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EEG Measures of Facial Expression Recognition

Madeleine Werhane
mwerhane@pugetsound.edu

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University of Puget Sound

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Abstract

The purpose of this study was to explore the role of the human mirror neuron system (hMNS) in the accurate identification of emotional facial expressions. Electroencephalography (EEG) was used to record Mu wave activity while participants preformed a series of video-matching tasks, in which they discriminated between facial stimuli by either emotional expression or model identity. A polygon-matching task was used as a baseline measure for mirror neuron activity. Mu Suppression Indices were calculated and compared between the identity-matching and emotion-matching conditions. Mu suppression was significantly increased in the emotion-matching condition, suggesting that the mirror neuron system is engaged to a greater extent during emotional facial expression processing than general face processing. Future research should further investigate this engagement of the hMNS, especially in relation to peripheral feedback mechanisms that might also be involved in recognizing emotional facial expressions.

EEG Measures of Facial Expression Recognition

Our lives are rich with emotional information. A mother embraces her child as he cries about his swollen and scraped knee. A basketball player glares into the eyes of his opponent, preparing for the opening tip of the game. Companies use emotions to help sell their products, while politicians manipulate them to persuade crowds. Emotions even penetrate the cyber realm, frequenting our emails and messages as emoticons. As a social species, the ability to process and understand these emotional signals is central to our daily function. Without it, we would be incapable of deciphering the intentions or motivations of those around us. Various strategies are used to communicate our emotions to each other. Sometimes they are voluntary—involving the vocalization of our thoughts and feelings. Other times they are subconscious—occurring through minute vocal, facial, or postural changes. All of this emotional information is constantly being detected and interpreted, with much of it processed instantly on a subconscious level.

Facial expressions serve as one important route through which we gain emotional information. Without this superficial cue, obtaining implicit knowledge about the internal state to other individuals would become increasingly more challenging. Although facial expressions involve highly complex and varied muscular movements, most people are able to agree upon and distinguish between a vast spectrum of expression, doing so with a high degree of accuracy as to their corresponding emotion. Exactly how people are able to perform such as task has been the central question of many psychological studies over the past couple of years, as well as what type of cognitive or neurological mechanisms allow for this ability to be so swift and automatic for the general population.

Several theories have been proposed regarding the mechanisms involved in facial expression recognition. Some of the leading hypotheses stem from the theory of embodied cognition, which asserts that people gain implicit knowledge of other minds through the simulation of other's motor actions, making associations with that motor action and their our own internal states (Perry, Troje, & Bentin, 2010). Evidence for this theory has been presented through research investigating both peripheral and central neural mechanisms. Facial mimicry, when an observed facial expression is subconsciously reproduced using one's own muscles, is one peripheral phenomenon that has been studied to help understand this process. People both overtly and covertly mimic facial expressions of those around them (Dimberg, Thunberg, & Elmhead, 2002). Theorists argue that this mimicry is a type of simulation technique, and is required for the ability to correctly identify emotions from the faces of other people. Niedenral et al. (2001) and Oberman et al. (2007) reported that participants preformed worse at identifying the emotions portrayed in pictures of facial expressions when they were unable to move their face. Similarly, individuals with autism spectrum disorder (ASD)—who do not participate in facial mimicry at all—show severe deficits in their ability identify emotions from facial expressions (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006). These reports, along with a large body of supporting literature, serve as compelling evidence that facial mimicry plays a critical role in the recognition of emotional facial expressions.

One central system that has also been implicated in the recognition and understanding of emotions is the mirror neuron system (MNS). Mirror neurons are neurons that are activated when performing motor actions (e.g., reaching for a ball), as well as when observing another person perform the same motor action. Thus, the name "mirror neuron" refers to the literal mirroring of an observed behavior as if the observer preformed it themselves. Similar to bodily movements, facial expressions involve very complex and specific muscle actions, and recent studies have investigated the role of mirror neurons in recognizing facial expressions. These studies have found that when mirror neuron activity is inhibited, participants are unable to effectively discriminate between different types of facial expressions (Pitcher, Garrido, Walsh, & Duchaine, 2008).

Although many studies have reported compelling evidence implicating various roles of mirror neurons, many suffer from important methodological limitations. Stimulus control is often a limitation of these studies, as a result of the complex tasks designed to test the unique properties on the mirror neuron system (Muthukumaraswamy, Johnson, & McNair, 2004; Oberman, Pineda, & Ramachandran, 2007; Pitcher et al., 2008). Because of this, it is not clear whether the findings of these studies can be attributed to the suggested internal "mirroring" process, or rather a change in the stimulus presented. Thus, this study not only seeks to investigate the role of the human mirror neuron system in facial expression recognition, but also to determine whether mirror neuron activity reflects the internal task of identifying emotional facial expressions, or is simply a response to facial expressions as an external stimulus.

To examine the role of the hMNS in facial expression recognition, we measured mirror neuron activity while participants preformed a video-matching task testing their ability to distinguish between various emotional facial expressions. Mu wave activity (8-13 Hz), an indirect measure for mirror neuron activity (Gastaut & Bert, 1954), was measured using electroencephalography (EEG). According to the findings of previous similar studies, we predict that there will be a higher degree of Mu suppression during the emotion-matching task, as compared to the identity-matching task.

Method

Participants

Participants in the study were fifteen undergraduate students from the University of Puget Sound (n = 15; M = 6, F = 9), ranging is age from 18-21 years. Participants were recruited using on-campus advertising techniques, and were compensated fifteen dollars for partaking in the study. Written and informed consent was received prior to testing.

Procedure:

Stimuli: Stimuli consisted of videos of models making facial expressions or rotating simple polygons. Stimuli were presented on a computer monitor, appearing centrally in grayscale against a black background. On-screen duration of video-stimuli was approximately 4,000 ms. Videos of facial expressions were obtained from the Facial Expressions and Emotion Database from the University of Munich (Wallhoff, 2006). Facial stimuli were pilot tested by 20 university students. For pilot testing, participants indicated which emotion was best depicted by each stimulus. Video-stimuli selected for the study had the highest agreement rating for a singular emotion, using an evaluation criterion measuring the proportion of agreement to disagreement (EC $\geq$ 0.8 agreement). The final set of stimuli consisted of two male and two female models (3, 5, 8, 16) expressing one of four basic emotions (happy, sad, surprise, disgust). The same set of facial expression videos was used for both the identity and emotion task conditions.

A second set of stimuli was used in the baseline polygon-matching condition. Videos of polygon stimuli corresponded to one of four simple polygonal categories (square, triangle, pentagon, kite). The stimuli rotated centrally at a rate of --, rotating either clock-wise or counter clock-wise. The direction of rotation was determined randomly and varied across testing sessions.

EEG: Mirror neuron activity was measured while participants preformed a series of video-matching tasks. Electrical brain activity was measured using an encephalograph acquisition unit (MP36 4-channel system, Biopac Systems Inc.). EEG was recorded from four scalp electrodes, manually placed in the standard 10-20 positions Cz, C2, C4, and O2. An electrode at standard Fpz position was used as a ground, and electrode on the right ear lobe was used as a reference. Electrodes were also placed above and below the right eye to measure the frequency of blinking during recording. Electrode sites were cleaned (ethanol) and lightly abraded as a method to reduce the impedance between the skin and electrode. Standard 10-20-electrolytic gel was also applied to each site prior to electrode application. Net impedance across electrodes was below 10 kΩ for all participants, and was recorded before and after each testing session. All channels were recorded continuously throughout the testing session, collecting approximately thirty minutes of data at a sampling rate of 500 Hz. Task and stimulus onset and cessation were identified using the time record obtained from Matlab. Data were processed after collection using EEGLAB software (provided by Mathworks, Inc.).

Task: Once electrode application was complete, participants were seated approximately 36 cm away from the computer monitor screen on which the video-stimuli were presented. Participants preformed three types of video-matching tasks: 1) an emotion-matching task; 2) an identity-matching task; and 3) a polygon-matching task. For the emotion-matching task, participants were asked to identify whether a pair of videos depicted the same emotion, while ignoring the identity of the model in the video. This task tested the ability to accurately identify emotions from facial expressions. For the identity-matching task, participants were asked to identify whether a pair of videos contained the same person, while ignoring their facial expression. This task tested their general ability to recognize architectural differences in faces, an independent ability from recognizing facial expressions. For the polygon-matching task, participants were ask to decide whether a video pair contained the same rotating shape. This served as a baseline condition, to which both the identity-matching and emotion-matching tasks could be compared.

Video pairs were presented in blocks containing four video pairs (See Figure 1 for depiction of the task). The blocks were organized by task type (face emotion-matching, face-identity-matching, or shape identity-matching), so that participants completed a total of eight blocks of each task (total trial run length of 24 task blocks). The type of task alternated throughout the session, and was counter-balanced between participants. Each task block was followed by a 26000 ms break. During this break, participants reported the number of matching pairs they observed during the previous block according. Participants were asked to sit as still as possible and refrain from talking during the task block itself. This was used to help minimized noise in the EEG recording due to additional motor movements or planning preformed by the participant.

Video pair type was counter-balanced across participants so all face emotion/model identity combinations were observed. Each participant viewed the same number of pair-type combinations (16 total of each type; same emotion/same identity; same emotion/different identity; different emotion/same identity; different emotion/different identity). Inter and intra pair-order was also randomized to account for stimulus order effects.

Results

Mu suppression was measured by calculating the relative Mu Suppression Index (Oberman, Ramachandran, & Pineda, 2008) for the identity and emotion-matching tasks for each of the electrodes located over the somatosensory cortex (Cz, C2, C3). Participant EEG data was separated and concatenated by task (Emotion, Identity, Polygon). A Fast Fourier Transform (FFT) analysis was then used to determine the frequency power spectra for each task. Once the spectra were obtained, the Riemann sum was calculated between 8-13 Hz (frequency oscillation range for the Mu wave) to determine task Mu power. The power of the Mu wave activity during both the emotion-matching and identity-matching conditions were then compared to the power during the baseline condition (polygon-matching) by calculating a log ratio for both groups. This log power ratio served as the Mu Suppression Index, depicting the relative level of mu activity in both the emotion-matching and identity-matching tasks to the baseline levels of Mu activity.

Mu suppression indices were analyzed using a two-way analysis of variance conducted at an alpha level of .05. For the C4 electrode location, there was a main effect of task on mu suppression, $F(1,12) = 5.261$, $p = .04$, indicating that mu suppression was increased during the emotion-matching task, as compared to the identity matching task. There were no other main effects found at the other scalp locations.

Discussion

It was predicted that Mu suppression, an indirect measure of mirror neuron activity, would increase while participants preformed the emotion-matching task, as compared to when they preformed the model identity-matching task. This prediction was supported, as the Mu wave activity was observed to significantly decrease during the emotion-matching condition, as compared to the identity-matching condition. This finding suggests that mirror neuron activity increased while participants preformed the emotion task, and that the human mirror neuron system is involved in identifying emotional facial expressions, but not in general facial recognition. Since the stimuli were identical during both tasks, the hMNS is differentially activated by task demands and not by differences in stimuli. Thus, these results suggest that recognizing emotions in others' faces relies on the human mirror neuron system, whereas recognizing face identity does not.

It should be noted that although this study addresses one of the common confounds of previous mirror neuron studies, it still maintains its own limitations. The use of Mu suppression as a measure of mirror neuron activity limits the findings of the study, in that it has an indirect relationship with mirror neuron activity. Similarly, the focused analysis of Mu wave activity provides only information on that isolated event, putting forth the in the possibility that other neurological components involved in facial expression recognize may have been undetected. Thus, future research should seek to replicate this study with more direct and global neurological measures, such as functional magnetic resonance imaging (fMRI) or magnetoencephalography (MEG), in order to gain more insight as to the exact relationship between facial expression processing and the human mirror neuron system.

While the findings of this study implicate the involvement of the hMNS in the process of identifying emotional facial expression, the relationship between this central embodiment mechanism with other peripheral mechanisms (e.g., facial feedback) is still unknown. Given the close location of the mirror neurons activated by processing facial expression to the motor cortex (Pitcher, Garrido, Walsh, & Duchaine, 2008), it is plausible that there be a relationship between the mechanism that underlies facial mimicry and mirror neuron activation. Future research should seek to clarify whether there is a relationship between these two phenomena, as well as investigate whether they are in fact two distinct mechanisms, or a conjoined neurological process.

References

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

Dimberg, U., Thunberg, M., & Elmehed, K. (2002). Unconscious facial reactions to emotional facial expressions. *Psychological Science, 11,* 86-89.

McIntosh, D. N., Reichmann-Decker, A., Winkielman, P., & Wilbarger, J. (2006). When mirroring fails: Deficits in spontaneous, but not controlled mimicry of emotional facial expressions in autism. *Developmental Science, 9,* 295-302.

Muthukumaraswamy, S. D., Johnson, B. W., & McNair, N. A. (2004). Mu rhythm modulation during observation of an object-directed grasp. *Cognitive Brain Research*, *19(2),* 195-201.

Niedenral, P. M., Brauer, M., Halbertadt, J. B., & Innes-Ker, A. (2001). When did her smile drop? Facial mimicry and the influences of emotional state on the detection of change in emotional expression. *Cognition and Emotion, 15,* 853-864.x

Oberman, L. M., Ramachandran, V. S., & Pineda, J. A. (2008). Modulationlation of mu suppression in children with autism spectrum disorders in response to familiar or unfamiliar stimuli: The mirror neuron hypothesis. *Neuropsycologia, 46,* 1558-1565.

Oberman, L. M.,Winkielman, P., & Ramachangran, V. S. (2007). Face to face: Blocking expression-specific muscles can selectively impair recognition of emotional faces. *Social Neuroscience, 2,* 167-178.

Perry, Troje, & Bentin (2010). Exploring motor system contributions to the perception of social information: Evidence from EEG activity in the mu/apha frequency range

Pitcher, Garrido, Walsh, & Duchaine. (2008). Transcranial magnetic stimulation disrupts the perception and embodiment of facial expressions. *The Journal of Neuroscience, 28,* 8929-8933.

Wallhoff, F. (2006). *Facial Expression and Emotion Database*. (T. U. München, Producer). http://www.mmk.ei.tum.de/~waf/fgnet/feedtum.html.

Figure 1.

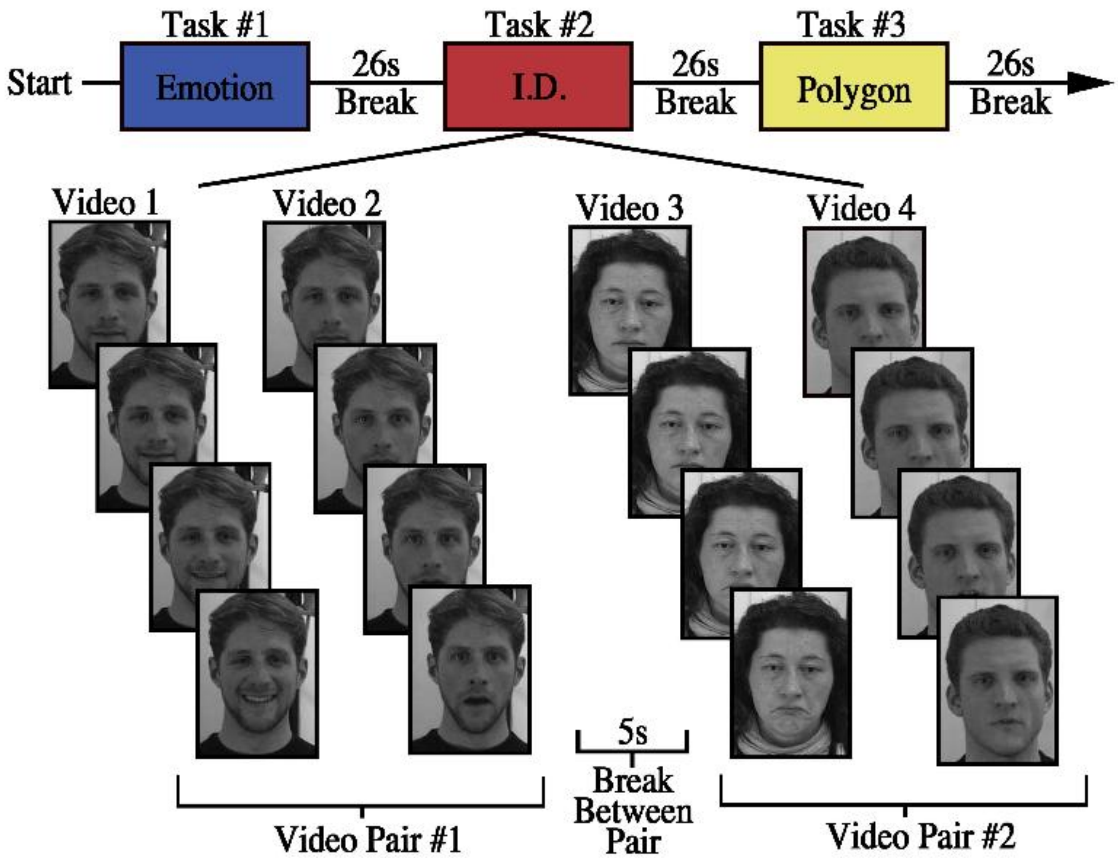

Figure 1. Video-matching task procedure. Participants preformed a series of three video-matching tasks in alternative blocks, with each block containing four video-pairs. Participants reported the number of matching pairs within each previous block during the inter-block break. A total of eight blocks of each task (emotion-matching, identity-matching, polygon-matching) appear throughout the testing session. Task responses and brain activity were recorded throughout the entirety of the testing session. This particular diagram depicts a portion of an identity-matching task. Video Pair #1 models a matched pair, which Video Pair #2 models a mismatch.

Figure 2.

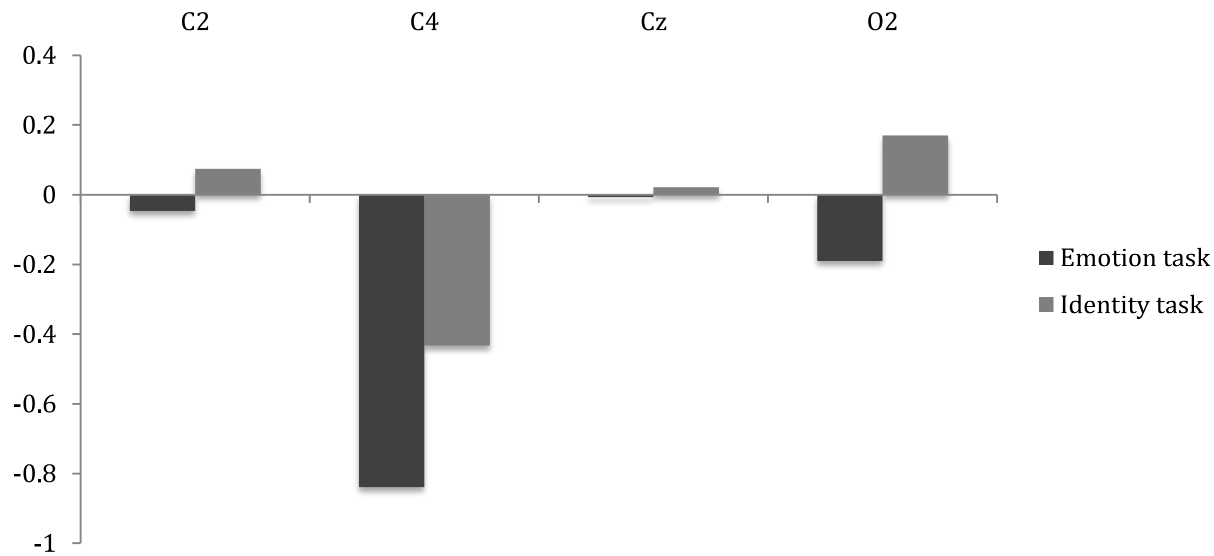

Figure 2. Mu suppression indices across scalp locations for the emotion and identity-matching tasks. Indices were calculated as the log ratio of mu wave power (8-13 Hz) between the task and the baseline condition (polygon-matching task). Mu indices for the emotion and identity-matching tasks were calculated and compared across each scalp location. Mu suppression as significantly increased in the emotion-matching condition, as compared to the identity-matching condition, in the C4 scalp location. There were no significant differences found between the conditions at any of the other scalp locations.