AN EMOTIONAL BIAS IN PROCESSING FACIAL EXPRESSIONS:

SIMILARITIES AND DIFFERENCES ACROSS AGE

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AN EMOTIONAL BIAS IN PROCESSING FACIAL EXPRESSIONS:

SIMILARITIES AND DIFFERENCES ACROSS AGE

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LIST OF SYMBOLS AND ABBREVIATIONS

ERP	Event-Related Potential
SST	Socioemotional Selectivity Theory
μV	Microvolt
RT	Reaction Time
IAPS	International Affective Picture System
EEG	Electroencephalography
SOA	Stimulus Onset Asynchrony
CMS	Common Mode Sense
DRL	Driven Right Leg
EOG	Electrooculogram
ms	Milliseconds
cm	Centimeters

SUMMARY

Previous research indicates that young adults (aged 18-30) tend to exhibit a "negativity bias" such that they enhance processing of negative emotional stimuli compared to neutral stimuli. Because of age-differences in emotion regulatory goals, older adults (aged 60+) often exhibit enhanced processing for positive rather than for negative stimuli – a "positivity effect." I examined age-related differences in processing emotional facial expressions using event-related potentials (ERPs) elicited by task-relevant emotional (i.e., angry, sad, happy) and neutral face images and concurrent task-irrelevant central and peripheral probes. The results indicate that young and older have similarities and differences in their processing of emotional expressions. Both groups exhibit enhanced processing of all emotional facial expressions. This suggests that there is neither a "negativity bias" nor "positivity effect" in processing task-relevant emotional facial expressions. Instead, both young and older adults enhance processing of all emotional expressions compared to neutral expressions and therefore exhibit an "emotional bias." Young and older adults differ in how the emotional faces affect processing of concurrent stimuli. Emotion enhanced processing of concurrent stimuli presented in other areas of the visual field only for the young adults.

CHAPTER 1

INTRODUCTION

There are many unanswered questions regarding how facial expressions of emotion are processed and whether this processing remains stable or changes with age. Do young adults enhance processing of only negative emotional faces (e.g., angry or sad) or all emotional facial expressions (e.g., angry, sad, and happy)? Is there a change with age such that older adults enhance processing of only positive emotional faces (e.g., happy)? Can emotional faces enhance processing of stimuli presented in other areas of the visual field? First the research that gives rise to these questions will be reviewed and then the current study will address these questions.

The literature provides a mixed view on how emotional stimuli are processed. One line of research has shown that threatening stimuli enhance perceptual processing (e.g., Eastwood, Smilek, & Merikle, 2001; 2003). Additionally, research has suggested that negative emotional stimuli, not necessarily threatening, receive enhanced processing or capture and hold attention (e.g., Pratto & John, 1991). However, other research has shown a bias for enhanced processing of and deployment of attention to emotional stimuli in general and not specifically threatening or negative stimuli (e.g., Nummenmaa, Hyönä, & Calvo, 2006). Because of age differences in emotion regulatory goals, it is not clear if older adults show these same enhancements for negative stimuli.

Socioemotional selectivity theory (SST) often predicts different results for young and older adults' processing of and deployment of attention to emotional stimuli (Carstensen, Isaacowitz, & Charles, 1999; Mather & Carstensen, 2005). SST holds that individuals perceive their time left to live as either limited or open-ended, and that this perception influences the experience of emotion and the interaction with emotional stimuli. In addition, SST states that people are motivated by two primary goals. One goal is regulating emotion to increase positive affect. The other goal is to acquire knowledge. The central tenet of the theory is that when an individual perceives their time as limited (e.g., an older adult nearing the end of life) they will be most motivated by the goal to regulate their emotions and experience positive affect at the expense of knowledge acquisition. In contrast, an individual that perceives time as open-ended (e.g., young adults) will be motivated to acquire knowledge to help in the future. Moreover, if the two goals are opposing, they will choose to acquire knowledge at the expense of regulating emotions.

SST has been applied to predictions of the deployment of visuospatial attention to emotional stimuli. SST predicts that older adults should focus on regulating emotions. Specifically, it is predicted that older adults should attend more to positive emotional stimuli compared to neutral stimuli. Moreover, older adults should reduce processing and attend less to negative emotional stimuli compared to neutral stimuli (Mather & Carstensen, 2005) to help regulate their emotions and promote personal well-being. Some research has indicated that older adults withdraw attention from negative information in order to attend more to positive information (Mather & Carstensen, 2003; Isaacowitz et al. 2006a; 2006b).

In summary, changes in processing goals with advancing age predicts different patterns of emotional processing biases for young and older adults. Younger adults may have a bias towards only negative stimuli or all emotional stimuli (positive and negative). In contrast, for older adults, a different pattern of processing and attentional deployment to emotional stimuli is predicted by SST. Older adults may bias their attention towards positive stimuli and away from negative stimuli. Following is a more thorough review of the evidence supporting these different predictions.

1.1 Emotional Processing Biases in Young Adults

1.1.1 Negative Processing Biases in Young Adults

Young adults have been shown to have a bias to enhance processing of threatening and negative emotional stimuli. A special advantage for detecting threat is often argued in evolutionary terms (e.g., Öhman & Minerka, 2001). It would be beneficial for an organism to detect threatening information in the environment quickly so the threatening situation can be avoided or defense mechanisms can be employed. An organism that can do this will be more likely to live to pass on its genes. For example, it would be to an individual's advantage to quickly detect the presence of a poisonous snake so that it can be avoided. Similarly, it would be beneficial to detect a threatening look from another individual and then avoid them or act to diffuse the situation.

Research has indicated that humans are particularly adept at detecting threatening information. Several researchers have reported a threat detection advantage in young adults. For example, Öhman, Flykt, and Esteves (2001) found a detection advantage for snakes and spiders among non-threatening distractors (flowers and mushrooms) in a visual search task. Response times (RTs) were faster for the detection of snakes and spiders (compared to flowers and mushrooms) and the RTs did not increase with the number of distractors. This flat search slope (when RT does not increase as the number of distractors increases) is an indication that the search process is automatic and occurs preattentively (Schneider & Shiffrin, 1977). These results indicate that threatening stimuli (e.g., snakes and spiders) are detected preattentively and automatically capture attention.

Similar results have been found with threatening facial expressions. Öhman, Lundqvist, and Esteves (2001) found a threat detection advantage in visual search using threatening schematic faces. Similarly, Horstmann and Bauland (2006) used photographs of real faces in a visual search task. They found that angry faces were detected faster among happy distractors compared to happy faces among angry distractors. Taken together, these results demonstrate that threatening emotional stimuli are detected faster than positive emotional stimuli by young adults. The authors argue that their results indicate that threatening information is processed preattentively.

Event-related potentials (ERPs) have also been used to examine threat detection in younger adults. Holmes, Kiss, & Eimer (2006) used ERPs to examine effects of attention on centrally presented fearful or neutral faces. They found that, at frontocentral scalp locations, the ERP to fearful faces was more positive compared to the ERP to neutral faces. This effect was visible at about 160 ms post-stimulus. It is argued that the earlier positive deflection in the ERP (160 – 220 ms) to fearful faces reflects a rapid detection of facial expression (Eimer & Holmes, 2007). This may be related to the same mechanism responsible for the preattentive detection for threat seen in the visual search paradigms. The later positive deflection in the ERP (220 – 700 ms) may reflect higher level processes such as the evaluation of emotional content (Eimer & Holmes, 2007).

Other groups have found that negative stimuli, not just threatening stimuli, receive enhanced perceptual processing. Taylor (1991) argues that negative events evoke rapid responses that are different than responses to positive or neutral events. The tendency to enhance processing of negative emotional stimuli has been termed a negativity bias (Cacioppo & Gardner, 1999). Moreover, negative information is considered to be more potent and salient than positive information (Rozin & Royzman, 2001). It is to our advantage to detect all negative information in our environment rapidly and act on this information quickly. Thus, negative stimuli capture attention as a mechanism to ensure that negative events can be detected and avoided.

To test the negativity bias, Pratto and John (1991) used an emotional Stroop task with positive and negative trait words and a color naming task. Negative trait words produced more interference in color naming. In addition, more negative traits were remembered in a free recall task compared to positive trait words. According to their results, negative information in general captures attention, an effect termed automatic vigilance. This is similar to the explanations for the preattentive detection of threat in visual search given above. Moreover, the authors assume that the differentiation of threatening from non-threatening does not occur until later on in the stimulus processing. Additionally, negative information is not necessarily recognized faster or more accurately than positive information (see Lappänen, Tenhunen, & Hietanen, 2003). However, through automatic vigilance, attentional resources can be reallocated to negative information and away from a primary task.

In another test of the negativity bias, Delplanque and colleagues (2006) used an oddball task to assess attention allocation to deviant emotional targets. In an oddball task, the standard targets are shown more frequently and the deviant targets are shown rarely. The deviant targets elicit a P3a component in the ERP because they are rare events. Delplanque and colleagues (2006) showed participants geometric shapes as the standard stimuli and pictures from the International Affective Pictures System (IAPS) that had negative, neutral, or positive valence as the deviant stimuli. The participants categorized the valence of the stimuli. The authors used the P3a component of the ERP as a dependent measure and interpreted it as a measure of the reallocation of attention to deviant or novel stimuli. The P3a was shown to be greater in response to the negative deviant stimuli compared to the neutral and positive deviant stimuli. These results were interpreted as evidence of a negativity bias in the reallocation of attention to deviant stimuli.

1.1.2 Emotional Bias in Young Adults

The previous studies demonstrate a bias towards threatening or all negative stimuli. However, there is also evidence for a general emotional bias, regardless of emotional valence, in attention allocation. Nummenmaa et al. (2006) found evidence for this emotional bias using eye-tracking while participants viewed emotional and neutral pictures. Relative to neutral, individuals were more likely to fixate unpleasant and pleasant images as well as spend a greater overall time looking at them. Moreover, there were no differences in fixations for unpleasant and pleasant pictures. These results suggest an emotional bias rather than a threat or negativity bias. A bias for emotion can be driven by the arousal induced by the stimuli (Nummenmaa et al., 2006). Neutral stimuli are not very arousing compared to negative and positive emotional stimuli. Therefore, attention can be attracted to any arousing emotional stimuli compared to neutral stimuli.

ERP evidence also suggests that there is a bias towards all emotional stimuli compared to neutral stimuli. Eimer, Holmes, and McGlone (2003) found a frontocentral positive deflection in the ERPs to angry, disgusted, fearful, happy, sad, and surprised faces compared to neutral faces. These results suggest that all emotional stimuli receive preferential processing compared to neutral stimuli. Given their interpretation, this preferential processing reflects rapid detection of emotion and evaluation of the emotional expression and negative and positive stimuli receive the same preferential processing. Given these results, there may not be a threat or negativity bias but rather an overall emotional bias.

1.1.3 Summary of Young Adult Processing Biases

The research reviewed shows mixed results for young adults. The studies have either supported a threat and negativity bias or an emotional bias. Threat and negativity biases are argued based on the evolutionarily adaptability of detecting negative information (Öhman & Minerka, 2001) and the idea that negative is more potent than positive (Rozin & Royzman, 2001). An emotional bias is argued based on the idea that highly arousing stimuli, positive or negative, will receive preferential processing (Nummenmaa et al., 2006).

1.2 Emotional Processing Biases in Older Adults

1.2.1 Positivity Bias in Older Adults

Some researchers claim the threat or negativity bias may only apply to younger adults because older adults perceive their time left to live as limited and therefore focus on feeling positive affect to promote personal well-being (for a review see Mather & Carstensen, 2005). In particular, some research on older adults has found a positivity effect in the processing of emotional stimuli. The positivity effect in memory is that positive events are remembered better than negative events (e.g., Mather & Knight, 2005). The positivity effect in attention is that more attention is devoted to positive stimuli and less to negative stimuli (relative to neutral stimuli; e.g., Mather & Carstensen, 2003). The positivity effect found in older adults has been framed in the terms of SST (Carstensen, Isaacowitz, & Charles, 1999). In particular, because older adults perceive their time left in life as limited, they are motivated by the goal of emotion regulation. Attending to positive stimuli and avoiding negative stimuli helps to achieve this regulation, thereby promoting the experience of positive affect and maintaining personal well-being.

Using a dot-probe paradigm, Mather & Carstensen (2003) found support for SST in attention and memory. In particular, the authors showed that older adults detect a dot probe quicker (a) if it follows a neutral face compared to following a negative face, and (b) if it follows a positive face compared to a neutral face. Additionally, older adults showed better memory for positive faces compared to negative faces. In other words, older adults exhibited a positivity effect in attention and memory. The authors suggest that these results support an attentional bias such that older adults avoid negative stimuli yet prefer positive, which subsequently reduces memory for negative stimuli while improving memory for positive stimuli. However, there was no direct measure of future time perspective or the goal states that were active in older adults during the task.

Further evidence of older adults exhibiting a positivity effect in their deployment of attention has been provided by Isaacowitz and his colleagues. Isaacowitz et al. (2006a) used eye-tracking to assess younger and older adults looking preferences while freely viewing synthetic faces displaying happiness, sadness, anger, and fear. These emotional faces were paired with a neutral facial expression and the faces were presented in the periphery. The study showed that older adults had a preference for looking towards happy faces. Additionally, older adults showed a tendency to look away from angry faces. These results show a positivity effect in the deployment of overt attention.

In another study, Isaacowitz et al. (2006b) used a dot-probe paradigm in conjunction with eye-tracking. They showed participants a synthetic face with a happy or sad emotional expression paired with a face showing no emotion (a neutral face). A dot probe followed in the location of one of the faces. The eye-tracking results showed that older adults tended to look toward happy faces and away from sad faces. Using reaction time to the probe, they showed older adults responded relatively faster when the probe replaced a happy face. These results again support a positivity effect in the deployment of overt attention for older adults. However, there was no direct measure of future time perspective or the goal states that were active in older adults during the task. Therefore, these results can only tentatively provide support for SST.

1.2.2 Threat Detection in Older Adults

In contrast to the positivity effect demonstrated for older adults in previous research, Mather and Knight (2006) reported that older adults exhibit a threat detection advantage that is similar to younger adults'. In a visual search task using schematic faces, older adults detected negative faces faster than happy or sad faces. Young and older adults both demonstrated faster reaction times when detecting a discrepant negative face among neutral face distracters compared to detecting a positive face among neutral face distracters. These results indicate that older adults have a threat detection advantage.

Hahn, Carlson, Singer, & Gronlund (2006) replicated the threat detection effect in older adults using different schematic faces in visual search. By analyzing the response time distributions, they concluded that threat detection is an automatic process for the fastest proportion of responses. They argue that a controlled search occurs for some trials when the initial automatic threat detection fails to detect the threatening target. Moreover, they concluded that older adults can disengage from threatening distracters quicker than younger adults. Taken together, their results suggest that older adults detect threat quickly, possibly automatically, and then are able to use a controlled process to disengage from the threatening stimuli.

1.2.3 Summary of Older Adults Processing Biases

The reviewed studies show evidence that older adults may have different biases or preferences in their deployment of attention to emotional stimuli compared to younger adults. Research shows that older adults show a bias towards positive stimuli and away from negative stimuli (e.g., Isaacowitz et al., 2006a; 2006b). However, older adults do show threat detection that is similar to young adults (Mather & Knight, 2006). It is unclear whether older adults enhance processing of only negative, only positive or all emotional stimuli.

1.3 Motivations for the Current Study

Mienaltowski, Corballis, Blanchard-Fields, & Parks (2006) attempted to answer whether young adults have a negative bias or an emotional bias in processing emotional faces. In addition, they tested whether these processing biases change with age. They presented neutral, happy, angry, and sad faces at fixation and presented a probe over the face at fixation 400 – 800 ms later. Participants were asked to detect the probe and the emotional faces were task irrelevant. The authors examined the amplitude of the P1 component in the ERP elicited by the probe. The amplitude of the P1 component serves as an index of the enhancement of visual processing due to visuospatial attention the P1 component increases in amplitude under attentive conditions (Mangun & Hillyard, 1995). The results of the P1 to the probe indicated that younger adults deploy more attention to the probes appearing over emotional faces (happy, angry, and sad) compared to the neutral faces. There were no differences between happy, angry, and sad. These results indicate younger adults have a bias for all emotional stimuli. In contrast, older adults show reduced attention to angry faces compared to neutral, happy, and sad faces. There were no differences between neutral, happy, and sad. This provides partial support for the positivity effect predicted by SST and suggests that older adults withdraw attention from angry faces. However, in this experiment, the faces were task-irrelevant. It is unclear how these processing biases might change if the emotional faces were made task-relevant. The studies reviewed above that showed a positivity effect did not make the emotion task-relevant while the studies that showed threat detection in older adults did make the emotion task-relevant. However, these studies used different methodologies. Therefore, the current study addresses young and older adults processing biases to task-relevant emotional stimuli so a comparison can be made to the Mienaltowski et al. (2006) study within the same paradigm.

Another issue that motivated the current study is how emotion can affect processing of other stimuli. It has been found that fear can enhance perception of concurrently presented stimuli. Phelps, Ling and Carrasco (2006) found that a fearful face at fixation could reduce the threshold for contrast of peripheral stimuli compared to a neutral face at fixation. These results indicate that emotional stimuli can enhance perception in the entire visual field. The current studied sought to extend these results to other emotional faces (e.g., angry, sad, and happy) and to determine if this phenomenon changes with age.

1.4 The Current Study

The current study presented task-relevant emotional and neutral faces at fixation concurrently with task-irrelevant probes at fixation and in the periphery above the face to young and older adults. Negative (i.e., angry and sad) and positive (i.e., happy) emotional faces were presented to test a negativity bias versus an emotional bias and to determine whether this changes with age. Enhanced processing only for negative emotional facial expressions would constitute evidence for a negativity bias. Enhanced processing for only positive emotional facial expressions would constitute evidence for a positivity effect. Finally, enhanced processing for all emotional stimuli would constitute evidence for an emotional bias. The responses to the emotional faces were all compared to responses to faces with neutral expressions to determine any processing biases.

The central and peripheral probes were used to determine how the emotional stimuli affect information processing. Phelps, Ling and Carrasco (2006) found that a fearful face could enhance sensitivity for contrast of peripheral stimuli. Given this idea, the response to the central and peripheral probes should be greater with an emotional face compared to a neutral face. This would conform to the idea that emotional stimuli can enhance sensitivity in the entire visual field. In other words, emotion can produce a general sensory gain effect that enhances processing for all stimuli in the visual field. In the Phelps, Ling, and Carrasco (2006) study, emotion acted independently of visuospatial attention to enhance the sensitivity for the perception of contrast. These results suggest that emotion can independently enhance perceptual processing through a sensory gain mechanism.

In summary, the current study attempted to address several conflicting findings in the literature. The issues of a negativity bias versus emotional bias for young adults were explored using task-relevant emotional facial expressions. The negativity bias and a positivity effect were also examined for older adults to determine if SST applies to the processing of task-relevant emotional facial expressions. Moreover, the current study examined how emotional facial expressions can affect processing of concurrent stimuli and how this changes with age.

1.5 Electroencephalography, Event-Related Potentials, and Components

The current experiment used measures of event-related potentials (ERPs) as dependent variables. Event-related potentials are changes in the electroencephalogram (EEG) that coincide with an event. The ERP consists of positive and negative voltage deflections (often termed "components") that can be measured at various electrode positions on the scalp. ERPs are thought to reflect the activity of neurons that become active at the presentation of a stimulus or time-locked to an event (Lopes da Silva, 1999). The ERP is assumed to sum with the ongoing EEG, and thus, the ERP must be extracted from the EEG. This is accomplished by averaging the activity associated with identical events resulting in the noise approaching zero and leaving only the signal (Lopes da Silva, 1999).

After the ERP is extracted it needs to be quantified for statistical comparisons between conditions in the experiment. In the current experiment, I quantified the amplitude of the P1 and N1 components generated by the probes. Components are thought to reflect the combined activity of specific neural generators and are therefore sensitive to different conditions (Coles & Rugg, 1995). Both the P1 and N1 components are sensitive to changes in spatial attention such that larger P1 and N1 amplitudes are obtained for attended compared to unattended stimuli (Mangun & Hillyard, 1995; Luck, Woodman, & Vogel, 2000). There were some problems with the young adults ERPs such that they had non-zero baselines in the neutral face conditions (see Figure 6 and Figure 10). Therefore, the difference between the P1 and N1 components was a dependent measure in the current experiment. This allows for a comparison of the waveforms despite having a non-zero baseline in one condition.

The ERPs elicited by the faces were also used as a dependent measure. A frontocentral positive deflection in the ERP is generally elicited by emotional faces compared to neutral faces starting as early as 120 ms after the face is presented (Eimer & Holmes, 2007). This may reflect early detection of emotional expressions (Eimer & Holmes, 2007). Additionally, a broader and more centrally distributed positive deflection occurs at 250 ms and after (Eimer & Holmes, 2007). This may reflect the evaluation of the emotional facial expressions.

Taken together, these ERP measures allowed for a comparison of how emotional and neutral faces are processed. The ERP elicited by the face showed the earliest measure of processing the faces. The ERP to the probes allowed an assessment of later processing of the faces. These ERPs give an idea of the processing of emotional faces that occurs at 500 ms and 1500 ms after the face is presented.

CHAPTER 2

METHOD

2.1 Participants

The young adult participants were 15 students from the Georgia Institute of Technology who participated for extra-credit in their classes. For the young adults, the age range was 18 – 22 years (*M* = 20.1). Additionally, 15 older adults (aged 60 – 80 years, *M* = 67.2) participated in the experiment. The older adult participants were recruited from a database of older adults living in the Atlanta, Georgia area. Older adults participated in exchange for an honorarium. The participants had normal or corrected-to-normal vision and gave written, informed consent.

2.2 Stimuli

The stimuli included facial expressions from 32 different individual targets adapted from the NimStim Face Stimulus Set (Research Network on Early Experience and Brain Development). There were four images associated with each individual (128 total images in the stimulus set). The individuals consisted of young men and women of varying race. In each image the individual was displaying either an emotional expression (including angry, sad, and happy) or no emotional expression (neutral). The faces were converted to black and white with approximately equal luminance within an individual target. Additionally, a pilot study indicated that angry, sad, and happy faces were rated as having similar emotionality. Emotionality combines arousal and valence and indicates the absolute difference from neutral. The faces were centered in a box that measured approximately 8.5 cm horizontally and 10.5 cm vertically (subtending approximately 8.5

x 10.5 degrees of visual angle). A checkerboard served as the probe for the experiment. The checkerboard consisted of alternating black and white squares. The checkerboard was centered horizontally and presented at fixation or 9 degrees above fixation. The checkerboard measured approximately 5 x 5 cm (approximately 5 x 5 degrees of visual angle).

2.3 Design

The experimental design was mixed with age group as a between-subjects factor and with emotional expressions, probe location, and stimulus onset asynchrony (SOA) as within-subjects factors. Age group had two levels, young and older adults. Emotional expressions had four levels including angry, sad, happy, and neutral. Probe location had two levels, center (at fixation) and up (6 degrees above fixation). SOA had two levels, 400 – 600 ms and 1400 – 1600 ms. This yielded 16 within-subjects conditions. There were 84 trials for each condition. There were 1344 experimental trials in the experiment and these were divided into 21 blocks of 64 trials per block. Trials were randomized and each block contained 4 trials of each condition. Face identity was selected at random. One block of 64 trials was presented as practice.

To start a trial (see Figure 1 for an illustration of the sequence of a trial), a fixation cross was presented for 1000 ms. Next, the face was displayed for 2000 ms. On half of the trials, following an SOA of 400 – 600 ms, the task-irrelevant checkerboard probe appeared at fixation or in the periphery above fixation for 100 ms. On the other half of the trials, the probe appeared after an SOA of 1400 – 1600 ms. The participant indicated if the face was emotional or neutral by pressing the “A” or “L” key, respectively.

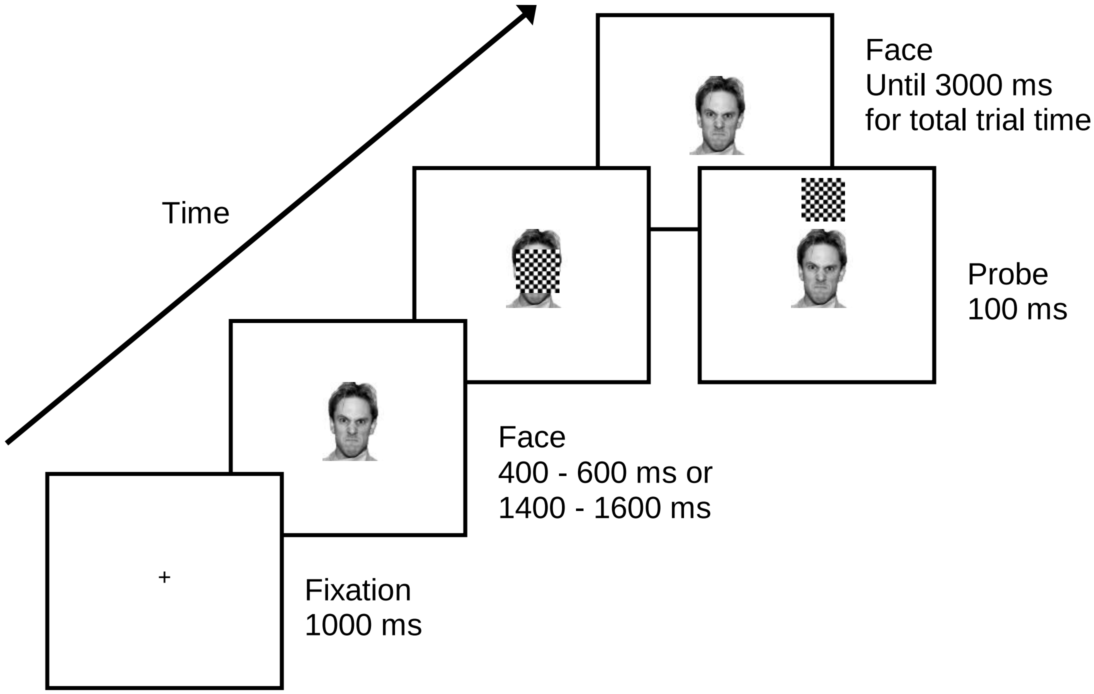

Figure 1: Illustration of the sequence of a trial.

2.4 Procedure

Participants were given informed consent and demographic forms to complete. The basic procedure was explained and then participants were fitted with the electrodes (see Electrophysiological Recording below). Participants were then seated with their chin in a rest to maintain a viewing distance of approximately 60 cm from the computer screen.

To begin the experiment, participants read an instructional screen describing the task. The instructions indicated that it is very important to maintain fixation, minimize blinking during the trials, and respond whether the face is emotional or neutral as quickly and accurately as possible by pressing the "A" key for emotional and the "L" key for neutral. Additionally, they were instructed that they would have 2 seconds to respond.

Participants completed one practice block followed by 21 experimental blocks. Short breaks were offered between blocks.

2.5 Electrophysiological Recording

Electrophysiological data was recorded using a BIOSEMI Active-Two amplifier system. The scalp potentials were recorded from 32 electrode sites. These sites included the standard 10-20 locations (electrodes FP1, FP2, F7, F3, Fz, F4, F8, C3, Cz, C4, P7, P3, Pz, P4, P8, T7, T8, O1, Oz, and O2). The remaining electrodes were from a 10-10 system (electrodes AF3, AF4, FC1, FC2, CP1, CP2, PO3, PO4, FC5, FC6, CP5, and CP6; Nuwer et al., 1998). Odd numbers refer to electrodes over the left hemisphere, even numbers refer to electrodes over the right hemisphere, and electrodes over the midline are labeled with “z”.

Vertical electrooculogram (EOG) was calculated offline as the difference between electrodes positioned above and below the left eye. Horizontal EOG was calculated offline as the difference between electrodes positioned on the outer canthi of the left and right eyes. Two additional electrodes served as reference electrodes. These electrodes were the common mode sense (CMS) and driven right leg (DRL), respectively. The EEG was digitized at 512 Hz.

2.6 Electrophysiological Analyses

Digital filtering was done offline using a high pass 0.1 Hz and low pass 30 Hz zero phase shift Butterworth filter (12 dB/oct). Continuous EEG was segmented into 800 ms segments beginning 100 ms prestimulus and continuing up to 700 ms poststimulus. Horizontal and vertical ocular artifacts were corrected in each segment according to the Gratton, Coles, and Donchin (1983) ocular correction procedure. Segments were then baseline corrected by setting the average of the 100 ms prestimulus baseline to zero. Additional artifact correction was conducted by rejecting segments from all channels containing activity greater than 100 μV and less than -100 μV. Participants were excluded from the analysis if less than 30 trials remain in any condition (5 young adults and 2 older adults were excluded based on these criteria leaving the 15 in each group included in the analyses). Participant averages for each emotion, probe location, and SOA were formed. Grand average waveforms were formed from the subject averages in each condition.

Measures of the differences between the P1 and N1 components elicited by the probes and statistical analyses were also performed on participant average waveforms at electrodes P7/8 and PO3/4. These electrodes were chosen as the focus of analyses for the P1/N1 difference because previous research has found attentional effects of the P1 and N1 components to be most apparent at occipital-temporal electrode sites (Mangun & Hillyard, 1995; Luck, Woodman, & Vogel, 2000). The P1 and N1 components were defined as the average of five data points centered at the largest voltage of appropriate valence within a particular time window (P1: approximately 60-150 ms; N1: approximately 150 -200 ms). The P1 and N1 time windows were chosen according to their time course in the grand average waveform of all conditions. The P1 and N1 amplitudes were measured for each emotion, probe location, and SOA. The N1 amplitude was then subtracted from the P1 amplitude and this difference was examined to see if it changed with age, emotion, and SOA. Peripheral and central probes were examined in separate analysis because peripheral and central P1 mechanisms of attention may differ (Handy & Khoe, 2005).

The ERPs elicited by the faces were used as a dependent measure. I tested for a frontocentral positive deflection in the ERPs for emotional faces compared to neutral faces starting at 95 ms after the face is presented (Eimer & Holmes, 2007). The mean amplitude was collected for five intervals (95-135 ms, 135-230 ms, 230-300 ms, 300-450 ms, and 450-700 ms; Eimer, Holmes, & McGlone, 2003) for the participant average waveforms at F3/Fz/F4, C3/Cz/C4, and P3/Pz/P4. Because the short SOA probes overlapped with the 450-700 ms interval, only the long SOA probe trials were used to examine the ERPs elicited by the faces.

2.7 Behavioral Analyses

Reaction time (RT) and proportion correct were collected for the emotional/neutral judgment made for the faces. These were analyzed to see if there were any differences in RTs or proportion correct in making the judgment of emotional for the angry, sad or happy faces or the judgment of neutral. Additionally, RT and proportion correct were analyzed to see if there are any differences between age groups for the emotional/neutral judgment.

CHAPTER 3

RESULTS

3.1 ERPs Elicited by Faces

The ERPs elicited by the emotional faces were examined to determine the earliest emotional processing biases evident for young and older adults. Enhanced processing is defined as a more positive deflection in the ERP for an emotional face compared to a neutral face. Enhanced processing only for negative emotional facial expressions would constitute evidence for a negativity bias. Enhanced processing for only positive emotional facial expressions would constitute evidence for a positivity effect. Finally, enhanced processing for all emotional stimuli would constitute evidence for an emotional bias.

If you examine Figure 2 and Figure 3, you can see that young adults show a more positive ERP to each emotional face compared to the neutral faces and the ERPs to the emotional faces are indistinguishable. Similarly, Figure 4 and Figure 5 show a similar pattern in older adults suggesting that both young and older adults enhance processing of all the emotional faces.

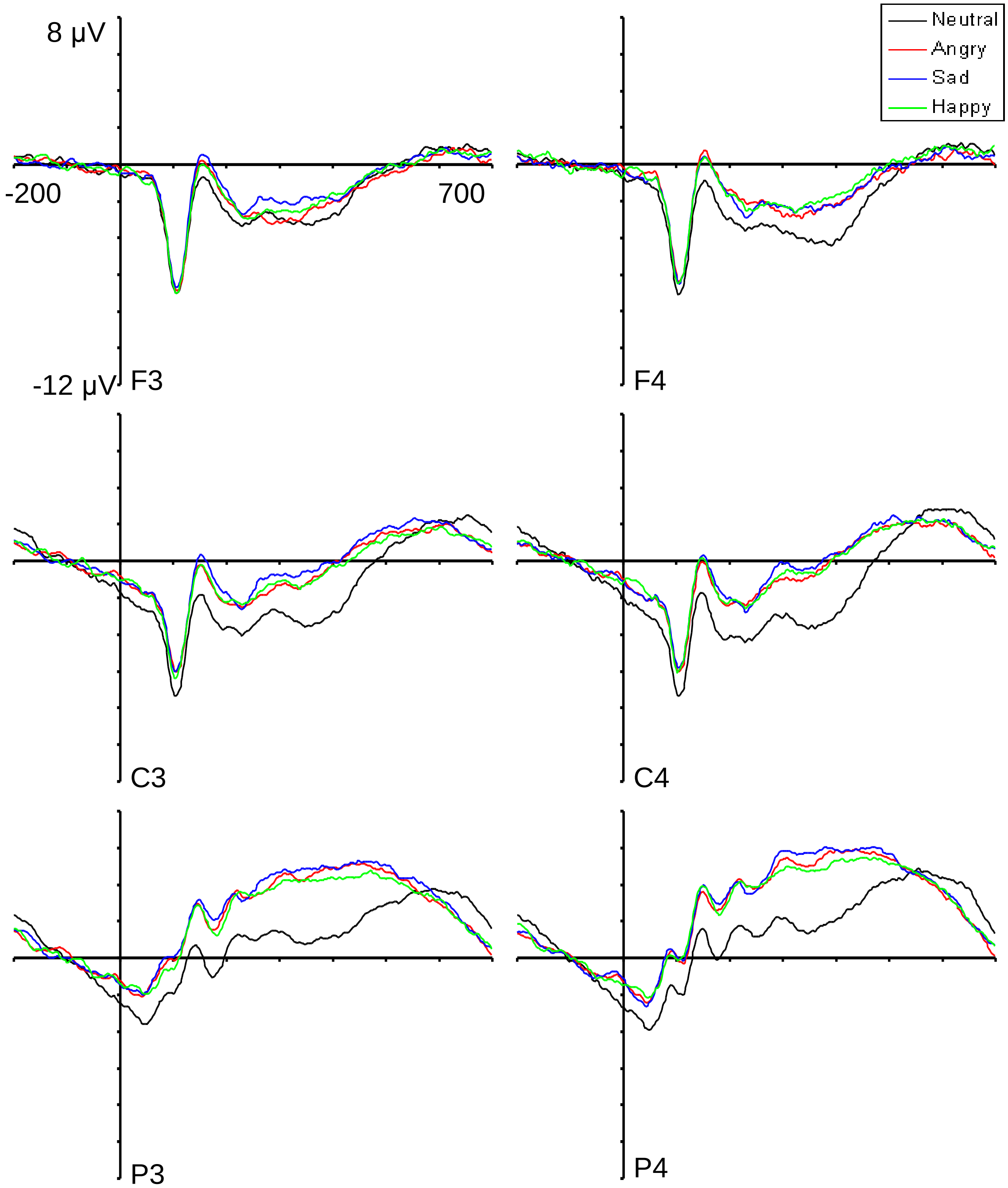

Figure 2: Young adult ERPs elicited by faces at lateral electrode sites.

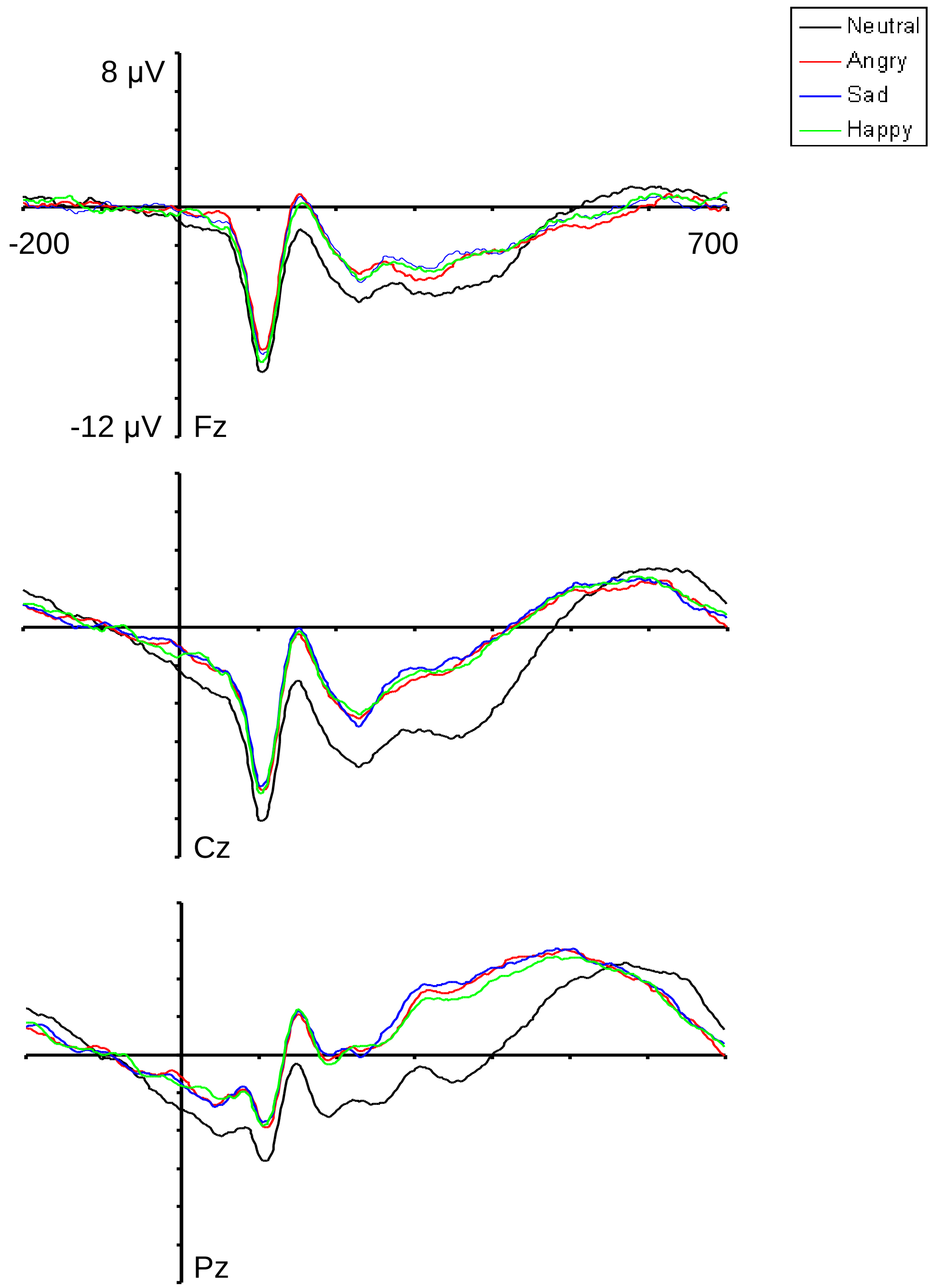

Figure 3: Young adult ERPs elicited by faces at midline electrode sites.

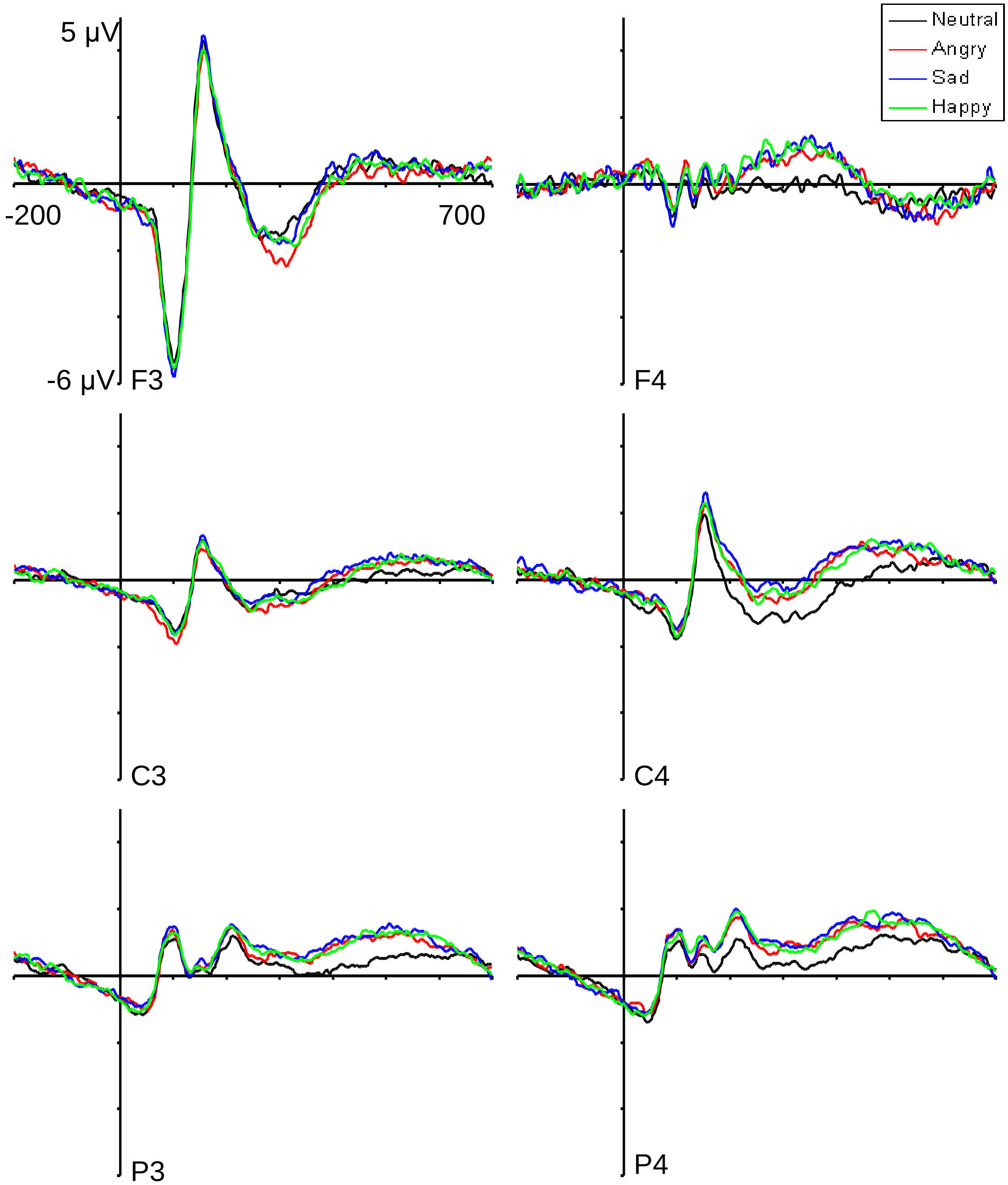

Figure 4: Older adult ERPs elicited by faces at lateral electrode sites.

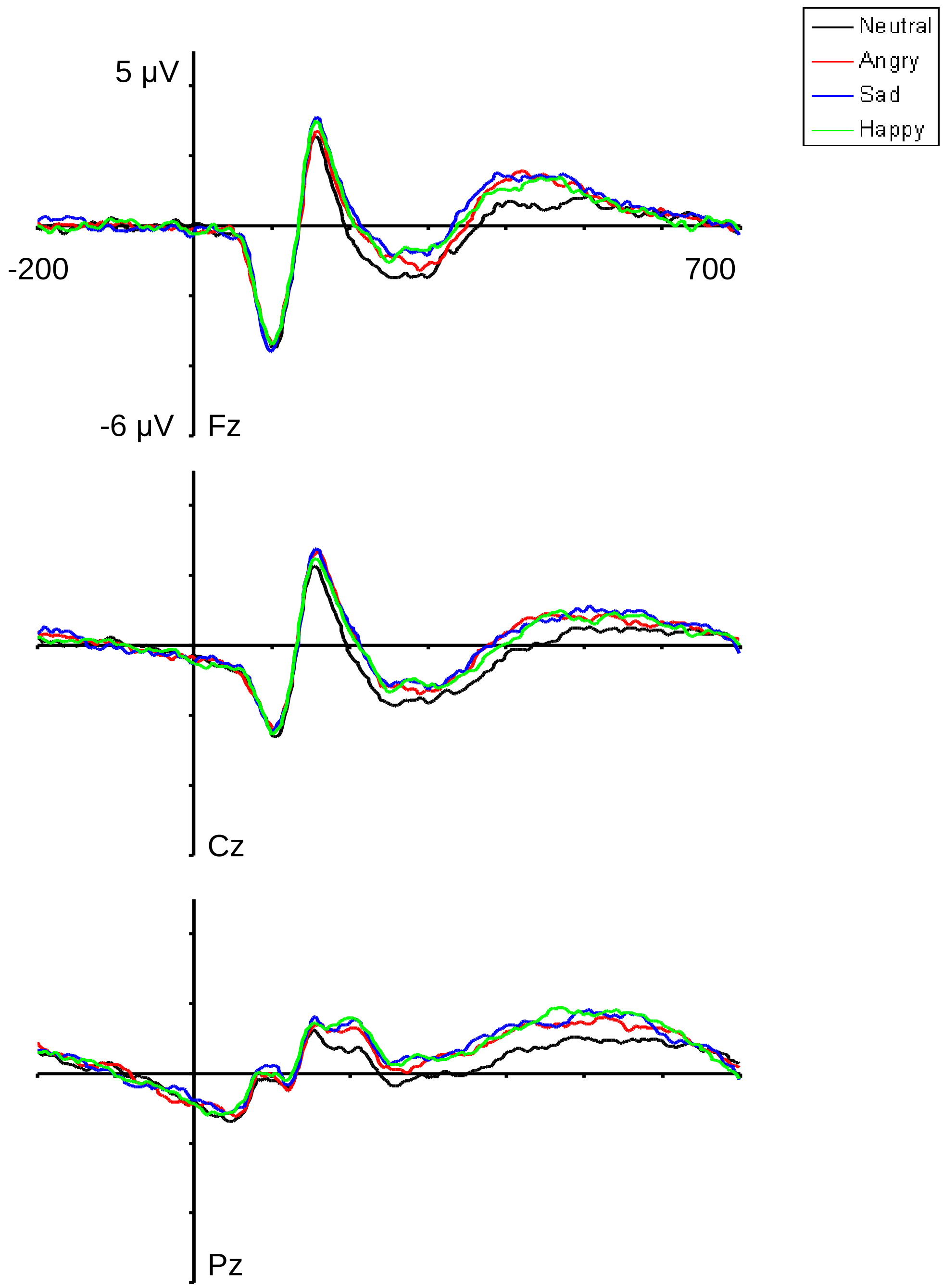

Figure 5: Older adult ERPs elicited by faces at midline electrode sites.

Mean amplitudes were calculated in five separate time windows (95-135 ms, 135-230 ms, 230-300 ms, 300-450 ms, and 450-700 ms) and were averaged across lateral electrodes F3/4, C3/4, and P3/4 and across the midline electrodes Fz, Cz, and Pz. A mixed-model analysis of variance (ANOVA) was conducted on the mean amplitude for ERPs elicited by the faces differences in a 2 (age group: young, old) by 5 (time interval: 95-135, 135-230, 230-300, 300-450, 450-700 ms) by 2 (electrode location: lateral, midline) by 4 (emotion: angry, sad, happy, neutral) mixed-model design, with age group as a between-subjects factor and time interval, electrode location and emotion as within-subjects factors. The main effects of age group ($F(1,28) = 44.02$, $p < .05$), time interval ($F(4,112) = 44.02$, $p < .05$), electrode location ($F(1,28) = 31.21$, $p < .05$), and emotion ($F(3,84) = 36.07$, $p < .05$) were all statistically significant. The emotion by age group ($F(3,84) = 15.73$, $p < .05$), time by location ($F(4,112) = 30.73$, $p < .05$), time by location by age group ($F(4,112) = 10.98$, $p < .05$), time by emotion ($F(12,336) = 11.57$, $p < .05$), time by emotion by age group ($F(12,336) = 8.16$, $p < .05$), location by emotion ($F(3,84) = 9.83$, $p < .05$), and time by location by emotion ($F(12,336) = 3.79$, $p < .05$) were all statistically significant. The location by emotion by age group ($F(3,84) = 1.53$, $p = .21$) and time by location by emotion by age group ($F(12,336) = 1.68$, $p = .07$) were not statistically reliable. To understand the critical time by emotion by age group interaction, planned comparisons (paired-samples *t*-tests, 2-tailed, $\alpha = 0.05$) were conducted separately for young and older adults at each time interval.

During the 95 – 135 ms interval, young adults had larger amplitudes to angry, sad, and happy faces compared to neutral faces at lateral electrode sites and at midline electrode sites (see Table 1). In contrast, during the 95-135 ms interval, older adults did not show any statistically reliable differences between the neutral and emotional faces at the lateral or midline electrodes (see Table 2). These results suggest that young adults show a bias towards enhanced processing of all emotional facial expressions starting 95 ms after the onset of the face, but older adults do not show any bias during this time interval.

During the 135 – 230, 230 – 300, and 300 – 450 ms intervals, young adults had larger amplitudes to angry, sad, and happy faces compared to neutral faces at lateral electrode sites and at midline electrode sites (see Table 1). Additionally, during the 135 – 230, 230 – 300, and 300 – 450 ms intervals, older adults had larger angry, sad, and happy faces compared to neutral faces at lateral electrode sites and at midline electrode sites (see Table 2). As can be seen in Table 2, a few of the comparisons were marginal or not statistically reliable. However, the overall pattern shows differences between each of the emotions and the neutral faces. These results suggest that both young and older adults show a bias towards enhanced processing of all emotional facial expressions by 135 ms after the onset of the face and this enhanced processing persists 450 ms after the onset of the face.

During the 450 – 700 ms interval, young adults did not show any statistically reliable differences between emotional and neutral faces at lateral or midline electrode sites (see Table 1). However, during the 450 – 700 ms interval, older adults had larger amplitudes to angry, sad, and happy faces compared to neutral faces (see Table 2). These results suggest that young adults do not continue to show a bias towards emotional facial expressions in the 450 – 700 ms after the onset of the face. However, older adults do continue to show biases towards emotional faces compared to neutral faces during this time interval.

Taken together, the results of the ERPs elicited by the faces support an emotional bias for both young and older adults. However, older adults are slower in showing this bias and the bias persists longer compared to the young adults. This may indicate that older adults take longer to process the faces. These results indicate that young and older adults have similar biases in processing task-relevant emotional facial expressions. Both young and older adults have an emotional bias and there is no evidence for a negativity bias or positivity effect in the current results.

Table 1: Young adults planned comparisons for ERPs elicited by faces. All comparisons are made relative to neutral faces. All comparisons have 14 degrees of freedom. Asterisks denote significance at $p < 0.05$.

Time	Electrode	Emotion	t-value	p-value
95 – 135	Lateral	Angry	3.93	0.002*
		Sad	4.83	< 0.001*
		Happy	3.61	0.003*
	Midline	Angry	5.22	< 0.001*
		Sad	6.34	< 0.001*
		Happy	3.80	0.002*
135 – 230	Lateral	Angry	5.24	< 0.001*
		Sad	6.02	< 0.001*
		Happy	4.77	< 0.001*
	Midline	Angry	6.48	< 0.001*
		Sad	7.79	< 0.001*
		Happy	5.84	< 0.001*
230 – 300	Lateral	Angry	3.86	0.002*
		Sad	5.23	< 0.001*
		Happy	3.86	0.002*
	Midline	Angry	4.34	0.001*
		Sad	6.72	< 0.001*
		Happy	4.63	< 0.001*
300 – 450	Lateral	Angry	6.30	< 0.001*
		Sad	8.99	< 0.001*
		Happy	5.77	< 0.001*
	Midline	Angry	5.57	< 0.001*
		Sad	7.00	< 0.001*
		Happy	5.39	< 0.001*
450 – 700	Lateral	Angry	0.39	0.700
		Sad	0.68	0.508
		Happy	0.00	0.998
	Midline	Angry	1.39	0.187
		Sad	0.80	0.437
		Happy	0.86	0.405

Table 2: Older adults planned comparisons for ERPs elicited by faces. All comparisons are made relative to neutral faces. All comparisons have 14 degrees of freedom. Asterisks denote significance at $p < 0.05$. Tildes denote marginal significance at $p < 0.1$.

Time	Electrode	Emotion	t-value	p-value
95 – 135	Lateral	Angry	0.10	0.919
		Sad	0.04	0.850
		Happy	0.19	0.852
	Midline	Angry	0.93	0.368
		Sad	0.72	0.482
		Happy	0.82	0.427
135 – 230	Lateral	Angry	1.48	0.160
		Sad	2.18	0.047*
		Happy	2.02	0.063~
	Midline	Angry	2.53	0.024*
		Sad	3.78	0.002*
		Happy	2.75	0.015*
230 – 300	Lateral	Angry	0.75	0.465
		Sad	2.41	0.031*
		Happy	1.60	0.130
	Midline	Angry	2.08	0.056~
		Sad	3.54	0.003*
		Happy	3.30	0.005*
300 – 450	Lateral	Angry	1.14	0.171
		Sad	2.47	0.027*
		Happy	1.19	0.253
	Midline	Angry	2.84	0.013*
		Sad	3.27	0.006*
		Happy	2.46	0.028*
450 – 700	Lateral	Angry	1.78	0.098~
		Sad	2.71	0.017*
		Happy	2.82	0.014*
	Midline	Angry	2.16	0.049*
		Sad	2.83	0.013*
		Happy	2.95	0.010*

3.2 ERPs Elicited by Central Probes – Short SOA

The ERPs elicited by the central probes that were presented centrally over the face at 400 – 600 ms SOA were examined to determine the allocation of visuospatial attention to emotional faces compared to neutral faces at this point in time (see Figure 6 for young adult waveforms and Figure 7 for older adult waveforms). The amplitude of the peak to peak differences between the P1 and N1 components of the ERPs elicited by the probes presented over the emotional and neutral faces were compared at electrodes P7/8 and PO3/4. This measure was used to determine any biases in the allocation of visuospatial attention to emotional faces compared to neutral faces 500 ms after the onset of the face. These comparisons were used to test for a negativity bias versus a positivity effect versus an emotional bias.

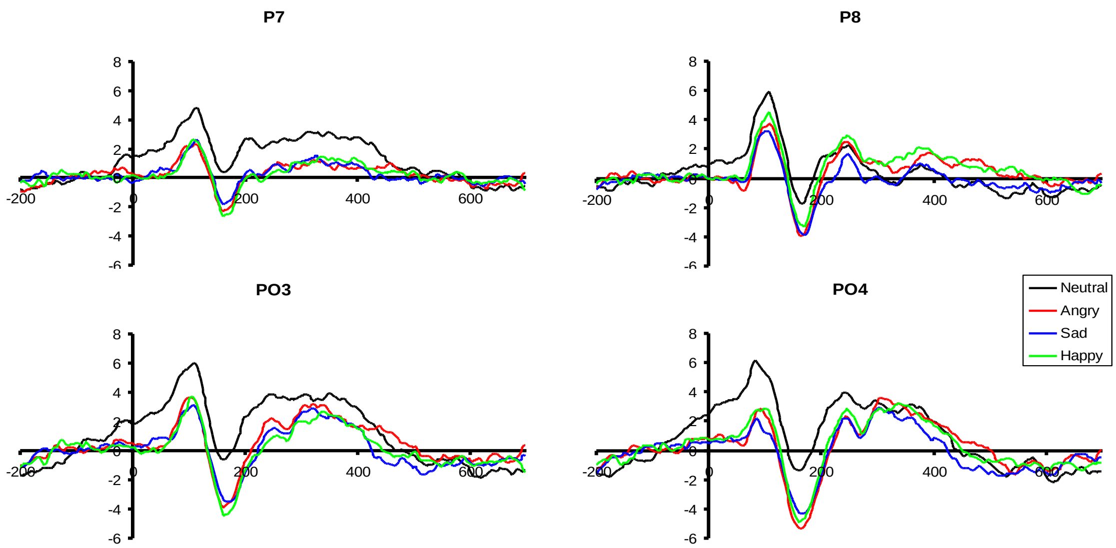

Figure 6: Young adult ERPs to probes located centrally over the faces at short SOA.

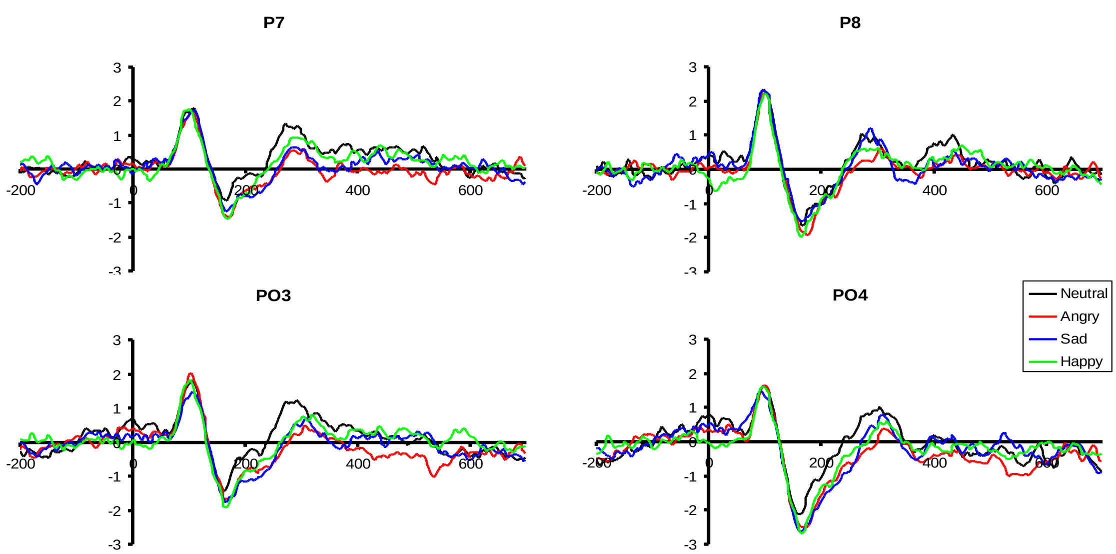

Figure 7: Older adult ERPs to probes located centrally over the faces at the short SOA.

A mixed-model analysis of variance (ANOVA) was conducted the P1/N1 differences in the ERPs elicited by the short SOA central probes in a 2 (age group: young, old) by 4 (electrode: P7, P8, PO3, PO4) by 4 (emotion: neutral, happy, angry, sad) mixed-model design, with age group as a between-subjects factor and emotion and electrode as within-subjects factors. The main effect of age group ($F(1,28) = 10.06$, $p < .05$), electrode ($F(3,84) = 13.62$, $p < .05$) and the electrode by emotion by age group interaction ($F(9,252) = 1.95$, $p < .05$) were both statistically significant. All other main effects and interactions were not statistically reliable (all $F < 2$, $p > 0.12$). To understand the critical electrode by emotion by age group interaction, planned comparisons (paired-samples *t*-tests, 2-tailed, $\alpha = 0.05$) were conducted separately for young and older adults at each electrode.

Young adults had larger P1/N1 differences at electrode PO3 for probes over angry and happy faces compared to neutral faces. In addition, young adults had larger P1/N1 differences at electrode P7 for probes over happy faces compared to neutral faces (see Figure 8 and Table 3). These results indicate that young adults have a bias in their allocation of visuospatial attention to angry and happy faces compared to neutral faces.

Older adults had larger P1/N1 differences at electrode P7 for probes over angry and sad faces compared to neutral faces. In addition, older adults had larger P1/N1 differences at electrode PO3 for probes over angry faces compared to neutral faces. Older adults had marginally significant larger P1/N1 differences at electrode PO4 for probes over angry and sad faces compared to neutral faces (see Figure 9 and Table 4). These results indicate that older adults have a bias in their allocation of visuospatial attention to angry and sad faces compared to neutral faces.

The ERPs elicited by the central probes show similar results to the ERPs elicited by the faces themselves with some differences. Young adults did not show enhancement for probes presented with sad faces and older adults did not show enhancement for probes presented with happy faces. This may have occurred because it is difficult to manipulate visuospatial attention at fixation (Handy & Khoe, 2005). Combined with the ERPs elicited by the faces, the central probe results support an emotional bias in processing facial expressions.

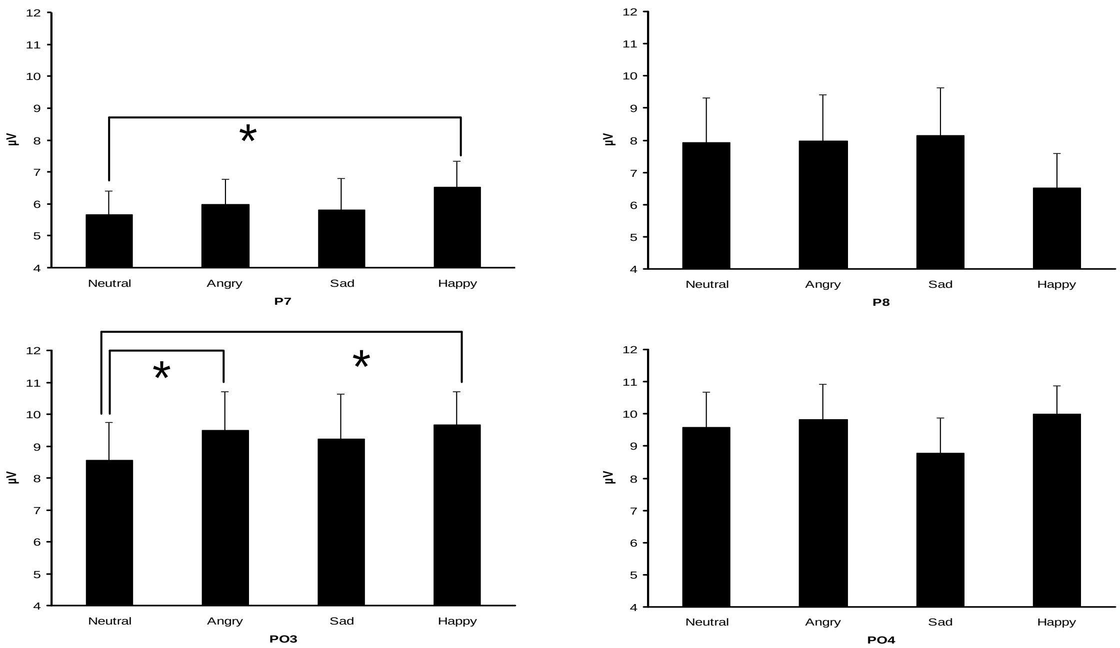

Figure 8: Young adult P1/N1 differences to probes located centrally over the faces at the short SOA. Asterisks denote significance at $p < 0.05$.

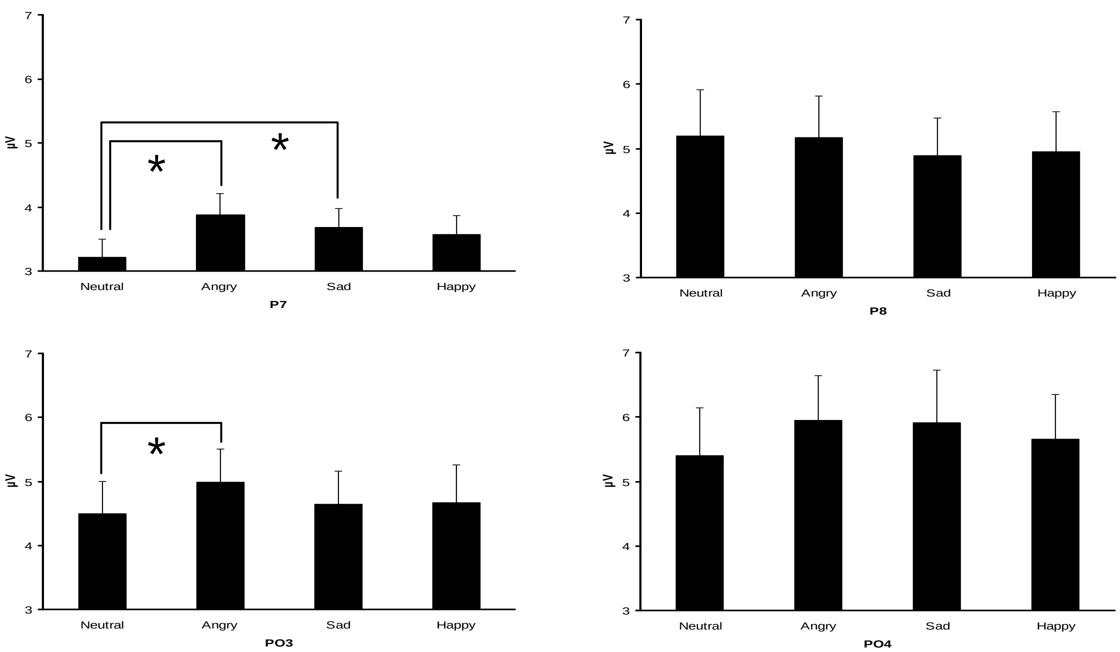

Figure 9: Older adult P1/N1 differences to probes located centrally over the faces at short SOA. Asterisks denote significance at $p < 0.05$.

Table 3: Young adults planned comparisons for ERPs elicited by central probes at the short SOA. All comparisons are made relative to neutral faces. All comparisons have 14 degrees of freedom. Asterisks denote significance at $p < 0.05$.

Electrode	Emotion	t-value	p-value
P7	Angry	0.83	0.423
	Sad	0.28	0.783
	Happy	2.79	0.015*
P8	Angry	0.10	0.920
	Sad	0.43	0.676
	Happy	0.04	0.968
PO3	Angry	2.64	0.019*
	Sad	1.21	0.245
	Happy	2.48	0.026*
PO4	Angry	0.51	0.617
	Sad	1.52	0.151
	Happy	0.69	0.501

Table 4: Older adults planned comparisons for ERPs elicited by central probes at the short SOA. All comparisons are made relative to neutral faces. All comparisons have 14 degrees of freedom. Asterisks denote significance at $p < 0.05$. Tildes denote marginal significance at $p < 0.1$.

Electrode	Emotion	t-value	p-value
P7	Angry	3.10	0.008*
	Sad	2.30	0.038*
	Happy	1.50	0.157
P8	Angry	0.14	0.892
	Sad	1.11	0.284
	Happy	0.86	0.406
PO3	Angry	3.05	0.009*
	Sad	0.65	0.528
	Happy	0.79	0.442
PO4	Angry	2.07	0.057~
	Sad	1.90	0.078~
	Happy	0.75	0.466

3.3 ERPs Elicited by Peripheral Probes – Short SOA

The ERPs elicited by the peripheral probes that were presented above the face at 400 – 600 ms SOA were examined to determine the allocation of visuospatial attention to a location in the periphery concurrent with the presentation of emotional faces and neutral faces (see Figure 10 for young adult waveforms and Figure 12 for older adult waveforms). The amplitude of the peak to peak differences between the P1 and N1 components of the ERPs elicited by the probes were compared for the emotional faces and the neutral faces. This measure was used to determine if emotional faces could enhance processing in all locations within the visual field and thereby enhancing attentional allocation to the peripheral probes. If there is enhanced processing for peripheral probes presented with the emotional stimuli compared to neutral, then that is evidence that emotion can enhance processing of concurrent stimuli.

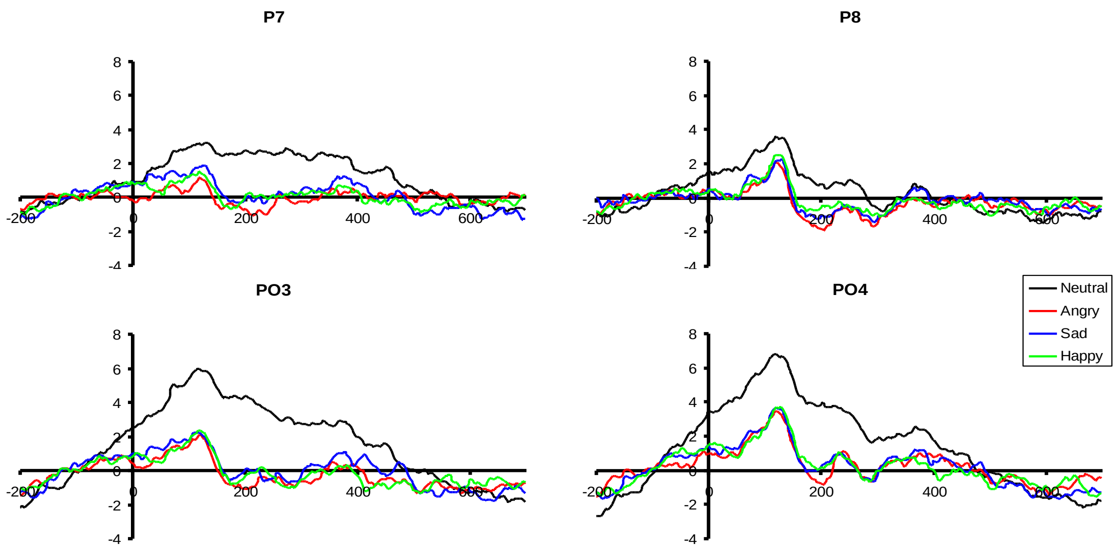

Figure 10: Young adult ERPs to probes located peripherally above the faces at short SOA.

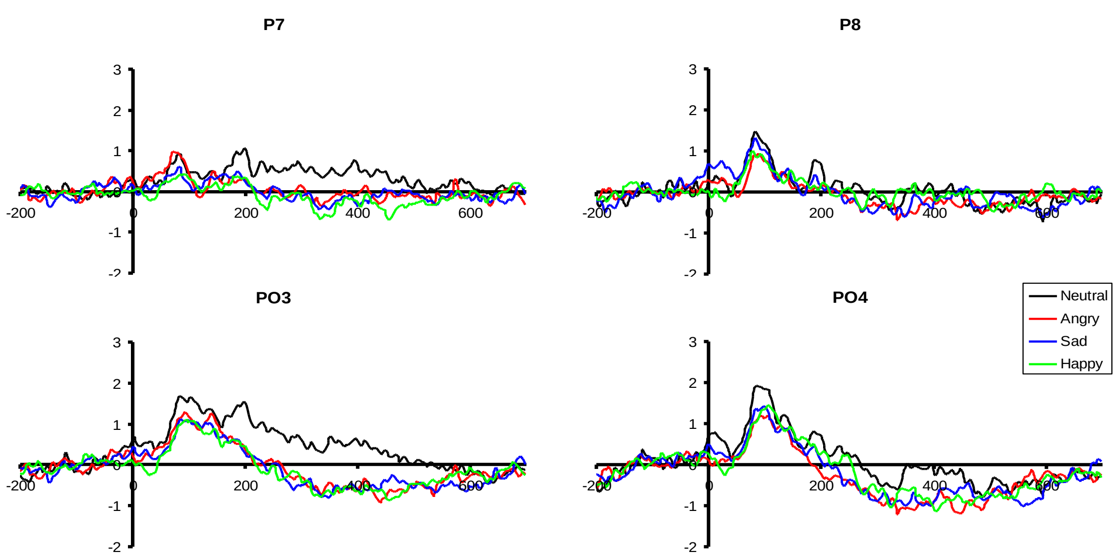

Figure 11: Older adult ERPs to probes located peripherally above the faces at short SOA.

A mixed-model analysis of variance (ANOVA) was conducted the P1/N1 differences for the short SOA peripheral probes in a 2 (age group: young, old) by 4 (electrode: P7, P8, PO3, PO4) by 4 (emotion: neutral, happy, angry, sad) mixed-model design, with age group as a between-subjects factor and emotion and electrode as within-subjects factors. The main effects of age group ($F(1,28) = 18.82$, $p < .05$), electrode ($F(3,84) = 9.93$, $p < .05$), and emotion ($F(3,84) = 4.71$, $p < .05$) were all statistically significant. The electrode by age group ($F(3,84) = 3.76$, $p < .05$) and the emotion by age group interactions ($F(9,252) = 6.27$, $p < .05$) were both statistically significant. All other interactions were not statistically reliable (all $F < 1$). To understand the critical emotion by age group and electrode by age group interactions, planned comparisons (paired-samples *t*-tests, 2-tailed, $\alpha = 0.05$) were conducted separately for young and older adults at each electrode.

Young adults had larger P1/N1 differences at electrode PO3 for probes above angry, sad, and happy faces compared to neutral faces. Additionally, young adults had larger P1/N1 differences at electrode PO4 for probes above happy faces compared to neutral faces. However, the differences between probes above angry and sad faced compared to neutral faces were only marginally reliable. Moreover, young adults had larger P1/N1 differences at electrode P7 for probes above angry and sad faces compared to neutral faces. In addition, young adults had larger P1/N1 differences at electrode P8 for probes above angry faces compared to neutral faces (see Figure 12 and Table 5). Taken together, these results indicate that for young adults emotional faces can enhance the processing of stimuli in other locations of the visual field.

Older adults had no statistically reliable differences (all *t* < 1.99). These results suggest that, for older adults, emotional faces do not enhance the processing of stimuli in other locations for older adults.

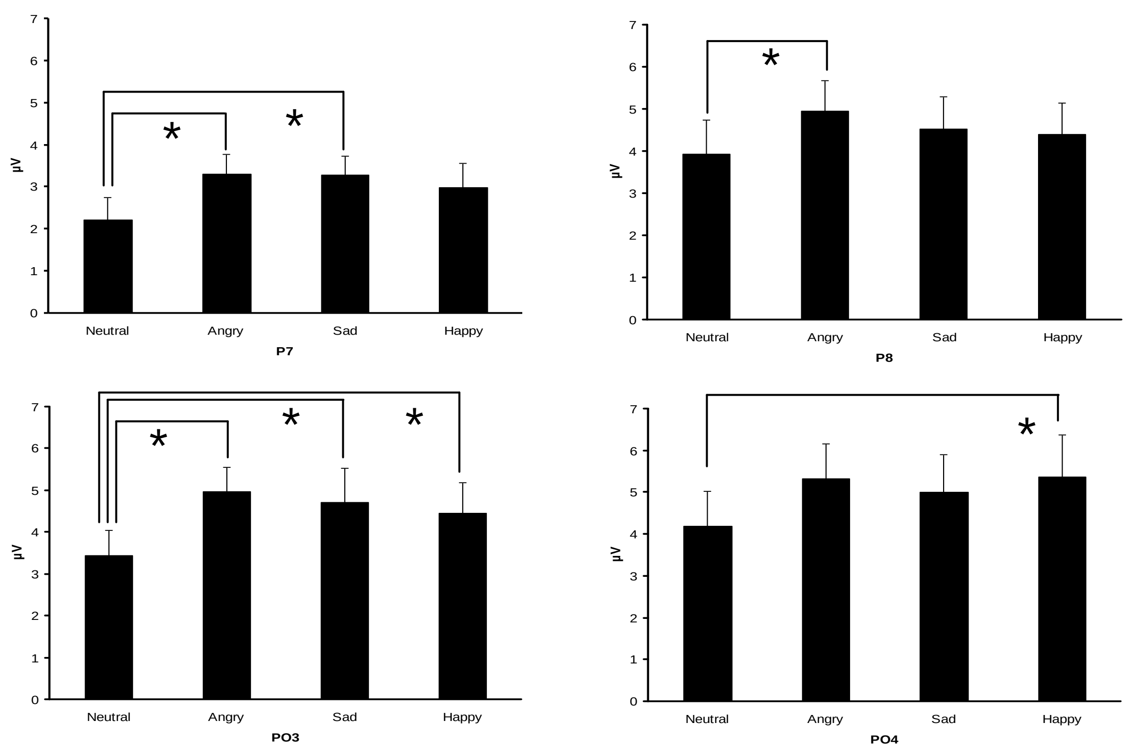

Figure 12: Young adult P1/N1 differences to probes located peripherally above the faces at short SOA. Asterisks denote significance at $p < 0.05$.

Table 5: Young adults planned comparisons for ERPs elicited by peripheral probes at the short SOA. All comparisons are made relative to neutral faces. All comparisons have 14 degrees of freedom. Asterisks denote significance at p < 0.05. Tildes denote marginal significance at p < 0.1.

Electrode	Emotion	t-value	p-value
P7	Angry	2.68	0.018*
	Sad	2.30	0.037*
	Happy	1.62	0.128
P8	Angry	2.43	0.029*
	Sad	1.48	0.161
	Happy	1.40	0.182
PO3	Angry	3.52	0.003*
	Sad	2.71	0.017*
	Happy	2.77	0.015*
PO4	Angry	1.81	0.092~
	Sad	1.78	0.097~
	Happy	2.36	0.033*

3.4 ERPs by Central and Peripheral Probes – Long SOA

The ERPs elicited by the probes at 1400 – 1600 ms were examined to determine if any emotional processing biases persist for 1500 ms after the onset of the face. A mixed-model analysis of variance (ANOVA) was conducted on the P1/N1 differences for the long SOA central probes in a 2 (age group: young, old) by 4 (electrode: P7, P8, PO3, PO4) by 4 (emotion: neutral, happy, angry, sad) mixed-model design, with age group as a between-subjects factor and emotion and electrode as within-subjects factors. Only the main effects of age group ($F(1,28) = 4.56$, $p < .05$) and electrode ($F(3,84) = 4.79$, $p < .05$) were statistically significant. All other main effects and interactions were not statistically reliable (all $F < 1$). The same analysis was conducted on the P1/N1 differences for the long SOA peripheral probes. The main effects of age group ($F(1,28) = 28.06$, $p < .05$) and electrode ($F(3,84) = 13.04$, $p < .05$) were statistically significant. The electrode by age group interaction $F(3,84) = 3.95$, $p < .05$) was statistically significant. All other main effects and interactions were not statistically reliable (all $F < 1$). These results indicate that any biases present in young and old adults do not persist for 1500 ms after the onset of the face.

3.5 Behavioral Results

Reaction time (for correct responses only) and accuracy were analyzed to determine if young and older adults were faster or more accurate to respond to emotional faces compared to neutral faces. Mixed-model analyses of variance (ANOVA) were conducted on reaction time and accuracy in a 2 (age group: young, old) by 4 (emotion: neutral, happy, angry, sad) mixed-model design, with age group as a between-subjects factor and emotion as a within-subjects factor (see Figure 14).

For the reaction time data, the main effect of emotion was significant ($F(3,84) = 11.99$, $p < .05$). However, the emotion by age group interaction failed to reach significance ($F < 1$). The contrasts reveal that the main effect is due to responses to angry, sad, and happy faces being faster than responses to neutral faces ($t(14) = 4.41$, $p < 0.05$; $t(14) = 4.63$, $p < 0.05$; $t(14) = 3.76$, $p < 0.05$, respectively). The main effect of age group reveals that older adults were slower overall than young adults ($F(1,28) = 5.99$, $p < .05$). These results indicate that both young and older adults were faster to respond that a face was emotional compared to neutral.

For the accuracy data, the main effect of emotion was not statistically reliable ($F < 1$). The main effect of age group revealed that older adults were less accurate overall compared to young adults ($F(1,28) = 4.67$, $p < .05$). The interaction of emotion and age group was significant ($F(3,84) = 4.71$, $p < .05$). To further explore the interaction, separate ANOVAs were conducted for young and older adults. The young adults showed a main effect of emotion ($F(3,84) = 9.05$, $p < .05$) such that young adults were more accurate in their responses to angry, sad, and happy faces compared to neutral faces ($t(14) = 3.08$, $p < 0.05$; $t(14) = 2.36$, $p < 0.05$; $t(14) = 3.28$, $p < 0.05$, respectively). The older adults failed to show a statistically reliable main effect of emotion ($F < 1$). These results indicates that young adults were more accurate in respond that a face was emotional than neutral. However, older adults had similar accuracy for emotional and neutral faces.

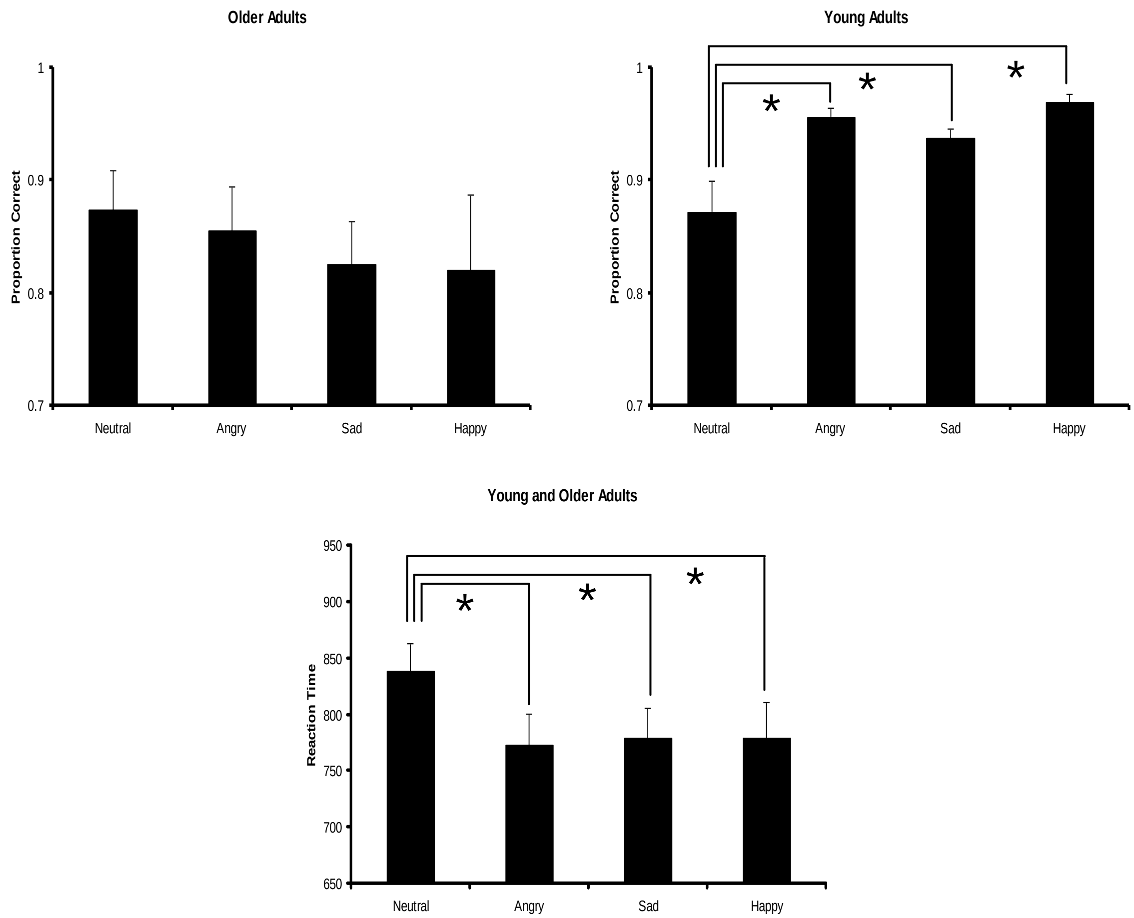

Figure 13: Reaction time and accuracy for young and older adults. Asterisks denote significance at $p < 0.05$. Both, young and older adults had faster RTs to emotional faces.

CHAPTER 4

DISCUSSION

4.1 An Emotional Bias in Young and Older Adults

The ERPs elicited by the faces and probes show remarkable similarities between young and older adults. Both young and older adults showed enhanced processing of all the emotional expressions (angry, sad, and happy) compared to neutral faces. These results replicate those of Eimer, Holmes, and McGlone (2003) who found a frontocentral positive deflection in the ERP to emotional faces compared to neutral faces. These results suggest that all emotional stimuli receive enhanced processing compared to neutral stimuli and this does not change appreciably with age. Following the interpretation of Eimer, Holmes, and McGlone (2003), this enhanced processing reflects rapid detection of emotion and evaluation of the emotional expression. Moreover, negative and positive stimuli receive the same enhanced processing.

The only differences between young and older adults were the onset and persistence of this enhanced processing as revealed by the ERPs to the faces. In particular, young adults showed this enhanced emotional processing in the earliest interval measured (95 – 135 ms) after the onset of the face while older adults didn't show the enhancement until the second interval (135 – 230 ms). Additionally, younger adults no longer enhanced emotional processing in the latest interval (450 – 700 ms) after the onset of the face while older adults still showed the enhancement in this interval. However, what are most striking are the similarities between young and older adults such that they both exhibit enhanced processing of all emotional faces compared to neutral faces.

The implications of the behavioral data follow very closely to the electrophysiological data. Both young adults and older adults were faster and more accurate to respond to emotional faces then neutral faces. Older adults were also faster to respond that emotional faces were emotional compared to responding that neutral faces were neutral. Therefore, even though older adults were generally slower and less accurate, the behavioral data suggests again that both young and older adults have a bias towards all emotional facial expressions compared to neutral faces.

Taken together, the results of the ERPs elicited by the faces, the ERPs elicited by the probes, and the behavioral data indicate that both young and older adults processing of angry, sad, and happy faces compared to neutral faces. In other words, both young and older adults have an emotional bias when processing task-relevant emotional expressions.

4.2 Age Differences in the Effect of Emotion on Concurrent Stimuli

The results of the ERPs elicited by the probes have several implications. When the probes were presented concurrent with emotional faces, younger adults had enhanced perceptual processing as measured by the P1/N1 difference compared to the probes concurrent with neutral faces. Moreover, this occurred whether the probes were presented centrally over the face or peripherally above the face. These results indicate that emotional faces can act to increase the sensitivity to stimuli in the entire visual field. This is similar to the findings of Phelps, Ling, & Carrasco (2006) who showed that centrally presented fearful faces can increase sensitivity to contrast in peripheral locations of the visual field. The results of the current study extend these findings to other emotional faces (i.e., angry, sad, and happy). These results indicate that emotional stimuli can enhance processing above and beyond the normal enhancement by visuospatial attention. Emotion may increase the sensitivity of the system to help detect important events in other locations of the visual field and not only where the emotional stimuli is located. However, older adults did not show this effect. Older adults may not effectively use the emotional facial expressions to enhance their sensitivity to other stimuli in the visual field. It may be the case that older adults do not have sufficient resources to enhance processing throughout the visual field and need to focus their resources on the central task.

4.3 Task-relevant vs. Task-irrelevant Emotion

Interestingly, the older adult results conflict with the results from the Mienaltowski et al. (2006) study. The current study found that older adults deploy more visuospatial attention to probes concurrent with angry and sad faces compared to neutral faces. The Mienaltowski et al. (2006) study found that older adults withdrew attention from angry faces. However, there is a major difference in the tasks between the Mienaltowski et al. (2006) study and the current study that can explain the discrepant findings. The current study asked the participants to judge whether the faces were emotional or neutral while the Mienaltowski et al. (2006) study asked the participants to detect the probes. Because the current study made the emotion task-relevant, it is not surprising that older adults could not withdraw attention from the angry faces because this would impede their task performance. Older adults may prefer to withdraw attention from angry faces when they are able to but this tendency isn't so strong as to override their task goals. However, this does provide evidence that these differences are a goal-related outcome and not because of physiological degradation in older adults. Older adults can process negative information when it is task-relevant, but may prefer to avoid negative information if it is not task-relevant. Future research should focus on what older adults do in everyday situations when they encounter negative information.

The current study's results do not support a strong version of socioemotional selectivity theory (SST). SST would predict that older adults would show enhanced processing of positive emotional expressions and reduced processing of negative emotional expressions. However, older adults enhanced processing of angry, sad, and happy faces. This suggests that older adults have an emotional bias while processing task-relevant emotional faces. SST states that if older adults face conflicting goals of gathering information and emotion regulation, then older adults will choose to regulate their emotions. In the current study, older adults needed to gather information to make a choice as to whether the faces were emotional or neutral and this task overrode any preferences to avoid negative information. Older adults clearly chose to focus on the negative stimuli to gain information to perform their task accurately. However, the current study cannot directly address SST because, like previous studies (e.g., Mather & Carstensen, 2003; Isaacowitz et al., 2006a, Isaacowitz et al., 2006b; Mienaltowski et al., 2006), there was no direct measure of future time perspective or the goal states that were active in older adults during the task. Future studies need to measure these to provide any definitive confirming or disconfirming evidence for SST predictions in the processing of emotional information.

4.5 Summary

The current study suggests that both young and older adults have a bias in processing emotional faces compared to neutral faces. Young adults did not show evidence of a negativity bias but rather a bias to enhance processing of all emotional facial expressions. Additionally, older adults did not show any evidence of a positivity effect. Older adults were similar to young adults in showing a bias towards enhancing processing for all emotional facial expressions. In face, older adults showed the strongest enhancement for the negative emotional faces, and therefore, the results cannot support SST. At least in regard to task-relevant faces, young and older adults have an emotional bias.

The results also suggest that, at least for young adults, emotional facial expressions can enhance processing of stimuli in other areas of the visual field that occur concurrent with the emotional face. This suggests that emotion acts to enhance arousal or increase sensitivity to stimuli throughout the visual field. However, this may decrease with age because older adults did not show evidence for the same phenomenon.

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