on head-centric kinesthetic communication such as facial expressions are insufficient. Fraiberg (1979) found that mothers of blind infants who only paid attention to facial expressions noticed little emotional signalling and mistakenly judged their babies to be just bored. However, when these mothers were trained to pay attention to whole-body movement, they were able to notice and identify that their babies' mental states were in fact engaged. This finding supported that it is important to take the entire body into account in order to fully embody and understand nonverbal communication.

Tronick and Cohn (1989) observed that parents with high PEM actually did not necessarily automatically understand their children's needs, but they were successful in adjusting their interactive miscoordination, which established secure attachment in the children. Sahi and Belsky (2011) hypothesized that as the parent embodied their child's mental states, the child understood that they have mental states that can be embodied. This child would then have the confidence to communicate their mental states with others and respond to others' mental states in the same embodied fashion.

Meltzoff (2007) found that even a very young child is able to understand other's minds by mapping the similarities and differences between the self and the other via imitation. In infancy and early childhood, imitation functions as a foundation for communication and understanding others (Meltzoff & Williamson, 2010). Even newborns are capable of imitation. It was found in hospital settings that even infants who are just 42 minutes old can begin to imitate facial expressions and infants 12 to 21 days old imitated adults' facial expressions such as tongue protrusion (Meltzoff and Moore, 1989, 1997).

As they grow older, infants get better at imitation and can even imitate after a period of delay from observation of the action. Meltzoff (1988) conducted an experiment where an adult taught 14-month-olds an act, but allow them to only observe the act and not imitate it. When tested four months later, they were able to imitate the act, even when the adult who demonstrated the act was passive and did not give a template for them to copy. This showed that the infants did not simply copy what they saw, but a possible explanation is that the infants have embodied that action during observation and stored it in their long term memory. Thus, it appears that mirror neuron system underlying embodiment does not simply copy actions. Instead, the mirror neurons appear to store useful movements associated with the actions for later application.

Importance of Intentions

When children are developmentally mature enough to understand intentions, they do not simply embody and imitate the actions they observed, but they actually infer the intended action and imitate the goal of the act, not the literal sequence of movements (Marshall & Meltzoff, 2011). In one study, infants saw an adult struggling and failing to pull apart a dumbbell-shaped object. When infants were actually given that object, they did not copy the exact movements the adult actor used, but used a different method to successfully pull apart the object (Marshall & Meltzoff, 2011). The infants understood that the intention of the adult's action was to pull apart the dumbbell-shaped object and on the other hand, the struggling process was only the adult's attempt at accomplishing the goal, that the struggling movements themselves were not intended motions. The infants' ability to understand intentions in this experiment supports that we do not merely embody sequences of movements others make.

Intentions are an essential part of social communication. In a recent study, Gray (2012) found that participants who perceived that others had good intentions found more pleasure in receiving messages from them and even reported that unpleasant situations such as experiencing pain became more bearable. What is more interesting is that when good intentions were perceived, they reported that food even tasted better. We can infer from the various empirical findings that intentions are deeply integrated and enhance the understanding of others through embodied cognition.

Influence of Love on Embodied Understanding

Though embodied cognition may not necessarily require learning, it is enhanced when familiarity and love is present. When one falls in love, their already well-functioning embodied cognition machinery extends to include their beloved. This is even reflected in the language couples use. Those in a relationship use the word "we" significantly more to describe themselves compared to those not in relationships, even if their partner is not there with them (Ortigue et al., 2010). Due to this extension of self that includes our partners, Ortigue et al. (2010) proposed that we understand the intentions of our partners significantly better than that of strangers or friends. For example, we notice first when our beloved is not feeling very well and we understand the meaning and intentions of our beloved's incomplete sentences or utterances that makes little sense to others (Ortigue et al. 2010).

There is consistent evidence that supports that we understand our partner much like we understand ourselves because they are so integrated into our own body schemas. We even feel pain when our significant others are in pain. In a fascinating fMRI study, Singer et al. (2004) found that female participants experienced pain when they saw their partner experiencing pain. Researchers gave painful electrical stimulation to either the female participant or to their partner. The fMRI results showed that the response in the brain to when only their partner was given pain stimulation was actually similar to when they themselves were given the pain stimulation (Ortigue et al., 2010). Thus, we can mentally experience our beloved's pain as if it is our own. Niedenthal (2007), who also extensively studied embodied cognition, described embodiment as understanding others' actions by re-experiencing first-hand the perceptual, somato-visceral, and motor aspects of the acts. Thus, it appears that complete embodiment would occur when we lose the boundary in between self and other and experience what others experience.

Ortigue et al. (2010) argued that this is because love primes embodiment. The argument was based on the evidence that love and embodiment are actually mediated by many of the same brain areas (Ortigue et al., 2007). Some of these areas are the middle insula, superior parietal lobule, and the angular gyrus (Ortigue et al., 2007; Ortigue et al., 2010). The insula is related to embodiment of emotions and the parietal lobule is covered by the parietal cortex where the mirror neurons are found. The angular gyrus is activated when a person falls in love, but it is also critical in integrating information that is about the self (Ortigue et al., 2010).

Understanding and Empathising with Dissimilar Others

It was first proposed that we can understand others because we assumed that they are much like us and we saw how we may better understand those we know and love. However, how do we understand and empathize with others who we judge to be different from us? In an interesting study, Lam, Meltzoff, and Decety (2009) showed participants photographs of people in two different groups and asked them to report feelings of empathy when the two groups are described to experience pain. The first group was described to have a medical condition unrelated to sensory functions, thus able to have sensory experiences just like the participants. The second group was described to have a medical condition that distorted their sensory experiences. The participants judged the second group to be dissimilar from them and thus could not use embodiment to understand them. They ended up using information processing to empathize that the pain that the second group must be feeling, but they failed to understand the second group's pain in a first person perspective. The participants in the study reported more empathy for the first group because they were able to internalize the pain and feel it in a first person perspective. Nonetheless, the participants reported empathy for the second group, but to a lesser degree.

Nonetheless, embodied cognition is not the only mechanism fundamental to understand the kinematics of an action. In Lam et al.'s (2009) experiment, participants were able to use this alternate, strictly information based, cognitive pathway to understand others since they were unable to actually relate to them using their own past experiences. However, as Zajonc (1980) proposed, since the affective embodied cognition is much stronger than the information processing cognition, a significant difference was still observed between empathising with others who were perceived to be similar to self and others who were perceived to be different. We could understand dissimilar others in theory, by processing the information we are given, but is not the same as feeling their pain as our own. We automatically rely on embodied cognition in social interactions as it is our default mechanism. However, in cases where we socially interact with those who we perceive to be far too different from ourselves, we may need to override the default mechanism by using the information processing cognition.

Summary

Most recent research supports the mirror neuron system to be the neural network that enables embodied cognition. And current research findings suggest the parietal region of the brain to play a central role in the mirror neuron system. The mirror neurons, neurons that fire in response to both actions and observations, in the human brain were found in the inferior parietal lobule and evidences of inter-brain synchronization was found in the right centroparietal regions. The brain areas that are activated during egocentric distance determination are in the parietal cortex and so are some of the brain areas activated during the feeling of love.

Embodied cognition is not our only cognition, but it is certainly the most active cognition, especially during social interactions. We show signs of embodied cognition as infants and it develops as we develop. We use embodied cognition to understand the actions, intentions and emotions of those who we perceive to be similar to us. Usually, this includes everyone, as we all have the same neural network that governs a body living in gravitational field. However, when we perceive someone to be too different from ourselves or when we have a neural deficit that makes us unable to use embodied cognition, we can resort to the slower information processing cognition.

Future Directions

Currently, neuroscience studies involving brain scans are still very much separated from more studies that are more oriented in the social psychology direction. In future research, a real time experiment on brain synchronization during action and action observation with a variety of participants using fMRI could prove to be an important source of empirical support for the role of mirror neurons in embodied cognition. It would be significant to look at mirror neuron activation of couples – those theoretically with a better understanding of one another – and compare that to mirror neuron activation between strangers or dissimilar others. It would also be valuable evidence to study brain synchronization of parent and child to monitor the role of mirror neurons in connection between a child and their main caregiver, which may be one of the closest neural connections that can be found.

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