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The Effects of Age and Task on Visual Emotion Processing

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THE EFFECTS OF AGE AND TASK ON VISUAL EMOTION PROCESSING

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By
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Younger adults’ perception of and attention to facial stimuli are enhanced by positive and negative emotional expressions, with negativity leading to a greater benefit than positivity. Conversely, older adults demonstrate a positivity bias, devoting more attention to positive stimuli and less to negative. It is unclear if age differences in these attentional preferences emerge due to differences in how their perceptual systems respond to positive and negative stimuli. Emotional facial expressions elicit enhanced P1 and N170 components of visually-evoked event-related potentials (ERP) over posterior scalp regions associated with vision. The current study examined the extent to which angry and happy facial expressions evoked differential patterns of P1 and N170 enhancements in younger \( (n = 21, \text{ages 18-30}) \) and older \( (n = 20, \text{ages 60-76}) \) adults. Participants were presented with happy, angry, and neutral faces under four instructional conditions: passively view, passively view but consider emotion, categorize emotion, and categorize gender. ERPs were recorded from the posterior scalp electrodes of a 128-channel high density electrode array and were time-locked to the onset of facial stimuli. The recordings were segmented and averaged based on the instructional condition and emotional expression of the stimulus. Analyses of the average P1 and N170 latencies revealed no age differences. Overall, participants displayed larger amplitude P1 and N170 to all stimuli when asked to categorize gender or emotionality. Contrary to expectations, both younger and older adults displayed larger N170 amplitudes for angry
and happy expressions relative to neutral ones. Although older adults display a positivity bias in allocating attention to emotional stimuli, in the current study, younger and older adults both displayed an enhanced N170 for emotional faces relative to neutral faces, suggesting that the perceptual systems of younger and older adults are similarly engaged in processing positive and negative facial expressions at early time points.
Introduction

Emotional information is processed preferentially over non-emotional information (Isaacowitz, Wadlinger, Goren, & Wilson, 2006b; Leclerc & Kensinger, 2008; Murphy & Isaacowitz, 2008), and humans tend to process negative information more quickly than positive or neutral information if that information is threat-related (Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001). Moreover, humans are biologically prepared to respond to threat (Öhman & Dimberg, 1978; Öhman, Eriksson, & Olofsson, 1975; Seligman, 1970) because it leads to increased chances of survival (Öhman, 2005). Past research has found that younger and older adults differentially process emotional stimuli in their environments. Specifically, younger adults display a negativity bias in that negative emotional stimuli receive more attention and a greater investment of perceptual resources than do non-negative stimuli (Baumeister, Bratslavsky, Finkelauer, & Vohs, 2001; Carretié, Hinojosa, Albert, & Mercado, 2006; Compton, 2003; Rellecke, Sommer, & Schacht, 2012). In contrast, older adults display a positivity bias in that, after preferentially attending to all emotional stimuli more than to neutral, they shift their focus toward the more positive stimuli available (Carstensen, Isaacowitz, & Charles, 1999; Isaacowitz, Allard, Murphy, & Schlanger, 2009; Isaacowitz et al., 2006a, 2006b; Mather, 2012; Murphy & Isaacowitz, 2008).

Negative information may be processed preferentially by younger adults relative to positive or neutral information because of its relation to threat. Therefore, it is intriguing that older adults seem to process positive information preferentially over negative information. Researchers have hypothesized several reasons for the positivity
bias that older adults display. The first potential explanation for this positivity bias is socioemotional selectivity theory (SST; Carstensen et al., 1999). SST states that, as people grow older and have a more limited sense of how much time remains in life, they tend to focus more on emotion regulation strategies rather than knowledge-seeking goals. Older adults seem to use emotion regulation strategies in order to maximize positivity in their lives and ignore negativity. The second explanation for this positivity bias is expressed in the Aging Brain Model (ABM; Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011). The ABM proposes that older adults experience a deterioration of neural connections, especially within the amygdala, and that this lessens older adults’ reactivity to negative stimuli. The amygdala is involved in feeling and recognizing fear and anger (Adolphs, Tranel, Damasio, & Damasio, 1994, 1995), as well as memory for emotional stimuli (Adolphs, Cahill, Schul, & Babinsky, 1997). Proponents of the ABM argue that aging is accompanied by reduced amygdala activity; therefore, older adults respond preferentially to positive stimuli because positive stimuli still evoke increased levels of arousal in older adults, whereas negative stimuli do not (Cacioppo et al., 2011). On the other hand, younger adults respond preferentially to negative stimuli because their amygdala still maximally react to arousing stimuli that signal threat. Thus, older adults may respond preferentially to positive stimuli because the neural circuitry in the amygdala that deals with fear and anger may be operating sub-optimally in old age.

Two other possibilities also exist but go beyond the scope of this thesis. Advancing age is often accompanied by elevated levels of pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor α (TNFα). These cytokines cause older adults to exhibit symptoms of “sickness behavior” (Inagaki, Muscatell, Irwin, Cole,
& Eisenberger, 2012), such as cognitive decline, social withdrawal, and avoidance of negative emotion, among other symptoms. Inflammation also leads to increased amygdala activation when participants view socially threatening stimuli, such as angry faces. However, in general, older adults show less amygdala activation in response to negative stimuli than to positive stimuli (Gunning-Dixon et al., 2003; Iidaka et al., 2002; Mather et al., 2004), so it is likely that elevated cytokines are not responsible for a positivity bias in older age. Finally, it is also possible that these hypotheses are not mutually exclusive. For instance, older adults may be more motivated to avoid negative stimuli than younger adults, and, consequently, display a positivity bias. Actively ignoring negative stimuli or reappraising them in a more positive light would yield less amygdala activity (St. Jacques, Dolcos, & Cabeza, 2008). Also, differences in amygdala activity could arise from changes in motivation via long-term potentiation, where certain neural circuits are made stronger by repeated use. When motivated to implement goals that regulate one’s reaction to negative stimuli, the resulting shifts in the patterns of long-term potentiation could also yield age differences in amygdala activity. Investigating each of these possibilities is a complex process, as they each require measuring longitudinal changes in biomarkers associated with health or longitudinal changes in motivation to regulate one’s emotion throughout adulthood.

The current study examined the first two possible explanations for the differential pattern in emotion processing that emerges when comparing younger and older adults by collecting both behavioral data and electrophysiological data that reflected participants’ reactions to the onset of emotional faces. Numerous researchers have demonstrated that emotion processing differences exist between older and younger adults using behavioral
tasks (Carstensen et al., 1999; Isaacowitz et al., 2006a, 2006b; Mather, 2012; Murphy & Isaacowitz, 2008). Also, there is evidence for age-related differences in the activation of certain brain structures, such as the amygdala, when adults are presented with negative stimuli (Cacioppo et al., 2011; Inagaki et al., 2012). In order to better understand the forces that might be driving these age differences, it is important to observe when during the emotion perception process the differences begin to emerge. There has been limited work investigating the timing of age differences in emotion perception. The current study examined visually-evoked event-related potentials in order to investigate age-related differences early on in the time course of neural activity (100-200 ms after stimulus onset) during facial emotion processing. In addition, the degree to which emotion processing is directly relevant to participants’ reactions to facial stimuli was manipulated in order to investigate emotion processing over a range of possible attentional investment conditions (Rellecke et al., 2012), from passive (no decision required) to active (decision required). The early time course of neural activity of younger and older adults during each condition (true passive viewing, emotional passive viewing, gender decision, and emotion decision) was compared for faces displaying each of three different emotions (happy, angry, and neutral). Ultimately, this study had two aims. The first aim was to examine when and to what extent aging impacts early emotion processing in the visual cortex. The second aim of this study was to investigate whether differences in visual emotion processing arose with different instructional conditions designed to manipulate the relevance of emotion to stimulus processing.
Age Differences in Emotion Processing

Emotion processing consists of one’s perception of the emotional components of a stimulus in the environment, one’s reaction to that stimulus, and emotion regulation (e.g., reappraisal or suppression) that may emerge if the stimulus evokes an arousing response (Ochsner & Gross, 2005; Phillips, Drevets, Rauch, & Lane, 2003). One’s perception of a stimulus in the environment may include attention to and categorization of that stimulus based on its emotional salience (or how emotionally evocative the stimulus is) as well as based on the specific valence or kind of emotion conveyed by that stimulus. Furthermore, one’s reaction includes thoughts, emotions, and behaviors evoked by a stimulus relative to the goals that the individual holds with respect to processing that stimulus.

As mentioned above, younger adults display a negativity bias, as they preferentially attend to and remember negative information over neutral or positive information (Carretié et al., 2006; Compton, 2003; Rellecke et al., 2012). Negative events have more of an impact on the thoughts and behaviors of younger adults than other categories of events because they have a more lasting effect on younger adults’ subjective experience of emotion (Baumeister et al., 2001; Mickley & Kensinger, 2008). Also, younger adults use more energy trying to avoid a negative mood than trying to induce a positive mood (Baumeister et al., 2001; Baumeister, Heatherton, & Tice, 1994; Tice, Bratslavsky, & Baumeister, 2001). In addition, younger adults tend to think about negative information more than positive or neutral information when they are making decisions (e.g., Forgas, 1998). Finally, younger adults tend to focus more on negative images than positive or neutral images (Isaacowitz et al., 2006b). Taken together, these
studies suggest that younger adults display deeper or more careful processing of negative emotional events. 

One reason why younger adults may display a bias toward negative information is that the act of thinking about and remembering negative information increases one’s chance for survival more than thinking about and remembering positive information (Öhman, 2005). This is supported by the finding that negative information, especially information related to threat, is processed preferentially by the brain (Eastwood et al., 2001; Fox et al., 2000; Hansen & Hansen, 1988; Öhman et al., 2001). Normally, when one encounters a visual stimulus, this information is passed from the thalamus to the occipital cortex. At the same time, the amygdala is sending information to the occipital cortex, and, as a result, the processing of emotional stimuli is enhanced in perceptual regions. Crude, low-level details from negative stimuli are shared more rapidly along magnocellular channels across the cortex, especially when the negativity is tied to a potential threat in the individual’s environment (Bocanegra & Zeelenberg, 2011). This preferential processing is important to survival because quickly noticing a threat facilitates the mobilization of a response to or retreat from the threat and could mean the difference between life and death.

In contrast to younger adults, older adults display a positivity bias, or a tendency to preferentially focus on positive information. Specifically, in one study, older adults preferentially gazed at happy faces over neutral faces and looked away from angry faces paired with neutral faces (Isaacowitz et al., 2006a). Also, older adults have faster response times to a dot probe when it replaces a happy face than when it replaces an angry face (Isaacowitz et al., 2006b; Mather & Carstensen, 2003). Because the dot probe
Task is a measure of selective attention, this suggests that older adults allocate more attention to happy faces than to angry faces. Older adults also have a better memory for positive information than they do for negative information (Carstensen & Mikels, 2005). Moreover, older adults are more responsive to training that leads them to focus on positive stimuli than they are to training that leads them to focus on negative stimuli (Isaacowitz & Choi, 2011). There is also evidence that older adults may suppress negative emotional information (Isaacowitz et al., 2006a, 2006b; Mather & Carstensen, 2005; Mienaltowski, Corballis, Blanchard-Fields, Parks, & Hilimire, 2011), even though researchers have shown that negative information is much more salient than positive information (Baumeister et al., 2001; Isaacowitz, Toner, & Neupert, 2009; Rozin & Royzman, 2001).

**Socioemotional Selectivity Theory (SST)**

The most widely accepted explanation for the emergence of age differences in emotion perception is socioemotional selectivity theory. SST states that an individual’s perception of time influences how they prioritize social goals (Carstensen et al., 1999). Older age is typically associated with a more limited sense of time because one’s time left in life decreases as one gets older. SST posits that, as individuals begin to perceive their time as limited, they begin to focus on positive information while ignoring negative information. This emotion regulation strategy maximizes the amount of positivity in one’s life and minimizes negativity. A number of studies support this prediction. For instance, several studies have shown that older adults are better at maximizing positivity in their relationships and minimizing negativity even during times of tension (Birditt & Fingerman, 2005; Birditt, Rott, & Fingerman, 2009).
There are several types of conflict resolution strategies that one can use when one experiences problems in a relationship, ranging from passive to active depending on whether the person avoids or confronts the problem (Rusbult & Zembrodt, 1983). Conflict resolution strategies also range from constructive to destructive depending on whether the strategy is likely to improve or damage the relationship. Some examples of constructive strategies are discussing the problem and waiting for things to change, whereas some examples of destructive strategies are arguing and ignoring the other person. Using participants’ verbal descriptions of conflicts that they experienced in close relationships as well as problematic relationships, Birditt and Fingerman (2005) found that regardless of one’s relationship type and level of distress, older adults are less likely to argue in response to interpersonal conflict and more likely to do nothing, whereas younger people are more likely to engage in yelling as a response to conflict. Similarly, Birditt et al. (2009) interviewed adult parent-child dyads about their interpersonal tensions and found that both partners were more likely to self-report the past use of constructive rather than destructive strategies, but that older adults, or the parents of adult children, endorsed proportionately more constructive strategies to ameliorate tension because of the sustained long-term investments that they have already made into their relationships with their children. These studies suggest that older adults are motivated to implement emotion regulation strategies in their relationships in order to maximize positivity in their daily lives and to minimize negativity.

Due to the effects of negative emotions on their well-being, older adults may be more motivated to use emotion regulation strategies than younger adults. Although we can note the above findings for interpersonal relationships, research also suggests that
these tendencies drill down to more basic levels of analysis, including the simple perception of emotional stimuli. For instance, Isaacowitz and Choi (2011) found that older adults who were trained to go against their natural tendency to focus more on positive stimuli and instead to focus more negative stimuli reported being in a worse mood afterwards than did younger adults also trained to focus on negative stimuli, as well as adults of all ages who were trained to focus on positive stimuli. In other words, when asked to act against their default emotion regulatory goal state, older adults are adversely impacted. It is possible that negative emotional stimuli have more of an immediate effect on the well-being of older adults than that of younger adults; thus, older adults work to avoid experiencing negative stimuli more so than do younger adults in order to regulate their emotions.

SST states that, unlike older adults who are focused on maximizing positive emotions, younger adults are focused on knowledge-seeking goals. Researchers define knowledge-seeking goals as the need for individuals to use social interactions to pursue information and/or novel experiences (Carstensen et al., 1999). Individuals tend to engage in knowledge-seeking to learn more about the world. By gaining experience within the world, those who hold knowledge-seeking goals can refine their interests and become more specialized in their careers and hobbies (Baltes, 1997). Of course, having these new experiences often is associated with the risk of encountering negativity and disappointment along the way. Those with an expansive view of the future (those with an unlimited sense of time) are more likely to prioritize novelty and knowledge-seeking and display a greater tolerance for negativity (Carstensen, 1992; Carstensen et al., 1999; Fung, Carstensen, & Lutz, 1999; Murrell & Mingrone, 1994; Scheibe & Carstensen,
2010). For younger adults, focusing on negative information can be helpful for making long-term choices and in avoiding mistakes that could impede their ability to pursue future goals. Tolerating negativity also prevents those with a more expansive sense of future time from ignoring opportunities that are more wrought with the potential for an unpleasant outcome, as having more time left in life allows for additional opportunities to rebound from loss or disappointment (Carstensen et al., 1999).

Past research examining age differences in the strategies that people use to solve everyday problems have found that older adults are better at implementing emotion regulation strategies than are younger adults, especially during interpersonal problems, partly due to older adults’ greater awareness of emotion in everyday situations (Blanchard-Fields, 2007). Older adults experience less negative emotion than do younger adults, which supports the premise that older adults are more focused on emotion regulation goals than younger adults (Carstensen, et al., 1999; Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Lawton, 2001) and/or are more effective at applying emotion regulation or avoiding emotion-inducing situations (Blanchard-Fields, 2007).

Because of younger adults’ difficulty in anticipating negative emotional situations in their environment, younger adults are more likely to experience negativity than are older adults. When faced with negativity, younger adults are then forced to display response-focused emotion regulation strategies like denial or suppression (Scheibe & Carstensen, 2010). Older adults, on the other hand, are less open to experiencing negativity and, as a result, minimize the need for response-focused emotion regulation through preventive thoughts and actions.
There are several ways in which older adults and other individuals with a limited sense of time attempt to maximize positive emotions. For instance, they can maximize positive feelings and minimize negative feelings by interacting with people who they know well, as close others are familiar and are part of a track record of emotionally meaningful experiences (Carstensen et al., 1999). Another way that individuals try to maximize positivity is by avoiding negative stimuli, like conflicts, altogether. When conflict cannot be avoided, individuals may balance their negative appraisals with positive ones, placing the negativity in a larger context of a more pleasant history of interactions (Carstensen, Gottman, & Levenson, 1995; Carstensen, Graff, Levenson, & Gottman, 1996; Levenson, Carstensen, & Gottman, 1993, 1994). For example, in one study of conflict between couples, older couples had a tendency to intersperse positive comments about their love for their partner with negative comments about undesirable characteristics displayed by their partner (Levenson et al., 1993). The above strategies are referred to as antecedent-focused strategies (Gross, 1998), as they involve an individual (a) recognizing the potential for negativity before the negativity actually emerges, and (b) implementing an action-oriented strategy to remove one's self from the environment, or a reappraisal strategy to view the unpleasant experience or stimulus in a new and appropriately positive light. SST predicts that older adults are more motivated than younger adults to use antecedent-focused strategies to minimize their exposure to negatively arousing stimulation (Mather & Carstensen, 2005; Scheibe & Carstensen, 2010). Moreover, when exposed to negative stimuli under passive viewing conditions, older adults will spontaneously shift their attention away from negative aspects of the display toward the more positive ones (Isaacowitz et al., 2006b). A spontaneous shift
toward positive and away from negative stimuli (i.e., the positivity bias) is believed to reflect older adults’ default goal of pursuing emotionally meaningful experiences and requires a conscious effort to successfully implement (Mather, 2012).

**Aging Brain Model**

Another account for why older adults focus more on positive than on negative or neutral material lies in the Aging Brain Model (ABM; Cacioppo et al., 2011). Whereas SST states that older adults prioritize emotional goals as a method of mood regulation and maintaining emotional closeness, the ABM states that impairments in amygdala and adrenergic functioning lead to a diminishing impact of negative stimuli on emotion processing. The aging brain model contains three assumptions: (1) As one ages, negative stimuli are less effective at activating the amygdala, whereas the amygdala’s reactivity to positive stimuli does not change; (2) Decreased amygdala activation by negative stimuli is associated with decreased emotional arousal in response to these negative stimuli; and (3) Because older adults experience less emotional arousal in response to negative stimuli, they no longer display a memory advantage for negative stimuli that exists for younger adults, which leads to increased well-being in older adults (Cacioppo et al., 2011).

Past neuroimaging research supports ABM. For example, there are several fMRI studies in which older adults displayed more amygdala activity in response to positive pictures than in response to negative pictures or no difference in amygdala activation between neutral and negative images (Gunning-Dixon et al., 2003; Iidaka et al., 2002; Mather et al., 2004). In contrast, younger adults show a similar level of amygdala activity for positive and negative pictures, and showed greater activation to emotional pictures
relative to neutral ones. Furthermore, when asked to rate the pictures, older adults rated the negative pictures as less emotionally arousing than younger adults. In one study (St. Jacques et al., 2008), older adults rated negative pictures as being similar in arousal to neutral pictures, but younger adults reported greater arousal from these negative images relative to neutral images. Moreover, older and younger adults rated positive pictures as similarly emotionally arousing. Overall, older adults’ reduced reactivity to negative stimuli suggests a positivity effect that is driven by a suppression of the influence of negativity.

The ABM serves as a viable alternative to SST when accounting for age differences in emotional reactivity to stimuli; however, data do not always support the ABM. For instance, although older adults show less physiological reactivity to negative emotional stimuli, behavioral studies have found that negatively arousing stimuli are still sometimes more effective than neutral stimuli at capturing older adults’ attention. For instance, Charles, Mather, and Carstensen (2003) found that older adults spend proportionately the same amount of time looking at negative images and positive images as do younger adults. They also found that both younger and older adults spend more time looking at negative images than looking at positive images. Furthermore, Mather and Knight (2006) found that both older and younger adults detected a negative face in a crowd of neutral faces more quickly than a positive face in a crowd of neutral faces, which suggests that there is an attentional advantage for negative stimuli even in older age. Also, Isaacowitz, Allard, et al. (2009) found that the positive gaze preference in older adults does not emerge until 500 ms after stimulus onset. This suggests that older adults are willing to attend to negative stimuli in early time frames, only to later
disengage from the negative stimuli. This is consistent with past findings that
demonstrate older adults' memory disadvantage for negative stimuli in that older adults
invest less attention to negative stimuli than to positive stimuli. Given the reduced
investment of attention to negative stimuli, these stimuli may have less of an impact on
older adults’ subjective experience of emotion. Interestingly, these data are often taken as
support for SST but could conceivably also support the ABM.

The two theories differ in terms of their underlying biological mechanisms.
Whereas SST suggests that frontal regions of the cortex are more actively involved in
emotion regulation with age, the ABM suggests that advancing age is associated with
brain-related deterioration that disrupts emotion processing, especially deterioration of
the connectivity of cortical regions with subcortical structures involved in negative
emotion detection. Damage to these latter circuits will disrupt our experience of emotion.
There is evidence that amygdala lesions lead to decreased emotional arousal in response
to negative stimuli similar to the decreased emotional arousal for negative stimuli seen in
older adults (Adolphs, Russell, & Tranel, 1999; Berntson, Bechara, Damasio, Tranel, &
Cacioppo, 2007; Winston, Gottfried, Kilner, & Dolan, 2005). Specifically, several studies
have shown that people with amygdala/anterior temporal lesions rate negative emotional
stimuli as less arousing than age- and gender-matched controls, but they rate positive and
neutral stimuli similarly to age- and gender-matched controls. Again, these patterns are
similar to those found in the behavior of older adults in past studies (Adolphs et al., 1999;
Berntson et al., 2007). Furthermore, in both patients with amygdala/anterior temporal
lesions and older adults, differences in emotional arousal cannot be attributed to difficulty
in the recognition and categorization of emotion stimuli. For example, Berntson et al.
(2007) found that people with amygdala/anterior temporal lesions were not impaired at recognizing or labeling negative emotional images. Similarly, studies that controlled for the amount of cognitive load found that older adults are just as good at recognizing facial emotions as younger adults (Mienaltowski et al., 2013; Orgeta, 2010).

Although the ABM suggests that older adults’ reduced amygdala response to negative emotional stimuli leads to the positivity effect mentioned earlier, it is important to note that, in older adults, the neurological connections between the amygdala and other brain regions might also account for the positivity effect. More specifically, for older adults, the amygdala has a richer connectivity with the frontal lobe than with the visual cortex, whereas the converse is true for younger adults (St. Jacques et al., 2008). Frontal lobe activation is associated with emotion regulation. This fits with prior evidence that suggests that older adults are generally better at emotion regulation than younger adults and argues against the ABM. Amygdala activation is inversely correlated with frontal lobe activity, whereas amygdala activation is positively correlated with emotional reactions (Phan et al., 2005; Taylor, Phan, Decker, & Liberzon, 2003).

Normally, inputs sent to the visual cortex are elaborated upon by multiple brain areas, including the amygdala. Visual input may reach the amygdala early on, allowing for the amygdala to tag that input as being emotionally relevant. It is possible that the amygdala of older adults receive this input and then act less strongly to enhance the activity of visual cortices than do the amygdalae of younger adults because of the degradation of connections between the visual cortex and the amygdala. However, a reduction in any signal boost to the visual cortex provided by the amygdalae of older adults can also be explained by emotion regulatory frontal lobe activity. This latter
possibility is supported by evidence that older adults initially attend to negative stimuli when they are related to threat (Isaacowitz, Allard, et al., 2009; Mather & Knight, 2006), but that older adults then look away and also do not display a memory advantage for negative stimuli.

**The Current Study**

Rellecke and colleagues (2012) manipulated younger adults’ attention to emotional facial expressions using instructional conditions that focused participants on the emotional cues of the stimuli or which deemphasized these cues. That is, in some conditions, the emotions that were displayed were relevant to the task being performed, whereas, in others, emotions were not relevant to the task being performed. Emotion processing was operationalized using components of waveforms segmented based on the onset of emotional faces and recorded over occipital, temporal, and parietal regions of the scalp. Electrodes over these sites allowed for the assessment of visually-evoked cortical responses to angry, happy, and neutral faces as indexed by positive and negative going peaks and inflection points within 220 ms after face stimulus onset for each instructional condition. Rellecke and colleagues hoped to find that emotion led to enhancements of two components of the event-related potential, the occipito-parietal P1 (or P100) emerging 80-120ms after face onset and the occipito-temporal N170 emerging 170-220 ms after face stimulus onset.

In response to the onset of emotional faces, angry and happy faces elicited greater amplitude P1 and N170 components, regardless of the instructional conditions (Rellecke et al., 2012). Prior research on attentional cueing demonstrates that, when endogenously or exogenously (internally or externally, respectively) cued to attend to a particular
location in space, the emergence of a stimulus in this cued location leads to an enhanced positive going peak (or P1) approximately 100 ms after stimulus onset (Hillyard, Vogel, & Luck, 1998; Kraut, Arezzo, & Vaughan Jr., 1985; Martínez et al., 1999). This enhanced peak is tied to faster detection times when participants are asked to identify the location of a visual target that appears on the display (Curran, Hills, Patterson, & Strauss, 2001). Consequently, Rellecke and colleagues (2012) interpreted the P1 enhancement that they observed for angry and happy faces as evidence of the ability of emotional faces to capture attention (relative to neutral faces) regardless of the conditions under which the emotional faces were displayed to the participants (i.e., task relevant or not task relevant).

Prior research on face recognition has revealed that a negative-going peak follows the P1 and is greatest in amplitude when an attended stimulus is a face (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Eimer, 2000). Although an N1 component is evoked for other visual stimuli, the N170 seems to be associated with activity occurring in face fusiform regions and reflects additional cognitive and perceptual processes associated with the social importance of facial stimuli (Batty & Taylor, 2003; Blau, Maurer, Tottenham, & McCandliss, 2007; Schyns, Petro, & Smith, 2007; Sprengelmeyer & Jentzsch, 2006). Rellecke and colleagues (2012) found that angry and happy faces elicited larger amplitude N170s than did neutral faces, with angry faces eliciting a slightly larger response than happy faces. Again, these findings emerged regardless of instructional condition for a young adult sample, suggesting that emotion processing happened in an automatic fashion and impacted how visual perceptual regions of the cortex reacted to the facial stimuli.
When taken together, these findings suggest that, for younger adults, the emotional features of facial stimuli command additional scrutiny from the cortex and elicit what appears to be greater activity for attentional and categorization purposes. These findings are consistent with prior research demonstrating the impact that emotions have on stimulus perception (Compton, 2003; Phelps, Ling, & Carrasco, 2006; Smith, Cacioppo, Larsen, & Chartrand, 2003). Emotions are evolutionarily relevant to humans and merit additional consideration for response generation purposes. In light of the aforementioned differences observed in the reactions of younger and older adults to emotional stimuli, the current study sought to determine whether the emotional features of faces would impact the neurophysiological reactions of older adults in the same way that they impact younger adults, using Rellecke and colleagues’ (2012) pattern of findings as a starting point. Given that older adults (a) are motivated to regulate their reactions to negative expressions of others relative to younger adults, or (b) experience less arousal from intense negative expressions (e.g., angry expressions) than do younger adults, older adults were expected to display larger amplitude P1s and N170s when evoked by happy emotional faces than when evoked by angry and neutral expressions, but younger adults were expected to display a larger amplitude P1 and N170 for both happy and angry expressions relative to neutral. This expectation is consistent with prior ERP research on older adults’ visually-evoked reactions to emotional faces.

For example, Hilimire, Mienaltowski, Blanchard-Fields, and Corballis (2013) examined the processing of emotional faces in older and younger adults by assessing the modulation of the Fronto-central Emotional Positivity (FcEP) component of the EEG measured over frontal electrodes while participants indicated when they saw a visual
probe appear over photographs of emotional faces which were displaying a happy, sad, angry, or neutral expression in a go/no go task. The FcEP reflects early enhanced processing of emotional facial expressions by the prefrontal cortex (Eimer & Holmes, 2007). The FcEP is the average of a positive-going waveform within three different time windows (110-130 ms; 165-185 ms, and 225-350 ms). The early time windows (before 200 ms) represent more automatic processing of emotional stimuli, whereas the later time window represents a more controlled form of processing such as conscious evaluation of a stimulus and cognitive control reactions such as emotion regulation. In early time frames, greater average amplitude represents enhanced automatic early processing of a stimulus. Hilimire and colleagues (2013) found that, in the early time window (110-130 ms), younger adults had a larger FcEP for negative faces, whereas older adults had a larger FcEP for positive faces, thus demonstrating an automatic early positivity effect for older adults and an automatic early negativity effect in younger adults. Early in stimulus processing, older and younger adults automatically allocate more attention to happy and angry faces, respectively. Because older adults showed an enhanced FcEP for happy faces in the early time frame, a cognitive control account for this positivity effect observed in older adults was viewed as less convincing by the authors.

In another study, Mienaltowski et al. (2011) examined older and younger adults’ attention to emotional faces using the P1 component of visually-evoked responses to the onset of a checkerboard probe appearing over an emotional face displaying a happy, angry, sad, or neutral expression. Similar to Hilimire et al. (2013), researchers employed a go/no go task in which participants indicated when they observed a checkerboard probe appear over a centrally-presented emotional face (400-800 ms after the onset of the face).
Past research demonstrates a perceptual boost for stimuli that appear immediately after a threat-related stimulus (Bocanegra & Zeelenberg, 2011; Phelps et al., 2006). Thus, a larger P1 amplitude for the checkerboard probe would indicate enhanced attention to the preceding facial stimulus. Overall, younger adults showed a larger amplitude P1 when a checkerboard probe appeared over angry, happy, and sad faces than when the probe appeared over neutral faces. Older adults, however, displayed a smaller amplitude P1 for a checkerboard probe that appeared over angry faces than for neutral faces. A positivity effect was not observed in the older adult data, so these findings suggest that younger adults devote more attentional resources to negative stimuli than to other categories of emotional stimuli, whereas older adults suppress attention to negative stimuli rather than enhance their attentional allocation to positive stimuli.

Similarly, Kisley, Wood, and Burrows (2007) found that older adults allocate less attention to negative stimuli instead of allocating more attention to positive stimuli. Participants viewed negative, positive, and neutral images for 1 second, and then were asked to categorize the images as positive, negative, or neutral. Kisley et al. (2007) measured the mean amplitude of the Late Positive Potential component (LPP), a waveform that appears over the central parietal area from 300-500 ms post-stimulus. The modulation of the LPP is positively correlated with the arousal level of a participant in response to a stimulus, and the LPP is involved in the selective processing of emotional stimuli according to their motivational salience (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp et al., 2000; Schupp, Cuthbert, et al., 2004; Schupp, Öhman, et al., 2004; Weinberg & Hajcak, 2010). Larger average LPP amplitude indicates that the participant is selectively attending to a stimulus because of its motivational salience.
Kisley et al. (2007) found that the age of a participant was significantly negatively correlated with their LPP in response to negative stimuli such that the older a participant was, then the more the LPP was attenuated in response to negative stimuli. Furthermore, an age-related modulation of the LPP in response to positive stimuli was not observed. In other words, older adults find negative stimuli to be less motivationally salient than do younger adults, whereas they do not exhibit an age-related change in their response to positive stimuli. This suggests that older adults are not using cognitive control in order to attend to positive stimuli over negative stimuli. Instead, it suggests that older adults demonstrate less reactivity to negative emotional stimuli, which is consistent with the ABM.

Taken together, these studies suggest that younger adults selectively attend to negative emotional stimuli at early time frames. In contrast, older adults seem to selectively attend to happy emotional stimuli and to suppress their reaction to angry stimuli at a very early stage in visual processing (at around 100 ms). It seems that older adults attend more to happy than to angry stimuli in tasks in which emotion is not explicitly relevant (Hilimire et al., 2013); however, in tasks in which emotion is relevant, older adults are able to allocate attention to negative emotional stimuli (Mather & Knight, 2006), and they do not display strong emotion recognition deficits when told to attend to emotional features of faces (Mienaltowski et al., 2013; Orgeta & Phillips, 2008). This evidence suggests that manipulating explicit attention to emotion could affect older adult’s neurophysiological responses to negative stimuli. Specifically, given past findings taken as evidence for SST, under passive viewing conditions where emotion is not relevant to making a judgment, we would expect that older adults would ignore negative
stimuli, such as angry faces, as their default mode is to regulate their reactivity to negativity. In contrast, when emotion is relevant to making a judgment about a stimulus, such as in emotion recognition tasks, past research suggests that older adults might attend more to these emotional features, be they negative or positive in nature, in order to use the relevant information to successfully follow instructions. To date, there have been no studies that examine the early time course of visual emotion processing using electroencephalography in older adults in order to determine whether task relevance moderates older adults’ electrophysiological reactions to facial stimuli, and, thus, this represents a gap in the literature. The current study extends the literature on visual emotion processing by filling this gap in the literature.

Although the instructional conditions in the study by Rellecke et al. (2012) did not influence the differential prioritization of emotions by the visual cortex in younger adults, it may be that the older adults’ visual cortex reactivity is influenced by the relevance of emotion to the task at hand. In other words, given that SST and the ABM are both developmental theories that include young adults as the early stage of development, Rellecke and colleagues’ results for younger adults alone cannot address which theory accurately predicts age-related change in emotion processing. Remember that the instructional conditions did not lead younger adults to display differential reactivity from the visual cortex despite the purposeful manipulation of attentional, or task, relevance. It is impossible to address which theory - SST or ABM – best captures the impact that aging has on emotion processing with just a younger adult sample. Rellecke and colleagues’ findings are consistent with both the idea that younger adults do not prioritize emotion regulation as much as older adults do and that younger adults' amygdala and
associated networks are intact. SST and ABM both support the prediction of differences in emotion processing between older and younger adults; however, the point of contention is when and to what extent those differences occur. Therefore, a study that examines the effect of task relevance on older adults’ prioritization of emotion has the potential to determine which hypothesis (ABM or SST) best accounts for the positivity effect observed in older adults.

If older adults are choosing not to prioritize negative emotions, as posited in SST, then they should show emotion regulation effects when they are not instructed to focus on emotion (i.e., conditions in which they are asked to passively view the facial stimuli or to identify the gender of the target depicted by the stimuli). However, when older adults are asked to focus on emotion (i.e., conditions in which they are instructed to passively view the facial stimuli while considering the emotions being expressed or to identify the emotion expressed by the target depicted in the stimuli), then they should show emotion prioritization which is similar to that of younger adults. According to SST, older adults use cognitive control to regulate their response to negative emotional stimuli when those emotions are not relevant to their current goals, but, when those emotions are relevant to their goals, like when asked to attend to or use the emotional aspects of stimuli, then older adults should prioritize negative stimuli over other categories of stimuli just as younger adults. This means that if SST holds, (a) in conditions where emotion is not relevant, older adults should show lesser amplitudes for P1 and N170 for angry faces relative to neutral faces and greater amplitudes for P1 and N170 for happy faces relative to neutral faces; but (b) in conditions where emotion is relevant, older adults should show
the same enhanced P1 and N170 amplitudes as younger adults to angry and happy faces relative to neutral.

In contrast, if older adults are experiencing amygdala and adrenergic degradation, as posited by ABM, then task relevance should have no effect on the reactivity of the visual cortex of older adults to emotional stimuli. Furthermore, older adults should show smaller amplitude P1s and N170s in response to angry faces relative to neutral or happy faces. This is because ABM posits that older adults experience degradation of the amygdala and adrenergic system in the brain, and thus, older adults are unable to adequately process negative emotional stimuli, even when those stimuli are relevant to the task at hand.

Method

Participants

Twenty-one younger adult participants, ages 18-30 ($M = 21.6; SD = 3.1$) were recruited via Study Board and email invitation to participate in this experiment in exchange for course credit (in the case of those who were recruited from Study Board) and a $20 gift card. Twenty older adult participants, ages 60-81 ($M = 68.8; SD = 4.2$) were recruited from the community via letters and phone calls inviting them to participate in the study. Older participants were screened for dementia using a telephone version of the Mini-Mental Status Exam. Older adults were compensated for their time with a $20 gift card. Older adults were screened for visual acuity problems, and each participant was allowed to wear corrective lenses if they required them to see the facial stimuli and/or to complete paper-and-pencil questionnaires.
Overview of Procedure

Participants were recruited for the study and scheduled for a session. Older adults completed brief health and dementia screens in advance of being scheduled. During the experimental session, researchers explained the procedure to participants and asked for their informed written consent (IRB #13-349; see consent form in Appendix A). The participant’s head was measured first to ensure that he or she could be properly fitted with an EEG net. If the participant’s head size was within the parameters to fit in a net, researchers then took measurements and made marks in the center of the participant’s scalp with a red china marker. Participants completed a series of paperwork that included the Brief Edinburgh Handedness questionnaire, neuropsychological screening, and a short battery of personality measures. The personality assessments included: the Center for Epidemiological Studies Depression Scale, the View of Self survey, the Emotion Regulation Questionnaire, the Behavioral Inhibition System and Behavioral Activation System questionnaire, and a demographics questionnaire. Next, participants were directed toward a testing room where researchers fitted them with the properly sized EEG net and started the computerized testing sequence for the emotion perception task. Researchers then instructed the participant to remain as still as possible during the experiment and to limit their blinking. Participants were seated at a distance of 55cm from the monitor. Participants completed the four blocks of trials for the emotion perception task, and afterwards were debriefed (see Appendix B for debriefing form).

Materials: Screening Measures and Personality Assessments

Telephone screening administered before the experimental session. A telephone screening was used during the recruitment process to rule out older respondents
who may have dementia or other serious health problems that could impact emotion perception performance (see Appendix C). The screening contains questions about basic information about the respondent (such as name, address, and telephone number), a telephone version of the mini mental state exam (e.g., Folstein, Folstein, & McHugh, 1975), and a medical history questionnaire. The telephone version of the Mini Mental State Examination consists of 21 items and was used to rule out participants who may have dementia. The examination contains questions that test the orientation, registration, attention, calculation, recall, and language of the participant. Participants must have gotten at least 17 out of 21 points on the TMMSE in order to participate in this study. Sample questions include: “What is the date?”, “Begin with 100 and count backward by 7”, and “Tell me, what is the thing called that you are speaking into.”

**Brief Edinburgh Handedness Inventory.** The Brief Edinburgh Handedness Inventory is a 10-item measure that was used to assess to what extent participants use their left and right hands for different activities such as writing and opening a box (Oldfield, 1971; see Appendix D). The survey contains two columns for each activity (one for right hand and one for left hand), and participants indicated their responses by putting two crosses in one column if they used that hand exclusively, and one cross in each column if they used both hands equally for that task. The younger adult participants in this study were predominantly right-handed (Right = 16, Left = 1, Ambidextrous = 4), as were the older adult participants (Right =19, Left = 0, Ambidextrous = 1). The 18-month test-retest reliability for the scale has been reported to be .98 (Ransil & Schachter, 1994).
Neuropsychological screening. The Neuropsychological Screening was used to learn about the participants’ medical history, which could affect the quality of the EEG data (see Appendix E). It was administered in the lab to ensure that health issues that might not have been revealed during the telephone screening were caught. Participants answered a total of 13 yes or no questions, in addition to providing an explanation for any questions for which they answered yes, and participants provided information about the medications that they were currently taking. Based on their responses to questions, participants could be excluded from participation or from data analysis. For example, if participants had significant neurological problems or a stroke, they were excluded from participation. Sample questions include: “Have you ever been examined by a neurologist or neuropsychologist?” and “Do you have a history of balance problems?” Based on the responses provided by the participants, no one was excluded for neurological problems that would have impacted their ability to participate in this study.

Snellen Visual Acuity Test. The Snellen Visual Acuity Test (Precision Vision; [www.precision-vision.com](http://www.precision-vision.com)) was used to assess older participants’ visual acuity. Participants looked at a chart containing 20 rows of capital letters, decreasing in size. The participants stood one meter away from the chart and read the lowest row of letters that they could see, yielding a Snellen fraction that was later converted to a logarithm of the minimum angle of resolution (log MAR) value. The average visual acuity of the older sample was 0.16, and the range was 0 to 0.40. No participants were excluded due to having a substantially impaired visual acuity.

Center for Epidemiological Studies Depression Scale (CES-D). The Center for Epidemiological Studies Depression Scale is a 20-item scale that was used to assess
participants’ symptoms of depression (Radloff, 1977; see Appendix F). Participants used a four-point Likert-type scale to indicate how often they experienced certain scenarios, where a = rarely or none of the time (less than one day), b = some or a little of the time (1-2 days), c = occasionally or a moderate amount of the time (3-4 days), and d = most or all of the time (5-7 days). Sample scenarios included: “During the past week, I felt that people dislike me” and “During the past week, I did not feel like eating. My appetite was poor.” Each item’s response was converted to a corresponding value from 0 to 3. The internal consistency for items on this measure typically is 0.85 (Radloff, 1977), and was 0.90 for the current study. A total score was calculated by adding the individual item’s responses, creating a scale ranging from 0 to 60.

**View of Self Survey.** The View of Self Survey was used to assess a participants’ standing on the Big Five personality traits (openness, conscientiousness, extraversion, agreeableness, and neuroticism; Rammstedt & John, 2007; see Appendix G). This scale, which is a smaller version of the Big Five Inventory (BFI-44), consists of 10 items. Participants rated how well each statement applied to their personality using a 1 to 5 Likert rating scale, where 1=disagree strongly, 2=disagree a little, 3=neither agree nor disagree, 4=agree a little, and 5=agree strongly. Sample statements include: “I see myself as someone who is outgoing, sociable” and “I see myself as someone who tends to be lazy.” Test-retest reliability for this measure is typically 0.75 (Rammstedt & John, 2007).

**Emotion Regulation Questionnaire (ERQ).** The emotion regulation questionnaire (ERQ) was used as an exploratory measure. The ERQ is a ten-item questionnaire that assesses how individuals use reappraisal and suppression as emotion
regulation strategies in their daily lives (Gross & John, 2003; see Appendix H).

Participants rated each statement on a 1 to 7 Likert-type scale where 1 = strongly disagree, 4 = neutral, and 7 = strongly agree. Sample statements include, “When I want to feel more positive emotion (such as joy or amusement), I change what I’m thinking about”, “When I want to feel less negative emotions (such as sadness or anger) I change what I’m thinking about”, and “I control my emotions by changing the way I think about the situation I’m in.” The internal consistency for the subscales was .81 for reappraisal and .85 for suppression in the current study.

**Behavioral Inhibition System/Behavioral Activation System Questionnaire (BIS/BAS)**. The Behavioral Inhibition System/Behavioral Activation System (BIS/BAS) Questionnaire is used to assess a participant's response to stimuli in their environments, specifically approach and avoidance responses (Carver & White, 1994; see Appendix I). The combined scales consist of a total of 24 statements. The BAS scale has three subscales, each of which focuses on different aspects of incentive sensitivity, and measure different aspects of approaching pleasant stimuli. The subscales of the BAS include: Drive, which consists of four questions; Reward Responsiveness, which consists of five questions; and Fun-Seeking, which consists of four questions. The BIS, which measures participant's regulation of motivation to move away from unpleasant stimuli, consists of a total of seven questions. Finally, there are four filler questions. Participants who score high on the behavioral inhibition system scale are more nervous than individuals who score lower. Furthermore, individuals who score high on the behavioral activation system questionnaire are happier than those who score low on the behavioral activation system scale. Participants rated each statement on a 1 to 4 Likert rating scale.
where 1=very true for me, 2=somewhat true for me, 3=somewhat false for me, and 4=very false for me. Sample statements include, "A person's family is the most important thing in life", "When I get something I want, I feel excited and energized", and "I feel pretty worried or upset when I think or know somebody is angry at me". The internal consistencies were .80 for Drive, .60 for Fun-Seeking, .76 for Reward-Responsiveness, and .79 for Avoidance (BIS) in the current study.

**Lab demographics questionnaire.** The lab demographics questionnaire was used to assess whether the sample of participants was representative of the target population (older adults in Kentucky, and the United States; see Appendix J). This questionnaire asks participants about their ethnic background, their age, and their highest level of education. It also contains questions about jobs that the participant has held.

**Emotion Perception Task**

Participants were presented with facial stimuli, one at a time, under varying instructional conditions. The instructions manipulated the degree to which the participants had to focus on the emotions of the facial stimuli. In other words, the instructions were used to define whether or not the emotions expressed by the facial stimuli were relevant to the participant’s consideration of and response to the stimuli. The following four instructional conditions were adapted for use from Rellecke et al. (2012) for this study: (1) true passive viewing (TPV): participants were instructed to focus on a fixation point found at the center of the display and to observe each stimulus that appears on the screen without responding; (2) emotion passive viewing (EPV): participants were instructed to focus on a fixation point at the center of the display and then to focus on the emotion being expressed by each facial stimulus as they appeared without responding; (3)
*gender decision (GD)*: participants were instructed to focus on a fixation point at the center of the display, to look at the facial stimulus that appeared, to judge the gender of the stimulus, and then to provide a gender categorization response (male/female) with a button press; and (4) *emotion decision (ED)*: participants were instructed to focus on a fixation point at the center of the display, to look at the facial stimulus that appeared, to judge the emotion expressed by the target (angry/happy/neutral), and to press one of three buttons to reflect this categorization.

Trials in the emotion perception task were blocked relative to these four instructional conditions. All participants completed the TPV block followed by the EPV block. After these two blocks, the remaining two blocks used the GD and ED instructions and were counterbalanced across participants, as in Rellecke et al. (2012). The TPV condition was meant to capture the participant’s default mode for processing emotional facial stimuli, as they were simply observing the stimuli and not responding and the emotions were not relevant to what participants were being asked to do. In the EPV condition, participants did not respond but were actively considering the emotion on the face. Here emotion was relevant to what the participants were being asked to do during the task. In the GD condition, as in the TPV condition, the emotions expressed by the facial stimuli were not relevant to the task, and participants were simply identifying the gender of the target by pressing one of two buttons on a button box. In the ED condition, participants were again considering the emotions expressed by the facial stimuli. However, they were also using that emotional information to develop a response. Participants responded by pressing one of three buttons on a button box to indicate that a stimulus expressed a positive emotion, a negative emotion, or no emotion.
**Stimuli.** The emotion perception task used color photographs of 70 different people each displaying angry, happy, and neutral facial expressions which were taken from the NimStim Face Stimulus Set (Tottenham et al., 2009) and the Karolinska database (Lundqvist, Flykt, & Öhman, 1998), for a total of 210 photographs. The emotions expressed on the angry and happy faces varied from 40-100% intensity, capturing the normal range of emotional intensities displayed in day-to-day interpersonal interactions. In order to ensure uniformity, all images were edited in the same way, by cropping an ellipsoid of the face (see Figure 1) and copying and pasting that ellipsoid onto the center of a black background. The stimuli were within an area of 126 × 180 pixels (4.45 cm × 6.35 cm). Face stimuli were presented randomly during the trials, but each of the face stimuli was presented only once per instructional condition. Each face was presented in the center of the screen on a black background.

**Task organization.** Overall, participants completed four blocks of trials with 210 trials (three emotions × 70 targets) per block. At the beginning of each trial, a fixation cross appeared on the center of the screen for between 400 and 600 ms. Next, a randomly selected face stimulus appeared on the center of the screen for between 800 and 1000 ms. After this face was presented, in the passive viewing conditions, a blank screen lasting between 400 and 600 ms followed the presentation of the face. In gender decision and emotion decision conditions, a response screen listing the possible button/response combinations appeared for between 400 and 600 ms. During the GD and ED conditions, participants pressed a button to indicate their response either during the presentation of the face, or during the response screen. If the participant responded during the face presentation, the blank screen appeared instead of the response screen. Please note that
Figure 1. These are the events that occurred during each trial. Participants first focused their gaze upon a fixation cross that appeared in the center of the screen for between 400 and 600 ms. Next, participants focused their attention on a face for between 800 and 1000 ms. In TPV participants just looked at the face, in EPV participants observed the emotion on the face, in GD participants chose which gender the person in the picture was, and in ED participants chose which emotion the person in the picture was displaying. Finally, the face was followed by a blank screen in TPV and EPV tasks, or a response screen in GD and ED tasks for between 400 and 600 ms. Please note that during the GD and ED trials that the participant could answer during the time that the face was presented. If this happened, the face was followed by a blank screen for between 400 to 600 ms. If the participant did not answer during the face, then a response screen indicating the possible responses appeared for 400-600 ms. Facial stimuli were taken from both the NimStim Face Stimulus Set (Tottenham et al., 2009) and the Karolinska database (Lundqvist et al., 1998), and modified to crop out hair and background features.

the timing ranges presented above reflect jittered timing in these trials; such timing was used to prevent expectancy effects (Handy, Green, Klein, & Mangun, 2001) and is consistent with past research examining the impact of aging and emotion on ERPs.
(Hilimire et al., 2013; Mienaltowski et al., 2011). Events always occurred in the same order. Please refer to Figure 1 for the time course of events in each trial.

**Electrophysiological recording.** During the emotion perception task, continuous electroencephalogram (EEG) was recorded from a 128 electrode array from Electrical Geodesic, Inc. The left mastoid was used as a reference, and the AFz electrode (sitting just over the brow line) served as a ground. Impedance was kept below 5Ω and conductivity was ensured by wetting the sponges attached to the electrodes with a solution made up of potassium chloride, baby shampoo, and distilled water. Signals were filtered (NetStation) with a band pass of 0.03-70 Hz as well as with a notch filter of 60 Hz; the sampling rate was 250 Hz. Offline, the continuous EEG was corrected for blinks and eye movements using NetStation software. This also involved visually examining the continuous EEG of each participant to double-check NetStation’s cataloguing of anomalous voltages in order to check for bad electrodes.

The EEG recording was segmented into epochs of -200 to +800ms relative to the onset of the face stimuli. Segmentation was tied to triggers imported from E-Prime based on the onset of the facial stimuli. The recording was then recalculated to average reference. Event related potentials (ERPs) were calculated for the edited data, and the 200 ms pre-stimulus time point was used as a baseline. Epochs were discarded if they displayed amplitudes beyond -200 or +200 µV. Epochs were also discarded if they contained artifacts (eye blinks, muscle movements, etc.). In addition, the segmented ERP data was averaged at each posterior electrode for each participant by emotion and instructional condition. From these individual averages, peaks (including latencies and amplitudes) were detected to reflect the P1 and N170 components emerging from the
onset of the facial stimuli. Each participant had 12 average voltage values and 12 latency values for each P1 and N170 component per posterior electrode (one value for each emotion (3) within each condition (4)).

**Initial electrophysiological data reduction.** Preliminary data reduction for the electrophysiological recordings was done with a custom code written in Python which extracted peak voltage and latency data for posterior scalp electrodes for each condition during time periods that included the P1 and N170 components from the NetStation data file. The code yielded a total of 768 P1 and 768 N170 average peaks and average latencies per participant (i.e., using average waveforms of three emotions x four instructional conditions for each of 64 electrodes). For the P1 component, the peak detection code identified the local maximum occurring at each electrode between 56 and 148 ms after stimulus onset (cf. Rellecke et al., 2012). For the N170 component, the peak detection code identified the local minimum occurring at each electrode between 124 and 220 ms after stimulus onset. The output from Python was then transferred to Statistics Package for the Social Sciences (SPSS version 21) for further analysis. To ensure the accuracy of the Python peak detection program, manual visual inspection was also used to ensure that inflection points were reported in the SPSS database.

Each participant had peak voltages and latencies for the P1 and N170 components of ERP waveforms emerging after the onset of angry, happy, and neutral facial expressions in each instructional condition at 64 posterior electrodes. Separate analyses were conducted to examine the impact of emotion and instructional condition on the P1 and N170 peak voltages. Latencies were examined to determine if they were consistent
with Rellecke et al. (2012), but otherwise were not further analyzed as the hypotheses for
the current study were limited to the peak amplitude voltages.

For analyses tied to the P1 component, a principal components analysis was first
performed to identify a cluster of posterior electrodes that contributed the most variance
to the participants’ neurophysiological responses to the onset of the face stimuli.
Preliminary data suggested that approximately 20-25 occipito-parietal electrodes
maximally loaded on the first component. In order to simplify our analyses, we focused
exclusively on occipito-parietal electrodes 66, 70, 71, 72, 75, 76, 83, and 84. Separate
averages were calculated for each instructional condition × emotion cell. The internal
consistency for these electrodes ranged from .96 to .98 for younger adults and .78 to .97
for older adults for P1 voltage amplitude. No appreciable differences in findings emerged
by breaking down the EEG data by hemisphere for the P1 component.

For analyses tied to the N170 component, the peak voltage for five left (58, 64,
65, 68, 69) and for five right (89, 90, 94, 95, 96) hemisphere occipito-temporal electrodes
were each averaged to create a left and right hemisphere N170 voltage (prior EGI-based
N170 operationalization; Mercure, Cohen Kadosh, & Johnson, 2011). Please refer to
Figure 2 for a diagram of electrodes included in P1 and N170 component analyses.
Figure 2. This figure is taken from p. 125 of the Geodesic Sensor Net Technical Manual Electrical Geodesics, Inc. (2007). Geodesic Sensor Net Technical Manual. Please note that the electrodes toward the top of the page are located on the participant’s face, whereas the electrodes toward the bottom of the page are located on the back of the participant’s head. Please also note that the left and right sides of the figure correspond to the left and right side of the participant’s head, respectively.

- = representative P1 mentioned in Appendix L
- = electrodes used to calculate N170
**Segment inclusion.** Analyses conducted on P1 and N170 amplitudes were based on approximately 61 good segments per instructional condition per emotion type ($SE = 1.2$). A mixed-model ANOVA was conducted to examine the possible effects of age group, emotion, and/or instructional condition on the number of good segments that went into individual participant averages after filtering out eye movements and blinks. This ANOVA did not yield main effects of age or condition, but did yield a main effect of emotion, $F(2, 78) = 16.18, p < .001, \eta^2_p = .293$, which was qualified by a condition × emotion interaction, $F(6, 234) = 2.32, p = .034, \eta^2_p = .056$. Overall, fewer good segments were included in the averages for happy cells ($M = 60.5, SE = 1.2$) than angry ($M = 61.9, SE = 1.2$) or neutral cells ($M = 62.2, SE = 1.2$), and this difference was larger in the ED instructional condition than in the other instructional conditions (i.e., three segments versus ~one segment). It is worth noting that, overall, there was one fewer happy stimulus than angry or neutral stimulus included in each instructional condition due to a coding error in the stimulus presentation program’s design. Overall, however, approximately 87% of the possible trials included in the task were included in participant waveform averages. In their study, Rellecke et al. (2012), at maximum, were able to include 50 good segments per emotion per instructional condition.

**Results**

The current study used a 2 (age group: young, old) × 3 (emotion: neutral, angry, happy) × 4 (condition: TPV, EPV, GD, ED) mixed-model design, with the between-subjects factor of age group, and within-subjects factors of emotion and condition. Mixed-model analyses of variance (MANOVA) were conducted on response accuracy, overall reaction time (for GD and ED), reaction time for correct trials (GD and ED), P1
peak amplitude and latency, and N170 peak amplitude and latency. Independent samples t-tests were also conducted to examine whether there was an age difference in average scores on the measures (CES-D, ERQ, BIS/BAS), and correlations were conducted to examine the relationships between scores on the measures and response time, response accuracy, P1 amplitude, and N170 amplitude.

**Behavioral Measures**

The participants’ behavioral responses in the gender decision and emotion decision conditions were examined to determine the average reaction time and accuracy for each emotional expression. These data were found in the E-Prime output file that was created after the participant completed the Emotion Perception Task. Each participant had an average response time, an average response time for correct trials, and an accuracy score for each emotion for the GD and ED conditions. A 2 (age group) × 3 (emotion) × 2 (decision conditions: ED, GD) mixed-model ANOVA conducted on response accuracy revealed a marginal effect of emotion, $F(2, 78) = 2.52, p = .09, \eta^2_p = .06,$ and an effect of age group, $F(1,39) = 6.61, p = .01, \eta^2_p = .15$ on accuracy. Least significant difference post-hoc contrasts revealed that accuracy for neutral faces was less than accuracy for emotional faces. Older adults had lower response accuracy rates than younger adults for both GD and ED conditions. Please refer to Table 1 for percent accuracy.
Table 1

Mean Accuracy by Emotion for GD and ED Trials

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Younger Adults</th>
<th>Older Adults</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>Neutral</td>
<td>93.5%</td>
<td>3.7%</td>
<td>83.1%</td>
</tr>
<tr>
<td>Angry</td>
<td>96.3%</td>
<td>2.2%</td>
<td>87.9%</td>
</tr>
<tr>
<td>Happy</td>
<td>95.2%</td>
<td>2.0%</td>
<td>89.4%</td>
</tr>
</tbody>
</table>

*Note: Older adults had lower response accuracy rates than younger adults.*
A 2 (age group) × 3 (emotion) × 2 (decision conditions: ED, GD) mixed-model ANOVA conducted on overall reaction time on all trials revealed main effects of emotion, $F(2, 78) = 21.654, p < .001, \eta_p^2 = .36$, and age group, $F(1, 39) = 12.73, p = .001, \eta_p^2 = .25$, on reaction time. Planned contrasts revealed that reaction times for angry faces ($M = 934$ ms, $SE = 36$ ms) were shorter than those for neutral faces ($M = 1165$ ms, $SE = 58$ ms), $F(1, 39) = 46.68, p < .001, \eta_p^2 = .55$, and that reaction times for happy faces ($M = 896$ ms, $SE = 41$ ms) were shorter than those for neutral faces, $F(1, 39) = 20.93, p < .001, \eta_p^2 = .35$. Older adults ($M = 1136$, $SE = 55$ ms) had longer reaction times than younger adults ($M = 860$, $SE = 54$ ms) for both GD and ED conditions.

A 2 (age group) × 3 (emotion) × 2 (decision conditions) mixed-model ANOVA conducted on reaction time for correct items revealed effects of emotion $F(2, 76) = 154.69, p < .001, \eta_p^2 = .80$, task $F(1, 38) = 10.40, p = .003, \eta_p^2 = .22$, and age group $F(1, 38) = 10.79, p = .002, \eta_p^2 = .22$. Planned contrasts revealed that for correct trials participants had longer reaction times for angry faces than for neutral faces $F(1, 38) = 170.94, p < .001, \eta_p^2 = .82$, and that for correct trials participants had longer reaction times for neutral faces ($M = 932$ ms, $SE = 21$ ms) than for happy faces ($M = 726$ ms, $SE = 18$ ms), $F(1, 38) = 185.63, p < .001, \eta_p^2 = .83$. Participants had longer reaction times in the ED condition ($M = 895$ ms, $SE = 20$ ms) than in the GD condition ($M = 723$ ms, $SE = 18$ ms). Older adults ($M = 867$ ms, $SE = 26$ ms) had longer reaction times for correct trials than younger adults ($M = 751$ ms, $SE = 26$ ms) for both GD and ED conditions. This ANOVA also revealed an emotion × task interaction, $F(2, 76) = 24.65, p < .001, \eta_p^2 = .39$, and an emotion × task × age group interaction, $F(2, 76) = 4.89, p = .01, \eta_p^2 = .11$. Please refer to Table 2 for mean performance by condition.
Table 2
Mean Response Times for Correct Trials

<table>
<thead>
<tr>
<th>Condition</th>
<th>Emotion</th>
<th>Younger Adults</th>
<th>Older Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SE</td>
</tr>
<tr>
<td>GD</td>
<td>Neutral</td>
<td>637</td>
<td>24</td>
</tr>
<tr>
<td>GD</td>
<td>Angry</td>
<td>665</td>
<td>26</td>
</tr>
<tr>
<td>GD</td>
<td>Happy</td>
<td>640</td>
<td>25</td>
</tr>
<tr>
<td>ED</td>
<td>Neutral</td>
<td>870</td>
<td>32</td>
</tr>
<tr>
<td>ED</td>
<td>Angry</td>
<td>900</td>
<td>33</td>
</tr>
<tr>
<td>ED</td>
<td>Happy</td>
<td>792</td>
<td>29</td>
</tr>
</tbody>
</table>

Note: Please note that the listed mean response times are in milliseconds. All participants had the longest response times for correct trials for angry faces presented during the ED condition. Older adults had longer reaction times for correct trials regardless of condition and emotion.

In order to clarify the emotion × task × age group interaction, a 3 (emotion) × 2 (age group) mixed-model ANOVA was conducted because the variables of interest for this study were emotion and age. This ANOVA revealed an effect of emotion $F(2, 76) = 28.97, p < .001, \eta^2_p = .43$, but there was no emotion by age group interaction. Because there was no interaction, an additional analysis was conducted using a 2 (decision conditions) × 2 (age group) mixed model ANOVA in order to examine whether the task was driving the emotion × task × age group interaction. This ANOVA revealed an effect of task $F(1, 39) = 97.70, p < .001, \eta^2_p = .72$, as well as a marginal age group × task interaction $F(1, 39) = 3.16, p = .08, \eta^2_p = .07$. Least significant difference post-hoc tests revealed that older adults had longer reaction times than younger adults for correct trials for both tasks, however the age difference in reaction times was greater for ED than for
Furthermore, there was a marginal emotion × age group interaction $F(2, 76) = 2.52, \ p = .09, \ \eta^2_p = .06$. Least significant difference post-hoc tests revealed that both older and younger adults responded faster to happy faces than to angry faces, with their response times for neutral faces falling between their reaction times to happy and angry faces.

**Electrophysiological Measures**

**P1 Amplitude.** A 2 (age group) × 3 (emotion) × 4 (instructional condition) mixed model ANOVA was conducted on P1 amplitude. This ANOVA yielded a main effect of instructional condition, $F(3, 117) = 16.98, \ p < .001, \ \eta^2_p = .30$. Planned contrasts revealed that the P1 amplitude was greater for EPV than for TPV, $F(1, 39) = 6.87, \ p = .01, \ \eta^2_p = .15$, that P1 amplitude was greater for GD than TPV, $F(1, 39) = 26.87, \ p < .001, \ \eta^2_p = .41$, and that P1 amplitude was also greater for ED than TPV. Please see Table 3. Drawing attention to the emotion on the face or asking participants to use facial details to generate a response led to larger amplitude P1. Furthermore, the ANOVA revealed a condition × age group interaction, $F(3, 117) = 7.27, \ p = .001, \ \eta^2_p = .13$. Post-hoc least significant difference contrasts revealed that older adults’ P1 amplitude was smaller than that of younger adults, and that, with older adults, the ED condition evoked the largest P1 amplitude, whereas, with younger adults, the GD condition evoked the largest amplitude P1. Again, see Table 3.
Table 3

Mean P1 Amplitude and Standard Error by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Young Adults</th>
<th>Older Adults</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SE</td>
<td>M</td>
</tr>
<tr>
<td>TPV</td>
<td>7.00</td>
<td>0.72</td>
<td>3.51</td>
</tr>
<tr>
<td>EPV</td>
<td>7.39</td>
<td>0.70</td>
<td>3.73</td>
</tr>
<tr>
<td>GD</td>
<td>8.36</td>
<td>0.72</td>
<td>3.83</td>
</tr>
<tr>
<td>ED</td>
<td>8.20</td>
<td>0.76</td>
<td>3.98</td>
</tr>
</tbody>
</table>

*Note: For both older and younger adults, EPV, GD, and ED evoke larger amplitude P1s than TPV. Younger adults also display larger amplitude P1s than older adults.*
**P1 Latency.** A 2 (age group) × 3 (emotion) × 4 (instructional condition) mixed model ANOVA was conducted on P1 latency. This ANOVA yielded main effects of condition, $F(3, 117) = 14.77, \ p = .001, \ \eta_p^2 = .28$, and emotion, $F(2, 117) = 3.48, \ p = .04, \ \eta_p^2 = .08$, on P1 latency but not age group. Planned contrasts revealed that participants displayed longer P1 latency for EPV than for TPV, $F(1, 39) = 5.67, \ p = .02, \ \eta_p^2 = .13$, and participants displayed shorter P1 latency for ED than for TPV, $F(1, 39) = 9.81, \ p = .003, \ \eta_p^2 = .20$. There was no difference in P1 latency values for TPV and GD. Please see Table 4. Furthermore, planned contrasts revealed that angry faces ($M = 130 \text{ ms}, \ SE = 2 \text{ ms}$) evoked a P1 at marginally longer latencies than neutral faces ($M = 129 \text{ ms}, \ SE = 2 \text{ ms}$), $F(1, 39) = 3.524, \ p = .07, \ \eta_p^2 = .08$. There was no difference in P1 latency values for happy ($M = 128 \text{ ms}, \ SE = 2 \text{ ms}$) and neutral faces.

Table 4

Mean P1 Latency and Standard Error by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>$M$</th>
<th>$SE$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPV</td>
<td>129</td>
<td>2</td>
</tr>
<tr>
<td>EPV</td>
<td>132</td>
<td>2</td>
</tr>
<tr>
<td>GD</td>
<td>129</td>
<td>2</td>
</tr>
<tr>
<td>ED</td>
<td>126</td>
<td>2</td>
</tr>
</tbody>
</table>

*Note:* Please note that latencies are listed in milliseconds. Both older and younger participants displayed longer P1 peak latencies for EPV than for other conditions.

**N170 Amplitude.** A 2 (age group) × 2 (hemisphere: left, right) × 3 (emotion) × 4 (instructional condition) mixed model ANOVA was conducted on N170 amplitude (see Figures 1 and 2 for ERP waveforms). This ANOVA yielded main effects of hemisphere, $F(1, 39) = 9.93, \ p = .003, \ \eta_p^2 = .20$, emotion, $F(2, 78) = 10.70, \ p < .001, \ \eta_p^2 = .22$, and
condition, \( F(1, 39) = 45.59, \ p < .001, \eta_p^2 = .54 \) on N170 amplitude. Planned contrasts revealed that larger N170 amplitudes were evoked in the right hemisphere (\( M = -3.32 \mu V, SE = 0.37 \mu V \)) than in the left hemisphere (\( M = -2.34 \mu V, SE = 0.31 \mu V \)), \( F(1, 39) = 9.93, \ p = .003, \eta_p^2 = .20 \). Furthermore, planned contrasts revealed that angry faces evoked larger amplitude N170s than neutral faces, \( F(1, 39) = 18.63, \ p < .001, \eta_p^2 = .32, \) and that happy faces evoked larger amplitude N170s than neutral faces, \( F(1, 39) = 15.07, \ p < .001, \eta_p^2 = .28 \). Please see Figure 3. Finally, planned contrasts revealed that EPV, \( F(1, 39) = 15.90, \ p < .001, \eta_p^2 = .29 \), GD, \( F(1, 39) = 44.57, \ p < .001, \eta_p^2 = .53 \), and ED, \( F(1, 39) = 69.98, \ p < .001, \eta_p^2 = .64 \), all evoked larger amplitude N170s than TPV. Please see Figure 4. Please see Figure 5 for younger adult P1 and N170 waveforms and Figure 6 for older adult P1 and N170 waveforms.

![Figure 3](image-url)

**Figure 3.** Happy and angry faces evoked larger amplitude N170s than neutral faces in both younger and older adults. Please note that the further the bar is to the left, the larger the negative deflection, and thus, the larger the N170 amplitude.
Figure 4. EPV, GD, and ED evoke larger amplitude N170s than TPV, with ED evoking the greatest negative deflection in the N170. Please note that the further the bar is to the left, the larger the negative deflection, and thus, the larger the N170 amplitude.

**N170 Latency.** A 2 (age group) × 2 (hemisphere) × 3 (emotion) × 4 (instructional condition) mixed model ANOVA was conducted on N170 latency. This ANOVA yielded main effects of emotion, \( F(2, 78) = 6.84, \ p < .002, \eta^2_p = .15 \), and condition, \( F(3, 117) = 20.432, \ p < .001, \eta^2_p = .34 \), on N170 latency but not age group. Planned contrasts revealed that N170s evoked by angry faces (\( M = 193 \text{ ms}, SE = 2 \text{ ms} \)) had a longer latency N170s than neutral faces (\( M = 190 \text{ ms}, SE = 2 \text{ ms} \)), \( F(1, 39) = 14.63, \ p < .001, \eta^2_p = .27 \). There was no difference in N170 latency between neutral faces and happy faces (\( M = 191 \text{ ms}, SE = 2.19 \text{ ms} \)). Furthermore, planned contrasts revealed that N170s evoked in the EPV condition had a longer latency than N170s evoked in the TPV condition, \( F(1, 39) = 35.36, \ p < .001, \) and that N170s evoked by faces in the ED condition had a shorter latency than N170s evoked by faces in the TPV condition, \( F(1, 39) = 4.15, \ p < .048, \eta^2_p = .10 \). Please see Table 5.
Table 5

Mean N170 Latency and Standard Error by Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>$M$</th>
<th>$SE$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPV</td>
<td>190</td>
<td>2.44</td>
</tr>
<tr>
<td>EPV</td>
<td>196</td>
<td>2.20</td>
</tr>
<tr>
<td>GD</td>
<td>192</td>
<td>2.35</td>
</tr>
<tr>
<td>ED</td>
<td>186</td>
<td>2.22</td>
</tr>
</tbody>
</table>

*Note:* EPV elicits a longer latency N170 than TPV. ED evokes a shorter N170 latency than TPV. There is no difference between TPV and GD.
Figure 5. Younger adult ERP Waveforms averaged across angry, happy, and neutral faces. The peak at around 100 ms corresponds with the P1 component, whereas the trough just before 200 ms corresponds with the N170 component.
Figure 6. Older adult ERP waveforms averaged for angry, happy, and neutral faces. The peak at around 100 ms corresponds with the P1 component, whereas the trough just before 200 ms corresponds with the N170 component.
Age Differences on the Individual Difference Measures

Independent samples $t$-tests were conducted in order to investigate differences in mean scores on the measures (CES-D, BIS/BAS, and ERQ, see Table 6) for older and younger adults. Younger adults had higher scores on the CES-D than older adults, $t(38) = 2.46, p = .02$. There was a significant difference in the mean scores of younger and older adults on the BIS, such that younger adults had higher scores than older adults on the BIS, $t(38) = 2.31, p = .03$, on BAS Drive, $t(38) = 2.83, p < .01$, on BAS Fun-Seeking, $t(38) = 4.03, p < .001$, and on BAS Reward Sensitivity, $t(38) = 2.21, p = .03$. Please note that exploratory correlational analyses between behavioral data and electrophysiological data are reported in Appendix K, as are exploratory correlational analyses between the individual difference measures and the electrophysiological data. Given that relationships were not hypothesized in the conceptualization of this thesis, the analyses are provided for informational purposes.
Table 6

Age Differences on Individual Difference Measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Younger Adults</th>
<th></th>
<th>Older Adults</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>CES-D</td>
<td>11.71</td>
<td>7.17</td>
<td>5.75</td>
<td>8.35</td>
</tr>
<tr>
<td>ERQ-Reappraisal</td>
<td>31.75</td>
<td>5.97</td>
<td>29.60</td>
<td>5.07</td>
</tr>
<tr>
<td>ERQ-Suppression</td>
<td>14.80</td>
<td>4.97</td>
<td>12.70</td>
<td>5.48</td>
</tr>
<tr>
<td>BAS Drive</td>
<td>11.55</td>
<td>2.61</td>
<td>9.35</td>
<td>2.30</td>
</tr>
<tr>
<td>BAS Fun-Seeking</td>
<td>12.35</td>
<td>1.90</td>
<td>9.90</td>
<td>1.94</td>
</tr>
<tr>
<td>BAS Reward-Responsiveness</td>
<td>18.15</td>
<td>1.76</td>
<td>16.80</td>
<td>2.09</td>
</tr>
<tr>
<td>BIS</td>
<td>22.20</td>
<td>3.69</td>
<td>19.30</td>
<td>4.22</td>
</tr>
</tbody>
</table>

Note: Older and younger adults had significantly different scores on all individual difference measures except for the ERQ-Reappraisal and the ERQ-Suppression.
Discussion

The current study extends the findings of Rellecke et al. (2012) by examining age differences in how the visual cortex processes emotional faces. Differences in emotion processing were indexed by the amplitude of the P1 and N170 ERP components. Larger P1 amplitude indicates that a participant is focusing more attention on processing a stimulus, whereas larger N170 amplitude indicates that a participant is focusing more cognitive and perceptual resources toward categorizing a facial stimulus. Time differences in the peaks of the P1 and N170 allowed us to explore a temporal component of processing, as well. Thus, the goals of the current study were to determine whether differences in emotion processing would arise in older and younger adults, and when these differences in emotion processing would arise. The overarching goal of this study was to determine whether SST or ABM was the most likely explanation for previous findings that showed differential emotion processing in younger and older adults.

Participants in the current study engaged in four different tasks while EEG data were recorded. The four tasks (TPV, EPV, GD, and ED) were based on those used by Rellecke et al. (2012). The tasks were designed to manipulate the degree to which emotion was relevant to the task and the degree of processing that was required in order to complete the task. ERPs were analyzed in order to determine whether differences in emotion processing would arise and when those differences took place. Knowledge about whether or not differences emerged in younger and older adults’ neurophysiological reactions to emotional stimuli and knowledge about when such differences emerge can be used to evaluate theories that account for age differences in emotion processing, like SST and ABM.
If SST best explains differences that emerge between younger and older adults in the literature, we expected to observe an age group × emotion × instructional condition interaction for P1 and N170 amplitude. Specifically, in younger adults, we expected that angry faces would evoke a larger P1 and N170 amplitude than happy or neutral faces regardless of condition. These predictions fit this model for younger adults because younger adults are less focused on emotion-regulation goals and more focused on knowledge-seeking goals due to an expansive view of time (Carstensen et al., 1999; Carstensen et al., 2003; Mather & Carstensen, 2005). Therefore, younger adults are more likely to be influenced by negative emotional stimuli than by positive or neutral emotional stimuli. Additionally, if SST was the most likely explanation for age differences in the literature, we expected that, for older adults, happy faces would evoke larger P1 and N170 amplitudes than angry or neutral faces in the TPV and GD conditions. This is because older adults are more focused on regulating emotions, and when emotion is not relevant to a task, older adults are likely to use an emotion regulation strategy to minimize the impact of the emotions on their subjective experience (Birditt et al., 2009; Blanchard-Fields, 2007; Carstensen et al., 1999; Carstensen et al., 2000; Lawton, 2001). Furthermore, for older adults we expected that angry faces would evoke larger P1 and N170 amplitudes than happy and neutral faces in the EPV and ED conditions. This is because emotion is relevant to these tasks, and SST posits that older adults choose to engage in emotion regulation when emotion is not relevant to them, but that, when emotion is relevant, older adults should be able to focus on emotion just like younger adults (Carstensen et al., 1999).
Contrary to our expectations, we found that older and younger adults process emotional faces similarly. Specifically, both older and younger adults displayed larger P1 amplitudes for faces presented during tasks in which they were required to make a decision about the details of the faces than for tasks which did not require facial features to be used to inform a decision. This finding corroborates previous literature that states that P1 is an indicator of visual attention (Curran et al., 2001; Mienaltowski et al., 2011; Rellecke et al., 2012). In other words, participants should be allocating more attention to stimuli for which they have to make a decision relative to stimuli for which they did not have to make a decision. Furthermore, we found no effect of emotion during the time frame of the P1 component. This contrasts with the findings of Hilimire et al. (2013), but the differences in findings between these two studies could be due to differences in the psychological processes corresponding to the P1 and FcEP components as well as the brain areas generating them (visual cortex versus frontal lobe). It is possible that we did not observe differences in the P1 component because 80-100 ms after stimulus onset is too early to observe salience-related differences in attention. Instead, it is possible that participants allocate the same amount of attention to each facial stimulus until later time frames when the most salient stimuli are processed more deeply.

Furthermore, we observed age-related differences in the P1 amplitude that were based on condition. Specifically older adults displayed larger P1 amplitude for ED than for any other conditions, whereas younger adults displayed larger P1 amplitude for GD than for any other condition. This may represent differences in the way in which older and younger adults process emotion and what is important to older and younger adults. For example, if older adults are more focused on regulating emotions and maintaining
relationships, then it would be logical that when emotion is relevant that they would pay more attention to those emotional faces than to faces displaying emotions in other conditions. Additionally, younger adults may be more focused on forming new relationships, especially romantic relationships, and they may find that gender of a face is more important to them than the emotions expressed by the face.

We found that angry and happy faces elicited larger N170 amplitude than neutral faces. The enhanced N170 for emotional faces relative to neutral faces indicates that participants were likely engaging more cognitive and perceptual resources for processing emotional faces than for processing neutral faces. This is consistent with the findings of Rellecke et al., (2012), as well as previous literature that states that emotional information is more salient than neutral information (Isaacowitz et al., 2006b; Leclerc & Kensinger, 2008; Murphy & Isaacowitz, 2008). It is logical that more salient information would elicit more processing than less salient information (Ochsner & Gross, 2005; Öhman, 2005; Phillips et al., 2003).

There are several reasons that could explain why our findings seem to diverge from SST. First of all, the timing of our observations relative to stimulus onset could explain why our findings do not directly support SST. Specifically, the time frame of our analyses could be too early to observe differences in emotion processing. This is consistent with previous literature which states that differences in emotion processing between older and younger adults are only reliably observed 500 ms after stimulus presentation (Isaacowitz, Allard, et al., 2009). Second, it is also possible that SST may not adequately explain the differences that are observed between younger and older adults in the literature. Finally, it is also possible that SST holds only for later time points
of stimulus processing and that a different phenomenon is occurring at earlier time points that is based on the type of task being used.

ABM

If ABM best explains the differential emotion processing that emerged between younger and older adults in previous studies, we expected to observe an age group × emotion interaction for P1 and N170 amplitude. Specifically, in younger adults we expected that angry faces would evoke larger P1 and N170 amplitudes than happy or neutral faces regardless of condition. These predictions are logical for younger adults because ABM posits that degradation of the amygdala and adrenergic system occurs in older adults (Cacioppo et al., 2011). In younger adults, these systems should still be intact, thus younger adults should show this default pattern of more salience for negative stimuli regardless of condition. Additionally, in older adults, it was expected that happy faces would evoke larger P1 and N170 amplitudes, regardless of condition. This prediction is logical for older adults because ABM posits that the reason that differences emerge in emotion processing between older and younger adults is because of degradation that takes place in the amygdala and adrenergic system of older adults. Given this theory, older adults should be unable to focus on negative emotional material, thus, they will focus on happy faces over both neutral and angry faces for all conditions.

Contrary to our expectations, we found that the visual systems of older and younger adults responded similarly to emotional faces during the first 200 ms after the onset of facial stimuli. Specifically, there was no effect of emotion on P1 amplitude. However, there was an effect of emotion on N170 amplitude, and this effect was the same for both older and younger adults. In other words, angry and happy faces evoked
larger N170 amplitude regardless of condition for both older and younger adults. Although our findings are not entirely consistent with those reported in Kisley et al. (2007), it is worth noting that their data, as well as our own, support the possibility that both positive and negative stimuli evoke greater activation along the scalp than do neutral stimuli. Admittedly, our data may underestimate the impact that emotion has on the P1 component evoked by emotion faces in posterior regions of the scalp, given that other studies find evidence for enhanced P1 amplitude evoked by negative faces for younger adults (Rellecke et al., 2012; Smith et al., 2003), whereas we do not. Perhaps our strongest evidence that runs counter to the idea of negative suppression in older adults is the finding that angry facial expressions evoked larger amplitude N170s in both younger and older adults relative to neutral expressions. This outcome suggests that emotional faces may facilitate younger and older adults’ face processing, possibly by making emotional faces more salient for categorization. This finding is logical given past research which states that emotional stimuli are more salient than non-emotional (neutral) stimuli (Isaacowitz et al., 2006b; Leclerc & Kensinger, 2008; Murphy & Isaacowitz, 2008).

**Alternative Explanations**

It is possible that in past studies which have found a positivity effect that older adults are making a conscious decision (via controlled processing) to allocate less attention to negative stimuli. For example, the age-related decrease in the LPP arousal level observed by Kisley et al. (2007) could be characteristic of a decrease in motivation to focus on negative stimuli. In the current study, at early time frames, older adults responded similarly to younger adults, which is strong evidence against a neural model of
degradation—at least in the visual cortex and posterior parts of the brain involved in generating the P1 and N170 components such as the striate and extrastriate cortex. Given this pattern of results, if a positivity effect exists for older adults, it probably does not emerge in the visual system before 250 ms after stimulus onset. Thus, if age-related differences in brain reactivity to emotional stimuli occur, these differences occur at a later time frame and/or in a different part of the brain. This possibility is supported by research that shows that the preference of older adults for happy faces does not emerge until 500 ms after stimulus onset (Isaacowitz, Allard, et al., 2009). The possibility of age-based emotion processing differences at later time frames is also supported by prior ERP studies examining younger and older adults’ differential response to emotional faces (Hilimire et al., 2013; Mienaltowski et al., 2011).

It is also possible that neither SST nor ABM adequately explains differences in emotion processing that occur in younger and older adults. If this is the case, it will be necessary to formulate new hypotheses about why emotion processing differences emerge between younger and older adults in the literature. Perhaps biomarkers associated with aging, as well as circulating levels of pro-inflammatory cytokines could explain age-related differences in emotion processing. A meta-analysis of emotion recognition and attention tasks has found that positivity and negativity preferences are not significantly different from each other in older and younger adults (Murphy & Isaacowitz, 2008). This supports the notion that SST may not fully explain trends in age-based emotion processing.
Limitations

This study is not without its limitations. Specifically, it could be that the effects we found with a small sample size \((n = 20 \text{ for older and } n = 21 \text{ for younger adults})\) do not extend to the general population. Also, most of our participants were recruited from Bowling Green, Kentucky, which could mean that these results only apply to people in that area. Additionally, the participants in this study were highly educated, and they self-selected for a study of brain functioning, which could mean that our sample is not necessarily representative of the general population. The current study also used a different task than previous studies which examined age differences in visual emotion processing, which makes it difficult to compare our findings. Another potential limitation of this study is that we did not control for the intensity of the expressions on the faces that we used. Furthermore, in the current study, data were only analyzed for early time frames for visually evoked potentials (before 225 ms after stimulus onset), and our data only represent the activity of the brain areas involved in generating the P1 and N170 ERP components, which limits the scope of our results to the early time frames for neural activity occurring in the striate and extrastriate cortex.

Despite these limitations, the current study extends the literature by supplementing the findings of Rellecke and colleagues (2012) by including older adults. To date, very few studies have used EEG in order to examine emotion processing differences between younger and older adults. The studies which do examine age and emotion processing have used only one type of task. In contrast, the current study employed four different tasks which were designed to manipulate both the relevance of emotion to a task and the depth of processing required. For example, TPV provided an
index of neural activity during default processing that takes place when an individual scans his or her environment. Furthermore, EPV provided an index of neural activity that occurs when an individual simply notices the emotion on a face in his or her environment. Finally, GD and ED tasks allowed us to examine deeper processing in which an individual had to make a response. Our manipulation of the depth of processing through the use of a variety of tasks allowed us to analyze another dimension of emotion processing that occurs in older and younger adults. This may allow for more generalization of our findings due to the fact that emotional faces are viewed in many contexts in real life. The current study was also the first study of its kind to use the N170 component in order to compare differences in emotion processing in older and younger adults. Finally, the current study adds to the literature by exploring which theory, SST or ABM, is most likely to explain differential emotion processing in younger and older adults.

Summary

In summary, the visual systems of younger and older adults respond similarly to emotional faces. The current study examined neural recordings in the visual cortex during early time frames associated with automatic processing of emotional face stimuli. The results of the current study suggest that aging does not impact early emotion processing in the visual cortex. Furthermore, processing differences arise in the visual cortex as a result of different instructional conditions. Specifically, P1 and N170 amplitudes were modulated by task. Participants had larger amplitude P1 and N170s for tasks in which they had to make a decision relative to tasks in which they did not. Overall, the current study suggests that the visual systems of older and younger adults work very similarly in
the way in which they automatically process emotional faces at early time frames. Furthermore the current study suggests that if differences arise in neural processing of emotional faces, they probably arise in later time frames associated with controlled processing, which argues against a model of brain degradation such as ABM. However, it remains unclear whether SST could still accurately characterize the responses of older adults to emotional stimuli.
References


APPENDIX A

PARTICIPANT INFORMED CONSENT DOCUMENT

Project Title: Neural Correlates of Emotion Recognition

Investigators: Nicole Chambers, Department of Psychology, and Dr. Andrew Mienaltowski, Department of Psychological Sciences, Western Kentucky University, (270) 745-2353

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your signed agreement to participate in this project.

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and the possible risks of participation. You are welcome to ask any questions that you might have to help improve your understanding of the project. A basic explanation of the project is written below. Please read this explanation and discuss any questions that you might have with the researcher.

If you decide to participate in the project, please sign on the last page of this form in the presence of the person who explained the project to you. You should be given a copy of this form to keep.

A. Nature and Purpose of the Project:

This project is examining how people of different ages recognize emotion in facial expressions in terms of behavioral responses using a computer as well as brain activity.

B. Explanation of Procedures:

The purpose of this research is to see how people react to faces during different types of tasks. You will be asked to view a set of faces and during some of the tasks you will be required to give a response to the face depending on the prompt. Your head will be measured at the beginning of the session to determine the correct size EEG (electroencephalography) sensor net. A trained research staff member will then fit you with a sensor net. The net will measure scalp EEG – naturally occurring changes in electrical signal related to brain activity as you examine stimuli on the computer display. Before the net is placed on your head, it will be immersed in a non-toxic, hypoallergenic electrolyte solution, and small sponges within each of the electrodes will soak up the solution. These EEG measurements will help to describe how you think about emotions that you perceive in the facial expressions of others.

C. Discomforts and Risks of Participation:

There are no known risks associated with participation in these experiments. However, should you become tired, you are free to quit at any time. Also, you will be wearing a net that is soaked in potassium chloride, baby shampoo, and water solution. This means that your hair may be damp after the experiment. You are welcome to dry off or blow dry your hair in the lab. There are opportunities to take breaks between tasks in the experiment. Please do not hesitate to ask the experimenter for time for a break should you need one.

D. Benefits of Participation:

Your participation will help to further our efforts to understand how people of different ages recognize emotions in others, as well as neural correlates of emotion recognition. Emotion recognition is important to our social experiences. Through experiments like these, we hope to explore those factors and cues that contribute to successful emotion recognition. Once the experiment is complete, we would be happy to share the results with you.

WKU IRB# 13-349
Approval - 3/5/2015
End Date - 3/5/2016
Expedited
Original - 4/10/2013
E. Confidentiality of Your Responses:
During this study, you will be asked for some personal information (name, age, gender, etc.). This information will be confidential and will only be used by the experimenter. The data that is collected about you will be kept private. To protect your privacy, your records will be kept under a code number rather than by name. Your records will be kept in locked files and only study staff will be allowed to look at them. We are only interested in group information. The reporting of the experimental results will only contain group mean results and will contain NO personal information about individual participants, including performance during the experiment. Your name and any other fact that might point to you will not appear when results of this study are presented or published. To make sure that this research is being carried out in the proper way, the primary investigators and Western Kentucky University Institutional Review Board will review study records.

F. Compensation for Participation:
You will receive two Study Board credits and $10 in gift cards for each hour of participation.

G. Costs to You:
Other than your time there are no costs to you to participate in this study.

H. In Case of Harm or Injury:
Reports of injury or reaction should be made to Andrew Mienaltowski, by phone at (270) 745-2353 or by e-mail at andrew.mienaltowski@wku.edu. Neither Western Kentucky University nor the principal investigators have made provision for payment of costs associated with any injury resulting from taking part in this study.

I. Questions about the Study:
If you have questions about the study, please contact Andrew Mienaltowski at (270) 745-2353.

J. Refusal/Withdrawal:
Refusal to participate in this study will have no effect on any future services that you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time and with no penalty.

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

Participant signature: ___________________________________ Date: ____ / ____ / ____

Signature of witness: ______________________________________

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT
THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Paul Mooney, Human Protections Administrator
TELEPHONE: (270) 745-2139

WKU IRB# 13-349
Approval - 3/5/2015
End Date - 3/5/2016
 Expedited
Original - 4/10/2013
APPENDIX B

Debriefing

Thank you for your participation. The purpose of this study is to learn how adults recognize emotion in the facial expressions of other people. In this study you were asked to consider the emotional state of strangers depicted in a set of facial photographs. These photographs included a wide range of emotions (e.g., anger, sadness, fear, etc.). We are interested in examining the impact of emotion on your brain’s response to the facial stimuli.

We also asked you to complete a set of personality and cognitive tests. Some research suggests that our personality and how we see ourselves both relate to the emotions that we might look for in other people. Additionally, performance on cognitive tests may or may not relate to a person’s ability to recognize emotions in the faces of others.

Your responses to all of the questions that you answered today will be examined at a group level. The groups’ average responses will be compared and contrasted to determine if there is some minimum level of emotional intensity that must be expressed for accurate emotion recognition to take place. This study will help us to understand how adults recognize emotions in the faces of others.

If you have any questions about our research, feel free to call us at the Lifespan Social Cognition Lab at WKU using the following phone number: (270) 745-2353.
APPENDIX C

TELEPHONE SCREENING PROTOCOL

Instructions for Interviewer: Read only those parts in bold to the respondent.

I will be asking you several questions over the course of this telephone interview. All of the information that you give me will remain confidential. No one other than the individuals working in the Lifespan Social Cognition Laboratory will see your answers to these questions. You may decline to answer any of the questions and you may stop this interview at any time. Do you have any questions?

First I would like to get some basic information about you.

Name: _____________________________________________________________

Address: _____________________________________________________________________________

Phone: _____________________________________________________________

Age: ______________ Date of Birth: _______________________________

Level of Education: ________________________________________________

How did you find out about our research? _______________________________________

_________________________________________________________________________

_________________________________________________________________________

Other researchers at the Center for Research on Aging are recruiting participants for different studies.

Can we give them your name? __________

If a respondent asks to stop the interview at any point during the screening, ask if they would be willing to answer questions in a personal interview with the research assistant.
TELEPHONE SCREENING PROTOCOL
MINI MENTAL STATE EXAM (TMMSE)

Now I am going to ask you some questions that will allow me to determine whether you meet the requirements for participation in this research. Again, all of the information that you give me will remain confidential. You may decline to answer any of the questions and you may stop this interview at any time. Do you have any questions?

ORIENTATION

What is the date today? (See answer sheet for additional orientation questions.) Ask the respondent for any omitted parts. Give one point for each correct answer.

REGISTRATION

May I test your memory? Then say the names of three unrelated objects, clearly and slowly, about one second for each: Apple, lamp, tower. After you have said all three, ask the respondent to repeat them. This first repetition determines the score but keep saying them until the respondent can repeat all three; give up to six trials. If the respondent does not eventually learn all three words, recall cannot be meaningfully tested.

ATTENTION & CALCULATION

Now begin with 100 and count backward by 7. Stop the respondent after five subtractions (93, 86, 79, 72, 65). Score the total number of correct answers.

If the respondent cannot or will not perform this task, ask: Please spell the word “world” backwards. The score is the number of letters in correct order; e.g. dlrow = 5.

RECALL

Can you tell me the three words that I asked you to remember?

LANGUAGE

Please repeat the following: No ifs, ands, or buts.

Tell me, what is the thing called that you are speaking into as you talk to me?

If the respondent does not meet the requirements for participation, say: Thank you very much for your time. Your name will be entered into our files. Enter name, final TMMSE score into the database and check the NO CALL BACK box.

If the respondent does meet requirements continue on to the Medical History Questionnaire.
<table>
<thead>
<tr>
<th>ORIENTATION (total pts. 8)</th>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the date?</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(1)</td>
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<tr>
<td>What is the day?</td>
<td></td>
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<td></td>
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<td>(1)</td>
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<tr>
<td>What is the month?</td>
<td></td>
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<td></td>
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<tr>
<td>What is the year?</td>
<td></td>
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<tr>
<td></td>
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<td>(1)</td>
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<tr>
<td>What is the season?</td>
<td></td>
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<td></td>
<td></td>
<td>(1)</td>
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<tr>
<td>Where are we:</td>
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<td></td>
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<tr>
<td>State</td>
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<td>County</td>
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<tr>
<td>Town</td>
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<td>REGISTRATION (total pts. 3)</td>
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<td>ATTENTION &amp; CALCULATION (total pts. 5)</td>
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<td>RECALL (total pts. 3)</td>
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<td>(1)</td>
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<tr>
<td>LANGUAGE (total pts. 2)</td>
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<td>(1)</td>
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<td>(1)</td>
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<tr>
<td>Total Score</td>
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<td>(at least 17 pts. required)</td>
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</tbody>
</table>
**TELEPHONE SCREENING PROTOCOL**  
**MEDICAL HISTORY QUESTIONNAIRE**

Read the following instructions to the respondent: *Now I am going to ask you some questions about your medical history. Again, if you do not feel comfortable answering any of these questions, you may refuse at any time. All of the information that you give me will remain confidential. Do you have any questions?*  
*(If the respondent does not agree to answer questions ask: Would you be willing to answer questions about your medical history in a personal interview with a research assistant? If the respondent says yes, say: Thank you for your time. A research associate from the Lifespan Social Cognition Laboratory will call you to schedule the interview.)*  
If the respondent agrees to answer questions say: *For the next few questions you may answer yes or no. Do you have...*

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High Blood pressure</td>
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<td></td>
<td></td>
<td>Stroke</td>
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<td></td>
<td>If yes, when?</td>
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<td></td>
<td></td>
<td>Do you have impairment from the stroke?</td>
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<td></td>
<td></td>
<td>Heart disease</td>
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<tr>
<td></td>
<td></td>
<td>Kidney disease</td>
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<tr>
<td></td>
<td></td>
<td>Neurological disease</td>
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<tr>
<td></td>
<td></td>
<td>Head Injury</td>
<td></td>
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<td></td>
<td></td>
<td>Of yes, was there loss of consciousness?</td>
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<td></td>
<td></td>
<td>For how long?</td>
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<tr>
<td></td>
<td></td>
<td>Other (specify)</td>
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<td></td>
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<td>Have you received treatment for psychological problems in the past 2 years (e.g. depression, anxiety)</td>
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<td>Have you had any difficulty sleeping in the past 2 weeks?</td>
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<td></td>
<td></td>
<td>Have you experienced any change in your sleeping patterns within the last 3 months?</td>
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<tr>
<td></td>
<td></td>
<td>Have you experienced any change in you eating patterns within the last 3 months?</td>
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<tr>
<td></td>
<td></td>
<td>Have you experienced any major change in your weight within the past 3 months?</td>
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<td></td>
<td></td>
<td>Have you had any difficulty with unexplained tiredness within the past 3 months?</td>
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<td></td>
<td></td>
<td>Have you had any difficulty with unexplained crying or irritability within the past 3 months?</td>
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<td>Do you use tobacco products?</td>
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<td></td>
<td></td>
<td>What product?</td>
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<td></td>
<td></td>
<td>How much per day?</td>
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</tr>
</tbody>
</table>

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83
If the respondent does not meet the requirements, say: **Thank you very much for your time. Your name will be entered into our files.** Enter name, final TMMSE score and medical history into database and check the NO CALL BACK box.

If the respondent does meet the requirements, say: **Finally, are you currently taking any medications? This includes prescription drugs, vitamins, aspirin, antacids, etc. Please indicate all recreational drugs and alcoholic beverages. This information will remain confidential.**

<table>
<thead>
<tr>
<th>Name of Medication</th>
<th>Amount of use (regular or occasional)</th>
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</table>

If the respondent does not meet the requirements, say: **Thank you very much for your time. Your name will be entered into our files.** Enter name, final TMMSE score, medical history, and medications into database and check the NO CALL BACK box.
**APPENDIX D**

**Brief Edinburgh Handedness Inventory**

Participant ID#: ______________

Have you ever had any tendency to left-handedness?  

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
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<tbody>
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</tbody>
</table>

Please indicate your preferences in the use of hands in the following activities by putting + in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put ++. If in any case you are really indifferent, put + in both columns.

Some of the activities require both hands. In these cases, the part of the task or object, for which hand-preferences is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all with the object or task.

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Writing</td>
<td></td>
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<tr>
<td>2. Drawing</td>
<td></td>
<td></td>
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<tr>
<td>3. Throwing</td>
<td></td>
<td></td>
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<tr>
<td>4. Scissors</td>
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<tr>
<td>5. Toothbrush</td>
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<td></td>
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<tr>
<td>6. Knife (without fork)</td>
<td></td>
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<tr>
<td>7. Spoon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Broom (upper hand)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Striking Match (match)</td>
<td></td>
<td></td>
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<tr>
<td>10. Opening Box</td>
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<td><strong>Total</strong></td>
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</tbody>
</table>
APPENDIX E

Neuropsychological Screening

Date: ____________ Experimenter Initials: ____________ Study: ____________

Participant ID #: _______ Handedness Score: _______ Gender: _______ Age: _______

1. Do you have a history of learning problems? ____Yes ____No
2. Have you ever been examined by a neurologist or neuropsychologist? ___Yes ___No
3. Do you have a history of a central nervous system disease ___Yes ___No
4. Do you have a history of high fevers? ____Yes ____No
5. Do you have a history of seizures? ____Yes ____No
6. Do you have a history of balance problems? ____Yes ____No
7. Do you have a history of vertigo or dizziness lasting longer than one hour? ____Yes ____No
8. Have you ever been diagnosed with an inner ear balance problem? ____Yes ____No
9. Have you ever lost consciousness? ____Yes ____No
10. Have you ever had dizziness that lead to nausea or disorientation? ____Yes ____No
11. Do you have persistent headaches? ____Yes ____No
12. Have you experienced an event that lead to brain trauma? ____Yes ____No
13. If you said yes to any of the above, please provide a brief explanation here:

14. Do you wear corrective lenses? ____Yes ____No

15. Please list all medications (include vitamins and herbal supplements) you are currently taking. Indicate the name, dosage, and frequency.
APPENDIX F

Center for Epidemiological Studies Depression Scale (CES-D)

Feelings Scale

Instructions: In this booklet, there are statements about the way that most people feel at one time or another. There is no such thing as a "right" or "wrong" answer because all people are different. All you have to do is answer the statements according to how you have felt during the past week. Don't answer according to how you USUALLY feel, but rather how you have felt DURING THE PAST WEEK. Each statement is followed by four choices. Circle the letter corresponding to your choice. Mark ONLY ONE letter for each statement. For example:

During the past week, I was happy.

a. Rarely or none of the time (less than one day)
b. Some or a little of the time (1 - 2 days)
c. Occasionally or a moderate amount of time (3 - 4 days)
d. Most or all of the time (5 - 7 days)

In the example, you could, of course, choose any ONE of the answers. If you felt really happy, you would circle "d". If you felt very unhappy, you would circle "a". The "b" and "c" answers give you middle choices. Keep these following points in mind.

1. Don't spend too much time thinking about your answer. Give the 1st natural answer that comes to you.
2. Do your best to answer EVERY question, even if it doesn't seem to apply to you very well.
3. Answer as honestly as you can. Please do not mark something because it seems like "the right thing to say".

1. During the past week, I was bothered by things that don’t usually bother me.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

2. During the past week, I did not feel like eating. My appetite was poor.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

3. During the past week, I felt that I could not shake off the blues even with help from my family or friends.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

4. During the past week, I felt that I was just as good as other people.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

To continue, please turn to page 2
5. During the past week, I had trouble keeping my mind on what I was doing.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

6. During the past week, I felt depressed.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

7. During the past week, I felt that everything I did was an effort.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

8. During the past week, I felt hopeful about the future.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

9. During the past week, I thought my life had been a failure.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

10. During the past week, I felt fearful.
    a. Rarely or none of the time (less than one day)
    b. Some or a little of the time (1 - 2 days)
    c. Occasionally or a moderate amount of time (3 - 4 days)
    d. Most or all of the time (5 - 7 days)

11. During the past week, my sleep was restless.
    a. Rarely or none of the time (less than one day)
    b. Some or a little of the time (1 - 2 days)
    c. Occasionally or a moderate amount of time (3 - 4 days)
    d. Most or all of the time (5 - 7 days)

12. During the past week, I was happy.
    a. Rarely or none of the time (less than one day)
    b. Some or a little of the time (1 - 2 days)
    c. Occasionally or a moderate amount of time (3 - 4 days)
    d. Most or all of the time (5 - 7 days)

To continue, please turn to page 3
13. During the past week, I talked less than usual.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

14. During the past week, I felt lonely.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

15. During the past week, people were unfriendly.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

16. During the past week, I enjoyed life.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

17. During the past week, I had crying spells.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

18. During the past week, I felt sad.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

19. During the past week, I felt that people dislike me.
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)

20. During the past week, I could not get "going".
   a. Rarely or none of the time (less than one day)
   b. Some or a little of the time (1 - 2 days)
   c. Occasionally or a moderate amount of time (3 - 4 days)
   d. Most or all of the time (5 - 7 days)
APPENDIX G

View of Self Survey

VoS Survey

View of Self (VoS) Survey

Instructions: For this survey, we are interested in knowing how well each of the following statements describes your personality. Using the rating scale (1 to 5) provided below, please indicate how much you agree with each of the following statements. Please indicate your response by writing a number in the space next to each statement.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree strongly</td>
<td>Disagree a little</td>
<td>Neither agree nor disagree</td>
<td>Agree a little</td>
<td>Agree strongly</td>
</tr>
</tbody>
</table>

____ 1. I see myself as someone who is reserved.
____ 2. I see myself as someone who is generally trusting.
____ 3. I see myself as someone who tends to be lazy.
____ 4. I see myself as someone who is relaxed, handles stress well.
____ 5. I see myself as someone who has few artistic interests.
____ 6. I see myself as someone who is outgoing, sociable.
____ 7. I see myself as someone who tends to find fault with others.
____ 8. I see myself as someone who does a thorough job.
____ 9. I see myself as someone who gets nervous easily.
____ 10. I see myself as someone who has an active imagination.
APPENDIX H

Emotion Regulation Questionnaire (ERQ)

Instructions and Items

We would like to ask you some questions about your emotional life, in particular, how you control (that is, regulate and manage) your emotions. The questions below involve two distinct aspects of your emotional life. One is your emotional experience, or what you feel like inside. The other is your emotional expression, or how you show your emotions in the way you talk, gesture, or behave. Although some of the following questions may seem similar to one another, they differ in important ways. For each item, please answer using the following scale:

1-----------------------------2-----------------------------3-----------------------------4-----------------------------5-----------------------------6-----------------------------7

strongly disagree  neutral  strongly agree

1. ____ When I want to feel more positive emotion (such as joy or amusement), I change what I’m thinking about.
2. ____ I keep my emotions to myself.
3. ____ When I want to feel less negative emotion (such as sadness or anger), I change what I’m thinking about.
4. ____ When I am feeling positive emotions, I am careful not to express them.
5. ____ When I’m faced with a stressful situation, I make myself think about it in a way that helps me stay calm.
6. ____ I control my emotions by not expressing them.
7. ____ When I want to feel more positive emotion, I change the way I’m thinking about the situation.
8. ____ I control my emotions by changing the way I think about the situation I’m in.
9. ____ When I am feeling negative emotions, I make sure not to express them.
10. ____ When I want to feel less negative emotion, I change the way I’m thinking about the situation.
APPENDIX I

BIS/BAS

Instructions: Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

____ 1. A person's family is the most important thing in life.
____ 2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
____ 3. I go out of my way to get things I want.
____ 4. When I'm doing well at something I love to keep at it.
____ 5. I'm always willing to try something new if I think it will be fun.
____ 6. How I dress is important to me.
____ 7. When I get something I want, I feel excited and energized.
____ 8. Criticism or scolding hurts me quite a bit.
____ 9. When I want something I usually go all-out to get it.
____ 10. I will often do things for no other reason than that they might be fun.
____ 11. It's hard for me to find the time to do things such as get a haircut.
____ 12. If I see a chance to get something I want I move on it right away.
13. I feel pretty worried or upset when I think or know somebody is angry at me.
14. When I see an opportunity for something I like I get excited right away.
15. I often act on the spur of the moment.
16. If I think something unpleasant is going to happen I usually get pretty "worked up."
17. I often wonder why people act the way they do.
18. When good things happen to me, it affects me strongly.
19. I feel worried when I think I have done poorly at something important.
20. I crave excitement and new sensations.
21. When I go after something I use a "no holds barred" approach.
22. I have very few fears compared to my friends.
23. It would excite me to win a contest.
24. I worry about making mistakes.
APPENDIX J

Lab Demographics Questionnaire

Instructions: The items in this questionnaire ask you for personal information that we can use to get a sense for how similar our group of volunteers is to those who participate in research at other institutions in the United States. All information that we collect from individuals will not be linked back to their identities. However, if you are uncomfortable providing a response for any of the following items, please do not respond to them. For the remaining items, please fill in the blank spaces or circle the response which best describes you.

1. Please indicate your gender: 1. Female 2. Male


3. Please indicate how many children you have raised or are currently raising. _______

4. Date of birth: ______/_____/______ and current age: _______ years

5. Do you consider yourself to be Hispanic or Latino? 1. YES 2. NO


9. If you are a student, please indicate your academic major:
   1. Arts (specify) ______________________
   2. Business (specify) ______________________
   3. Engineering (specify) ______________________
   4. Humanities (specify) ______________________
   5. Science (specify) ______________________
   6. Health (specify) ______________________
   7. Education (specify) ______________________
   8. Other (specify) ______________________

To continue, please turn to the other side of this page
Lab Demographics Questionnaire

10. What is your highest level of formal education (circle the highest level completed):
   A. Less than 12 years (How many of years completed? ______ years)
   B. GED (Age when you completed your GED: ______)
   C. High school diploma
   D. Technical/Vocational/Trade school diploma or certificate
   E. College Freshman
   F. College Sophomore
   G. College Junior
   H. Associate’s Degree
   I. Bachelor’s degree
   J. Master’s degree
   K. J.D., M.D., or Ph.D.


13. If you are currently or have recently been employed, what field is your job in?

________________________________________

14. If you are currently or have recently been employed, please describe the duties of your job?

________________________________________

15. In the past 5 years, have you engaged in volunteer activities to assist or instruct young adults (i.e., individuals aged 18-30)? 1. Yes 2. No

16. To what extent do you interact with young adults throughout the course of a typical week (including time spent at work, in classes, and/or during volunteer or extracurricular activities)?
   1. Rarely or none of the time (less than one day)
   2. Some or a little of the time (1 - 2 days)
   3. Occasionally or a moderate amount of time (3 - 4 days)
   4. Most or all of the time (5 - 7 days)

17. How would you rate your overall health at the present time? (please circle one rating)


19. Are you presently seeking psychological or psychiatric consultation and/or receiving therapy?
   1. Yes 2. No

   If yes…
   a. Are you currently being treated for depression? 1. Yes 2. No
   b. Are you currently being treated for excessive anxiety or nervousness? 1. Yes 2. No

20. Do you currently have any noticeable difficulty with vision for which correction, such as eyeglasses, has NOT been made? 1. Yes 2. No

21. Do you currently have any noticeable difficulty with hearing for which a correction, such as a hearing aide, has NOT been made? 1. Yes 2. No

22. Do you currently have any difficulty with writing? 1. Yes 2. No
APPENDIX K

Exploratory Correlations

Exploratory Correlations of P1 Amplitude and Behavioral Data. Pearson correlations were calculated in order to examine the relationships between P1 amplitude averaged for representative electrodes (66, 70, 71, 75, 76, 83, 84) and behavioral data. Interestingly, significant correlations only emerged for trials occurring in the GD condition. With respect to trials in which neutral faces appeared and participants responded correctly, there was a negative relationship between P1 amplitude and reaction time, $r(39) = -0.41$, $p < 0.01$, such that the larger the participant’s P1 amplitude was for neutral faces, the faster their reaction time was for neutral faces presented during GD trials. This same negative relationship was observed when examining the correlation between P1 amplitude for angry faces and reaction time for correct trials containing angry faces during the GD condition, $r(39) = -0.35$, $p = 0.03$. The larger a participant’s P1 amplitude was in response to angry faces, the shorter their reaction time was for correct trials for angry faces presented during the GD condition. Moreover, there was a positive relationship between P1 amplitude for angry faces and response accuracy for angry faces presented during the GD condition, $r(39) = 0.34$, $p = 0.03$, such that the larger a participant’s P1 amplitude was for angry faces, the greater their response accuracy was for angry faces presented during GD trials. With respect to happy faces, there also was a negative relationship between P1 amplitude in response to happy faces and reaction time for correct trials in which a happy face was presented during the GD condition, $r(39) = -0.33$, $p = 0.03$, such that the larger a participant’s P1 amplitude was in response to happy faces, the shorter their reaction time was during correct trials for happy faces presented during the GD trials. Additionally,
there was a positive relationship between P1 amplitude in response to happy faces and accuracy for happy faces presented during the GD condition $r(39) = .34, p = .03$, such that the larger a participant’s P1 amplitude was in response to happy faces, the greater their accuracy was for happy faces presented during the GD condition.

**Exploratory Correlations between P1 Amplitude and Individual Difference Measures.** Pearson’s correlations were calculated in order to examine the relationship between the individual difference measures (CES-D, BIS/BAS, and ERQ) and average P1 amplitude for neutral, angry, and happy faces for a group of representative electrodes (66, 70, 71, 75, 76, 83, and 84). For all participants there was a positive relationship between BAS Drive scores and P1 amplitude in response to neutral faces $r(38) = .37, p = .02$, in response to angry faces, $r(38) = .36, p = .02$, and in response to happy faces, $r(38) = .37, p = .02$, such that the larger the participant’s BAS Drive score was, the larger their P1 amplitude was in response to facial stimuli. These correlations were entirely driven by the older participants, as the correlation between BAS Drive and the P1 amplitude of older adults, but not younger adults, was significant for each emotion, neutral: $r(18) = .67, p < .001$; angry: $r(18) = .63, p < .01$; and happy: $r(18) = .66, p < .01$.

**Exploratory Correlations between N170 Amplitude and Behavioral Data.** Pearson’s correlations were calculated in order to examine the relationship between N170 amplitude and the behavioral data. There was a positive relationship between N170 amplitude in the left hemisphere in response to happy faces and reaction time for correct trials for happy faces presented during the ED condition, $r(38) = -37, p = .02$, such that the larger the N170 amplitude was in response to happy faces in the left hemisphere, the
longer the reaction time was for correct trials during which happy faces were presented during the ED condition.

**Exploratory Correlations between N170 Amplitude and Individual Difference**

**Measures.** Pearson’s correlations were calculated in order to examine the relationships between scores on the measures (CES-D, BIS/BAS, and ERQ) and N170 amplitude for neutral, angry, and happy faces for a group of representative electrodes on the left (58, 64, 65, 68, 69) and right (89, 90, 94, 95, 96) hemispheres. For all participants, the CES-D was positively correlated with N170 amplitude for the right hemisphere for neutral faces $r(39) = .38, p = .01$, for angry faces, $r(39) = .37, p = .02$, and for happy faces, $r(39) = .40, p < .01$, such that the higher a participant’s score was on the CES-D (i.e., the more depressive symptoms endorsed), the higher their N170 amplitude was in the right hemisphere for facial stimuli.

An additional set of Pearson’s correlations were calculated to examine the relationships between younger adults’ N170 amplitudes and score on the measures. For younger adults, there was a negative relationship between BAS Reward Responsiveness scores and N170 amplitude in the left hemisphere for neutral faces $r(18) = -.60, p < .01$, angry faces, $r(18) = -.65, p < .01$, and happy faces, $r(18) = -.61, p < .01$, such that the higher a younger adult’s score was on the BAS Reward Responsiveness scale, the smaller their N170 amplitude was in the left hemisphere for facial stimuli. For young adults, there was also a negative relationship between the ERQ Reappraisal and the N170 amplitude in the right hemisphere for neutral faces $r(19) = -.60, p < .01$, angry faces, $r(18) = -.59, p < .01$, and happy faces, $r(18) = -.58, p < .01$, such that the higher a younger adult’s score
was on the ERQ Reappraisal, the smaller their N170 amplitude was in the right hemisphere for neutral faces.

A final set of Pearson’s correlations were conducted in order to examine the relationship between older adults’ N170 amplitudes and scores on the individual difference measures. There was a negative relationship between ERQ Suppression scores and the N170 amplitude in the left hemisphere for neutral faces, $r(18) = -.52, p = .02$, for angry faces, $r(18) = -.48, p = .03$, and for happy faces, $r(18) = -.47, p = .04$, such that the higher an older adult’s score was on the ERQ Suppression measure, the smaller their N170 amplitude was in the left hemisphere in response to facial stimuli.