Running head: EMPATHY, MIRROR NEURONS, and HEART RATE

Relationship Between Empathy, Mirror Neuron Activity, and Heart Rate

Matt Novakovic, Eric Miller, Timothy Robinson
Gustavus Adolphus College
May 20, 2008

Abstract

We investigated the relationships between empathy, mirror neuron activity, and heart rate. Individuals with high empathy and low empathy were identified, and their mirror neuron activation and heart rate were measured with EEG and EMG, respectively. Participants engaged in conditions that involved watching a pendulum, static, and tapping motion, and conducting self-initiated tapping. This study provides evidence that mirror neuron activity has a marginally significant correlation to empathy and a significant correlation to the personality variables of extraversion and conscientiousness. Also, there is a non-significant but positive correlation between heart rate and empathy.

Relationship Between Empathy, Mirror Neuron Activity, and Heart Rate

Mirror neurons were discovered in the early 1990's when Giacomo Rizzolatti's research team noticed that that a class of F5 neurons in the premotor cortex fired when a monkey grasped a piece of fruit and saw someone else perform the same act (Rizzolatti, 2006). They showed that mirror neurons mediated understanding, rather than simply reflected the visual features of the objects that were observed. It has been shown that the ventral premotor cortex is involved in polymodal action processing in an execution-observation (mirror neuron) system (Binkofski, 2006). The mirror neuron system may be a precursor of language processing, and involved in the effortless understanding of other people's actions and intentions.

EEG mu suppression has been used as a non-invasive technique to measure mirror neuron activity (Altschuler, 1997). A recent study used EEG recordings in the 8-13Hz region to show that smokers, compared to non-smokers, do not exhibit mu suppression while observing addiction-related actions (Pineda, 2006). It was hypothesized that this leads them to direct more attention towards such actions. While most studies on mirror neurons show their existence in adults, a study by Lepage et al. (2006) showed that significant mu suppression occurs in children under 11 years old during the observation of object-oriented hand movements. This shows that the mirror neuron system is active in the immature human brain. Researchers have speculated that they may have potential as a diagnostic tool for particular disorders, such as autism.

A recent study by Oberman (2005) found that individuals with autism spectrum disorders (ASD), characterized by deficits in imitation ability and empathy, have a dysfunctional mirror neuron system. Mu-wave suppression was measured with an EEG

with electrodes placed over the premotor cortex for autistic children who were watching videos of a moving hand, a bouncing ball, visual noise or moving their own hands (Oberman, 2005). The ASD group had significant mu suppression to self-performed hand movements, but not to observed hand movements. This implies that empathy is related to mirror neuron activity (Iacoboni, 2006) and that it may be able to differentiate between individuals with high and low empathy.

By using a similar procedure to Oberman (2005), we tested mu (8-13Hz) suppression on an EEG for individuals who were identified as having high and low empathy by an online survey. In comparison to the study by Oberman and Pineda, we studied college students who were cognitively normal and differed only on their score on the empathy scale (Mehrabian, 1971). It was hypothesized that individuals with low empathy would show a lack of mu-suppression when observing hand tapping actions, while individuals with high empathy would show a significant level of mu-suppression when observing the hand tapping actions. Since previous studies have shown that antisocial behavior, which involves a lack of empathy and concern for others, is related to low heart rate activity (Kibler, 2004), heart rate was also measured to test whether it was related to empathy and mirror neuron activity.

Method

Participants

The participants were 241 undergraduate students at Gustavus Adolphus College. The participants were recruited from the introductory psychology classes and were given three points of extra credit in their course for completing the online surveys. 16 of the

participants were recruited based on having the highest or lowest scores on the empathy scale, and they conducted the four experimental conditions.

Procedure

The study was conducted over the course of two semesters. The standard Big 5 Personality Survey and the Questionnaire Measure of Empathetic Tendency (Mehrabian, 1971) were administered on Survey Monkey, an online survey system. The participants who were in the higher and lowest percentiles on the empathy scale were recruited to conduct the four conditions that involved measuring mirror neuron activity. Neither the experimenters, nor the participants, were aware of the empathy group to which the participants belonged to. This made the study effectively double-blind.

The experiment took place in a room that wasn't illuminated. We placed an ear piece with electro-gel on the ear of each participant, an ECI cap with electro-gel on the two electrodes over the premotor cortex of each participant, and a pulse (PPG) measure on the index finger of each participant. The ECI cap and PPG measure were held in place with a shoulder strap and connected to a MP35 Biopac System.

There were four conditions that were completed by the participants. They counted the number of cycles of a clock pendulum on a video screen, counted the number of taps of a human hand on a keypad on a video screen, observed static on a video screen, and performed self-initiated tapping on a keypad at 1 tap/second. Each participant conducted a set of two full trials of the tasks in a randomized order. The participants were advised to keep quiet, still, and focused during the trials.

The acquisition was set for 60.0 seconds. During each task, EEG (0.5-35Hz) and PPG data were recorded. The mu-activity was attained by an FFT transformation of the

8-13Hz region and heart rate was measured by finding the difference between adjacent peaks on the PPG recordings.

Results

The relationships between empathy, mirror neuron activity, and heart rate were analyzed. Mu suppression, a measure of mirror neuron activity, was calculated for the various conditions by the methods established by Oberman et al. (2005). Mu suppression is the mu activity of a particular task divided by the mu activity of the static task. The high empathy group (N=10) had an average mu-suppression of 0.882 for watching tapping motion while the low empathy group (N=6) had an average mu suppression of 1.11 during this task, which was marginally significantly different at 95% confidence, according to an independent samples t-test ($p<0.055$).

The high empathy group also had an average mu-suppression of 1.26 during the pendulum task, while the low empathy group had an average mu-suppression of 1.01 during this task, which was not significantly different ($p<0.330$). The high empathy group had an average mu suppression of 0.931 during the self-initiated tapping task, while the low empathy group had an average mu suppression of 1.41 during this task, which was significantly different ($p<0.036$). The mean mu suppression values of the tasks are shown on Figure 1, while the significance data is shown on Table 1.

To explore the correlation between the tasks, a paired sample t-test was conducted which showed that comparing the mu suppression for watching tapping action and conducting self-initiated tapping has a t-value of 0.319 ($p<0.228$). Comparing the mu suppression for the watching tapping and pendulum tasks has a t-value of 0.238

($p<0.354$), while the comparing the mu suppression for conducting the self-initiated tapping and pendulum tasks has a t-value of 0.052 (0.848). These values are listed on Table 2. This shows that there wasn't a significant difference between the mu suppressions of the various tasks.

Heart rate and empathy were not significantly correlated, with a t-value of 0.445 ($p<0.084$), where the high empathy group had a heart rate of 81.82 bpm and the low empathy group had a heart rate of 70.29 bpm (Figure 2). After taking into account the scores on the Big 5 Personality Variables of the individuals in the high and low empathy groups, a few other interesting effects were observed. Mu suppression for watching tapping was significantly correlated to extroversion ($p<0.046$) and negatively correlated to conscientiousness ($p<0.031$), as shown on Table 3.

Discussion

This study provides evidence that mirror neuron activity has a marginally significant correlation to empathy and a significant correlation to the personality variables of extraversion and conscientiousness. It is shown that high empathy individuals have higher mirror neuron activity than low empathy individuals when observing hand movements and when performing self-initiated hand movements. These results are consistent with the findings that ASD children have low mirror neuron activity while observing hand movements (Oberman, 2005). The finding that the pendulum task mu suppression and empathy were not significantly correlated is not surprising, given that this task does not involve the observation of biological action sequences. Also, the finding that there is no significant correlation between the various tasks, which should have been the highest for the mu suppressions of the watching tapping task and the

conducting self-initiated tapping task, is probably due to the high variability of scores for self-initiated tapping, as shown by the error bars on Figure 1.

There was a trend that revealed that lower heart rate was associated with lower empathy, but it was not significant. This result is consistent with the study by Kibler et al. (2004) which showed that antisocial personality is associated with low heart rate. The significantly correlations between watching tapping mu suppression and the personality variables of conscientiousness and extroversion, on the other hand, showed that there may be factors, besides empathy, that increase mirror neuron activity.

The limitations of the study had to do with the small sample size (N=16), which was spread out over two semesters. The first semester group (N=10) used a different survey system than the second semester group (N=6) and there may have been differences between the types of people who volunteered to conduct the study in these populations. But the greatest limitation was getting consistent results from the EEG recordings. Any small movement in the experimental setting affected the mu activity of the EEG, which is why the participants were told to remain still and focused during their tasks. It took a few trial runs to get consistent results, but there were possible confounding variables that could have affected the EEG recordings.

Despite the limitations, the study provides physiological evidence, as measured by mirror neuron activity and heart rate, of a difference between high empathy and low empathy individuals. It is clear that mirror neurons, the new frontier of neuroscience, are implicated in many types of behaviors and this experiment shows that it has a correlation with empathy in cognitively normal college students, not only in individuals with disorders such as autism. Future studies should focus on testing the correlation between personality variables, such as extroversion and conscientiousness, and mirror neuron

activity, since this study provided preliminary evidence for such a relationship.

References

Altschuler, E.L. et al. (1997). Person see, person do: human cortical electrophysiological correlates of monkey see monkey do cells. *Soc. Neurosci.*: **23**(2); 1848.

Binkofski, F., Buccino, G. (2006). The role of the ventral premotor cortex in action execution and action understanding. *J. of Physiology – Paris*, **99**; 396-405.

Iacoboni, M., Dapretto, M. (2006). The mirror neuron system and the consequences of its dysfunction. *Neuroscience,* **7**; 942-951.

Kibler, Jeffrey L., Prosser, Vicki L., Ma, Mindy (2004). Cardiovascular correlates of misconduct in children and adolescents. *J. of Psychophysiology*, **18**; 184-189.

Lepage, Jean-Francois, Theoret, H. (2006). EEG evidence for the presence of an action observation-execution matching system in children. *Euro. J. of Neurosci.* **23**; 2505-2510

Mehrabian, A., Epstein, N. (1971). A measure of emotional empathy. *J. of Personal. Psych.* 526-543.

Oberman, Linsay M. et al. (2005). EEG evidence for mirror neuron dysfunction in autism spectrum disorders. *Cognitive Brain Research*: **24**; 190-198

Pineda, Jaime Owner A., Oberman, Lindsay M. (2006). What goads cigarette smokers to smoke? Neural adaptation and the mirror neuron system. *Brain Research*: **1121**; 128-135.

Rizzolatti, G. Fogassi L., Gallese V. (2006). Mirrors in the mind: a special class of brain cells reflects the outside world, revealing a new avenue for human understanding, connecting and learning. *Scientific American*; 54-69

Figure Captions

Figure 1: Mean mu-suppression for the conditions versus empathy. There is a marginally significant effect of empathy on the mu suppression of watching tapping ($p<0.055$) and a significant effect of empathy on the mu suppression of conducting self-initiated tapping ($p<0.036$). There is no significant of empathy on pendulum mu suppression ($p<0.330$). Watching tapping mu suppression and conducting tapping mu suppression were not significantly correlated ($p<0.228$).

Figure 2: Mean heart rate (bpm) versus empathy. Heart rate is not significantly correlated to empathy ($p<0.084$), but they show a positive trend ($t=0.445$).

Table 1: The 2-tailed significance between the mu-suppression of the conditions and empathy are shown.

Table 2: Pearson correlation and 2-tailed significance of a paired sample t-test of the conditions are shown.

Table 3: Pearson correlation and 2-tailed significance for the relationship between watching tap suppression and heart rate (bpm) and the variables of personality and empathy are shown.

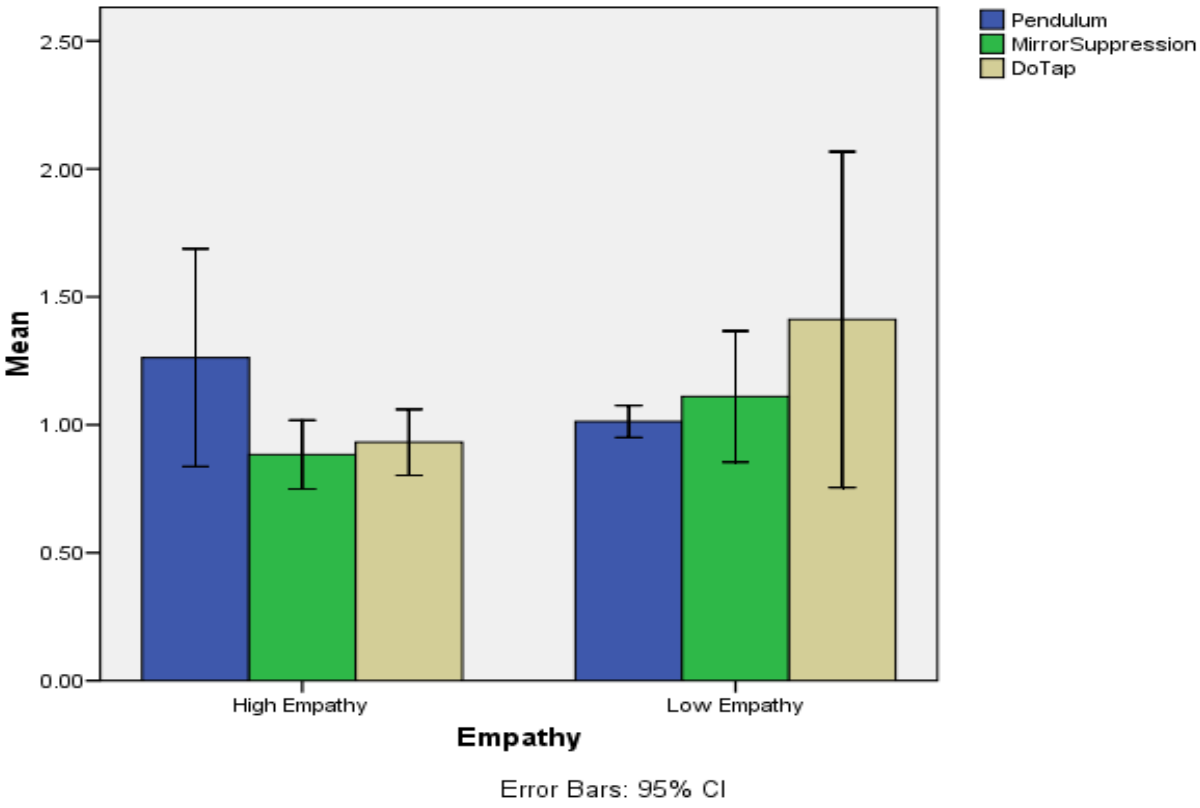

Figure 1: Mean mu-suppression versus empathy.

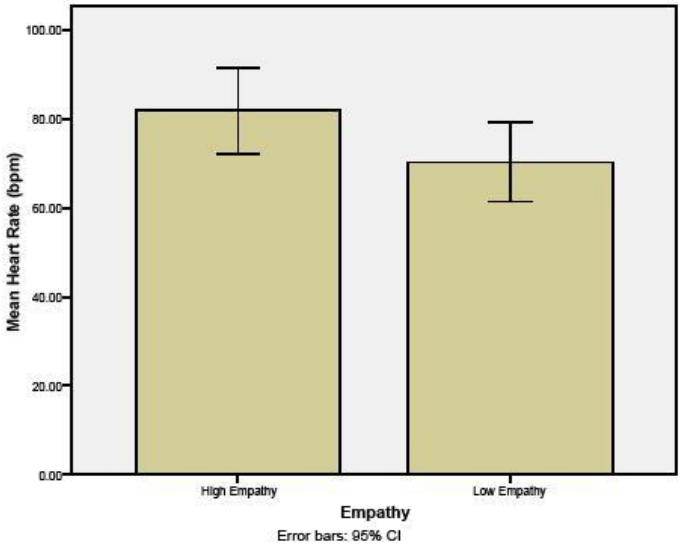

Figure 2: Mean heart rate (bpm) versus empathy.

Table 1: The 2-tailed significance between the mu-suppression of the conditions and empathy.

	Sig.
Pendulum Mu Suppression + Empathy	0.330
Watching Tap Mu Suppression + Empathy	0.055
Conducting Tap Mu Suppression + Empathy	0.036

Table 2: Pearson correlation and 2-tailed significance of a paired sample t-test of the conditions.

	t (sig.)
Watching Tap + Pendulum Mu Suppression	0.238 (0.354)
Conducting Tap + Pendulum Mu Suppression	0.052 (0.848)
Watching Tap + Conducting Tap Mu Suppression	0.319 (0.228)

Table 3: Pearson correlation and 2-tailed significance for the relationship between watching tap suppression and heart rate (bpm) and the variables of personality and empathy.

	Extroversion	Conscientiousness	Empathy
	t (sig.)	t (sig.)	t (sig.)
Watching Tap Suppression	0.504 (0.046)	-0.539 (0.031)	0.489 (0.055)
Heart Rate (bpm)	-0.067 (0.804)	-0.209 (0.438)	0.445 (0.084)