Understanding Others by Understanding the Self: Neurobiological Models of Empathy and their Relevance to Personality Disorders

Jason Morrison, MD[1]

ABSTRACT

Introduction: The ability to accurately infer the thoughts, intentions and emotional states of others has often been associated with the concept of empathy. Deficits in this ability are common in those with personality disorders. **Method:** Current neurocognitive models of empathy-related abilities and the biological research to support them are discussed. **Results:** There is evidence that observing the actions of others activates regions of the observer's brain involved in executing the analogous action. It is proposed this motor resonance is used to cortically simulate observed movements. Simulation may permit access to the thoughts and emotions of the observer when they make a similar action. This information could then be used to infer the intentions of the observed person. **Conclusion:** The relevance of these models to clinical aspects of personality disorders is discussed.

Key Words: Empathy, personality disorders, mirror neurons

RÉSUMÉ

Introduction: Le fait de pouvoir déchiffrer correctement les pensées, les intentions et les émotions d'une autre personne a souvent été associé au concept d'empathie. L'incapacité de faire ainsi se retrouve fréquemment chez les personnes présentant des troubles caractériels. **Méthodologie:** Nous discuterons des modèles neurocognitifs traitant du développement des habiletés d'empathie et des recherches biologiques sous-jacentes. **Résultats:** À l'évidence, l'observation des agissements des autres stimule les régions du cerveau de l'observateur qui alors tend à agir de la même façon. Nous formons l'hypothèse qu'une telle 'résonance' stimule le cortex de l'observateur – ce qui lui permet d'avoir accès aux mêmes pensées et aux mêmes émotions que celles de la personne observée. **Conclusions:** Nous discuterons de la pertinence de ces modèles dans l'intervention clinique auprès de personnes présentant des troubles caractériels.

Mots-clefs: Empathie, troubles de la personnalité, les cellules 'miroir'.

INTRODUCTION

Everyday we make judgments about the emotions, thoughts and intentions of the people around us. Often without conscious deliberation, we quickly and accurately note things such as the subtext of a conversation, or subtle signs of distress in another person. Often these observations lead to elaborate inferences about their thoughts and desires that some authors have said is akin to mind-reading (Frith & Frith, 1999). In many ways this ability is the grease that facilitates social life, as these quick inferences allow us to modify our interactions with others and to respond appropriately to their desires, even when there has been little directly communicated.

This ability is often associated with the concept of empathy. Over the last century "empathy" has been used to describe a variety of related phenomena such as the ability to discriminate the emotional states of others, the capacity to take the perspective of another, and the evocation of a shared affective response, among others (reviewed by Wispé, 1987). In the clinical setting a therapist is considered very empathic when she can accurately infer and anticipate the thoughts and feelings of her patient. In this paper, the term empathy will be used in its broadest sense, referring to the full range of psychological and interpersonal skills that are involved in identifying and understanding the perspective of another person.

Empathy and Psychopathology

The importance of empathy-related skills to everyday functioning is obvious to those treating people with psychiatric disorders. From the boy with Asperger's syndrome who cannot decipher reciprocal social interactions and has no friends, to the girl with social phobia who believes others are constantly scrutinizing her, to the psychotic teenager who misinterprets other's actions as malevolent, problems with empathy-related abilities are an important cause of dysfunction in psychopathology.

This is especially true in those with personality disorders. In Axis I disorders poor interpersonal functioning is often a consequence of the prominent cognitive, perceptual, and physical symptoms and often improves when these symptoms remit. However, in Axis II disorders, problems with interpersonal functioning tend to be more severe than with Axis I disorders (Skodol et al., 2003), and are a core symptom rather than a consequence of the disorder. This is reflected in the DSM-IV general criteria for a personality disorder (see Figure 1, American Psychiatric Association, 1994). Difficulties in "perceiving and interpreting self, other people, and events" and in "interpersonal relationships" are two of the four core areas of dysfunction cited in criterion A. These two interrelated dimensions nicely describe the main function of empathic skills.

It is interesting to note that perception of self and perception of others is linked in these diagnostic criteria. This implies that for people with personality disorders, deficits in empathy-related skills may be related to a more general perceptual problem involving the self as well.

New research into the brain mechanisms of empathy offers some intriguing hypotheses about why perception of self and

[1]Resident, Dept. of Psychiatry, McGill University
jason.morrison@mail.mcgill.ca

others may be linked. An emerging neurocognitive model suggests that inferences about the emotions of others are made by first stimulating their actions cortically. This simulation may allow the observer to access his own associated emotions during similar movements, and to then use this information to infer the emotions of the other person. In this way, we see the world as a mirror of our self; a provocative idea that resonates with both phenomenology in psychiatric disorders, and with concepts in psychodynamic theory.

This paper will focus on neurocognitive mechanisms thought to underlie the phenomenon of empathy, and finish by considering insights these models bring to the phenomenology and treatment of personality disorders.

Neurobiological Models of Empathy

Most people have had the experience of unconsciously mimicking the actions of someone they were watching. For example, seeing someone yawn usually elicits a reflexive yawn in the observer, or a football fan absorbed in a game might find himself leaning to dodge an opponent along with the player on television. Early 20th century psychologists called this phenomenon “motor mimicry” and felt it might be a primitive form of empathy (Bavelas et al, 1987). Variations of motor mimicry are particularly evident early in development. Infants begin to imitate movements and facial expressions from birth, and it is thought that imitation is a key source of a child’s learning, especially in the pre-linguistic years (Meltzoff & Moore, 1997). Nonetheless, as the early investigators felt, this reflexive imitation is a long way from the more subtle and cognitive empathy abilities in adults.

A number of discoveries in the past 10 years have allowed researchers to connect imitation and empathy in a much more plausible way. Proceeding from the theoretical to the biological, a cognitive model for understanding self-generated movements will be presented, and then built upon to show how a brain network representing self-generated actions could be used to predict the actions of others. Lastly, exciting new discoveries in neurobiology that link theory to biology will be discussed.

Understanding our own intentions: the “forward model”

Many of the theories pertaining to mechanisms of empathy have emerged from investigations of how biological motion is perceived and analysed. It is perhaps not immediately obvious, but perception of movement plays an important role in our understanding of the world. At a basic level, movement helps people identify other people. For example, from 3 months of age, babies can distinguish biological movement from non-biological movement (Fox & McDaniel, 1982). As well, Johansson (1973) attached small lights to the joints of people walking in a dark room, and showed that subjects could readily identify human movement from moving light arrays showing non-human movement.

Movement also plays an important role in self-awareness. For example, our movements are a major contributor to our sense of agency: we get constant feedback that we are a conscious being via the translation of our intentions into movement. One of the more important areas of work for models of empathy has taken a closer look at this translation: how are our movements recognized as being self-generated?

At first, imagining a movement as being anything other than self-generated may be difficult. In everyday life, the impression that our movements are self-initiated is a seamless perception that does not require conscious deliberation. However, disruption of this perception occurs with the delusions of passivity seen in psychosis, where the person feels an external force controls their movements, speech or thoughts. In addition, with the use of a mechanical hand to delay the time between initiating a movement and feeling the returning sensory information, it is also possible to disrupt this perception experimentally (Wolpert et al., 1995).

There is growing body of work examining the question of how the brain distinguishes whether incoming sensory information, such as a moving finger, is the result of a self or non-self generated movement. A “forward” model has been elaborated to explain how this might be achieved (Wolpert et al, 1995; Wolpert et al., 2003). It is theorized that throughout development, the cerebellum builds up a “database” of the sensory feedback received for every action undertaken – everything from simple actions like waving the hand, to more complex actions like hitting a baseball. For example the precise muscle force, acceleration, and direction required to swing a bat would be stored, as well as physical characteristics of the bat and ball. With repetition and experience, this database grows, and the cerebellum becomes able to predict the sensory feedback that would result upon completing a given action. When a movement is initiated, it is proposed that a copy of the motor command is sent to the cerebellum allowing anticipation of the sensory feedback. If the actual sensory feedback matches the predicted feedback, the signal passing to the rest of the brain is attenuated and the movement is perceived as self-generated. If it does not match, the signal is not attenuated and the movement is perceived as externally generated. This type of model is called a “forward” model because information is sent ahead at the time of movement initiation.

In the case of a moving finger, signals initiating movement are sent from the premotor cortex to both the muscles of the finger, and to the cerebellum. The returning sensory information is compared to the predicted sensory feedback and if they match, the signal will be attenuated and perceived as self-driven.

Empirical research with humans is just beginning, but there is preliminary neuroimaging data to support this theory. Blakemore et al (1998) found in an fMRI study that the somatosensory cortex was less activated in self-generated than externally generated touch. This supports the idea that sensory afferent attenuation is involved in distinguishing self-generated movements. Imamizu et al. (2000) found a distinctive cerebellar activation that was present after subjects learned to use a new tool. They concluded this was an image of the internal representation of a motor sequence, although this requires further investigation.

Understanding the forward model is important because it posits a neural structure that is a surrogate for an internal representation of self. The proposed action database in the cerebellum represents an accumulation of an individual’s motor experience and is used to interpret and predict incoming sensory information to help create a coherent and consistent response to external and internal stimuli. In addition, via its central role in distinguishing self from non-self movements, it would play a critical role in establishing and maintaining the self/non-self boundary that characterizes normal mental life. The cognitive models of empathy explored in the next section often imply the existence of a similar database or internal model for information on emotions and intentions. The forward model thus provides a starting point for imagining these structures.

Understanding others: a projection of ourselves

As discussed earlier, everyday human interactions rely upon the ability to make quick and accurate inferences about the thoughts, emotions and future actions of others. Blakemore and Decety (2001) have proposed this is achieved via a mechanism similar to that proposed in the forward model, albeit in reverse order.

They propose that when we observe another person initiate a movement, we map the sensory information about their movements onto the internal database of actions proposed in the forward model. By comparing the observed action with the repertoire of self-generated actions stored in the cerebellum, the brain can predict what action will likely be undertaken. For example, upon seeing someone's hand begin to move toward an apple, this visual information is sent to the cerebellum. In the cerebellum, cross-referencing this information with the possible self-generated motor actions that begin in this way, a short list of probable actions (e.g. "the person will grasp the apple and bring it to the mouth", "they will place it elsewhere"), and less probable actions ("they will pick it up and throw it") is generated. Additional information could refine the list even further, such as the subject's direction of gaze, another person pointing at the apple, or the environmental context.

Of course in everyday life inference are made not only about a subject's next action, but also about the associated thoughts, intentions and emotions. Decety and Blakemore (2001) suggest this is achieved by working back from the cerebellar representation of a given action to the intention that most often leads to that action. Whichever cognitions or emotions most often trigger the action in the observer would be used to infer the emotional state or thoughts of the observed subject. For example, for someone who likes to eat apples, a common precipitant to grasping an apple might be hunger, and so the most salient inference might be that the observed person is hungry. For someone who is more preoccupied with cleanliness and order, the most salient thought might be to tidy up, and so they might infer the person would put the apple in the cupboard.

This mechanism may also account for how we detect the emotional state from a facial expression. For example, when one sees someone smiling, this would activate the sensory cortical areas for the corresponding mouth, face and eye movements, map them onto the cerebellar database, which from there could map back to the common thoughts or emotions that lead to this motor activity (e.g. happiness or "he's thinking something funny").

Despite some preliminary biological research, this model remains very theoretical. However, a class of neurons has recently been discovered whose function provides a biological substrate for this type of cognitive model.

Mirror neurons and a simulation theory of empathy

The premotor cortex is involved in the planning and execution of movements, and is arranged in a homuncular fashion similar to the primary motor cortex sitting just behind it. In the macaque monkey, an area of the ventral premotor cortex called F5 is involved in the control of hand and mouth movements (Rizzolatti et al., 1988). In the mid-nineties, a class of neurons was discovered in F5 that fired not just during self-generated movements, but also when observing that same movement in another monkey (Gallese et al., 1996; Rizzolatti et al., 1996). Due to this quality, the authors called these "mirror" neurons. Neurons with similar properties have also been found in the superior temporal sulcus (STS), and the inferior parietal lobule, and are thought to form an integrated "mirroring system" in the brain (Rizzolatti et al, 2001).

Of particular importance is that these neurons fire only during the initiation or observation of actions, not just movement. For example, they fire in response to observing another monkey grasp an object, but not to observing simple opening and closing of the hand. They also do not fire to grasping by non-living objects such as a mechanical hand (Rizzolatti et al., 2001). This suggests they code for a particular relationship in motor terms between subject and object. In other words, they are coding for intention, and not just for movement (Gallese & Goldman, 1998).

Mirror neurons represent a plausible organic substrate that begins to bridge the gap between the cognitive models of empathy and actual biology. First, they provide evidence that there are cells that respond specifically to observed movements. The fact that they are found in brain areas that also plan movements is intriguing. In addition, since their firing is linked to particular actions and intentions, there is no need to link with a separate structure (such as the putative action database in the cerebellum) in order to decode the intention from the motor action.

Gallese (2003a,b) has proposed that action observation leads to activation of the mirror neurons that also plan and initiate this action in the observer. He suggests that this resonant firing leads to a cortical simulation of the movement without actual motor imitation. That is, seeing someone reach for an apple triggers the same cortical neurons involved when the observer reaches for an apple, only the motor component is not initiated. However, the simulation permits direct connections to the limbic and frontal structures thought to contain information about the emotions and thoughts associated with this movement.

Subsequent studies have moved beyond vision to investigate possible mirror links with other sensory modalities. Kohler et al. (2002) found neurons in macaque premotor cortex that fire upon initiating, seeing, or hearing a particular action.

Although much of this work so far has been with non-human primates, there are a growing number of studies supporting a mirror system in humans. A variety of studies using electroencephalography (EEG), magnetoencephalography (MEG), and transcranial magnetic stimulation (TMS) have shown that activation of the prefrontal cortex during action observation is similar to during action execution (reviewed in Rizzolatti et al, 2001). One study reported a finding in humans analogous to mirror neurons. Hutchison et al. (1999) recorded from individual neurons in the anterior cingulate cortex in conscious patients during neurosurgery, and found that among a group of neurons that responded to the experience of pain, one responded both to feeling pinprick, and also to observing the surgeon receive a pinprick.

Neuroimaging studies using fMRI have added further support to the idea of a mirror system in humans. Iacobini et al. (1999) found that during both observation and imitation of a motor action, analogous structures to the mirroring system in macaques (i.e. the ventral premotor cortex, posterior parietal cortex and posterior STS) were activated in humans. Subsequent studies have also found mirroring effects with seeing and feeling touch (Keysers et al., 2004).

As the simulation model predicts, these imaging studies support the notion that observing a given movement causes a resonant firing of neurons in the same areas responsible for the corresponding movement in the observer. The next step would be to provide evidence of a connection between the action representation and the associated emotions or thoughts. This is difficult to demonstrate in monkeys, but there is now preliminary data from human imaging studies to support this connection.

Carr et al. (2003) found that both observing and imitating a variety of facial expressions activated very similar brain regions, including the fronto-temporal areas activated in previous studies on the putative mirroring system in humans. They also found that these areas, as well as the insula and amygdala, were more activated during imitation. They hypothesized that actions are represented in fronto-temporal mirror areas, and then link up to their associated emotion via projections through the insula to limbic structures such as the amygdala. Wicker et al. (2003) found observing faces and feeling disgust activated similar structures in the anterior amygdala and the ACC. This study also found insula activation, but only in the disgust condition and not the pleasant condition.

Clearly, research investigating this hypothesis in humans is just beginning. Not surprisingly the precise brain areas and the order in which they are activated remains hotly debated (Carr et al., 2003; Blakemore & Decety, 2001; Preston & de Wall, 2002; Gallese, 2003a,b). Nonetheless, there is remarkable consistency in the human work so far to suggest that as with monkeys, there is a mirroring system involving the ventral premotor cortex and inferior parietal areas that responds to action observation much as it does to action execution. Furthermore, that connections between this system and the limbic area (perhaps via the insula) may be involved in connecting a represented action to its associated emotion.

Implications for Personality Disorders

The simulation model of empathy predicts that people make inferences about the intentions and actions of others based on their own internal repertoire of intentions and actions. Our default is to suspect that others will act as we have acted in the past. By extending the model to human emotions and thoughts, it suggests that we believe others will feel as we ourselves would feel or think in the same situation. This theory has relevant implications for work with personality disorders.

As discussed earlier, a core dimension of personality pathology is a problem in perceiving and interpreting both self and others. This fits very well with the simulation models: if it is true that we perceive the world based on our internal model of ourselves, it would necessarily be the case that disordered perceptions of self and others would go together. In fact the model implies that distorted perceptions of others are really the consequence of a dysfunctional internal model of self. This could be useful in planning a treatment strategy.

Following from the model, there are two approaches that could be used to decrease this perceptual distortion. The first would be to try and teach the patient that their perceptions of other's intentions are incorrect. By teaching them to question their interpretations, and use more reliable methods to derive their inferences, these distortions might be overcome, leading to better interpersonal functioning. A second approach would be to focus on the distorted or negative sense of self directly. Based on the mirroring theory, treatments that focused on modifying maladaptive thoughts and perceptions about self should at the same time improve the way that others are perceived. In theory, this second approach would be more efficacious as it addresses distortions of both self and other simultaneously. It is unclear to what extent distorted perceptions of self change in step with distorted perceptions of others during the course of treatment for personality disorders. It is however an interesting and testable hypothesis.

The simulation theory of empathy also provides a number of provocative links with concepts in psychodynamic theory germane to personality disorders. For example, the defense mechanisms projection and projective identification have traditionally been considered immature defense mechanisms (Valliant, 1993). However, in the simulation theory, a process akin to projection is proposed as the mechanism underlying all empathic understanding. This view parallels Kleinian and Object Relations theory where projection and projective identification are considered universal mechanisms involved in normal psychic development as the infant traverses the paranoid position (Klein, 1975).

This raises the question of whether it is the content of the projection or the psychic mechanism itself that is maladaptive. It could be that the mechanism of projection is a universal and neutral psychic function, and in people with a healthy self-image and a functioning mirroring system, it is adaptive and thus largely invisible. However, in those with a troubled or immature perception of self, the projections are distorted and inaccurate, and thus stand out as a maladaptive defense. The more frequent use of projection and projective identification by those with personality disorders may simply reflect the higher rates of disordered self-perception in this population.

Another possibility is that the direct mirroring and projection implied by the simulation theories is important early on in development, but that their persistence in the mature adult may be a type of neurodevelopmental problem associated with psychopathology. This would parallel Klein's view that many forms of character pathology result from fixation in the paranoid position (Klein, 1975).

Kohut is the psychoanalyst who most famously emphasized the importance of empathy in therapy, and discussing a "mirroring system" in the brain underlying empathy brings to mind his concept of the "mirroring transference". He felt that consistent failure by a parent to empathically attend to a child's needs could lead to a damaged "self" and various types of personality pathology (Kohut & Wolf, 1978). He felt that empathically recognizing and mirroring the patient's needs in therapy could bridge this developmental lacune, and lead to a repaired self. This requires a highly developed sense of empathic acuity where the therapist can feel what the patient feels from moment to moment; a process where there is vicarious experiencing of an emotional perspective and a shared affective response. Mirror neurons may be the biological substrate via which Kohut was able to make this empathic connection.

The simulation theory also meshes well with general psychodynamic treatments in child psychiatry. For example, play therapy has been an important modality of treatment for young children with mood and behaviour problems. The rationale for play therapy is that young children do not have the cognitive and linguistic capacity to articulate thoughts and feelings like adults in traditional therapy, and so play is used as a window to their internal world (Coppolillo, 1996). The idea is that insight into how they understand themselves and the world can be gained by observing how they attribute thoughts and intentions to the toys and therapist. Certainly the simulation model would suggest that this is indeed a very prudent way to understand the child's internal representations, as toys represent an excellent, developmentally appropriate screen upon which to project their developing internal model of self.

Limitations and Future Directions

Although the findings related to the mirror system are exciting, the theories remain quite speculative, and several issues remain to be addressed.

First of all, several years of replication and further study are needed to better establish the validity of these ideas in actual biology. A compelling piece of evidence would be demonstrated impairment in empathic ability following injury to the brain areas implicated in the mirroring system in humans. In addition, discovery of mirror neurons in other animals might allow evolutionary insights as to whether this is a phenomenon of primates, or a more generalized mechanism of perception, conserved in evolution across many species.

There are important conceptual problems as well. For example, the simulation theory does not account for how we attribute thoughts and intentions to people that are not directly observed, such as those we read about, or hear described. There is a large literature on "theory of mind"- the processes via which we attribute mental states to self and others - that has been reviewed extensively elsewhere (Frith & Frith, 1999; Baron-Cohen et al., 2000; Frith & Frith, 2003). Although theory of mind accounts and simulation accounts of empathy are not completely incompatible, there is disagreement about how beliefs and desires are represented in the brain, and attempts to reconcile the two are underway (see Gallese, 2003a).

Another difficulty is that most people are able to articulate an understanding of other people that is objectively quite different from how they see themselves. As some in the self-psychology literature have written, the empathic therapist can "comprehend the experience of others from their own unique perspective, which is often very different from 'what I would feel if I were actually in their place'" (Baker & Baker, 1987, p.2). Although the simulation theory explains well how it is possible to vicariously experience the emotional state of another person, it does not explain how a therapist could know the idiosyncratic cognitions that a given patient associates with these emotions. Rather than simply using their own associated cognitions, the therapist must make guesses based on earlier information from the patient, their experience from other patients, etc. Thus, simulation cannot be the only way in which we make inferences about others. There must be a more nuanced mechanism that allows other information to be used besides simply an automatic mirroring leading to an inference. Simulation theories need to propose mechanisms that explain when and why the inferences they derive are ignored or overruled.

Lastly, an elegant theory would integrate the intuitive connections between motor mimicry phenomena, early childhood social learning via imitation, and the findings with mirror neurons.

One possibility is that the fast, automatic initial interpretation of others uses the mirroring system, but that this information is then modified or suppressed by more explicitly conscious reasoning. Perhaps in infants the mirror neuron simulations lead to overt imitation, but that during development the motor component is increasingly inhibited by cortical (and possibly conscious) mechanisms, leaving only brain simulations in mature adults.

This type of developmental hypothesis could be investigated with neuroimaging and EMG studies in children to see if there is a more robust connection between action observation and actual motor imitation compared to adults. Unfortunately, there are no studies explicitly testing the mirroring system hypothesis in children or even immature non-human primates. Certainly there are many practical problems with trying to functionally image children, especially if interaction is required. These difficulties would increase with even younger children, and might limit the feasibility of this sort of work.

People with psychiatric disorders are another important population that has not been studied thus far. Given that psychiatry is the main area in medicine in which problems with empathy-related skills arise, they might be an ideal group to investigate the mirror system hypothesis. There are numerous questions that could be investigated. Does poor empathy imply a defect in the mirroring system? For example, do people with autism spectrum disorders have deficits in mirroring systems? If so, to what extent is this modifiable? Can improvements in self-other distinction and empathy during therapy be correlated with activation of different brain regions in imaging studies? This is potentially a very rich area of investigation for psychiatry.

For now, clinicians will have to be satisfied with the less tangible but equally intriguing conceptual possibilities that this research provokes, bringing us a little closer to integrating clinical observations with neurophysiology.

FIGURE 1

DSM-IV General Diagnostic Criteria for a Personality Disorder

An enduring pattern of inner experience and behaviour that deviates markedly from the expectations of the individual's culture. This pattern is manifested in two (or more) of the following ways:

- cognition (i.e. ways of perceiving and interpreting self, other people, and events)
- affectivity (i.e. the range, intensity, lability, and appropriateness of emotional response)
- interpersonal functioning
- impulse control

The enduring pattern of behaviour is inflexible and pervasive across a broad range of personal and social situations.

The enduring pattern leads to clinically significant distress or impairment in social, occupational, or other important areas of functioning.

The pattern is stable and of long duration, and its onset can be traced back at least to adolescence or early adulthood.

The enduring pattern is not better accounted for as a manifestation or consequence of another mental disorder.

The enduring pattern is not due to the direct physiological effects of a substance (e.g. a drug of abuse, a medication) or a general medical condition (e.g. head trauma).

REFERENCES

American Psychiatric Association (1994). Diagnostic and Statistical Manual of Mental Disorders, 4th Ed.

Baker, H.S. & Baker, M.N. (1987). Heinz Kohut's self psychology: an overview. *American Journal of Psychiatry*, 144:1-9.

Baron-Cohen, S., Tager-Flusberg, H., & Cohen, D.J. (2000). *Understanding other minds: perspectives from developmental cognitive neuroscience, 2nd edition*. Oxford University Press.

Bavelas, J.B., Black, A., Lemery, C.R., & Mullett, J. (1987). Motor mimicry as primitive empathy. In Empathy and its development, N Eisenberg & J Strayer (Eds.), Cambridge University Press.

Blakemor,e S.J. & Decety, J. (2001). From the perception of action to the understanding of intention. *Nature Reviews Neuroscience*, 2, 561-567.

Blakemore, S.J, Wolpert, D.M. & Frith, C.D. (1998). Central cancellation of self-produced tickle sensation. *Nature Neuroscience*, 1, 635-40.

Carr, L., Iacoboni, M., Dubeau, M.C., Mazziota, 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, 5497-5502.

Coppolillo, H.P. (1996). Use of play in psychodynamic psychotherapy. In Child and Adolescent Psychiatry: *A Comprehensive Textbook, 2nd editon* , M Lewis (Ed.),Williams & Wilkins.

Frith, C.D. & Frith, U. (1999). Interacting minds – a biological basis. *Science*, 286, 1692-1695.

Frith, U., & Frith, C.D. (2003). Development and neurophysiology of mentalizing. Philosophical Transactions of the Royal Society of London B Series, 358, 459-473.

Fox, R., & McDaniel, C. (1982). The perception of biological motion by human infants. *Science*, 218, 486-487.

Gallese, V. (2003a). The manifold nature of interpersonal relations: the quest for a common mechanism. Philosophical Transactions of the Royal Society of London B Series, 358, 517-528.

Gallese, V. (2003b).The roots of empathy: the shared manifold hypothesis and the neural basis of intersubjectivity. *Psychopathology*, 36, 171-180.

Gallese, V., & Goldman, A. (1998). Mirron neurons and the simulation theory of mind-reading. *Trends in Cognitive Science*, 2, 493-501.

Gallese, V., Fadiga, L., Fogassi, L. & Rizzolatti, G. (1996). Action recognition in the premotor cortex. Brain, 119, 593-609.

Hutchison, W.D., Davis, K.D., Lozano, A.M., Tasker, R.R. & Dostrovsky, J.O. (1999). Pain-related neurons in the human cingulated cortex. *Nature Neuroscience*, 2, 403-405.

Iacoboni, M., Woods, R.P., Brass, M., Bekkering, H., Mazziotta, J.C. & Rizzolatti, G. (1999). Cortical mechanisms of human imitation. *Science*, 286, 2526-2528.

Imamizu, H., Miyauchi, S., Tamada, T, Sasaki, Y., Takino, R., Putz, B., Yoshioka, T., Kawato, M. (2000). Human cerebellar activity reflecting an acquired internal model of a new tool. *Nature*, 403, 192-195.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. Perception and Psychophysics, 14, 201-211.

Keysers, C., Wicker, B., Gazzola, V., Anton, J.L., Fogassi, L., Gallese, V. (2004). A touching sight: SII/PV activation during the observation and experience of touch. *Neuron*, 42, 335-346.

Klein, M. (1975). Love, guilt and reparation: and other works 1921-1945. Hogarth Press.

Kohler, E., Keysers, C., Umilta, M.A., Fogassi, L., Gallese, V., Rizzolatti, G. (2002). Hearing sounds, understanding actions: action representation in mirror neurons. *Science*, 297, 846-848.

Kohut, H. & Wolf, E.S. (1978). The disorders of the self and their treatment: an outline. *International Journal of Psychoanalysis*, 59, 413-425.

Meltzoff, A.N. & Moore, M.K. (1997). Explaining facial imitation: a theoretical model. *Early Development and Parenting*, 6, 179-192.

Preston, S.D. & de Waal, F.B.M. (2002). Empathy: its ultimate and proximate bases. Behavioural and Brain Sciences, 25, 1-72.

Rizzolatti, G., Camarda, R., Fogassi, L., Gentilucci, M., Luppino, G., & Matelli, M. (1988). Functional-organization of inferior area-6 in the macaque monkey; II. Area F5 and the control of distal movements. *Experimental Brain Research*, 73, 491-507.

Rizzolatti, G., Fadiga, L., Gallese, V. & Fogassi, L ,(1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research*, 3, 131-141.

Rizzolatti, G., Fogassi, L, &Gallese, V, (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience*, 2, 661- 670.

Skodol, A.E., Gunderson, J.G., McGlashan, T.H., Dyck, I.R, Stout, R.L., Bender, D.S., Grilo, C.M., Shea, M.T., Zanarini, M.C., Morey, .LC., Sanislow, C.A. & Oldham, J.M. (2002). Functional impairment in patients with schizotypal, borderline, avoidant, or obsessive-compulsive personality disorder. *American Journal of Psychiatry*, 159(2):276-83.

Vallian,t J., (1993). The wisdom of the ego. Howard University Press.

Wicker, B., Keysers, C., Plailly, J., Royet, J-P., Gallese, V., Rizzolatti, G. (2003). Both of us disgusted in my insula: the common neural basis of seeing and feeling disgust. *Neuron*, 40, 655-64.

Wispé, L. (1987). History of the concept of empathy. In Empathy and its development, N Eisenberg & J Strayer (Eds.), Cambridge University Press.

Wolpert, D.M., Doya, K. Kawato, M. (2003). A unified computational framework for motor control and social interaction. *Philosophical Transactions of the Royal Society of London B Series*, 358, 593-602.

Wolpert, D.M., Ghahramani, Z., & Jordan, M.I (1995). An internal model for sensorimotor integration. *Science*, 269, 1880-1882.