MIRROR NEURON FUNCTION: AN EXAMINATION OF DIFFERENCES
RELEVANT TO EMPATHY AND AUTISM

HONORS THESIS

Presented to the Honors Committee of
Texas State University
in Partial Fulfillment
of the Requirements

for Graduation in the Honors College

by

Erin Celeste Timperlake

San Marcos, Texas
May 2014
MIRROR NEURON FUNCTION: AN EXAMINATION OF DIFFERENCES

RELEVANT TO EMPATHY AND AUTISM

Thesis Supervisor:

________________________________
Crystal D. Oberle, Ph.D.
Department of Psychology

Approved:

________________________________
Heather C. Galloway, Ph.D.
Dean, Honors College
FAIR USE AND AUTHOR’S PERMISSION STATEMENT

Fair Use

This work is protected by the Copyright Laws of the United States (Public Law 94-553, section 107). Consistent with fair use as defined in the Copyright Laws, brief quotations from this material are allowed with proper acknowledgment. Use of this material for financial gain without the author’s express written permission is not allowed.

Duplication Permission

As the copyright holder of this work I, Erin Celeste Timperlake, authorize duplication of this work, in whole or in part, for educational or scholarly purposes only.
ACKNOWLEDGEMENTS

I would like to express my very great appreciation to my thesis supervisor, Dr. Crystal Oberle, for her guidance and encouragement in completing this project. I would also like to thank Professors John Hood and Diann McCabe for their help and support in the development of this topic. My grateful thanks are also extended to Dr. Heather Galloway and the Texas State University Honors College. Special thanks should be given to Genelle Sanders for her valuable and constructive suggestions and keen proofreading skills. I would also like to take this moment to thank my college sponsors, Dr. and Mrs. Roger Timperlake, who have provided me with endless support and wisdom throughout my lifetime. Lastly, I would like to thank my roommates and friends, Amanda Dorta and Sarah Miller, for tolerating my obscure sleep schedule and interest in this subject. I promise we can find something else to talk about now.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vi</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Background on Mirror Neurons</td>
<td>1</td>
</tr>
<tr>
<td>Previously Proposed Relationships to Empathy and Autism</td>
<td>3</td>
</tr>
<tr>
<td>Purpose and Significance of the Study</td>
<td>4</td>
</tr>
<tr>
<td>II. LITERATURE REVIEW</td>
<td>6</td>
</tr>
<tr>
<td>Mirror Neurons and Behavior</td>
<td>6</td>
</tr>
<tr>
<td>Mirror Neurons and Empathy</td>
<td>7</td>
</tr>
<tr>
<td>Sex Differences in Empathy</td>
<td>12</td>
</tr>
<tr>
<td>Autism and Mirror Neuron Dysfunction</td>
<td>14</td>
</tr>
<tr>
<td>Sex Differences in Autism</td>
<td>16</td>
</tr>
<tr>
<td>III. DISCUSSION</td>
<td>19</td>
</tr>
<tr>
<td>Discussion of Past Research</td>
<td>19</td>
</tr>
<tr>
<td>Implications and Applications</td>
<td>20</td>
</tr>
<tr>
<td>Future Research</td>
<td>21</td>
</tr>
<tr>
<td>Conclusion</td>
<td>22</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>23</td>
</tr>
</tbody>
</table>
ABSTRACT

This thesis presents a comprehensive review of past research to investigate whether evidence supports that the mirror neuron system of the brain is the physiological mechanism behind our ability to empathize with others. Regarding sex differences in empathy, females are regarded to be more empathetic than male counterparts. Research indicates females frequently score higher on empathy quotients, social sensitivity, and emotion recognition than males, and these behavioral differences correspond to changes in the mirror neuron system. Regarding autism and empathy, research indicates individuals diagnosed with autism have markedly diminished levels of empathy, and possible dysfunction of the mirror neuron system. Sex differences in mirror neuron function may further be related to the greater prevalence of these disorders in males than females.

Key words: Mirror neurons, empathy, autism, sex differences
I. INTRODUCTION

Background on Mirror Neurons

Mirror neurons were discovered in the early 1990s at the University of Parma while researchers were investigating macaque monkeys’ action performance (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Electrodes implanted in the F5 pre-motor cortex of the monkeys’ brains revealed an interesting reaction from the neurons. It was observed that the same neuron fired both when performing an action as well as when that same action was observed. The neurons were believed to be a part of the brain’s motor system and correlated with specific goals rather than specific actions. The discovery of these mirror neurons has altered the way psychologists believe humans interact with others.

Mirror neuron activation in response to observed action is more than just motor preparation, but also understanding. The activation of the mirror neurons in observation is representative of an individual’s mental processing as a formation of an image of the action (Rizzolatti et al., 1996). This mental image formed in observation will later be used when planning or preparing for the action (Rizzolatti et al., 1996). In the observer, the meaning of the observed action does not result from the emotion it evokes, but by matching of the observed action with the motor activity that occurs when the observer performs the same action (Rizzolatti et al., 1996).
The evidence that distinguishes mirror neurons from pre-motor neurons that fire in advance of movement execution comes from further study by Rizzolatti and colleagues (1996). Using electroencephalography (EEG) measures of macaques’ motor processes, activation of mirror neurons was observed in response to observation of an action. However, this activation of the neurons was not followed by the action for which the monkey had mentally prepared. The monkey observing another monkey grabbing for food does not move his fingers. Another important aspect is that activation ceases when the food is made available to him. Whereas, if these neurons were related to pre-motor neurons then activation would have increased in response to preparation of movement execution, not decreased. This supports the idea that mirror neurons are involved in more than just motor preparation, but also awareness of another’s perception in performing an action.

Although humans were presumed to have a mirror neuron system (MNS), for many years, it was difficult to find conclusive evidence. The invasive measure of single-cell recordings, used to directly study neurons, has been avoided. Since mirror neurons could not be directly recorded, mu rhythm suppression has been utilized in studies. Mu rhythm is the EEG measurement of the pattern of oscillating electrical frequencies (Braadbaart, Williams, & Waiter, 2013; Cuevas, Cannon, Yoo, & Fox, 2014). Motor neurons are normally suppressed by input through action observation or movement execution, which is why it is used indirectly to measure mirror neuron function (Braadbaart et al., 2013).

Studies using mu rhythm suppression in relation to MNS function were met with skepticism since evidence of mirror neurons in humans was lacking. Multiple studies
determined that suppression of mu rhythm did indicate an activation of the MNS (Braadbaart et al., 2013; Oberman et al., 2013). However, concrete proof of the existence of the MNS in humans could not be provided until single cell recordings could be conducted.

With the development of new techniques to placate symptoms of epilepsy, opportunities to conduct single-cell recordings of mirror neurons in humans have become possible. Research conducted at the UCLA Medical Center on patients with intractable epilepsy attempted to identify seizure foci in the brain using intracranial depth electrodes implanted in the brain (Wheeler, 2013). Electrodes were implanted with the intent to develop a surgical treatment; however, their use provided neuroscientists with the opportunity to directly observe mirror neurons in humans (Wheeler, 2013). This study provided a unique chance to demonstrate the existence of the MNS.

UCLA’s single-cell recording study provided direct electrophysiological evidence for the existence of mirror neurons in the human brain (Keysers & Gazzola, 2010). Results confirmed these neurons are located in areas of the brain associated with the MNS, the ventral pre-motor cortex and inferior parietal lobe, as well as extending beyond into other areas of the brain (Keysers & Gazzola, 2010). Establishing evidence of mirror neurons in the human brain further spurred research towards understanding the function of these neurons. However, additional research still needs to be conducted to fully understand the presence of the MNS in the human brain.

**Previously Proposed Relationships to Empathy and Autism**

When Giacomo Rizzolatti and his colleagues first discovered mirror neurons at the University of Parma, they believed these neurons had the potential to explain how and
why we empathize with others (di Pellegrino et al., 1992; Rizzolatti et al., 1996; Winerman, 2005). According to these researchers, observing a particular action and performing the same action invokes the same activation in these neurons. This may explain why we flinch when we see another individual trip or cry when watching a sad movie. Mirror neurons are implicated in the study of empathy for this reason.

Other researchers proposed that a defect in the MNS of individuals with autism or autism spectrum disorder (ASD) could explain their difficulty in translating action observation to action understanding (i.e., interpreting the actions and intentions of others) and their diminished empathizing ability (Gallese, Rochat, & Berchio, 2013; Hamilton, 2013). Individuals diagnosed with ASD, more commonly found in males than females with a ratio of 5:1, share three similar impairments: social interaction, verbal communication, and non-verbal communication (Baio, 2013; Gallese et al., 2013). These communicative and social deficits encompass a lack of a "theory of mind" whereby individuals with ASD frequently misunderstand others’ perspective.

Relevant to the MNS, research reveals that mirror neuron therapy (introducing people to various stimuli to activate the MNS) has resulted in improvement of comprehension of the intentions and actions of others (McGarry & Russo, 2011). Examination of the successes and failures of these therapies could identify the function of these neurons and further our understanding of the role they play.

**Purpose and Significance of the Study**

This thesis presents a comprehensive review of previous research to investigate whether the MNS is responsible for the process of empathizing with others. Much of research concerns sex differences in MNS function and the corresponding sex differences
in empathetic ability. Prevalence of ASD, which is associated with diminished empathetic ability, is also studied.

Although mirror neurons have recently been discovered, there is an abundance of research examining the function and process of these neurons. What we know about them is rapidly increasing and the sooner we identify their role, the more we understand motor learning and empathy, as well as organic causes and symptoms of ASD. Understanding the relationship between mirror neuron function and sex will further current knowledge of ASD, as well as sex differences in empathizing with others.
II. LITERATURE REVIEW

Mirror Neurons and Behavior

The relevance of mirror neurons is far reaching, with numerous studies examining their role in motor learning, communication, and empathy. The most palpable role that the neurons play is their role in motor learning. If mirror neurons comprise the neurophysiological center transforming visual information into motor commands, then they would indeed play a significant role in observational learning (Lago-Rodriguez, Lopez-Alonso, & Fernández-del-Olmo; 2013). Observational learning has proven to improve an observer’s efficiency in execution strategy and yields better performance than physical practice alone (Al-Abood, Davids, & Bennett, 2001; Buchanan & Dean, 2010). Observational learning incorporates imitation, which is an important development technique in children, and mirror neurons are proposed as the mechanism behind this method of motor learning (Braadbaart et al., 2013).

Related to motor learning, there is existing research supporting the idea that mirror neurons are responsible for action identification and social learning (Burgess, Arnold, Fitzgibbon, Fitzgerald, & Enticott, 2013). Studies have shown a positive correlation between empathy self-report and MNS activation, as well as observations of impaired imitation and empathy in ASD (Baird, Scheffer, & Wilson, 2011; Hunter, Hurley, & Taber, 2013).
Mirror Neurons and Empathy

Empathy allows us to relate to others and our environment. If mirror neurons are the mechanics behind this function, then they are essentially the key to what makes us who we are by defining our interactions with others. While some psychologists support this idea, it is still highly debated. Since the discovery of mirror neurons in humans, research in the field of cognitive empathy has exploded. However, it is difficult to draw supported conclusions with the little amount of understanding we have. Several theories have been presented to explain the function and role of the MNS in humans.

The first individual to bring the idea of empathy to light was Theodore Lipps in 1903 (Montag, Gallinat, & Heinz, 2008). Empathy was perceived as how we recognize the mental states of other people (Montag et al., 2008). Although the idea has evolved over time, empathy is still defined as “the experience of understanding another person’s condition from their perspective” (“Psychology Today,” 2013). In today’s field, there are three different forms of empathy: cognitive empathy, motor (sensory) empathy, and affective (emotional) empathy.

Cognitive empathy is known as the ability to recognize and attribute mental states to others (Edele, Dziobek, & Keller, 2013). It can be defined as the ability to recognize others intentions during their actions. Experiencing emotional states of others can lead to an understanding of reasons for action, leading to identification of the behavior intentions (Corradini & Antonietti, 2013). This form of empathy is based on our ability to (a) process the actions of others through observation of their behavior and facial expressions and (b) assign an emotional state in order to determine their intention. Cognitive empathy
is used in conversing with others. By observing facial expressions and posture, it is possible to interpret another’s interest in the topic.

Motor, or sensory, empathy is the phenomenon of experiencing similar sensory input as the individual experiencing the stimulus firsthand (Loggia, Mogil, & Bushnell, 2008). This is the form of empathy behind experiencing sensory pain when observing an individual who is experiencing a type of pain. A matching sensory experience is suggested to be the response of activation of the MNS during observation, as well as during the immediate experience of the pain (Avenanti, Bueti, Galati, & Aglioti, 2005; Hutchison, Davis, Lozano, Tasker, & Dostrovsky, 1999). This explains why we may cringe when observing an individual trip or stub their toe.

Affective, or emotional, empathy is known as “the experience of feelings congruent with another’s emotional situation” (Edele et al., 2013). This experience is also referred to as emotional contagion, when you feel physically along with the other person as if their emotions are contagious. An example of this would be crying in response to a scene of a movie in which the character is sad or crying. Emotional empathy is a connection between individuals resulting in a genuine concern for the other’s well being.

Understanding how these different forms of empathy function could potentially illuminate the role of the MNS in the process of empathizing with others. The MNS is the proposed biological center for humans’ use of empathy during interactions with others. Evidence for this idea comes from (a) behavioral studies that examined the link between imitation and empathy, (b) function neuroimaging studies that reveal a positive correlation between mirror neuron activation and self-reported empathy scores, and (c)
observations of impaired imitation and empathy in individuals with ASD. These studies provide insight into how activation of the MNS is expressed in human behavior.

The MNS seems to respond to observation of others' actions and processes the visual information into identifiable goals by establishing a relationship between the action and corresponding intentions (Corradini & Antonietti, 2013). This function can be applied to both cognitive and affective empathy. Facial expression is a commonly used communication technique allowing us to nonverbally express our thoughts and emotions. An individual with a functioning MNS would be capable of identifying facial cues and ascribing a specific intention or emotion to each expression.

Emotionally expressive facial expressions demand subtle shifts in expression, which is why they are often used as a stimulus of imaging studies of mirror neurons to identify the role of these neurons in social cognition (Corradini & Antonietti, 2013). A study conducted using preadolescent participants supported the idea that the MNS is linked to both the subjective experience of emotion as well as the identification of the same emotion in other individuals (Pfeiffer, Iacoboni, Mazziotta, & Dapretto, 2008). Functional MRI results revealed that activation of the MNS in subjects during observation and imitation of facial expressions was positively correlated with the level of empathetic skill (Pfeiffer et al., 2008). This supports the idea that the MNS is involved in everyday social functions.

Empathy is part of a group of related processes, including imitation. Imitation is an observational learning technique that has been linked to function of the MNS. A study examining imitation of facial expressions revealed a correlation between imitation accuracy and empathetic ability (Braadbaart, de Grauw, Perrett, Waiter, & Williams,
Effective imitation of emotion in another's facial expression requires the observer to have a previous understanding of the relationship between the emotional state behind the expression as well as the motor plan for producing the expression (Braadbaart et al., 2014; Carpenter, 2006).

Instances in which individuals lose the ability to imitate others provide further support for a link between observation and perception in emotional recognition. Emotion recognition was examined in individuals prevented from imitating muscle contraction in facial expressions (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). Participants’ accuracy in identifying the expressed emotion was significantly diminished. Further support comes from individuals with Moebius syndrome in which the ability to move facial muscles is hindered (Cole, 2001). Individuals with this syndrome were unable to recognize the emotions expressed by others.

Considering the different types of empathy, mirror neurons may serve as the unifying framework. Neuroimaging studies support this concept, revealing that in different neural regions of the brain, pathways activate independently depending on the type of empathy being observed (Bien, Roebroeck, Goebel, & Sack, 2009; Shamay-Tsoory, Aharon-Peretz, & Perry, 2008). Correlations have also been found between grey matter in these mirror neuron areas and empathetic behavior (Cheng, Tzeng, Decety, Imada, & Hsieh, 2006). A positive correlation was discovered between grey matter volume and empathetic traits, which suggests that the MNS is involved in development of empathetic traits (Cheng et al., 2009).

Chartrand and Bargh (1999) conducted a study observing unconscious motor mimicry action, which they called the “chameleon effect.” Chartrand and Bargh observed
individuals’ tendency to automatically become engaged in behavior observed previously in another. They considered this reaction to be a “perception-behavior” link. These mimicked behaviors included actions as shaking one's foot and facial expressions such as smiling. They considered this effect to be a passive and cognitive process requiring very little association with an affective or an emotional state. They discovered a higher frequency of motor imitation in individuals with higher cognitive empathy scores. Their findings provide evidence for a link between observation and perception in regard to empathy.

Further evidence for the MNS’s role in the different types of empathy comes from imaging studies of motor empathy’s involvement with pain and disgust. Functional MRI results revealed that the processing of one’s own emotional experience and the observation of another individual undergoing a similar experience may engage overlapping neural matter (Singer et al., 2004; Wicker et al., 2003) The results also showed the relative activation of these neural networks correlated with participants' individual differences in empathic abilities (Singer et al., 2004). These studies provide evidence that the relationship between observation and perception involves empathy.

Discovering the neural networks for empathy is important to the field of mirror neuron research and has supported the idea that the MNS is involved in the empathy process. There is still limited knowledge of mirror neurons ascribing an emotional or mental state to another individual. A fMRI study attempted to identify the differential neural networks involved in “self” and “other” related attribution of emotional states (Schulte-Rüther, Markowitsch, Fink, & Piefke, 2007). The researchers of the study discovered attribution of emotion either to a facial expression or to the self activates brain
areas involved in emotional processing, as well as the MNS. Their study indicated that mirror neuron mechanisms attribution of emotions in the self in the process of empathetic intrapersonal cognition. These results provide support of the MNS’s involvement in social cognition, including detection and identification of intent, emotional states, or empathy. The MNS’s function in emotional social interactions substantiates the neural origin of the observer’s resonance of the emotional state of another individual.

The current understanding of the MNS suggests that it is broadly involved in the empathy process. The future for MNS research is to identify its role in the forms of empathy, including motor, emotional, and cognitive empathy. Further research needs to be conducted in order to identify the function of the processes involved with MNS and empathy.

**Sex Differences in Empathy**

Culturally, it is a common belief that women are the more empathetic and emotional of the sexes, and behavioral research supports this belief. Women’s interactions tend to be more intimate than men’s, despite equal levels of motivation for empathy in both sexes (Clark & Reis, 1988). Secondly, considerable research on cognition has revealed that women tend to be superior in verbal and social abilities (Halpern, 2000; Wakabayashi, Sasaki, & Ogawa; 2012). Women consistently demonstrate greater accuracy in identifying and interpreting non-verbal cues than the opposite sex (Hall, 1978). Finally, support for the belief that women are the more empathetic sex was largely based on self-report data on empathy quotients, which may have resulted in a bias due to the culturally supported idea that women were more
sensitive to emotions (Groen, Wijers, Tucha, & Althaus, 2013). Imaging techniques a
onbiased support to research sex differences in empathetic abilities.

Recent neuroimaging studies, which remove the aforementioned bias, have only
begun to illuminate sex differences in empathetic ability and their underlying neural
mechanisms. Currently, the research focuses on sex differences in cognitive empathy,
including identification, inference, and imagination of the observer's feeling while
observing expressions of another individual (Schulte-Rüther, Markowitsch, Shah, Fink,
& Piefke, 2008). An imaging study required male and female participants to indicate the
extent of their emotional response to images exhibiting pain and suffering, in different
contexts, compared to emotionally neutral images of scenes and landscapes (Mercadillo,
Diaz, Pasaye, & Barrios, 2011). The results of this study revealed that females had more
activation in the brain regions related to cognitive empathy than their male counterparts.

As information of mirror neurons has increased, researchers have become better at
designing studies that identify and isolate mirror neuron activation providing better
insight into sex differences. Research examining sex differences in mirror neurons
reveals significant differences between the sexes; females showed significantly more
suppression of mu rhythm than male participants (Cheng, Tzeng, Decety, Imada, &
Hsieh, 2006). A similar study revealed both males and females exhibited activation
related to pain empathy, but females showed greater mu suppression for pain empathy, as
well as in non-pain simulations (Yang, Decety, Lee, Chen, & Cheng, 2008). This finding
supports the existence of sex difference in MNS activation.

A recent event-related potential (ERP) study examined sex differences in brain
activation to congruent and incongruent actions and attempted to isolate attention bias by
adding a second task. The secondary task separated selective attention from the action-processing task, which was automatic rather than guided by subjective evaluation (Proverbio, Riva, & Zani, 2010). Females showed a significantly greater response in the neural areas of the cortex associated with mirror neurons when viewing congruent actions. The results of this study suggest that action-processing differs between males and females. This data provides evidence that there exists a sex difference within the action-processing center of the brain, the MNS.

In order to determine the function of the mirror neurons in the human brain, it is important to recognize how they may differ between the sexes. Clearly defining how these neurons differ could unlock the potential to understand how and why they work to connect us with others. Further evidence comes from individuals with a diminished MNS function. Individuals with autism have a dysfunction in the MNS as well as an inhibited ability to empathize with others.

**Autism and Mirror Neuron Dysfunction**

Autism or ASD is characterized by deficits in three areas: social interaction, verbal communication, and non-verbal communication (Gallese et al., 2013). Among the symptoms concerning these deficits is the diminished ability to empathize with others, and impaired ability to interpret the actions and intentions of others. However, certain characteristics remain prevalent. Exploring the connection between autism and MNS function furthers the understanding of how symptoms of ASD arise.

Currently, the neurobiology behind ASD is little understood, but recent studies suggest dysfunction of the MNS may be responsible for social-relating characteristics of the disorder (Enticott et al., 2012). The broken mirror theory of autism has been proposed
as an explanatory model for these symptoms. The broken mirror theory suggests that a
dysfunction of the MNS may result in the chief diagnostic signs of ASD, which are social
isolation, lack of eye contact, poor language capacity, and absence of empathy
(Ramachandran & Oberman, 2006). Mirror neurons have been implicated in perception
of other’s intention, interpretation of emotion, and empathy (Ramachandran & Oberman,
2006).

Evidence for the broken mirror theory comes from using imaging techniques to
compare activation in individuals with and without ASD. An electromyography (EMG)
recording study used healthy children and children with ASD as participants to examine
MNS activation during observation (Cattaneo et al., 2007). Observation of an action led
to mirrored activity in healthy participants, but this response was absent in those with
ASD. This study suggests a deficit in motor chains to understand intention.

EEG recordings have revealed disruption of mu rhythm suppression in individuals
with ASD. An early study conducted comparing individuals with ASD to a healthy
control group revealed intact mu suppression during execution (Oberman et al., 2005).
This response was absent in ASD participants during observation of action execution
(Oberman et al., 2005). Replication of this study revealed similar results and additionally
revealed a correlation between mu attenuation and imitative abilities (Bernier, Dawson,
Webb, & Murias, 2007).

Investigation into the MNS’s role in the symptoms of autism may offer an
explanation for the development of the disorder. Research suggests there are sex-
differences in the activation of mirror neurons and ASD has been linked to a dysfunction
of the MNS. Examining sex differences in ASD could further current understanding of
the MNS’s role in how symptoms of the disorder may arise. This could provide information necessary for improving the course of diagnosis and potential treatments.

**Sex Differences in Autism**

The majority of individuals diagnosed with ASD are male. The current statistics regarding male to female ratio of ASD is estimated to range from 5.5:1.4 to 16.8:4.0 (Center for Disease Control and Prevention, 2007). Examining the current evidence for sex differences in mirror neuron function could lead us to evidence of why this disorder tends to affect males more than females. Moreover, the broken mirror theory of ASD proposes that MNS dysfunction is responsible for the core social and cognitive deficits in individuals with ASD.

Sex differences in ASD symptoms are variable, but general patterns surface. Females with ASD tend to have greater communication deficits than males, who tend to experience more restricted, repetitive, and stereotyped behaviors than girls (Hartley & Sikora, 2009). Young males with ASD were found to show an increased amount of unusual motor movements and abnormal use of their body (Hartley & Sikora, 2009; Lord et al., 1982). Sex differences were most prominent in young children (Hartley & Sikora, 2009). Using IQ as a control, a study of sex differences in ASD, conducted by Lord et al. (1982), observed higher rates of restricted or repetitive behaviors, and inappropriate play in males. A similar study conducted by McLennen, Lord, and Schopler (1993) yielded the same results, but it was also observed that early adolescent males tended to display greater deficits in reciprocal social interaction and communication.

Despite the research supporting the idea that there are sex differences in ASD, there are few studies that focus on females with the disorder. The existing data suggests
that there are subtle differences between the sexes that could play a significant role in the differential way that ASD manifests itself in males and females (Hartley & Sikora, 2009).

Further research with males, however, has revealed results that support the broken mirror theory of ASD. A study of the effect of MNS activation during a perceived task revealed a dysfunction in individuals with ASD (Cattaneo et al., 2007). The study examined the normal activation of the MNS during task observation and task performance and compared it to activation in individuals with ASD. In healthy individuals, the observation of the action led to mirrored activation within the MNS, but this mirrored activation was absent in individuals with ASD. The absence of activation in individuals with ASD suggests a deficit in linking or representing motor chains for understanding intention.

Mindblindness is defined as a lack of a “theory of mind” when one understand the perspective (thoughts and feelings) of another. Having mindblindness is essentially the inability to empathize with others (Baron-Cohen, 2011). Mindblindness is frequently labeled as a symptom of ASD. Some individuals with the disorder severely lack the ability to recognize and interpret the actions of others (Baron-Cohen, 2011). Current studies involving theory of mind and ASD are attempting to provide concrete proof that mindblindness is linked to the function of the MNS. A severe dysfunction in the MNS has been observed in individuals with complete mindblindness, as well as a slight dysfunction of the MNS in individuals who have difficulty interpreting explicit actions (Baron-Cohen, 2011). This evidence supports the idea that mirror neurons play a role in how we interpret and attribute others’ emotions and actions.
The role of mirror neurons in ASD is still little understood. Researchers have only managed to scrape the surface of both the MNS and ASD. However, there is a considerable amount of evidence that supports the broken mirror theory of ASD. Continued research will hopefully lead to a better comprehension of the disorder, as well as potential for better methods of treatment and diagnosis.
III. DISCUSSION

Discussion of Past Research

Research has confirmed the presence of the MNS in the brain and has explored its role in various forms of empathy. Whether or not the MNS is the neurological basis behind the process of empathy has yet to be confirmed. Location of the MNS has found to be extensive throughout the brain and activation tends to vary according to the form of empathy being observed.

Although the link between the MNS and empathy has yet to be supported, differences between the sexes suggest its role. Females are considered to be the more empathetic sex. Correlation studies reveal a link between high self-reported empathy and stronger MNS activation. While research continues to clarify the role of the MNS and empathy, it does suggest that females tend to be the more emotionally intelligent sex. Research supports the idea that females are more efficient at interpreting and comprehending actions of others than their male counterparts.

Activation of the MNS in a wide range of action and observation of performance, such as facial expression, interpretation, and motor mimicry, strongly suggests that the MNS serves a neurological basis for action understanding. The activation of the MNS to variable degrees for a variety of actions indicates the location of the neurons may serve a
specific purpose in identification. Location of mirror neurons in the brain may account for the different types of empathy.

Studies conducted using individuals with ASD correlate the dysfunction of the MNS in individuals with the disorder. A key symptom of ASD is the diminished ability to comprehend or interpret another’s actions or intent. The correlation between the dysfunction of the MNS and diminished empathetic ability suggests that the MNS plays a significant role in empathy. Considering the significant difference in the prevalence of ASD between the sexes, as well as increased activation of MNS in females compared with males, sex differences in the MNS could potentially play a role in the development of the disorder.

**Implications and Applications**

Identifying the sex differences of the MNS could possible provide insight into the prevalence of ASD in males and its expression of symptoms between the sexes. ASD tends to express itself differently among individuals, including between the sexes. The current method of diagnosis relies on chief diagnostic signs, such as social isolation, lack of eye contact, poor language capacity, and absence of empathy. Defining how these symptoms express themselves between the sexes would lead to earlier, more efficient forms of diagnosis.

Determining the role of the MNS in empathy could possibly provide new information on how autism and its symptoms may arise. This knowledge could also provide the information necessary to improve current treatment methods of the symptoms of ASD. A current form of treatment, known as mirror neuron therapy, has had success in improving the social functioning of an individual with ASD. This form of therapy
attempts to stimulate the regions of the brain overlapping with the MNS to strengthen neural connections (Wan, Demaine, Zipse, Norton, & Schlaug, 2010). A study conducted using music as the method for activating MNS found success in this form of therapy. Individuals undergoing mirror neuron therapy were shown to have increased communication, even in non-verbal individuals with ASD, and improved motor function.

The broken mirror theory provides a possible explanation for symptoms of ASD. Evidence of the MNS’s role in action-understanding and empathy as well as evidence of a dysfunction in individuals with ASD provide the main support for this theory. This theory provides much insight into the symptoms of ASD, as well as a potential explanation for how they may arise in individuals. However, it is unlikely that MNS dysfunction alone can provide the answer for why this disorder may occur. It is necessary to continue to explore the validity of the broken mirror theory, as well as the role of the MNS in empathy and behavior.

**Future Research**

Science is far from determining the cause of ASD, but there is a growing need for more information. The estimates for children affected with autism have been increasing each survey year. It is currently estimated that one child in 68 has been identified with autism (Baio, 2014). ASD and its relationship to the function of the MNS should continue to be studied. The limitations of existing studies of MNS function often are small sample sizes. A comprehensive study should be conducted in order to better identify the sex differences in MNS function, furthering the knowledge of sex differences in empathy.

There is a lack of recent information on sex differences relating with symptoms of individuals with ASD. There are very few studies that explore the relationship between
sex differences and ASD symptoms in depth. There is a significant difference in the ratio of males and females diagnosed with the disorder, so few studies of autism represent both sexes equally. Future studies should attempt to represent both sexes. Considering females are diagnosed later than males, it is important to determine how symptoms of ASD express themselves between the genders in order to improve current standards of diagnosis.

Studies regarding the current methods of diagnosis are necessary in order to improve their efficacy. The cost of behavioral treatment can also vary between $40,000 to $60,000 per child annually (Lavelle et al., 2014). These costs could potentially be reduced if diagnosis and implementation of treatment occur earlier in children with the disorder. The total social cost for care of children with ASD was an estimated 9 billion dollars for 2011 (Lavelle et al., 2014). Considering this cost, it is necessary to increase our understanding of autism in order to improve treatment and decrease costs of care.

**Conclusion**

The knowledge we have of the relationship between mirror neuron function, empathy, and autism is far from complete. As research continues to explore the relationship between mirror neuron function and empathy, the role of the MNS in symptoms of autism will become more defined. Examination of previous research suggests sex differences in MNS function, which could be potentially be related to prevalence of autism in males. Future research regarding symptoms of autism in females needs to be conducted before the existence of this relationship can be assumed.
REFERENCES


suppression to observed and executed actions in autism spectrum disorders. Social
emotions relates to empathy and interpersonal competence in children.
NeuroImage, 39, 2076-2085.
Proverbio, A. M., Riva, F., & Zani, A. (2010). When neurons do not mirror the agent's
intentions: Sex differences in neural coding of goal-directed actions.
Neuropsychologia, 48, 1454-1463. doi:10.1016/j.neuropsychologia.2010.01.015.
A double dissociation between emotional and cognitive empathy in inferior
frontal gyrus versus ventromedial prefrontal lesions. Brain, 132, 617-627.
and theory of mind mechanisms involved in face-to-face interactions: A
functional magnetic resonance imaging approach to empathy. Journal of


