University of Nevada, Reno

Neural Correlates of Facial Perception and Emotional Recognition

A thesis submitted in partial fulfillment
of the requirements for the degree of

Bachelor of Science in Neuroscience and the Honors Program

by

Courtney Matera

Dr. Michael Webster, Thesis Advisor

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We recommend that the thesis
prepared under our supervision by

COURTNEY MATERA

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Neural Correlates of Facial Perception and Emotional Recognition

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Michael Webster, Ph.D., Thesis Advisor

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Tamara Valentine, Ph. D., Director, **Honors Program**

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Abstract

Current models of face perception hold that expressions are encoded relative to a norm or neutral face. Anti-expressions are created by projecting an expression (e.g. a happy face) through the neutral face to form the opposite facial shape (anti-happy). The two faces thus differ from the norm by the same physical amount, but may differ in their emotional salience. The role of expressions and anti-expressions as related to the brain response from a psychological aspect is still unknown but imperative to nonverbal communication. This study will examine the nature of this norm-based coding by comparing neural responses to an expression and its anti-expression. The study used electroencephalography (EEG) recordings to test the relative strength of expressions and anti-expressions. We found there was a significant brain response when a subject was presented with a pairing of expressions versus anti-expressions as well as expressions versus neutral faces using real faces. The results of these studies helped to reveal how the brain represents information about faces and facial expressions. These findings can also support further research on the importance of the recognition of expressions, paired emotions and nonverbal communication in patients with neurological disorders that do not have that trigger.

Acknowledgment

This research was supported by the Honors Undergraduate Research Award. We thank our colleagues, graduate students and professors from University of Nevada, Reno who provided their skills and knowledge that greatly assisted and contributed to the research.

We thank Michael Webster, PhD of psychology, supervising this research project; as well as Sean O'Neal and Scott Gwinn who contributed their time to help set up the experiment, create the stimuli and conditions as well as run through the experiment. Without these people, this research would not have been possible.

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Introduction

Faces are among the most important and salient visual stimuli that humans encounter, and pose enormous challenges to visual processing. All faces are structurally similar (e.g. two eyes and a nose), and thus individuals differ only in subtle ways according to the higher-order relationships or configurations between features such as mouth, eyes and eyebrows (Chan, 2009; Maurer, Grand, & Mondloch, 2002). Moreover, the visual system ignores variations in the image such as lighting or pose changes in order to identify individuals (for example, to tell from different viewing angles and poses that those features belong to the same person), while at the same time detecting variations in facial features (e.g. to tell if the person is happy or angry) (Calder & Young, 2005). A complex network of neural systems are engaged in solving these perceptual problems (Haxby, Hoffman, & Gobbini, 2000), but the actual mechanisms underlying face perception remain poorly understood.

This project will examine the neural correlates and coding strategies underlying the perception of facial expressions. A small number of six basic expressions are universally recognized and innate (happy, sad, angry, disgusted, afraid, surprised) (P. Ekman, 1992). Of those six emotions, an individual can infer which emotion might be present from just the slight movement of another individual's mouth or eyebrows (Wood, Rychlowska, Korb, & Niedenthal, 2016). The standard model is that, like facial identity, these expressions are encoded relative to a neutral face or norm (A. L. Skinner & Benton, 2010). This model predicts the existence of anti-expressions or faces that lie on opposite sides of the norm; more specifically, relative to a neutral face in the center, in one direction away from the center leads to one of the basic six expressions and on the directionof the continuum model leads to the anti-expression, which is geometrically the opposite of the features (e.g. eyebrows, mouth, eyes and cheeks) of the basic expression. The word opposite refers to the muscle movements used on each of the features to make an expression being reversed to create the anti-expression. However, while expressions and anti-expressions are physical opposites, it remains unclear how they are processed perceptually or psychologically.

The motivation behind this study is related to the shapes and space in which the features of a face are located that gives information about the expression and anti-expression (which are on equivalent but opposite sides of the continuum mentioned above). If all that mattered was the information about a shape, then there would be equal neural responses when presented with both an anti-expression and an expression; however, it is known that expressions have special meaning with differences in the psychological aspects as well as trigger features so an expression may result in a stronger response. Regarding neutral faces in a norm based model, it is also expected that an expression would create a stronger response due to the more distinctive stimuli. David Leopold claimed that faces were coded relative to the average and the response depends on the distinction of the face (Leopold, Rhodes, Müller, & Jeffery). In the present work, I will examine the relative salience of basic facial expressions and faces that have the opposite configurations (as seen in Figure 2 on page 12), as well as test the importance of a neutral face in the representation of expressions. The work will involve EEG recordings and the SSVEP technique to measure face-selective neural responses for different expressions. This technique would allow for the rapid alternation of paired stimuli which would highlight significance in responses between the two.

Facial expressions are thought to be universal or innate and their identification is important for survival. Being able to distinguish between facial expressions and developing a psychological attribution to them is critical for an individual’s ability to pick up on social cues and improve communication, with facial expressions playing “crucial roles in non-verbal communication” (de Santana, de Souza, & Feitosa, 2014). These facial expressions set a precedent for the mood of a conversation or give insight into how a person might behave or be feeling, which then allows the other person to respond in the most efficient manner. Moreover, many disorders have a disassociation with emotion and expressions such as emotion-induced blindness, asbergers, autism, and schizophrenia. Understanding the basis for neural processing of expressions could provide insight into whether people with these disorders attribute different feelings to a particular emotion or if they instead feel nothing at all. To process basic emotions and nonverbal “social cognitive information” there is brain activation mainly in the temporal region of the parietal occipital lobe. Previous research has suggested that in people with some of the disorders listed above, there is a decrease in activation of these areas associated with specific face neural correlates for basic emotion (Goldschmidt et al., 2014).

Background

Facial expressions correlate with the anatomy and physiology of underlying muscle movements (Neth & Martinez, 2009). However, the response to stimuli of such expressions seems to have special psychological significance because the expressions tend to convey the emotional state of the individual. For example, a smile can represent happiness or joy (Rotenberg, 2011).

Facial Expressions

Facial expressions are a series of configural shapes on a face in space that are arranged in stereotyped ways (Neth & Martinez, 2009; Andrew L. Skinner & Benton). The space they are configured in can also be defined as psychological space, where features are geometrically aligned against a “norm” face (Adolphs, 2002; Neth & Martinez, 2009). A norm face is defined as the center of psychological space and the features can either be graphed on a continuum from that center or be identified as a discrete expression- an expression that is clearly defined within the six expressions that have been distinguished (Adolphs, 2002; Chan, 2009; Andrew L. Skinner & Benton).

Innately Recognized Expressions

There are six expressions that have been identified and are recognized innately and cross-culturally based on different facial arrangements (Paul Ekman, 1994; Izard, 1994; Neth & Martinez, 2009). The basic expressions have been determined to be happiness, anger, fear, disgust, sadness and surprise (Neth & Martinez, 2009). In order to distinguish between these different expressions, an observer draws upon prior knowledge and takes a holistic approach not only to asses that a smile means happy or a face means frowning but also if that expression is genuine or superior (Rotenburg, 2011). Expressions are also thought to be broken down into one of two categories, discrete or dimensional (Chan, 2009; A. L. Skinner & Benton, 2010). The discrete category means that the expression conveys a specific emotion and dimensional suggests that facial expressions are conveyed on a dimensional valence that takes into account the pleasantness or arousal of a particular face (Chan, 2009; A. L. Skinner & Benton, 2010).

The established expressions play a critical role in nonverbal communication whether it is producing an emotional response, conveying an emotional response, or serving as a form of social communication (Adolphs, 2002; de Santana et al., 2014). The facial features of the expresser's face helps to identify a peer, their state of emotion and nature as well as the feelings or intentions of a person by association of what emotions an individual has encountered before while seeing those specific geometric compositions on previous expressers faces (de Santana et al., 2014; Izard, 1994). This strengthens the innate bond already created between expressions and emotions felt as an individual identifies the expression.

Recognizing and Perceiving Expressions

The two main components that build off each other and help an individual determine and assess the facial expression are recognition and perception (Adolphs, 2002). Perception relates to the process that occurs in relation to a stimulus, which relies sole on early sensory cortices and helps with configural processing of the relations between different facial features (Adolphs, 2002). Other aspects that can affect the perception of facial expressions is the distance at which the face is seen or how the features are arranged (Neth & Martinez, 2009). Recognition is one level higher in processing information and is not based purely on configural process but also incorporates knowledge that has been acquired to give us information about the world and memory (Adolphs, 2002). Another component that can be factored in is something called categorization which categorizes stimuli based on the visual appearance as well as what prior knowledge one has about them which can incorporate the innate knowledge of expressions as discussed earlier (Adolphs, 2002; Neth & Martinez, 2009). This drawing back on prior knowledge of visual appearances relates to the previous paragraph that discussed Izard's (1994) belief in a link created between an expression and the feelings experienced by the observer when they saw the same specific expression on previous expressers' faces. The importance of recognizing and perceiving faces and these facial expressions is to be able to obtain vital information about social contexts of the emotion which helps with communication and mediating social behaviors (Chan, 2009). This information can give insight to social cues and how facial expressions contribute to social development. However, previous experiences and prior knowledge form the areas that create emotion based on expressions and can sometimes vary from one individual to another which can alter or bias the perception of the facial expressions from the observer (Chan, 2009).

Anti-expressions

As denoted in the paragraphs above, expressions are stereotyped variations in faces that can be represented as specific changes relative to a neutral face or norm. Anti-expressions are the opposite changes relative to the norm. Each facial feature location on a prototype face has a specific distance and direction that differ based on each expression created (Loffler, Yourganov, Wilkinson, & Wilson, 2005). In order to achieve the anti-expression, those specific computed markers for each expression are then moved in the direct opposite direction of the expression face (Andrew L. Skinner & Benton, 2012; Watson & Clifford, 2002). Essentially, the expression and anti-expression result in the same magnitude away from the neutral face. Due to this similarity, the response the brain produces may be symmetric because they are the same distance from the norm (A. L. Skinner & Benton, 2010; Andrew L. Skinner & Benton, 2012). However, due to the psychological aspect of expressions and the link they have to emotions and feelings of the observer, there may be no meaning or relevance of an anti-expression as the participant perceives the stimuli because they instead appear as an uninterpretable deformation of a face (A. L. Skinner & Benton, 2010).

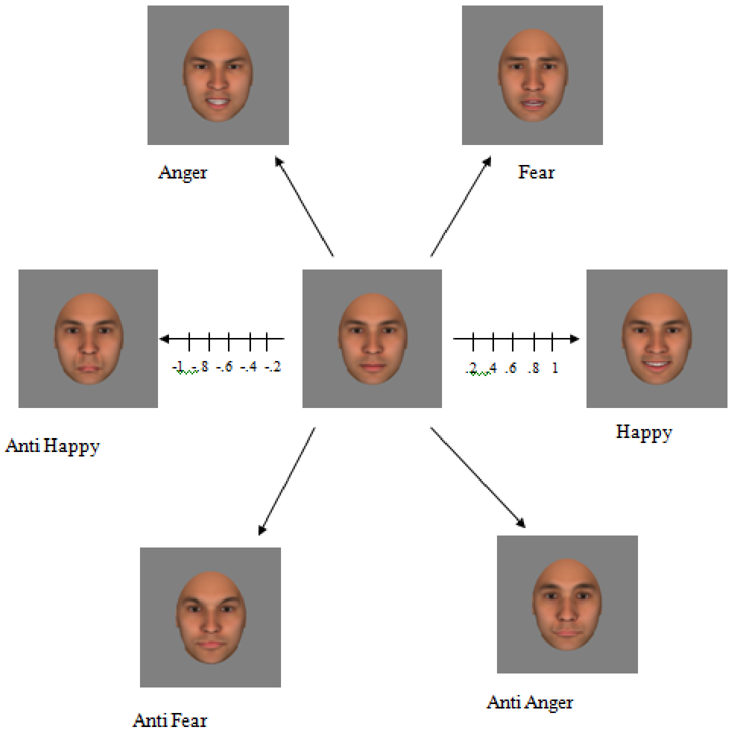

Figure 1. Continuum of faces graphed in relation to a norm face.

Significance

Expressions and anti-expressions, and the perception and recognition of emotions have been studied a number of times, each assessing if there are specific neural correlates of expression perception. This experiment tests the theories of Skinner and Watson in their attempts to portray that when an observer is presented with pictures of an expression and anti-expression, there is a meaning attached to the recognizable facial expression. Based on the prior studies discussed in the background and introduction, when presented with a face, there should be a signal in the brain indicating that a face appeared. If the expressions that are used are the same magnitude away from a norm face as an antiexpression, this signal should be symmetric. However, this experiment attempts to show that because there is also an emotional connection to an expression and that people have seen the specific geometric alignments of these facial features in real life and with previous life experience, the signal produced should then be asymmetric. The asymmetry portraying the significance of the way the features are aligned creating a stronger neural response to the stimuli. This information and data can show the importance of dissecting facial features and distinguishing between different expressions as they produce different responses and emotions. Researching if a facial expression that is universally known can give a stronger signal than an anti-expression, that is not as easily distinguished, would answer the question of whether there is a psychological emotional link to expressions viewed. This experiment specifically focuses on whether expressions elicit a stronger neural response than neutral faces or anti-expressions and to see if in fact there are specific neural correlates of expression perception that causes this.

Hypothesis

My null hypothesis is that each of the expressions and anti-expressions should be similar and produce the same neurological responses because each of the stimuli are faces with different geometric configurations that are on equal and opposite sides of the neutral face. This predicts that the EEG signals would oscillate at six hertz as the stimulus faces are presented. However, there may be a change in the brain's responses to different expressions and anti expressions if they differ in their perceptual and psychological significance. The four conditions tested were average versus expression using synthetic faces, average versus expression using real faces, anti-expressions versus expressions and male versus female using neutral expressions. If there is a perceptual significance to a specific stimulus, then instead of getting an EEG signal at only six hertz, a participant would also have a signal at three hertz since the two stimuli differ. My hypothesis is when an expression and antiexpression stimulus are presented in succession; there will be an additional signal at three hertz, along with the six hertz signal resulting from the psychological attribution of the image of an expression.

Methodology

Participants

Seven undergraduate psychology students at the University of Nevada, Reno (X male) with a mean age of Y (*SD* = *Z*) participated in the experiment as part of the psychology course PSY375. Optical corrections were worn if required. Consent following IRB protocols was collected prior to beginning testing.

Commented [OSG1]: You may need to ask Sean for this if you don't already have it

Stimuli

Synthetic Images

Synthetic facial images were created using the program FaceGen. This program can be used to generate three dimensional head models according to certain specifications, such as gender, race and expression. Facial images produced by this program have been used in similar studies and have been shown to produce similar results to photorealistic images during human face processing experiments (Rosania, 2011; Thoma, Soria Bauser, & Suchan, 2013). One typical Caucasian male and one typical Caucasian female face were generated with neutral expressions (i.e. not displaying any specific emotion) (see figure 1). Each of these head models were then augmented using sliding scales available in FaceGen, to display the emotional states 'happy, 'anger' and 'fear' (see figure 2). Multiple expressions and male and female images displaying these emotions were used to help ensure that any observed effects could not simply be attributed to the properties of a single image and instead reflect more general processing of emotion. For each sex and emotion an anti-expression image was also created. This was done by moving the aforementioned sliding scales in FaceGen for each emotion to the opposite side of the neutral

Commented [OSG2]: You'll notice throughout that I've suggested taking out any mention of the other emotions as I think this will only confuse readers. At the end of the introduction you could mention of six basic emotions we chose to test three partly because of time constraints and also mention your methods points about that during image creation these appeared to be the most clearly expressed emotions.

starting point. As previously discussed in the Introduction, this process creates an image that is the physical opposite to an original emotional face but does not represent any recognizable emotional state (see figure 2).

The sliding scales used to generate the expressions and anti-expressions range from +1 (creating the strongest expression) to -1 (creating the strongest anti-expression), with 0 being a neutral face. The magnitudes chosen were values that allowed each face to express the strongest emotion while also ensuring that the anti-expressions still resembled a "normal" face without impossible contortions. In order to make sure the anti-expressions weren't contorted too greatly, each face generated required different values for each expression created on FaceGen. Fear was set at .6 and -.6 for the anti-expression happiness was represented by a smile set at .5 and -.5 Anger was set at .5 and -.5. The final images including male and female versions displaying each of the three expressions and their anti-expression, as well as the two neutral version (14 images in total) were cropped using a standard ellipse with a standard width and height of 198 x 264 pixels. These were presented on a NEC AccuSync 120 monitor with a working resolution of 1280 x 960 pixels and a refresh rate of 60 Hz. At a distance of 57 cm the images subtended visuals angles of 6.3 x 8.4 degrees.

Figure 2. Synthetic female (left) and male (right) faces generated using FaceGen, showing neutral expressions.

Commented [OSG3]: I haven't read your introduction but if it's not already in there I'm sure Mike will be emphasizing that you need to clearly explain the concept of a theoretical face space in which faces can be conceptualized as points that are defined by their direction (type of emotion, or race, or identity etc) and distance (strength degree of that emotion being/how expressive they are) from a central norm/neutral face. This concept can be referenced to:

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology*, *43*(2), 161-204.

And as I'm sure you know we're looking at whether anti-expression are also represented similarly in this space. Most other aspects of faces seem to be setup in terms of opposites however with expressions there's no reason why these socially meaningless anti-expressions should be given the same weight (i.e. produce the same level of activation) as a 'true' emotion.

Commented [OSG4]: Sean and I didn't communicate clearly enough on this and I assumed he would provide you with these details, so there's no way you could've known to include this stuff.

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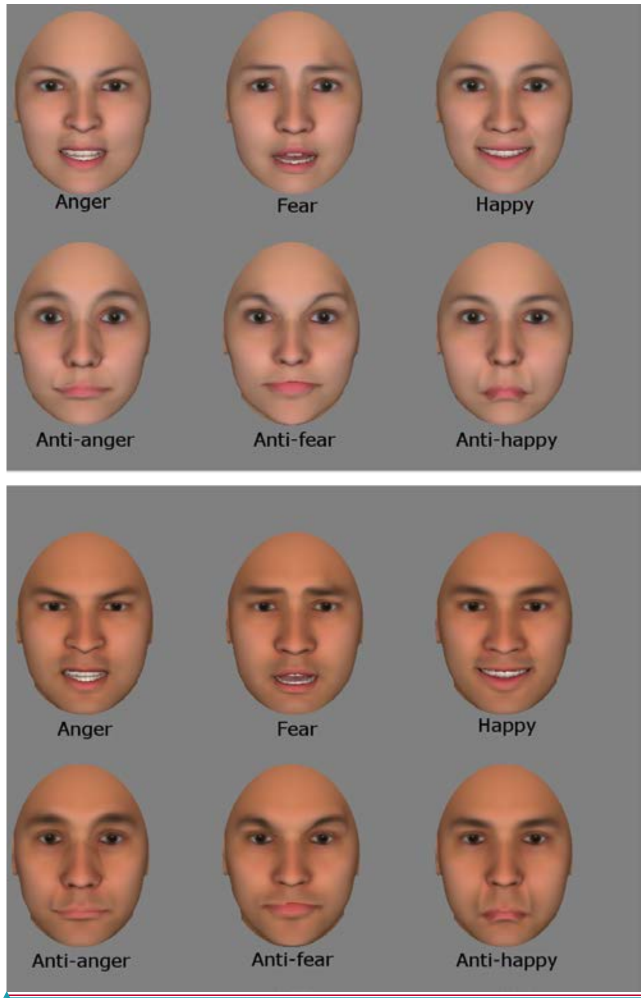

Figure 3. Synthetic female (top) and male (bottom) faces generated using FaceGen, showing the three expressions of anger, fear and happy and their anti-expressions below.

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Photo-realistic images

In addition to the synthetic images created using FaceGen, digital photographs of real individuals display the emotions happy, anger, and fear were collected. One male and one female

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showing each expression were selected from the Radboud Database (Langner et al., 2010) (see figure 3). As these were real individuals it was not possible for them to display anti-expressions. These images were cropped using a standard ellipse with a standard width and height of 303 x 407 pixels and were also presented on the same NEC AccuSync 120 monitor. At a distance of 57 cm the images meant the subtended visuals angles of 9.6 by 12.9 degrees.

Figure 4. Photorealistic male (top) and female (bottom) images taken from the RAFD database showing neutral, happy, fear and anger.

Procedure

Stimulus presentation

Images were presented using a technique known as Fast Periodic Visual Presentation (FPVS) ((!!! INVALID CITATION !!! {}; Rossion, Prieto, Boremanse, Kuefner, & Van Belle, 2012), sometimes also referred to as Rapid Serial Visual Presentation (RSVP) or Steady State

Evoked Potentials (SSVEP). This technique presents pairs of faces in rapid alternation at a fixed frequency. A single trial consisted of a 30 s sequence in which faces would alternate six times per second (i.e. at a rate of 6 Hz). Faces alternated by modulating the contrast of one image from zero to full contrast then back to zero in a sinusoidal fashion, at which point the next image varied in contrast following the same pattern (see figure 4). The experiment was divided into four conditions, each consisting of 12 trials. The order of conditions was counterbalance across participants. In the first condition a synthetic neutral face alternated with an expressive version of the same face. Each gender and expression were shown in two of the 30 s trials (two genders * three expression * two repetitions = 12 trials). In the second condition a photo-realistic neutral face alternated with an expressive version of the same face. In the third condition a synthetic face showing an expression was alternated with the same face showing the relevant anti-expression. In the fourth condition the synthetic neutral male face was alternated with the synthetic neutral female face. The fourth condition consisted of 12 repetitions of the same sequence. During each trial participants were instructed to remain fixated on a white cross displayed in the center of the screen, behind which the faces were being presented, and respond by pressing the space bar on the keyboard whenever the cross changed color. This color changed occurred randomly eight times during a trial. This task was included to ensure participants remained focused during the experiment.

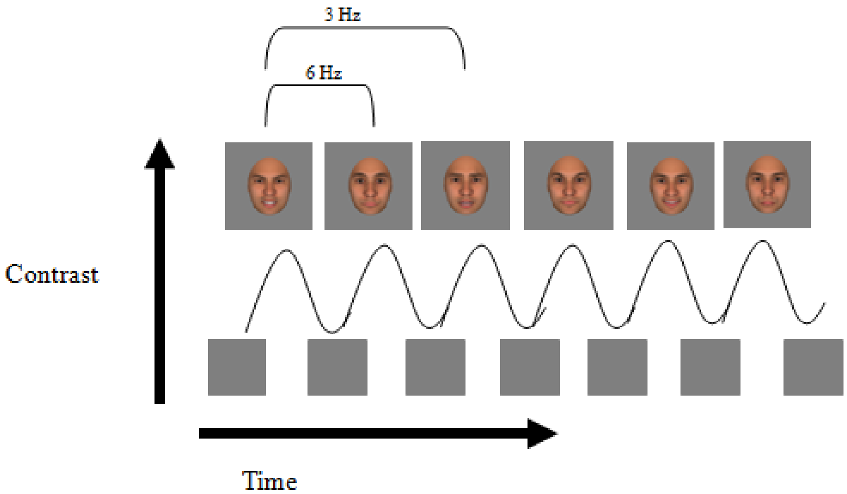


Figure 5. Figure shows an example of image alternations using contrast modulation in a single trial.

EEG recording

EEG recordings were taken using a BioSemi 128 system at a sampling rate of 2048 Hz. Participant~~’~~s’ head circumference was first measured in order to size them for a cap. The cap consisted of a 128 different wells for each specific electrode location. Distance from the nasion (between the eyes) to the inion (back of the head) was also measured so that the center well would be placed directly in the middle of the head and can get the most accurate ~~of~~ readings. Each of the wells along the cap was then filled with Sigma Gel electrode conductive gel and ~~then~~ each electrode~~s~~ was then connected to the appropriate -well~~s,~~ T~~t~~hree additional sensors were placed around the right eye and one on the left eye to detect eye movements and blinks.

Before beginning testing the signal from each electrode~~s~~ was inspected and adjusted until all fell within an offset of -20 to +20. Participants were told to refrain from blinking while a trial was being run.

Keywords

Expression in relation to this thesis is defined as the specific geometric placing of eyebrows, mouth, eyes, and nose to create a facial expression that can be readily recognized (Adolphs, 2002; Neth & Martinez, 2009; A. L. Skinner & Benton, 2010). Anti-expressions can be defined as the direct opposite facial configuration in terms of the shape changes created by the facial muscles (A. L. Skinner & Benton, 2010; Andrew L. Skinner & Benton, 2012; Watson & Clifford, 2002). The three expressions used in this experiment are happiness, fear and anger. Happiness is used to define the expression of an upward facing mouth and slightly squinted eyes. The facial image used to define fear is a face that is grimacing, teeth showing and eyebrows slightly raised. Anger is defined by angled down eyebrows, slightly squinted eyes and a slightly upturned mouth. Each corresponds to innate and stereotyped patterns of "facial action" that are readily recognized as expressions by others. These expressions can be contrasted with a "neutral expression" of emotion and corresponds to an average of all expressions creating the baseline expression. The features on the face such as the mouth, eyebrows, eyes, and cheeks are at a baseline level. The antiexpression is in essence a "deformation of faces" that should have no meanings "in relation to various real expressions" and are created by face morphing along the same value system as the expression (A. L. Skinner & Benton, 2010)

Results

Analysis

Commented [OSG5]: Here I think you should have an analysis section describing the steps we took during the analysis which I listed near the start of the power point slides

Files were recorded at 2048 Hz and then re-sampled at 512 Hz and in order to reduce line noise, a 60 Hz notch filter was used. There was also a .1 Hz to 120 Hz Butterworth band pass filter to filter out additional noise as well as cut down the recording time that stimuli were not being shown. For one subject, there were noisy channels that showed distortions unrelated to the data collected and four electrodes were interpolated. The signals from each electrode were re-referenced to all 128 electrodes and for each condition, the time periods within each condition were averaged. This is what is called the Fast Fourier Transform (FFT) and transforms the data from time to frequency. A baseline subtraction was computed for each participant's FFT and grand averages of both the FFT (which shows amplitude) and baseline subtractions (showing strength and significance) were computed and then displayed in the figures shown below.

Assessment

The results were assessed based on each of the different trials including: average versus expression using synthetic faces, average versus expression using real faces, expressions versus anti-expressions, and then gender. These trials were used to compare expressions that are baseline expressions with expressions that are seen in the physical world as well as to compare physical world expressions and expressions that are not physically possible to replicate. The gender trial was tested to use as a control as a face that is equal and opposite distance from the neutral face and are both seen in the physical world so therefore should emit the same signal. It should be noted that only six of the participants were used for the results due to electrical signals that were distorted by >300 microvolts across multiple epochs that were not related to eye blinks and only five participants' data were used for the average versus expression using real faces trial due to technical difficulties. The results of each condition are portrayed in four different figures. The first image (Figure 5) is the microvolts of activity graphed for each of the different Hertz frequency signals from two to seven. . The next two images are the activity at a six hertz signal which the graph shows five hertz to seven hertz graphed through a baseline subtraction to eliminate noise and create a baseline at zero to emphasize the differences in values at six or three Hertz; followed by a topographical map of the six Hertz signal and where the activity resulted across the occipital region of the brain. Finally, the last two figures were the same as the previous two figures except the activity was graphed through the subtracted baseline in relation to the three-hertz signal. In each of the graphs, results are based on electrodes PO8, PO10 and PO12 and the averages of the responses for each of the different expressions (anger, fear, and happiness). These electrodes correspond to the occipital-parietal region of the brain with even numbers representing the right hemisphere of the brain and low numbers corresponding to the medial placement of the electrodes. A one – tailed distribution was created and the z-scores were compared to see if the significance was greater than zero or not. The z-scores were calculated and assessed for significance, where if $p<.001$, then it is a significant response. In the neutral versus expression (synthetic faces) for 6Hz was 53 with $p<.001$ and for 3 Hz was .73 with $p = .233$. For the average versus expression faces (real faces) the z-score for 6 Hz was 53.815 with $p<.001$ and for 3 Hz was 7.1 with $p<.001$. In the expression versus anti-expression trial, the z-score for 6 Hz = 69.047 with $p<.001$ and for 3Hz = 5.938 with $p<.001$ and finally in the gender trial, the z-score for 6 Hz = 40.023 with $p<.001$ and for 3Hz = 11.581 with $p<.001$. The first trial of average versus expression using synthetic faces did not have a significant value to establish a three Hertz signal in addition to the six Hertz.

Commented [OSG6]: I'd divide the results up into separate sections each with their own subheadings for each condition

For the first condition of average versus expression using synthetic faces, the results were displayed in Figures 5 and 6 where there is a visible signal at six Hertz, however there is not a significant signal at the three Hertz frequency (Figure 7). In Figures 6 and 7 the topographical heat maps of the brain were generated which shows the level of activation in a region of the brain ranging from blue (baseline) to red (the most activity) and there seems to be brain activity in the right and left occipital-parietal regions, however the signals were not very strong across the brain.

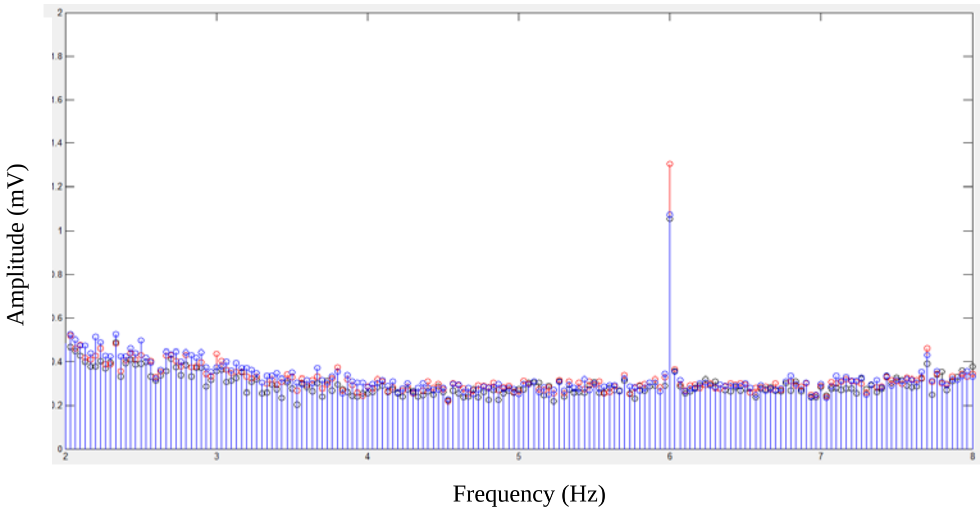


Figure 6. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of average versus expression using synthetic faces where each microvolt signal is graphed as a point on the graph at each frequency (Hz).

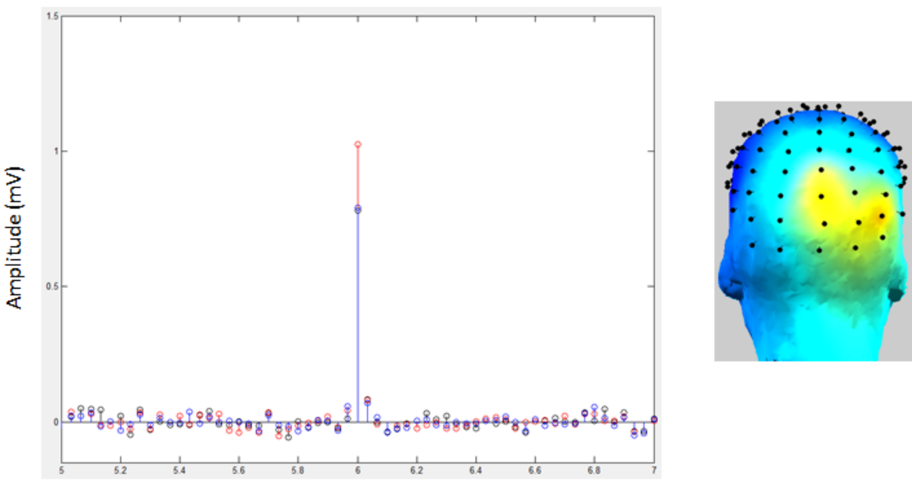
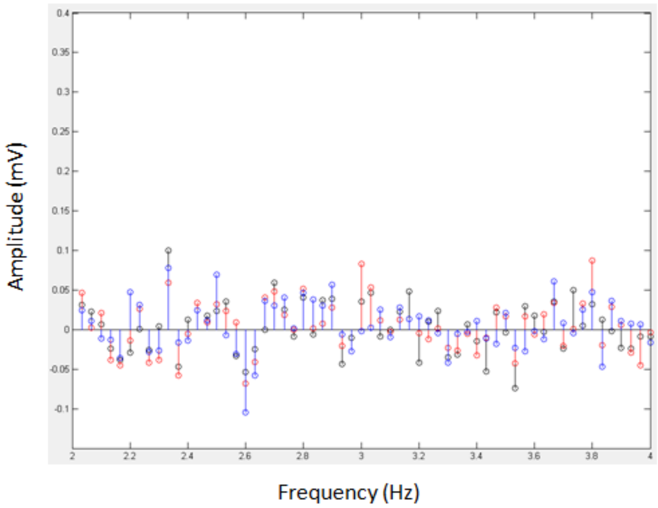


Figure 7. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of average versus expression using synthetic faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies five and seven. There is a heat map of activated brain regions at six Hertz.



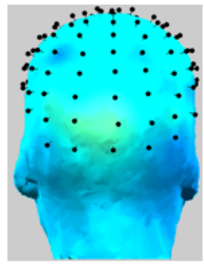


Figure 8. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of average versus expression using synthetic faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies two and four. There is a heat map of activated brain regions at three Hertz.

The figures below represent the condition of the average versus expressive faces using the real faces form RAFD. Looking at the figures 8 and 9, there appears to be strong distinct signals at both the three Hertz frequency and six Hertz. In the topographical map of figure 8, there is a strong signal coming from the right occipital-parietal area near the superior temporal gyri where faces are thought to be recognized. However, at the three Hertz signal topographical map in figure 9, there are medium strength signals ranging all over the occipital region of the brain and strong brain signals coming from both halves of the occipital-parietal areas of the brain where facial recognition areas are thought to be located as well.

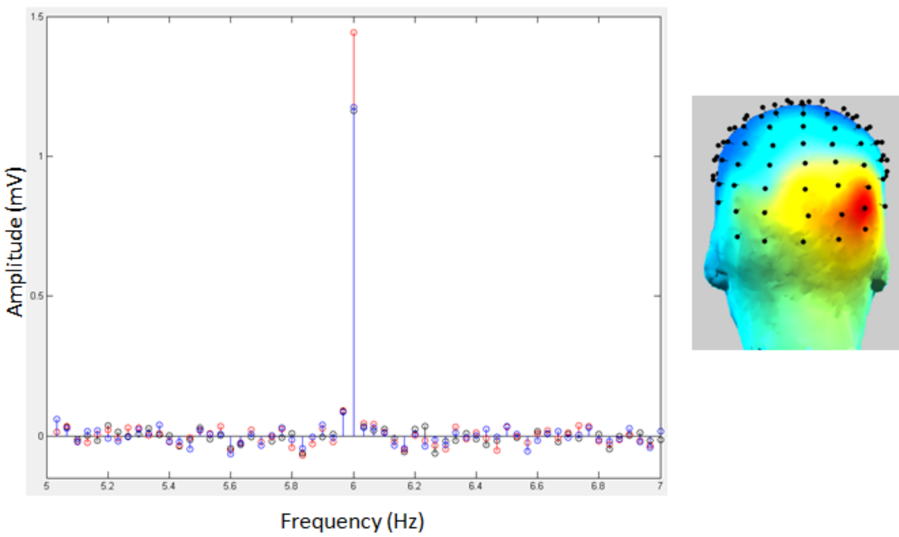


Figure 9. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of average versus expression using real faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies five and seven. There is a heat map of the activated brain regions at six Hertz.

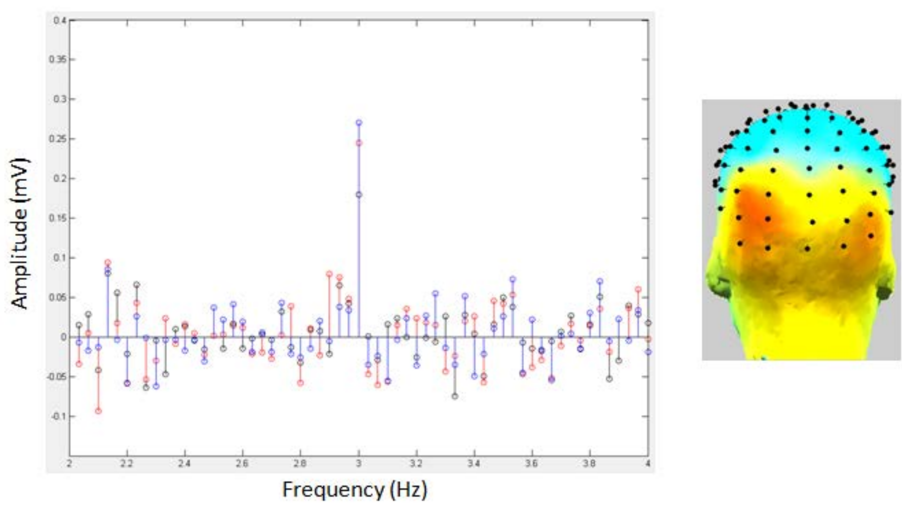


Figure 10. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of average versus expression using real faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies two and four. There is also a heat map of the activated brain regions at three Hertz.

In condition three of the experiment, the expression was tested against the anti-expression, the graphs represented by Figures 10 and 11, produced a significant response at both the 3 Hertz frequency and 6 Hertz.   Figure 10 displays the topographical map of the brain activity at 6 Hertz which alludes to a strong signal elicited from the right occipital-parietal region of the brain where facial recognition area is located. In Figure 11, the picture that displays the topographical map of the brain activity at 3 Hertz, the responses are more broadly based, however, the medium strength signals appear to be coming from the center occipital region as well as the same right occipital-parietal region as the 6 Hertz response.

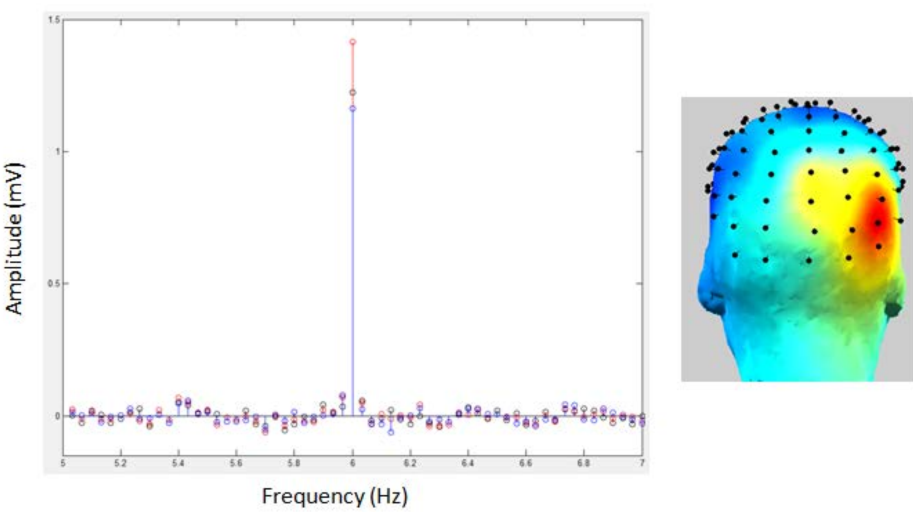


Figure 11. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of expression versus anti-expression using synthetic faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies five and seven. There is also a heat map of activated brain regions at six Hertz.

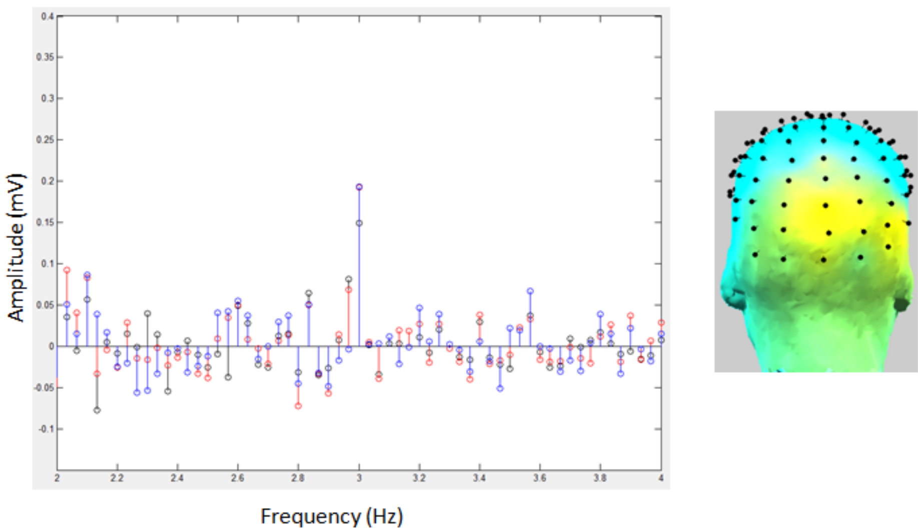


Figure 12. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of expression versus anti-expression using synthetic faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies two and four. There is also a heat map of the activated brain regions at three hertz.

In the final condition of gender, Figures 12 and 13 show the results from the gender control condition graphed by subtraction baseline and a signal at both six hertz and three hertz appeared. The six hertz signal displayed on the topological heat map of the brain appeared to show up in the right hemisphere near the occipital parietal region, like other trials discussed before. However, there was a difference in the region of the topological heat map of the brain when created at the three hertz signal. This map showed that the regions of the brain activated were spread out across the entirety of the occipital visual region instead of just one specific location in the brain, related to the FFA and facial recognition locations.

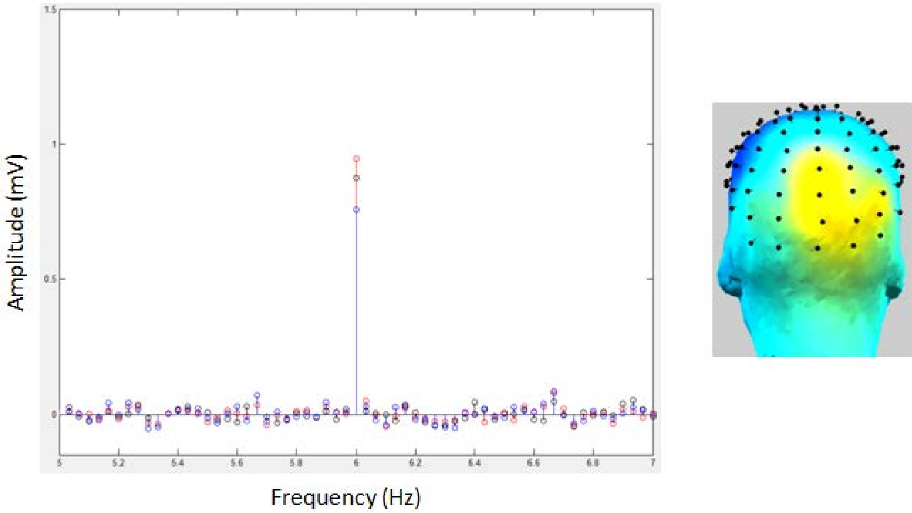


Figure 13. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of male versus female neutral expression using synthetic faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies five and seven. There is also a heat map of the activated brain regions at six Hertz.

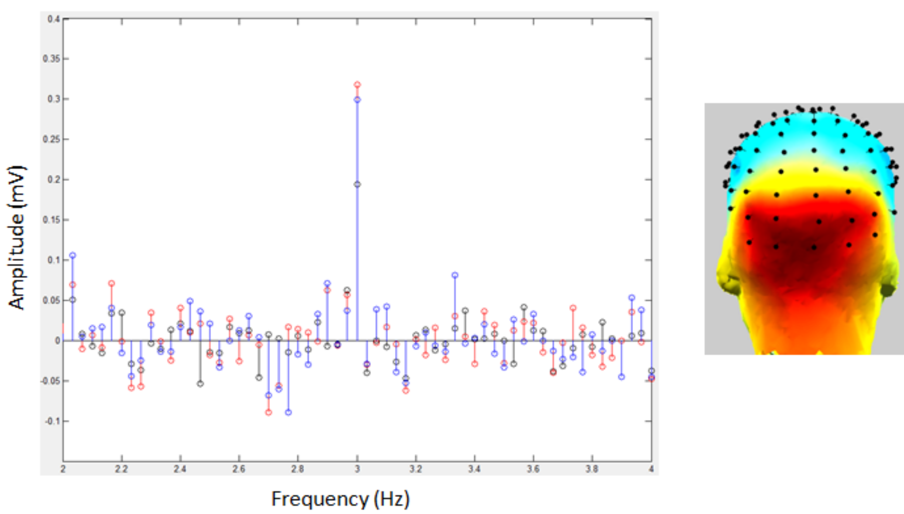


Figure 14. Averaged EEG responses of electrodes PO8, PO10, and PO12 for the condition of male versus female neutral expression using synthetic faces where the subtraction baseline was used to graph points on the graph at each frequency between frequencies two and four. There is also a heat map of activated brain regions at three Hertz.

Discussion

From the data collected, there appears to be an asymmetric brain signal for both the average versus expression trial using real faces and the expression versus anti-expression using synthetic faces. There was no significant difference in the condition of neutral versus expression using synthetic faces but there was an asymmetric neural response for the male versus female condition with neutral expressions. The male versus female condition was used to serve as a control because they were a pair of faces that were opposites but both were expected to be biologically important. Overall, these results suggest that there is in fact some significant perceptual aspect when participants observed expressions, anti-expressions and neutral faces there was not only recognition of facial features, but also in the ways in which the features were configured on the face. These results supported the hypothesis but bigger effects were found supporting the idea that expressions are coded in a special way or have more salience possibly due to the fact that there may be more neurons correlated with coding expressions or that they are more psychological and people attend to them more. Another major finding within this experiment was a difference between average and expressions using real faces and a reason this could have occurred is that they were distinctive faces with a stronger stimuli set that relates back to Skinner and Benton when they claimed that neutral faces may be coded as a default so neurons may be activated less when presented with a neutral face versus a stronger stimulus like an expression which varies from the average face. When looking at the heat maps of the brain activation, the regions that were activated were localized more in the temporal cortex which is where facial recognition areas are located. While the trial of gender neutral faces resulted in the same asymmetric signal, one being at six hertz the other at three hertz, the regions activated differed from the previous trials. The activation shown on the topological brain map (Figure 13) shows that there was not one specific facial region activated, but instead the entire occipital region and visual space was activated. There are a couple reasons among many that could explain this unexpected result which may have been due to low level feature differences meaning that the responses could be stronger based on brightness or could have been a result of the sensitivity to the stimuli meaning that one gender could have been more salient to each individual subject; however, it is not possible to tell which gender may have been more salient from the SSVEP technique because it only shows that one stimulus is more significant than another, just not which exact stimulus was stronger.

Conclusion

This experiment tested the strength of neural responses to stimuli of basic expressions, neutral expressions, and anti-expressions. With the asymmetry of responses collected at 6Hz, this represented that the stimuli presented had a differences in strength of neural responses where responses were evoked at 3 Hz as well as 6 Hz. The data collected in the experiment showed that there were asymmetric neural responses to expressions using real faces and anti-expressions, and to expressions versus a neutral face. Some implications of these asymmetries for understanding face perception are consistent with norm-based code in which neutral faces elicit weaker responses. The norm based code is the continuum that faces are graphed in relation to a neutral face which in fact becomes the baseline; suggesting that any expression that differs from this face will create a stronger response than to the neutral face. It also suggests that actual expressions engage greater neural processing than anti-expressions potentially because there are neural circuits specifically for coding real expressions. Anti-expressions, while they are the same magnitude away from a neutral face as an expression, are not physically possible in nature so there is an ambiguity of the faces that may make it difficult for the brain to code as a real expression. Thus while expressions and anti-expressions are equivalent in terms of their configural distance from the norm, they are not processed equivalently by the brain as measured with evoked potentials.

For further investigation, the different factors that could be changed from this experiment are the luminance of the pictures used for each gender, incorporating the other three expressions (sadness, surprise and disgust) to see if there are different responses to different expressions, and graphing all of the results separately for each expression rather than averaging them all together. Other experiments could also be added on to this one including a behavioral study that would ask subjects to look at expressions, anti-expressions and neutral faces and rate them based on their perceived strength of the expression. This rating method may indicate how an anti-expression is perceived by individuals and if they are able to identify a possible expression based on the ambiguity of the face. Another experiment that might be able to be done is an adaptation experiment where a subject is adapted to one of the two stimuli, whether it is an expression or anti-expression, and then run a paired SSVEP experiment again to see if there is a stronger response with the opposite stimulus that the subject was not adapted to. This adaptation technique may give insight to if individuals can be adapted to anti-expressions and cause their neural responses to have a significant response when shown it compared to an expression (which has already been portrayed through this experiment that the expression elicits a stronger response than its anti-expression).

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