

Running head: AGE RELATED EFFECTS OF EMOTIONS ON BRAIN POTENTIALS

Age Related Effects of Emotions on Brain Potentials

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### Abstract

This experiment will use event-related brain potential (ERP) measures to investigate the time course of emotional expression processing across six emotions (happy, sad, anger, fear, disgust, and neutral) in young and older adults. The experiment had participants perform a gender-discrimination task irrelevant to emotion. At frontocentral electrode locations approximately 160ms post stimulus, younger adults demonstrated a greater positivity for fearful faces as compared to neutral faces. Older adults showed no such effect. When presented with emotional expressions younger adults showed early activation at pre-frontal electrodes followed by activation at more posterior electrode sites. This also contrasted with older adults, who demonstrated persistent pre-frontal activations that began around 160ms and persisted until 800ms. Older adults' absence of a positivity elicited by fearful expressions relative to neutral expressions and the presence of an increased pre-frontal activation offers some support for the socio-emotional selectivity theory, which holds that older adults use cognitive emotion processes to regulate emotional stimuli.

### Age Related Effects of Emotions on Brain Potentials

The recognition of emotional facial expressions plays an important role in non-verbal communication and human social interactions. Accurate recognition and processing of emotions are necessary skills to properly function within society. Emotional expressions induce certain neural responses that provide immediate behavioral feedback in social situations (Ohman, Lundqvist, & Esteves, 2003). Despite extensive research in this area, there still is much controversy pertaining to the neural networks responsible for these reactions. Functional magnetic resonance imaging (fMRI) research and some event-related potential (ERP) research implicate distinct neural pathways responsible for the perception of distinct emotions (Adolphs, 2002, Batty & Taylor 2003). However, other ERP studies have demonstrated that the neural encoding of faces is the same regardless of the emotional information on the face (Eimer & Holmes, 2002). This experiment will use ERP measures to determine whether processing distinct emotions elicits distinct neural responses from the human brain. In addition to this first objective, this study will attempt to contribute to the field of emotional processing by comparing ERP waveforms obtained from young and older adults. There is very little research exploring emotional processing in older adults and the current research will determine if older adults process emotions via the same neural pathways as younger adults.

#### *Emotional Processing in Younger Adults:*

In an attempt to answer the first question, neuroimaging studies have shown distinct brain regions responsible for different steps of emotional processing. The initial perceptual analysis of faces recognizes static structural features of the face used for identification and takes place in the inferior occipital gyrus and in the middle fusiform gyrus (Haxby, Hofman, & Goodman, 2000). Whereas, the superior temporal sulcus processes dynamic aspects of the face such as expression,

eye movement, and mouth movements (Labar et al., 2003). The amygdala and orbitofrontal cortex are believed to be responsible for the rapid processing of emotional and motivational significant facial expressions, while the prefrontal cortex, anterior cingulate, and somatosensory cortex have been linked to conscious representation of facial expression and to thoughts and reactions (Adolphs, 2002). These individual processes put together represent a possible neural network for the processing of emotions.

The findings of these fMRI studies identify certain neural networks involved in emotional recognition. However, due to the temporally inaccurate nature of fMRI, researchers have turned to ERPs (event-related potentials) in order to get a more comprehensive picture of the timeline involved in emotional recognition. One particular study finds that in young adults, the detection and analysis of fearful faces relative to neutral faces consists of two phases as seen in *Figure 1*. The first phase is an initial, rapid registration of facial expression over prefrontal brain areas which occurs approximately 120 ms post stimulus. This first phase is characterized by a sharp positivity in ERPs evoked by fearful faces relative to those elicited by the neutral emotion. The second phase is characterized by an extended processing of emotional faces reflected by a broad distribution in ERPs beginning around 200 ms that continues well beyond 1000 ms, at more posterior brain regions (Eimer and Holmes, 2002).

A follow up to the original Eimer and Holmes (2002) ERP study looked at six distinct emotions: angry, disgusted, fearful, happy, sad, and surprised. The experiment presented a pair of faces in the peripheral vision of the participant. A fixation point was presented in between each pair of faces which were centered in the middle of the screen. In an emotionally relevant task the participant determined whether the face showed a neutral expression or an emotional expression. The ERP waveform elicited in this study was identical to those found in previous

studies across all emotions. As seen with in previous research looking at fearful faces versus neutral faces at the Fz electrode, there was an enhanced positivity for emotional relative to neutral faces starting at about 160ms. However, the onset of the positivity was delayed as compared to the previous study, a likely side effect of the peripherally placed stimuli. Despite the delayed effect, an additional enhanced negativity for fearful relative to neutral faces was elicited at lateral posterior electrodes between 220 and 320msec at the N170 component. The N170 component is normally elicited in response to the structural features of faces (Balconi & Lucchiari, 2005). Furthermore, the study found that the face-specific N170 component was unaffected by emotional expressions which supports the theory that structural encoding is entirely insensitive to information derived from emotional facial expressions (Eimer & Holmes, 2003). The researchers mentioned the emotionally relevant task as a potential confound to the study, because it is possible that cognitive factors could play a role in the witnessed effects (Eimer and Holmes, 2007).

On the other hand, there is ERP evidence that argues that distinct neural systems are activated while processing particular emotions. Researchers use this evidence to argue that since different parts of the brain are associated with different emotions they should have ERP signatures. For example, the amygdala has been identified in the processing of fear (Labar et al., 2003) whereas the insular cortex has been linked with both the recognition and the experience of disgust (Aldoph, 2003). Therefore, since neural activities associated with distinct emotions are spatially different from one another they should also be temporally different, and they should elicit distinct ERPs as a result. One such study found distinct ERP modulations for different emotions (Batty & Taylor, 2003). More specifically, they found latency and amplitude

differences existed among all emotional expressions at 140ms (N170 component)<sup>1</sup>.

Furthermore, the studies found that positive emotions evoked N170 significantly earlier than negative emotions, and the amplitude for fearful faces was larger than for neutral or surprised faces. Additionally, the studies showed that at longer latencies (330-420ms) negative emotions elicited later, distinctive activations (Batty & Taylor, 2003)

The primary goal of this proposed study will be to clarify this apparent conflict and to determine if distinct waveforms are elicited from the six distinct emotions: angry, disgusted, fearful, happy, sad and neutral. In addition to the clarification of whether distinct neural pathways are elicited for different emotions, an equally worthy question exists regarding how emotional processing differs with older age. Although emotional recognition and processing is important at any age very little is known about the process in older adults.

#### *Age Related Changes in Emotion Recognition*

The majority of aging research has concentrated on the observation that most cognitive abilities decrease with age. In order to compensate for this loss, some research has shown that older adults engage more of their brains in order to perform the same tasks as younger adults (Reuter-Lorenz, 2002). Despite these reported cognitive deficits, all functions may not decline in older age. Research has found that older adults have intact physiological mechanisms to detect emotion and, in some instances, experience greater emotional salience compared to younger adults (Carstensen and Charles, 1998).

fMRI research has demonstrated that older adults have a different neural activation pattern than younger adults when processing emotion. More specifically, relative to younger adults, older adults have less activation in their limbic systems, with greater activation in the anterior cingulate gyrus (Gunning-Dixon et al., 2002). Another neuroimaging study looking at

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<sup>1</sup> The exception was an effect at 100 ms (P1) which occurred globally across all emotions.

brain activation in response to the presentation of fearful stimuli found reduced amygdala activation in older adults as compared to younger adults (Mather et. al, 2004). Despite these findings, there are no ERP studies that directly examine the temporal aspects of facial emotional processing in older adults. One experiment looked at non-facial pictures that induced certain emotions, and they found that older adults showed “an enhanced subjective arousal but a dampening of brain activity associated with early processing” (Wood and Kisley, 2006). The socioemotional selectivity theory (SST) helps explain this reduction in activation to negative emotional stimuli witnessed in older adults. This theory suggests that older adults foster the maintenance of positive emotional experiences while suppressing negative emotional experiences like fear (Carstensen et al., 2000). The argument is these emotion regulatory behaviors facilitate adaptive social functioning throughout adulthood (Fredrickson & Carstensen, 1990). This study will seek to explore whether this suppression of brain activity in response to negative facial expressions can be witnessed in older adults through electrophysiological measures.

### *The Present Study*

Current research is limited in its findings. One branch of research found distinct ERPs, with differences in the face-relevant N170 component (Batty & Taylor, 2003) when younger adults were presented with distinct emotional expressions. While another vein of research found no differences between emotions, finding instead differences in frontocentral (with respect to the electrodes) waveforms when emotional expressions were compared to neutral expressions (Eimer & Holmes, 2002). Though both arguments are compelling, only limited conclusions can be drawn from either because of the cognitive confounds associated with emotionally relevant tasks in both studies.

Additionally, there is some research that hints toward a difference in emotional processing between older and younger adults, however there is no definitive answer to this or any of the questions proposed.

The ultimate goal of this experiment is to accurately chart the timeline of emotional recognition across age and the six basic emotions. This will be accomplished by attempting to eliminate confounds that plagued earlier emotional research in younger adults and to contribute to the very sparse literature that that exists on emotional processing in older adults. More specifically, cognitive and attention related confounds will be eliminated by providing participants with an emotionally irrelevant goal, but a face-relevant task for a foveally presented stimuli. In this manner, attention related delays and potential cognitive-emotional confounds seen in earlier research will be minimized. The current research will use electrophysiological measures to assess emotional processing while participants are presented with a standardized set of emotional faces. Comparisons will be made across age and emotion to determine whether older adults elicit different ERP waveforms than younger adults, and to also determine if those differences are consistent with the SST. The new measures taken in this research should lead to a more comprehensive picture of emotional processing in older and younger adults.

## Methods

### *Participants*

Participants were recruited on a volunteer basis from the Atlanta Metropolitan Area. Thirteen younger adults between the ages of 18 and 30 (8 men and 5 women) participated. The younger adults received extra credit in their classes for their participation and were recruited from the student body at the Georgia Institute of Technology. Eleven older adults between the ages of 60 and 78 (6 men and 5 women) were recruited by soliciting them from an established



participant pool. The older adults were paid 20 dollars for their participation in this experiment (10 dollars per hour).

### *Stimuli*

The stimulus set is made up of 96 distinct faces. These are made up of 8 female faces and 8 male faces, each of which demonstrates six emotions: disgust, sadness, happiness, anger, fear, and neutral. The stimulus set has been rated independently on the perceived emotion it elicits and has been standardized across all six emotions. Furthermore, each picture has been standardized to have the same luminance, color, and size. Each picture was presented at the center of the screen, subtending approximately three degrees of visual angle.

### *Design and Testing Procedure*

The experiment was broken down into seven blocks. All the blocks were identical and the division merely allowed the participants to rest in between blocks. Each block consisted of 96 randomly presented faces from a standardized stimulus set of sixteen different faces, each of which demonstrated six emotions. Participants were placed in a dimly lit, sound attenuated room 100 cm in front of a computer screen. Head movement was limited through the use of a chin rest. A keyboard captured responses. The participant's task was to correctly identify the gender of the face presented to them. The participants pressed the Z key on a standard keyboard if the face was female and the M key if the face was male. Prior to the experimental trials each participant was presented with ten practice trials in order to be familiarized with the task. During these practice trials the participant saw "correct!" on the screen if the answer was answered correctly and "incorrect" if it was answered incorrectly.

A single trial, as represented in *Figure 2*, consisted of a fixation cross presented in the center of the screen for 200 ms followed by the stimulus for 300 ms, followed by a blank screen for 1500 ms to allow time for the participant to determine the gender of the face on the screen. A face-oriented task was chosen in order to make sure the participant was attending to the face while it was on the screen.

#### *ERP Recording and Data Analysis*

Electrophysiological data collection consisted of recording EEG from a BIOSEMI Active-Two amplifier system. Scalp potentials were recorded from 32 scalp electrode sites according to a modified 10-20 system (Ag/AgCl electrodes mounted in an elastic cap). Particular attention was paid to prefrontal electrodes. Bipolar horizontal and vertical electrooculograms (EOGs) were recorded from additional Ag/AgCl electrodes placed around the eyes in order to monitor eye blinks and saccades. Data was recorded continuously during the experiment at a sampling rate of 500 Hz and band-pass filtered from 0.1 to 30 Hz. All scalp electrodes were referenced to an electrode placed on the left mastoid; the data was re-referenced offline to the average across all electrodes. The raw EEG was then segmented into epochs, including a 200 ms pre-stimulus baseline. Prior to data analysis, trials with eye movements were corrected (or rejected if a threshold of 100  $\mu$ V in EOG channels was reached). Trials with other identifiable artifacts were rejected manually. In addition, data was thrown out if the participants did not perform the gender differentiation task with at least 80% accuracy. Furthermore, data were discarded if excessive eye movements or blinks occurred, or if the participant fell asleep at any time during the experiment. Average waveforms were then computed for each condition for each subject. Finally, the grand average ERP waveforms were computed for each condition using the data from all subjects.

### *Statistical Analysis*

In order to draw conclusive results from these findings, repeated measures of analyses of variance (ANOVAs) were performed on ERP mean amplitudes obtained to distinguish between the different age groups and emotions. For younger adults at the Fz electrode, analysis was conducted with respect to the amplitudes of successive latencies (80-120, 130-170, and 210-350ms post stimulus, respectively). For older adults at the Fz electrode, analysis was conducted with respect to the amplitudes of successive latencies (80-120, 140-180, 205-345ms post stimulus, respectively). These analyses were conducted separately for posterior electrodes Oz, P8 and P7 to relate time to facial expressions, age, and hemisphere (left vs. right, for lateral electrodes only). Furthermore, paired samples T-tests were run to explore significant differences found by the repeated analysis of variance. The paired-sample t-tests compared mean amplitudes of all emotions relative to neutral.

## Results

### *Younger Adults*

Consistent with Eimer's research (Eimer & Holmes, 2002); all six emotions elicited the same basic waveform shape. Frontocentrally (i.e., at electrode sites ...), the waveform consisted of an initial sharp positivity that occurred between 150 and 200ms followed by a broader distribution that persisted well beyond 800ms. The first phase was characterized by a sharp positivity in emotional ERPs relative to those elicited by the neutral emotions, across all emotions. The second phase was characterized by an extended processing of emotional faces reflected by a broad distribution in ERPs that occurred after the initial positivity. This broad distribution was witnessed at later posterior brain regions. This distribution is best illustrated in *Figure 3* where all emotions were averaged and represented as a colored line superimposed over the neutral emotion. Also consistent with Eimer's findings the scalp distributions demonstrate

that the positivity originates in a frontocentral region, at approximately 120ms, followed by a later posterior distribution of activity that occurs between 320-800ms.

Also consistent with Eimer's research, a main effect of valence ( $F(1,12)=3.511, p < 0.02$ ) was found at the Frontocentral-Enhanced Positivity (FcEP) location, the positivity occurring between 130 and 170ms located at the frontocentral electrodes. After further investigation a significant difference ( $t(12)=-3.358, p < .007$ ) was found between the emotions of fear and neutral. The emotions of anger, disgust, happy, and sad did not differ significantly from neutral during this time interval. Additionally, there were no main valence effects between 80 and 120ms or between 210-350ms.

In the posterior electrodes there were no main valence effects between 80 and 120ms, 130 and 170ms, or 210 and 350 ms. Consequently, a difference in the N170 component was not seen across emotion. Furthermore, in contrast with Eimer's findings, there was no increase in negativity with respect to fearful faces compared to neutral in the period between 210 and 350 ms. The posterior emotional effects are shown in *Figure 5* which show ERPs to neutral and emotional faces obtained at the P8 electrode. No statistically significant differences between emotions were found in any of the posterior electrodes.

### *Older Adults*

Older adults demonstrated a similar waveform to younger adults across all emotions including neutral as shown in *Figure 7*. Frontocentrally, all emotions elicited two distinct phases. These phases were characterized by an initial positivity that started at about 160ms, followed by a broadly distributed negativity that lasted until approximately 500ms. Similar to younger adults, older adults experienced a positivity frontocentrally at approximately 120 ms as demonstrated in scalp distributions in *Figure 6*. However, instead of a posterior positivity at

later as seen in younger adults, older adults demonstrated a persistent frontocentral positivity that was present well beyond 800ms. Another difference is also seen in *Figure 7* in the graph of an emotional average superimposed over the neutral emotion for Fz. In contrast to younger adults, which show a marked positivity for all emotions as compared to neutral, older adults show no such positivity toward emotions.

This observation was statistically verified, because older adults showed no significant frontocentral or posterior main valence effects between 80 and 120ms, 140 and 180ms, or 205 and 345ms. The posterior waveforms observed at the P8 electrode are shown in *Figure 8*. Similar to the younger adults, there seemed to be no differences in the N170 component across emotion as reported in previous research.

### Discussion

The results confirm the successful reproduction of the waveform distribution illustrated in Eimer's research. This broad pattern of the waveform is defined by two phases. The first phase is characterized by an early positivity elicited at roughly 120ms, followed by a broadly distributed positivity and an enhanced negativity at lateral posterior sites that persists beyond 800ms. Also consistent with Eimer's findings an increased positivity to fearful as compared to neutral faces was found, a common, well documented product of fearful faces. The reproduction of this pattern in younger adults is an important step in itself. The successful reproduction of this pattern with novel stimuli, and in a different lab demonstrates that this emotional effect is reproducible and independent of the specific laboratory environment. More importantly this validates the proposition that differences found between older adults and younger adults are meaningful; they are not just as a product of environmental factors.

The enhanced positivity at the FcEP toward the negative emotion of fear as compared to neutral may be attributed to certain motivational effects. The early onset of these effects, at 120 ms, and the fact that these were recorded at the frontocentral region of the brain could mean that young adults actively regulate negative emotions. This almost immediate processing of negative emotions may allow individuals to react accordingly to potentially threatening stimulus from the environment. This need to react to potentially threatening stimulus may have an evolutionary basis, because in a potentially hostile environment it may have proven beneficial to react quickly to perceived threats.

The lack of posterior differences in the N170 component strengthens Eimer's argument that the processing of emotional faces is independent of the structural characteristics of the face. One possible explanation of this phenomenon is that the rapid processing of emotional facial expression occurs independently and in parallel to the creation of a perceptual representation of the face (Eimer & Holmes, 2003).

The early activation seen at approximately 160ms in the prefrontal regions, followed by a later activation at posterior sites, seem to suggest that higher order visual processing is only affected by emotion after it is processed initially at the frontocentral regions. Based on this assertion one could conclude this division of cognitive labor allows an almost immediate response to emotional stimuli; this immediate reaction would be especially advantageous in the presence of adverse stimuli.

The lack of positivity in older adults at the FcEP for emotional faces compared to neutral faces is consistent with Wood and Kislely's research, which observed an overall dampening of brain activity associated with the processing of emotional images. Furthermore, in contrast to the results obtained for younger adults, the older adults showed no increased activity when

presented with fearful faces. These findings suggest that with age, older adults show decreased reactivity to fearful information while maintaining reactivity for all other emotions. This is consistent with fMRI research that showed reduced amygdala activation in older adults as compared to younger adults (Mather et. al, 2004). This suppression of emotional information seems to suggest that older adults are better than younger adults at regulating socially-relevant emotional information.

This theory is consistent with the scalp distributions of older adults that show that the early prefrontal activation that is observed at approximately 120ms persists well beyond 800ms. This seems to suggest that older adults use distinct neural pathways to process emotion as compared to younger adults. This decrease in activity in response to fearful faces relative seems to suggest that older adults are not affected by negative emotions as much as younger counterparts. This greater activation of the prefrontal area even in later periods of processing seems to suggest that older adults may be actively regulating their emotions. One theory consistent with these findings is the socio-emotional selectivity theory, which suggests that older adults foster the maintenance of positive emotional experiences while suppressing negative emotional experiences like fear (Cartensen et al., 2000). The increased frontocentral activation combined with suppression of fearful facial expressions may provide further evidence that cognitive emotion regulatory processes facilitate this regulation of emotion.

In summary, the present study successfully reproduced the two-phased response to emotional facial expressions seen traditionally in younger adults, and found a very similar two-phased pattern elicited in older adults. The reproductions of these findings were done in a separate lab with different stimuli that eliminated potential cognitive confounds. The successful reproduction of these effects provides evidence this effect is generalized to all younger adults.

Additionally, an early frontocentral positivity followed by a later posterior positivity was witnessed in younger adults. This combined with the fact that no differences were found in the face-relevant N170 component support the theory that emotional information and structural information of facial expressions are processed in parallel pathways, allowing for more efficient processing and reaction to emotionally relevant stimuli. Furthermore, younger adults showed a greater neural activation in relation to fearful facial expressions as opposed to neutral expressions, and a greater positivity in relation to emotional as opposed to neutral facial expressions. However, older adults showed no such differences, and also showed greater frontocentral activation, which could be evidence for the regulation of socially relevant stimuli. Although the conclusions drawn from the scalp distributions should be taken cautiously due to the ambiguous nature of activation localization associated with ERP, this study is supportive of existing theories that demonstrate increased emotional regulation with age. Future studies could reproduce this study with further sub-sections of age groups in order to create a gradient of emotional regulation over the life-span rather than at the extremes of youth and age; in this manner a more complete picture of emotional processing and regulation can be created.

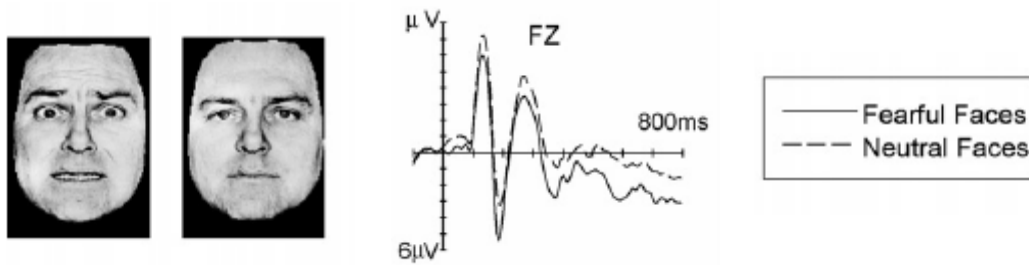


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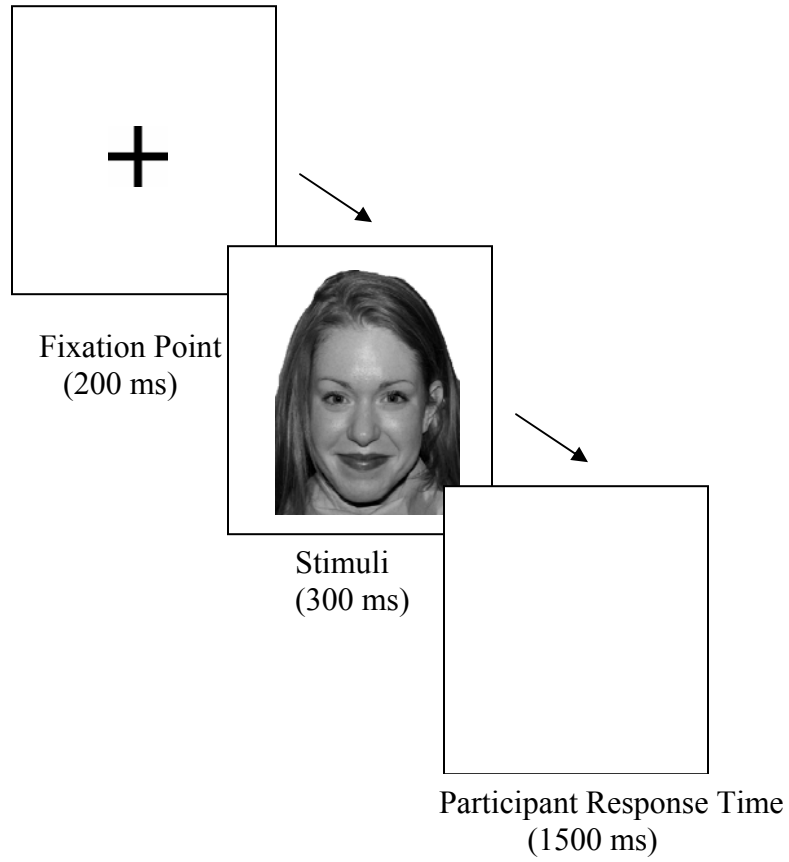
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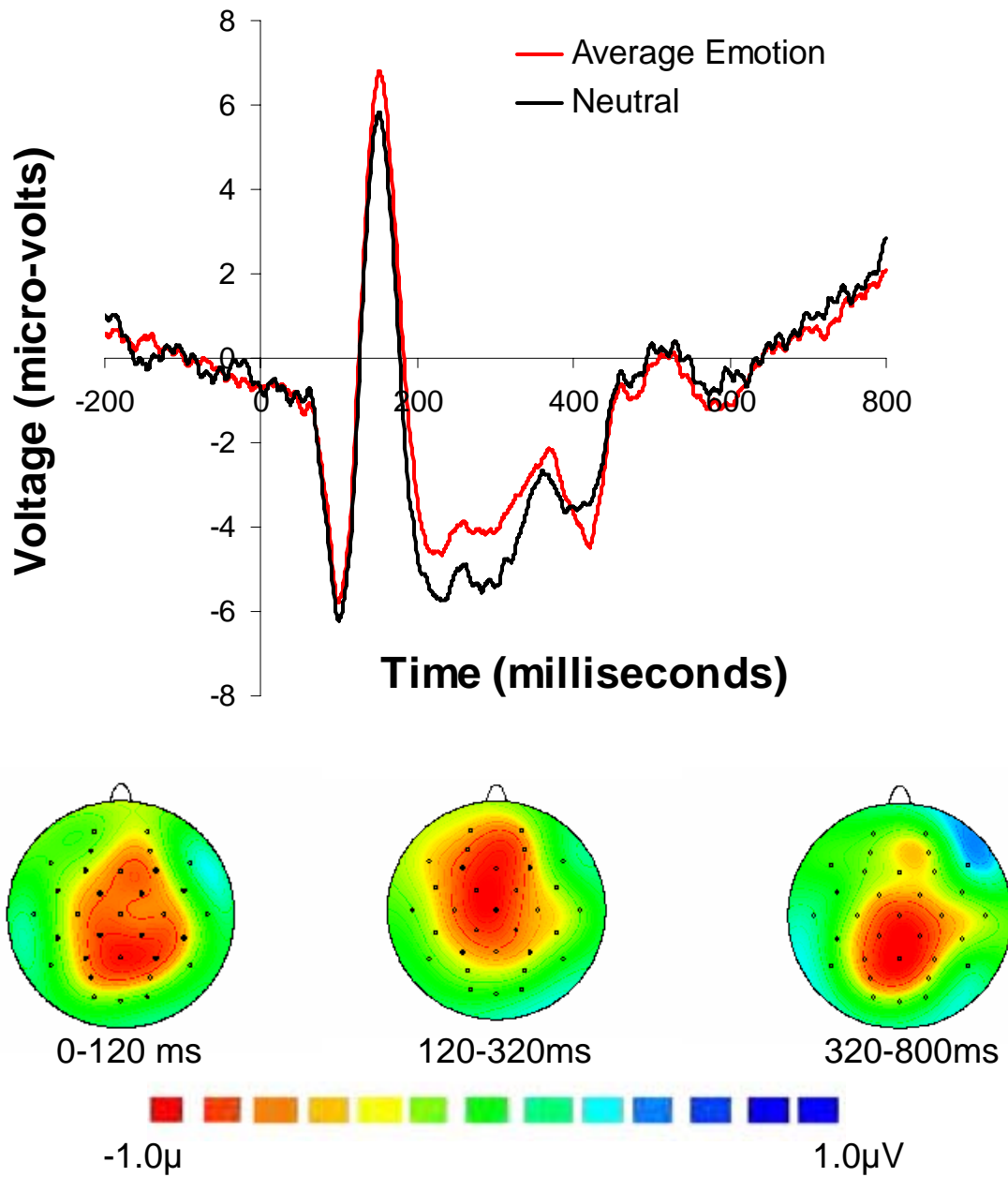
## Figures



*Figure 1:* Comparison of ERP waveforms of neutral and fearful faces (Eimer and Holmes 2002).



*Figure 2:* Shows the progression of the stimuli presentation for each trial.



*Figure 3: Scalp Distributions: differences in younger adults between neutral and emotional average at the Fz electrode.*

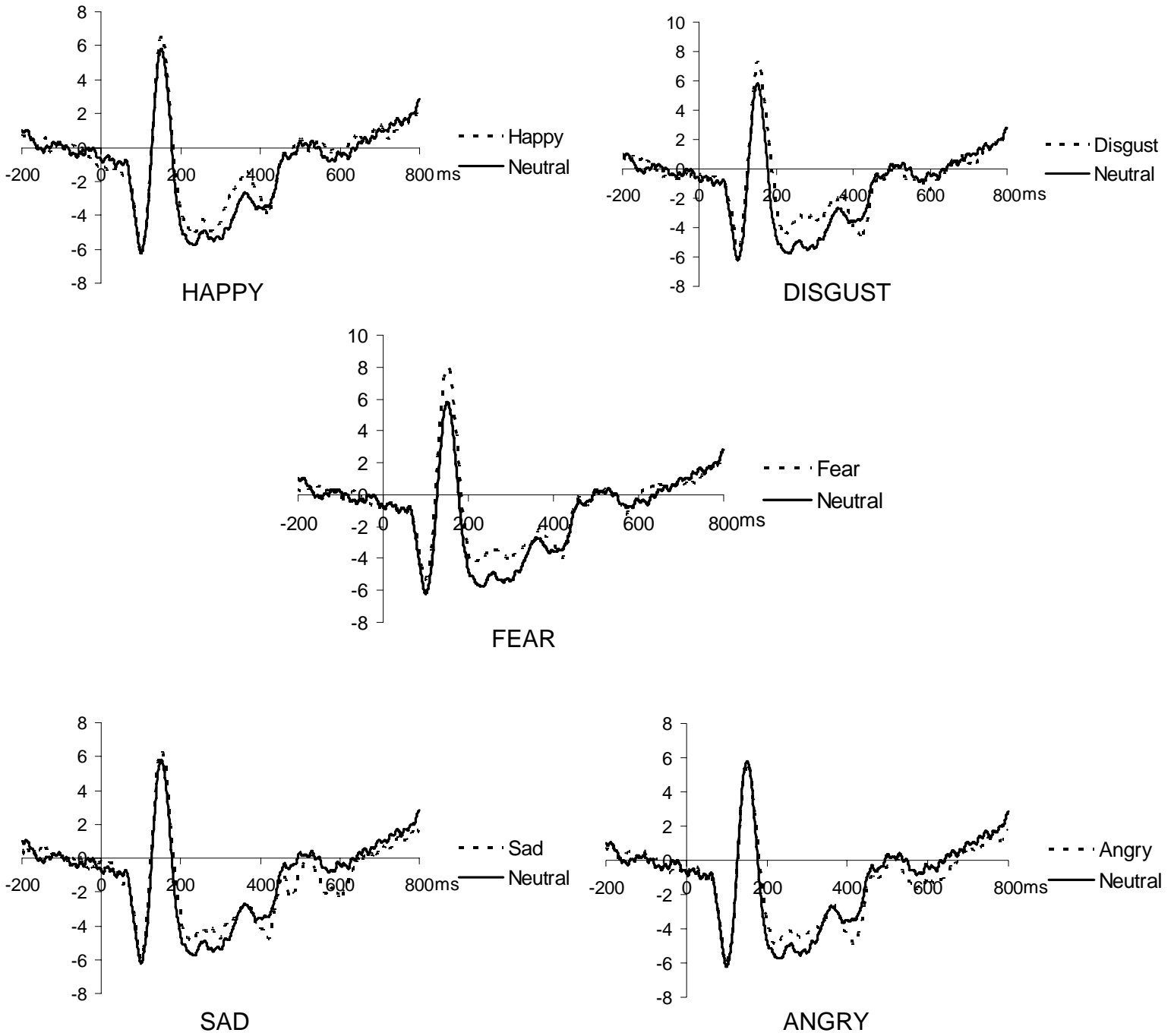


Figure 4: Younger Adults' ERPs to Neutral and Emotional Faces at Fz

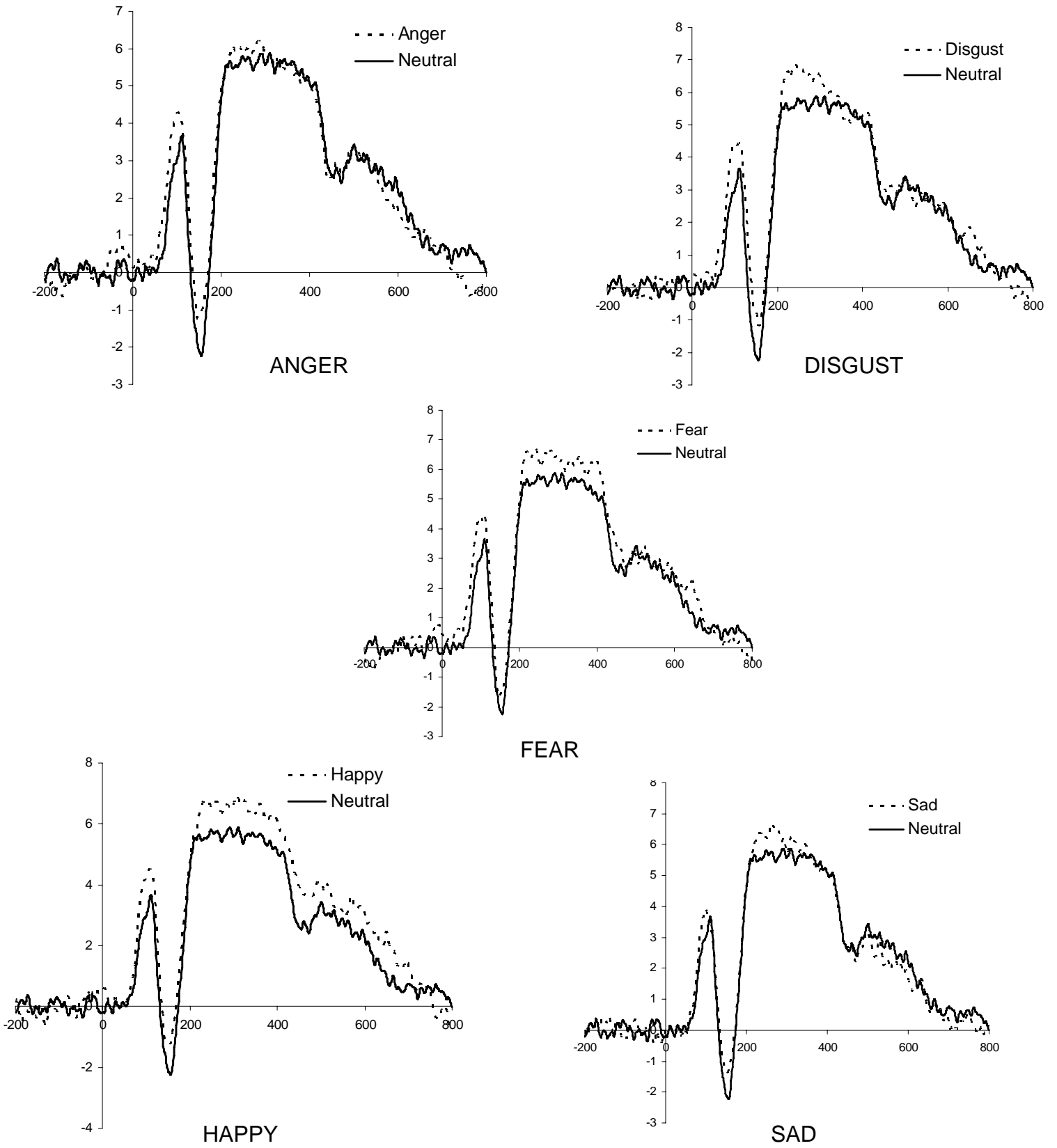
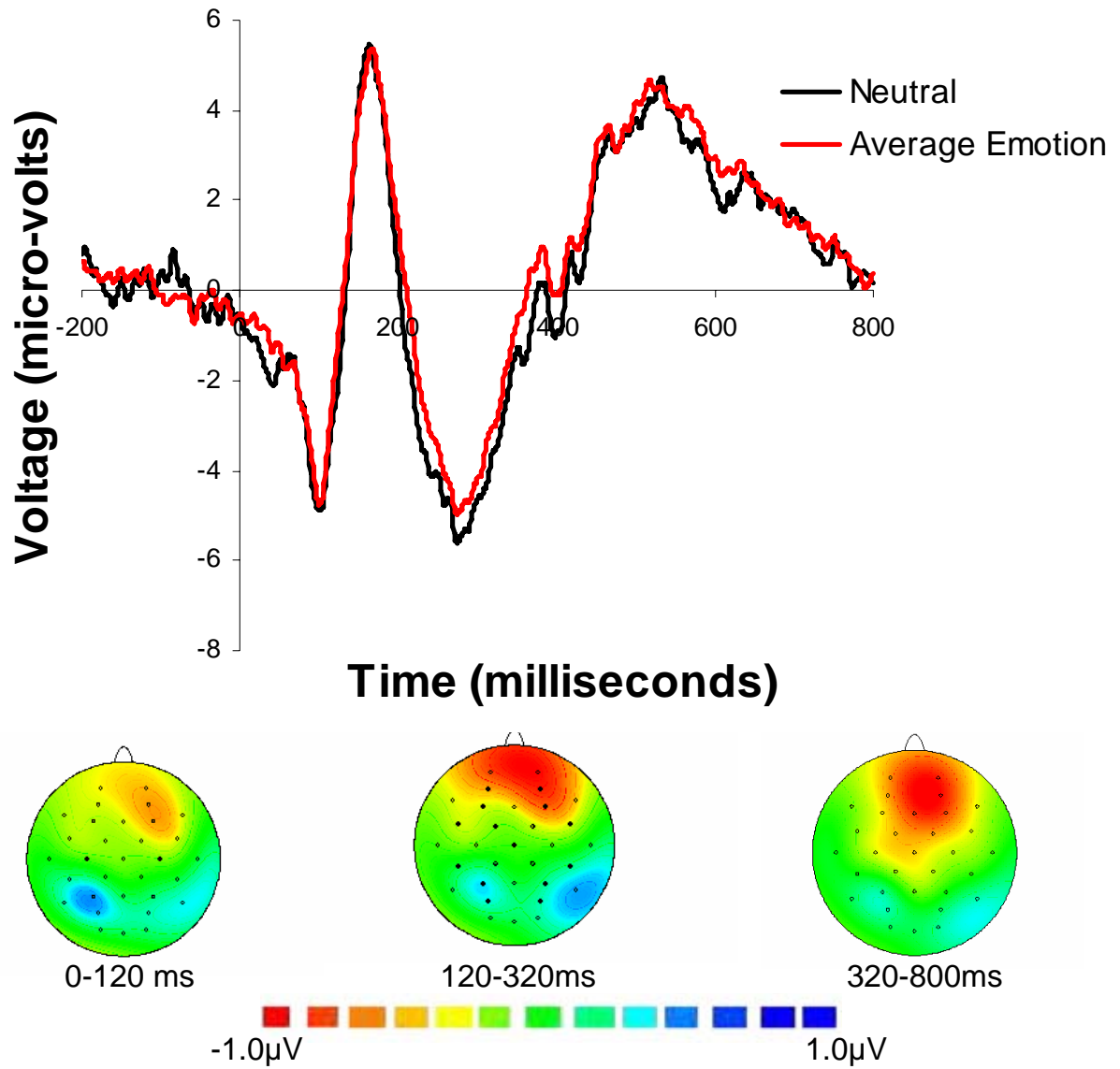


Figure 5: Younger Adults' ERP's to Neutral and Emotional Faces at P8



*Figure 6:* Scalp Distributions: differences in older adults between neutral emotional average at the Fz electrode.



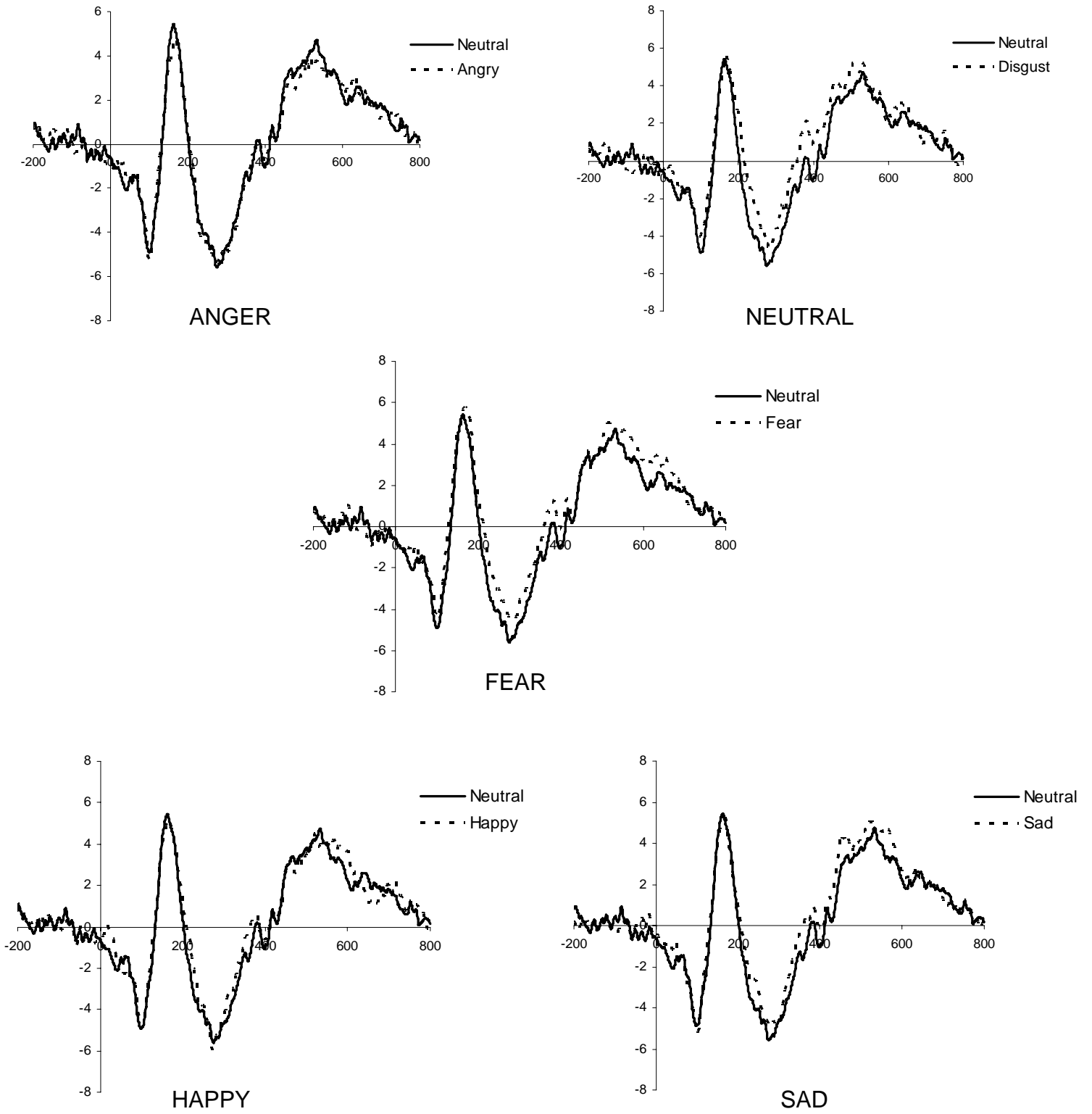


Figure 7: Older Adults' ERP's to Neutral and Emotional Faces at Fz

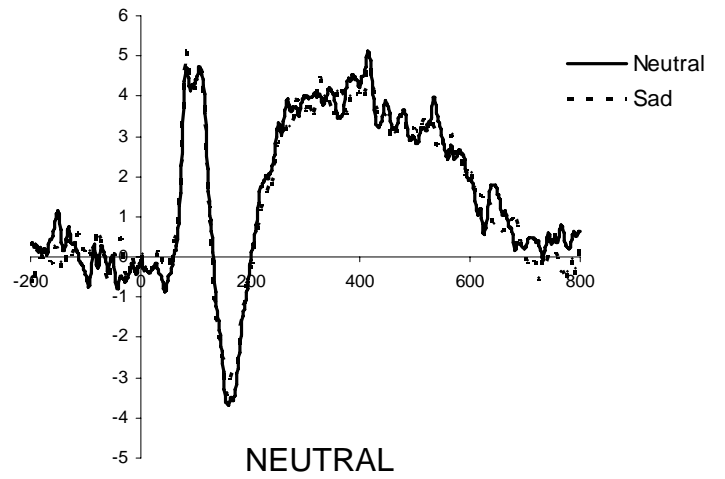
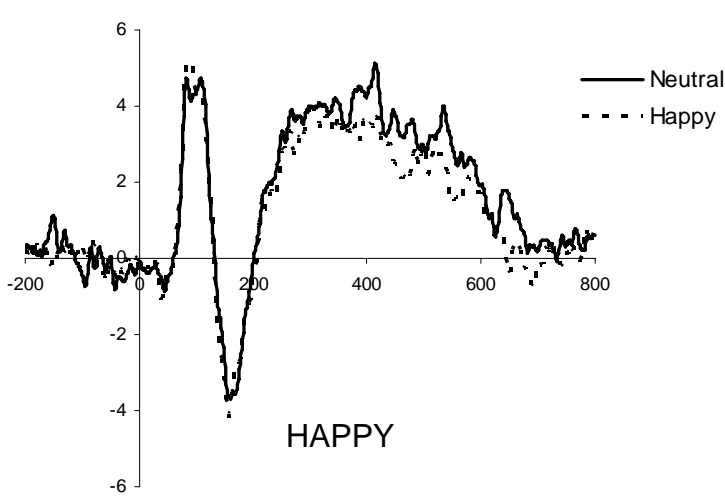
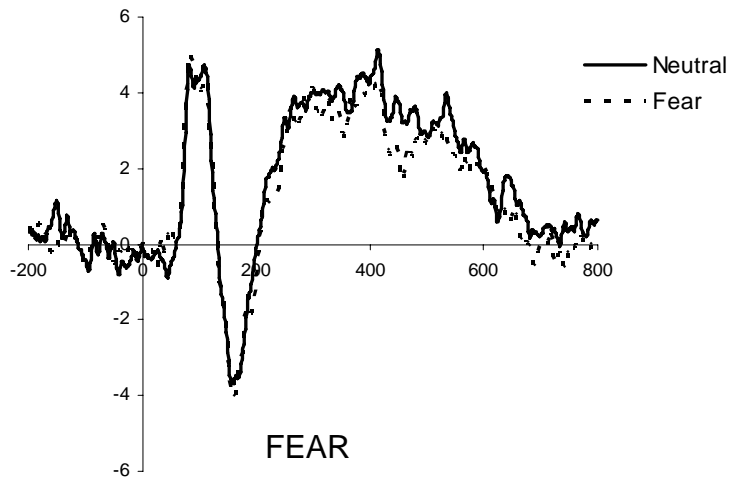
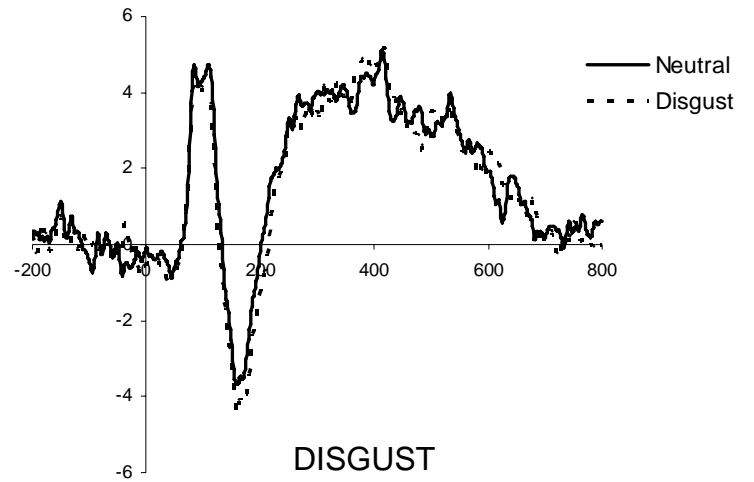
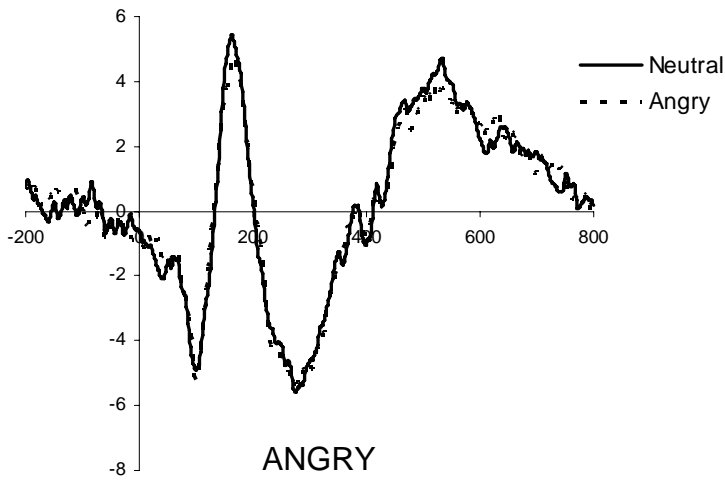


Figure 8: Older Adults' ERP's to Neutral and Emotional Faces at P8