Summer 2015

# EEG Investigation of Mirror-Neuron Activity Before and After Conscious Perception of Emotion in Faces

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Author Note

This work was completed through the supervision of David Andresen, Professor of Neuroscience and Psychology at the University of Puget Sound. This research was funded with a Keck Research Grant.

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Without the ability to interpret and understand others' actions, social organization and empathy is not possible. These abilities for social processing, action interpretation, and empathy were originally studied by examining the underlying neural mechanisms in the premotor cortex of monkeys (Rizzolatti et al., 1996; Ferrari et al., 2003; Caggiano et al., 2011). The studies looked at the brain activity of rhesus macaques and were able to generalize the results to humans because both have similar cortical functioning and constant electrical activity occurring from neurons, the basic cellular unit of the brain (Parker et al., 2002; Icoboni & Mazziota, 2007). The electrical activity can be measured using Electroencephalogram (EEG)—a physiological method of measuring the synchronization and de-synchronization of neurons in the brain generated by neurons constantly "firing," or producing electricity from changes in electrochemical gradient (Teplan, M., 2002). When thousands of neurons fire together in synchronization they produce greater electrical activity, and when they desynchronize there is a drop in electrical activity, which can then be measured as an index of brain activity.

The studies found evidence of a Mirror Neuron System (MNS) for action imitation and understanding due to the activation of visuomotor neurons when the monkeys did a particular action and when they watched another monkey perform the same action (Kurata & Tanji, 1986; Di Pellegrino et al., 1992; Gallese et al. 1996; Rizzolatti et al., 1996, 2004). These neurons in the f5 region (or visuomotor region) of the monkey cortex were deemed mirror neurons because they only fired when the subject observed an interaction between the hand or mouth of another monkey and an object (Rizzolatti et al., 2004).

Using the evidence of the MNS in monkeys as a starting point, testing in recent years has shifted to focus on the presence of the MNS in humans. EEG is a method of measuring the electrical activity in the human brain, and is especially useful in this study and in other studies of the mirror neuron system because it is noninvasive and can record activity across the whole brain simultaneously. EEG is also optimal because it allows researchers to examine specific regions of electrical activity such as the motor cortex or the Inferior Frontal Gyrus (IFG) examined in this study, due to the distributed placement of 32 electrodes on the scalp.

Mu-waves, or the specific electrical bands recorded from the motor cortex, are used as an index of activity of the MNS because in studies performed by researchers on both humans and monkeys, the de-synchronization or recorded suppression of EEG rhythm (mu-waves specifically) occurred during both active movements of subjects and when subjects observed actions done by others (Gastaut & Bert, 1954, Cochin et al 1998, 1999, Altschuler et al. 1997, 2000). This supports the hypothesis of a mirror neuron system present for action understanding and interpretation. Specifically, mu-wave suppression, or the decrease in power of EEG waves between 8 and 13 Hz, is measured when studying the perception of social cues such as facial emotions and interactions, and is foundational for action and emotion understanding. Mu-waves are used in this study to index activity of the mirror neuron system and cortical processing (Moore et al, 2012; Rizzolatti et al., 2001, 2004).

Mu-waves have been used to index the mirror neuron system, while other properties that affect mu-wave activity during stimulus presentation have not (see Figure 3 below). Two specific properties that have not been examined with respect to mu-waves are whether mu-waves are suppressed only when conscious perception occurs and how stimulus difficulty affects mu-wave suppression. In examining the effect of mu-wave suppression via EEG recording, greater insight can be obtained as to how the mirror neuron system is affected by conscious processing.

Although different task demands affect mu-wave suppression (Werhane, Chen, & Andresen, 2012), this is not the same as conscious perception and no studies have examined the change in mu-wave suppression (or mirror neuron activity) just before and just after conscious perception of a face has occurred. The actual change in mu-wave suppression when a stimulus goes from being unrecognizable to recognizable has not been directly tested. By continuously recording the change in mu-wave suppression as participants become consciously aware of a facial emotion, the purpose of this study is to determine whether or not the conscious processing alone effects mu-wave suppression or if the stimulus difficulty via the amount of visible noise modulates the mu-wave suppression. Through the use of EEG and a 6 second stimulus presentation with either sad or angry faces the participants perceive, it is hypothesized that there will either be an immediate drop in mu-wave suppression at the moment of conscious perception or that there will be a gradual decrease. For the final 3 seconds of stimulus presentation in which the participants are consciously aware of the face as it is recovered with visual noise two additional hypothesis are proposed: that there will be no change in mu-wave suppression or that there will be a gradual decrease as the noise increases back to 100%.

# Method

## Subjects

The sample was composed of 21 participants largely taken from the undergraduate population of the University of Puget Sound ranging in age from 19-62 years. Subjects' vision was normal to corrected normal and each participant was right handed. Each subject gave written consent to participate in the study and received $20 as compensation. This study was reviewed and approved by the University of Puget Sound Institutional Review Board.

**Experimental Setup**

A 32 channel Biosemi system was used on the scalp with reference electrodes placed on the left and right mastoids. Eye movements were monitored using reference electrodes on the left temporal and orbital. Data was processed to remove eye movement and EMG artifacts using principle component analyses in EMSE EEG analysis software. Other artifacts were removed using a recursive outlier detection algorithm in EMSE.

**Task and Stimuli**

Participants viewed 8 blocks of images with 20 faces each and 1 final block with 4 facial images. Each block consisted of angry and sad images. The images presented were held consistent across all participants. Each block was followed by a resting period for the participant in which they decided how long the break would be. To begin the next stimuli block the participant was instructed to press any key.

Before the trials began participants were instructed to indicate which facial emotion was being presented by pressing the left arrow key for an angry face or the right arrow key for a sad face. Each image was presented over a period of 6 seconds. Each face was shown at 100% noise which slowly lifted over a period of 3 seconds to reveal the face underneath. At 3 seconds the face was once again slowly covered with noise until 6 seconds, in which it was 100% covered (See Appendix A). To prompt participants to focus on the center of the screen and the facial images, one second before each trial began a red dot appeared on the center of the screen and remained present for the duration of the trial. Subjects were asked to refrain from blinking and moving until the 3 second rest periods in between each stimuli presentation.

## Results

Fourier transformation was used within EMSE EEG to align participants' data for two separate analyses. The first aligned all 21 participants' data to when they indicated the facial emotion with a keypress (with an average of 1.5 seconds after the beginning of the trial). The results show a gradual increase in mu-wave suppression over time until the face is fully revealed at 3 seconds, in which there is a sudden decrease back to baseline (See Appendix B) for the duration of the trial. The greatest amount of mu-wave suppression occurred at the moment the emotion was interpreted and indicated with the button press.

The second analysis aligned participant's data to the onset of the stimuli (See Appendix C). Mu-wave suppression occurred after the stimulus onset but was not strongly modulated by the amount of noise present. The amount of mu-wave suppression remained fairly constant after the first second of stimulus presentation.

## Discussion

The gradual increase in mu-wave suppression for the key press-aligned Fourier Transformation, when contrasted against the results of the stimulus onset-aligned results suggest that mu-wave suppression is related to the conscious perception of face stimuli. Due to the small change in mu-wave suppression that occurred when aligned to stimulus onset, it further supports the idea that mu-wave suppression is unrelated to the presence of low-level characteristics such as noise. Being the first study to continuously record the mu-wave suppression as participants view the stimuli, additional testing with more participants could provide further data to investigate this.

Additional studies may also be able to use faces that approach the participant from the background of the screen to the foreground, gradually increasing in size to mimic an approaching individual. This would be able to test the same conscious perception while mimicking a more natural social interaction. Other facial emotions could also be used to examine if mu-wave suppression varies depending on the strength of the emotion being expressed.

Additional data analysis are being completed with the results of this study, as the results presented are preliminary. Further analyses may include looking at the mu-wave suppression for individual participants, and by gender. Control stimuli were also included in the experiment in which no face appeared. The data for the control condition may be compared across the other two aligned conditions to examine whether the same mu-wave suppression occurred just from anticipating a face.

Additional studies may be included that could compare the mu-wave suppression of a normal population sample and individuals with autism. It has been proposed that individuals with autism have less mu-wave suppression than the average population, possibly relating to the trouble some autistic individuals experience with perceiving emotion (Dapretto et al., 2006). By comparing these two populations, more insight could also be gained into the relationship between mu-wave suppression, the Mirror Neuron System, and autism.

The initial findings of mu-wave suppression modulated by the conscious perception of facial emotions and not from noise may provide further support for the Mirror Neuron System being used in emotion interpretation.

**References**

Altschuler, E. L., Vankov, A.,Wang, V., Ramachandran, V. S., & Pineda, J. A. (1997). Person see, person do: Human cortical electrophysiological correlates of monkey see monkey do cell. *Social Neuroscience*, 68.1 (Abstr.)

Altschuler, E. L., Vankov, A., Hubbard, E. M., Roberts, E. Ramachandran, V. S., & Pineda, J. A. (2000). Mu wave blocking by observation of movement and its possible use as a tool to study theory of other minds. *Society for Neuroscience Abstracts*, *26,* 67.23 (Abstr.)

Caggiano, V., Fogassi, L., Rizzolatti, G., Pomper, J. K., Their, P., Giese, M. A., & Casile, A. (2011). View-based encoding of actions in mirror neuron of area F5 in macaque premotor cortex. *Current Biology, 21,* 144-148. doi: 10.1016/j.cub.2010.12.022

Cochin, S., Barthelemy, C., Lejeune, B., Roux, S., & Martineau, J. (1998). Perception of motion and qEEG activity in human adults. *Electroencephalography and Clinical Neurophysiology, 107,* 287-295.

Cochin, S., Bathelemy, C., Roux, S., & Martineau, J. (1999). Observation and execution of movement: Similarities demonstrated by quantified electroencephalography. *European Journal of Neuroscience, 11,* 1839-1842.

Dapretto, M., Davies, M. S., Pfeifer, J. H., Scott, A. A., Sigman, M., Brookheimer, S. Y., & Icobani, M. (2006). Understanding emotions in others: Mirror neuron dysfunction in children with autism spectrum disorder. *Nature Neuroscience, 9*, 28-30. doi: 10.1038/nn1611

Di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research, 91,* 176-180.

Ferrari, P. F., Gallese, V., Rizzolatti, G., & Fogassi, L. (2003). Mirror neurons responding to the observation of ingestive and communicative mouth actions in the monkey ventral premotor cortex. *European Journal of Neuroscience, 17*(8), 1703-1714.

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

Gastaut, H. J. & Bert, J. (1954). EEG changes during cinematographic presentation. *Electroencephalography Clinical Neurophysiology, 6,* 433-444.

Iacoboni, M. & Mazziotta, J. C. (2007). Mirror neuron system: Basic findings and clinical applications. *Annals of Neurology, 62,* 213-218. doi: 10.1002/ana.21198

Kurata, K. & Tanji, J. (1986). Premotor cortex neurons in macaques: Activity before distal and proximal forelimb movements. *The Journal of Neuroscience, 6*(2), 403-411.

Moore, A., Gorodnitsky, I., & Pineda, J. (2012). EEG mu component responses to viewing emotional faces. *Behavioural Brain Research, 226,* 309-316. doi: 10.1016/j.bbr.2011.07.048

Parker, G. J. M., Stephan, K. E., Barker, G. J., Rowe, J. B., MacManus, D. G., Wheeler-Kingshott, C. A. M., Ciccarelli, O., Passingham, R. E., Spinks, R. L., Lemon, R. N., & Turner, R. (2002). Initial demonstration of *in Vivo* tracing of axonal projections in the macaque brain and comparison with the human brain using diffusion tensor imaging and fast marching tractography. *NeuroImage, 15*(4), 797-809. doi: 10.1006/nimg.2001.0994

Rizzolatti, G., Fadiga, L., Fogassi, L., & Gallese, V. (1996). Premotor cortex and the recognition of motor actions, *Cognitive Brain Research., 111,* 131-141.

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

Rizzolatti, G. & Craighero, L. (2004). The Mirror-Neuron System. *Annual Review of Neuroscience*, *27*, 169-192. doi: 10.1146/annurev.neuro.27.070203.144230

Teplan, M. (2002). Fundamentals of EEG measurement. *Measurement Science Review*, *2*(2), 1-11.

Werhane, M. L., Chen, M. P., & Andresen, D. R. (2012, May). *Identification of Emotion in Faces Engages the Mirror Neuron System.* Poster presented at the conference of the Association for Psychological Science, Chicago, IL.

**Appendix A**

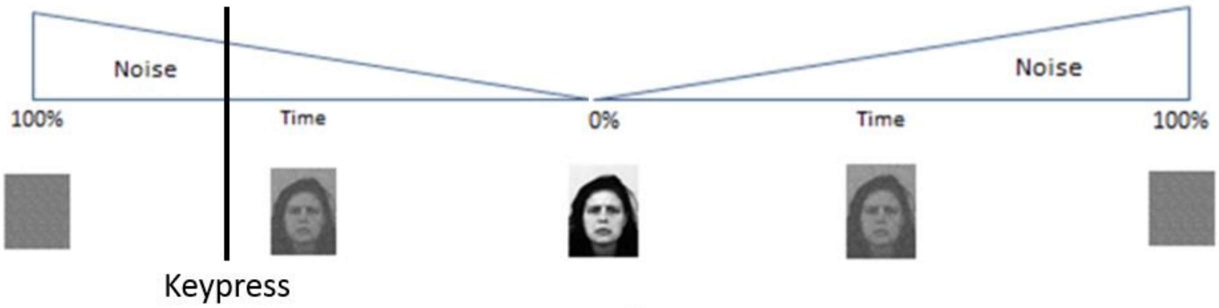


*Figure 1.* Stimulus presented to participants over a period of 6 seconds. Average keypress occurred around 1.5 seconds after stimulus onset.

**Appendix B**

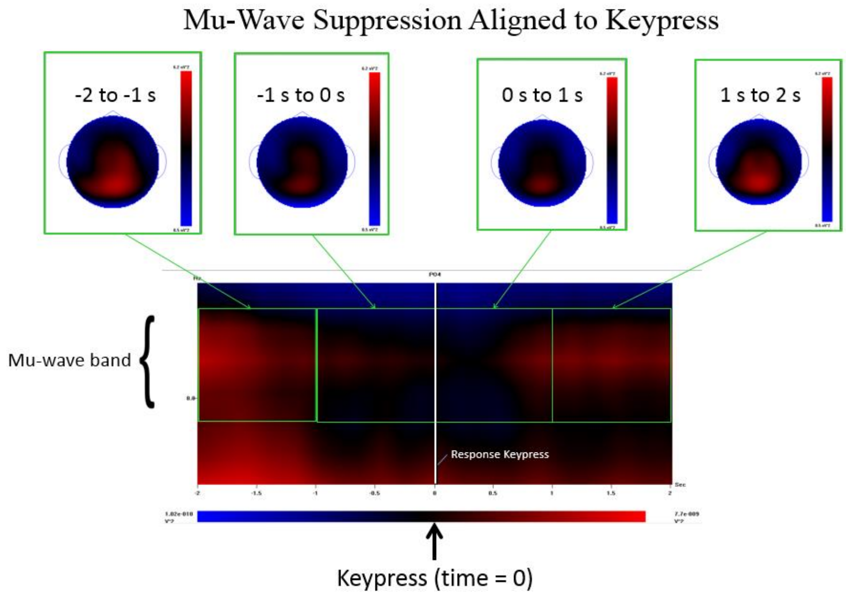


*Figure 2*. Mu-waves were more suppressed as participants became aware of the face appearing out of noise, with maximum suppression around the time they made their response.

**Appendix C**

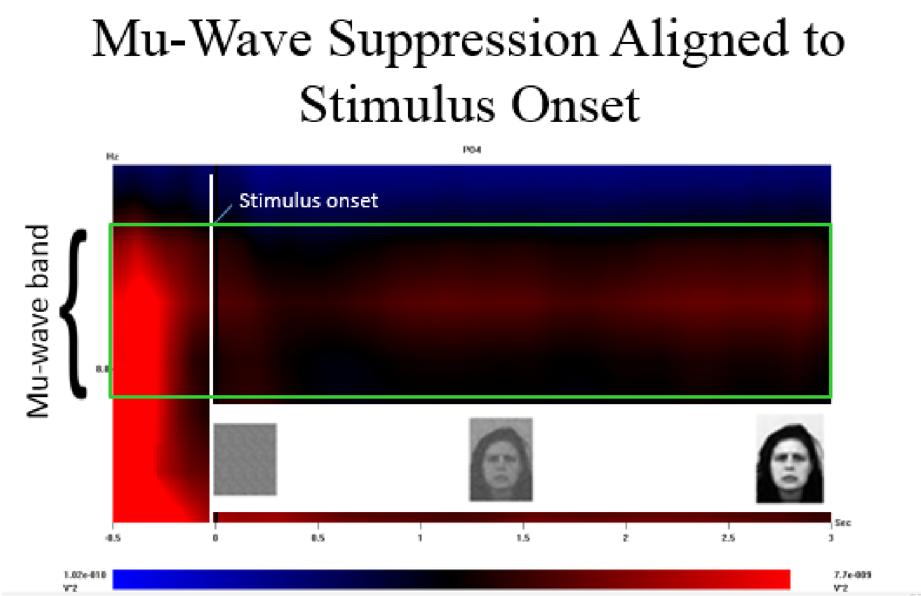


*Figure 3*. Mu-wave suppression occurred after stimulus onset, but was *not* strongly modulated by level of noise in the image.