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Stimulus Dependence in Mirror Neuron Systems

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Stimulus Dependence in Mirror Neuron Systems:

Differences in Face and Body Emotion Processing

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Abstract

This study examined how stimuli content (emotionally expressive face and body images) influenced the location of mirror neuron activity as indexed by EEG mu-wave suppression. Participants completed an emotion-identification task in which they viewed black and white images of bodies and faces and identified them as displaying either fear or anger while their brain activity was recorded with EEG. This study predicted that emotional face stimuli would produce mu-wave suppression in posterior areas of the brain while expressive gestural-based body stimuli would produce suppression in the more central areas of the brain. EEG analysis indicated that both face and body stimuli induced significant mu-wave suppression, but face and body stimuli did not differ in amount of mu-wave suppression across regions of interest.

Keywords: mirror neurons, electroencephalography, faces, bodies

Stimulus Dependence in Mirror Neuron Systems: Differences in Face and Body Emotion Processing

First discovered in the brains of macaque monkeys in the early 1990's, mirror neurons have increasingly become the focus of much modern research regarding social cognition. The mirror neuron system seems to be widely implicated in modern research as the neural seat of social cognitive behaviors like empathy, theory of mind, and imitation because of its properties of activation. Mirror neurons are typically activated not only when an individual engages in an action itself, but also when the individual observes another engaging in the same action (Uddin, Iacoboni, Lange, & Keenan, 2007). It is this linked activation of self performance combined with the activation following the observation of another that makes the mirror neuron system an attractive neural explanation of how an individual relates to others—a fundamental function of human life. A similar pattern of activation was quickly found in the human brain around the inferior frontal gyrus and the inferior parietal lobule using function magnetic resonance imaging, otherwise referred to as fMRI (Shaw & Czekóová, 2013). However because of its relative inexpensiveness and convenience, the degree and location of mirror neuron activation can be measured perhaps equally as well with electroencephalography (EEG) through the oscillations in the 8-13 Hz frequency (mu) band, otherwise referred to as mu-wave suppression (Oberman, Pineda, & Ramachandran, 2007).

Although the location of mirror neuron activity has typically been attributed to the posterior inferior frontal lobe and the rostral inferior parietal lobe in the human brain, these findings have not been conclusive across studies (Iacoboni & Mazziotta, 2007). Neurologically, one theory suggests that mirror neuron activation originated from strong associations that developed between the observations of the sensory outcomes of our own actions and the motor programming of the action being performed. These associations become so strong that the actual performance of the action by an individual is no longer needed and the sensory representation of the action by another is enough to activate the corresponding motor representation (Shaw & Czekóová, 2013). Based on this theory of MNS processing, it seems logical to implicate motor areas of the brain (typically frontal regions) and sensory processing regions (attributed to mainly the parietal lobe). However, rather than only seeing mu-wave suppression in the frontal and parietal lobes, Oberman et al. (2007) found that the mirror neuron system may be a broader network of function, encompassing not only the frontal areas of the brain such as the inferior frontal gyrus but expanding into more centralized areas such as the limbic system. If the MNS is based on a pattern of association between motor and sensory systems, why might mirror neuron systems be activated in different locations of the brain other than the frontal and parietal lobes?

One possible explanation as to why mirror neuron activity may differ in location is the content of what the individual is actually perceiving and its implied action. Faces displaying emotions might be particularly pertinent to the mirror neuron system, as individuals seem to reference their own experience and facial expressions of emotions in order to recognize and infer the emotions of others (Moore, Gorodnitsky, & Pineda, 2012). Faces that convey emotion may be especially critical for MNS since the motor movements associated with a specific emotion (such as the downturn of the mouth and clenching of the jaw when angry) may be indicative of subsequent actions associated with said emotion (such as physical fighting), thus allowing the observer to learn the intention of the emotional individual and respond in a socially appropriate manner (Iacoboni, 2007). While few studies have examined the effect of facial stimuli on mirror neuron activity, one EEG study found that when viewing emotional faces (e.g. anger, fear, surprise, disgust, etc.), participants exhibited greater activation in anterior frontal sites than central and parietal sites (Balconi & Mazza, 2010). However, when considering that many of the facial visual processing centers are located towards the posterior of the brain, such as the middle fusiform gyrus and inferior occipital gyrus, it seems likely that these areas of the brain would be involved in mirror neuron activity in response to faces (Rossion, Hanseeuw, & Dricot, 2012).

Almost equally as relevant for the mirror neuron system is the interpretation of bodies—especially when they convey emotions. Knowledge of one's own expressive gestures can facilitate the understanding of what another individual is trying to convey through their own body language, such as fear or danger, and contribute to continued survival (de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004). Very few studies have used EEG and expressive body images, but work done by de Gelder et al. (2004) with functional MRI suggests that viewing bodily expressions of fear activates central structures such as the premotor cortex, middle frontal gyrus, and the parietal cortex. It seems quite possible that emotionally expressive images of faces and bodies can not only produce mirror neuron activity, but can also influence where it might occur in the brain.

The purpose of the proposed study is to examine how stimuli content influences the relative location of mirror neuron activity through mu-wave suppression. Participants will a view series of face and body images on the computer that express the emotions anger and fear. Participants will categorize each face and body image by their representative emotion using a designated key press while their mu-wave activity is recorded through EEG. I predict that viewing emotionally expressive face images will result in activity localized in the posterior area of the brain while expressive body images will result in more centralized activity.

Methods

Participants

Twenty individuals participated in this experiment. These participants were University of Puget Sound students enrolled in summer-term classes or otherwise present on campus during the summer months. Participants were provided a $20 incentive in exchange for their participation.

Procedures and Materials

Participants were first hooked up to the electroencephalograph (EEG). The EEG used in this study was a 32-channel Biosemi active electrode system, with 32 electrodes attached to a fitted cap in a standard 10-20 configuration. After assessing the necessary size based on the participant's head circumference, the cap (equipped with plastic-coated holes compatible for electrodes) was fitted onto the head and a plastic syringe with a blunt edge was used to fill the holes with conductive gel (specifically known as Signa Gel). Once the holes were filled with sufficient levels of gel, electrodes were placed into the holes. Electrodes were also placed on the mastoid process behind each ear for reference and under the right eye to measure blinking artifacts. Facial electrodes were attached with adhesive small disks that are both easily and painlessly removed upon completion.

After the participants were completely hooked up to the EEG, they were presented with images of faces and images of bodies exhibiting emotion driven gestures (the emotions for both conditions being anger and fear) on a computer while the participant's mu-wave activity was recorded through the EEG. The face images were gathered from the Psychological Image Collection at Stirling (2015) and were gray-scaled, normalized, and standardized to a size of 232 x 366 pixels. The body images were retrieved from de Gelder & Van den Stock (2011) and a small black square (approximately 108 x 52 pixels) was placed over each blank face to avoid any potential interfering face processing. See Figure 1 for examples of face and body images. With each body and face image presentation, the participant was required to choose what emotion the image was portraying by pressing a specific key on the keyboard. The key choices for each emotion remained on the screen in order to ensure that the participant did not forget which emotion was associated with a certain key. Participants completed a total of 40 trials, with multiple breaks provided throughout the study. After the study was complete, participants were unhooked from the EEG and provided with their $20 incentive.

Results

EEG waves were analyzed using fast Fourier transform to produce an event-related power spectral density curve for the entire two-second window the each stimulus was presented. Mu-wave activity .5 s before stimulus presentation was used as baseline, and a log ratio was computed for each trial type, expressed as log(stimulus/baseline). Both face and body stimuli induced significant mu-wave suppression when compared to baseline activity (all $ps < .001$). However, face and body stimuli did not differ in amount of mu-wave suppression across regions of interest, suggesting that the location of mirror neuron activity for faces and bodies did not differ in location (see Figure 2).

Discussion

These results suggests there is no difference in overall mu-wave suppression between face and body stimuli. The location of mu-wave suppression also did not vary by stimulus type. The fact that the location of activity did not differ between stimuli suggests that the human mirror neuron system supports understanding of emotional content independent of stimulus type and specialized cortical processing regions. The independence of the mirror neuron system from specialized face and body processing regions has been found in other research, with the main areas involved in mirror neuron activity including those related to sense of movement and the production of movement (Spaulding, 2013). Rather than being tied with the specialized processing of stimuli, the mirror neuron system appears to be more crucial for the interpretation of action.

Because mu-wave suppression varies through time, future research may focus on examining the dynamics of mu-wave suppression through time using time-frequency wavelet decomposition. Perhaps face and body stimuli will differ within particular time frames after stimulus onset. This study integrated suppression across the entire two-second stimulus presentation window, thus we were not initially able to look at mu-wave suppression throughout the time the stimulus was presented. Another potential limitation may be the use of EEG to examine the location of mirror neuron activity. Given its poor spatial resolution, EEG may not be the best neuroimaging method to determine relative mirror neuron activity. Future research may use methods with better spatial resolution such as fMRI to investigate if their truly is a difference between the location of face and body processing by mirror neurons. Certainly as time progresses more research will appear on mirror neurons and its potential status as the neural basis of empathy and other complex social behaviors like imitation.

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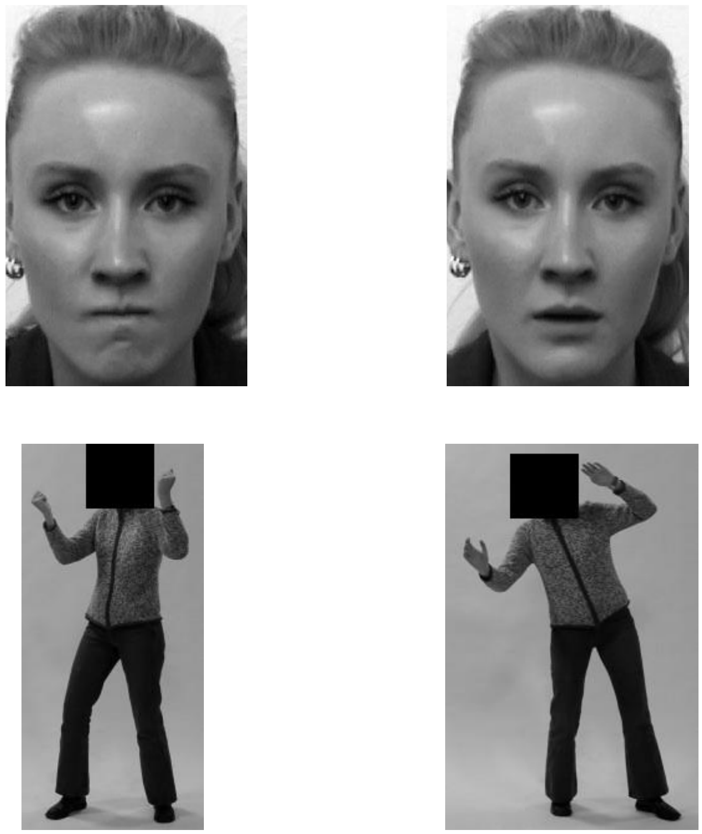

Figure 1. Emotional face and body images used to assess mu-wave activity. For both types of images, photographs on the left represent the emotion anger and the images on the right represent fear. Face images were adapted from datasets retrieved from http://pics.psych.stir.ac.uk/. Body images were adapted from "The Bodily Expressive Action Stimulus Test (BEAST). Construction and validation of a stimulus basis for measuring perception of whole body expression of emotions," by B. de Gelder and J. Van den Stock, 2011, *Frontiers in Psychology, 2*.

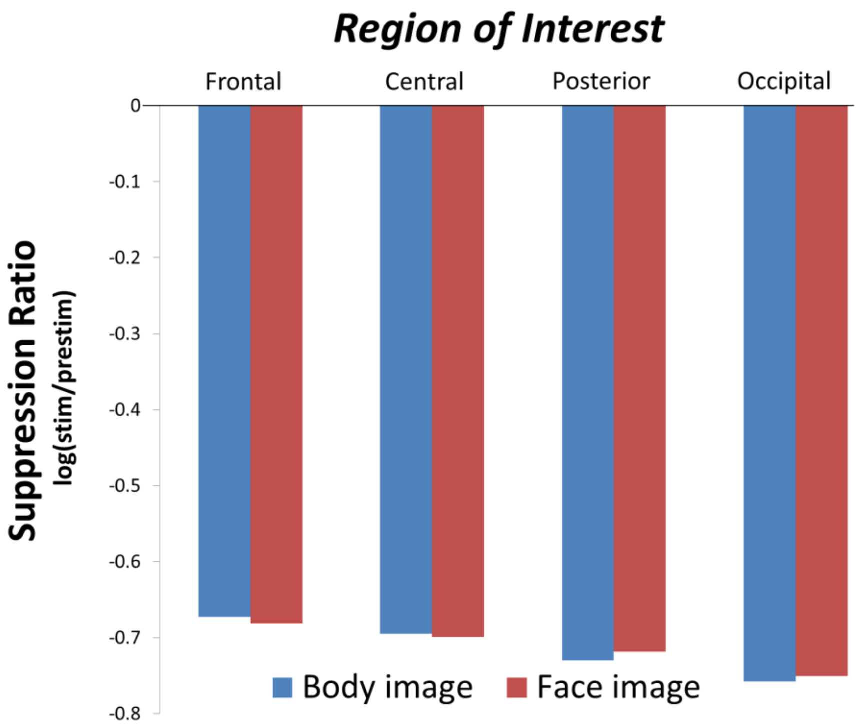

Figure 2. Resulting mu-wave suppression ratio based on region of interest for face and body images. Shorter bars indicate greater suppression.