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The Role of Emotion and Empathy in Embodied Simulation in the Mirror Neuron System: Where Buddhism and Neuroscience Converge

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THE ROLE OF EMOTION AND EMPATHY IN EMBODIED SIMULATION IN THE MIRROR NEURON SYSTEM (MNS): WHERE BUDDHISM AND NEUROSCIENCE CONVERGE

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The Role of Emotion and Empathy in Embodied Simulation in the MNS: Where Buddhism and Neuroscience Converge

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The human mirror neuron system (MNS) offers a clear connection between phenomenology, philosophy of mind and cognitive science that has profound implications for understanding the actions, emotions and intentions of others. The MNS exemplifies an integration of first-person subjective levels of lived-bodily experience, and third-person objective accounts stemming from within cognitive neuroscience, which is known as neurophenomenology. This approach has important implications for understanding the role that emotion and empathy play in embodied simulation in the MNS. Similarly, neurophenomenology and the study of the MNS are important for closing the explanatory gap in philosophy of mind, and for surmounting the mind-body problem. The explanatory gap refers to a “gap” in our understanding of how to relate first-person, subjective levels of experience with a third-person, objective and scientific account stemming from within neurophysiology and brain science (Bayne, 2004; Lutz and Thompson, 2003). Studies involving Buddhism and neuroscience have also recently been important for illuminating phenomenal experience and neurobiology, in ways that may shed light on the explanatory ‘gap,’ by identifying the neural correlates of compassion, emotional regulation and attention.

In this thesis, I intend to argue that both Buddhist meditation and neuroscience are converging on illuminating the mind-body relationship in general, and the importance of emotion and empathy in the MNS in particular, with respect to how we connect with others. Studies with meditation and neuroscience are now illuminating how Buddhist meditation practices boost the activity of the neural correlates of compassion and empathy, by increasing feelings of compassion and empathy for others. The convergence of Buddhism and neuroscience is thus very important for understanding how we connect with each other. Hence, I will argue in this thesis that only a contemplative neuroscience approach is truly capable of illuminating the important role that emotion and empathy plays in embodied simulation in the MNS.

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CHAPTER I

INTRODUCTION

The human mirror neuron system (MNS) offers a clear connection between phenomenology, philosophy of mind and cognitive science that has profound implications for understanding the actions, emotions and intentions of others. Given that the MNS is a trimodal system composed of mirror neurons in the premotor cortex that respond to motor, visual, and auditory stimulation, such as when an action is performed, observed, or heard (D'Ausilio, 2007), the role of the audio-visual MNS for understanding the actions and emotions of others illuminates the importance of phenomenological approaches to embodied cognition for philosophy, Buddhist meditation and neuroscience. For example, the MNS exemplifies an integration of first-person subjective levels of lived-bodily experience, and third-person objective accounts stemming from within cognitive neuroscience, which is known as neurophenomenology. This approach has important implications for understanding the role that emotion and empathy play in embodied simulation in the MNS. Neurophenomenology and the study of the MNS are important for closing the explanatory gap in philosophy of mind, and for surmounting the mind-body problem. The explanatory gap refers to a "gap" in our understanding of how to relate first-person, subjective levels of experience with a third-person, objective and scientific account stemming from within neurophysiology and brain science (Bayne, 2004; Lutz and Thompson, 2003). Lastly, a neurophenomenological method of investigation is also being invoked in recent studies with Buddhist meditation and neuroscience, by identifying the neural correlates of compassion, emotional regulation and attention, which is a contemplative neuroscience approach for closing the explanatory gap as well.

In this thesis, I intend to argue that both Buddhist meditation and neuroscience are converging on illuminating the mind-body relationship in general, and the importance of emotion and empathy in the MNS in particular, with respect to how we connect with others. Through exploring studies on Buddhist compassion meditation and neuroscience, I intend to show the importance of emotion and emotion-regulation by examining the phenomenon of neural plasticity in the brain. The brain is able to rewire itself, in order to increase positive emotion, by engaging in compassion meditation and mindfulness. Positive emotional states may be defined as the experience of contentment, joy, interest, pride, and love (Fredrickson, 2001, pg. 3), as well as happiness, satisfaction, being at ease, calmness and gratitude. Similarly, the role of emotion in the MNS is now receiving a great deal of attention, especially since positive emotion preferentially engages the coupling of both auditory and visual (AV) information in the MNS (Warren et al., 2006). AV integration in the MNS plays an important role in action perception and understanding (McGarry et al., 2012), including empathy or the ability to understand another individual's mental state (Oberman et al., 2005, pg. 191). Moreover, because the role of the MNS in intentional action understanding and attunement involves the importance of emotions and empathy, as an intersubjective manifold for understanding and experiencing the emotions and intentions of others (Gallese et al., 2002), the MNS functions as an embodied simulation mechanism for understanding the emotions and intentions of another person's embodied mind, which has important implications for intersubjectity and mindfulness. Thus, the MNS is a trimodal system of audio-visual neurons that plays an important role in action understanding and recognition (D'Ausilio, 2007), which has now been implicated in intentional action understanding, embodied simulation, theory of mind and imitation learning, and empathy or empathic mirroring (Oberman et al., 2006; Oberman and Ramachandran, 2009a; Rizzolatti et al., 2001).

Given that the MNS responds to the observed actions of another person, embodied simulation mechanisms in the MNS play a pivotal role in understanding and experiencing the actions, intentions and emotions of others, which illustrates the importance of empathic mirroring and intersubjectivity. Similarly, according to Indo-Tibetan Buddhism, our sense of personal identity is strongly reinforced by our intersubjective relations with others (Wallace, 2001, pg. 211). In fact, the central Buddhist insight practice of "the four applications of mindfulness" is a means for gaining insight into the nature of oneself, others and the relations between oneself and the rest of the world. This practice provides a basis for cultivating a deep sense of empathy (Wallace, 2001, pg. 209). Furthermore, according to Buddhism, compassion is based upon empathy, but in a profound sense insight into the nature of oneself, and others, and the relation between oneself and the rest of the world is also based upon empathy (Wallace, 2001, pg. 213). This suggests very strong parallels between Buddhist meditation and the role of empathy in the MNS. In so far, Buddhist meditative practices offer that we can train our minds to be more compassionate and empathic, through mindfulness and specific contemplative practices such as compassion meditation that improve how the brain functions. Lastly, I will argue that because the role of emotion in embodied simulation in the MNS plays an important role in empathic mirroring, only a contemplative approach that incorporates both Buddhist meditation and neuroscience is truly capable of illuminating the role that empathy plays in the MNS. Moreover, Buddhist meditative practices increase positive emotion, and the experience of positive emotion has been shown to enhance AV integration in the MNS (Warren et al., 2006), in addition to increasing the neural activity of several brain areas where mirror neurons are now either localized or implicated. Buddhist meditative practices thus increase positive emotion, which increases the neural sensitivity of the MNS for AV integration, and empathy. In this thesis, I argue for a contemplative neuroscience approach to the study of emotion and empathy in the MNS, an approach that is supported by recent studies with Buddhist meditation and neuroscience, along with the important role of empathy in embodied simulation and mindfulness. Currently, no empirical studies exist that examine the cognitive effects of mediation on the MNS, which is surprising given that the MNS is very important for several forms of empathy (Fan et al., 2011; Lamm et al., 2010), in addition to the fact that positive emotion has now been shown to enhance the audio-visual facilitation of the MNS (Warren et al., 2006; Dr. Pineda, 06/23/2010, personal conversation). Thus, it will be my contribution in this thesis to illuminate what is already known about the connection between positive emotion and empathy in the MNS, and both positive emotion and empathy in studies involving Buddhist meditation and neuroscience, in order to illustrate how important studies involving meditation and the MNS are for understanding the role of emotion and empathy in the MNS. In Chapter Six, I propose new empirical studies involving the MNS and meditation, in light of such a discussion.

The human MNS illustrates a profound integration of audio-visual information processing that plays a pivotal role in action recognition and emotional understanding. For example, studies with mirror neurons have provided a unifying neural hypothesis for how individuals understand the actions and emotions of others (Gallese et al., 2004). Researchers have suggested that the MNS provides concrete evidence for the shared representations of perception and action, which are crucial for the production of empathy (Gallese et al., 2002, pg. 36). The role of the MNS in action understanding is significant because it implies that within our understanding of actions; we are also able to understand the underlying intentions, thoughts and emotions, and motivations behind the actions of others (Oberman et al., 2006), which include the very mental states of others. Empathy entails the existence of neurobiological mechanisms for understanding another individual's mental state (Oberman et al., 2005, pg. 191), as we can walk in the mental "shoes" of another, by being able to simulate the mental states motivating the actions and behavior of others. Mental states are shared with the experiences of others through the neurobiological properties of the MNS, which are embodied simulation mechanisms that enable us to put ourselves in another person's shoes, by simulating their thoughts and emotions. Empathy refers to a change in an emotional state that results from contemplating someone else's emotional state, and experiencing an emotion that is similar in quality to the emotion experienced by another person (Light and Coan, 2009). In addition, Buddhist contemplative practices such as mindfulness and compassion meditation are very insightful, and important for illuminating the neural underpinnings of empathy in the MNS. Such contemplative practices focus on the relation between both the self and others, as a means for cultivating empathy and compassion (Wallace, 2001), and recently mirror neurons have even been referred to as the 'Dalai Lama' neurons for compassion. In so far, this means that the MNS forms a manifold for empathic mirroring and intersubjectivity, by which we share in the lived experience of emotions, actions and intentions of others, through watching their bodily movements and actions. The role of the MNS in intentional action understanding and attunement with others thus involves the importance of emotions and empathy as an intersubjective manifold for understanding and experiencing the emotions, thoughts and intentions of others (Gallese et al., 2002).

The MNS is significant for it provides a unifying neural hypothesis for action understanding and emotion (Gallese et al., 2004), by linking together subjective levels of experience with objective accounts stemming from within neurophysiology. Recent studies involving compassion meditation, mindfulness practice, and neuroscience are important for providing insight into how positive emotion can re-wire the brain, an account of neural plasticity. For example, studies involving compassion meditation and mindfulness at Dr. Richie Davidson's neuroscience lab at the University of Wisconsin at Madison have shown the brain's ability to change, grow and rewire itself. The brain circuits related to happiness are changeable, a fact that illuminates the ability to increase positive emotion, and reduce negative emotion, through engaging in the Buddhist practices of compassion meditation and mindfulness. Buddhist compassion meditation has now been shown to enhance neural activity in the fronto-partietal area (Lutz et al., 2004), where the fronto-parietal mirror neuron network is localized. Compassion training (CT) programs that are based on compassion meditation have also now been shown to enhance neural activity in the inferior parietal lobule (Weng et al., 2013), where mirror neurons are localized. The inferior parietal lobule is involved in the observation and imitation of facial expressions of basic emotions (Gallese, 2006a, pg. 21). Cognitively-Based CT has also been shown to increase neural activity in the inferior frontal gyrus and dorsomedial PFC when attempting to infer others' emotions (Mascaro et al., 2013), which are areas where mirror neurons are now also localized. The inferior frontal gyrus is a gyrus of the frontal lobe, which is now thought to be involved in emotional empathy (Pineda, 2005), with respect to inferring or simulating the emotional state of another, and hence experiencing it as well. The dorsomedial PFC is an area of the prefrontal cortex involved in perspective taking, theory of mind, and intersubjectivity (Gallese, 2006a). Lastly, mindfulness meditative practice has recently been shown to increase compassion and empathy, and gray matter density in the temporo-parietal junction (TPJ) (Hozel et al., 2011), where mirror neurons are implicated (Oberman et al., 2008). The TPJ is region of the brain where the temporal and parietal lobes meet, which is involved in social cognition and theory of mind, including perspective taking and the ability to infer the mental states of others, and both compassion and empathy (Holzel et al., 2011, pg. 8).

The relationship between meditation or neural plasticity and the MNS is significant, given that positive emotion has now been shown to preferentially engage the coupling of both auditory and visual information in the MNS (Warren et al., 2006). Recent studies by Dr. Jaime Pineda's lab at UC San Diego have shown that autistic children show a more typical MNS response to watching the actions of other people, while those children are experiencing positive emotions. This suggests that positive emotion increases the neural activity or sensitivity of the MNS, and auditory-visual processing in particular, which has important implications for empathy as well. In fact, it is known that both empathy and positive emotional experience are associated with the engagement of the prefrontal cortex (PFC) (Light and Coan, 2009, pg. 1214), where mirror neurons are now implicated (Oberman et al., 2006). The role of the PFC in emotional processing and executive functioning make this region particularly interesting to study, with respect to empathy. Empathy requires the ability to hold emotional information in mind, through working memory, and to switch attention between one's own emotional state and the state of another, which requires cognitive flexibility (Light and Coan, 2009, pg. 1212). The ability to orchestrate an appropriate emotional response, that makes use of the information about one's own emotional state and the emotional state of another, is likely due to empathic mirroring and embodied simulation mechanisms in the MNS. Similarly, as empathy is associated with dynamic changes in the PFC during positive emotion in children, positive emotional experiences in children enhance both empathy and executive function in the PFC (Light and Coan, 2009), which has important implications for intentional attunement mechanisms in the MNS in general, and autism in particular.

The ability to accurately infer or simulate others' mental states from facial expressions and emotions, which is crucial for the production of empathy, is radically impaired in children with autism (Oberman et al., 2005; Oberman et al., 2006). For example, children with autism are deficient at reading the emotions of other individuals, including facial expression and the expression of both emotions and body language. This is now thought to be due to defective intentional attunement mechanisms in the MNS, which are caused by a lack of embodied simulation (Gallese, 2006a). Deficits in embodied simulation suggest that children with autism are deficient in their ability to simulate the actions and behavior of other children (Gallese, 2006a), including their mental states and facial expressions. A further indication of embodied simulation deficits in autistic individuals is exemplified by imitation deficits, including facial expressions and gestures (Gallese, 2006a, pg. 21). Furthermore, a recent study involving the perceptual processing of emotional faces strongly supports the simulation account of a mirroring mechanism (Moore et al., 2012), which is the first study to report distinct EEG mu responses to the observation of both positive and negative valence in emotional faces. Moreover, compassion meditation has recently been shown to enhance empathic accuracy and related neural activity, with respect to inferring others' mental states from their facial expressions and emotions (Mascaro et al., 2013). This study was based on the Tibetan Buddhist practice called *metta*, or loving-kindness. The study conducted at Emory University found that compassion meditation, based on this Tibetan model, can effectively boost one's ability to empathize with others, by way of reading their facial expressions (Mascaro et al., 2013). Compassion-based meditation programs can thus significantly improve a person's ability to read the facial expressions of others (Mascaro et al., 2013), by boosting the neural basis of empathy. Compassion meditation may therefore be important for improving social functioning, given that positive emotion increases the sensitivity of the MNS for auditory-visual processing, and empathy or empathic accuracy, which suggests an important role of Buddhist compassion meditation in therapy for social cognitive disorders, such as autism.

In addition, studies with the somatotopic auditory MNS in humans are also illustrating that there is a link between the motor MNS and empathy, given that individuals who scored higher on an empathy scale activated this auditory system more strongly (Gazzola et al., 2006, pg. 5055). Given that compassion meditation has been shown to increase both positive emotion and empathy, it should also enhance the auditory processing in the MNS, which can be empirically tested. In fact, long-term meditation practitioners that have more than 10,000 hours of practice in Buddhist meditation (Lutz et al., 2008, pg. 1), and are perceived in their communities as embodying qualities of compassion, show greater empathic neural responses when listening to the sounds of other people's suffering, during compassion meditation practice (Lutz et al., 2008), compared to control subjects. Moreover, studies with primates have already shown that positive emotions preferentially engage the coupling of auditory and visual information via the MNS (Warren et al., 2006), which increases AV integration in the MNS.

The role of positive emotions or happiness in learning and cognition is now receiving great attention in the cognitive science community (Immordino-Yang and Damasio, 2007). The experience of positive emotions might therefore make humans more sensitive and empathetic, by enhancing the neural processing in the MNS associated with intentional action understanding, emotion and empathy. In so far, the experience of positive emotion thus boosts the neural basis of empathy in the MNS, so we are more in tune to the facial expressions, emotions, and body language of others. This suggests that positive emotion increases the neural activity and sensitivity of the MNS, and AV processing in particular, which, in turn, produces an increase in empathy, or empathic accuracy for reading facial expressions and mirroring. Research now indicates that the happier we feel, the more readily we can learn and retain new information, a fact that has vast implications for illuminating how Buddhist meditation practices that increase happiness and empathy can affect AV processing within the MNS.

I conclude my thesis project by proposing in Chapter Six some future MNS studies involving emotion and Buddhist compassion meditation and mindfulness practice, including how short-term vs. long-term mediation affects AV processing in the MNS. In short, given that Buddhist compassion meditation increases positive emotion or happiness through neural plasticity, along with boosting the neural basis of empathy (Mascaro et al., 2013), and mindfulness practice increases compassion and empathy (Holzel et al., 2011), Buddhist meditation practice should therefore lead to an increase in the MNS response to audio-visual stimuli, auditory sound, facial emotion, and even intentional attunement.

CHAPTER 2

CONTEMPLATIVE SCIENCE: THE CONVERGENCE OF BUDDHISM AND NEUROSCIENCE

2.1 Descartes' Foundations, His Legacy, and the Mind-Body Problem

In order to understand the important implications of the role of embodiment or embodied cognition in action understanding and recognition, and in particular the mirror neuron system, we must first frame the question of embodiment within its historical context. Perhaps more than any other modern philosopher of mind, Descartes formulated our fundamental notions of the mind and its relationship to the body, and in doing so he created one of the most difficult puzzles for modern philosophy, *the mind-body problem*. Descartes asserted that the mind is an immaterial substance whose essence is thinking, whereas the body is a material substance whose essence is spatial extension, and also that no substance can have more than one essence, which jointly entail the doctrine of Cartesian Substance Dualism that has plagued the study of the mind and its relationship to the body for centuries. Descartes's mind-body problem is also central to addressing issues in the study of consciousness, given that the "mystery" of consciousness proves the existence of connections between the mind and the body.

Today, however, the topic of embodied cognition has recently enabled philosophers of mind and cognitive scientists to argue that in order to understand the mind, we must also take into account the psychological role and metaphysical status of the body in human cognition, which has significant implications for the mind-body problem. In fact, conscious bodily movement and coordination not only play a central role in action understanding and intentional attunement with others, which I will explore in detail with respect to the mirror neuron system, but also the intentional movements of our own bodies and hence our embodied actions are fundamental to the evolution of our social cognition. Furthermore, Buddhist contemplative practices are also quite capable of furthering our understanding of the mind-body relationship, as mindfulness meditation and practice asserts that the body and mind are found to be naturally coordinated and embodied (Varela, Thompson and Rosch, 1993, pg. 29). This is especially true when the mindfulness practitioner simply lets go, and forgoes trying to achieve a particular state of activity, as mindfulness meditation and reflection is then found to be a completely natural and embodied activity (Varela, Thompson and Rosch, 1993, pg. 29). At this level of embodied reflection, one achieves a certain condition that phenomenologically feels neither purely mental nor purely physical; for it rather is a specific kind of mind-body unity (Varela, Thompson and Rosch, 1993, pg. 29). Moreover, studies involving Buddhist meditation and neuroscience are becoming very important for showing how meditation affects emotional processing and regulation in the brain, including happiness, compassion and empathy, which has important implications for developing a neuroscience of consciousness, and for neurophenomenology in particular, by illuminating the mind-body relationship (Lutz and Thompson, 2003). It will be my purpose in the first part of this thesis to describe briefly some of the most important contributions to our understanding of embodied cognition that are being made in contemporary cognitive science and the philosophy of mind, including phenomenology, cognitive neuroscience, contemplative neuroscience, artificial intelligence, and mental representation theory.

2.1.2 Introduction to the Role of the MNS in Embodied Cognition, Empathy and Phenomenology

The investigation of the central role of embodiment in cognition is having a profound effect on both contemporary philosophy of mind and contemporary cognitive science. For example, a central question of embodiment theory is how the brain coordinates bodily movement and sensorimotor knowledge within the environment, in order to couple together both perception and action in the endogenous generation of adaptive behavior. The mirror neuron system (MNS) plays an important role in embodied cognition, given that embodiment specifically structures our recognition of actions and understanding, via the neural mechanisms in the MNS that are involved in action observation and execution. Furthermore, a correct account of the human MNS demonstrates a clear connection between phenomenology and cognitive science that has profound implications for understanding the actions and intentions of others. More precisely, given that the MNS is a trimodal system composed of audio-visual mirror neurons that respond to motor, visual, and auditory stimulation (D'Ausilio, 2007), a correct account of the role of the MNS for action understanding and recognition illuminates the importance of phenomenological approaches to embodied cognition in philosophy and cognitive science. In this essay, I intend to explore a non-reductive, neurophenomenological approach that will support the thesis that the MNS plays an important role in embodied cognition including action recognition and understanding, emotion and empathy. Moreover, action perception and understanding in the MNS is intimately linked to empathy, given that empathy entails the existence of neurobiological mechanisms for understanding another individual's mental state (Oberman et al., 2005, pg. 191). The MNS thus provides a mechanism for understanding and simulating the mental states of others, through empathy and embodied simulation.

Through exploring the mechanism of action understanding based upon the MNS, an account will emerge which (1) is conceptually very similar to the proposal for how action understanding takes place according to phenomenologists, and in particular according to Merleau-Ponty (Gallese et al., 2004), and (2) will show that embodiment plays a very important role in action understanding and recognition within the MNS. On the one hand, the tradition of phenomenology has made great contributions toward our understanding of consciousness and intentionality, through the study of first-person or subjective experience, which includes the use of Buddhist meditation and mindfulness practices. On the other hand, cognitive neuroscience has also made great contributions toward our understanding of human cognition, through the use of third-person, objective neurobiological and causal-functional accounts of the embodied brain in its relation to the world. By using a two-sided or *neurophenomenological* method of investigation, I will show that the MNS illustrates an integration of both first-person and subjective lived-bodily experience, and also third-person objective accounts stemming from within cognitive science and neuroscience. Therefore, a neurophenomenological approach to the study of embodied cognition will receive support from a detailed empirical account of the important role of the MNS for intentional action understanding, emotion and empathy, and recent studies involving Buddhist meditation and neuroscience.

2.1.3 Introduction to Neurophenomenology for the MNS and Buddhist Meditation

Neurophenomenology refers to the philosophical project in the philosophy of mind and cognitive science to bring together first-person, subjective levels of experience and emotion, including feelings, sensations and introspection within a paradigm that also includes third-person, objective approaches stemming from within neurobiology. Such a quest follows in the tradition of neurophenomenology put forth by the late neuroscientist Francisco Varela, which illustrates an intriguing project to marry together phenomenology, our first-person or narrative description of our own feelings, emotions, thoughts and bodily experiences that are subjective, with an objective, neurobiological account that can make progress in cognitive science. It should also be noted that Varela was very involved in the *Mind and Life* dialogue with the Dalai Lama, in which neuroscientists and Buddhist scholars discussed the potential of developing a scientific investigation of the nature of consciousness. The subjective levels of experience that include our thoughts, feelings and introspective awareness often refer to the contemplative practices of Buddhist meditation, which enable the practitioner to explore the nature of the mind, and its relation to the body, through introspection alone. Such an embodied approach to both the philosophy of mind and cognitive science is supported by Buddhist contemplative practices such as mindfulness (Varela, Thompson and Rosch, 1993), for the use of embodied reflection is central to achieving the unity of the mind-body relationship. In this respect, the practitioner phenomenologically feels a specific kind of mind-body unity, which is a certain condition of accomplishment in the mindfulness practice of meditation and awareness (Varela, Thompson, and Rosch, 1993). Such embodied approaches to cognitive science that incorporate contemplative practices have also led to an increased interest in contemplative neuroscience as well, for studying the mind-body relationship. In so far, one of the most intriguing areas has been to attempt to develop a neuroscience of consciousness, where subjective levels of experience and brain dynamics could be integrated together to advocate neurophenomenology (Lutz and Thompson, 2003). Thus, because neurophenomenology is of central interest to the study of the role of emotion and empathy in the mirror neuron system, and the intersection of meditation and neuroscience, it represents a very important approach for this thesis.

2.1.4 Introduction to Neurophenomenology Part II: The Explanatory Gap

Neurophenomenology represents a non-reductive approach in the philosophy of mind, as it strives to link neural behavior and phenomena in such a way as to illustrate the profound role of the body and its sensations, and experiences in our daily life, while correlating such bodily experiences with their underlying neurophysiology. This project has recently become popular with philosophers of mind and cognitive scientists that are interested in embodiment. This includes the role of the body in shaping cognition, and in particular the importance of the body and intentional body movements in action understanding and recognition, along with the role of emotion in embodied cognition. In the first part of this essay, the use of neurophenomenology and non-reductive approaches for illuminating the role of embodiment in cognition, including its role in surmounting the mind-body problem, will be a central focus. In this respect, the working hypothesis of neurophenomenology is that phenomenological accounts of the structure of experience, and their counterparts in cognitive science relate to each other through reciprocal constraints (Varela, 1996, pg. 343). The key point here is that by emphasizing a co-determination of both accounts, one can then explore the challenges, insights, and contradictions between them (Varela, 1996, pg. 343), such that both domains of phenomena have equal status. In so far, it is quite easy to see how scientific and neurobiological accounts illuminate mental experience, but the reciprocal direction, from experience to science, is what is typically ignored (Varela, 1996, pg. 343). Varela asserts that such a program may provide a theoretical or methodological remedy for the hard problem of consciousness, where there is the problem of associating our phenomenal consciousness, or experience of pain and pleasure, with cognitive mental events that are explained with neurophysiological data and neuroscience. This results in a "gap" in our understanding, known as the explanatory gap, between the phenomenal or "what it's like" character of experience, and the physical nature of the brain and body (Bayne, 2004, pg. 350). In fact, several philosophers of mind, including Tim Bayne, Shaun Gallagher, and Evan Thompson have invoked the use of neurophenomenology for addressing the explanatory gap in the philosophy of mind, which I will now briefly discuss.

The explanatory gap refers to a "gap" in our understanding of how to relate first-person, subjective levels of experience with a third-person, objective and scientific account stemming from within neurophysiology and brain science (Bayne, 2004; Lutz and Thompson, 2003). According to Chalmers, it is the explanatory gap that makes the hard problem of consciousness hard (Chalmers, 1995), and if one can 'close the gap,' that person would undoubtedly solve the hard problem of consciousness. However, given that consciousness is perhaps the most difficult and challenging problem for philosophers of mind and cognitive scientists, this is a problem that will likely not be solved for several years, unfortunately. There is hope, however, among those individuals who are quite sympathetic to neurophenomenology, for such advocates feel that we can close the gap by merely developing better models of phenomenality, and better models of neuronal activity (Bayne, 2004, pg. 350). It is this relationship between phenomenology and brain science that my thesis ultimately explores, given the very way in which brain science is concerned with explaining the way that physical processes of the brain conspire to produce the phenomena of human experience. Such an approach will be pivotal for exploring empathy in the MNS, and the intersection of Buddhist meditation and neuroscience as well. Furthermore, both the role of emotion and empathy in the MNS and studies involving meditation and neuroscience exemplify the efficacy of neurophenomenology for closing the explanatory gap, which I will discuss in section 2.8.1 and 2.8.2. Hence, although there is no real difference between contemplative neuroscience and the neurophenomenological approach, given that studies with meditation and neuroscience are one important example of neurophenomenology today, studies involving both empathy in the MNS and Buddhist meditation each have distinctive contributions to make for closing the explanatory gap, which I will also address in section 2.8.1 and 2.8.2 as well. These contributions are very important today for surmounting long-standing problems in the philosophy of mind and cognitive science, such as the explanatory gap and the hard problem of consciousness.

2.2 Enactivism about Perception and Evolutionary Approaches

Given that embodied cognition shows great promise in advancing our understanding of the connection between the mind, the brain, the body, and its relation to the world, several philosophers of mind have recently made substantial contributions to our understanding of the embodied mind through the development of the *enactive* approach to cognition (Noë, 2004; Thompson, 2007). The enactive approach to cognition asserts that the human mind emerges from the self-organizing processes that interconnect the brain, body, and its situation in the environment at multiple levels, especially via the coordination of bodily action and sense perception (Thompson, 2007, pg. 56). Furthermore, recent advances in the study of artificial intelligence and artificial life demonstrate the ability to simulate embodiment through designing "autonomous robots" (Boden, 2001), or artificial agents, that are capable of navigating and evolving within the environment, in addition to exploring the relationship between mind and life. Moreover, because the evolutionary function of the brain is to process information in ways that leads to the endogenous generation of adaptive behavior, it is clear that only within an evolutionary framework can we begin to understand how action and perception are possible. Evolutionary psychology thus shows great promise in providing philosophers and cognitive scientists with an evolutionary framework, or paradigm, in which to view the computational and information-processing capacities of the brain as cognitive adaptations (Tooby and Cosmides, 1997), which also provide necessary connections to the body. Hence, the basic idea that evolutionary psychology can provide us with an evolutionary tool for examining the nature of information-processing adaptations is therefore very useful for the fields of cognitive science and the philosophy of mind, as the brain evolved to create adaptive behavior through coordinating sensory-motor systems within the environment.

2.2.1 The Body and the Environment: The Role of the Body in Shaping Cognition

A "body schema" is the action-guiding content of sensorimotor knowledge. Since the body schema and our bodily perception enable us to navigate within the environment (Bermudez et. al, 1995, pg. 235), the way in which the body actively organizes its sense experience via sensorimotor knowledge produces an ecological interaction between the body and the environment. The philosopher of mind Alva Noë asserts in his enactive view that perceptual experience acquires content solely and wholly due to our possession and exercise of practical bodily knowledge (Noë, 2004, pg. 34). Bodily perception and movement therefore shapes the way in which we perceive reality to be, as a lived-bodily experience (Rohrer, 2007, pg. 5). In this respect, we learn about the world and our environment through exploring it, as embodied minds in action that actively walk, touch, smell, listen, and use language in order to forge connections between the social and physical environment (Noë, 2004).

The obvious strength of the enactive approach to embodied cognition is that it takes into account valuable insights from the subjective levels of lived-bodily experience, which include emotions and shared experiences that also invoke the use of language and metaphor, along with encompassing objective scientific approaches to the study of the brain and body (Thompson, 2007). Given that physical facts about our bodies ultimately place constraints on the types of bodily movements and actions that we can engage in, our bodily actions also include sensorimotor knowledge about our past environments, insofar as that knowledge is calibrated to the environments in which the human organism evolved (Tooby and Cosmides, 1997, pg. 8). One important advantage of the enactive approach to perception is that it explains how the movements of the body and sensorimotor knowledge jointly shape perceptual content and experience in response to the environment (Noë, 2004), consistently with an evolutionary paradigm. This line of thinking asserts that since embodied agents are quite capable of structuring their own sensory information in response to the environment (Pfiefer and Bongard, 2007, pg. 58), sensory-motor coordination and bodily movement thus induce sensory stimulation, which provides the basis for perception and learning (Pfiefer and Bongard, 2007, pgs. 119-20). The study of embodied cognition is therefore not only quite capable of explaining the evolution of the brain and how it endogenously coordinates bodily action and perception, but it also ushers in a new revolution within cognitive science whereby we can no longer view intelligence without also taking into account the effects of the whole living body on cognition (Pfeifer and Bongard, 2007).

2.3 The Evolution of Social Cognition: An Overview of the Mirror Neuron System

Evolutionary psychology asserts that we possess cognitive adaptations for social exchange and interaction (Tooby and Cosmides, 1991a), for evolution should have selected for a cognitive ability to understand the actions that are performed by others, with respect to their intentions and emotions, along with a capacity to recognize how bodily movements and behaviors are ultimately motivated toward achieving a particular goal. In fact, this is exactly what neuroscientists have recently observed within the MNS in both humans and monkeys (Buccino et. al, 2005). The MNS provides clear evidence for an information-processing adaptation within our cognitive neural architecture for social cognition, in terms of action understanding and recognition, which involves the effects of body movements and actions on cognition. Moreover, as evolutionary theory is useful to modern "naturalized" epistemological theory by viewing the brain as both a computational system and an evolved biological system, we can develop a task analysis that defines the nature of the adaptive information-processing problem that the adaptation solved (Tooby and Cosmides, 1994); in addition to explaining the evolution of the brain and the body itself. Hence, we can learn more about the nature of the embodied mind and how it acquires knowledge through the use of evolutionary theory and task analyses, given that evolution should have created a mesh between the computational properties of the human mind and the regularities of the world (Shepard, 1987). Thus, as evolutionary psychology begins to have a more profound impact on cognitive science and the philosophy of mind, in terms of its ability to properly address the nature of the brain and its cognitive neural architecture as an information-processing adaptation, such insights will also help to illuminate the evolution of embodied cognition.

2.3.1 Cognitive Neuroscience, Embodied Cognition, Mirror Neurons and Empathy

Another argument for the embodiment approach in the philosophy of mind stems from recent contributions that cognitive neuroscience is also making toward understanding embodied cognition. Recent studies in cognitive neuroscience have made significant progress in demonstrating the role of the motor system in cognition, especially with respect to action understanding, imitation, and even language (Tettamanti et. al., 2005), which reveal the adaptive roles that thought and language have played in our evolutionary past. There is currently a great wealth of research being conducted in cognitive neuroscience that can further our understanding of the connection between action and perception and the relationship between the body and cognition. The MNS plays an important role in embodied cognition, given that embodiment specifically structures our recognition of actions and understanding, via the neural mechanisms in the MNS that are involved in action observation, perception and execution. Because brain activity and thought are intimately linked to action, mirror neurons in the brain activate when we watch others engaging in a particular activity (Fogassi et. al, 2005). Such action perception in the MNS also involves the existence of neurobiological mechanisms for understanding the mental states of others, through empathy (Oberman et al., 2005). Embodiment and empathy plays a very important role in action understanding and recognition within the MNS, as within our understanding of actions, we are also able to understand the underlying thoughts, intentions and emotions, and motivations behind their actions. Much of the information processing that occurs in the brain must therefore be devoted to learning about the embodied actions of others, in addition to being able to keep track of where such actions take place in the environment. This also illustrates an interesting feedback mechanism, where the brain controls the body, and the effects of the body control the brain (Pfeifer and Bongard, 2007). The MNS in the motor cortex thus responds both when we perform a particular action and when we observe it in others. Given that thinking normally also generates visual imagery, our thought must also have a motor component, especially since the neural circuits in our brain that support visual imagery are connected to larger sets of neurons that are distributed throughout the body (Tooby and Cosmides, 1997). More generally, an argument for the embodiment approach to cognition is that it is impossible to have an adequate understanding of the mind that does not take into account the profound connections between the visual brain, the active living body, and the environment. The coupling together of sensory and motor systems is thus necessary for embodied social cognition within the situated environment.

2.3.2 The MNS is an Evolutionary Adaptation for Action Perception and Understanding

Since the neural circuits in the brain are also designed to generate motion and behavior in response to the environment, the same MNS that plays a pivotal role in understanding the actions and emotions of others is also active within the motor cortex when we engage in a particular behavior (Gallese et. al., 2004). This means that the MNS, which has now been observed in macaque monkeys and humans (Buccino et. al., 2005), provides impressive evidence for an evolutionary adaptation within higher primates for action understanding, which must have played a fundamental role in the evolution of social and embodied cognition. The MNS has also been shown to have a visual and auditory response system, given that the audio-visual mirror neurons fire when an action is performed and observed, in addition to firing simply when the sound of an action is heard (Buccino et. al., 2005, pg. 355). The fact that listening to action-related words or sentences can also directly activate the mirror neurons within the motor system indicates an adaptive role that language has also played in the evolution of embodied cognition. Language provides a mechanism for understanding bodily movement and action as embodied patterns of action (Glenberg, 1997, pg. 19) that are connected to the environment.

2.3.3 Developmental Psychology and Embodied Cognition in Infants

Investigating the contributions that the fields of cognitive and developmental psychology are making toward understanding embodied cognition can make a further argument for the embodiment approach to human cognition. Given the fact that the MNS plays a direct role in understanding the actions and intentions of others (Fogassi et. al., 2005), along with the role that language plays in comprehending actions and emotions, it is of little surprise that infants also display a remarkable capacity for facial imitation and language acquisition. Newborn infants are capable of engaging in impressive displays of facial imitation even after they are only a few days old (Gallagher, 2006, pgs. 70-1), which also implies an underlying MNS through which action imitation and understanding may be encoded (Rizzolatti et. al., 2001). Some philosophers of mind and psychologists also assert that facial imitation requires a developed body schema, because studies with newborn infants suggest that there must be an innate body schema present in order to account for their behavior (Gallagher, 2006).

Such an innate body schema could only be the result of an evolutionary adaptation for understanding the actions and emotions of others, and even the infant's ability to have an awareness of its own face also requires a primitive perceptual element of body image (Gallagher, 2006, pg. 73). Studies in developmental psychology and infant cognition are becoming more important for generating a new understanding of embodied cognition, especially since natural selection cannot select for adaptive behavior directly, but rather it can only select for genes that guide developmental programs which can produce behavior (Tooby and Cosmides, 1991a). The way in which the brain and the body collectively organize sense experience and sensorimotor knowledge thus produces an ecological interaction between the embodied mind and the environment (Bermudez et. al., 1995). The relationship between perception and action is essential to understanding the evolution of embodied cognition, and several philosophers of mind assert that by showing how the body shapes perception within infant cognition, we can begin to develop a more general framework for understanding embodied cognition (Gallagher, 2006, pg. 127).

2.3.4 Infant/Embodied Cognition and the Role of Empathy and Emotions

Infants display a remarkable ability to learn about emotion through their mothers, including fear, distress, and empathy (Preston and de Waal, 2002, pg. 8). Given the proposed role of empathy in the formation and maintenance of social bonds (Anderson and Keltner, 2002, pg. 21), the ability of infants to display empathy and emotions is certainly a cognitive adaptation for social exchange and interaction, since social mechanisms for displaying empathy and shared emotions would obviously enhance survival and reproductive success. Likewise, as studies with mirror neurons have also provided a unifying neural hypothesis for how individuals understand the actions and emotions of others (Gallese et. al., 2004), some researchers have suggested that mirror neurons may provide concrete evidence for the shared representations of perception and action that are crucial for the production of empathy, as a ground of intersubjectivity (Gallese et. al., 2002, pg. 36). Furthermore, because mirror neurons enable an observer to understand an agent's intentions, actions, and emotions (Fogassi et. al., 2005, pg. 662), the ability to understand the actions and intentions of others is clearly a fundamental attribute of social behavior (Iacoboni et. al., 2005, pg. 0001). Embodied action understanding and imitation must have played a pivotal role in our social evolution, especially since studies with mirror neurons illustrate that there is a functional analogy between the neural mechanisms that mediate action observation and those involved in action execution (Rizzolatti et al., 2001, pg. 667). Such neural mechanisms will certainly prove to be pivotal for understanding the neural basis of embodiment (Winkielman et al., 2009). Hence, the philosopher of mind Shaun Gallagher believes that mirror neurons provide impressive evidence for a shared level of human experience and action understanding, which integrates first-person subjective experience with an objective account stemming from within neurophysiology (Rohrer, 2007).

2.3.5 Embodied Simulation in the MNS and Mind Reading: Mental Representation Reformulated

The MNS illustrates a profound ability to experience the emotions and intentions of others through embodied simulation, as a basis for understanding another person's mind, and this ability to mirror the emotions, intentions and sensations of others has important implications for both neurophenomenology and the role of the MNS in embodied cognition. For example, because the mechanism of action understanding based upon the MNS is conceptually very similar to proposals for how action understanding takes place according to leading phenomenologists, and in particular according to Merleau-Ponty (Gallese et al., 2004), mind reading in the simulation theory is analogous to simulating goal-states. The phenomenological implications of the MNS and simulation theory are that we are, in fact, simulating or empathically experiencing the emotions, intentions and mental states of others as we engage in intentional action understanding and attunement. This means that when we observe the intentional behavior of another person, embodied simulation mechanisms within the MNS generate a specific phenomenal state of intentional attunement, which essentially maps the intentions of another person onto our own intentions (Gallese, 2006, pg. 10). In other words, when we observe the actions and emotions of others, we are really doing more than just merely observing or inferring the intention behind a particular action. In so far, we are actually experiencing the same action-types, emotion-types, and intention-types through internal representations that are activated as if we are performing the very same action, or experiencing the very same emotion and intention of others.

A central idea of the embodied approach to cognition is that cognitive processes emerge from the recurrent sensorimotor patterns that govern perception and action in autonomous agents (Thompson, 2007, pg. 13). Given that the MNS is a clear example of cognitive processes that govern perception and action, studying the MNS shows great potential in making contributions to our understanding of neurophenomenology and embodied cognition. One important contribution is the ability of the MNS to reformulate our concept of mental representation and action understanding, through the direct-matching hypothesis, which asserts that we understand actions by mapping the visual representation of the observed action right onto our motor representation of the same action (Rizzolatti et al., 2001). The concept of mental representation is reformulated from a view consisting of abstract representations of formal logic, which are expressed in propositional format (Garbarini, 2004, pg. 105), to a spatio-temporal and dynamic representational structure that is intrinsically linked to the field of action, and can be expressed in the same terms that control it. Research on the MNS thus reinterprets the role of the motor system within the entire schema of the central nervous system, which has important implications for the mind-body problem in going beyond the dichotomy of thought and action (Garbarini, 2004). The view that embodied cognition can emerge from active perception, along with the proposed role of the MNS in understanding the actions, intentions and emotions of others in neuroscience is now leading to a *mind in life* view of embodied cognition. The *mind in life* view asserts that bodily experience is rooted in the vital systems of the living organism, and interconnected with other individuals via bodily action and interaction (Garbarini, 2004, pg. 105), an account of which now follows.

2.4 The Continuity of Mind and Life: Evan Thompson's Enactive Approach

Another recent contribution to the enactive approach for understanding embodied cognition, and the relationship between the mind and life, is illustrated in Evan Thompson's *Mind in Life: Biology, Phenomenology, and the Sciences of Mind* (Thompson, 2007). Thompson's enactive approach to embodied cognition asserts that the human mind emerges from the self-organizing processes that interconnect the brain, body, and environment at multiple levels (Thompson, 2007, pg. 56), which is why embodied cognition shows great promise in explaining how the brain coordinates bodily action and movement in the environment. Thompson's account provides an extremely fruitful way to explore the interconnection between mind, life, consciousness, and issues in the phenomenology of embodied cognition, along with providing a perspective to the philosophy of mind that also benefits from cognitive science and empirical investigations.

As one of the defining principles for both life and artificial life is that they exemplify patterns of self-organization (Boden, 2001, pg. 11), the concepts of emergence and autonomy have also recently enabled philosophers to make valuable connections between mind and life (Thompson, 2007). Thompson's enactive approach illustrates how life and mind share the common principles of self-organization, for he asserts that where there is life there also exists the mind. In this respect, the mind emerges from within the self-organizing principles that connect the brain, body, and the environment at multiple levels (Thompson, 2007, pg. 56). This view invokes the notion of organismic life as "autopoiesis," whereby all living things are cognitive systems. Since the central feature of life indeed appears to be self-organization, which involves the emergence of order along with its spontaneous development, such autonomy often arises through an interaction with the environment (Thompson, 2007, pg. 58). This illuminates an extremely important point for Thompson, given that cognitive processes emerge from recurrent sensorimotor patterns that govern perception and action in embodied agents, which are situated in the environment (Thompson, 2007, pg. 13).

Thompson's version of enactivism provides an explanation for how sensory-motor coordination in the environment structures sensory information, such that cognitive processes emerge from within the interactions between the brain, body, and the environment. The enactive approach also unites both the phenomenological and biological aspects of life, by integrating first-person subjective levels of lived-bodily experience with a scientific and objective account of biology. Since the concepts of emergence and autonomy are often connected through the idea of functionality in biological systems, form follows function in evolved systems, and the notion of form is also important for phenomenology. Thompson's use of the enactive approach within the relationship between mind and life exemplifies how autonomy is a fundamental characteristic of biological life (Thompson, 2007, pg. 18), insofar as there is a deep continuity of life and mind that emerges from the self-organizing processes of sensorimotor behavior.

2.5 Situated Cognition and Embodied Approaches to Artificial Intelligence

As several philosophers of mind and cognitive scientists are now embarking on a new understanding of embodied cognition, the fields of artificial intelligence (AI) and artificial life (A-Life) will undoubtedly make substantial contributions to our understanding of the nature of the brain, and its connection to the body and the environment. For example, as philosophers of mind begin to examine the effects of sensorimotor embodiment on perception and experience, it is clear that the topic of embodied cognition directly addresses the mind-body problem (Pfeifer and Bongard, 2007). More precisely, the embodiment approach highlights the relationship between the mind/body and its connections to the environment, which certainly helps to explain how the movements of the body and sensorimotor knowledge act to shape perceptual content and experience (Noë, 2004). Since the topic of consciousness in general, and the relationship between life and cognition in particular, are directly relevant to the embodiment approach to human cognition, it seems that cognitive science and both A-Life and AI can make significant contributions to understanding the relationship between mind and life. The fields of AI and A-Life are also now shifting toward examining various embodied aspects of cognition, and in particular the connection between action and perception within the environment (Brooks, 2001). Given that traditional approaches to AI and robotics have tended to be disembodied (Brooks, 1999), in that they were only concerned with simulating the computational properties of the mind or brain, AI is now moving toward an embodied approach that explores the relationship between action and perception. Similarly, recent advances in the study of AI and A-Life demonstrate the ability to simulate embodiment through designing autonomous robots (Boden, 2001), or agents, that are capable of navigating and evolving within the environment, which provides cognitive scientists with a synthetic methodology to understanding bodily movement and biological complexity (Pfeifer and Bongard, 2007). Such a synthetic methodology toward understanding embodied cognition is also likely to have a profound effect on how philosophers approach the topic of the embodied mind. In fact, Daniel Dennett believes that by designing artificially embodied agents, AI and A-Life researchers are in fact resolving deep issues that pertain to the mind-body problem (Pfiefer and Bongard, 2007, pg. 74).

2.6 Embodied Approaches to AI and A-Life Involve Sensorimotor Coupling

Embodied approaches to AI and A-Life are radically beginning to change our conceptions of life, evolution, and cognition in an attempt to illuminate the computational properties of the mind and life itself, which encode sensory perception and bodily movement within the natural world. For example, one of the fundamental discoveries in embodied AI and A-Life is that a coupling between sensory and motor systems is essential for intelligent behavior (Pfeifer and Bongard, 2007, pg. 48). Given that the emergence of adaptive behavior results from an interaction with the environment, the strength of the embodied perspective to AI and A-Life is that it considers an approach to designing and analyzing embodied agents, which examines how both neural systems and body morphologies emerge from within an evolutionary process (Pfiefer and Bongard, 2007, pg. 86). However, because adaptive behavior is the result of the agent interacting within the situated environment, the embodied approach to AI and A-Life is very similar to the enactive approach to embodied cognition, for it depends on the coupling between the brain, body, and the environment (Pfiefer and Bongard, 2007, pg. 20). As the central feature of life appears to be self-organization, which involves the emergence of order along with its spontaneous development, AI and A-Life researchers can only design for emergence rather than trying to create a specific behavior, because behavior only results from within an agent-environment interaction (Pfiefer and Bongard, 2007, pg. 87). Moreover, as the fields of AI and A-life have become primarily concerned with designing embodied agents that are autonomous, mobile, and quite capable of adapting within dynamically changing environments (Brooks, 2001, pg. 409), the embodied perspective exemplifies a behavior-based approach, by making a connection between perception and action. Since much of the research in A-Life is devoted to understanding evolution, understanding how embodied systems emerge from an evolutionary process is an important contribution to AI (Pfeifer and Bongard, 2007, pg. 54), especially since it involves the coupling of sensory and motor systems in the environment. Hence, as the function of the brain is to generate behavior that is appropriate to our environmental circumstances (Tooby and Cosmides, 1997, pg. 4), cognitive processes emerge from recurrent sensorimotor patterns, that govern perception and action in autonomously situated and embodied agents (Thompson, 2007).

2.7 Phenomenology, Cognitive Science, and Neurophenomenology: An Integrated, Dual Aspect Approach to Embodiment

The topic of embodiment within cognitive science and the philosophy of mind indicate the real possibility of combining phenomenological approaches to consciousness and intentionality with objective neurobiological measures. What I want to argue is that, cognitive neuroscience and phenomenology, when taken in conjunction, are crucial to understanding the embodiment approach to human cognition, and in particular the role of the MNS in embodied cognition. Or otherwise put, the investigation of the MNS provides a paradigm case for the method of neurophenomenology. Because embodiment encompasses the lived-bodily experiences of emotions, feelings, intentions, sensations, and actions which are coupled to the brain's ability to coordinate both bodily movement and sensorimotor knowledge within the environment, only such an integral approach can shed light on the role of the body in cognition. Neurophenomenology strives to use the first-person experience of subjective levels of consciousness, together with neurobiological evidence, in order to account for the lived-bodily dimensions of embodiment that encompass the interior elements of experience. In contrast, up until recently, cognitive science and neuroscience have been primarily concerned with more scientific and objective third-person accounts of human experience and cognition, by appealing primarily to neurobiological accounts of consciousness, emotion, action and cognition.

However, today the topics of emotion and intentional action understanding are beginning to change the paradigm through which we view the relationship between the body and cognition (Winkielman et al., 2009, pg. 252), in order to bridge the connection between phenomenology and brain/bodily function in the study of embodied cognition. Moreover, the embodied approach to human cognition is benefiting greatly from the study of the MNS, precisely because the general theory of the MNS exemplifies the ability to integrate both first-person, subjective levels of lived-bodily experience with a third-person, objective and neurobiological account of cognition. The leading merits of such a dual-aspect embodiment-driven approach to cognition in general, and a correct account of the MNS in particular, are that they illuminate connections between the mind and the body that are necessary for an accurate understanding of action recognition, emotion and empathy in embodied cognition. Hence, it has been proposed that the MNS and the functional mechanisms they underpin, embodied simulation, can ground within a unitary neurophysiological explanatory framework important embodied aspects of human social cognition (Gallese, 2008), which can be linked to the experiential domain of action.

2.8 Neurobiological Approaches to Consciousness: Problems and Recent Breakthroughs

Neurobiological approaches to the nature of consciousness were first developed and advanced by both Crick and Koch in the early to mid 1990's, which helped to establish the field of consciousness as a legitimate topic in academia. Crick and Koch (1990) proposed that consciousness is due to synchronized neuronal processes, or neural correlates, that enable us to be conscious of what we see. The neuronal groups or ensembles thus fire in synchrony through the process of phase locking, and visual awareness and attention are intimately bound together in their theory. Some of the strengths of their neurobiological approach to consciousness are that it makes use of a wealth of data and resources pertaining to visual perception and awareness, along with postulating a solution to the binding problem. The binding problem pertains to the question of how the brain can bind together various sensory modalities into the experience of perceptual unity, by binding together all the different neurons of an ensemble that are responding to the aspects of a perceived object (Crick and Koch, 1990). Some obvious limitations of the theory proposed by Crick and Koch are that their neurobiological approach to consciousness makes no reference to motor processes or embodied aspects of cognition, in addition to the fact that it is a materialistic and reductive approach to consciousness. Such reductive approaches to consciousness tend to remove the phenomenal aspects of experience in favor of neurobiology (Chalmers, 1996). Furthermore, the *Mind and Life* conferences today aim to bring together neuroscientists, Buddhist scholars, and philosophers of mind, along with the Dalai Lama in order to address the problems of studying consciousness within a scientific framework, which has recently led to some fascinating discoveries in brain science and Buddhism that I will discuss in section 2.8.2.

Neurobiological approaches to consciousness and conscious experience are much more advanced today, and brain monitoring techniques are certainly far more accurate, but such approaches still have been plagued by reductionism, and a disregard for the lived-bodily experiences that are by nature phenomenological. Moreover, the very motivation for neurophenomenology, as a non-reductive approach to embodiment and human experience, was initiated in response to such reductive and materialistic approaches to consciousness. Some of the common problems of neurobiological approaches to consciousness thus stem from the fact that the approaches have often led to only computational and dynamical models of brain systems, which often tend to neglect the role of the body and emotion in cognition. Rather than viewing the mind as embodied, neurobiological approaches to consciousness have far too often asserted that the mind is created by the brain, without addressing the necessary conscious experiences of embodiment that are crucial to having an adequate understanding of human cognition. Today, however, most philosophers of mind and cognitive scientists are advocates of the embodied approach to cognition, especially with respect to developing a more accurate approach to understanding the mind-body problem, and the mystery of consciousness. In fact, given that neurophenomenology assumes a neural signature of subjective experience, it also favors an embodied approach to neural dynamics that specifies the cooperative interaction between the brain, body and environment (Lutz and Thompson, 2003, pg. 41). The integration of subjective experience and brain dynamics in the study of the neuroscience of consciousness has recently demonstrated the efficacy of neurophenomenology, along with the important discoveries that can come from this approach in studying meditation and neuroscience, which I will discuss in section 2.8.2 and also in Chapter Three.

2.8.1 The Explanatory Gap and Neurophenomenology in the MNS: Distinctive Contributions

The neurophenomenology of embodiment is also closely linked to recent research in the MNS, especially since the MNS may provide important insights into the hard problem of consciousness, for "closing" the explanatory gap. Several philosophers of mind have now suggested the role of phenomenology for bridging embodied cognition and brain function (Borrett, 2000). For example, using Scheler's notion of the essence of the person, which is not reducible to the merely psychological or merely physical dimensions of the person (Moran and Mooney, 2006, pg. 207), neurophenomenology pursues an embodied and large-scale, non-reductive dynamical approach to the neurophysiology of consciousness (Thompson and Varela, 2001). The explanatory gap in the study of consciousness, which I introduced earlier in Chapter Two, refers to a "gap" in our understanding of how to relate first-person, phenomenological characters of experience and data to third-person, objective and scientific accounts (Lutz and Thompson, 2003), which is something that the role of the MNS in embodied cognition is quite capable of making substantial contributions toward. Similarly, the hard problem of consciousness pertains to the question of how neurobiological, or physical systems in the brain can be the source of phenomenal consciousness, such as the "what it's like" experience of pain, pleasure, emotion and sensations. Given that the MNS illustrates a clear connection between phenomenology and cognitive science that has profound implications for understanding the actions and intentions of others, the MNS can certainly provide a meaningful bridge between phenomenology and cognitive science for explaining phenomenal aspects of intentionality and consciousness. The MNS provides a mechanism through which we can simulate and control bodily actions and experiences (Gallese et al., 2002, pg. 35), given that it enables us to understand and experience the actions, emotions and intentions of others, which therefore shows great promise in furthering our understanding of consciousness and intentionality.

The distinctive contributions that the role of empathy in the MNS and neurophenomenology are capable of making toward "closing" the explanatory gap involve the importance of simulating or experiencing the actions, emotions and intentions of others. For example, the MNS exemplifies a neurophenomenological approach for integrating subjective experience and brain dynamics, by providing a shared representation of perception and action that is crucial for the production of empathy (Gallese et al., 2002, pg. 36). This allows us to simulate or experience the mental states and emotions of others. In so far, every time we observe another person performing a particular action, our MNS responds as if we are performing the same action, as empathy and the mirror matching system functions as an intersubjective manifold for understanding and experiencing the actions, emotions and intentions of others (Gallese, 2002). Such mirror mechanisms of action understanding not only allow us to understand the intention of observed actions, including the thoughts, feelings and emotions that motivated the behavior, along with simulating or experiencing them ourselves, but they also play a pivotal role in directly decoding the emotions and sensations that others experience (Gallese, 2005). Thus, the role of the MNS in intentional action understanding and attunement involves a direct appeal to emotions and empathy, as an intersubjective manifold for understanding and experiencing the emotions and intentions of others (Gallese et al., 2002). Therefore, the MNS is capable of furthering our understanding of how to relate first-person, phenomenological characters of experience to third-person, objective and scientific accounts, by linking mirror neurons to the phenomenal experience of both others and ourselves, through embodied simulation. Hence, because the theory of the operations of the MNS demonstrate an integration of both first-person subjective descriptions of lived-bodily experience and also third-person, objective accounts provided by cognitive neuroscience, this theory has important implications for surmounting the hard problem of consciousness, and for closing the explanatory gap. The following section addresses another approach of neurophenomenology that is important for helping to illuminate the role of emotion and empathy in the MNS, which is the convergence of Buddhism and neuroscience that is also making distinctive contributions toward closing the explanatory gap now.

2.8.2 The Neuroscience of Consciousness and First-person Approaches: Buddhist Meditation

Neurophenomenology attempts to integrate subjective levels of experience and brain dynamics in order to understand the so-called "mysteries" of consciousness (Lutz and Thompson, 2003). For example, one of the greatest strengths of neurophenomenology is that it pursues an embodied and large-scale, non-reductive dynamical approach to the neurophysiology of consciousness (Varela, 1995; Thompson and Varela, 2001; Varela and Thompson, 2003), which has recently led to breakthroughs in the study of consciousness. Studies involving Buddhism and neuroscience have recently been important for illuminating phenomenal experience and neurobiology, in ways that may shed light on the explanatory 'gap' in our understanding of the relation between first-person phenomenological data to third-person behavioral data, in the study of consciousness (Lutz and Thompson, 2003, pg. 31). One way of trying to close the gap is to adopt an approach to studying the neuroscience of consciousness that incorporates Buddhist meditative practices. In fact, contemplative neuroscience studies involving both Buddhist meditation and cognitive neuroscience exemplify a neurophenomenological approach for closing the explanatory gap, by illustrating the neural correlates of compassion, altruism, and emotional regulation. In so far, one important contribution that contemplative neuroscience is making that is distinctive to addressing the explanatory gap is that it is furthering our understanding of dynamical systems theory, in the integration of subjective experience and brain dynamics. By showing how neural synchrony and phase coherency are involved in meditative experiences (Lutz et al., 2004), studies involving meditation aim to forge connections between large-scale, integrative mechanisms of neural synchrony and conscious processes underlying emotion, compassion, and empathy. The neurophenomenologial approach of contemplative neuroscience thus aims to incorporate cognitive science and phenomenology in the study of the neuroscience of meditation, in order to illuminate the importance of neural synchrony for understanding the dynamical systems involved in meditative experience. Neural synchrony appears to be the fundamental mechanism for the study of brain processes underlying mental training (Lutz et al., 2004), and therefore the ability to combine neuroimaging brain information with first-person, subjective reports provide a particularly promising neurophenomenological approach to studying the brain mechanisms underlying meditation. Hence, the neurophenomenological approach to meditation is quite capable of making distinctive contributions toward closing the explanatory gap, by combining quantitative measures of neural activity or third-person behavioral data, with first-person phenomenological data about the subject's inner experience.

Recent studies involving Buddhist meditation and neuroscience have been conducted with two different brain-imaging techniques, electroencephalogram (EEG), and functional magnetic resonance imaging (fMRI), which provide us with excellent temporal and spatial resolution, respectively. The use EEG for studying the cognitive effects of meditation has revealed the important aspects of neural plasticity and synchrony, which demonstrate the brain's ability to change, grow and rewire itself, along with forming synchronous neural connections as well. Neural plasticity is another important distinctive contribution that the study of contemplative neuroscience can make toward closing the explanatory gap. The neuroscientific study of meditation is clearly helping to illuminate the plasticity of brain circuits that underlie complex regulatory mental functions, such as attention regulation and monitoring (Lutz et al., 2008). In fact, recent fMRI studies with Buddhist meditation and neuroscience have shown that meditative experience is associated with increased cortical thickness (Lazar et al., 2005), and EEG studies involving long-term meditators have shown the ability to self-induce high-amplitude gamma synchrony, during mental practice (Lutz et al., 2004). Cortical thickness refers to the regional grey matter density (Holzel et al., 2011), or the density of grey matter in cortical areas that corresponds to the size of anatomical regions of the brain (Gallese, 2006a). High-amplitude gamma synchrony refers to high-amplitude gamma-band activity in the 25-42 Hz frequencies, which display phase synchronizations of oscillating neural activity (Lutz et al., 2004, pgs. 16370-73). Interestingly, only long-term Buddhist practitioners show such patterns, as they were able to self-induce sustained high-amplitude gamma-band oscillations and phase synchrony during meditation (Lutz et al., 2004). More recently, fMRI studies involving Buddhist compassion meditation have shown that the brain can re-wire itself, through the phenomenon of neural plasticity, in order to increase positive emotion and empathy. This has a profound influence on cognition in general, and embodied cognition in particular, with respect to the MNS, which is a focus of this project that will be addressed throughout Chapters Three to Six.

Compassion meditation has recently been shown to increase happiness or positive emotion, and empathic accuracy (Mascaro et al., 2013), and mindfulness meditation has been shown to increase both compassion and empathy, along with grey matter density in the temporo-parietal junction (Holzel et al., 2011), where mirror neurons are localized. Furthermore, mindfulness practices, in general, increase the well-being and contentment of its practitioners, in addition to making us more in tune to the well-being of others. Taken together, these findings suggest the importance of neuroscientific research for understanding how meditation affects the brain, which has profound implications for our emotional, cognitive, and social health and well-being. In addition, meditation also appears to improve the sensitivity and neural functioning of the MNS, by boosting the neural basis of empathy and compassion, and thus social cognition. Similarly, the *Mind and Life* dialogue with several of the neuroscience researchers that are doing cutting edge research with Buddhist meditation, such as Richie Davidson at the University of Wisconsin at Madison, have been instrumental for coordinating conferences on Buddhism and neuroscience with the Dalai Lama, in addition to involving Buddhist monks in their research studies. The Dalai Lama has participated in several *Mind and Life* conferences on brain science and Buddhism, involving philosophers of mind, neuroscientists, and Buddhist scholars in order to demonstrate the importance of the convergence of Buddhism and brain science. Such collaborations, which have already enhanced our understanding of the mind and consciousness, have been published in leading journals. In fact, Davidson and his collaborator Antoine Lutz at Wisconsin have published several neuroscience articles involving Buddhist meditation and neuroscience, along with articles on the neuroscience of consciousness. Lutz has also published several articles on neurophenomenology with the philosopher of mind Evan Thompson (Lutz and Thompson, 2003), which has also been very influential for encouraging philosophers of mind and cognitive scientists to embrace the advantages of neurophenomenology for addressing issues such as the explanatory gap, and the mind-body problem.

As studies with meditation and neuroscience move toward illuminating how Buddhist meditation practices boost the activity of the neural correlates of compassion and empathy, by increasing feelings of compassion and empathy for others, it is clear that studies with Buddhist meditation and neuroscience will only improve our understanding of the brain and emotion. Moreover, both the study of the MNS and a contemplative neuroscience approach for studying emotion and cognition thus illuminate the efficacy of neurophenomenology for making progress in closing the explanatory gap. Lastly, the neurophenomenology of the MNS that I develop in this thesis provides basic support for this contemplative neuroscience approach, in moving toward a neuroscience of consciousness in general, and an integration of Buddhist meditation and neuroscience in particular. Such a contemplative neuroscience approach is essential for illuminating the important role that emotion and empathy play within the MNS, especially since meditation increases positive emotion, which, in turn, increases the sensitivity of the MNS for both AV processing and empathy, or mirroring. The convergence of Buddhism and neuroscience is thus very important for understanding how we connect with each other, in terms of empathy and compassion. In the next chapter, I will describe recent studies with Buddhist meditation and cognitive neuroscience in more detail, in order to reveal the deep connection between the role of emotion and empathy in the MNS, and both neurophenomenology and Buddhist meditation.

CHAPTER 3

STUDIES ON MEDITATION AND NEUROSCIENCE: EEG, fMRI, AND MIND AND LIFE DIALOGUE

3.1 Electroencephalogram (EEG) Studies Involving Meditation: Neural Synchrony and Plasticity

The convergence of Buddhism and neuroscience has revealed several interesting aspects of the brain and cognition that have important implications for understanding the role of emotion and empathy in the MNS in general, and the relationship between neurophenomenology and meditation in particular. For example, the use of electroencephalogram (EEG) for studying the cognitive effects of meditation has revealed the important aspects of neural plasticity and synchrony, which demonstrate the brain's ability to change, grow and rewire itself, along with forming synchronous neural connections as well. The use of EEG for the neuroscientific study of meditation is clearly helping to illuminate the plasticity of the brain circuits that underlie complex regulatory mental functions, such as attention regulation and monitoring (Lutz et al., 2008). Two broad categories of meditation that have received recent neuroscientific study with EEG are the focused attention (FA) and open monitoring (OM) techniques of meditation. In fact, there are some remarkable parallels between the processes involved in FA meditation, as described in several mediation texts, and recent neuroscience conceptualizations of attention (Lutz et al., 2008, pg. 163). FA and OM practices do correlate to the mindfulness and awareness aspects of *samatha* meditation, which are discussed in an influential review article that is titled, "Attention Regulation and Monitoring in Meditation." However, in the context of this review, the account of FA and OM practices appear to be drawn from a more generic account of practices that seek to develop the ability to focus on an object for an unlimited time, such as in the FA meditation, or in the absence of an object, as in the OM meditation. In so far, the generic account of *samatha* that is offered in this review article is sometimes called "common *samatha*" (Lutz et al., 2007, pg. 29), and the authors of the review article acknowledge that these styles of meditation are found with some variation in several meditation traditions, including Zen, Vipassana and Tibetan Buddhism (Lutz et al., 2008, pg. 163). The authors state that both styles are also implicated in secular interventions that draw on Buddhist practices, such as mindfulness-based stress reduction as well (Lutz et al., 2008, pg. 163). Furthermore, the researchers cite the source for these practices in their studies, along with how they are adapted, by offering and drawing upon generic and schematic descriptions of FA and OM meditations, which appear in Table 1 (Lutz et al., 2008, pg. 164). They also provide a discussion of FA and OM mediation in boxes 1 and 2, respectively (Lutz et al., 2008, pg. 164). The description of FA meditation includes directing and sustaining attention on a selected object (i.e. breath sensation, detecting mind wandering and distractors (i.e. thoughts)), the disengagement of attention from distractors and the shifting of attention back to the selected object, and the cognitive reappraisal of an object (i.e. 'just a thought,' it is okay to be distracted) (Lutz et al., 2008, pg. 164). In contrast, OM meditation involves no explicit focus on objects, and non-reactive meta-cognitive monitoring (i.e. for novices, labeling of experience), along with a non-reactive awareness of automatic cognitive and emotional interpretations of sensory and perceptual stimuli (Lutz et al., 2008, pg. 164). Interestingly, FA training is initially used for OM meditation, in order to calm the mind and reduce distractions, and thus as FA advances, the well-developed monitoring technique becomes the main transition point into OM practice. Here, in the OM practice, one aims to remain only in the monitoring state, by being attentive moment-by-moment to anything that occurs in the meditative experience, without focusing on any explicit object (Lutz et al., 2008, pgs. 164-5). Thus, I would now like to briefly discuss some of the findings from the FA and OM studies with EEG and meditation covered in this review article, before moving on to another study.

Several studies have reported expertise-related changes in attentional processing and brain structures in those proficient in FA meditation (Carter et al., 2005; Brefczynski-Lewis, 2007; Lazar et al., 2005). For example, in long-term meditators with at least 19,000 hours of practice, there is reduced activity in the neural systems that are implicated in regulating attention, which reflects a decrease in the amount of effort required to sustain the intended focus (Lutz et al., 2008). Evidently, FA induces a trait change whereby the attention rests more readily and stably on the intended or chosen focus (Lutz et al., 2008, pg. 164). Therefore, the regulative skills involved in sustaining focus are invoked less and less frequently. Eventually, the ability to sustain focus becomes progressively effortless. FA training is thus thought to create long-term changes in the neural circuitry involved in both selective and sustained attention, and such advanced levels of concentration are now thought to correlate with a significant decrease in emotional reactivity as well (Lutz et al., 2008, pg. 164). Extensive FA training therefore improves a practitioner's ability to sustain attention on a particular object, for a prolonged period of time (Lutz et al., 2008, pg. 165). In addition, OM meditation studies are thought to lead to a clear and reflexive awareness of the implicit features of one's own mental life (Lutz et al., 2008, pgs. 164-5). Such awareness enables the practitioner to more readily transform both cognitive and emotional habits. Similarly, long-term practice of OM meditation is also thought to result in enduring changes in mental and brain function (Lutz et al., 2008, pg. 165). Furthermore, because OM mediation involves the cultivation of awareness of the subjective features of a given moment, such as emotional tone, it likely engages processes involved in monitoring one's own body state (Lutz et al, 2008, pg. 165), which may include processes involved in interoception, or the perception of internal bodily responses as well. This has some interesting implications for both embodied reflection and the mind-body problem in particular. Hence, the long-term practice of OM meditation is now thought to result in important changes in both mental and brain function (Lutz et al., 2008, pg. 165), including greater emotional flexibility and an improvement in the capacity to disengage from aversive emotional stimuli following OM training.

With respect to making important connections between neurophenomenology and meditation, long-term practitioners can certainly generate more stable and reproducible mental states, compared to untrained subjects (Lutz et al., 2008, pg. 167), and they can also describe these states more accurately, through phenomenological reports. For example, the neurophenomenology approach to meditation draws attention to the need to combine quantitative measures of neural activity, such as EEG and functional magnetic resonance imaging (fMRI), with first-person data about the subject's inner experience, in order to illuminate the mind/brain. Arguably, the correlations between phenomenological reports and simultaneously measured brain activity should be systematically stronger for long-term meditators (Lutz et al., 2008, pg. 167), because they are better able to report veraciously on the content and processes of their mind. This is significant, given that another area of important research is to study meditation practices that deliberately invoke an emotional state of empathy, affection and compassion for others (Lutz et al., 2008), such as in an emotional version of the OM meditation study that follows.

The finding of a high-amplitude pattern of gamma synchrony, in long-term meditators, during an emotional version of OM meditation supports the idea that the state of OM might be best understood in terms of dynamic global states (Lutz et al., 2008, pg. 167; Lutz et al., 2004). For example, neural synchrony appears to be a promising mechanism for the study of processes underlying mental training (Lutz et al., 2004, pg. 16369), as mental training involves temporal integrative mechanisms that may involve both short-term and long-term neural changes in the brain, in terms of neural plasticity. This important study that is titled, "Long-term Meditators Self-Induce High-Amplitude Gamma Synchrony During Mental Practice," showed that long-term meditators self-induce high-amplitude patterns of gamma synchrony, during the mental practice of non-referential loving-kindness and compassion (Lutz et al., 2004). In so far, non-referential compassion practice aims to produce a specific emotional state, namely, an intense feeling of loving-kindness (Lutz et al., 2007, pg. 45). This state of unconditional loving-kindness and compassion is described as an "unrestricted readiness and availability to help living beings" (Lutz et al., 2004, pg. 16369). The state of non-referential compassion is necessarily other-centered, but it is "non-referential" in that it does not have any specific object or focus, such as a specific person or group of persons (Lutz et al., 2007, pg. 46). However, in other meditations that are also a part of their long-term training, practitioners did focus on particular persons or groups of beings (Lutz et al., 2004). Because benevolence and compassion pervade the mind as a way of being in this meditation, this state is called "pure compassion" or "nonreferential compassion," which is known in Tibetan as *dmigs med snying rje* (Lutz et al., 2004, pg. 16369). Furthermore, during the training session, control subjects were first asked to think of someone that they care about, such as their parents or a loved one, and to let their minds become invaded by feelings of love or compassion by imagining a sad situation, wishing freedom from suffering and well-being for those involved (Lutz et al., 2004, pg. 16369). Moreover, after some training, the subjects were then asked to generate such feeling toward all sentient beings, without thinking specifically about anyone in particular (Lutz et al., 2004). In fact, during the EEG data collection period, both controls and long-term practitioners thus tried to generate this non-referential state of loving-kindness and compassion. During the neutral or resting states, all of the subjects were asked to be in a non-meditative or relaxed state (Lutz et al., 2004, pg. 16369).

In effect, this meditation has two aspects, which are the cultivation of compassion and the cultivation of objectless awareness or OM (Lutz et al., 2007). The study involved eight long-term Buddhist practitioners, who underwent mental training in the same Tibetan Nyingmapa and Kagyupa traditions for 10,000 to 50,000 hours, over a time period ranging from 15 to 40 years. They were compared with a group of ten healthy novice meditators in the study (Lutz et al., 2008; Lutz et al., 2004). When compared with the novice meditators, the long-term meditators self-induced higher-amplitude sustained EEG gamma-band oscillations and long-distance phase synchrony, in particular over the lateral fronto-parietal electrodes, while meditating (Lutz et al., 2008, pg. 167-8; Lutz et al., 2004). Such synchronized neural firing patterns are thought to play an important role in the formation of transient networks, that integrate distributed neural processes into highly ordered cognitive and affective functions (Varela et al., 2001; Lutz et al., 2004; Lutz et al., 2008), which are an important for inducing synaptic changes in neural structures. Plasticity is therefore an adjective describing the capacity of neuronal structures to change, in connection with various meditative practices. Furthermore, just as the high-amplitude gamma synchrony occurred over the lateral fronto-parietal electrodes, so too did the cultivation of compassion meditation trigger neural synchrony in an area of the brain where the fronto-parietal mirror neuron network is localized (Molnar-Szakacs et al., 2006, pg. 923). The correlation between the cultivation of compassion and empathy, and the appearance of neural synchrony over the fronto-parietal area where mirror neurons are localized, thus supports the importance of a contemplative neuroscientific approach to the role of emotion and empathy in the MNS. Moreover, because these brain mechanisms are still not completely clear, the ability to combine neuroimaging and neurodynamic information with first-person, subjective reports thus provides a particularly promising neurophenomenological approach to studying the brain mechanisms underlying meditation.

Given that the emotional OM study with long-term meditators showed robust gamma-band EEG oscillations, and long-distance phase-synchrony during the generation of the non-referential compassion meditative state, it is not surprising that EEG studies with meditation have also focused on synchronized neural firing, along with the possibility of consciousness being linked to phase synchrony. For example, if meditation training involves temporal integrative mechanisms, which can induce short-term and long-term neural changes, the temporal integration of information is likely due to synchronized neural firing. EEG has an excellent temporal resolution in the millisecond range, which allows the exploration of fine temporal dynamic processes (Lutz et al., 2007, pg. 76). Dynamical system theory therefore provides a vocabulary that is most conducive to such an approach (Borrett et al., 2000), for incorporating cognitive science and phenomenology in the study of the neuroscience of meditation. Neural synchrony thus appears to be the fundamental mechanism for the study of brain processes underlying mental training (Lutz et al., 2004), as oscillatory neural synchrony is a fundamental mechanism for implementing coordinated communication, between spatially distributed neurons (Lutz et al., 2007, pg. 77).

Synchrony occurs in the brain at multiple spatial and temporal scales in local, regional and long-range neural networks, which give rise to dynamical global states in the brain, in response to meditative practices. In fact, sensory evoked potentials, which are EEG signals that are triggered by external stimulation, have demonstrated that mental factors such as sensation, attention, intellectual activity and the planning of movement all have distinctive electrical correlates at the surface of the skull (Zeman, 2001). It is for this reason that EEG has been the most popular imaging tool with which to study meditation, up until recently, for EEG is a non-invasive technique that measures the electrical potentials on the scalp (Cooper, 2003). Furthermore, at the cellular level, oscillatory or phase synchrony refers to the mechanism by which a population of oscillating neurons fires their action potentials in temporal synchrony, with precision in the millisecond ranges (Lutz et al., 2007, pg. 77). Moreover, at the population level, neuronal synchrony is best analyzed by looking at the common average oscillatory neural activity, among a given population of neurons (Lutz et al., 2007, pg. 77). The oscillatory activity of neurons can thus be measured from the macro-scale of scalp recordings in EEG. As a general principle, synchrony has been proposed as a mechanism to 'tag' the spatially distributed neurons that participate in the same process and, consequently, to enhance the salience of their activity compared to other neurons (Singer, 1999; Lutz et al., 2007). In short, it is for this reason that EEG methods in neuroscience have been extremely popular with studies involving meditation, which aim to forge connections between large-scale, integrative mechanisms of neural synchrony and conscious processes.

3.2 Meditative Experience and Increased Cortical Thickness: Implications for ADD & ADHD

Given that meditative experience in long-term meditators has illustrated the profound ability of the brain to grow and change, as theorized by the notion of neural plasticity, it is clear that meditative practice can help one to develop the attributes of attention, emotional regulation and cognitive flexibility that can enhance one's emotional well-being and happiness. For example, meditative experience and training is now showing how mental training can lead to short-term and long-term neural changes, within the temporal integrative mechanisms encoding attention, such as in FA training. Similarly, a recent functional magnetic resonance imaging (fMRI) study examined the neural basis of "one-pointed concentration," which is practiced in order to strengthen attentional focus, and to achieve a tranquil state in which preoccupation with thoughts and emotions is gradually reduced (Brefczynski-Lewis et al., 2007). This study helped to identify the neural correlates of attentional expertise in long-term meditation practitioners, who utilized a basic form of concentration meditation. This finding has important implications for both attention-deficit disorder (ADD) and attention-deficit hyperactive disorder (ADHD). In fact, this study showed a correlation between the number of hours of concentration meditation practice, and the neural plasticity of the mechanisms underlying attentional expertise. Concentration meditation has been reported to improve performance on multiple components of attention (Brefczynski-Lewis et al., 2007). Perhaps individuals that are diagnosed with ADD or ADHD should try to develop their attentional regulation through forms of concentration meditation, such as FA, rather than being subscribed drugs that limit creativity and also have harmful side effects.

Changes in EEG and cortical thickness have been reported in long-term compassion meditation practitioners (Lutz et al., 2004), as well as Buddhist insight meditation practitioners (Lazar et al., 2005).

The latter study strongly suggests that meditation experience is associated with increased cortical thickness (Lazar et al., 2005), for the study revealed increased thickness in cortical regions related to sensory, auditory and visual perception in people who meditated regularly. Moreover, it also showed that regular meditation might slow age-related thinning of the frontal cortex. Most of the brain regions that were identified to change through meditation were found in the right hemisphere, which is essential for sustaining attention. In so far, Buddhist insight meditation may also offer important techniques for developing, and sustaining attention in individuals with ADD or ADHD, as attention is the focus of the meditation itself. More recently, fMRI studies with mindfulness-based stress reduction (MSBR) meditation have shown increased gray matter density in brain areas associated with compassion and empathy (Holzel et al., 2011), and in areas associated with emotional regulation as well. Lastly, recent studies with compassion meditation and fMRI have shown the ability of the brain to increase positive emotion (Lutz et al., 2008) and empathy or empathic accuracy (Mascaro et al., 2013), which both have very interesting implications for understanding the role of emotion and empathy in the mirror neuron system. In the following two sections I discuss much more some of these recent findings with Buddhist compassion meditation and mindfulness, along with providing a discussion of their relevance to mirror neurons, empathy and intersubjectivity.

3.3 fMRI Studies Involving Compassion Meditation, Compassion Training, and Mindfulness

fMRI studies involving Buddhist meditation and mindfulness practice have recently received a great deal of attention in the scientific journals and popular media, especially since they have shown meditation to affect emotional regulation, happiness, and areas of the brain involved in empathy and compassion. For example, recent studies with compassion meditation have shown the ability of the brain to rewire itself, through neural plasticity, in order to increase positive emotion and empathy, along with compassion and altruism (Lutz et al., 2008; Weng et al., 2013; Mascaro et al., 2013). One important fMRI study titled, “Regulation of the Neural Circuitry of Emotion by Compassion Meditation: Effects of Meditative Expertise,” investigated the empathic response to another person’s pain, while both novice and long-term meditation practitioners generated a loving-kindness-compassion meditation state (Lutz et al., 2008). The meditative practice studied here involved the generation of a state in which an unconditional feeling of loving-kindness and compassion pervades the whole mind, as a way of being with no other consideration (Lutz et al., 2008, pg. 1). This study is significant, in that it addresses the contemplative Buddhist practice of loving-kindness and compassion, where loving-kindness is the wish of happiness for others, and compassion is the wish to relieve others' suffering (Lutz et al., 2008, pg. e1897). According to this tradition, as a result of this meditative practice, feelings and actions for the benefit of others arise more readily, when relevant situations arise (Lutz et al., 2008, pg. 1). This practice does not require concentration on particular objects, memories or images, just like in the emotional version of the OM meditation study that I discussed earlier (Lutz et al., 2004), for both studies involve the use of "pure compassion" or "non-referential compassion" (Lutz et al., 2008, pg. 7). Similarly, this study also invokes the same training session, where subjects are first asked to think about someone that they care about, such as a parent, sibling or loved one, and to let their mind be invaded by a feeling of altruistic love (wishing well-being) or of compassion (wishing freedom from suffering) toward those persons (Lutz et al., 2008, pg. 8). Furthermore, after some training the subjects then generate such a feeling toward all sentient beings, without thinking specifically about someone (Lutz et al., 2008, pg. 8). While in the fMRI scanner, the subjects then try to generate this non-referential state of loving kindness and compassion. The resting state used in the study was a non-meditative state without specific cognitive content, and with a lack of awareness or clarity of the mind (Lutz et al., 2008, pg. 8), which in Tibetan means, "*sem lung ma bstan*," or literally neutral (*lung ma ten*) mind (*sem*). The purpose of this study was thus to examine the brain circuitry engaged by the generation of this state of compassion, or compassion and loving-kindness meditation state, in both long-term Buddhist meditators and novice meditators, in response to neutral and emotional human sounds using fMRI.

The hypothesis of this study was that concern for others that is cultivated during this form of meditation enhances affective processing, in response to sounds of distress, and that this response to emotional sounds is hence modulated by the degree of meditative training (Lutz et al., 2008, pg. 1). The results showed that long-term meditators showed greater activation in the amygdala, temporo-parietal junction (TPJ), and right posterior superior temporal sulcus (pSTS), in response to all sounds, including negative sounds of distress, along with both positive and neutral sounds. The amygdala is an almond-shaped set of neurons located deep in the brain's medial temporal lobe, which plays a key role in the processing of emotions (Gallese, 2006a). The pSTS is an area of the brain involved in mind reading tasks (Gallese, 2006a), in addition to responding to biological motion and the processing of a variety of social signals (Pineda, 2005). The vicarious experience of another's internal state, such as "distress as" or "distress with," is a shared affective response that is hypothesized to be a mirror neuron network, in which the same networks engaged during first-hand experience of affect also sub serve empathic responses (de Waal, 2008; Decety and Jackson, 2004; Engen and Singer, 2012). In addition, the MNS, including the intraparietal sulcus, pSTS, and premotor cortex, plays an important role in understanding others' motor goals and actions (Rizzolatti and Sinigaglia, 2010, Gallese, 2006a), and is important for several forms of empathy (Fan et al., 2011; Lamm et al., 2010). The intraparietal sulcus is located on the lateral surface of the parietal lobe, and its principal functions are perceptual-motor coordination and visual attention, and it is also thought to be involved in interpreting the intent of others (Oberman and Ramachandran, 2009b). In fact, the MNS provides concrete evidence for the shared representations of perception and action that are crucial for the production of empathy (Gallese et al., 2002, pg. 36).

Furthermore, studies with the somatotopic auditory MNS are illuminating that there is a link between the motor MNS and empathy, given that individuals who scored higher on an empathy scale activated this auditory system more strongly (Gazzola et al., 2006, pg. 5055). Clearly, long-term compassion meditation practitioners would score higher on an empathy scale when compared to novices, which suggests a very plausible role of the MNS underlying the results of this study. Moreover, the TPJ is a region where mirror neurons are now also implicated (Oberman et al., 2008), which is associated with compassion, empathy and perspective taking (Holzel et al., 2011). Therefore, it is not surprising that there would be greater activation in this area, along with the pSTS, in response to emotional sounds. Long-term compassion meditators thus showed greater detection of emotional sounds, and hence enhanced mentation in response to emotional human vocalizations (Lutz et al., 2008, pg. 1), as a result of enhanced neural processing in the TPJ, pSTS, and both the amygdala and insula in response to human distress sounds, or vocalizations (Lutz et al., 2008). The insula is a portion of the cerebral cortex that is involved in several diverse functions linked to emotion, such as consciousness, perception, motor-control, self-awareness, cognitive function, and interpersonal experience (Pineda, 2008). Interestingly, the study found greater activation in a circuit commonly recruited during the reading of others' mental states, including the TPJ and pSTS, in response to these sounds during compassion meditation (Lutz et al., 2008, pg. 5). Taken together, the data from this study indicates that the mental expertise to cultivate positive emotion alters the activation of brain circuits, by enhancing the neural processing in circuits linked to empathy and theory of mind, in response to emotional stimuli. The MNS is now thought to be the neurobiological correlate of empathy and theory of mind. One highly plausible explanation for the data in this study is that the cultivation of positive emotion, through compassion meditation, increases the sensitivity of the MNS underpinning the neural basis of empathy.

A second study that is now worth addressing, before moving on to discussing an important mindfulness fMRI study, involves compassion training that is titled, "Compassion Training Alters Altruism and Neural Responses to Suffering" (Weng et al., 2013). Compassion training (CT) is typically based on compassion meditation and/or loving-kindness meditation, in which the contemplative practitioner practices generating and feeling care, connection, and love for others and/or reflects on others' suffering and human interdependence (Salzberg, 2002). This recent CT study showed that compassion training alters altruism and neural responses to suffering (Weng et al., 2013), in response to images of suffering that depicted emotional distress, physical pain, or acts of violence (Weng et al., 2013, pg. 1174). For example, the study examined whether compassion may be systematically trained, given that very little is known about an individual's capacity to cultivate compassion through training. Given that compassion is a key motivator of altruistic behavior, the study addressed whether short-term CT increases altruistic behavior, and also whether individual differences in altruism are associated with training-induced changes in neural responses to suffering (Weng et al., 2013, pg. 1171). In fact, contemplative traditions assert that compassion can be enhanced with meditation training, which can result in greater real-world altruistic behavior (Lutz et al., 2008). In CT, compassion is thus cultivated toward different people, including loved ones, strangers, and even difficult persons, and studies indicate that CT can also improve personal well-being. However, the neural mechanisms by which CT alters altruistic responses to human suffering remain unknown (Weng et al., 2013). In this CT study, the researchers investigated whether short-term CT would enhance altruistic behavior toward a victim encountered outside of the training context (Weng et al., 2013, pg. 1172). Altruistic behavior was assessed and tested for using the redistribution game, which is a novel economic decision-making task that models both unfair treatment of a victim and costly redistribution of funds to the victim as well (Weng et al., 2013, pg. 1172). Furthermore, they measured brain activation before and after two weeks of training using fMRI, and investigated whether increased altruism could be explained by training-induced changes in the neural response to human suffering (Weng et al., 2013, pg. 1172). It was hypothesized that CT would increase altruistic behavior by enhancing the neural systems involved in the recognition and understanding of another person's suffering, and also the emotional regulation of responses to suffering that thus support helping behavior (Weng et al., 2013, pg. 1172).

The researchers compared the altruistic responses of participants given CT, with responses of participants given an active control intervention of reappraisal training. For example, compassion trainees cultivated compassion for different targets, such as a loved one, the self, a stranger, and a difficult person (Weng et al., 2013, pg. 1173), and the reappraisal trainees practiced reinterpreting personally stressful events, in order to decrease negative affect. In so far, both of the training programs and interventions trained emotion-regulation strategies that promote well-being, but they differed in that the goal of CT was to increase empathic concern and the desire to relieve suffering, whereas the goal of reappraisal training was to decrease one's personal distress (Weng et al., 2013, pg. 1172). In this respect, reappraisal training provided an ideal control for CT, because although the combination of decreased distress and increased empathic concern predicts helping behavior, reappraisal training only decreases distress without enhancing concern or empathy (Weng et al., 2013, pg. 1172). Training consisted of practicing either compassion or reappraisal using guided audio instructions, via the Internet or compact disc, for 30 minutes per day for two weeks (Weng et al., 2013, pg. 1173). The researchers tested whether CT could affect altruistic behavior outside of the training context, using the redistribution game that I previously mentioned, which is an economic decision-making task that models both unfair treatment of a victim and costly redistribution of funds to the victim (Weng et al., 2013, pg. 1173). Participants used anonymous online interactions, which they were told involved live players, and they were instructed in only purely economic terms, which never involved instructing participants to use the training that they received, in addition to enforcing real monetary consequences for their behavior. Participants first observed a dictator (endowed with $10) transfer an unfair amount of money ($1) to a victim who had no money, and because compassionate behavior is specifically evoked by unfairness, all participants observed the same unfair dictator offer (Weng et al., 2013, pg. 1173). Furthermore, after witnessing this violation, participants could choose to spend any amount of their own endowment ($5) to compel the dictator to give twice that amount to the victim. The participants were then paid the amount that was left in their endowment, after making the decision. Data was then only analyzed for participants who reported, at the end of the protocol, that they believed they were playing against real people in the game, which meant that they therefore believed the paradigm (Weng et al., 2013, pg. 1173). Significantly, the redistribution rank was much higher for those participants who underwent the CT program (24.5) in comparison to the reappraisal-training group (17) (Weng et al., 2013, pg. 1174).

The researchers also used fMRI tasks and stimuli in order to determine whether altruistic behavior was predicted by changes in neural responses to human suffering, by scanning participants before and after training while they employed their emotion-regulation strategy (Weng et al., 2013, pg. 1173). For example, participants in both groups were presented with images of human suffering and non-suffering (neutral condition). Images of suffering depicted emotional distress, physical pain, or acts of violence, such as burn victim or a crying child (Weng et al., 2013, pg. 1174). Neutral images depicted people in non-emotional situations, such as working or walking down a street. The compassion trainees were instructed to invoke feelings of compassion, while silently repeating compassion-generating phrases (Weng et al., 2013, pg. 1173). In contrast, reappraisal trainees were instructed to decrease negative emotions by silently reinterpreting the emotional meaning of the images. Participants were instructed to regulate their emotional responses to the images over three blocks (Weng et al, 2013, pg. 1174). Interestingly, the pattern of neural changes in CT suggests that increased altruistic behavior is achieved by enhancing neural mechanisms that support understanding other's states, greater fronto-parietal executive control, and up-regulation of positive emotion systems (Weng et al., 2013, pg. 1177). This is significant, given that the MNS is involved in understanding the mental states of others, along with the fact that greater executive control is found in the area where the fronto-parietal mirror neuron network is localized (Molnar-Szakacs et al., 2006, pg. 923). Moreover, the fact that positive emotion systems are implicated in an increase in altruistic behavior is significant for the role of emotion in the MNS, given that positive emotions boost the neural basis of empathy in the MNS. The results from this very important study suggest that compassion can be cultivated by training.

Since compassion is a key motivator of altruistic behavior (Weng et al., 2013, pg. 1171), short-term compassion training in this study increased altruistic behavior, which was associated with training-induced changes in neural responses to suffering (Weng et al., 2013). The study found that in healthy adults, compassion training increased the altruistic redistribution of funds to a victim, which they encountered outside of the context of the training itself (Weng et al., 2013, pgs. 1171-74). Furthermore, the researchers found that the increased altruistic behavior, which resulted from compassion training, was associated with altered activation in brain regions implicated in social cognition and emotion regulation (Weng et al., 2013). These areas included both the inferior parietal cortex and dorsolateral prefrontal cortex (DLPFC), and also in the DLPFC connectivity with the nucleus accumbens (Weng et al., 2013, pg. 1171), which is significant given that mirror neurons are localized in the inferior parietal lobule and PFC (Oberman et al., 2006). The inferior parietal cortex integrates information from different sensory modalities and plays an important role in a variety of higher cognitive functions, including the ability to interpret the actions of others, and mirror neurons have recently been found here (Chong et al., 2008). The DLPFC is an area of the prefrontal cortex associated with positive emotions, which is active during voluntary or social smiling, and perspective taking in empathy (Pineda, 2008).

The emotional meaning constructed around another's suffering includes how much a person cares about the suffering of another. Such caring reflects the psychological processes of valuing the other (Batson, 2011), along with evaluating the other's relevance for the self (Goetz et al., 2010). This can be understood in terms of empathic mirroring and embodied simulation mechanisms in the MNS, where the "objectual other" becomes "another self" (Gallese, 2006a). Here, the role of empathy in the MNS provides an intersubjective manifold for understanding and experiencing the emotions and intentions of others. Since the concept of embodiment refers to the role of our bodies in shaping our personal identities, along with the experience of our own bodies and sensations, it also includes the experiences and emotions of others (Rohrer, 2007, pg. 9), as a basis for human intersubjectivity. In this respect, the fact that compassion training also enhances responses toward other people demonstrates that compassion is interpersonal (Weng et al., 2013, pg. 1172), which helps to illuminate the important role of empathy and intersubjectivity in the MNS. In other words, since compassion training has been empirically linked with personal benefits, such as increased positive emotions (Dunn et al., 2008), the experience of positive emotion increases the neural basis of empathy in the MNS, which may explain why compassion training can increase positive emotions toward people who are suffering (Kilmecki et al., 2012). Hence, the increased engagement of neural systems involved in the understanding of the suffering of other people can certainly be explained, in part, by the role of the MNS in understanding and simulating the emotions of others (Gallese, 2002; Gallese, 2004; Gallese, 2006a). The researchers in this CT study concluded that their results suggest that compassion can be cultivated through training, and that greater altruistic behavior may emerge from increased engagement of neural systems implicated in understanding the suffering of other people, executive and emotional control, and reward processing (Weng et al., 2013, pgs. 1171-78).

The last fMRI meditation study to be discussed in this section involves mindfulness-based training. Significantly, in just eight weeks such training showed profound changes in areas of the brain where compassion, empathy, and emotional regulation are implicated. For example, this study involved the use of Mindfulness-Based Stress Reduction (MSBR), one of the most widely used mindfulness training programs that has been reported to produce positive effects on psychological well-being, including increased happiness, contentment, and decreased stress (Holzel et al., 2011). The study also showed that mindfulness practice leads to increases in regional brain gray matter density (Holzel et al., 2011), which is an important aspect of neuroplasticity. MSBR changed the size of key regions of the brain after just eight weeks of training. Increases in gray matter concentration were found in the left hippocampus, which is involved in learning, memory and emotional regulation, and in the temporo-parietal junction (TPJ) that is important for perspective taking, empathy and compassion. Furthermore, these are both functions that people report changes in after meditation and yoga. The significance of this study is that mindfulness practice can make us more empathetic and compassionate. Furthermore, since mirror neurons are also thought to be implicated in the TPJ area of the brain, it is not surprising that the TPJ is also involved in social cognition, including the ability to infer states such as desires, intentions and goals of other people (Holzel et al., 2011, pg. 8; Van Overwalle, 2009); which has now been linked to mind-reading and embodied simulation in the MNS. Moreover, given that there is evidence of greater activation of this region during feelings of compassion in meditators (Lutz et al., 2008), meditative practices such as mindfulness and compassion meditation do appear to enhance the neural activity or sensitivity of the MNS, thereby boosting the neural basis of empathy or mirroring. I would now like to discuss a recent compassion meditation study, and its implications for the MNS.

3.4 Compassion Meditation: Based Upon Empathy and Intersubjectivity (Interdependence)

fMRI studies on compassion meditation have been pivotal in illuminating how the brain can rewire itself, because of neural plasticity, in order to increase positive emotion. A very recent study at Emory University has also shown that compassion meditation increases empathy, which is titled, "Compassion Meditation Enhances Empathic Accuracy and Related Neural Activity." For example, a compassion-based meditation study using fMRI showed that compassion meditation could significantly improve a person's ability to read the facial expressions of others (Mascaro et al., 2013). Compassion meditation was shown to boost empathic accuracy, in terms of accurately inferring others' mental states from facial expressions. This has very important implications for the role of mirror neurons in empathy or empathic mirroring, and in particular the ability to simulate the mental states of others through embodied simulation, or "mind reading." The simulation theory in the MNS proposes that people come to read minds by, in effect, putting themselves in another person's shoes, by using their own minds to simulate the mental states or processes that are likely to be operating in the other (Pineda, 2005, pg. 64). This includes the ability to accurately infer, or simulate others' mental states from facial expressions. In fact, failure to do this is one of the deficits in autism that has been linked to a dysfunctional MNS for both empathy and theory of mind abilities, a fact that suggests an important role for compassion meditation in therapy for children and adults with autism. Furthermore, recent studies at UCSD have confirmed the important role of a simulation account of perceptual processing of emotional facial expressions, which is based on a sensorimotor mirroring mechanism that was measured with distinct EEG mu responses (Moore et al., 2012). EEG measurements of the MNS are often conducted through mu suppression responses (Oberman et al., 2005; Oberman et al., 2006; Pineda, 2005; Oberman et al., 2008), over the sensorimotor cortex. Taken together, these recent findings thus suggest an intriguing study for the role of compassion meditation in enhancing the empathic accuracy of the MNS, as an empirical study that will be discussed in Chapter Six.

The details of the compassion meditation study at Emory University are very important for helping to illuminate the significance of empathy and intersubjectivity in compassion meditation, through the notion of interdependence. For example, the compassion meditation protocol that was used in the study is known as Cognitively-Based Compassion Training (CBCT), which includes aspects of mindfulness practice and meditation, along with a practice that focuses more specifically on training people to analyze and reinterpret their relationship with others (Mascaro et al., 2013). Although secular in presentation, the CBCT derives from the 11^{th} century Tibetan Buddhist *lojong* tradition (Mascaro et al., 2013, pg. 3). However, in its operationalization CBCT employs several important modifications to traditional *logong* teachings. All discussions of soteriological or existential themes (i.e. the attainment of Buddhahood, Karma) are omitted. Second, the participants receive instructive sessions for concentrative (i.e. shamatha) and mindful-awareness (i.e. vipassana) practices at the beginning of the course (Mascaro et al., 2013, pg. 3). These foundational meditational practices were an assumed prerequisite for commencing *lojong* training in a traditional Buddhist context (The Dalai Lama, 2001), even though they were not specifically included in traditional *lojong* curricula. The course content of CBCT proceeds according to the following schedule, which focuses on each topic for one week, over an eight-week CBCT: developing attention and stability of mind, cultivating insight into the nature of mental experience, cultivating self-compassion, developing equanimity, developing appreciation and gratitude for others, developing affection and empathy, realizing wishing and aspirational compassion, and realizing active compassion for others (Mascaro et al., 2013, pg. 4).

A fundamental goal of most meditative practices is to enhance compassionate thoughts, feelings and behavior toward others (The Dalai Lama, 1995; Wallace, 2001). Compassion is based upon empathy, which requires insight into the nature of oneself, and others, and the relationship between oneself and the rest of the world is also based upon empathy (Wallace, 2001, pg. 213). In fact, as long as one is actively engaged in society, one's very sense of personal identity is strongly reinforced by one's intersubjective relations with others (Wallace, 2001, pg. 211). This is significant, for mindfulness practice provides a basis for cultivating a very deep sense of empathy, which is perhaps why compassion meditation and mindfulness practices are so successful at increasing both positive emotion and empathy[1]. CBCT aims to condition one's mind to recognize how we are all interdependent, and that everyone desires to be free from suffering, at a deep level, which is based on the Tibetan Buddhist practice called *metta*, or loving-kindness (Mascaro et al., 2013). The fundamental idea is that the feelings we have about people can be trained in optimal ways (Mascaro et al., 2013). According to the Dalai Lama, no one can be happy on one's own, for our own happiness is dependent on the happiness of those around us, as we are all interdependent (The Dalai Lama, 1995). Furthermore, individual human consciousness is inherently intersubjective, formed as it is within the dynamic interrelation between the self and the other (Thompson, 2001, pg. 1). This fundamental notion of interdependence in CBCT and mindfulness therefore helps to

[1] Different types of empathy, such as empathic concern, empathic happiness, and empathic cheerfulness involve the generation of some degree of positive emotion (i.e. goodwill) (Light and Coan, 2009, pg. 1215). Increasing positive emotion increases different types of empathy, which are implicated in the MNS, and thus positive emotion boosts the neural basis of empathy in the MNS.

illuminate the important role that empathy or empathic mirroring plays in embodied simulation in the MNS, by providing an intersubjective manifold for understanding and experiencing the emotions and intentions of others (Gallese, 2006a). The CBCT study found that compassion meditation based on this Tibetan model could effectively boost one's ability to empathize with others, by way of reading their facial expressions, which is why compassion meditation is so important for understanding the role of the MNS in emotion understanding and empathy. Moreover, given that the study showed increased activity in two areas of the brain that are central for our ability to recognize the emotional states of others (Mascaro et al., 2013), which are the inferior frontal gyrus (IFG) and the dorsomedial prefrontal cortex (dmPFC), it is significant that mirror neurons are now implicated and thought to be localized in the IFG (Pineda, 2008), and dmPFC. The cultivation of positive emotions in compassion meditation thus boosts the neural basis of empathy, which can be explained by increasing the sensitivity of neural processing in the MNS for empathy, and hence the intersubjective manifold for understanding and simulating the facial expression of emotions.

3.5 Studies Involving The Emotion of Love: Being 'Happy in Love,' Happiness & Cognition

Recent fMRI studies have shown that reward pathways in the brain, like the ventral tegmental area (VTA) that are critical for reward processing and learning, are active when human subjects are experiencing both love and happiness (Acevedo et al., 2011; Reynaud et al., 2010). The VTA is part of the mesolimbic dopamine system, which is a crucial part of the reward pathway that sends dopamine neurons to the nucleus accumbens (Acevedo et al., 2011). The nucleus accumbens plays an important role in pleasure, including laughter, reward, and reinforcement learning (Acevedo et al., 2011). These studies provide empirical evidence that pleasure and happiness played an important role in the evolution of reward pathways in the brain. For example, it is widely accepted that the activation of dopamine-rich sites, such as the VTA, are evoked in response to rewards like food and monetary gains (Acevedo et al., 2011, pg. 10). Dopaminergic fibers originate in the VTA, and indeed dopamine plays a key role in both attachment states and reward processing (Stein and Vythilingum, 2009, pg. 240). During fMRI, when subjects who are 'happy in love' viewed a picture of their romantic partner, it led to the activation of the right VTA and the right caudate (Stein and Vythilingum, 2009, pg. 240). The caudate is one of three basic structures that make up the basal ganglia, which is involved in voluntary movement, learning and social behavior (Stein and Vythilingum, 2009). The basal ganglia is a brain region located at the base of the forebrain that is strongly interconnected with the cerebral cortex, thalamus, and brainstem, which is associated with a variety of functions including voluntary motor movement, procedural learning, eye movement, cognition and emotion (Stein and Vythilingum, 2009). Similarly, responses to images of a long-term love partner were also associated with brain systems that have been identified as being important for the 'liking' of primary rewards (Acevedo et al., 2011, pg. 10). Such responses illustrate a recruitment of the brain systems that mediate the 'liking' or 'pleasure' aspect of a reward. This major pattern also emerged from examining the common fMRI activations for maternal attachment as well (Acevedo et al., 2011). Furthermore, individuals who were "deeply" in love showed increased activation of brain regions associated with pleasure and motivation, when viewing a picture of their loved one (Reynaud et al., 2010, pg. 265). Such regions included the VTA, caudate anterior cingulate cortex (ACC), and the left insular region, and the more intense the passion, the greater the activation in theses areas (Reynaud et al., 2010, pg. 265). The ACC appears to mediate the affective dimension of pain processing, and the motivational aspects of response selection (Gallese, 2006a, pg. 19), which is implicated in the activation of shared neural circuitry for experiencing the sensations of others, as in the case of pain. High dopamine levels in the brain were associated with a preference for a specific mate that triggered concentrated attention, coupled to unflinching motivation and goal-oriented behavior.

Other fMRI studies illuminated the role of reward and motivation in emotional systems that are associated with early intense romantic love (Aron et al., 2005). Hence, it is not surprising that positive emotions, such as love and happiness, influence memory, learning, creativity, short-term attention, and even both goal-directed behavior and motivation (Reynaud et al., 2010), given that emotion played a pivotal role in the evolution of reward pathways in the brain. Recent studies have also used fMRI to identify the functional neuroanatomy of pleasure and happiness (Kringelbach and Berridge, 2009), in moving toward a scientific study of pleasure and happiness in the brain. Lastly, the role of positive emotions in learning and cognition is also receiving great attention today in the cognitive science community, with respect to learning and early education in children. Apparently, the happier we feel, the more easily we can both learn and retain new information (Immordino-Yang and Damasio, 2007). Positive affect has been significantly linked with an increased capacity for creativity and novel thinking (Rowe et al., 2007, pg. 383). Thus, the role of positive emotions in education can have a profound effect on the body and cognition (Immordino-Yang and Damasio, 2007), which affects how efficiently children can learn new concepts, and develop new ideas in light of knowledge attained.

Emotion and motivation both played a crucial role in the evolution of reward pathways in the brain (Cardinal et al., 2002). It is not surprising, then, that the emotions of pleasure, happiness and even love would cognitively enhance the attributes of learning, memory, and motivation that helped to shape adaptive behavior, over evolutionary time. For example, the experience of positive emotions that accompanied the receipt of rewards clearly helped to influence how the brain evolved to process information about the world, which surely enhanced reproductive success. The dopamine neurons of the VTA and substantia nigra have long been identified with the processing of rewarding stimuli (Schultz et al., 1997, pg. 1594). Reward anticipation has also been shown to improve hippocampus-dependent long-term memory formation, along with predicting stronger fMRI activity in reward-related brain areas, including the substantia nigra (Wittmann et al., 2005). The substantia nigra is a brain structure located in the mesencephalon (midbrain) that plays an important role in reward, addiction, and movement (Wittmann et al., 2005). Furthermore, this data is consistent with the hypothesis that activation of dopaminergic midbrain regions enhances hippocampus-dependent memory formation (Wittmann et al., 2005). IR an adaptive organism must be able to survive in its environment; it must be able to predict the presence of food, danger, and even potential mates (Schultz et al., 1997, pg. 1593), all of which involve the mechanisms of reward learning. Since the receipt of a reward enhanced an organism's happiness, and hence its reproductive success, it is not surprising that evolutionarily 'old' emotional systems in the brain are now proving to be pivotal for cognitive learning and information processing. Studies involving the role of emotion in cognition are also addressing the role of the amygdala in emotional processing, and its effects on learning, memory, and attention.

3.6 Mindfulness and the Convergence of Buddhism and Neuroscience

The study of Buddhist meditation and mindfulness practice is clearly ushering in a new 'mindfulness revolution,' which is not only furthering our understanding of the role of emotion and cognition in bodily function, but it is also showing how meditation and mindfulness practice can improve cognitive social functioning. For example, the mindfulness-based stress reduction (MBSR) study discussed earlier illustrated how, through participating in just an eight week training program, subjects showed greater gray matter density in cortical areas associated with emotional regulation, compassion and empathy, and executive decision making (Holzel et al., 2011). The MBSR training program also showed a decrease in stress, and correlatively increased happiness. The fact that an increase in regional grey matter density resulted from this short MSBR training program reinforces the theory of neural plasticity. Similarly, the fact that mindfulness practice and Buddhist compassion meditation can make us more empathetic and compassionate, along with enhancing our well-being and happiness, suggests that there are significant long-term benefits of meditation. First, studies strongly indicate that mindfulness-based meditation can change the size of key regions of the brain that improve emotional regulation, in addition to increasing compassion, empathy, and happiness, all of which improve our ability to interact socially with others. Such mindfulness meditation studies have thus shown that meditation increases both empathy and compassion, which increases our ability to be empathetic and compassionate. Second, compassion meditation studies are also illustrating the brain's ability to change, grow and rewire itself through neural plasticity, as the brain circuit's related to happiness are changeable. Compassion meditation studies are therefore pivotal for showing how the brain can rewire itself, in order to increase positive emotion, which shows that one long-term benefit of meditation is improved happiness and contentment. Third, the cultivation of positive emotions through compassion meditation can improve our social cognitive functioning, by increasing our empathic accuracy for reading the facial expressions of others, which thus increases our attention to others' well-being and happiness. This is significant, because it helps to affirm the fact that our own happiness and well-being are dependent upon the happiness of others, as the Tibetan Buddhist practice of loving-kindness asserts. Fourth, and perhaps most importantly, the experience of positive emotions increases the sensitivity of the MNS, which boosts the neural basis of empathy for empathic mirroring and mind reading. Hence, only a contemplative neuroscience approach can truly illuminate the important role that emotion and empathy play in embodied simulation in the MNS, because such contemplative practices alter the neural circuitry involved in empathy and emotion, which are underpinned within the MNS.

3.7 Differences in Observed Effects for FA, OM, Loving Kindness and Compassion Meditation

It is important to clarify the differences in observed effects for each of the meditative practices that I have already discussed in this chapter, including FA, OM, loving kindness and compassion, before moving towards a new understanding of compassion, empathy and neuroscience. For example, the FA study that I discussed at the beginning of this chapter illustrated how FA increases the ability to regulate attention, as the neural systems that are implicated in sustaining and regulating attention show reduced activity after prolonged FA training (Lutz et al., 2008). Several studies have reported expertise-related changes in attentional processing and brain structures in those proficient in FA meditation (Carter et al., 2005; Brefczynski-Lewis, 2007; Lazar et al., 2005). This reflects a decrease in the amount of effort required to sustain intended focus (Lutz et al., 2008). Eventually, the ability to sustain focus becomes progressively effortless. FA training is therefore thought to create long-term changes in the neural circuitry involved in selective and sustained attention, which thus improves a practitioner's ability to sustain attention on a particular object for a prolonged period of time (Lutz et al., 2008, pg. 165). In contrast, OM meditation studies do not focus on the sustained attention of a particular object, for there is no explicit focus on objects. Rather, OM meditation studies are thought to lead to a clear and reflexive awareness of the implicit features of one's own mental life (Lutz et al., 2008, pg. 164-5). The long-term practice of OM meditation is also thought to result in enduring changes in mental and brain function (Lutz et al., 2008, pg. 165). However, unlike the changes due to FA training that enable the practitioner to achieve great levels of attention and focus, with very little effort, the long-term practice of OM meditation is now thought to result in greater emotional flexibility, and an improvement in the capacity to disengage from aversive emotional stimuli. Thus, these observed effects for OM meditation appear to involve the cultivation of awareness of subjective features, such as emotional tone, which likely engages the processes involved in monitoring one's own body state (Lutz et al, 2008, pg. 165).

A third different observed effect that is important to clarify is the finding of a high-amplitude pattern of gamma synchrony, in long-term meditators, during an emotional version of OM meditation. This important study demonstrated an effect that was only observed in long-term meditators, while engaging in a specific meditative state of unconditional loving-kindness and compassion. In so far, non-referential compassion practice aims to produce a specific emotional state, namely, an intense feeling of loving-kindness (Lutz et al., 2007, pg. 45), but it is "non-referential" in that it does not have any specific object or focus, such as a specific person or group of persons (Lutz et al., 2007, pg. 46). The observed effects of neural synchrony in this emotional version of an OM study, which is based on the generation of the non-referential compassion meditation state, thus appears to be a promising mechanism for the study of processes underlying mental training (Lutz et al., 2004, pg. 16369). This important observed effect has therefore helped to show how mental training involves temporal integrative mechanisms that may involve both short-term and long-term neural changes in the brain, in terms of neural plasticity.

A fourth observed meditation effect, which is clearly different from the three previous studies, involves compassion meditation. This study is based on the same fundamental premise of non-referential loving-kindness and compassion, as in the third study above involving the emotional version of OM meditation. However, the OM emotional study invoked the use of EEG methods for monitoring brain states, and it did not involve any stimuli, whereas this fourth meditation study uses fMRI and the use of emotional auditory stimuli. The purpose of this fMRI study was to examine the brain circuitry engaged by the generation of this state of compassion and loving-kindness meditation, in both long-term Buddhist meditators and novice meditators in response to neutral and emotional human sounds, or vocalizations. The observed effects of this study showed that concern for others that is cultivated during this form of meditation enhances affective processing, in response to sounds of human distress, and this response is clearly modulated by the degree of meditative training (Lutz et al., 2008, pg. 1). In fact, long-term meditators showed greater activation in the amygdala, temporo-parietal junction (TPJ), and right posterior superior temporal sulcus (pSTS), in response to all sounds, including negative sounds of human distress, along with both positive and neutral sounds. During meditation, activation in the insula was greater during presentation of negative sounds only, in long-term meditators compared to novices. Long-term compassion meditators therefore showed greater detection of emotional sounds, and enhanced mentation in response to emotional human vocalizations (Lutz et al., 2008), which was due to enhanced neural processing in the TPJ, pSTS, amygdala, and insula for negative sounds (Lutz et al., 2008). This study indicates that the mental expertise to cultivate positive emotion alters the activation of brain circuits, by enhancing the neural processing in circuits linked to empathy and theory of mind.

A fifth study that shows clear differences in observed effects is the compassion training (CT) study that I have already discussed, which showed how CT increases altruism and neural responses to suffering (Weng et al., 2013). Given that compassion is a key motivator of altruistic behavior, the study addressed whether short-term CT increases altruistic behavior, and also whether individual differences in altruism are associated with training-induced changes in neural responses to suffering (Weng et al., 2013, pg. 1171). Contemplative traditions assert that compassion can be enhanced with meditation training, which can result in greater real-world altruistic behavior (Lutz et al., 2008). The observed effects in this CT study showed that the pattern of neural changes, due to CT, suggest that increased altruistic behavior is achieved by enhancing the neural mechanisms that support understanding other's states, greater fronto-parietal executive control, and up-regulation of positive emotion systems (Weng et al., 2013, pg. 1177). This is significant, given that the MNS is involved in understanding the mental states of others, along with the fact that greater executive control is found in the area where the fronto-parietal mirror neuron network is localized (Molnar-Szakacs et al., 2006, pg. 923). The fact that positive emotion systems are also implicated in the increase in altruistic behavior is significant for the role of emotion in the MNS, given that positive emotions boost the neural basis of empathy in the MNS.

The results from this very important study thus suggest that compassion can be cultivated by training. Since compassion is a key motivator of altruistic behavior (Weng et al., 2013, pg. 1171), short-term compassion training in this study increased altruistic behavior, which was associated with training-induced changes in neural responses to suffering (Weng et al., 2013). Furthermore, the researchers found that the increased altruistic behavior, which resulted from compassion training, was associated with altered activation in brain regions implicated in social cognition and emotion regulation (Weng et al., 2013). These areas included both the inferior parietal cortex and dorsolateral prefrontal cortex (DLPFC) (Weng et al., 2013, pg. 1171), which is significant for mirror neurons are localized in the inferior parietal lobule and PFC (Oberman et al., 2006), and have recently been found in the inferior parietal cortex (Chong et al., 2008). The researchers in this study therefore concluded that their results suggest that compassion can be cultivated through training, and that greater altruistic behavior may emerge from increased engagement of neural systems implicated in understanding the suffering of other people, executive and emotional control, and reward processing (Weng et al., 2013, pgs. 1171-78).

The sixth meditation study that I would now like to briefly clarify, in terms of differences in observed effects, is the CBCT study at Emory University. This important study showed how compassion meditation enhances the empathic accuracy for reading the mental states of others, from facial expressions (Mascaro et al., 2013). This fMRI study was based on the Tibetan Buddhist tradition that includes a practice called *metta*, or loving-kindness, through which they developed a cognitively based compassion training (CBCT) program for compassion meditation. The fundamental premise is that we can train our minds to analyze and reinterpret our relationship with others, in order to condition our minds to realize that we are all interdependent, and that everyone desires to be happy and free from suffering (Mascaro et al., 2013). The study found that compassion meditation based on this Tibetan model could effectively boost one's ability to empathize with others, by way of reading their facial expressions, which is why compassion meditation is so important for understanding the role of the MNS in emotion understanding and empathy. Furthermore, the observed effects of this fMRI study showed increased activity in two areas of the brain that are central for our ability to recognize the emotional states of others

(Mascaro et al., 2013), which are the inferior frontal gyrus (IFG) and the dorsomedial prefrontal cortex (dmPFC). This new finding is quite significant, given that mirror neurons have now been both implicated and localized in the IFG (Pineda, 2008), and dmPFC. The observed effects of this CBCT study are thus clearly different from any of the other contemplative neuroscience studies, for CBCT enhances the empathic accuracy for inferring others' mental states from facial expressions, which may be important in therapy for social cognitive disorders, such as autism.

3.8 Towards a New Understanding of Compassion, Empathy and Neuroscience

One of the most impressive recent advances to come out of affective neuroscience, especially contemplative neuroscience is the quest to develop a neuroscience of compassion and empathy. For example, compassion meditation and mindfulness practices have now led to the development of compassion training (CT) programs across the country, in addition to mindfulness centers at some of the most prestigious medical universities in the country. CT and compassion meditation programs have shown that such training increases altruism, and the neural responses to suffering (Weng et al., 2013), which is significant given that mirror neurons are implicated in several forms of empathy. Such training emphasizes the interpersonal attributes of empathy and compassion, but it is also quite important to note that the cultivation of compassion, through CT, increases positive emotion in individuals as well (Dunn et al., 2008)[2]. In fact, through reinterpreting our relationship with others, and studying the neural mechanisms underlying compassion and empathy, along with how such mechanisms may be strengthened and improved through contemplative practices, we are able to illuminate the important role that affective processing and emotional valence play in our daily lives. Moreover, because the MNS is involved in the vicarious experience of another's internal state, the shared affective response mechanisms in the MNS that are engaged during the first-hand experience of affect also subserve empathic responses (de Waal, 2008; Engen and Singer, 2012; Gallese and Goldman, 1998). I will now provide a detailed account of the

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[2] Increases in positive emotion that were induced through loving-kindness meditation have been shown to produce increases in a range of personal resources, including mindfulness, purpose in life, social support, and decreased illness (Fredrickson et al., 2008).

role of emotion and empathy in embodied simulation in the MNS, for these neural mechanisms are clearly involved in compassion and empathy.

CHAPTER 4

EMBODIMENT PLAYS A PIVOTAL ROLE IN ACTION UNDERSTANDING AND RECOGNITION: EMBODIED SIMULATION IN THE MNS

4.1 Intentional Attunement and Embodied Simulation in the MNS: Intersubjectivity

The MNS illuminates the phenomenal or subjective levels of lived-bodily experience, and feelings or emotions that are necessary in order to understand the intentions of another person's actions and behavior, especially from the perspective of simulation theory. Because the human MNS is active during both the first- and third-person experience of actions and emotions (Gallese, 2004, pg. 400), when we observe another person's actions we activate a network of parietal and premotor areas that are also active when we perform the same or similar actions. The proposed role of the MNS in intentional action understanding and attunement involves the importance of emotions and empathy as an intersubjective manifold for understanding and experiencing the emotions and intentions of others (Gallese et al., 2002). Understanding another individual's mental state is pivotal to empathy or empathic mirroring. The MNS functions as an embodied simulation mechanism for understanding another person's mind, and to experience or mirror the emotions, intentions and sensations of others that has important implications for neurophenomenology and the role of the MNS in embodied cognition.

This process of intentional action understanding constitutes an important contribution of the role of the MNS to embodied cognition, for it allows for a self-other overlap, in mapping the representation of an observed action to the self (Winkielman et al., 2009, pgs. 244-45). In so far, the MNS mediates between the multimodal experiential knowledge we hold of our lived body, and the experience we make of others (Gallese, 2006, pg. 9), which is intersubjective. Such body-related experiential knowledge thus enables a direct grasping of the meaning of the actions performed by others, and of the emotions and sensations they experience (Gallese, 2006, pg. 9). In other words, internal representations of the body states associated with these actions, emotions, and sensations are evoked in the observer, 'as if' he/she is performing a similar action, or experiencing a similar emotion or sensation (Gallese, 2006, pg. 10). Mirror neurons thus play a pivotal role in an execution/observation matching system, as a mechanism for coordinating a representation of the self with another (Bernier and Dawson, 2009, pg. 267), which has resulted in advances in our understanding of the role of neurophenomenology in embodied cognition. An argument in favor of a non-reductive, neurophenomenological account of the role of embodiment in human cognition is that only such an approach is capable of describing the role of embodied simulation mechanisms in the MNS for action understanding, as a neural basis for embodiment and intersubjectivity. Neurophenomenology therefore provides us with a methodological framework for addressing the role of embodiment in human cognition, while including subjectivity.

4.2 The Role of MNS in Intentional Action Understanding and Attunement

Given that the MNS and the simulation theory strongly suggest an underlying neurobiological mechanism for how we can understand the actions and emotions of others, the fact that the MNS can enable us to understand the intentions that motivated a particular action exemplifies the importance of the phenomenology of intentionality. For example, Horgan and Tienson's Phenomenology of Intentionality (PI) thesis in "The Intentionality of Phenomenology and the Phenomenology of Intentionality," asserts that mental states that are cited as paradigmatically intentional, when conscious, have phenomenal character that is inseparable from their intentional content (Horgan and Tienson, 2002, pg. 520). The PI thesis of Horgan and Tienson is consistent with the recent findings of the MNS, given that the phenomenal character of the mental states that are intentional, which include the underlying intentions, thoughts, and emotions motivating a particular action are inseparable from their intentional content. In so far, the representations of the goal-states and intentions of external agents can also become the objective component of the phenomenal model of intentionality, as well as from the perspective of observing a goal-directed action via the MNS (Gallese and Metzinger, 2003, pg. 381).

4.3 The Role of Empathy as a Basis for Intersubjectivity in the MNS

The role of empathy in the MNS certainly provides an intersubjective manifold for understanding and experiencing the emotions and intentions of others. Empathy entails the existence of neurobiological mechanisms for understanding another individual's mental state (Oberman et al., 2005, pg. 191), in that it enables us to simulate or experience the mental states, emotions, feelings, and sensations of another person who is embodied like us. The MNS is connected intimately with lived-bodily subjective experience, and the feelings or emotions that are necessary in order to understand the intentions of another person's actions and behavior (Winkielman et al., 2009). The MNS functions as an embodied simulation mechanism for understanding the emotions and intentions of another person's embodied mind (Gallese, 2006a), through intentional attunement mechanisms. Intentional attunement is a direct form of experiential understanding of others, which is achieved by modeling the behavior of others as intentional experiences (Gallese, 2006b, pg. 15), by simulating the thoughts, motivations, intentions, and emotions underlying the action and behavior of others. Intentional attunement mechanisms thus model intentional experiences on the basis of shared neural systems in the MNS, which underpin both what others do and feel, and what we do and feel (Gallese, 2006a).

4.3.1 Empathic Mirroring: Stein's Phenomenology of Empathy and Emotion

Edmund Husserl was a leading figure in the 20th century phenomenological tradition, and Edith Stein was one of Husserl's best students. Stein's phenomenology of emotions and empathy pertain directly to the notion of the lived body (*Leib*) and the physical body (*Korper*), which act to constitute the bodily expression of feeling and emotion as an essential feature of embodiment. The lived body, for Stein, is the living and feeling, acting and sensing source of consciousness and intentionality (Moran and Mooney, 2006, pg. 235). Our way of responding toward others is exemplified in an ability to move like others, as an attribute of lived experience that resembles aspects of simulation in the MNS.

According to Stein, we fundamentally understand each other by moving our bodies in the same way, and empathy is the phenomenal experience of mirroring others by being poised to act in a certain way. Stein's view suggests that our mental states and emotions are written all over our bodies, and that we recognize the thoughts and emotions of others through empathic mirroring. Such an idea is virtually identical to the notion of embodied simulation, or the ability to mirror the emotions, sensations and intentions of others via the MNS. In fact, the audio-visual mirror matching system in the human MNS directly mediates between the multimodal experiential knowledge we have of our own lived body, and the experience that we have of others (Gallese, 2006b, pg. 9). Furthermore, both Husserl and Stein assert that empathy is a unique and irreducible kind of intentional experience (Thompson, 2001, pg. 16), where we experience another person as a unified whole through empathy. This kind of empathy is due to the coupling of the bodies of the self and other's in action (Thompson, 2001, pg. 17), which illustrates a clear connection between phenomenology and recent findings of the MNS in cognitive neuroscience.

Empathy is deeply grounded in the experience of our lived-body, and it is this experience that enables us to directly recognize others as persons like us (Gallese, 2002, pg. 35). For example, empathy entails the capacity to experience what others do experience (Gallese, 2006a, pg. 20), while being able to attribute these shared experiences to others and not to the self. The embodied simulation of actions, sensations, and emotions are therefore crucial for both empathy and empathic mirroring. Similarly, the mirror matching mechanism within the MNS not only suggests that a relationship may exist between action control and action representation (Gallese, 2001, pg. 39), but the MNS also provides us with a capacity to both perceive and experience, in a meaningful way, the actions, emotions and intentions of others. Furthermore, because the MNS appears to support the reconstruction of what it would feel like to be in a particular emotion, pheonomenologically, by means of simulation of the related body state (Gallese, 2006, pg. 8), the implications of this process for empathy is profoundly obvious. In so far, our capacity to conceive of the acting bodies of others as persons like us depends on the constitution of a shared meaningful interpersonal space (Gallese, 2006, pg. 9). This 'shared manifold' is characterized at both a phenomenological level and a functional level (Gallese, 2001), which I will now discuss.

The phenomenological level is the one responsible for the sense of similarity we experience, of being individuals within a larger social community of persons like us (Gallese, 2001, pg. 45), which can also be called the empathic level. Similarly, Buddhist mindfulness practice is a means of gaining insight into the nature of oneself and others, and the relation between oneself and the rest of the world (Wallace, 2001, pg. 209), which provides the basis for cultivating a deep sense of empathy. In so far, actions, emotions and sensations become meaningful because we can share them, which thus constitute the shared manifold of intersubjectivity in the MNS. The functional level of the 'shared manifold' is characterized as embodied simulation (Gallese 2002; Gallese, 2004; Gallese 2006), by which our brain/body system models its interactions with the world (Gallese, 2006, pg. 9). Understanding through the MNS is therefore achieved by modeling a behavior as an action, through the help of a motor equivalence between the observed action and the actions of the observer (Gallese, 2001, pg. 39). We can understand the thoughts and intentions of others by pretending or imagining to be in their mental "shoes," by using our own embodied mind as a model for the mental states of others (Gallese, 2002).

4.3.2 Husserl's Theory of Intersubjectivity and Lived Empathy: MNS, Empathy & Intentionality

Husserl's theory of intersubjectivity and lived empathy asserts that we take the experiences of others and project them as analogical imagery onto our own body, and this notion closely resembles the kind of empathy that arises in the MNS, which is due to the coupling of the bodies of both the self and another. For example, the key experience of Husserl's theory of intersubjectivity is empathy, for lived empathy enables the association of our lived bodies with the lived body of another. Consciousness for Husserl is intentional, in the sense of directedness towards external objects and openness to the world (Depraz, 2001, pg. 170). Martin Heidegger revitalizes this concept of consciousness by deepening intentionality into a self-transcendence of Dasein, as openness to the world where intentionality is viewed as *care*, in the form of concern for non-people and solicitude for people (Robert Hanna, 04/15/08, Phil 4040 lecture). Husserl's theory of intersubjectivity and lived empathy is more directly based than Heidegger's on the experience of the lived body, in terms of the coupling of the lived-body of a person with another body, as a holistic experience (Depraz, 2001, pg. 171), like empathy in the MNS.

This process of intersubjectivity and lived empathy leads to the ability to simulate or imagine the thoughts, feelings, and experiences of another, which follows from the analogy of the subject's own body and the body of another, into a move toward the other person's interior life (Gallagher, 2006, pg. 81). The role of inference, simulation and imagination thus plays an important role in empathy, in terms of being able to walk in the mental "shoes" of others. Empathy is intentional, in the sense that it is due to intentional attunement mechanisms in the MNS, which enable us to understand and experience the mental states of others (Gallese, 2002; Oberman et al., 2005; Gallese, 2006a), through simulation. Intentional attunement is a direct form of experiential understanding of others, which is achieved by modeling their behavior as intentional experiences on the basis of the activation of shared neural systems that underpin what others do and feel, and what we do and feel (Gallese, 2006a, pg. 15). This modeling mechanism is embodied simulation, which mediates between the multimodal experiential knowledge we hold of our lived body, and the experience we make of others (Gallese, 2006a, pg. 15). Such body-related experiential knowledge thus enables a direct grasping of the sense of the actions performed by others, including the emotions and sensations they experience (Gallese, 2006a, pg. 15). This is why intentionality is so important for empathy. Furthermore, the move toward the inner life of another person is what Husserl calls 'analogical ap-presentation,' and it resembles the ability to experience the intentions and emotions of others through empathy, via the embodied simulation mechanisms in the MNS. In so far, the MNS mediates between the multi-level personal experience we entertain of our lived body, and the implicit certainties we simultaneously hold about others (Gallese, 2005, pg. 23). Such personal and body-related experiential knowledge therefore enables us to understand the actions performed by others, and to directly decode the emotions and sensations they experience (Gallese, 2005, pg. 23). In other words, within our ability to understand the actions of others, we are also able to understand the underlying thoughts, emotions and intentions behind their actions, and to simulate or experience them ourselves. Hence, the MNS evolved in order to represent the feelings, emotions and intentions of others' such that we can consciously experience them ourselves, through empathy or empathic mirroring (Gallese, 2009). Husserl's theory of intersubjectivity and lived empathy therefore appears to be a mutual discovery through experiencing the embodiment of another person, where we can access another individual's internal mental states and lived-bodily experiences through empathy, which is analogous to the function of empathy in the MNS via embodied simulation.

4.3.3 The Role of Positive Emotions in the MNS

Positive emotions have also been implicated within the MNS. For example, studies in the primate MNS have demonstrated that the experience of positive emotions preferentially engages the auditory-motor MNS (Warren et al., 2006). Positive emotional valence and the arousal properties of positive vocalizations were shown to have a profound effect on the ability of the MNS to engage the coupling of auditory and visual information, via the MNS (Warren et al., 2006, pg. 13067). Recent studies have also demonstrated that there is a profound connection between positive emotions and cognition (Immordino-Yang and Damasio, 2007), as new connections between cognitive, emotional, and social functioning are illuminating the critical role of emotion in education. Similarly, recent studies with highly functioning ASD children, which have a dysfunctional MNS for action understanding and recognition, have shown that when ASD subjects are happy and comfortable in the laboratory, they are capable of understanding actions more like children with a normally developing MNS (Dr. Pineda, 06/23/2010, personal conversation). Such findings suggest that the experience of positive emotions is capable of improving the function of embodied simulation mechanisms in the MNS, including autism. Buddhist compassion meditation practice may therefore prove to be important for therapy in autism. In fact, researchers at the University of Wisconsin at Madison are already studying the effects of yoga on ASD children, which are effective at improving emotional well-being, by reducing stress and anxiety.

4.4 The Role of the MNS in Imitation Learning and Theory of Mind Abilities

The human MNS is also thought to play a critical role in higher order cognitive processes such as imitation learning, and theory of mind (ToM) or mind reading abilities (Oberman et al., 2005). According to the 'direct-matching hypothesis,' we understand the actions of another individual when we map the visual representation of the observed action onto our motor representation of the same action (Rizzolatti et al., 2001, pg. 664). Given that the MNS responds when an action is performed, observed, or heard, it has now been implicated in imitation learning (Oberman et al., 2006; Oberman et al., 2008). In fact, the capacity to associate the visual representation of an observed action with the motor representation of that action can lead to imitative learning (Rizzolatti et al., 2001). Imitating means simulating the actions and intentions or emotional states of others, by means of a shared neural state that is realized in two different bodies, as the "objectual other" becomes "another self" (Gallese, 2006a, pg. 15). This formulates the basis of learning through imitation, as we map the visual representation of an observed action onto our own motor representation. Once another individual's actions are represented and understood in terms of one's own actions, it is then possible to predict the mental state of the observed individual, thereby leading to theory of mind abilities (Oberman et al., 2005, pg. 191).

The term 'theory of mind' (ToM) refers to the awareness that others have beliefs and intentions that are different than our own, and those beliefs and intentions guide or direct others' behavior (Bernier and Dawson, 2009, pg. 269). This ability to impute mental states to others is a crucial aspect of social cognition and action understanding, which I discussed earlier in Chapter Three in the CBCT study. It allows for the understanding of others' beliefs, goals, and intentions, along with allowing for the ability to predict what others will do in a given situation. The simulation theory proposes that children come to read minds by, in effect, putting themselves in another person's shoes, by using their own minds to simulate the mental states or processes that are likely to be operating in the other (Pineda, 2005, pg. 64). Theory of mind is thus linked to empathy, which respect to understanding the mental states of others.

4.5 Merleau-Ponty's Theory of Motor Intentional Behavior and Grasping Actions/Intentions

According to Merleau-Ponty, perceiving and acting upon objects in the world are the most basic modes of intentionality, and these perceptions and actions have an intentional content that is "pre-predicative," which follows from his phenomenological account of motor intentional behavior (Kelly, 2000, pg. 15). For example, Merleau-Ponty's phenomenological account of motor intentional behavior asserts that when we grasp an object, we are in fact directing ourselves toward it, and therefore the action is intentional (Kelly, 2000, pg. 20). This seems smoothly consistent with the important study conducted by Iacoboni et al. (2005), which showed how the MNS is involved in understanding the intentions behind observed grasping actions, when the actions are embedded in a particular context that cues their intentions. Similarly, grasping actions, for Merleau-Ponty, identify an object "pre-predicatively," for it does not give the kind of information about an object that can be used in a descriptive sentence about it. Rather, it identifies the object in terms of the bodily movements required to grasp it successfully (Kelly, 2000, pg. 20). Thus, Merleau-Ponty's phenomenological account of motor intentional behavior is also quite similar conceptually with recent studies of the MNS that pertain to the observation of an object-directed grasp, which I will now briefly discuss.

Recent studies with the MNS and electroencephalography (EEG) have shown that a mu suppression, which is a suppression of EEG oscillations in the mu frequency (8-13Hz) over the sensorimotor cortex, occurs when observing, performing, or hearing actions in individuals with a properly functioning MNS (Oberman et al., 2006; Oberman et al., 2005). The sensorimotor cortex is a critical component of the human MNS (Pineda, 2008), which plays a pivotal role in imitating and simulating the action and behaviors of others. What is interesting for Merleau-Ponty's phenomenological account of motor intentional behavior, and studies pertaining to mu rhythm modulations in the MNS during the observation of an object-directed grasp, is that there is a much greater mu rhythm suppression during the observation of an object-directed grasp, compared to an open hand condition (Muthukumaraswamy et al., 2004). Such studies with the MNS thus help to illustrate the relevance of Merleau-Ponty's phenomenological account of motor intentional behavior, for understanding the intentions behind observed goal-directed hand actions, in terms of phenomenology.

4.5.1 Phenomenological Implications of Mu Rhythms: MNS Activity

The phenomenological implications of mu rhythms in the study of the MNS can help us to deepen our account and understanding of the neurophysiological basis of the MNS for embodiment, empathy, and both imitation learning and action understanding. Given that mu suppression is correlated with MNS activity, mu rhythms reflect mirror neuron activity and the capacity to imitate. Imitation learning is ultimately linked to understanding the reason or intention behind an action, and the mu rhythm properties of the MNS respond most strongly to imitation, followed by action execution, and then the observation of actions themselves (Aziz-Zadeh et al., 2006, pg. 2967). The fact that the properties of the MNS respond most strongly to imitation therefore illuminates the underlying premise of this essay, for the neural processes associated with embodiment are most active while engaged in the higher-level cognitive processes of intentional action understanding. This includes simulating the mental states of others,' which are involved in learning through imitation. This activity of the MNS, during imitation learning, is directly reflected in studies involving EEG and mu rhythm suppression over the sensorimotor cortex. Mu suppression thus responds to social interaction, and specifically the embodied actions of another individual that most strongly reflect the capacity to imitate.

In the laboratory mu suppression, as a measure of MNS activity, is reflected by the ability of a subject to identify with the individual performing a hand or arm action on a tv screen, which involves identifying with the person on the screen from a third-person perspective. The subject is then required to imitate, or replicate the motor behavior displayed on the screen, which results in greater mu suppression (Oberman et al., 2005). Because the process of action observation and execution that is involved in imitation learning has been directly linked to intentional attunement mechanisms in the MNS, studies with imitation learning and mu rhythms support the neurophenomenological perspective that meaning is grounded in the social experience of action. Moreover, given that the neural mechanisms in the MNS are thought to have originally evolved in order to coordinate sensorimotor integration, the MNS is more active during the execution of an action compared to when it is observed.

4.6 Deficits in Autism: Mu Rhythms and Action Observation/Execution

Studies involving mu rhythms and the MNS in children with Autism Spectrum Disorder (ASD) have now suggested that such children have a dysfunctional MNS for recognizing the actions and intentions of another individual, which I have already briefly discussed in section 4.3.3 and Chapter Three. A research collaborator of mine at UC San Diego, Dr. Jaime Pineda, conducted a unique study in 2005 that I just described, which addressed the mu rhythm modulation in children with ASD in response to observing a hand movement in a video, and imitating the same hand movement (Oberman et al., 2005). In this study, typical individuals showed appropriate mu suppression in response to both observing the hand movement in the video, and when they executed the hand movement themselves. However, the ASD children only showed a normal mu suppression of EEG oscillations when they performed the hand movement themselves, which suggests that they have a dysfunctional MNS for action observation and recognition (Oberman et al., 2005). Individuals with ASD are believed to have defective intentional attunement mechanisms within the MNS, for understanding the actions and intentions of another person.

The neurophenomenological implications of the 2005 study for children with ASD strongly imply that a dysfunctional MNS for action understanding and recognition can explain why ASD children have deficits in imitation learning and theory of mind. This means that ASD individuals are not capable of learning from the actions of other individuals, including the ability to understand or simulate the intentional mental states of others,' or even to empathize with their pain and suffering. The deficits encountered in autism are believed to be due to mirroring failures in the ability to map the mental representation of the self to the representation of the other (Williams et al., 2004). Mirroring failures appear to be due to a reduction in the self-other mapping, including the representation of the observed action to the self (Winkielman et al., 2009, pg. 277). Such autistic individuals are therefore also incapable of engaging in the direct matching between the sensory (visual and auditory) description of a motor act and its execution (Gallese, 2009, pg. 166). In so far, deficits in ASD individuals are thus believed to be due to impairment in the self-other overlap that normally accompanies spontaneous mirroring, via embodied simulation in the MNS (Winkielman et al., 2009, pg. 244-45). Recent findings point to a fundamental deficit in the spatial focusing of auditory attention in autism (Teder-Salejarvi et al., 2005a), which is also a key factor that impedes both social interaction and sensory-guided behavior.

In a follow up study, Dr. Pineda's group found that autistic individuals did show mu suppression while observing the hand action in the video, but only when a family member performed the hand action, which suggests a role of family in therapy (Oberman et al., 2008). This finding suggests that familiarity and perhaps empathy, or an emotional bond, increases the MNS response to action understanding and intentional attunement in ASD children, given that ASD children showed a more typical MNS response to the hand movement in the video, when it was the hand of a parent, sibling, or guardian (Oberman et al., 2008). Familiarity therefore enhances the sensitivity of the MNS in children with ASD. I will discuss the implications of this new finding in Chapter Six, in future MNS studies.

CHAPTER 5

THE MNS FUNCTIONS AS AN EMBODIED SIMULATION MECHANISM FOR EMOTION: ROLE OF EMBODIMENT IN EMOTION

5.1 Experiencing the Emotions and Intentions of Others via the MNS

As described in Chapter Four of this essay, the embodied simulation mechanisms in the MNS play a pivotal role in understanding the actions and intentions of others, and because this also includes the emotions, thoughts, and feelings that motivated a particular action, I will now provide a more detailed account of the role of embodiment in emotion. The link between emotion and embodiment is central to current theories of embodied cognition (Winkielman et al., 2008, pg. 269), which suggest that the active engagement of sensorimotor processes is an integral part of the process of emotional perception, understanding, learning and influence. The MNS is a very likely candidate for helping to illuminate the role of embodiment in emotion, for the MNS originally evolved mechanisms for sensorimotor integration (Gallese, 2008). The MNS has now been demonstrated to possess mirror-like phenomena for domains other than just the motor one (Keysers and Fadiga, 2009), including the somatosensory and emotional systems that appear to provide a neurophysiological basis to phenomena such as embodiment and empathy. The subjective sense of how one feels is theorized to be based upon representations of the body that occur in the anterior insula (Pineda, 2008, pg. 7), as the function of the insular cortex, in the brain, is to encode body representation and subjective emotional experience. This neurophysiological basis for the representation of the body and the subjective experience of emotion is assumed to provide a foundation for emotions, and perhaps even for self-awareness. This could also allow for the simulation of future actions, in order to use the feelings generated by a simulation to guide decision-making (Pineda, 2008, pg. 7). This account of the anterior insula helps to illuminate the fact that emotional experience, and feelings are always embodied and situated (Varela and Depraz, 2005, pg. 76). Such a view is consistent with the embodiment view in which emotional perception involves simulating the relevant state in the perceiver, using somatosensory resources (Winkielman, 2008).

5.2 Mirroring Emotions and Sensations: Stein's Phenomenology of Emotions Again

Stein's phenomenology of emotions and empathy can also provide us with a deeper account of the important role of embodiment in emotion, for both mirroring and subjectively experiencing emotions and sensations, via embodied simulation mechanisms in the MNS. Stein's phenomenology of emotion and empathy can be directly linked to the phenomenology of embodiment, where every feeling or emotion, by its nature, demands a direct bodily expression or active expression of the lived body, or *Leib* (Moran and Mooney, 2006, pg. 233). Mindfulness awareness and meditation is also quite important for illustrating this integral role of the body in emotion and cognition, through embodied reflection (Varela, Rosch and Thompson, 1993). The lived body, for Stein, is thus the living and feeling, acting and sensing source of consciousness and intentionality (Moran and Mooney, 2006, pg. 235). Hence, our way of responding toward others is exemplified in an ability to move like others, as an attribute of lived bodily experience that resembles important aspects of embodied simulation in the MNS. Such an ability to move like others closely resembles the role of the MNS in imitation learning.

5.3 The Role of Embodiment in Experiencing Emotions: A Basis for Intersubjectivity

As the thesis of embodiment asserts that the mind is not located in the head, but instead is embodied in the whole living organism that is, in turn, embedded in its environment (Thompson, 2001, pg. 3), Merleau-Ponty's phenomenology of embodied perception supports the radical idea that consciousness is embodied throughout the living body. Merleau-Ponty asserts that pre-reflective consciousness is characteristic of all perception, and that consciousness and intentionality is spread throughout the body, for intentional agency and perception is experienced with and through the body (Robert Hanna, 04/22/08, Phil 4040 lecture). In so far, the MNS certainly appears to be a neurobiological correlate of emotion and bodily intentionality. Merleau-Ponty's notion of pre-reflective consciousness in perception is quite compatible with the embodied simulation mechanisms in the MNS, whereby we can directly understand the meaning of the actions and emotions of others, by internally replicating or simulating them, as a basis for intersubjectivity. Embodied simulation mechanisms in the MNS play a pivotal role in understanding the actions of others, and because this includes the emotions and feelings that motivated a particular action, it thus illuminates the role of emotion in embodiment.

5.4 Deficits in Embodied Simulation for Emotion, Empathy and Intention: Autism

The mirror neuron theory of autism proposes that dysfunction in the execution/matching system interferes with the acquisition of internal representations of others' observed behavior, expressions, movements and emotions (Bernier and Dawson, 2009, pg. 261). The dysfunctional MNS prevents the individual with autism from having an immediate, direct form of experiential understanding of others. In so far, there is impairment in the shared neural systems for embodied simulation underpinning what others do and feel, and what we do and feel (Gallese, 2006a, pg. 15). This is significant, for the body helps to implement the mind, in that the conceptual system for emotion relies on sensorimotor simulations (Barrett and Lindquist, 2008, pg. 246). Such a theory illuminates the importance of the execution/matching system for simulating and experiencing the emotions and feelings of others. The deficits in social impairments, including empathy and ToM in autism are thus hypothesized to cascade from this lack of immediate, experiential understanding of others' (Bernier and Dawson, 2009, pg. 277).

5.5 The MNS Evolved in Order to Represent Intentions, Feelings, and Emotions

Given that the embodied simulation theory suggests that we can experience the emotions and intentions or mental states of others via the MNS, this implies that the MNS evolved to represent not only the physical aspects of action observation and recognition, but also the underlying intentions, thoughts, and feelings and emotions that motivated the action itself (Oberman et al., 2006, pg. 1). This has important implications for my argument. The ability to understand the actions and intentions of others is clearly a fundamental attribute of social behavior and embodied cognition (Iacoboni et. al., 2005, pg. 0001). Emotion is always embodied and situated (Varela and Depraz, 2005, pg. 76), but the MNS evolved in order to represent the feelings, emotions and intentions of others' such that we can consciously experience them for ourselves (Gallese, 2009). The role of empathy within the MNS is a clear example of this, for empathy provides a shared manifold of understanding between ourselves and the embodied mind of another, through which we actively experience another person's thoughts, feelings and emotions underlying a particular action they are engaged in. Furthermore, we experience another person as a unified whole through empathy, and this sort of empathy occurs through the immediate 'pairing' or coupling of the bodies of the self and other, in action. Because empathy is made possible by mirroring mechanisms that allow us to infer and simulate the feelings, beliefs, and intentions of others (Pineda et al., 2009, pg. 143), given the importance of intentional action understanding for empathy, it includes the simulation of externally observable motor behaviors along with subtler, internal bodily states and feelings. When we perceive others expressing a given basic emotion such as disgust, the same brain areas are activated as when we subjectively experience the same emotion (Gallese, 2009, pg. 170). This suggests that our capacity to empathize with others is mediated by embodied simulation mechanisms, that is, by the activation of the same neural circuits underpinning our own motor, emotional, and sensory experiences (Gallese, 2009, pg. 170). Mirror neurons were likely selected during the evolutionary processes because they provide the adaptive advantage of understanding the mental states of others, in an effortless and automatic way (Iacoboni, 2009, pg. 132), through simulation. It seems likely that the MNS evolved in order to represent intentions and emotions of others, given that it thus directly underpins basic action understanding and cognition (Gallese, 2009).

5.6 Implications for Emotion, Cognition, and Consciousness: Convergence

The kind of empathy supported by mirror neuron activity is very likely to be pre-reflective and automatic (Iacoboni, 2009, pg. 131), which entails the existence of neurobiological mechanisms for understanding the mental states of others (Oberman et al., 2005). This also suggests that the kind of embodied simulation process implemented by the MNS, which helps us to understand the actions and intentions of others, is also very likely to be pre-reflective and automatic. Empathy is automatic in the sense that we can automatically simulate or experience the mental states and emotions of others, though embodied simulation mechanisms in the MNS for empathy or empathic mirroring. The 'shared manifold' hypothesis thus asserts that the particular dimension of social cognition is embodied, in that it mediates between the multimodal experiential knowledge of our own lived body, and the way we experience others

(Gallese, 2009, pg. 166). In so far, the MNS appears to support the reconstruction of what it would feel like to be in a particular emotion, by means of simulation of the related body state (Gallese, 2006, pg. 8). The implication of this process for empathy should therefore be quite obvious. Furthermore, our understanding of the important role of empathy and intersubjectivity in the MNS is also improved by recent studies involving Buddhist compassion meditation. Such studies show how compassion meditation increases the empathic accuracy for reading facial expressions and emotion (Mascaro et al., 2013). This occurs by enhancing the neural basis of empathy, which is the MNS. It is hypothesized that this increase in empathic accuracy improves our ability to experience the emotions of others,' through embodied simulation and empathic mirroring in the MNS, by boosting the manifold of intersubjectivity for reading facial expressions and emotions. Moreover, studies with the MNS demonstrate that there are neural mechanisms mediating between the multi-level personal experience we entertain of our lived body, and the implicit certainties that we simultaneously hold about others (Gallese, 2005, pg. 23). For Husserl, the body entertains a dual reality of spatial externality and internal subjectivity (Husserl, 1925, pg. 197). Such personal and body-related experiential knowledge enables us to understand the actions performed by others, and to directly decode and experience the emotions and sensations that they experience (Gallese, 2005, pg. 25), through embodied simulation.

Neural perspectives on emotion, intention, and consciousness also suggest that intentions and emotions arise together (Lewis and Todd, 2005, pg. 210), and that emotions compel us to pursue goals, for directed attention is always both intentional and emotional (Freeman, 2000). Studies involving loving-kindness meditation have shown that the positive emotions, which are induced through meditative practice, produced increases in a wide range of personal resources (Fredrickson et al., 2008). Here, loving-kindness meditation produced increases, over time, in the daily experience of positive emotions, which, in turn, produced increases in mindfulness, purpose in life, social support, and decreased illness symptoms (Fredrickson et al., 2008, pg. 1). Emotion is therefore defined as a property of intentional behavior. Furthermore, it is also consistent with the role of the MNS in understanding the actions, intentions, and emotions of others. Moreover, Buddhism asserts that the four applications of mindfulness is a means for gaining insight into the nature of oneself, others, and the relations between oneself and the rest of the world (Wallace, 2001, pg. 209). The MNS is responsible for the phenomenal awareness of the embodied mind, and its relations with the world (Gallese, 2005, pg. 27). Mindfulness practice plays an important role in emotional regulation, along with increasing compassion and empathy (Holzel et al., 2011), and it also focuses us toward the phenomenology of embodied perception. As emotion is essential to all intentional behaviors (Freeman, 2000), it is likely that a new understanding of the importance of the role of emotion in the MNS for action understanding and intention will take place, due to the contributions of neurophenomenology and Buddhist meditation. The role of embodiment in emotion will certainly influence new biological theories of consciousness, where the phenomenological experience of consciousness must include the important role of the body in both emotion and cognition.

5.7 Embodiment and Human Cognition: Mind Reading and First-Person Experiences

Given that the MNS functions as an embodied simulation mechanism for understanding the emotions and intentions of another person's embodied mind or actions, shared circuits in the MNS allow for both the first person experience (*I* do, *I* feel) and third person perspective (knowing what *he* does or *he* feels) (Keysers and Gazzola, 2009, pg. 23). Furthermore, it seems that only the MNS-based approach to embodiment is capable of capturing both first and third person experiences. Through embodied simulation mechanisms in the MNS, observing what other people do or feel thus appears to be transformed into an inner representation of what we would do or feel, in a similar situation (Keysers and Gazzola, 2009, pg. 22). This indicates the existence of a dynamic neural basis for the mirroring processes in the MNS involved in social cognition, through which we can simulate one's mental states.

CHAPTER 6

IMPLICATIONS FOR NEW MNS STUDIES INVOLVING EMOTION AND BUDDHIST MEDITATION

6.1 Meditation and Neural Plasticity

Recent studies involving Buddhist meditation and neuroscience have illuminated the ability of the brain to change, grow and rewire itself through the phenomenon of neural plasticity, which has important implications for the role of emotion in cognition in general, and MNS studies involving Buddhist meditation in particular. For example, meditation studies involving EEG and fMRI brain imaging techniques, which I have already discussed, have shown how Buddhist meditation and mindfulness practice can increase attention, emotional regulation, positive emotions, and both empathy and compassion. In so far, fMRI studies involving compassion meditation have shown how increasing positive emotion can help to rewire the brain, through neuroplasticity, as the brain circuits related to happiness are changeable. Similarly, because the cultivation of positive emotions or happiness, through compassion meditation, is capable of rewiring the brain, this has vast implications for overcoming trauma or post-traumatic stress disorder (PTSD), by thus reducing negative emotion. Furthermore, compassion-training (CT) programs have recently received great interest in the neuroscience community. Such programs are typically based on compassion meditation or loving-kindness mediation (Salzberg, 2002). As CT programs are based on contemplative practices, they often involve the subject or practitioner practicing feeling care, connection and love for others, along with reflecting on others' suffering and human interdependence (Salzberg, 2002). CT programs are now significant because they are known for their ability to increase positive emotions in individuals (Dunn et al., 2008), in addition to leading to increased neural activity in areas where mirror neurons are implicated; such as the inferior parietal lobule (Weng et al., 2013), inferior frontal gyrus (Mascaro et al., 2013), and the posterior superior temporal sulcus (Lutz et al., 2008). Compassion meditation studies have important implications for understanding the role of emotion and empathy in the MNS, including empathic mirroring and intersubjectivity, because compassion is based upon empathy. CT studies increase positive emotion and empathy, which certainly involve the MNS.

The CBCT study at Emory University that I already discussed in Chapter Three showed that a compassion-based meditation program could significantly improve a person's ability to read the facial expressions of others (Mascaro et al., 2013), which has important implications for empathy and the MNS. The study was based on aspects of compassion meditation and mindfulness, which focuses on training people to analyze and reinterpret their relationships with others (Mascaro et al., 2013). The CBCT program showed that compassion-based meditation could boost the neural basis of empathy, which is now thought to reside in the MNS (Oberman et al., 2005; Oberman et al., 2006). In so far, the CBCT program showed that compassion meditation enhanced the empathic accuracy of inferring others' mental states from facial expressions (Mascaro et al., 2013), which is likely due to embodied simulation mechanisms in the MNS for empathic mirroring and mind reading (Gallese, 2006a; Gallese, 2005). Furthermore, this study helps to illuminate the important role of empathy and intersubjectivity in the MNS, which is implicated in reading facial expressions and simulating the mental states of others.

A recent study conducted by Jaime Pineda's lab at UCSD, which I mentioned earlier, supports the simulation theory for the perceptual processing of emotional faces. The study found that observers recruit the neural circuitry involved in creating their own emotional facial expressions in order to recognize the emotions, and simulate the thoughts and feelings of others (Moore et al., 2012). Taken together, these results do suggest that compassion mediation boosts the neural basis of empathy in the MNS, which explains why the CBCT program showed enhanced empathic accuracy for reading the facial expressions of others. The fact that compassion meditation increases positive emotion also suggests that the experience of positive emotions increases the sensitivity of the MNS in making us more empathic, by enhancing the neural processing in the MNS associated with emotion and empathy. Compassion mediation and the cultivation of positive emotions have also been shown to alter the activation of neural circuitries linked to empathy and ToM, in response to emotional stimuli (Lutz et al., 2008), which I discussed in Chapter Three. Long-term compassion meditators showed enhanced neural processing in response to auditory sounds of human distress (Lutz et al., 2008), in the posterior superior temporal sulcus and the temporo-parietal junction (TPJ), where mirror neurons are implicated. These results are consistent with studies with the somatotopic auditory MNS in humans, which has shown that there is a link between the motor MNS and empathy, given that individuals who scored higher on an empathy scale activated this auditory system more strongly (Gazzola et al., 2006, pg. 5055). The fact that compassion mediation and the cultivation of positive emotions alter the activation of neural circuitries linked to empathy and ToM (Lutz et al., 2008), which involve the MNS, thus strongly suggest that only a contemplative neuroscience approach is capable of illuminating the important role of emotion and empathy in embodied simulation in the MNS. The findings in both compassion meditation studies may therefore be explained by the fact that positive emotion increases the sensitivity of the MNS for auditory-visual processing, which ultimately boosts the neural basis of empathy within the MNS. Compassion meditation may be important in therapy for individuals with ASD, given that the ability to accurately simulate the mental states of others, from facial expressions, is fundamentally impaired in ASD, which is now thought to be due to a dysfunctional MNS (Oberman and Ramachandran, 2009b).

6.2 Emotion and Cognition

The role of positive emotion in the MNS is now gaining significant attention, specifically for the fact that positive emotion preferentially engages the coupling of both auditory and visual information in the MNS (Warren et al., 2006), which has important implications for studying emotion and cognition. For example, the experience of positive emotions affects auditory-visual (AV) processing in the MNS, by increasing the sensitivity of the neural processing in the MNS for AV integration. Given that AV or sensory integration plays a fundamental role in language development (Oberman and Ramachandran, 2009b), language development and AV integration have now been shown to be pivotal for ToM abilities, or mind reading. Similarly, ToM and mind reading abilities in the MNS are closely linked to the production of empathy, which I have already discussed in this essay, for empathy entails the existence of neurobiological mechanisms for understanding another individual's mental state (Oberman et al., 2005, pg. 191). ToM and mind reading in the MNS are thus essential for understanding the mental states of others (Oberman et al., 2006), and in particular for the ability to simulate the mental states of others from their facial expressions and emotions (Gallese, 2006a, pg. 21). Given that compassion meditation has now been shown to increase empathic accuracy for reading facial expressions, it is quite significant that the cultivation of positive emotion can increase the sensitivity of the MNS for AV processing, which underpins the neural basis of ToM and empathy in the MNS. Furthermore, deficiencies in ToM and AV integration in the MNS are now implicated in autism (Oberman and Ramachandran, 2009b), in terms of a dysfunctional MNS for AV processing. Children with autism are deficient at AV or multi-sensory integration that is necessary for language development (Oberman and Ramachandran, 2009b). Studies by Dr. Pineda at UCSD, which I already mentioned, have recently shown that autistic children exhibit a more typical MNS response to watching the actions of other people, while experiencing positive emotions (Dr. Pineda, 06/23/2010, personal conversation).

The importance of emotion and emotional regulation for attention, goal-directed behavior, and motivation has important implications for future studies with the MNS involving emotion and Buddhist meditation. For example, Buddhist mindfulness practices have been shown to improve emotional regulation and executive decision-making (Holzel et al., 2011), in addition to improving attention regulation and focus through both Buddhist Insight meditation and focused attention, respectively (Lazar et al., 2005; Lutz et al., 2008). Buddhist meditation and mindfulness practices, then, have important implications for executive function and goal-directed behavior, given that emotion and motivation are closely linked to executive control (Pessoa, 2009). The experience of positive emotion that is cultivated in such contemplative practices should only enhance cognitive control and directed attention, with respect to facilitating the emotional regulation systems that impact both attention and motivation, and thus executive control (Pessoa, 2009; Ochsner and Gross, 2005). Furthermore, basic positive emotional states, such as contentment, have also been shown to relate to empathy in children, given that both positive emotional experience and empathy are associated with the engagement of the prefrontal cortex (Light et al., 2009, pg. 1214), which is involved in executive function. In fact, Dr. Pineda's lab also showed that autistic children only show a typical MNS response to watching the hand movements of others in a video when a parent, guardian or sibling performed the hand movement (Oberman et al., 2008). This suggests that empathy, or a positive emotional bond, appears to increase the MNS response to action observation in autism, which indicates a role for family in therapy for ASD children. Moreover, the role of positive emotions in learning and cognition is also receiving great attention in the cognitive science community (Immordino-Yang and Damasio, 2007). In other words, the happier we feel, the more easily we can learn and retain new information, a fact that has vast implications for AV processing within the MNS that enables ToM and mind reading in empathy. Thus, I would now like to propose some new future MNS studies involving emotion and Buddhist meditation.

6.3 Proposed Future MNS Studies Involving Emotion and Buddhist Meditation

Given that Buddhist compassion meditation and mindfulness practices have been shown to increase positive emotion, empathy or empathic accuracy, and compassion (Lutz et al., 2008; Mascaro et al., 2013; Holzel et al., 2011), it is significant that none of these studies have directly measured the MNS. In fact, such contemplative neuroscience studies have only directly measured brain areas where mirror neurons are localized. These areas include the inferior parietal lobule (Weng et al., 2013; Buccino et al., 2005), the inferior frontal gyrus (Mascaro et al., 2013; Gallese, 2006a), the posterior superior temporal sulcus (Lutz et al., 2008; Rizzolatti and Sinigaglia, 2010), and the frontal parietal lobe (Lutz et al., 2004; Molnar-Szakacs et al., 2006), along with the temporo-parietal junction (Holzel et al., 2011). This section of the thesis therefore proposes future MNS studies involving emotion and Buddhist meditation that can directly measure activity of the MNS using mu rhythm suppression, which I have already discussed in Chapter Four of this essay. For example, the modulation of the MNS for action observation and execution can be studied by monitoring the suppression of mu rhythms in the EEG frequency (8 to 13 Hz) over the sensorimotor cortex. Recent studies with the MNS have also suggested that action-related sounds, and words can modulate the activity of the MNS (Moore et al., 2012; Le Bel et al., 2009, Buccino et al., 2005). The auditory components of action play an important role in action perception and understanding (McGarry et al., 2012). In fact, it is well known that listening to action-related words and sentences activates fronto-parietal motor circuits within the MNS (Tettamanti et. al., 2005; Buccino et. al., 2005), which has now encouraged studies of the auditory properties of the human MNS (D'Ausilio, 2007). Furthermore, recent research demonstrates that auditory perception in human actions elicits activation of the human MNS similar to that during the visual perception of action (Gazzola et al., 2006). The role of emotion in AV integration is of central interest now for addressing the deficits in autism that are due to a dysfunctional MNS for action understanding and recognition, and higher level cognitive functions such as imitation learning, ToM or mind reading, and empathy. Therefore, as the role of emotion in executive function continues to receive greater attention in the field of cognitive science and neuroscience, research on autism and the MNS will benefit from exploring the role of AV facilitation in the MNS for multi-modal representation (McGarry et al., 2012; Le Bel et al., 2009); along with further addressing how positive emotion enhances AV integration in the MNS. Hence, the following study proposes exploring how short-term vs. long-term meditation affects AV processing in the MNS, which has important implications given that positive emotion increases neural processing within the MNS for AV integration and empathy, or empathic mirroring.

This proposed MNS study involving emotion and Buddhist meditation thus aims to address how meditation and mindfulness practices, which increase both happiness and empathy, can affect AV processing within the MNS. It is hypothesized that positive emotion increases the neural activity and sensitivity of the MNS for AV processing, which, in turn, produces an increase in empathy, or empathic accuracy for reading facial expressions and mirroring. The ability to accurately infer or simulate other's mental states from facial expressions is important for optimal social functioning (Mascaro and Rilling, 2013), which is impaired in individuals with autism. The CBCT study at Emory University that I have already discussed showed that such training improved empathic accuracy for reading facial expressions. In fact, recent studies conducted by Dr. Jaime Pineda's lab at UCSD have now confirmed the role of simulation and sensorimotor mirroring in the perceptual processing of facial emotions, by using EEG methods for measuring mu rhythm suppression (Moore et al., 2012). Given that these findings represent the first study to support a simulation account of perceptual face processing, based on a mirroring mechanism using distinct EEG mu responses, this method can now be invoked for looking at how the CBCT study can boost the neural basis of empathy; by measuring the MNS using EEG mu rhythm responses. If compassion meditation increases empathy and happiness, then this should increase the accuracy of the MNS for reading facial expressions and emotion, through simulation and mirroring.

Since positive emotion preferentially engages the coupling of auditory-visual information or AV processing in the MNS (Warren et al., 2006), Buddhist compassion mediation should therefore increase the MNS response to audio-visual stimuli in this proposed study, which is reflected by greater EEG mu suppression. Furthermore, since action-related sounds also trigger the MNS for action understanding (Keysers and Luciano, 2009), it has already been shown that individuals who scored higher on an empathy scale activated the somatotopic auditory MNS more strongly (Gazzola et al., 2006, pg. 5055), given that there is a functional link between the motor MNS and empathy. Studies with compassion meditation should thus increase the MNS response to auditory sound, as indexed by greater EEG mu suppression, given that compassion meditation has been shown to increase empathy (Mascaro et al., 2013). In fact, as I discussed in Chapter Three, a compassion study conducted at the University of Wisconsin at Madison showed that compassion meditation that cultivated positive emotion altered the activation of circuitries linked to empathy and ToM, which are implicated in the MNS, in response to emotional stimuli (Lutz et al., 2008). Compassion meditation should therefore increase the MNS response to action-related sounds, and even the sounds of human distress that were used in this study (Lutz et al., 2008), especially since the response to emotional sounds was modulated by the degree of compassion meditation training (i.e. greater cultivation of positive emotion results in higher empathy).

Studies with compassion meditation and the MNS have important implications for intentional attunement and embodied simulation as well. Studies conducted by Marco Iacoboni at UCLA, which I already discussed in Chapter Four, showed that the MNS could infer the underlying intention of a hand grasping an object in a picture, such as a coffee mug or tea kettle (Iacoboni et al., 2005). Compassion meditation should also increase the MNS response to the pictures used in this important study, for intentional attunement. This also suggests an important role of compassion meditation in therapy for autistic children, for autism has been linked to deficits in intentional attunement mechanisms in the MNS that are due to a lack of embodied simulation (Gallese, 2006a). Such deficits in intentional attunement can also explain the severe problems autistic children experience in inferring or simulating others' mental states, from the facial expressions of emotions (Gallese, 2006a). This suggests an important role of compassion meditation in therapy for autistic children. Lastly, since the MNS responds to execution of a movement, in addition to the audio-visual representations of the same movement (Pineda, 2005), compassion meditation should result in a greater MNS response to audio-visual representations of embodied actions, which can be measured through EEG mu suppression. Hence, by studying how short-term vs. long-term mediation affects AV processing in the MNS, we may illuminate how positive emotion increases the sensitivity of the MNS for AV processing in general, and empathy or empathic mirroring in particular. In short, given that Buddhist compassion meditation increases positive emotion through neural plasticity, along with boosting the neural basis of empathy (Mascaro et al., 2013), Buddhist meditation should thus lead to an increase in the MNS response to audio-visual stimuli, auditory sound, facial expressions of emotion, and intentional attunement.

6.4 Concluding Remarks: Philosophical and Empirical Reflections

The general theory of the operations of the MNS demonstrates the importance of neurophenomenological approaches to consciousness and intentionality, which has important implications for surmounting the mind-body problem in the philosophy of mind. Studies with mirror neurons have provided a unifying neural hypothesis for how individuals understand the actions and emotions of others (Gallese et. al., 2004). Researchers have now also suggested that the MNS provides concrete evidence for the shared representations of perception and action that are crucial for the production of empathy (Gallese et. al., 2002, pg. 36). Studies with Buddhist meditation and mindfulness practice have recently demonstrated the phenomenon of neuroplasticity, where the brain can rewire itself by increasing positive emotion, which has fascinating implications for understanding the role of emotion and empathy in the MNS. What Buddhism has to offer us is that we can train to be more empathic, through mindfulness and specific contemplatives that change or improve how the brain works. This includes the neural basis of empathy in the MNS. Such mirror mechanisms of action understanding thus play a pivotal role in imitation learning, ToM or mind reading, and empathy.

The proposed role of the MNS in intentional action understanding and attunement involves a direct appeal to emotions and empathy, as an intersubjective manifold for understanding and experiencing the emotions and intentions of others (Gallese et al., 2002). Buddhist meditation and mindfulness practice offers us insight into the relation between oneself, others, and the relations between oneself and the rest of the world (Wallace, 2001, pg. 209), as a means of cultivating empathy through intersubjectivity. As compassion is based upon empathy, it is significant that the CBCT study focuses on the interdependence of all human beings, along with the desire to be happy and free from suffering, which boosts the neural basis of empathy. Moreover, this study showed that CBCT increases empathic accuracy for inferring others' mental states from facial expressions, which is now thought to be due to embodied simulation mechanisms in the MNS for mind reading and empathy. CBCT training may help ASD individuals that have a dysfunctional MNS for reading facial expressions and emotion.

In this thesis, I have argued for a non-reductive, neurophenomenological approach to embodied cognition, by way of describing the embodied simulation mechanisms in the MNS for action understanding and recognition, emotion and empathy. Because the theory of the operations of the MNS demonstrate an integration of first-person subjective descriptions of lived-bodily experience, and also third-person objective accounts provided by cognitive neuroscience, this theory also significantly supports the study of Buddhist meditation with neuroscientific methods of inquiry. Furthermore, because Buddhist compassion meditation has been shown to increase positive emotion and empathy (Mascaro et al., 2013), and mindfulness practices have been shown to increase positive emotion, and empathy and compassion (Holzel et al., 2011), both contemplative practices offer great insight into the role of emotion and empathy within the MNS. Moreover, the experience of positive emotions might therefore make humans more sensitive and empathetic, by enhancing the neural processing in the MNS associated with intentional action understanding, emotion and empathy. In so far, the experience of positive emotion thus boosts the neural basis of empathy in the MNS, so we are more in tune to the facial expressions, emotions, and body language of others. This suggests that positive emotion increases the neural activity or sensitivity of the MNS for AV processing, which, in turn, produces an increase in empathy, or empathic accuracy for reading facial expressions and mirroring. Research on the MNS and meditation strongly supports the argument that only a contemplative neuroscience approach can truly illuminate the role of emotion and empathy in embodied simulation in the MNS, given that Buddhist mediation and mindfulness practice increase both positive emotion and empathy. Undoubtedly, the MNS constitutes a mechanism of shared affective response, in which the same networks engaged during first-hand experience of affect also subserve empathic responses (de Waal, 2008; Decety and Jackson, 2004; Engen and Singer, 2012), which is very important for compassion. Research on the neuroscience of compassion will therefore truly benefit from further study of the MNS. To conclude, research now indicates that the happier we feel, the more readily we can learn and retain new information, which has vast implications for illuminating how Buddhist meditation practices that increase happiness and empathy can affect the AV processing in the MNS that underpins empathy.

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APPENDIX

LANGUAGE PLAYS A CENTRAL ROLE IN OUR EMBODIED COGNITION VIA THE MNS: ROLE OF EMBODIED SIMULATION IN LANGUAGE PROCESSING

A.1 Language Shapes Embodied Human Experience

I would now like to discuss the central role of language in embodied cognition in human persons, in order to deepen this account of the MNS. The capacity to associate the visual representation of an observed action with the motor representation of that action can lead to imitative learning (Rizzolatti et al., 2001), and learning by imitation is also a key feature of language acquisition (Billard and Arbib, 2002). For example, language acquisition and cognitive development directly relates to the relationship between embodiment and both the cultural and physical environment, for language refers to the complex social situations in which the embodied human mind is embedded (Glenberg, 1997). As recent studies have also shown that audio-visual mirror neurons respond to the effects of hearing action-related words or sentences (Buccino et. al., 2005), learning language stimulates the activity of the motor system by activating the fronto-parietal motor circuits (Tettamanti et. al., 2005), which illustrates an important role of language in embodied cognition. Since the audio-visual mirror neurons also encode actions independently of whether or not the actions are performed or observed (Kohler, 2002, pg. 846), the human brain is pre-wired for both engaging in and understanding actions, along with imitating others. Similarly, language comprehension provides a more direct interaction with the physical and social environment (Glenberg, 1997, pg. 2), for language comprehension invokes the use of embodied representations for possible patterns of action within the environment (Glenberg, 1997, pg. 18).

Since we come to understand language by creating embodied conceptualizations of the social and physical situations that language describes (Glenberg, 1997, pg. 19), the integration of representations between both language and the environment are understood as embodied patterns of action. Further support for the strength of the MNS approach to embodied linguistic cognition therefore stems from the development and acquisition of language, as language plays a pivotal role in activating the motor system within both the brain and the body, in addition to forging a direct connection between the social and natural world in which the embodied mind is situated. Moreover, if language activates the motor system for coordinating action movement and representation through a linguistic modality alone, this has important phenomenological implications for the proposed role of embodied simulation mechanisms in the MNS for language processing. The fact that listening to action-related words or sentences can activate the mirror neurons within the motor system therefore illustrates an adaptive role that language has also played in the evolution of embodied cognition, as language provides a mechanism for understanding bodily movement as embodied patterns of action (Glenberg, 1997, pg. 19), that are connected to the environment. Recent evidence gathered in cross-cultural language acquisition studies reveals that the necessary and partially constitutive role of embodiment in cognition is being shaped not only by neurophysiology, but also by the particular socio-cultural practices that accompany language acquisition (Rohrer, 2007).

A.2 Effects of Action-Related Sounds, Words and Sentences on the MNS

Recent studies with electroencephalography (EEG) and the MNS have confirmed the role of the MNS in action understanding via both action-related sounds and action-related words or sentences, which has significant implications for our understanding of the process of listening to action-related sounds and words that modulate the activity of mirror neurons in the motor cortex. For example, several research groups have shown that the suppression of EEG oscillations in the mu frequency (8-13Hz) over the prefrontal cortex is correlated with mirror neuron activity (Oberman et. al., 2006; Oberman et. al., 2005; Pineda, 2004). Although such studies have involved the EEG evidence for the action observation-execution mechanism within the MNS, which has recently been verified in children (Lepage and Theoret, 2006), the human MNS is now also thought to be involved in higher order cognitive processes such as language development. Similarly, action-related sounds that are produced by both hand and mouth movements also activate pre-motor areas in humans (Gazzola et. al., 2006), which provides impressive evidence for an auditory mirror system in humans for action understanding. Action coding can thus be represented at an abstract level, which can be accessed through auditory stimulation.

In fact, it is well known that listening to action-related words and sentences activates fronto-parietal motor circuits within the MNS (Tettamanti et. al., 2005; Buccino et. al., 2005), which has now encouraged studies of the auditory properties of the human mirror neuron system (D'Ausilio, 2007). Furthermore, it has been suggested that the mirror neurons in the premotor cortex may be involved in language processing (Hauk and Pulvermuller, 2004), as the processing of action related-words referring to leg, arm and face movements (eg. to kick, to pick, to lick) leads to distinct patterns of neurophysiological activity that can be recorded with EEG methods, which signifies the auditory response of the MNS to action-related words or verbs. Studies with the somatotopic auditory MNS in humans are also illuminating that there is a link between the motor MNS and empathy, given that individuals who scored higher on an empathy scale activated the auditory MNS more strongly (Gazzola et al., 2006, pg. 5055). Given that any account of human intersubjectivity cannot be complete without an understanding of language, such results with the MNS and action-related words and sentences have suggested that our understanding of language must rely on what I will call *the embodiment-based theory of language for action understanding and coding.*

A.3 The Embodiment-Based Theory of Language for Action Understanding and Coding

According to the embodiment-based theory of language for action understanding and coding, as applied to action-related sentences, the neural structures involved in action execution should also play a role in understanding the semantic content of the same actions (Gallese et al., 2006, pg. 138; Buccino et al., 2005, pg. 356). This has important implications for understanding the actions and intentions of others, given that a prediction of the embodiment theory of language is that when individuals listen to action-related sentences, their MNS is modulated as if they were performing the same action, or observing it being performed by another person. This strongly suggests the role of embodied simulation mechanisms within the MNS for language processing (Gallese, 2007; Gallese, 2009), which will be discussed shortly. Thus the neural structures within the MNS that preside over action execution and observation also respond to action-related sentences, as if an individual is performing the actions described in the sentences themselves.

A.4 Merleau-Ponty's Theory of the Role of Gesture and Body Movement in Language

Given the close connection between action recognition and understanding via language and the MNS, and its implications for language processing within the motor system, it is not surprising that the MNS is now thought to also play a pivotal role in complex action learning, including both gestures and articulation of speech. For example, several cognitive scientists believe that the observation/execution mechanism in the MNS is an ideal candidate for the hypothesized evolution of language from an earlier gestural communication system (Rizzolatti and Arbib, 1998). This notion seems very coherent with Merleau-Ponty's theory of gesture and body movement in language, for he asserts that language accomplishes thought, and gesture assists in that accomplishment as a part of language itself (Gallagher, 2006, pg. 121). If gesture were involved in the origin of language, then spoken language would gradually emerge from embodied movement, or as Merleau-Ponty puts it, "The body converts motor essence into vocal form through language," (Gallagher, 2006, pg. 107). As such, the description by Merleau-Ponty of what it means to understand an action is that, "The sense of gesture is not given, but understood, that is recaptured by an act of the spectator's part," (Gallese et al., 2004, pg. 397), which aptly expresses the direct experiential understanding of observed actions via the MNS. Furthermore, recent studies using transcranial magnetic stimulation have demonstrated a close link between action words and motor programs that suggests an evolutionary link between hand gestures and language, along with a role in speech perception for the motor system underlying speech production (Devlin and Watkins, 2007).

A.5 Connection Between Speech and Action Representation- Broca's Area

The discovery of the MNS suggests a strong link between speech and action representation (Rizzolatti and Arbib, 1998), and Broca's area, which is a region in the brain that was originally considering to be devoted only to speech production, also contains a representation of the hand (Rizzolatti et al., 2001, pg. 664). Brain imaging studies have shown that during the observation of hand/arm actions, there is an activation of the ventral premotor cortex that is centered to in Broca's area (Buccino et al., 2001), which is quite significant given that it implies that Broca's area is a goal-oriented area involved in the representation of hand and arm action goals. Several cognitive scientists and neuroscientists now think that the discovery of a representation of the hand in Broca's area provides evidence for an evolutionary link between the origin of language and the comprehension of hand actions, an idea that closely resembles Merleau-Ponty's thesis that gesture accomplishes thought as language. Thus, I would now like to briefly discuss the neurophenomenological implications of the embodiment-based theory of language for action understanding and coding for the mind-body problem, in light of the evidence for the modulation of the motor cortex by action-related words and sentences.

A.6 The Embodiment-Based Theory of Language for Action Understanding and Coding, and its Implications for the Mind-Body Problem

Studies using transcranial magnetic stimulation (TMS) have also demonstrated that listening to action-related sentences can modulate the activity of the motor system through the audio-visual mirror neurons (Buccino et. al., 2005), by illustrating that motor evoked potentials (MEPs) from the hand and foot muscles are modulated by listening to sentences that describe hand and foot related actions. For example, one of the predictions of the embodiment theory of language understanding is that when individuals listen to action-related sentences, their MNS is modulated in such a way that it should influence the excitability of the primary motor cortex, and therefore the production of the movements it controls (Gallese et al., 2006a, pg. 139).

The results of this study by Buccino et al. (2005) have provided good evidence for an embodiment-based theory of language for action understanding, given that the results showed that MEPs recorded from the hand muscles were modulated by listening to hand action-related sentences (Buccino et al., 2005, pg. 360). MEPs recorded from the foot muscles were also specifically modulated in this study, by listening to foot action-related sentences. Given that the language processing of action-related sentences in the brain modulates the motor system, and in particular the parts of the body that are represented in sentences that express motor content, this strongly suggests that embodied simulation mechanisms in the MNS are playing an important role in language processing (Gallese, 2009; Gallese, 2007). Moreover, because the recordings of MEPs occurred while listening to action-related sentences that expressed both hand and foot movements, the parts of the body that were represented in the action-related sentences responded as if they were actually performing the actions in the sentences. Hence, the processing of action-related language modulates the motor system, for the MNS responds to action-related sentences as if it is performing the actions described in the sentences themselves.

A.7 Husserl's Phenomenology of Linguistic Meaning: Embodied Semantics

Husserl's phenomenology of language and linguistic meaning can also provide more support for the embodiment-based theory of language for action understanding and coding. For example, Husserl asserts that the essence of linguistic meaning is sense-giving acts of linguistic intentionality (Robert Hanna, 03/12/08, Phil 4040 lecture), where this linguistic intentionality expresses the semantic essence of what is shared among speakers. Husserl's theory that, the semantic and linguistic intentionality of an individual act is what is shared through language, and that it is the semantic essence of language, strongly resembles the embodiment-based theory of language for action understanding and coding in the MNS, for understanding the semantic content of actions that are verbally described. As the sense-giving act of linguistic intentionality is the essence of language, according to Husserl, the ability to communicate linguistic intention through linguistic phrases describing actions also reflects embodied patterns of action in the world (Glenberg, 1997). The thesis of embodied semantics, in the audio-visual MNS, thus claims that the conceptual embodied representations that are accessed during linguistic processing are equivalent to the sensory-motor representations, which are required for the enactment of the action described (Aziz-Zadeh et al., 2006). The thesis of embodied semantics receives additional support from the fact that according to the neural exploitation hypothesis, language is linked to the experiential domain of action given that neural mechanisms that are involved in thought and language comprehension adapted from mechanisms in the MNS, which were originally evolved for sensorimotor integration (Gallese, 2008).

A.8 Embodied Simulation Mechanisms in the MNS for Language Processing

Because the embodied representations that are accessed during language processing are equivalent to the sensory-motor representations that are required for enacting the actions described (Aziz-

Zadeh et al., 2006), within action-related language, the neural exploitation hypothesis supports the view that language is built upon the basis of action. Given that evolution tends to be conservative, and that our brains evolved to coordinate action or bodily movement and sensorimotor knowledge within the environment, we can expect that other systems, such as language and emotion, be built upon the neural basis of action. As such, language seems to be such a system that language comprehension itself involves the simulation of action, by calling upon the neural systems otherwise used for perception, action, and emotional processing (Glenberg, 2008, pg. 43). We should expect then that the neural systems in the MNS that evolved to control action, and systems that feed into the control of action such as perception and emotional systems, will also be used during language processing and comprehension (Glenberg, 2008, pgs. 46-7), which is the idea of neural exploitation by language of action, perception, and emotional systems. In fact, recently Glenberg and colleagues provided some evidence for the simulation of emotions in sentence comprehension (Glenberg, 2008).

Motivation for this project came from the hypothesis that if the comprehension of sentences with emotional meaning requires the partial reenactment of emotional bodily states, then the simulation of congruent or incongruent emotions should either facilitate or inhibit language comprehension (Winkielman et al., 2008, pg. 281). Participants were required to judge whether the sentences described a pleasant or unpleasant event, while holding a pen between their teeth to induce smiling, or between their lips in order to induce frowning. Researchers found that the reading times for understanding sentences describing pleasant events were faster when participants were smiling than when they were frowning (Winkielman et al., 2008, pg. 281). Similarly, those sentences that described unpleasant events were understood faster when participants were frowning, compared to when they were smiling. The contribution of language to the role of embodiment in human cognition may thus be viewed as a rich store of sensorimotor regularities in the real world, and our representations of the social world are fundamentally connected with the actions that our bodies perform, so that these actions inform our concepts, language, and thinking (Semin and Smith, 2008, pgs. 2-3).

Given that the Broca's area, which is a frontal area for speech production, is almost constantly activated by action observation, recent findings with the MNS already suggest a possible evolutionary link between action understanding and verbal communication or language. Language connects all possible actions within a network expanding the meaning of individual situated experiences (Gallese, 2009, pg. 175). The action-related account of language proposed by neurophenomenology and its intersubjective framing suggest that the neuroscientific investigation of what language is and how it works should begin from the domain of action (Gallese, 2009, pg. 176). The MNS provides a matching mechanism for action understanding and recognition, including the ability to experience the emotions, sensations and intentions of others through embodied simulation mechanisms, which is also a very good candidate for grounding the social nature of language. Similarly, accumulating evidence shows that humans, when processing language by means of embodied simulation activate the motor system at several of the levels traditionally describing language (Gallese, 2009, pg. 176).

Two of the levels are most important for this discussion include embodied simulation at the vehicle level, that pertains to the phono-articulatory aspects of language, and the second level is defined as embodied simulation at the content level, which concerns the semantic content of a word, verb, or proposition (Gallese, 2009, pg. 176; Gallese, 2007). This is a significant aspect of the MNS that helps to illuminate the connections that can be made between both Husserl's phenomenology of language and linguistic meaning and cognitive neuroscience, especially since the MNS can access action content through sentences describing actions (Tettamanti et al., 2005). Because listening to action-related sentences modulates the motor system in the same way as observing actions or performing actions, researchers are now exploring the role of the MNS in the premotor cortex in language processing (Hauk and Pulvermuller, 2004), along with the hypothesis that the meaning of action-related words are represented in the sensory-motor cortices. Support for embodied simulation in language processing also follows from studies involving recordings of MEPs that I previously discussed, which occur while listening to action-related sentences that express hand and foot movements, for parts of the body that are represented in the action-related sentences respond as if they are actually performing the actions described in the sentences (Tettamanti et al., 2005).

Further studies that shed-light on the embodied simulation mechanisms for language processing in the MNS also appear to illuminate the role of motor simulation at the content level for both language comprehension and processing. For example, Hauk et al. (2004) used functional magnetic resonance imagery (fMRI) to record brain activity while people listened to verbs. When listening to verbs referring to leg actions, regions of the motor cortex that control the leg were particularly active, and likewise, when listening to verbs referring to hand actions, regions of the motor cortex that control the hand were particularly active (Glenberg, 2008, pg. 47). Similarly, Tettamanti et al. (2005) tracked areas of activation while people listened to sentences using verbs requiring mouth actions, such as "I eat an apple," hand actions "I grasp the knife," and leg actions, "I kick the ball" (Glenberg, 2008, pg. 47). As predicted by the role of embodied simulation mechanisms in language processing, and specifically the mechanisms of motor simulation at the content level, these sentences selectively activated areas of the brain associated with mouth, hand and leg actions, respectively. Embodied views have provided evidence showing that concepts and words are grounded in sensorimotor processes within our bodily states. During language comprehension, we make use of the same neural systems used for perception, action and emotion. This means that embodied motor simulation at the content level involves the brain regions that are associated with controlling the specific actions described in action-words, whereas embodied motor simulation at the vehicle level directly involves the motor-response of the body parts involved in the actions being verbally described (Gallese, 2007, pg., 663).