Running Head: Using Imitation to Engage Mirror Neurons to Treat Autism

An Approach to Treatment for Autism Spectrum Disorders Using the Sensory and Motor System to Simultaneously Target the Mirror Neuron System via Imitation

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September 24, 2009

Abstract

Imitation of others is thought to be a prerequisite to advanced social competencies in humans. Language acquisition, empathy, and Theory of Mind (ToM) all develop as children build a repertoire of motor movements via imitating others. The neurological substrates implicated in this behavior include the mirror neuron system (MNS). Research on children with autism (CWA) has demonstrated significant differences in imitative behavior and brain structure when compared to typically developing children. Given this information, it may prove beneficial to incorporate socially salient models and activities into treatments for autism and focus on imitation of intransitive motor tasks using peers as models. Specifically, imitation of full body actions, with simultaneous sensory input, of peers in a typical environment is discussed.

The ability to observe the actions of another and predict the outcome, as well as the intention, and emotion of the observed is a skill most humans acquire naturally. This ability is adaptive for survival in a social species – such as humans – because it allows us to work together toward a shared goal, thus increasing our chance of accomplishing the goal (Rizzolatti & Craighero, 2004). Additionally, learning is facilitated through imitation as we develop a sense of self versus others and procure the tools needed to survive in human culture (Meltzoff, 2007; Rizzolatti & Craighero, 2004). As we observe others we come to recognize how and why we might perform the same action, eventually giving us the ability to predict the intention and actions of those around us based on our own experience (Meltzoff, 2007). Presently, it is believed that the neural substrates most readily involved in this behavior are a network of neurons known as mirror neurons. However, there is much debate as to the degree of involvement, which will be discussed later. Impaired imitation in children has been linked to deficits in many areas, including the development of language, theory of mind, empathy and social cognition, which are also many of the manifestations of autism. Research examining the neurological and behavioral distinctions between children with autism and typically developing children reveals stark differences in imitative behavior as well as brain structure (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006; Williams, Waiter, Gilchrist, Perrett, Murray, & Whiten, 2006; Vivanti, Nadig, Ozonoff, & Rogers, 2008). Given this, I intend to argue that the deficits in imitation, in conjunction with the motor and sensory components of the mirror neuron system (MNS) in children with autism (CWA), crystallizes the need for a new approach to treat the core deficits of this disorder using motor imitation of a familiar model while simultaneously providing sensory input.

Mirror neurons, originally discovered by Gallese, Fadiga, Fogasse, & Rizzolatti (1996), in the ventral premotor cortex of macaque monkeys, fire when observing another monkey engaged in an action as if the observer were performing the action themselves. Since then, human mirror neuron equivalents have been found in several areas of the brain, including the posterior part of the frontal lobe and the anterior part of the inferior parietal lobule (IPL) (Iacoboni & Dapretto, 2006). Together these areas create a network that integrates motor movement with visual and somatosensory input (Iacoboni & Dapretto, 2006). More accurately, the superior temporal sulcus (STS) relays visual input to the IPL, but does not contain neurons that function as mirror neurons (Iacoboni & Dapretto, 2006). While patterns of motor neurons are indistinguishable whether a person is watching or performing an action, sensory mirror neurons, in the IPL, only fire if exposed to a goal-directed action, further implicating imitation as a learning device involving the MNS (Rizzolatti, Fabbri-Destro, & Cattaneo, 2009; Iacoboni & Dapretto, 2006). The involvement of the IPL adds the function of comprehension of the goal of an observed action, implicating the importance of salience in the imitative act (Rizzolatti, Fabbri-Destro, & Cattaneo, 2009).

Moreover, although not considered part of the MNS at this time, many scientists are exploring similar brain mechanisms that facilitate emotional mirroring between observed and observer (Gallese, Keysers, & Rizzolatti, 2004). This is the construct that binds us to each other as well as to our larger social group

(Singer, 2006). Research is expanding the known boundaries of what is directly mapped to our own brains when observing the experiences of another to include sensory stimuli as well as emotion (Gallese, Keysers, & Rizzolatti, 2004).

Interestingly, neurons in the insula and cingulate cortex are cytoarchitechtonically similar to mirror neurons in the motor cortex and have indeed been implicated in mirroring the emotions of at least pain and disgust (Rizzolatti, Fabbri-Destro, & Cattaneo, 2009; Singer, 2006). The mirroring of emotional and sensory states in typically developing children is subsequent to the ability to mentalize intention as described earlier because of the later maturation of the limbic and sensory systems (Singer, 2006). Whether defined as part of the MNS or not, dysfunction in these areas impedes the motivation to imitate, thus compromising learning. Further research may provide important information regarding the reasons that children naturally imitate.

Other functions of the MNS that have been posited include: (a) facilitation of empathy with another when past experience allows for understanding of motor movement, (b) determination of how the actions of another person relate to the self and modulation of attentional systems toward another persons behavior, (c) the fostering of joint-attention, (d) development of a repertoire of motor responses through imitative behavior, and (e) aid in the development of theory of mind (ToM) by drawing on knowledge gained through comparisons of self to others during imitative learning (Williams, et al., 2006).

Anatomical differences between neurotypical children and children with autism highlight common sense assumptions about imitative behaviors seen in

CWA. More specifically, studies have shown that CWA have thinner cortical matter in the MNS and related areas, such as the IPL and STS when compared to typically developing children (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). Furthermore, a correlation has been established between thinner cortical material and symptom severity in CWA (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). Indeed, if the foundations of social functioning, including language, ToM, and empathy are facilitated by the MNS through imitation, symptoms of autism could in part be viewed as being a result of a dysfunctional MNS (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006; Williams, 2008). While this finding is important, it should be noted that the technology used is incapable of measuring sub-cortical brain structures. Therefore, it is imprudent to assume that cortical thinning is solely responsible for symptom severity in CWA.

Other findings include diminished activity in the right parietal lobe in CWA when compared to controls during an imitation task (Williams, et al., 2006). The most significant difference in the Williams, et al., (2006) study was under activity in the parietal-temporal junction, an area associated with ToM, another skill believed to be built on the foundation of imitation.

In putting this information together one might be quick to develop an assumption that CWA do not imitate at all; such is not the case. Generally speaking, CWA do not perform as well as neurotypical children on imitation tasks (Ingersoll & Schreibman, 2006). However, upon closer examination, there are certain types of imitation with which CWA particularly struggle. One way to begin to tease this apart is to find out what CWA are attending to during observation and imitation tasks.

During tasks with a specific goal, children with high-functioning autism attend to the same visual areas as typical children. This pattern consists of a minimal amount of time looking at the face of a model and more time spent examining the action of the model (Vivanti, Nadig, Ozonoff, & Rogers, 2008). However, when the goal of the action is ambiguous, typical children spend more time looking at the face of the observed, presumably to infer the intention of the action. The result is that typical children significantly outperform their autistic counterparts in accuracy of imitating the model during ambiguous goal directed tasks (Vivanti, Nadig, Ozonoff, & Rogers, 2008).

When imitation tasks are divided into goal directed (transitive) and non-goal directed (intransitive), CWA show increased impairment with intransitive imitation tasks when compared to matched controls, while imitation of transitive tasks is impacted, but to a lesser extent (Gowen, Stanley, & Miall, 2008). This has led to the hypothesis that transitive and intransitive actions are processed by different neuronal pathways (Gowen, Stanley, & Miall, 2008). There is some discrepancy in the field regarding the neurological substrates responsible for differentiating and processing transitive and intransitive imitative tasks, but there is consensus that they should be differentiated. (For detailed discussion see Rumiati, Weiss, Tessari, Assmus, Zilles, Herzog, et al., 2005; Tessari, Canessa, Ukmar, & Rumiati, 2007; Molnar-Szakacs, Iacoboni, Koske, & Mazziotta, 2005; & Hamilton, 2008). The more accurate processing of transitive imitation tasks further illuminates the role of salience of the task to the observer during imitation tasks.

If the mirror neuron systems of CWA were indeed impaired then interference between neurons that occurs in typically developing children would not be expected to occur in CWA. A theory explaining increased reaction times when observing and producing incompatible motor actions posits an interference effect between groups of mirror neurons (Gowen, Stanley, & Miall, 2008). Previous research suggests that CWA perform goal-directed imitation closer to typical levels, but if there were indeed multiple pathways then interference during intransitive imitation tasks would be expected to produce less interference between mirror neurons. Gowen, Stanley, and Miall (2008) explored this issue and the results contradicted the expectation. CWA performed similarly to typical participants during transitive imitation, but struggled significantly more during intransitive imitation. The authors posit that CWA may rely exclusively on pathways used for transitive processing, thus accounting for the increased delay in intransitive imitation tasks. Another element included in this study was that of interpersonal interaction. Participants interacted with three sets of stimuli including a computerized dot, a dot controlled by a human, and a videotape of a human model that was the same sex as the participant. Both groups performed better when imitating stimuli involving human interaction over the computerized dot stimulus.

Functional magnetic imaging has revealed that when CWA are observing intransitive motor activities the visual processing areas of the brain are active; however, the premotor cortex remains inactive (Jackson, Meltzoff, & Decety, 2006). Usually during imitation tasks, other areas of the brain – including the contralateral somatosensory and motor areas as well as the IPL – are active as well (Jackson, Meltzoff, & Decety, 2006). Therefore, it may be that if CWA do not comprehend that the observed activity pertains to them in some way, they may process it as a passive observer, thus missing the opportunity to add skills to their motor and social repertoire. This could also shed light on the dual pathway processing of motor acts hypothesis as having more to do with not recognizing the "like me" qualities of the observed (Meltzoff, 2007, p. 126).

At first glance it would seem that using peers of CWA in lieu of adults as models may facilitate attention in CWA by engaging the "like me" qualities between observer and observed (Meltzoff, 2007, p. 126). Studies that examine using peers to model motor actions for CWA yield exciting results. Nikopoulos and Keenan (2004) used peers to model behaviors in an effort to increase initiation and reciprocal play behaviors in CWA. All participants in the study showed significant increases in the target behaviors after observing peers. Also, at one- and three-month follow up measurements, all participants had retained the new skills. While these results are exciting the size of the sample consisted of only three participants.

In school settings, the use of peer modeling has been shown to increase pro-social and imitative behavior in CWA (Garfinkle & Schwartz, 2002). Children were broken into small groups that were facilitated by an assistant to the teacher. The entire group was given an instruction to perform a motor act and then a group "leader" was selected to model the new behavior. All children imitated the leader and then were reinforced with social praise for the imitative behavior (Garfinkle & Schwartz, 2002, p. 30). Each child alternated being the leader for the group and then were allotted time to explore imitative objects in their own way. Later, children were exposed to free play time. When compared to baseline levels, CWA showed significant increases in imitative and pro-social behaviors after imitating their peers (Garfinkle & Schwartz, 2002). Similar to other peer modeling studies, the sample size is quite small, including three children diagnosed with autism and one child with documented developmental delays. However, the use of a multiple baseline design bolsters the validity of the study and should be a precursor to further research in this area. It should also be noted that this study is one of the few using *in vivo* modeling of a peer as opposed to a videotaped model.

Most research in this area incorporates the use of videotaping models, presumably in an effort to hold the independent variables constant, which is proper research protocol. However, the use of video in contrast to live models introduces a confound that may be affecting the results in these studies. I believe that more research is needed using live models in lieu of videotaped models to more accurately assess imitative behavior as it occurs naturally.

Concordantly, variation in mu rhythm in the MNS that occurs when observing the actions of another is understood as being correlated to the degree that the observer is relating to the observed (Oberman, Ramachandran, & Pineda, 2008). Simply put, the more "like me" the observed is to the observer, the higher the change in MNS brain waves in the observer (Oberman, Ramachandran, & Pineda, 2008; Meltzoff, 2007, p. 126). Evidence shows that when CWA are exposed to actions performed by strangers they have lower levels of mu rhythm changes than when observing family members or themselves (Oberman, Ramachandran, & Pineda, 2008). The impaired MNS of CWA is increasingly engaged when mirroring someone who is familiar. This supports the idea that social salience is an important factor when considering treatments for autism that focus on imitation (Oberman, Ramachandran, & Pineda, 2008).

This finding further suggests that dysfunction in the MNS and other systems may contribute to a lack of identification to others as being “like me” underscoring the impaired imitation skills seen in CWA (Oberman, Ramachandran, & Pineda, 2008; Meltzoff, 2007, p. 126). To overcome the deficits in the MNS of CWA, increased familiarity with the model of the motor movement may provide a useful tool to increase responsiveness and strengthen neural pathways used in imitation (Oberman, Ramachandran, & Pineda, 2008).

In contrast, research has shown that CWA demonstrate increased imitative behavior with adults who imitate them than with their non-imitative parents (Field, Nadel, Diego, Hernandez-Reif, Russo, Vchulek, et al., 2008). Additionally, current research reexamining data from a series of experiments in which an unfamiliar adult alternately imitated or sat motionless during interactions with a CWA found that more pro-social behaviors were exhibited towards the adult subsequent to having been imitated by the adult (Nadel, Martin, Field, Escalona, & Lundy, 2008).

Given what we know, this line of research may seem contradictory to the finding that familiarity increases MNS activity; however, it may not be. If the increase in mu rhythm change were a response to the salience of the activity rather than the agency of familiarity to the model, we would expect increased reaction when the child relates to either the actor or the activity. Moreover, we would expect to see the highest increases in brain activity and imitative behavior if both the actor and the activity are salient to the CWA. Previous research has established that CWA display increased amounts of social behavior during repeated exposures to imitative and playful adults; also naturalistic imitation interventions increase imitative behaviors (Field, Field, Sanders, & Nadel, 2001; Ingersoll & Schreibman, 2006). I believe that future research should differentiate variance due to familiarity from that due to imitating the CWA. This is an area where further study may yield important insights to treatments for autism.

We have established that the MNS is involved in the development of many needed social skills via imitation. However, we have not determined if the MNS is amenable to alteration through behavioral experience. Evidence supports the claim that the properties of the MNS are not solely innate or incapable of change, but rather alter through exposure to sensorimotor activities (Catmur, Walsh, & Heyes, 2007.) Thus, interventions targeting imitation of sensorimotor movements stand a chance of increasing functionality of the MNS as well as building the foundation of social interaction in those who are impaired in these areas.

Although it is well established that mirror neurons are involved, arguments against a MNS theory of autism elucidate the involvement and integration of many brain systems responsible for different aspects of human behavior. They articulate concern over focusing too narrowly on the MNS and in turn missing other important neural substrates that may be involved (Hamilton, Brindley, & Firth, 2007). This is a valid concern; however, it is possible that MNS dysfunction may be the underlying trigger to the abnormal development of the other brain systems involved in imitative, language, empathic, and ToM abilities (Hadjikhani, Joseph, Snyder, &

Tager-Flusberg, 2006). Other scientists have argued that the neurological studies on the MNS thus far fail to correlate the behavioral aspects of imitation, ToM, language acquisition, and empathy (Dinstein, Thomas, Behrmann, & Heeger, 2008). While it is true that no one study incorporated all of these constructs simultaneously, it is also true that these different constructs are being correlated as more information becomes available. This is a newer line of research and it is wise to temper excitement to avoid making assumptions while continuing to explore this area.

Hamilton, Brindley, & Firth (2007) argue that the deficits in CWA stem not from a generalized imitation deficit due to impairment in the MNS, but rather a lack of ToM that accounts for autistic symptoms. As described above, ToM is a skill built through acquisition of motor movements via imitation, which involves the MNS (Williams, 2006). The results found by Hamilton, Brindly, and Firth (2007) are not mutually exclusive with MNS research. Rather they add to the base of knowledge being created by the field. As a separate line of research, they do not as readily explain the complex observed phenomena.

Interventions currently exist that are designed to teach imitative behaviors to CWA and some of them have proven efficacious to some extent (Stahmer, Ingersoll, & Carter, 2003; Ingersoll & Schreibman, 2006). However, all of them use an adult instructor or therapist to directly interact with the child to teach new behaviors. I posit CWA should be put into small compatible groups in order to model behaviors of peers as opposed to adult therapists. This would capitalize on the knowledge that CWA demonstrate increased MNS activity when exposed to a stimulus that is somehow salient (Oberman, Ramachandran, & Pineda, 2008).

Ideally, these groups would function in a typical environment where exposure to the motor activities of typically developing children can be modeled as well. Within these groups, adult facilitators would work toward having the children imitate learned skills from each other. For example, a facilitator would teach one child a skill and have the others imitate the behavior. This can be done with both transitive and intransitive motor movement imitation, providing an opportunity for acquisition and mastery of both.

Using imitation of sensorimotor movement taps into the MNS, effectively strengthening neural pathways and bolstering the foundation of the MNS (Catmur, Walsh, & Heyes, 2007). Given the evidence that pathways in the MNS can change based on environmental input, exposure to an environment that will provide intense sensorimotor input, such as a gymnastics facility or a playground, may be shown to increase imitative behavior owing to the intensity and full body imitation. Research in this area may lead to important insights regarding innovative interventions for autism.

It is important to consider that if a task to be imitated consists of neither an understandable goal nor a model that can be related too in some way, CWA flounder and fundamental social learning opportunities are compromised. Providing an opportunity for CWA to learn appropriate behaviors from peers via imitation in a setting conducive to full-body motor movement and intense sensory input may be shown to ameliorate MNS dysfunction and promote fundamental social skills.

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