Emotion Regulation and Aging: A Neurophysiological Study

By

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ABSTRACT

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Cognitive emotion regulation (ER) pertains to the ability to change the way we attend to and experience emotional information and events. Older and younger adults, however, differ in the way that they attend to emotional information. Socioemotional Selective Theory (SST) suggests that as we age we become more adept at using cognitive ER strategies to reduce negative emotion because we have less time left in life. As a result of these motivational changes, a branch of SST, the positivity effect, proposes older versus younger adults attend to and remember more pleasant than unpleasant stimuli. Research that systematically examines different types of cognitive ER in controlled (reappraisal) and automatic (directed attention) contexts, using neurophysiological measures, has the potential to clarify the nature of the positivity effect. The present research capitalizes on the excellent temporal resolution of the late positive potential (LPP) which is sensitive to attention to emotion and the use of cognitive ER strategies: increasing emotional responses produces larger LPP amplitudes and decreasing smaller LPP amplitudes. Chapter one served to first evaluate whether cognitive ER impacts memory performance and if the LPP during a cognitive ER task was associated with memory performance in younger adults (N = 49). Subsequent research presented uses the LPP to understand whether younger (*n* = 49) and older adults (*n* =28) differ in: a) how they attend to emotional information during a passive viewing task (bottom-up); b) how they use two types of cognitive ER strategies, reappraisal (top-down) and directed attention (intermediary top-down);

c) how cognitive ER strategies impact memory performance. Results highlight several important contributions to the cognitive ER and aging literature. First, in the initial study results showed that instructions to increase emotional responses to unpleasant stimuli results in larger LPP amplitudes as compared to viewing or decreasing emotional responses. Memory performance in the increase and view conditions was better than the decrease condition. Additionally, larger LPP amplitudes in the increase and decrease conditions were associated with better memory performance. Second, older adults showed sustained attention to emotional stimuli; however younger and older adults did not show preferential attention to unpleasant and pleasant stimuli (respectively). Third, younger and older adults did not differ in their ability to use reappraisal as measured via the LPP, but did show differences in LPP amplitudes on the directed attention task to unpleasant stimuli. Younger, but not older adults showed larger LPP amplitudes to unpleasant stimuli presented with an arousing versus non-arousing focus. Fourth, age differences in memory performance did not emerge; however stimuli presented with an arousing focus were remembered more than those with a non-arousing focus. Fifth, only larger LPP amplitudes to unpleasant stimuli in the decrease condition (relative to a neutral maintain) were associated with better memory performance for younger and older adults. Taken together results suggest that older versus younger adults may sustain processing of emotional stimuli and that age differences in cognitive ER may lie within bottom-up cognitive ER tasks as opposed to reappraisal. Results hold promise that the LPP may be a useful tool for examining other types of cognitive ER strategies in younger and older adults.

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DEDICATION

To my mom and dad thank you for always encouraging me.

Your love and never ending support mean the world to me.

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GENERAL INTRODUCTION

Emotion regulation (ER) involves the ability to cognitively shift our experience of and attention to emotional information. Cognitive ER strategies, such as reappraising events to change their emotional meaning and significance, have an impact on an individual's well being and have been linked to self-acceptance, personal growth and a sense of purpose in life, as well as less depression and other negative mental health outcomes (Gross & John, 2003). Although there is a strong knowledge base about cognitive ER in younger adults, its nature and implications for adjustment in older adults remain unclear. Lifespan changes in cognitive ER are of particular relevance because of the more general cognitive changes that may occur over the course of adulthood. For example, Socioemotional Selectivity Theory (SST) suggests that older adults are increasingly motivated to focus attention on positive emotional information, and less motivated to focus on negative emotional information as our time left in life decreases (Carstensen, Isaacowitz, & Charles, 1999). A complementary component of SST, the positivity effect, has demonstrated differences between younger and older adults in attention and memory: that older adults show greater attention towards and memory for pleasant stimuli (Langeslag & van Strien, 2009), as well as greater memory for pleasant versus unpleasant stimuli; whereas younger adults have greater memory for and attention to unpleasant versus pleasant stimuli (Charles, Mather, & Carstensen, 2003; Mather & Carstensen, 2005; Scheibe & Carstensen, 2010). SST therefore suggests that how older adults change their experience of and attention to emotional information – perhaps via ER strategies - may have an impact on memory.

Despite the conceptual links between the positivity effect and ER, few studies have examined whether older adults show changes in cognitive ER that are consistent with the positivity effect. One possibility is that with age and “cognitive maturity” we become particularly adept at using cognitive ER strategies such as reappraisal to “focus on the positive” because of an increased awareness and understanding of emotion (Labouvie-Vief, DeVoe, & Bulka, 1989). Furthermore, older adults also report feeling more “in control” of their emotions (Gross et al., 1997). Thus, although aging is associated with some cognitive decline, emotional processing of positive material and the ability to reduce negative emotion via emotion regulation strategies may remain intact.

In addition to questions about the differences in how younger and older adults use cognitive ER strategies, it is unclear whether these strategies influence memory measures of the positivity effect. Only a few studies have targeted this question. For example, one study (Emery & Hess, 2008) found that when asked to decrease attention to emotional characteristics and focus more on neutral aspects of stimuli, younger, but not older adults declined in memory performance for experimental stimuli. However, it remains to be seen whether cognitive ER strategies (i.e. using reappraisal to increase and decrease emotional experiences or shifting attention via attentional deployment) influence memory. The research reported here is among the first to systematically examine the links among the positivity effect, across multiple cognitive ER strategies, and emotional memory in older versus younger adults.

One approach to examining the positivity effect and cognitive ER is to identify neural correlates of these processes. For example, some studies have used neuroimaging to assess the positivity effect. In one study, older adults show increased brain activity in the amygdala while viewing pleasant stimuli and reduced activation while viewing unpleasant stimuli (Mather et al., 2004). Younger adults in this same study, however, did not differ in amygdala activation between pleasant and unpleasant stimuli (Mather et al., 2004). If increased emotional processing of positive stimuli bolsters subsequent memory, then such preferential processing of pleasant stimuli may underlie the positivity effect in older adults. However several questions remain. For example, is it increased attentional processing of pleasant stimuli, or decreased processing of unpleasant stimuli that best explain this effect? Do cognitive changes (such cognitive ER strategies) in how older adults view positive stimuli, rather than the amount of attention, influence subsequent memory? Moreover, it is unclear whether this preferential attention is present throughout the processing of emotional stimuli, or if it emerges at later, more conscious stages of processing and during reappraisal or attentional deployment. A growing body of literature has examined cognitive ER using functional neuroimaging (e.g., Ochsner & Gross, 2005; Ochsner et al., 2004; Urry et al., 2006); however it lacks the temporal sensitivity to fully address these questions, particularly if cognitive changes occur within the first few hundred milliseconds of processing.

Scalp-recorded event-related potentials (ERPs) have the ability to capture changes in attention to and experience of emotion with millisecond precision. ERPs are the average amount of electrical brain activity recorded via electroencephalography (EEG) within a specified amount of time following the presentation of a stimulus (stimulus-locked) or generated as a result of a response (response locked) from a participant. This electrical activity occurs when numerous pyramidal cells generate postsynaptic potentials (PSPs) and summate to create dipoles which can be recorded at the scalp (Luck, 2005). The electrical activity at the level of the scalp generates these dipoles which contain a net positive and negative electrical charge. The late positive potential (LPP), an ERP, is particularly appropriate for addressing these questions because it reflects increased processing of and attention to emotional stimuli, such that the LPP is larger for pleasant and unpleasant versus neutral stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp et al., 2000; Schupp, Junghöfer, Weike, & Hamm, 2004) and is sensitive to the use of cognitive ER strategies (Hajcak & Nieuwenhuis, 2006; Moser, Hajcak, Bukay, & Simons, 2006; Moser, Krompinger, Dietz, & Simons, 2009). For example, LPP amplitudes are reduced when individuals are instructed to suppress emotional responses to unpleasant stimuli (Moser et al., 2006). Moreover, the LPP is an extended ERP lasting several seconds (Cuthbert et al., 2000; Schupp et al., 2000). Given these characteristics, and its temporal sensitivity, the LPP is an excellent candidate component to capture the positivity effect during emotional processing, as well as the changes in emotional processing that result from the use of cognitive strategies like reappraisal.

Currently, four studies have compared the LPP between older and younger adults: two studies examined the LPP while participants completed a valence categorization task of emotional pictures (Kisley, Wood, & Burrows, 2007; Wood & Kisley, 2006), one study investigated the association between the LPP during passive viewing and free recall memory (Langeslag & van Strien, 2009), and one study used a reappraisal paradigm with pleasant, unpleasant and neutral stimuli (Langeslag & van Strien, 2010). Wood & Kisley (2006) demonstrated that older versus younger adults have overall reduced LPP amplitudes to emotional stimuli, as well as slowed reaction times in categorizing the stimuli by valence. Additionally, younger adults showed larger LPP amplitudes to unpleasant versus pleasant stimuli, whereas older adults showed no difference between these types of emotional stimuli. In a follow-up study, LPP amplitudes to unpleasant stimuli were reduced with age; however, this was done in the context of a categorization task (Kisley et al., 2007) which could have potentially introduced other factors that minimized the positivity effect, such as how the picture should be rated according to social norms. During passive viewing paradigms, on the other hand, older adults show larger LPP amplitudes for pleasant stimuli, whereas younger adults have larger LPPs for unpleasant stimuli (Langeslag & van Strien, 2009). This same study also found that larger LPP amplitudes were associated with greater free recall in older adults. Thus, results provide mixed support for SST and the positivity effect as some demonstrate reduced LPP amplitudes to unpleasant stimuli with age and others increased LPP amplitudes to pleasant stimuli.

To date one study has examined the LPP in the context of reappraisal between older (60-77) and younger adults (18-26) in which participants were asked to increase and decrease emotional responses to pleasant and unpleasant stimuli and to view neutral stimuli (Langeslag & van Strien, 2010); however there were no age differences in the LPP between younger and older adults across the regulation conditions.

It is important to note that the type of task may influence when differences in emotional processing between younger and older adults emerge most clearly. A model suggested by Mather and Carstensen (2005) predicts that tasks that require cognitive control (top-down processing) will allow the positivity effect and motivational goals of SST to influence attention to emotion, as compared to automatic tasks (bottom-up processing; Mather & Carstensen, 2005). Figure 1 (adapted from Mather & Carstensen, 2005) outlines the conditions under which age differences should be found. For example, bottom-up tasks should require the use of the amygdala, a structure that shows little deterioration with age (Good et al., 2001; Grieve, Clark, William, Peduto, & Gordon, 2005). Bottom-up tasks are also not influenced by emotional goals or motivational factors proposed by SST, suggesting these tasks do not produce age differences in attention to emotion or in memory performance (Mather & Carstensen, 2005). For example, younger and older adults do not differ in how quickly they detect threatening faces (Mather & Knight, 2006). On the other hand, tasks that require cognitive control and top-down processes generally recruit regions of the prefrontal cortex, an area of the brain known to decline with age (Braver & Barch, 2002; Hedden & Gabrieli, 2004). As a result of this loss in cognitive control processes, emotional goals and motivation weigh much more heavily in how older adults attend to emotional information. That is, older adults should show reduced attention and memory for unpleasant and greater attention and memory for pleasant stimuli as compared to younger adults in top-down tasks (Mather & Carstensen, 2005). Overall, this model presents a framework in which attention and memory in older adults is dependent upon the task at hand, age-related changes in brain structure, and emotional goals and motivation.

Though support for some of the predictions of the top-down and bottom-up models have been documented, the measurements used may play a role in some inconsistencies within the literature. Three main methods that have been used to examine attention to emotion and cognitive ER in older age include EEG, fMRI, and behavioral methods and greatly differ in their temporal resolution. EEG is capable of tracking changes in attention that occur on the order of milliseconds whereas fMRI can track changes only over several seconds, and behavior sometimes provides the slowest temporal resolution of the three. Differences in temporal resolution may account for some inconsistencies in a model proposed by Mather and Carstensen (2005; see Figure 2 for a summary). For example, Mather and colleagues (2004), using fMRI, showed that older adults have greater amygdala activation to pleasant versus unpleasant stimuli whereas younger adults showed no differences in amygdala activation. As the amygdala was the region of interest for this particular study, then according to the model proposed by Mather and Carstensen (2005) age differences in a potentially bottom-up task should not have occurred. As fMRI measures changes in brain activity over several seconds, it may be possible that control processes are be recruited over this rather extended period of time. In contrast, behavioral studies show that younger and older adults do not differ in the amount of time taken to detect a threatening face among an array of faces (Mather & Knight, 2006); a task deemed bottom-up by Mather and Carstensen (2005). These differing results leave questions as to what types of tasks would be considered bottom-up in this literature. A discrimination task of this nature would appear to require more cognitive control, as compared to the Mather and colleagues (2004) passive viewing task. The three LPP and aging studies that have been conducted using passive viewing and passive viewing with valance categorization tasks, also provide mixed support for predictions for bottom-up tasks. For example, of the three studies (Langeslag & van Strien, 2009; Kisley et al., 2007; Wood & Kisley, 2006) only one documents support for predictions of bottom-up processing proposed by Mather and Carstensen (2005): no differences in LPP amplitudes between pleasant and unpleasant stimuli in older adults (Wood & Kisley, 2006).

Similar to the bottom-up approach, there is also inconsistent evidence for top-down models of attention to emotion and aging. For example, only one of the three fMRI studies that use cognitive ER tasks (requiring cognitive control) show results consistent with what is predicted by this model (van Reekum et al., 2007). In a gaze-directed reappraisal task van Reekum and colleagues (2007) demonstrated that amygdala activity was reduced and prefrontal activity was increased when older adults were asked to decrease negative emotion to unpleasant stimuli. Other studies using only a reappraisal task that instructs older adults to decrease responses to unpleasant stimuli do not find these same patterns of neural activation in older adults (Urry et al., 2006). Alternatively, an additional gaze-directed reappraisal task, showed similar results as Urry and colleagues (2006). Similar to the bottom-up model, behavioral measures have shown support for top-down processing differences between younger and older adults, where older adults are slower to react to probes following negative faces (Mather & Carstensen, 2003). EEG (specifically the LPP) also does not find differences in LPP amplitudes during a cognitive ER task between younger and older adults (Langeslag & van Strien, 2007). Taken together, these three measurements highlight the need to clarify what is considered a bottom-up and top-down task within this literature, as some similar tasks find differing results (e.g. passive viewing with and without valence categorization). In addition Schiebe and Carstensen (2010) also mention a need to develop a greater understanding for the temporal characteristics in attention to emotion among older adults. Of these three measures, only one has the temporal resolution capable of detecting relatively automatic processes, as well as some later stages of processing to emotional stimuli, the LPP.

Although results suggest that the LPP holds promise as a measure of the positivity effect and attention to emotion in older age, results are inconsistent. For example, is it increased attention to pleasant stimuli (Langeslag & van Strien, 2009) or decreased attention to unpleasant stimuli (Kisley et al., 2007) among older adults provides the best support the positivity effect? In addition, which types of tasks, bottom-up (passive viewing) top-down (cognitive reappraisal) or tasks that fall somewhere in between these two processes (attentional deployment) support predictions of the positivity effect? Furthermore, stimuli in these studies were also presented for a short duration (1000 ms), thus it will be important to examine an extended time course of emotional processing in relation to memory. Indeed, eye tracking research suggests that this preferential processing may not occur until 500ms following stimulus presentation (Isaacowitz, Allard, Murphy, & Schlangel, 2009). Some potential reasons as to why null results may have occurred in the previous cognitive reappraisal and aging study may involve this relatively short stimulus duration. The present study also includes highly arousing pleasant stimuli, erotica images, a type of stimulus that was not included in many previous LPP and aging studies. Moreover, few studies include a true valence baseline condition within a regulation task (e.g. viewing or maintaining emotional responses to pleasant and unpleasant stimuli). The addition of this type of condition within the present study helps to further evaluate the degree to which younger and older adults can increase and decrease emotional responses to emotional stimuli, as well as a true neutral viewing condition.

The research reported here capitalizes on the time course of the LPP, which can capture subtle and bottom-up changes in emotional processing that occur within the first few hundred milliseconds of processing, as well as top-down changes that occur thereafter. Moreover, the age range in the present research uses a sample of older adults with a minimum age of 65 and a maximum age of 83, an age range much higher than previous research (Langeslag & van Strien, 2009; 2010; Urry et al., 2006; Urry et al., 2009; van Reekum et al., 2007; Optiz et al., 2012). This older age range reflects the growing number of older adults that are living longer, and thus may provide greater external validity to the growing older population. The overall goal of this research is to establish whether neural measures of attention to emotion show differences between younger and older adults in how they attend to and regulate emotion as suggested by SST and the positivity effect.

The three chapters following this general introduction aim to examine bottom-up emotional processing, cognitive ER strategies and the impact of these strategies on memory performance. Chapter one (N = 49) seeks to examine preliminary effects of cognitive ER on long-term memory performance in younger adults. This chapter was submitted to Cognition and Emotion in July of 2011 and is currently under revision. Chapter two (*n* = 36 younger, *n* = 25 older) aims evaluate the LPP during the passive viewing of pleasant, unpleasant, and neutral stimuli and test the hypothesis that LPP amplitudes will not differ between younger and older adults. In addition we will also explore whether attention to specific subgroups of emotional stimuli show differing patterns in the LPP between younger and older adults. Chapter three (reappraisal: n = 40 younger, n = 26 older; directed attention: n = 39 younger, n = 22 older) aims to test whether older and younger adults differ in the ability to effectively use reappraisal (top-down) in relation to both pleasant and unpleasant stimuli (as measured by changes in the LPP) and test the hypothesis that older adults are more adept at reducing LPP amplitudes to unpleasant stimuli and increasing LPP amplitudes to pleasant stimuli. In chapter three age-related differences and similarities in the associations between reappraisal (measured via the LPP) and long-term memory for stimuli used in the cognitive ER tasks are examined. In addition to the reappraisal task, age differences in the LPP during a non-reappraisal ER (bottom-up) task in which attention is explicitly directed to more or less arousing portions of the stimuli (directed attention) is evaluated. We also test the exploratory hypothesis that reduced LPP amplitudes to unpleasant stimuli and larger LPP amplitudes to pleasant stimuli will be associated with greater well-being older adults. Well-being and adjustment were measured with the Ryff Scales of Psychological Well-Being and the Emotion Regulation Questionnaire (ERQ).

In sum, this research would be among the first of its kind to use behavioral and neurophysiological measures to examine cognitive ER and the positivity effect in older and younger adults, and to assess the implications of cognitive ER for emotional memory and well-being. A critical future direction in emotion and aging research is to increase our knowledge of the temporal characteristics of emotional processing in older adults in relation to the positivity effect (Scheibe & Carstensen, 2010). The LPP is an optimal target measure of cognitive ER to meet this goal because it affords the opportunity to systematically examine affective and cognitive processes underlying the positivity effect with excellent temporal sensitivity. Additionally, the LPP has the ability to measure aspects of the positivity effect and SST that behavioral measures alone may not be sensitive enough to capture. Findings from this research have the potential to clarify important empirical and theoretical questions about emotion and aging. The overall goal of the present research is to clarify whether the LPP can capture age-related differences in how younger and older adults attend to and regulate emotion as proposed by SST and the positivity effect. Following chapters one through three a discussion of findings and future directions in the field of cognitive ER and aging from a neural perspective is presented in the general discussion.

Figure i. Predictions of changes in attention to emotion based on top-down and bottom-up tasks.

This table is adapted from Mather and Carstensen (2005).

Influence on Cognition	Associated Brain Regions	Impact of Emotional Goals	Relevance for Emotional Attention	Relevance for Emotional Memory
Automatic/Bottom-up	Amygdala; Little decline with age	None/little	No age differences	No age differences in memory
Goal-directed/top-down/cognitive control	Prefrontal regions decline with age; reduces cognitive control ability	Impacted significantly by emotional goals/motivational factors	Older attend less to negative and as much or more to positive as younger adults	Reduced memory for negative in older adults and greater memory for positive (positivity effect)

Figure ii. Comparisons between measurements used to examine age-related differences in top-down and bottom-up processing, showing results either consistent or inconsistent with proposed hypotheses of SST and the speed of temporal resolution for each type of measure.

	EEG	**fMRI**	**Behavior**
Bottom-up	✗ Older adults have larger LPPs to pleasant and younger adults to unpleasant stimuli during passive viewing (Langeslag & van Strien, 2009). Passive view with valence categorization: ✗ -With age LPP amplitudes are reduced to unpleasant stimuli (Kisley et al., 2007). ✓ -Older adults do not differ in LPP amplitudes between pleasant and unpleasant stimuli (Wood & Kisley, 2006)	✗ Older adults show increased amygdala activity to pleasant stimuli during passive viewing (Mather et al., 2004)	✓ Detection of threatening faces does not differ between younger and older adults (Mather & Knight, 2006)
Top-Down	✗ Younger and older adults do not differ in LPP amplitudes to increase and decrease positive and negative emotion (Langeslag & van Strien, 2010)	✗ Decrease instructions to unpleasant stimuli does not reduce activation in the amygdala and increase prefrontal activation (Urry et al., 2006) ✓ Gaze-directed reappraisal reduces amydala and increases prefrontal activity versus increasing and attending to unpleasant stimuli (van Reekum et al., 2007) ✗ Gaze-directed reappraisal older adults do not show increased prefrontal activation when decreasing versus younger adults (Opitz et al., 2012)	✓ Older adults slower to react to probes following negative faces (Mather & Carstensen, 2003)

CHAPTER ONE

Emotion Regulation and Memory: An ERP Study

1.1 Abstract

The late positive potential (LPP) reflects increased attention to emotional stimuli and is modulated by emotion regulation strategies. Links between the LPP and cognitive processes that are sensitive to emotion regulation, like long-term memory, have yet to be explored. The present study examined associations between the LPP during a cognitive ER task and long-term memory. EEG was recorded while 49 adults increased or decreased their emotional responses to unpleasant pictures, compared to a baseline condition. Memory recognition was tested one week later. LPP amplitudes were larger when participants were asked to increase emotional responses, as compared to baseline and decrease conditions. Memory was greater for stimuli in the increase and baseline conditions compared to the decrease condition. However, larger LPP amplitudes in the decrease and increase conditions were associated with superior memory. The use of neurophysiological measures of emotional attention to clarify links between cognitive ER and memory are discussed.

Chapter one "Emotion regulation and memory: An ERP study", J. DeCicco, G. Hajcak, G. Bonanno, & T. Dennis, Cognition and Emotion, July 2011, currently under revision.

1.2 Introduction

Emotion regulation (ER) strategies serve to shift how we attend and respond to emotional information (Gross & Thompson, 2007). The ability to effectively employ cognitive ER strategies is associated with a range of outcomes from well being and life satisfaction (Gross & John, 2003) to resiliency following a traumatic event (e.g., Bonanno, Papa, Lalande, Westphal, & Coifman, 2004). The use of cognitive ER strategies may also impact cognitive processes, such as memory. For example, one study documented that suppressing facial expressions of emotion while viewing emotional film clips, as compared to a baseline condition, resulted in reduced memory for details of the films when measured minutes after the task (Richards & Gross, 1999). In a follow-up study, verbal memory for emotional slides was reduced in the suppression versus baseline condition (Richards & Gross, 2000).

Taken together, these studies suggest that cognitive ER strategies that serve to decrease or suppress emotional responses may interfere with emotional memory. Yet, one study also demonstrated that both expressive suppression and enhancement (increasing facial expression) have immediate detrimental effects on memory (Bonanno et al., 2004). Thus, links between cognitive ER and memory are unclear. All of these studies, however, focused on the regulation of facial expressions, which is typically unrelated to reductions in physiological and subjective emotional arousal (e.g., Gross & Levenson, 1993) and may not map on well to the regulation of subjective emotional experience. Therefore, it remains unclear how cognitive ER strategies to increase and decrease the experience of emotional stimuli influence subsequent memory for that material.

Although there are conflicting findings in the literature, most studies suggest that cognitive processes that increase rather than decrease the experience and processing of emotional stimuli will bolster the encoding of emotional material into memory (Dolcos & Cabeza, 2002; Dolcos, LaBar, & Cabeza, 2006). There may be several explanations for this effect. For example, if increased processing of emotional stimuli triggers increased arousal, higher levels of arousal may underlie facilitated attention (e.g., Hajcak & Nieuwenhuis, 2006). Another possibility is that the relatively reduced effort required to increase versus decrease emotional responses could preserve cognitive resources (Ochsner et al., 2004) in service of memory consolidation rather than the regulation of affective processing (Muraven, Tice, & Baumeister, 1998). Thus, links between ER and memory might operate via changes in both affective processing and arousal during encoding (Bradley, Greenwald, Petry, & Lang, 1992).

One electrocortical measure, the late positive potential (LPP), may be particularly well-suited for capturing changes in affective processing and arousal relevant to the impact of cognitive ER on memory. The LPP is a broadly distributed positive-going waveform that emerges around 200-300 ms following presentation of visual stimuli (Cuthbert et al., 2000; Schupp et al., 2000; Schupp et al., 2004) mainly observed in posterior regions of the scalp (Foti & Hajcak, 2008; Hajcak, Dunning, & Foti, 2007; Keil et al., 2002; Schupp et al., 2000). LPP amplitudes are larger to unpleasant and pleasant compared to neutral stimuli and have been correlated with increased subjective emotional arousal (Hajcak & Nieuwenhuis, 2006). Thus, the LPP is thought to reflect increased processing of emotional stimuli (Cuthbert et al., 2000).

Several studies have demonstrated the sensitivity of the LPP to cognitive ER instructions to increase and decrease emotion. Previous research has shown that LPP amplitudes decrease in response to directions to decrease emotional responses to unpleasant pictures (Moser et al., 2006) and pleasant pictures (Krompinger, Moser, & Simons, 2008). LPP is also sensitive to a range of instructions to increase and decrease emotional responses, including self- and situation-focused cognitive strategies (Moser et al., 2009), open-ended reappraisal instructions (Hajcak & Nieuwenhuis, 2006), and directed reappraisals (MacNamra, Ochsner, & Hajcak, 2011). Across these studies, effects occurred within 200 – 400 ms after stimulus onset. Importantly, only one of these studies demonstrated that LPP amplitudes were larger, relative to a baseline view condition, when individuals were instructed to increase their response to unpleasant stimuli (Moser et al., 2009). One possibility is that the highly arousing nature of the affective pictures combined with the relatively brief duration of the stimuli used in several of the studies (1000 ms) made it difficult for participants to "up-regulate" their emotional responses further. The present study included somewhat less arousing unpleasant stimuli compared to these previous studies, which might facilitate the detection of increase effects.

To our knowledge, there are no studies that examine the LPP in the context of cognitive ER and long-term memory performance. One study, however, established a link between the LPP during a passive viewing task and short-term memory, such that larger LPP amplitudes were associated with greater short-term free recall in older adults (Langeslag & van Strien, 2009). This suggests that the LPP is capturing increased attention to emotional material which in turn facilitates memory encoding, at least in the short term. In addition, Dolcos and Cabeza (2002) showed that emotional stimuli elicited larger LPP amplitudes compared to neutral stimuli, and that this emotion effect for remembered stimuli (short-term recall) was greater for emotional compared to neutral pictures during an early epoch (400-600 ms). In the present study, we extended this literature by examining the LPP in relation to cognitive ER and long-term memory (one week later). We predicted that long-term memory recognition will be superior for pictures viewed while participants were instructed to increase versus decrease their emotional responses to the pictures. However, we also predicted that above and beyond the effects of specific regulatory strategy (increasing or decreasing), emotional pictures that elicit enhanced LPPs, indicating increased attention and arousal, will be remembered better one week later. We included a baseline "viewing" condition, in which participants freely viewed emotional pictures, to test whether the increase versus baseline condition afforded an additional memory advantage, and whether this association was influenced by the magnitude of the LPP.

To summarize, the overarching goal of the present study was to examine a novel question: do changes in the LPP when participants are instructed to increase or decrease emotional responses predict memory for these stimuli one week later? We tested the following three hypotheses: First, consistent with previous research, LPP amplitudes will be larger in the increase versus decrease condition. Second, compared to a baseline viewing condition, directions to increase emotional responses to unpleasant stimuli will facilitate recognition memory for emotional stimuli one week later, whereas directions to decrease emotional responses will disrupt memory recognition. Third, regardless of cognitive ER context, larger LPP amplitudes will be associated with greater memory recognition.

1.3 Method

1.3.1 Participants

Sixty-three participants (38 females) aged 18 to 46 (M = 20.90, SD = 5.16) from an introduction to psychology participant pool were recruited for this study and were screened via self-report for any pre-existing mental illness diagnoses and psychotropic medications. Of the 63 participants, 62 returned to complete the memory recognition task; however ten participants were excluded due to excessive blinks and movement artifacts. Four additional participants were excluded due to a computer malfunction during the memory recognition task, for a total of 49

(31 females) participants. Race and ethnicity were as follows: 13 Caucasian, 3 African American, 9 Hispanic, 15 Asian, and 9 of more than one race.

1.3.2 Stimulus Materials

Stimuli were 75 unpleasant pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). These stimuli along with 75 distracters (from the IAPS) were included in the memory recognition task (Appendix A). The valence and arousal ratings for stimuli from the IAPS were as follows: ER task (valence: $M = 3.22$, $SD = 0.85$; arousal: $M = 5.25$, $SD = 0.89$); memory distactors (valence: $M = 3.54$, $SD = 1.01$; arousal: $M = 5.18$, $SD = 1.06$). Ratings for valence and arousal from the IAPS range from 1 to 9, with lower valence ratings indicating more unpleasant and lower arousal ratings indicating less arousing.

The cognitive ER task was programmed with Presentation software (Version 2, Neurobehavioral Systems, Inc.; Albany, CA) and presented on an IBM computer and 17" monitor. The memory recognition task was programmed using E-Prime (Version 1.2, Psychological Software). For both tasks, participants were seated 65cm from the computer screen.

PASW version 18 was used to perform all statistical analyses using general linear model (repeated measures ANOVA), paired t-test, and regression software. Greenhouse-Geisser corrections were as applied when assumptions of sphericity were violated. All post-hoc analyses reported were planned contrasts with the exception of one post-hoc analysis where Bonferroni corrections were used as noted.

1.3.3 Procedures and Measures

Informed consent was obtained from all participants prior to administration of demographic questionnaires. The first visit to the laboratory was approximately two hours and the second visit was approximately 30 minutes.

1.3.4 Emotion Regulation

Following the completion of the questionnaires and EEG set up, the ER task was administered. Participants were asked to either increase by amplifying the emotion they felt when viewing the stimulus, decrease by dampening down the emotion they felt or to just view the stimuli. EEG was recorded throughout this task (Appendix B).

The 75 unpleasant stimuli in the ER task were randomly distributed equally among the increase, view and decrease conditions. Stimuli and the order of conditions were randomly chosen for each participant. Stimuli were presented in blocks of five, for a total of five blocks per condition. A block began with the presentation of the instruction to either increase, view or decrease for 4500ms, followed by a black screen for 500ms. Stimuli were then presented for 2000ms in blocks of five with an inter-stimulus interval of 500ms. After all five stimuli were presented for a given block a black screen was presented for 1500ms prior to receiving the next instruction to increase, view or decrease. After all 75 stimuli were presented, the participant was instructed to take a short break and then to continue to the second presentation, where the same stimuli were presented in the same conditions as the first presentation. Though stimuli were presented in the same conditions, the order of those conditions was not the same as the first presentation.

1.3.5 Memory Recognition

One week after the cognitive ER task, participants returned to the laboratory to complete the memory recognition task. The 75 pictures from the cognitive ER task were randomly presented along with 75 distracter stimuli from the IAPS. Participants were asked to respond on a 4-choice response scale which varied whether participants were sure or unsure of their response (sure versus think) and whether the stimulus was previously viewed or not (old versus new): sure old, think old, sure new, think new (Appendix C). Each stimulus was presented for 2000ms, followed by a maximum of 5000ms for memory response prompt. Responses were recorded using the number pad on a keyboard and were reduced for analyses into correct (1 and 2 for old stimuli, 3 and 4 for new stimuli) and incorrect (3 and 4 for old stimuli, 1 and 2 for new stimuli).

1.3.6 *EEG Recording*

Electroencephalography (EEG) was continuously recorded with 64 Ag/AgCl electrodes sampled at 512Hz using an Actiview Two System (Biosemi, Amsterdam, Netherlands) during the ER task. The Biosemi system forms the ground electrode using Common Mode Sense active electrode and Driven Right Leg passive electrode during EEG acquisition. Electroocularagrams (EOG) were recorded from four electrodes placed 1cm to the right of the right eye and 1cm to the left of the left eye (HEOG) and 1cm above and below the left eye (VEOG).

1.3.7 EEG Data Reduction

Brain Vision Analyzer (Version 2.2, GmbH, Munich, Germany) was used to generate ERPs. Data were filtered offline with a high pass filter of .01 Hz and a low pass filter of 30 Hz and referenced offline to the average of the left and right mastoids. Eye movements and blinks were corrected using the method developed by Gratton, Coles, & Donchin (1983). The LPP (mean amplitude) was segmented between 0 and 1200ms with a baseline correction of 200ms prior to stimulus onset. The LPP was divided into two time windows based on visual inspection and those used in previous studies (e.g., Krompinger et al., 2008) showing the timing of early versus later epochs of the LPP: early (300-700ms) and late (700-1200ms). LPP amplitudes were averaged across electrodes P4, P6, P3, P5, PO3, PO4, Pz, and POz for each of the cognitive ER conditions (increase, view, and decrease) where the LPP was observed to be maximal. Artifacts were identified using the following criteria: data with voltage steps exceeding 75µV, maximum changes exceeding 105µV (within a given segment), maximum and minimum differences within a segment ±120µV, and activity lower than .2µV per 100ms and were excluded from analyses.

1.4 Results

1.4.1 Descriptive Statistics

Descriptive statistics (means and standard deviations) of the LPP in each condition are displayed in Table 1.1, as well as Figure 1.1.

1.4.2 Effects of Region, Window, and Presentation on the LPP

A 3(Region: right, left, and midline) X 2(Window: early and late) X 2(Presentation: first and second) repeated measures ANOVA was first conducted to determine if the LPP differed by window and region, and whether the LPP differed between the two presentations. As expected, there were no differences between presentations, $F(1,48) = 0.98$, $p = .32$, $\eta^2 = .02$. LPP amplitudes did differ by Window $F(1,48) = 65.81$, $p < .001$, $\eta^2 = .57$: LPP amplitudes were larger in the early versus late window $p < .001$. LPP amplitudes also differed by Region, $F(1.72, 82.90) = 42.90$, $p < .001$, $\eta^2 = .47$: LPP amplitudes were larger in the right and left compared to the midline region (both *p's* < .001). There were no differences between the right and left regions $p = .14$ and no significant interaction effects. Based on these results, subsequent analyses will average the LPP across left and right regions and first and second presentations.

1.4.3 Effects of Condition on the LPP

The first prediction was that LPP amplitudes in the increase condition would be larger than those in the decrease or view conditions. A 3(Condition: Increase, View, and Decrease) X 2(Window: Early and Late) repeated measures ANOVA confirmed the predicted main effect of Condition, $F(2,96) = 3.15$, $p = .04$, $\eta^2 = .06$, such that the increase condition generated larger LPP amplitudes than the view $p = .03$ and decrease $p = .04$ conditions (Figure 1.2). There were no differences in LPP amplitudes between the view and decrease conditions. LPP amplitudes were larger in the early $F(1,48) = 80.80$, $p < .001$, $\eta^2 = .62$, versus late window, $p < .001$. There was no significant interaction between condition and window.

1.4.4 Memory

A repeated measures ANOVA was conducted with memory scores as the dependent variable to test the hypothesis that pictures viewed in the increase condition would be remembered better than those viewed in the decrease condition. As predicted, the main effect of Condition, $F(1.77, 85.07) = 7.83$, $p = .001$, $\eta^2 = .14$, showed that memory was best for stimuli presented in the increase $p < .001$ and view conditions $p = .02$, as compared to the decrease condition (Figure 1.3). There was no significant difference between the increase and view conditions, $p = .24$.

1.4.5 LPP and Memory

Correlations were conducted to determine whether the LPP in a given condition (e.g., increase) was related to memory in that same condition. We predicted that larger LPP amplitudes across conditions would be associated with superior memory.

1.4.5.1 Increase. Larger LPP amplitudes in the early window were associated (at the level of a trend) with greater memory recognition for stimuli in the increase condition $r(47) = .26$, $p =$

.06. There was no significant associations, however, between LPP amplitudes in the late window and memory performance in the increase condition $r(47) = .20$, $p = .15$ (Figure 1.4).

1.4.5.2 View. There were no significant correlations between LPP amplitudes in the view condition and memory performance for stimuli shown in the view condition, both *p's* > .20.

1.4.5.3 Decrease. In both the early, $r(47) = .31$, $p = .02$, and late windows, $r(47) = .30$, $p = .03$, larger LPP amplitudes were associated with superior memory performance for stimuli in the decrease condition (Figure 1.5).

In sum, larger LPP amplitudes were associated with better memory performance in the increase (at the level of a trend) and decrease conditions. There were no significant associations between the LPP in the view condition and memory performance.

1.5 Discussion

Results of the present study documented that increasing emotional responses and "simply viewing" emotional pictures, relative to decreasing emotional responses, results in superior memory for the picture stimuli one week later. However, these differences between conditions may also relate to individual differences in the degree to which participants attend to and process emotional pictures during encoding, as measured by the LPP. That is, better memory performance in the increase (at the level of a trend) and decrease conditions were associated with larger LPP amplitudes. Inconsistencies in previous research on the effects of cognitive ER on memory may be due in part to the fact that these studies did not account for how cognitive ER strategies changed underlying emotional processing during encoding. By examining cognitive ER and long-term memory, the present study also adds to the small body of research showing links between the LPP and short-term emotional memory (e.g., Langeslag & van Strien, 2009).

Taken together, results of the present study contribute to our understanding of the processes through which cognitive ER influences memory.

In the present study, the effects of condition on the LPP contrast with previous studies, which most consistently showed that the LPP was sensitive to ER instructions to decrease (but not increase) emotion – e.g., LPP amplitudes were reduced for decrease versus view conditions, but LPP amplitudes did not differ for the increase versus view condition (Moser et al., 2006). The present study's use of somewhat less arousing pictures from the IAPS (*M* arousal of 5.25 in the present study, 6.24 in Moser et al. (2006), and 6.03 in Hajcak & Nieuwenhuis (2006) may have reduced the potential for ceiling effects to occur, which would facilitate the detection of increase effects. Moreover, the present study, unlike others (e.g., Moser et al., 2006), did not offer incentives for participants to perform the cognitive ER tasks; such incentives could have influenced how participants went about increasing and decreasing their responses. Conversely, the lack of a decrease effect in the present study may reflect a floor effect related to the reduced arousal properties of the unpleasant stimuli (cf. Ochsner, Bunge, Gross, & Gabrieli, 2002). This would make it relatively difficult to further reduce subjective emotional experiences. Future research should systematically vary duration, valence, and arousal properties of stimuli to test the boundary conditions under which increasing and decreasing are optimized (Krompinger et al., 2008).

As predicted, memory performance was greater in the increase compared to decrease condition; however, an equal memory advantage emerged for the increase and view conditions. Thus, although the LPP was greater in the increase versus view condition, the two conditions did not differ in memory performance. This suggests that the comparable memory effects for the two conditions may derive from similarities in processes not directly related to the LPP, such as peripheral physiological arousal (e.g. Parent, Varnhagen, & Gold, 1999).

The behavioral memory decrements for the decrease condition parallel previous research showing that expressive suppression results in decreased emotional memory (Bonanno et al., 2004; Richards & Gross, 2000). However, the mechanisms underlying effects of cognitive ER versus expressive regulation on memory are likely distinct. For example, previous studies hypothesize that the effort needed for expressive suppression (Richards & Gross, 1999) and enhancement (Bonanno et al., 2004) deplete resources available for memory encoding, resulting in reduced (short-term) memory performance. Because the current study used internal strategies, resource depletion may have been minimized. LPP findings clarify that the increase versus decrease condition likely led to better memory due to increased attentional processing and arousal (i.e., larger LPP amplitudes). Thus, the current study highlights the central role of emotional processing in emotional memory, and hints at the possibility that increased arousal might also be linked to the effects on memory. Future research should attempt to tease apart the effects of emotional processing and arousal on memory (Bradley et al., 1992), as well as assess other cognitive strategies that may influence emotional memory such as attentional deployment.

As predicted, larger LPP amplitudes in multiple ER conditions were associated with superior memory. This effect emerged for both the increase (at the level of a trend) and decrease conditions. Although behavioral results of the present study demonstrate that cognitive ER strategies do in fact influence long-term memory (e.g., greater memory in the increase and view versus decrease condition), neural measures of cognitive ER may be capturing a distinct cognitive process. For example, a recent study showed that LPP amplitudes to stimuli that were reappraised versus "just viewed" generated larger LPP amplitudes 30 minutes later than those there were not reappraised (MacNamra et al., 2011). These results suggest that cognitive ER strategies have an enduring impact on cognition – in this case, how emotional stimuli are processed and interpreted. This is consistent with the present study's finding that LPP amplitudes in the ER conditions (increase and decrease), but not the baseline viewing condition influenced memory.

The present study adds to the literature on emotional memory by focusing on links between ER and long-term memory and using neurophysiological measures that tracks shifts in attention to emotional information. Although previous studies have examined links between expressive regulation and short-term emotional memory (e.g., Bonanno et al., 2004) and links between the LPP and short-term emotional memory (Langeslag & van Strien, 2009), these studies have not examined long-term memory in relation to cognitive ER strategies that shift how emotional stimuli are processed, a key factor in memory encoding (Dolcos et al., 2006). The present study begins to address these important gaps in the literature. Long-term memory is of particular interest in relation to cognitive ER, given the role of cognitive ER in long-term cognitive and emotional adjustment (Yasik, Saigh, Oberfield, & Halamandaris, 2007). Future research, should simultaneously examine both short and long-term memory in relation to cognitive ER, and explore whether effects differ between recall and recognition memory, and across different modalities such as memory for words versus imagery. Additionally, future studies should examine the LPP for remembered versus misremembered emotional information. Other memory research has also utilized a "difference of memory" (Dm) measure to account for the degree of difference in ERPs for remembered versus misremembered information (Friedman & Johnson, 2000). Due to low trial counts for misremembered stimuli, we were not able to generate an LPP to perform these analyses.

The present study's methodological design differed in some key ways from previous studies, and some limitations should be noted when interpreting results. The present study did not compare memory for unpleasant emotional material with memory for pleasant and neutral material. The use of only unpleasant stimuli limited our ability to examine whether effects were truly unique for these types of stimuli, in contrast to positive and neutral stimuli. However, within the three conditions used, the view condition can be considered a baseline condition to which the increase and decrease conditions can be compared. Additionally, a growing body of literature has suggested that younger adults have a distinct preference for remembering unpleasant stimuli (Mather & Carstensen, 2005). The present study capitalized on this preferential attention by using only unpleasant pictures. Furthermore, this study used a blocked design (five stimuli per block with five blocks per condition randomly presented) in which one condition was given at a time, rather than randomly presenting conditions. We chose this design because repeatedly and rapidly alternating strategies used seemed less ecologically valid; however, the relatively short inter-stimulus interval between pictures within a block could have made it difficult for participants to up- or down-regulate emotional responses. Although fatigue or reduced reactivity could be potential explanations for the lack of a decrease effect, they are unlikely as there were no differences over time between presentation one and presentation two.

In summary, the present study provided evidence that cognitive ER strategies that serve to increase compared to decrease emotional responses bolster long-term emotional memory, but also clarified that this may depend on individual differences in the degree to which these strategies serve to increase attentional processing and arousal during encoding. In addition, the present study is among the first to examine the association between the LPP and long-term memory. Findings complement previous studies which instead examined changes in short-term memory performance related to the regulation of facial affect. Taken together, results highlight the importance of considering the cognitive ER context of memory encoding and consolidation. Findings highlight that cognitive ER not only has an impact on emotional well-being, but also has a lasting impact on core cognitive processes like memory.

Table 1.1 *Descriptive Statistics for the LPP: Increase, View, and Decrease conditions.*

Condition		Males (*n* = 18)	Females (*n* =31)	Total (N = 49)
Increase				
	Early	6.98(4.73)	9.56(5.31)	8.61(5.21)
	Late	4.77(3.49)	5.74(4.93)	5.38(4.44)
View				
	Early	5.79(3.78)	8.61(4.86)	7.57(4.66)
	Late	3.76(2.83)	5.01(4.18)	4.55(3.76)
Decrease				
	Early	5.79(4.62)	8.65(4.98)	7.60(5.00)
	Late	3.40(3.88)	5.27(4.18)	4.58(4.13)

Note. Table presents means and standard deviations (in parentheses). Units are in μV.

Figure 1.1 Visual depictions of descriptive statistics (mean LPP amplitudes) for each condition.

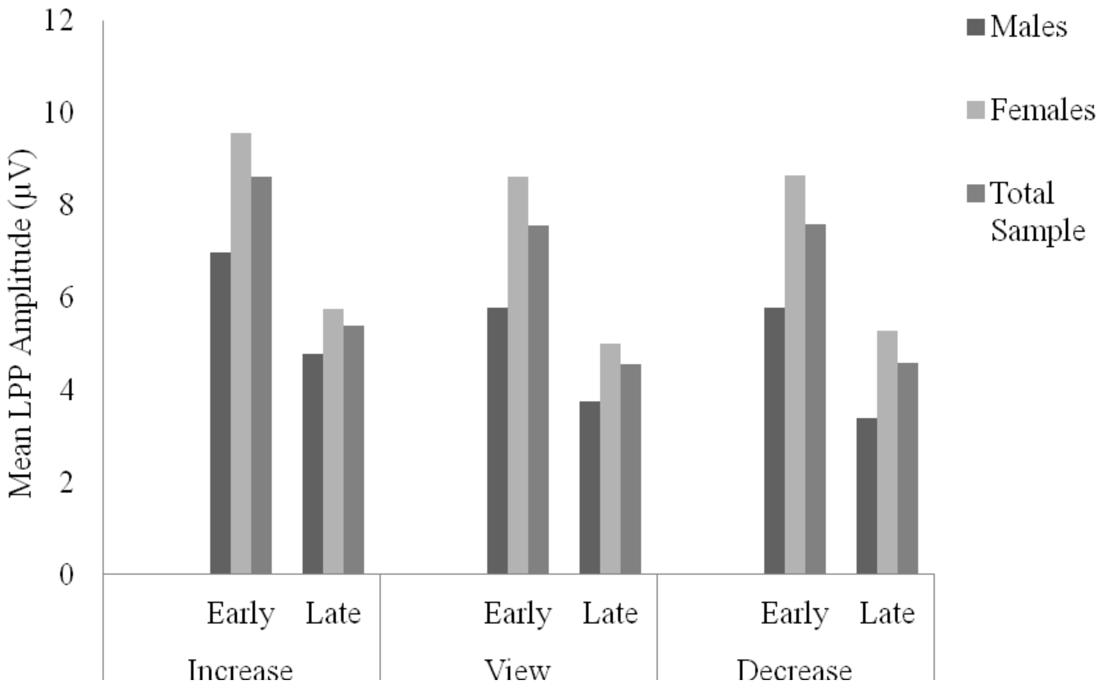


Figure 1.2 The LPP for the increase, view, and decrease conditions. The increase condition produced greater LPP amplitudes compared to the view and decrease conditions. There were no differences in the LPP between the view and decrease conditions.

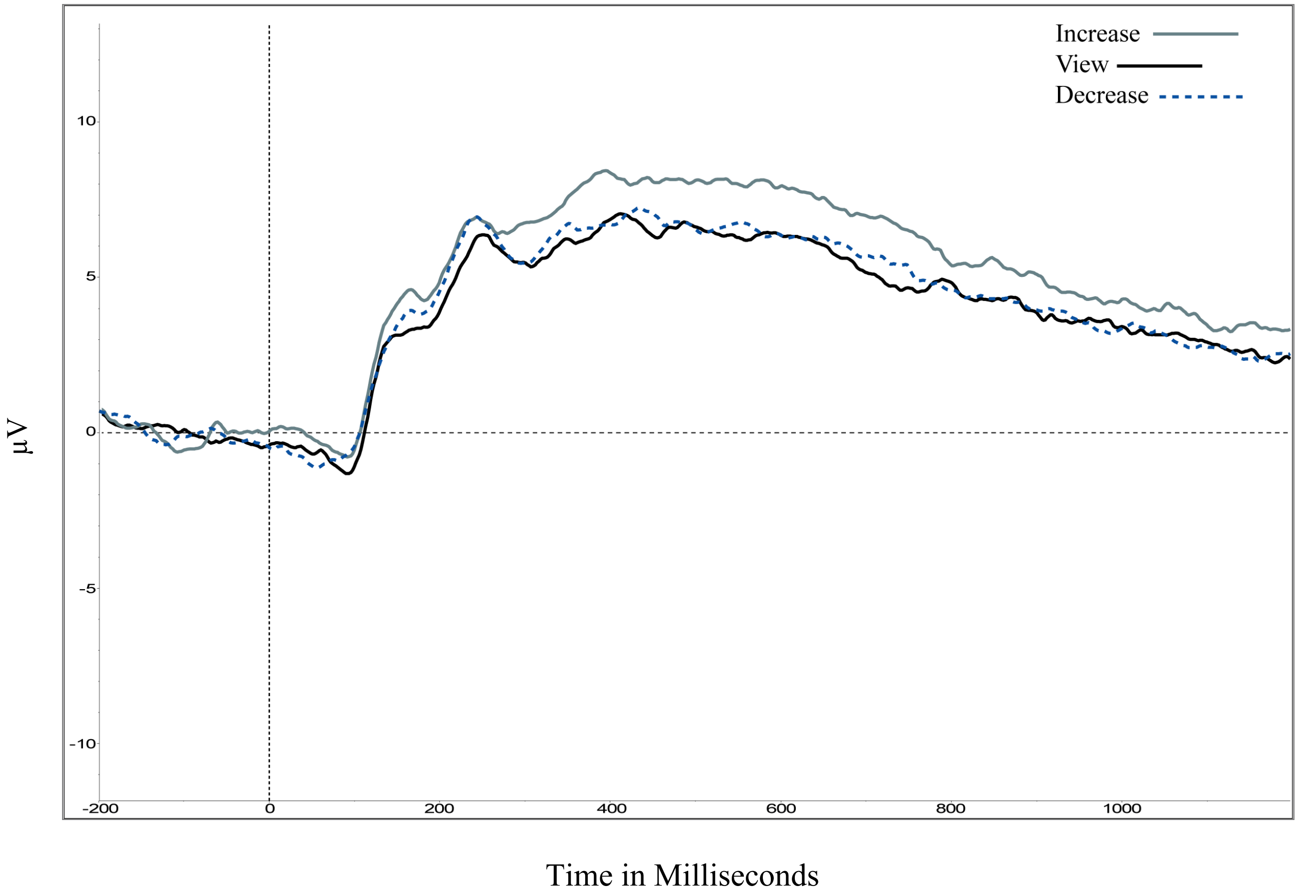


Figure 1.3 Memory performance was best for stimuli in the increase versus decrease condition. Stimuli were also remembered more in the view condition relative to the decrease condition. No differences occurred between the increase and view conditions.

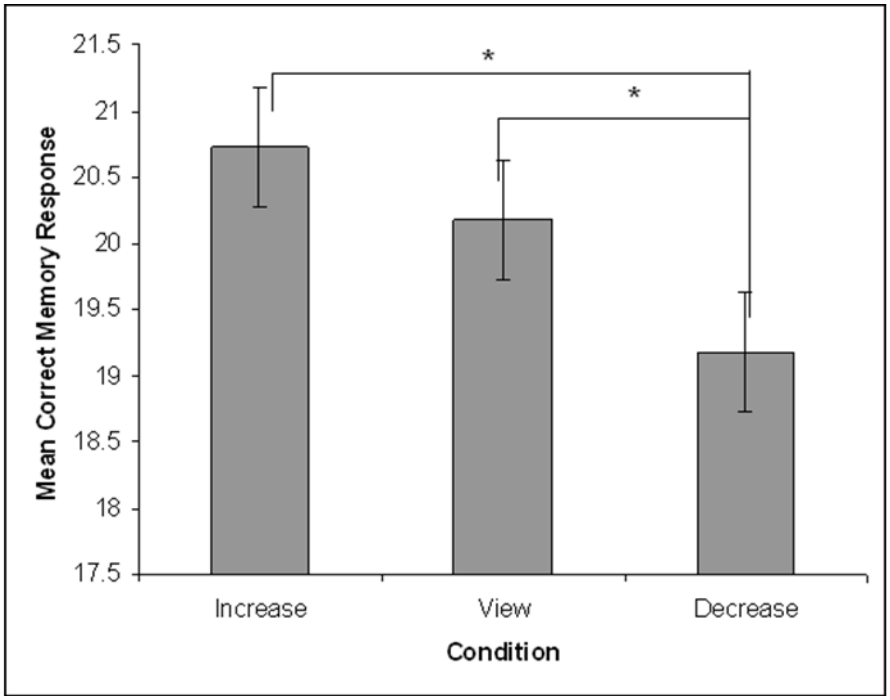


Figure 1.4 Larger LPP amplitudes in the increase condition were associated with better memory for stimuli shown in the increase condition (early window).

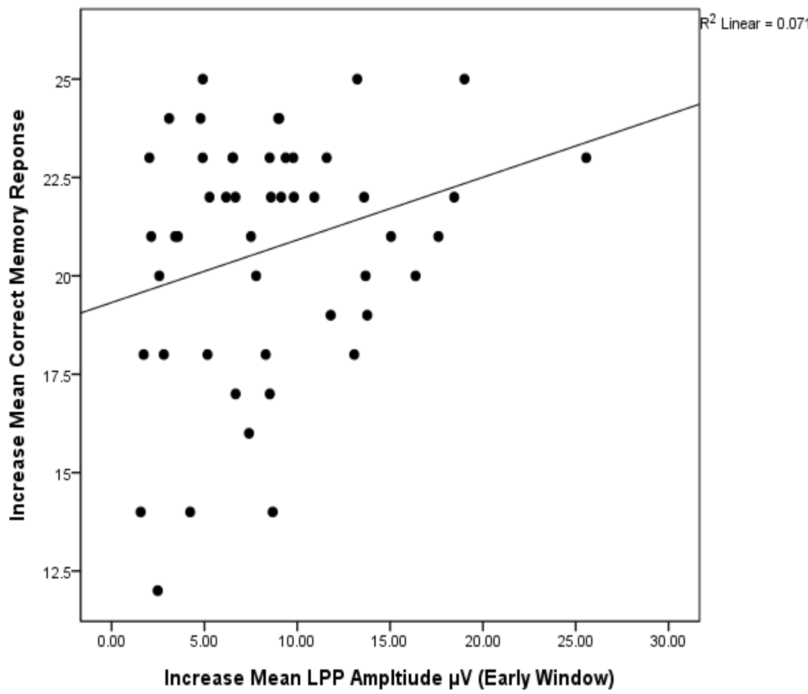
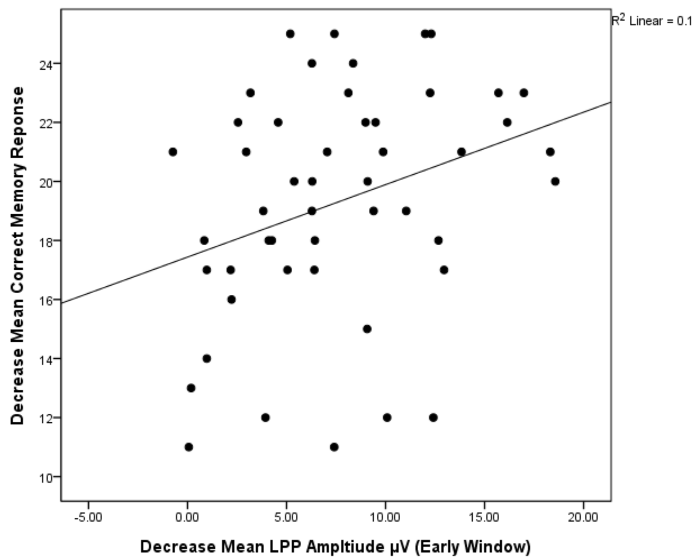
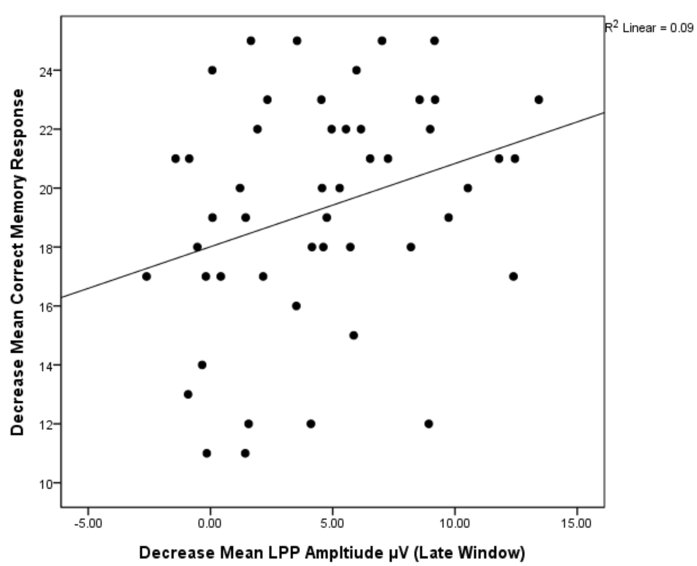


Figure 1.5 Larger LPP amplitudes in the decrease condition were associated with better memory performance for stimuli shown in the decrease condition in both the early and late windows.





CHAPTER TWO

A Neurophysiological Measure of Emotional Picture Processing in Older and Younger Adults

2.1 Abstract

Recent aging theories posit that younger and older adults differ in how they attend to emotional stimuli; however when the task involves automatic (bottom-up) processing, age differences should be less apparent. However, studies have produced mixed results for support of these hypotheses. The goal of the present study was to use the late positive potential (LPP), to evaluate the hypothesis that younger and older adults will not differ in LPP amplitudes to pleasant and unpleasant stimuli. A secondary goal was to evaluate whether these two age groups differed within specific picture categories of pleasant and unpleasant stimuli. In the present study, younger (n = 36) and older (n = 25) adults passively viewed pleasant, unpleasant, and neutral stimuli, while electroencephalography was recorded. Effects of emotional picture type on the LPP were consistent with previous research: LPP amplitudes were larger for pleasant and unpleasant versus neutral stimuli; however this effect was sustained for a longer period of time in older adults. No age differences emerged in the LPP among the different stimulus categories. Results suggest that younger and older adults may not differ in how they attend to highly emotional stimuli, but may differ in the degree to which they sustain emotional processing.

2.2 Introduction

Over the past decade a small, but growing body of literature has examined how younger and older adults differ in how they experience and process emotional information. Much of this research has documented that older adults focus more on positive emotional information and younger adults negative emotional information, known as the *positivity effect* (Carstensen & Mikels, 2005; Charles et al., 2003; Mather & Carstensen, 2005; Scheibe & Carstensen, 2010). Socioemotional Selectivity Theory (SST; Carstensen et al., 1999), one of the main theories of aging and emotion, suggests that these differences in attention to emotion are the result the amount of time we have left in life. That is, as we grow older and our remaining years declines we are increasingly motivated to focus more on positive emotions and events as compared to negative (Carstensen et al., 1999). In fact, on measures of self-report, older adults report feeling less negative emotion (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000). This theory predicts that older adults differ from younger adults in both their attention to emotion and emotional memory as a function of these motivational factors. As a result of these differences in attention to emotion between younger and older adults, they tend to show differences in memory performance, such that older adults remember more positive stimuli and younger adults more negative stimuli (Charles et al., 2003; Mather & Carstensen, 2005; Schiebe & Carstensen, 2010). Overall, the positivity effect not only refers to differences in memory performance between younger and older adults, but also observable differences in attention to positive and negative stimuli (Carstensen & Mikels, 2005; Charles et al., 2003; Schiebe & Carstensen, 2010). Taken together, SST provides a framework to suggest that these differences in attention to emotion (the positivity effect) are possibly a result of motivational changes that occur with age, particularly the amount of time left in life (Carstensen et al., 1999).

Behavioral studies provide support for the key hypotheses of SST and its primary tenet, the positivity effect. For example, older adults show a preference in gaze direction towards happy versus angry faces (Isaacowitz, Wadlinger, Goren, & Wilson, 2006) and are slower to react to the location of a dot following negative, but not positive facial stimuli. In terms of memory performance studies have demonstrated differences in memory performance in line with the positivity effect. When older, middle aged, and younger adults passively view pleasant, unpleasant, and neutral stimuli, the number of negative images recalled and recognized decreases with age (Charles et al., 2003). In addition, younger adults also tend to recall autobiographical events more negatively and older adults more positively (Kennedy, Mather, & Carstensen, 2004). Taken together, these studies suggest that older adults have a preference for pleasant stimuli, whereas younger adults show a preference towards unpleasant stimuli, and this can be measured both in terms of attention and memory.

Though SST and the positivity effect propose shifts in attention towards positive and away from negative emotion with age, different types of tasks may be more sensitive to showing these age-related differences. For example, when a task involves bottom-up processing of emotional information there should be little to no difference in activation in the amygdala with age (Mather & Carstensen, 2003). In top-down processing related tasks (e.g. cognitive ER), which require cognitive control and prefrontal regions, age-related motivational goals proposed by SST should facilitate attention towards positive stimuli and reduced attention to negative stimuli in older adults (Mather, 2006; Mather & Carstensen, 2005). A number of studies have using functional magnetic resonance imaging (fMRI) support hypotheses of greater attention to pleasant stimuli, but are inconsistent with predictions of the bottom-up processing model proposed by Mather and Carstensen (2005). For example when older adults perform a bottom-up task, passively viewing pleasant, unpleasant and neutral images, the amygdala shows greater activation for pleasant stimuli and no difference in amygdala activation for unpleasant stimuli (Mather et al., 2004). Other studies have also found that when asked to discriminate between different types of emotional faces, young and older adults differ in the brain regions that are activated, such that (Gunning-Dixon et al., 2003), younger adults activate the amygdala and other temporal lobe regions and older adults tend to show greater activation in left frontal lobe regions (Gunning-Dixon et al., 2003). Tasks involving processing of threatening and fearful faces also show similar patterns of BOLD activation where older adults show reduced activation in the amygdala and increased activation in prefrontal regions (Tesitore et al., 2005). In sum these three neuroimaging studies find results inconsistent with the bottom-up model proposed by Mather and Carstensen (2005), in that younger and older adults differ in patterns of activation to emotional stimuli. In other words, motivational goals proposed by SST should have little to no influence in bottom-up tasks and show no age-related differences in amygdala activation.

Similar to neuroimaging findings, research using scalp-recorded event-related potentials (ERPs) also provides mixed support for the bottom-up model. ERPs track changes in attention with millisecond precision, whereas the BOLD response, underlying fMRI, requires a number of seconds. As ERPs have greater temporal sensitivity than neuroimaging measures, they have the ability to track changes in attention that may occur automatically, particularly if they occur within the first few hundred milliseconds of processing.

One ERP that is particularly well-suited to track changes in attention to emotional stimuli is the late positive potential (LPP). The LPP is a broadly distributed positive going wave that emerges around 200 to 300 ms in posterior scalp regions (Foti & Hajcak, 2008; Hajcak, Dunning, & Foti, 2007; Keil et al., 2002; Schupp et al., 2000) and is larger to pleasant and unpleasant, as compared to neutral stimuli (Cuthbert et al., 2000; Hajcak & Nieuwenhuis, 2006; Schupp et al., 2000; Schupp et al., 2004). The LPP is most commonly studied using IAPS stimuli, but has also been known to be sensitive to emotional words and faces, where amplitudes are again larger to emotional versus neutral stimuli (Cuthbert et al., 2000; Herbert, Junghofer, & Kissler, 2008; Schupp et al., 2000). The LPP is also correlated with subjective arousal, where larger LPP amplitudes are associated with greater arousal ratings (Hajcak & Nieuwenhuis, 2006). As the LPP can track changes in attention to emotion over the course of stimulus presentation, it affords the opportunity to examine multiple stages of, as well as sustained emotional processing. Therefore, as the LPP has excellent temporal resolution it has the ability to clarify how hypotheses of SST and the positivity effect may function at a very basic neural level, as well as whether younger and older adults differ across multiple time windows or at specific time points in the processing of emotional stimuli. To date the vast majority of studies examining the LPP have done so within college aged samples; however a few studies have examined the LPP in older adults.

Two of the three studies that have been conducted using older adults and the LPP have done so within the context of a passive viewing paradigm mixed with a valence categorization task (Kisley et al., 2007; Wood & Kisley, 2006). One study found that older adults did not show larger LPP amplitudes to pleasant stimuli, but did evidence reduced LPP amplitudes to unpleasant stimuli with increasing age (Kisley et al., 2007). Wood and Kisley (2006), however, used the same task as Kisley, Wood and Burrows (2007) and found that older adults had reduced LPP amplitudes to pleasant and unpleasant stimuli, but no difference between the two types of stimuli. In contrast, Langeslag and van Strien (2009) documented that older adults show larger LPP amplitudes to pleasant stimuli and younger adults to unpleasant stimuli within a basic passive viewing paradigm. Additionally, larger LPP amplitudes (across all stimuli) for older adults only were associated with better memory performance (Langeslag & van Strien, 2009). Although these findings provide support for the hypotheses of SST and the positivity effect, with some showing reduced LPP amplitudes to unpleasant stimuli (Kisley et al., 2007) and others increased LPP amplitudes to pleasant stimuli (Langeslag & van Strien, 2009), they fail to find consistent patterns in attention to emotion that occur with age. Moreover, only the findings of Wood and Kisley (2006) support the bottom-up approach proposed in the aging literature.

Thus, taking the extant research using neural measures, fMRI studies document patterns of activation consistent with hypotheses of the positivity effect, but are inconsistent with the bottom-up model (Mather & Carstensen, 2004) - i.e., greater amygdala activation for pleasant stimuli and no change in amygdala activation to unpleasant stimuli in older adults -, whereas ERP studies, using the LPP, provide conflicting support for both the positivity effect and the bottom-up model. Results of the three LPP passive viewing studies may be different because the task contexts differed. That is, when participants were asked to categorize stimuli by their valence, it is possible that the stimuli were being viewed in relation to how others may rate the stimuli (i.e. what is socially acceptable). For example, some IAPS stimuli (e.g. mutilation images) would not be the type of stimulus that one would actively attend to if they were among a group of friends. In this context, they may instead look away or withdraw attention as they may behave differently within the context of what may be socially acceptable. Thus, this type of task could result in reduced LPP amplitudes to unpleasant stimuli as the categorization of stimuli may be viewed within social norms. In the purely passive viewing paradigm (Langeslag & van Strien, 2009), though results support an increase in attention to pleasant stimuli (positivity effect) in older adults, finding differences in a task that could be deemed bottom-up is contradictory to the bottom-up model. The present study used a passive viewing task without valence categorization in order to assess whether this type of bottom-up task can provide support for Mather and Carstensen's model of how SST maps onto more automatic tasks.

In sum, there is mixed evidence for whether SST and the positivity effect can be seen using the LPP and the context in which the LPP may capture these differences in emotional processing between younger and older adults. Furthermore, many of these studies do not use some of the more arousing stimuli within the IAPS, such as the erotica images (Langeslag & van Strien, 2009, 2010) and only present stimuli for 1,000 ms (Kisley et al., 2007; Langeslag & van Strien, 2009, 2010; Wood & Kisley, 2006). In order to fully understand the nature of SST and the positivity effect using the LPP it is important to understand whether all types of pleasant and unpleasant stimuli, as well as extended processing beyond 1000 ms, to examine whether support for these theories of aging and emotion can be found in the LPP.

Interestingly, recent work suggests that the LPP may be differentially sensitive to certain types of emotional content (Weinberg & Hajcak, 2010). Weinberg and Hajcak (2010) showed that LPP amplitudes were largest to mutilation and erotic stimuli from the International Affective Picture System (IAPS; Lang et al., 2008) followed by those indicating threat and affiliative stimuli. A difference in LPP amplitudes between categories of emotional stimuli has been documented among younger adults (Weinberg & Hajcak, 2010), but questions remain as to whether younger and older adults differ in how they attend to specific categories of emotional stimuli. Some research suggests that the positivity effect may emerge most clearly among low arousing words (Kensinger, 2008), however, can support for SST and the positivity effect be found within highly arousing stimuli such as the mutilation, threat, erotic, and affiliative images?

Taken together, the neuroscience literature examining emotional processing between older and younger adults is inconclusive. Research using the LPP, a highly sensitive measure of changes in attention and arousal to emotion has excellent temporal resolution, but provides mixed support for attention-related hypotheses and the positivity effect. Methodological issues include the type of task that has been used in previous studies (e.g. passive viewing versus passive viewing with valance categorization), the relatively short duration stimuli have been presented for (1,000 ms), and the types of stimuli used (mainly those that are not highly arousing among pleasant stimuli). The present study addresses these issues by using a passive viewing only task, presenting stimuli for 2,000 ms and using highly arousing pleasant and unpleasant stimuli. Based on previous research using the LPP there are three possibilities under which the positivity effect and SST may emerge: a) older adults may show larger LPP amplitudes to pleasant stimuli (e.g., Langeslag & van Strien, 2009) b) older adults may show reduced LPP amplitudes to unpleasant stimuli (e.g. Kisley et al., 2007) c) older and younger adults will not differ in LPP amplitudes between pleasant and unpleasant stimuli (Wood & Kisley, 2006). As some studies document reduced LPP amplitudes to unpleasant stimuli and other increased LPP amplitudes to pleasant stimuli, it remains to be seen whether a bottom-up passive viewing paradigm consistently shows evidence for the positivity effect or whether no age differences occur in this type of paradigm.

The primary purpose of the present study is to determine if younger and older adults do not differ of affective processing of pleasant and unpleasant stimuli measured via the LPP in a passive viewing task. Affective processing within this passive viewing paradigm is measured via the LPP over 2000 ms (divided into three time windows) in which pleasant, unpleasant, and neutral stimuli are presented. This is an important methodological improvement from previous passive viewing and aging LPP studies which only present stimuli for 1000 ms. As previous eye tracking research has suggested that older adults require additional time to locate arousing areas of an emotional stimuli (Isaacowitz et al., 2009), it is important to examine an extended period of processing, where older and younger adults may differ (i.e. beyond 1000 ms). Based on these previous studies we expect that younger and older adults may not differ in initial processing in the early window (e.g. around 500 ms), but may differ in later portions of the LPP, when cognitive control processes may begin to come online.

A secondary goal of the present study is to determine whether younger and older adults may show differing patterns of attention to emotion by picture content. The present study utilized the four categories that have been shown to produce the largest LPP amplitudes (mutilation, threat, erotic, and affiliative; Weinberg & Hajcak, 2010). As SST posits that older adults focus more on positive versus negative emotion because of less time left in life, we also included an additional category, mortality, to fully evaluate whether younger and older adults show evidence of SST and the positivity effect within distinct categories of emotional stimuli. Thus, we will also explore differences in LPP amplitudes between these two age groups in relation to other stimulus categories. Finally, we will explore associations between LPP amplitudes to pleasant, unpleasant and neutral stimuli and self-report measures of ER and well-being. We predict that larger LPP amplitudes to pleasant stimuli and reduced LPP amplitudes to unpleasant stimuli should be associated with greater well-being and higher reappraisal scores.

2.3 Method

2.3.1 Participants

The present study includes two age groups: 49 younger adults (aged 18 to 25: $M = 20.27$, $SD = 2.26$; 19 females) and 28 older adults (aged 65 and over: $M = 72.44$, $SD = 6.02$; 15

females). Younger adults were recruited from an introduction to psychology subject pool at Hunter College, whereas older adults were recruited using flyers and advertisements from the five boroughs of New York City. Older adults were screened for cognitive deficits prior to participation, using the Mini Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975). All older adults that were screened achieved a score of 24 or greater on the MMSE. Of the participants recruited for the study, nine younger adults were excluded due to excessive artifacts and four due to poor mastoid quality. Two older adults were excluded due to excessive artifacts and one due to poor mastoid quality. Thus, the final sample included 36 younger and 25 older adults. Race and ethnicity were as follows: 14 younger, 20 older Caucasian; five younger, five older African American; two younger, zero older Native Hawaiian or Pacific Islander; eight younger, zero older Asian; and two younger, zero older of more than one race.

2.3.2 Stimulus Materials

The passive viewing task consisted of 300 (see Appendix D for stimuli numbers) pleasant, unpleasant, and neutral stimuli from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). Stimuli were analyzed according to their generic valence (pleasant, unpleasant, and neutral), as well as by specific subcategories within the pleasant and unpleasant stimuli. The following categories were used based on those of Weinberg and Hajcak (2010) with the exception of the mortality category which was added: Pleasant (erotic and affiliative), Unpleasant (mutilation and threat). Neutral stimuli consisted of household objects and people with neutral expressions. The valence and arousal ratings for stimuli from the IAPS were as follows: Unpleasant: threat (valence: $M = 2.87$, $SD = 0.63$; arousal: $M = 6.00$, $SD = 0.59$), other (valence: $M = 3.28$, $SD = 0.08$; arousal: $M = 5.49$, $SD = 0.37$), mortality (valence: $M = 2.65$, $SD = 0.74$; arousal: $M = 5.37$, $SD = 0.83$), mutilation (valence: $M = 2.05$, $SD = 0.53$;

arousal: *M* = 5.99, *SD* = 0.67); Pleasant: other (valence: *M* = 6.90, *SD* = 0.61; arousal: *M* = 4.17, *SD* = 0.45), affiliative (valence: *M* = 7.05, *SD* = 0.71; arousal: *M* = 4.54, *SD* = 0.60), erotic (valence: *M* = 6.39, *SD* = 0.55; arousal: *M* = 5.78, *SD* = 0.79); Neutral: (valence: *M* = 5.05, *SD* = 0.20; arousal: *M* = 3.25, *SD* = 0.67). Ratings for valence and arousal from the IAPS range from 1 to 9, with lower valence ratings indicating more unpleasant and lower arousal ratings indicating less arousing.

The passive viewing task was programmed using E-prime (Version 2; Psychological Software) and presented on a 17" monitor via a Dell Optiplex computer. During the task, participants were seat 65cm from the computer monitor.

All statistical analyses were conducted using SPSS version 19 version. General linear model (repeated measures ANOVA), paired t-test, and Pearson's correlation software were used for planned contrasts. For analyses that violated assumptions of sphericity, Greenhouse-Geiser corrections were used when necessary. Any additional analyses that were unplanned used Bonferroni corrections where noted.

2.3.2.1 Questionnaires. Following informed consent, participants completed questionnaires about demographic information, as well as adjustment and emotion regulation.

2.3.2.1.1 Adjustment. The Ryff Scales of Psychological Well-Being (Ryff & Keyes, 1995) was used to assess six facets of well-being: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance. The Ryff scales ask participants to rate statements from one (strongly agree) to six (strongly disagree).

2.3.2.1.2 Emotion Regulation. The Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) was administered to measure the degree to which subjects chronically use reappraisal and suppression as ER strategies.

2.3.3 Procedures and Measures

Informed consent was given by all participants prior to beginning the experiment. Younger adults completed all questionnaires and EEG related tasks within the same visit. Though older adults were given the option to complete their cognitive assessment (MMSE) and questionnaire/EEG task within the same day, most opted to complete the cognitive assessment and questionnaires in one visit and the EEG portion in a subsequent visit. If split into two visits the second visit for older adults occurred within 10 to 15 days of the assessment. After informed consent was obtained and a brief description of the experiments is given, participants were fitted with an EEG cap and electrodes. EEG was recorded during the passive viewing task. Completion of questionnaires, EEG set up, and the passive viewing task lasted approximately one hour and 30 minutes. Younger adults were compensated with course credit and older adults were compensated $50 for their time.

2.3.4 Passive Viewing

The passive viewing task consisted of 300 pleasant (affiliative and erotic), unpleasant (mortality, mutilation, and threat) and neutral (neutral people and scenes) stimuli. All stimuli were randomly presented for 2000ms with a 1500 to 2000ms jittered inter-stimulus interval.

2.3.5 Electroencephalography (EEG)

EEG was recorded during the passive viewing task using 64 Ag/AgCl active electrodes (BioSemi, Amsterdam, Netherlands) and ActiView software (Biosemi) sampled at 512Hz. Horizontal electro-oculargrams (HEOG) and vertical electro-oculargrams (VEOG) were recorded from four electrodes placed approximately 1cm to the left and right and above and below the eye. HEOG and VEOG were used offline to correct for eye movements and blinks. ERPs were generated using Brain Vision Analyzer (Version 2.0.1, GmbH, Munich, Germany). Ocular correction was performed using Independent Component Analysis (Jung et al., 1998). Data were baseline corrected 200ms prior to stimulus onset, LPP segmented between 0 to 2000ms, re-referenced offline to the average of the left and right mastoids and filtered between 0.01Hz and 30Hz. In addition to these filters, a 60Hz notch filter was used to eliminate any 60 cycle noise for all participants. Any data with the following criteria were identified as artifacts and removed before data analysis: Voltage steps greater than 75µV/ms, amplitudes differences between intervals greater than 105µV, amplitudes less than -120 and great than 120µV, and activity less than 0.2 µV. Prior to data analysis, EEG data was further inspected for additional artifacts (e.g. eye blinks and muscle movements).

The LPP was quantified as the mean activity among electrodes O1, O2, Oz, PO3, PO4, POz for each of the following time windows over the course of 2000ms that stimuli were presented: 250-850 ms early; 850-1350 ms middle, and 1350-2000 ms, late. Time windows were chosen in this fashion to equally divide into approximately 500 ms epochs and to avoid averaging across too much time and losing potential distinctions in processing either by valence, category, or age. In addition, the early time window was closely matched that of previous passive viewing LPP and aging studies (Wood & Kisley, 2006; Kisley et al., 2007; Langeslag & van Strien, 2009).

2.3.6 Data Analysis

SPSS (version 19) general linear model repeated measures ANOVA, paired t-tests, and independent t-test software were used to examine hypotheses. Greenhouse-Geisser corrections were applied when assumptions of sphericity were violated.

2.4 Results

2.4.1 Descriptive Statistics

Table 2.1 presents the means and standard deviations of the LPP for both younger and older adults, as well as the sample as a whole, for pleasant, unpleasant and neutral stimuli within each time window. Additionally, Figure 2.1 visually depicts the mean LPP amplitudes for both younger and older adults, as well as the sample as a whole, for pleasant, unpleasant and neutral stimuli within each time window.

2.4.2 Effects of Valence and Age[1]

To test the hypothesis that younger and older adults would not differ in LPP amplitudes between pleasant and unpleasant stimuli, three repeated measures ANOVAs were conducted: 3(Valence: pleasant, unpleasant, neutral) X 2(Age: young, old) for each time window (early, middle, and late). **However, we also predicted that differences between younger and older adults may emerge at later time windows, when control processes may begin to come online. Overall, there should be a main effect of valence such that pleasant and unpleasant stimuli generate larger LPP amplitudes relative to the neutral stimuli.**

2.4.2.1 Early Window. As predicted there was a main effect of valence $F(1.70, 100.36) = 14.34, p < .001, \eta^2 = .19$, where LPP amplitudes were larger to pleasant $t(60) = -3.70, p < .001$

[1] Difference scores (e.g. pleasant – neutral; unpleasant – neutral) make it possible to control for basic processing of neutral stimuli. When analyses were conducted using difference scores (e.g. unpleasant – neutral LPP) for each time window there were no significant effects in the early window. Within the middle $F(1,59) = 3.71, p = .05, \eta^2 = .05$ and late $F(1,59) = 3.10, p = .08, \eta^2 = .05$ windows older adults showed larger LPP amplitudes overall, as compared to younger adults. No other effects were significant.

and unpleasant $t(60) = -4.73$, $p < .001$, as compared to neutral stimuli (Figure 2.2). LPP amplitudes did not differ between pleasant and unpleasant stimuli. Though younger adults showed larger LPP amplitudes overall, $F(1,59) = 5.68$, $p = .02$, $\eta^2 = .08$, there were no significant interactions with Age.

2.4.2.2. Middle Window. In the middle window, LPP amplitudes were only larger $F(1.69, 100.24) = 4.15$, $p = .02$, $\eta^2 = .06$ to unpleasant $t(60) = -2.29$, $p = .02$ versus neutral stimuli. No other differences in LPP amplitudes occurred between pleasant and unpleasant or pleasant and neutral stimuli. Younger adults again had larger LPP amplitudes overall $F(1,59) = 5.35$, $p = .02$, $\eta^2 = .08$. Additionally, there was a significant interaction between Valence and Age $F(2,118) = 2.78$, $p = .06$, $\eta^2 = .04$ such that older adults showed the expected effect of emotion on the LPP such that pleasant $t(24) = -2.52$, $p = .01$ and unpleasant $t(24) = -2.83$, $p = .009$ stimuli generated larger LPP amplitudes versus the neutral stimuli (Figure 2.3). Additional post-hoc paired t-tests for younger adults showed no significant differences between LPP amplitudes among the three types of stimuli. Independent post-hoc t-tests only revealed that younger adults had larger LPP amplitudes to unpleasant and neutral stimuli as compared to older adults [both $ts(59) > 1.91$, $ps \leq .05$].

2.4.2.3. Late Window. Within the late window younger adults displayed larger LPP amplitudes relative to older adults $F(1,59) = 5.35$, $p = .02$, $\eta^2 = .08$. No other significant effects emerged within the late window.

2.4.3 Stimulus Category and Age

The final analyses using the LPP were conducted to explore whether younger and older adults may differ in how they attend to specific types of pleasant and unpleasant stimuli, particularly those known to produce the largest LPP amplitudes (Weinberg &

Hajcak, 2010). Three 6(Category: affiliative, erotic, mortality, mutilation, threat, and neutral) X 2(Age: young, old) repeated measures ANOVAs were conducted to test these exploratory hypotheses (one for each window).

2.4.3.1. Early Window. A main effect of category emerged $F(4.13, 243.86) = 7.38$, $p < .001$, $\eta^2 = .11$, such that LPP amplitudes were larger to mutilation [at the level of a trend; $t(60) = -1.78$, $p = .08$] and threat $t(60) = 3.14$, $p = .003$, as compared to affiliative stimuli. Additionally, threat stimuli produced larger LPP amplitudes versus the mortality stimuli $t(60) = -2.91$, $p = .005$. All categories also generated larger LPP amplitudes relative to the neutral stimuli [all $ts(60) \geq 3.08$, all $ps \leq .003$]. Similar to previous analyses, younger adults produced larger LPP amplitudes as compared to older adults $F(1, 59) = 5.47$, $p = .02$, $\eta^2 = .08$. No significant interaction effect between Category and Age emerged.

2.4.3.2. Middle Window. Though a main effect of Category also occurred within the middle window $F(5, 295) = 3.50$, $p = .04$, $\eta^2 = .05$, effects were differed slightly as compared to the early window. LPP amplitudes were larger to affiliative versus erotic $t(60) = 2.09$, $p = .04$ and neutral stimuli $t(60) = 2.24$, $p = .02$. Threat stimuli produced larger LPP amplitudes as compared to the erotic $t(60) = -3.35$, $p = .001$, mortality $t(60) = -2.59$, $p = .01$ and neutral stimuli $t(60) = 3.43$, $p = .001$. Finally, mutilation stimuli produced larger LPP amplitudes as compared to the erotic $t(60) = -1.98$, $p = .05$ and neutral stimuli [at the level of a trend; $t(60) = 1.91$, $p = .06$]. LPP amplitudes were again larger for younger adults overall as compared to older adults $F(1,59) = 4.19$, $p = .04$. No other significant effects occurred.

2.4.3.3 Late Window. LPP amplitudes only differed between younger and older adults in that younger adults displayed larger LPP amplitudes as compared to older adults $F(1, 59) = 4.34$, $p = .04$. There was no significant effect of Category or interaction between Category and Age.

2.4.4 LPP and Self-report of ER and Well-Being

We predicted that greater well-being and higher reappraisal scores should be associated with larger LPP amplitudes to pleasant stimuli and reduced LPP amplitudes to unpleasant stimuli. Only three correlations emerged across the sample as a whole: reduced LPP amplitudes to mutilation stimuli in all three windows were associated with greater scores on the environmental mastery subscale [$rs < -.24$, $ps < .05$]. No significant correlations emerged for younger or older adults separately or with pleasant stimuli.

2.5 Discussion

The present study was only the second to use a purely passive viewing paradigm in comparing the LPP between younger and older adults, but doubled the amount of time stimuli were presented, increased the age of older adults, used highly arousing emotional stimuli and further analyzed age differences between specific stimulus categories. Consistent with previous research using a passive viewing paradigm with children (DeCicco, O'Toole, & Dennis, under review; Hajcak & Dennis, 2009; Solomon, DeCicco, & Dennis, 2012) and younger adults (Cuthbert et al., 2000; Schupp et al., 2000; Schupp et al., 2004; Hajcak & Nieuwenhuis, 2006), LPP amplitudes were larger to pleasant and unpleasant as compared to neutral stimuli (early window). Within the middle window only unpleasant stimuli were larger than neutral stimuli. In the middle window, however, older, but not younger adults did show larger LPP amplitudes to emotional versus neutral stimuli (i.e. sustained processing of emotional stimuli). Thus, the effect of valence was most robust in the early window as it was present for both ages, as compared to the middle window where only older adults showed a sustained difference between emotional and neutral stimuli. This study was the first to examine the LPP in relation to subcategories of pleasant and unpleasant stimuli in both younger and older adults. As no age differences between categories or emotional stimuli emerged between younger and older adults, results provide support Mather and Carstensen's (2005) bottom-up model of attention to emotion. Results highlight similarities in the way that younger and older adults process unpleasant and pleasant stimuli in a passive viewing context, but also suggest that older adults may process emotional information over a more sustained period.

The primary purpose of the present study was to test whether the primary tenet of SST, the positivity effect, would emerge during a bottom-up task. We were able to show that LPP amplitudes were larger to pleasant and unpleasant stimuli in the early window for the sample as a whole, and predicted null effects of age did occur. Additionally, consistent with predictions, older adults did show a sustained difference between emotional and neutral stimuli through the middle window. This effect was not seen, however, among younger adults. In fact, younger adults did not show expected differences between pleasant, unpleasant and neutral stimuli within the middle window. This suggests that younger and older adults may differ in how they process emotional stimuli at various stages, as seen in eye-tracking research (Isaacowitz et al., 2009). Additionally, as there was no effect of emotion for younger adults, this could potentially account for a lack of differences between pleasant and neutral stimuli for the sample as a whole in the middle window, as younger adults may process emotional information quite rapidly. For example in most of the LPP literature that uses college aged samples, effects of emotional stimuli on the LPP tend to occur within the early portions of the LPP around 200 to 800ms (e.g. Schupp et al., 2000, Schupp et al., 2004; Cuthbert et al., 2000; Hajcak & Nieuwenhuis, 2006).

Younger adults did show larger LPP amplitudes to unpleasant stimuli versus older adults; but also had larger LPP amplitudes overall. Although this is consistent with findings of Langeslag and van Strien (2009), where younger adults showed larger LPP amplitudes to unpleasant stimuli, we did not document larger LPP amplitudes to pleasant stimuli among older adults. This is suggestive that younger adults may be more reactive to emotional information in general, as compared to older adults. However, it is important to note that previous fMRI research suggests that older and younger adults may differ in cortical networks and regions of the brain responsible for emotional processing (Gunning-Dixon et al., 2003; Tessitore et al., 2005). Thus, overall amplitude differences could be due to the way in which brain structures may reorganize with age rather than differences in reactivity to emotional information. Though we did perform additional analyses footnoted in the results section that use difference scores (e.g. pleasant – neutral LPP) to control for these amplitude differences, they did not show meaningful changes.

A secondary goal of this study was to examine if younger and older adults were differentially sensitive to specific categories of emotional stimuli (mutilation, threat, mortality, erotica, and affiliative) to understand whether specific categories may account for previous inconsistent findings within the literature. For example, we predicted that older adults would show reduced emotional arousal and thus reduced LPPs to mortality images relative to other subcategories, as the amount of time left in life is a core motivational factor of SST (Carstensen et al., 1999). Thus, older adults should focus more on other positive aspects of their lives and less on the negative or impending future. Age differences in sensitivity to these subcategories did not occur; although as expected all emotional stimulus categories produced larger LPP amplitudes compared to neutral stimuli. Moreover, LPP amplitudes to mutilation and threat stimuli were larger than affiliative stimuli (early window). The additional category that differed from that of Weinberg and Hajcak (2010), mortality, produced smaller LPP amplitudes than the threat stimuli. In the middle window, effects were somewhat similar, however affiliative, threat, and mutilation images produced larger LPP amplitudes than erotic and neutral stimuli. In addition, LPP amplitudes were again reduced to mortality images as compared to threatening stimuli. As the modulation of the LPP emerged for older, but not younger adults in the middle window, it is possible that this reduction to mortality versus threatening stimuli may have been driven by older adults. However, an alternative interpretation could also include that the mortality stimuli may be less arousing than the threat stimuli, resulting in reduced LPP amplitudes as a function of arousal. Results of the present study do not show evidence for the positivity effect within this bottom-up paradigm among highly arousing stimuli and document expected effects of emotional stimuli on the LPP in general valence and within specific categories of stimuli.

Overall, there were few relations between ERQ and well-being subscales. Though the three correlations that did emerge were consistent with predictions (reduced LPP amplitudes to mutilation stimuli were associated with greater environmental mastery scores) there were no other significant associations. This could suggest that other measures of attention to emotion in the context of a regulation task could be associated with these measures, as compared to a more bottom-up type of task.

In relation to previous research using passive viewing paradigms, some results were inconsistent with previous research, but may be accounted for by some methodological differences. We did not find larger LPP amplitudes to pleasant stimuli in older adults (Langeslag & van Strien, 2009), but did show that younger adults had larger LPP amplitudes to unpleasant stimuli, but they also had larger LPP amplitudes to pleasant stimuli as compared to older adults. This differs however from Langeslag and van Strien (2009) who found larger LPP amplitudes to pleasant stimuli in older adults and larger LPP amplitudes to unpleasant stimuli in younger adults. Other studies that use a passive viewing paradigm have found reduced LPP amplitudes to unpleasant stimuli with increasing age (Kisley et al., 2007). The two studies by Kisley and colleagues (2006; 2007) focus on a reduction in the "negativity bias" with age, in that younger but not older adults appear to show larger amplitudes to unpleasant versus pleasant stimuli. This reduction in the magnitude of the LPP to unpleasant stimuli was also not found in the present study. Though some of the previous literature finds support for SST and the positivity effect in different ways (e.g. reduced LPP amplitudes to unpleasant stimuli and larger LPP amplitudes to pleasant stimuli), the present study did not find evidence to suggest the positivity effect occurs within a bottom-up task using highly arousing stimuli.

Although results of the present study are similar to that of one of the previous LPP and passive viewing studies (e.g. overall reduced LPP amplitudes in older adults, Wood & Kisley, 2006), the present study differed in some key ways from all three previous studies. One possible factor that can account for the differences in the results of these studies is in the types of stimuli that were used. For example, Langeslag and van Strien (2009) omitted the erotica stimuli and also used stimuli that were generally less arousing than those of previous studies (e.g. Moser et al., 2006; Krompinger et al., 2008). Additionally, Kisley and colleagues (2006; 2007) used pleasant stimuli that likely fell into either the affiliative or exciting categories, such as "pictures of ice-cream." As the erotica stimuli have been shown to produce larger LPP amplitudes relative to other pleasant stimulus categories within the IAPS (Weinberg & Hajcak, 2010), this could account for some differences in findings. Lastly, all three previous studies presented stimuli for 1,000 ms, as compared to 2,000 ms of the present study. Thus, many of the age related differences in emotional processing documented by these previous studies occur between 400 and 1000 ms (Wood & Kisley, 2006; Kisley, Wood, & Burrows, 2007; Langeslag & van Strien, 2009), a portion of time that is mainly accounted for as early processing in the present study (early window: 250-850 ms). We did not find age differences in the LPP within this time frame which could be reflective of more automatic/bottom-up processing, but did document differences within the subsequent window from 850 to 1350 ms, with sustained LPP effects for older adults. These differences in results highlight the importance of considering later stages of processing in examining age differences over extended periods of time, a time at which control processes and the positivity effect could emerge.

Unique to the present study was the analysis of stimulus categories to determine whether SST and the positivity effect may emerge within specific categories. Although we did not find differences between younger and older adults among these different categories, results are suggestive evidence to support SST and the positivity effect may be found within stimuli of lower arousal (Kensinger, 2008), particularly pleasant stimuli (e.g. lack of erotica stimuli in Langeslag & van Strien, 2009). As the present study did not find differences between picture categories or in the general valence categories (pleasant, unpleasant, neutral) between younger and older adults, this may indicate that these age groups may not differ in automatic processing of highly arousing stimuli.

Motivational goals proposed by SST and increased attention to pleasant stimuli hypothesized by the positivity effect are the two main factors that are thought to influence how older and younger adults attend to and process emotional stimuli (Carstensen et al., 1999; Carstensen & Mikels, 2005). The task used in the present study is an automatic, bottom-up type of task as it only requires participants to look at the stimuli as if they were watching television or a movie. Despite the fact that the bottom-up model suggests that younger and older adults should not differ much in how they attend to emotional material during an automatic task, previous LPP and aging studies have shown some mixed support for whether the positivity effect emerges in these types of (Langeslag & van Strien, 2009; Kisley et al., 2007) bottom-up tasks. As the results of the present study differ from those of two of the previous passive viewing LPP and aging studies, questions still remain as to whether a passive viewing paradigm is a true bottom-up task or whether it requires some cognitive control indicative of a top-down task. However, results do suggest that highly to moderately arousing stimuli, may create a task in which younger and older adults show little to no differences in how they attend to emotional information. This is an important contribution to the aging and emotion literature that examines the LPP, as it provides information about the methodological conditions under which the positivity effect and support for SST may emerge.

Some limitations should be considered when interpreting the results of the present study. First, this study used approximately 300 stimuli, a relatively large number (almost double) compared to the three previous LPP and aging studies and a much larger number of stimuli as compared to that of previous passive viewing LPP studies in both children (DeCicco et al., under review; Solomon et al., 2012; Hajcak & Dennis, 2009) and college aged samples (e.g. Hajcak & Nieuwenhuis, 2006). It is possible, however, that participants may have become fatigued, though the task was only 25 minutes long. Second, highly arousing images were used to explore evidence of the positivity effect occurred within these types of stimuli. Though most adult LPP studies utilize the mutilation stimuli, fewer tend to include the erotica stimuli. Thus, the inclusion of all highly arousing stimuli may have reduced the ability to detect differences between stimulus categories. Future research should systematically examine all types of low, moderate, and highly arousing emotional stimuli to determine if stimulus category may play a significant role in identifying differences in attention to emotion that occur with age. This type of design would help to further clarify the boundary conditions under which support for SST and the positivity effect may emerge.

In sum, results of the present study highlight that younger and older adults do not differ in how they attend to and process highly arousing pleasant and unpleasant stimuli and provide support for passive viewing as a bottom-up/automatic task outlined by Mather and Carstensen (2005). Future research should combine technology to examine the LPP in conjunction with eye-tracking methods. This could contribute to our understanding as to whether larger or smaller LPP amplitudes could be attributed to where younger and older adults are focusing their attention. For example, as older but not younger adults showed a sustained arousal effect through the middle window, it is possible that younger adults could have been using attentional focusing to shift their gaze to less arousing portions of a stimulus. Results of the present study contribute to our understanding of the conditions under which the LPP may support SST and the positivity effect, particularly in terms of stimulus choice, timing of effects, and the length of stimulus presentation.

Table 2.1 Mean LPP amplitudes for younger adults, older adults, and the sample as a whole.

	Young *n* = 36			Old *n* = 25			Total N = 61		
	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
Condition									
Pleasant	5.06(4.78)	1.93(4.33)	1.41(4.19)	2.32(4.37)	0.11(3.91)	-0.46(3.44)	3.94(4.78)	1.18(4.23)	0.64(3.98)
Unpleasant	5.27(4.96)	2.32(4.44)	1.22(4.15)	2.55(4.07)	0.22(3.77)	-0.52(3.20)	4.16(4.78)	1.46(4.27)	0.50(3.86)
Neutral	4.22(4.61)	2.04(4.00)	1.47(3.79)	1.37(4.28)	-0.92(4.09)	-1.36(3.54)	3.05(4.66)	0.82(4.26)	0.31(3.92)

Note: Standard deviations presented in parentheses. Units are in µV

Figure 2.1 Visual depiction of mean LPP amplitudes for young and old adults, as well as the sample as a whole. Data are displayed for each valence type (pleasant, unpleasant, and neutral) across each of the three time windows.

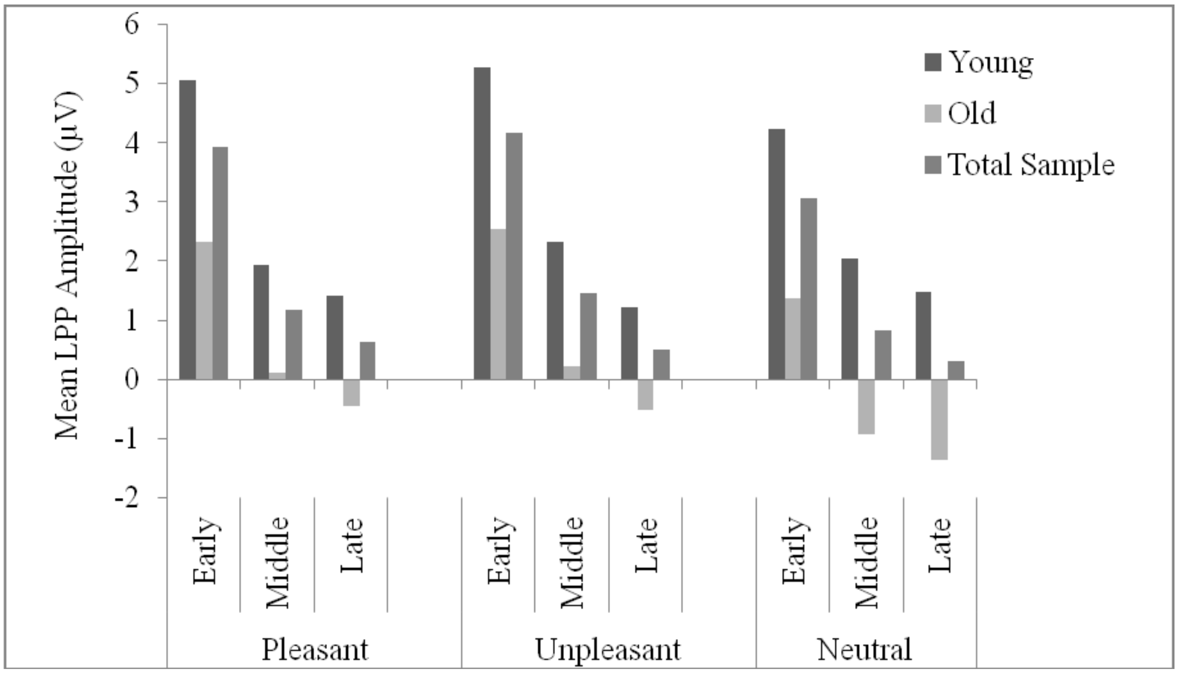


Figure 2.2 Mean LPP amplitudes for the pleasant, unpleasant, and neutral stimuli. LPP amplitudes in the early window were larger for pleasant and unpleasant as compared to neutral stimuli.

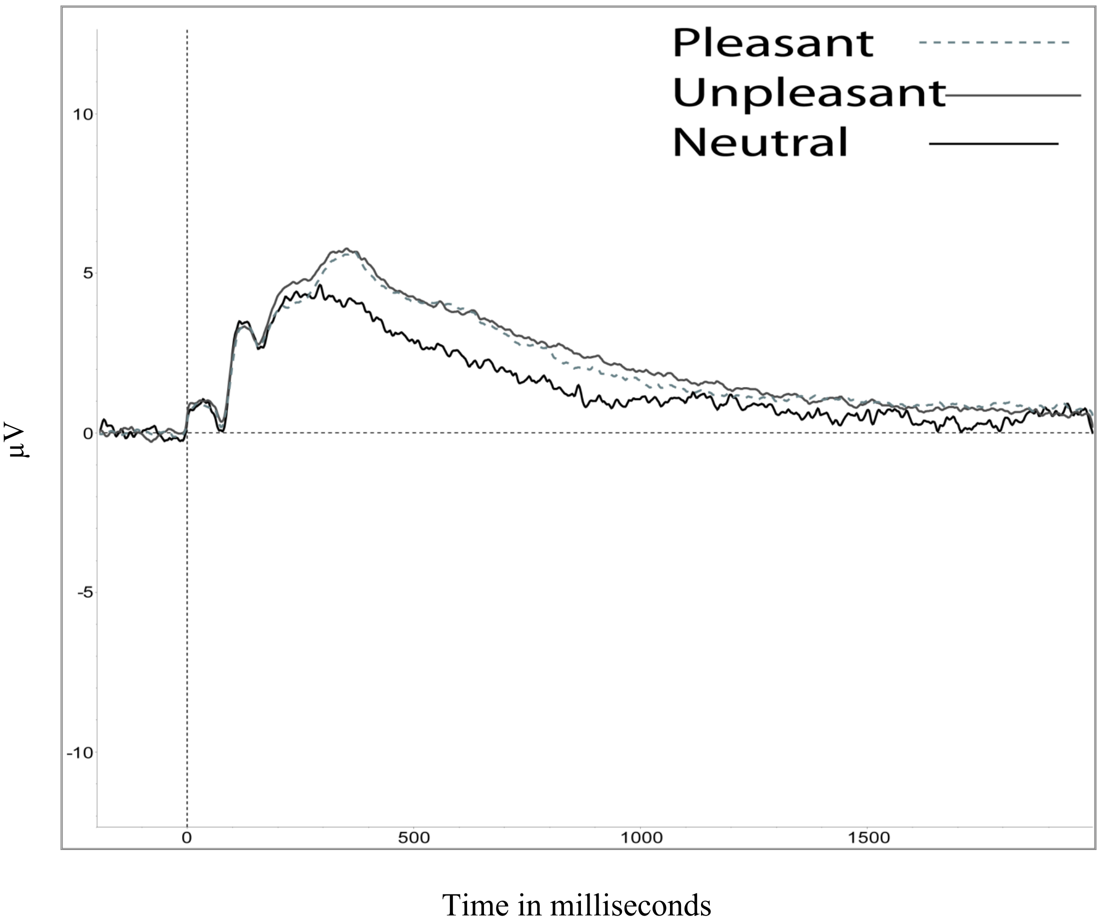
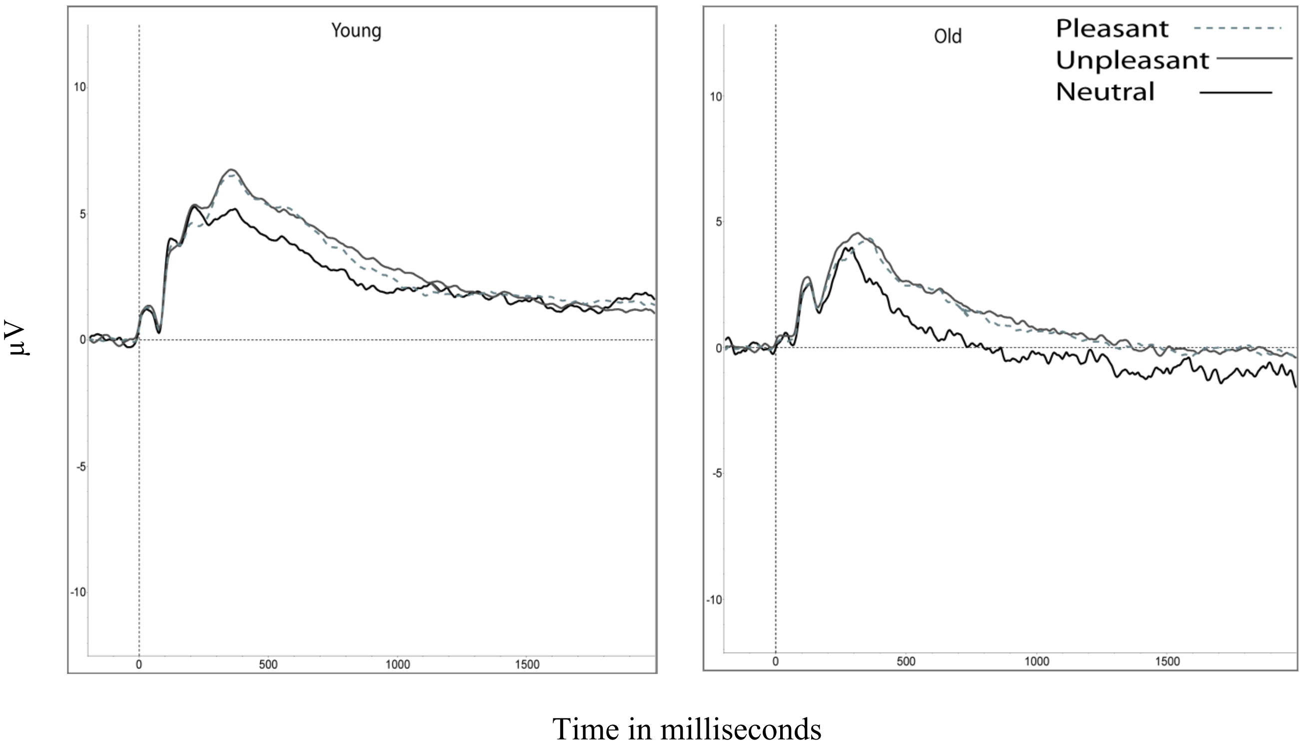


Figure 2.3 Mean LPP amplitudes for pleasant, unpleasant, and neutral stimuli. Older adults, within the middle window, showed larger LPP amplitudes for pleasant and unpleasant versus neutral stimuli, but younger adults showed no amplitude differences among stimuli.



CHAPTER THREE

Chapter 3: Regulating Emotion in Younger and Older Adulthood

3.1 Abstract

Prominent theories in aging and emotion have suggested that with age we become increasingly motivated to attend to positive emotion, resulting in improved ability to regulate emotion and greater memory for positive versus negative emotional information. To date, however, few studies have examined the hypotheses of these theories within multiple ER tasks that use neural measures with high temporal resolution. In the present study, younger (*n* = 40) and older (*n* = 28) adults completed a two cognitive ER tasks (reappraisal and directed attention), to evaluate different types of ER strategies differ between these two age groups, as the EEG was recorded to generate the LPP. Participants also completed a memory recognition task. The goals of the present study were to use the LPP to: a) determine whether older and younger adults differ in the ability to use two cognitive ER strategies that vary in the degree to which top-down (reappraisal) versus a moderately top-down (directed attention) cognitive processes are employed; and b) determine whether the use of reappraisal and directed attention influence memory for emotional stimuli, and whether individual differences in the LPP have a significant impact on these associations. Results revealed no age differences in the LPP during reappraisal, but showed that younger versus older adults showed a greater differences in attentional focusing to regulate their responses to unpleasant stimuli (i.e., LPP amplitudes were reduced). Memory analyses showed that, overall, neutral stimuli were remembered more often than pleasant or unpleasant stimuli for both the reappraisal and directed attention task. Results suggest that younger versus older adults show greater differences within directed attention, whereas more stringent top-down cognitive ER strategies like reappraisal may not change with age.

3.2 Introduction

Much of the literature examining cognitive ER strategies (e.g. reappraisal and directed attention) has focused on younger ages, particularly college aged students; however, a growing body of research has begun to explore how ER changes in older age. Theories of aging and emotion have suggested that as we age, we become more adept at regulating our emotions (Carstensen et al., 1999; Charles & Carstensen, 2007). One prominent theory within the emotional aging literature, Socioemotional Selectivity Theory (SST), proposes that this improved ability to regulate emotion is related to a perceived reduction in the time we have left in life, which influences our motivational goals related to emotion (Carstensen, 2006; Carstensen, Fung, & Charles, 2003; Carstensen et al., 1999; Carstensen, Isaacowitz, & Charles, 1999; Scheibe & Carstensen, 2010). Thus, SST suggests that with age we become increasingly motivated use ER strategies in such a way to increase emotional rewards (e.g. feeling more positive versus negative emotion; Carstensen, 2006; Schiebe & Carstensen, 2010). Self-report of emotion among older adults has provided support for this theory of aging where older adults not only report less negative emotion (Carstensen et al., 2000), but also greater control over (Gross et al., 1997), awareness, and understanding of emotion (Labouvie-Vief et al., 1989). In fact, as we age some self-report research suggests that we progressively engage more in the use of reappraisal, (viewing negative emotion in a more positive light) as an everyday strategy versus suppression of emotion (John & Gross, 2004).

The positivity effect is a component of SST which suggests as a result of these changes in emotional motivation, younger adults attend more to negative and older adults to positive emotional information (Carstensen et al., 1999). Using behavioral methods, Carstensen and colleagues (Carstensen & Mikels, 2005; Carstensen, Mikels, & Mather, 2006; Charles et al., 2003; Mather & Carstensen, 2005) and other research groups have provided support for this core tenet of SST, across multiple domains including gaze direction, attention, and most notably memory. These paradigms have demonstrated attentional preferences for positive information, as well as greater memory for positive stimuli among older adults. For example, eye tracking studies have demonstrated that older adults have a gaze preference for happy versus angry faces (Isaacowitz et al., 2006). In dot-probe paradigms older adults take longer to respond when a negative facial stimulus is presented prior to the probe and also show better memory for positive facial stimuli as compared to negative (Mather & Carstensen, 2003). In the first study to demonstrate age related differences in memory performance, older adults passively viewed pleasant, unpleasant and neutral stimuli, then were asked to recall as many stimuli as possible (Charles et al., 2003). Younger adults did remember more stimuli overall as compared to older adults and did not differ in the degree to which they remembered pleasant and unpleasant stimuli; however, within-group comparisons showed that older adults recalled a greater number of pleasant versus unpleasant stimuli (Charles et al., 2003). This disparity in memory performance has also been shown in autobiographical memory, where older adults tend to recall a greater number of false positive than false negative memories (Fernandes, Ross, Wiegand, & Schrver, 2008) and report fewer negative characteristics within negative autobiographical events (Comblain, D'Argembeau, & Van der Linden, 2005). In sum, behaviorally, there is significant support for hypotheses concerning the preferential processing and remembering of pleasant stimuli in older adults across multiple domains, including attentional allocation in eye tracking studies, dot probe paradigms, memory recall, and autobiographical memory.

Although the positivity effect pertains to preferences in emotional processing that stem from hypotheses of SST, the core feature of SST lies within how older adults regulate emotion.

A variety of cognitive ER strategies have been proposed in the literature, most notably the process model (Gross & Thompson, 2007; Gross, 1998) which articulates five stages of ER: situation selection, situation modification, attentional deployment, cognitive change (e.g., reappraisal), and response-focused modulation (e.g., suppression). These different strategies can also be broken up into two classes of ER strategies: antecedent- and response-focused (Gross & Thompson, 2007). Antecedent-focused strategies serve to modify attention to an emotional event prior to or just as the event is occurring; whereas response focused strategies attempt to modify an emotional experience after it has occurred.

Antecedent-focused strategies, such as attentional deployment and reappraisal, change how we attend to and process these emotional events. Attentional deployment can involve either *distraction* (Stifter & Moyer, 1991) from the emotional event where the individual focuses on something unrelated to the emotion or shifts attention to a different part of that emotional event or *concentration* (Wegner & Bargh, 1997) on a more intense portion of the emotional event. Thus, these shifts in attention to emotion can serve to increase or decrease the intensity of emotional experience. According to the process model of ER (Gross & Thompson, 2007), attentional deployment occurs just after situation modification, but before cognitive change (reappraisal).

In contrast to attentional deployment, reappraisal involves more cognitive manipulation such that a negative emotional event is reinterpreted in a more positive light (Foti & Hajcak, 2008; Gross & John, 2003; Gross & Thompson, 2007; Hajcak & Nieuwenhuis, 2006; Kalisch, Wiech, Herrmann, & Dolan, 2006; Ochsner et al., 2002; Ochsner & Gross, 2005). For example, if a person is in poor health in the hospital one could reinterpret this negative event to say the person is getting the best care by the doctors and they will get better soon. The ability to effectively use reappraisal strategies has been associated with a variety of positive self-reported outcomes such as greater autonomy, environmental mastery, personal growth, positive relations with others, sense of purpose in life, and self-acceptance, as well as reduced depression, greater self-esteem, optimism and life satisfaction (Gross & John, 2003). Thus, the modification of an emotional event prior to or just after it has occurred using antecedent focused strategies like attentional deployment and reappraisal (Gross & Levenson, 1993; 1997) may provide a greater benefit in reducing stress reactivity on the body from an emotional event. To date, however, few studies have simultaneously examined multiple stages of ER (such as reappraisal and attentional deployment), making it unclear whether age-related differences in ER emerge at one or more stages of processing.

Within the aging literature, some theories suggest that younger and older adults differ in the degree to which they use cognitive ER strategies. For example, the Selective Optimization and Compensation of Emotion Regulation (SOC-ER) model (Urry & Gross, 2010) suggests that with age a reduction in prefrontal cortices responsible for control process, reduces the likelihood of using strategies like reappraisal. As a result, older adults may engage in other strategies more frequently such as situation selection (e.g. selecting the types of emotional situations we place ourselves in). Thus, older adults compensate for this reduction in control processes by engaging in situation selection. The SOC-ER model also suggests that younger adults have a greater ability to recruit prefrontal control processes, and do not need to compensate for this same type of loss. Younger adults are therefore less likely to engage in situation selection as a regulatory strategy and use a cognitive strategy more frequently (Urry & Gross, 2010). Thus, one possibility is that younger adults are more adept at a range of cognitive strategies, including reappraisal and attention deployment.

In sum, SST and the SOC-ER model suggest that older and younger adults may differ in how they use cognitive ER strategies. However, there is a critical empirical gap in the SST literature, which suggests that older adults will show a preference for positive emotional information in terms of memory, and should regulate emotions more effectively particularly with increasing age: does SST and the positivity effect influence key cognitive ER strategies, such as reappraisal and attentional deployment. In general SST suggests that the positivity effect is most apparent when tasks require cognitive control (top-down) such as a regulation task, as compared to more automatic (bottom-up) processes like attentional deployment (Mather & Carstensen, 2005). Currently, it is unclear as to what types of tasks involving emotion are strictly bottom-up. For example, passively viewing emotional stimuli appears to be bottom-up as compared to cognitive reappraisal tasks which require cognitive control and are more indicative of top-down processing. Figure 1 highlights hypotheses of Mather and Carstensen (2005) showing which brain regions, how motivational goals and attention operate in a top-down or bottom-up task. As attentional deployment is not strictly passive viewing and requires shifts in attention (a type of cognitive ER strategy in the process model) it may fall in between bottom-up and top-down processing. Thus, these processing models suggest that effects of SST and the positivity effect emerge when cognitive control processes are required and motivational factors proposed by SST can play a role in preferential attention to emotion. In line with these predictions, one possibility is that older adults are more adept at reappraising negative events in a more positive light because of this preferential focus on and memory for pleasant stimuli. This hypothesis is also consistent with findings that emotional awareness, control, and cognitive understanding of emotion increase with age (Gross et al., 1997; Kessler & Staudinger, 2009; Labouvie-Vief et al., 1989). However, few studies have systematically examined the hypotheses of SST in relation to cognitive ER and memory in both younger and older adults, particularly from a neural perspective.

One way to clarify whether younger and older adults differ in their how they use cognitive ER strategies, and how the positivity effect (both attention and memory differences) may underlie these abilities is to identify neural correlates of these processes. In doing so, neural measures help to identify regions of the brain known to facilitate ER (prefrontal cortices) and emotional processing (amygdala). Thus, neural measures provide the opportunity to identify whether behavioral phenomena and theories of cognitive ER have a neural basis and can capture changes that behavioral measures may not be able to measure. To date, four studies have examined reappraisal in older adults using functional magnetic resonance imaging (fMRI; Urry, van Reekum, Johnstone, & Davidson, 2009; Urry et al., 2006; van Reekum et al., 2007) and one has compared younger and older adults (Optiz, Rauch, Terry, & Urry, 2012). These studies provide mixed support for the core hypotheses of SST. For example, Urry and colleagues (2006) found that older adults, like younger adults, did in fact show increased activation of prefrontal cortex and amygdala regions when asked to increase emotional responses to unpleasant stimuli, but did not show the expected reduction in amygdala activation and increased prefrontal activation when asked to decrease emotional responses. In a subsequent study, Urry and colleagues' (2009) instructions to increase and decrease emotional responses produced greater activation in medial prefrontal regions and corresponded to increased cardiac activity in the increase and decrease conditions, suggesting older adults were not very skilled at differentiating between regulation conditions to reduce reactivity from negative emotion across multiple physiological measures. To explore whether gaze-direction (attentional deployment) could account for differences in how older adults use directions to increase and decrease emotional responses, van Reekum and colleagues (2007) used a gaze-directed regulation task. In this sample of older adults, amygdala activation was reduced in the decrease versus increase and attend to conditions to unpleasant stimuli (van Reekum et al., 2007). More importantly when participants were instructed to decrease their emotional response, gaze accounted for the degree of activation in prefrontal regions (van Reekum et al., 2007). A follow-up study (Opitz et al., 2012) used a combination of reappraisal and attentional deployment comparing younger and older adults within the same paradigm. This study similarly showed that older adults demonstrated increased activity when increasing negative emotion, but did not show expected patterns of neural activity when asked to decrease negative emotion, as compared to younger adults (Opitz et al., 2012). This lack of down-regulation in older versus younger adults was due to a reduction of activation in regions of the prefrontal cortex known to facilitate reappraisal (Opitz et al., 2012). Overall, neuroimaging findings provide mixed results about how older adults may use reappraisal-like strategies to reduce negative emotion. As some results show a reduction in prefrontal regions (Optiz et al., 2012) others find a lack of an increase in activation in prefrontal areas and reductions in the amygdala (Urry et al., 2006) in response to reducing negative emotion. Even when designs are mixed and use a combination of reappraisal and attentional deployment (van Reekum et al., 2007, Optiz et al., 2012), results are still inconsistent.

To date, it appears as though neural evidence for SST and the positivity effect have mixed support within the neuroimaging literature. For example, some studies documented that older adults did not show expected patterns of neural activity when decreasing negative emotion (Urry et al., 2006; Opitz et al., 2012), while others have found that attentional deployment facilitates the ability to use reappraisal and does produce greater prefrontal and reduced amygdala activation in older adults (van Reekum et al., 2007). Interestingly, many of these fMRI studies have not exclusively compared younger and older adults within the same study, making it difficult to conclude whether younger and older adults truly differ in how they use cognitive ER strategies like reappraisal and attentional deployment. Given that SST posits that as we age we use reappraisal more frequently, fMRI findings should show increased prefrontal activation and reduced amygdala activation when older adults are asked to decrease negative emotional responses. Despite some evidence for SST and the positivity effect within these studies (van Reekum et al., 2007), the one study that did compare younger and older adults suggests that they differ in the ability to down-regulate negative emotion in a gaze-directed reappraisal task (Opitz et al., 2012). Though fMRI studies have shed light on how younger and older adults may differ in some respects of cognitive ER, they do so with high spatial, but limited temporal resolution. Thus, neuroimaging provides a great deal of information about structures of the brain that may be activated during cognitive ER tasks, but cannot provide information about changes in attention to emotion that occur rapidly. Event-related potentials (ERPs), however, have the ability to capture these changes with millisecond precision.

One ERP that is well-suited to capture changes in attention to emotional stimuli is the late positive potential (LPP; Schupp et al., 2000; Schupp et al., 2004; Cuthbert et al., 2000). The LPP emerges around 200 to 300 ms after a stimulus has been presented and is maximal in posterior regions (DeCicco, Solomon, & Dennis, 2012; Foti & Hajcak, 2008; Hajcak et al., 2007; Keil et al., 2002; Schupp et al., 2000). The LPP is known to reflect increased perceptual processing of and attention to emotional (pleasant and unpleasant) as compared to neutral stimuli, where amplitudes are larger to emotional versus neutral stimuli (Cuthbert et al., 2000; Hajcak & Dennis, 2009; Hajcak & Nieuwenhuis, 2006; Schupp et al., 2000; Solomon et al., 2012). The use of cognitive ER strategies also impacts the LPP such that when using a directed reappraisal

(DeCicco et al., under review; Dennis & Hajcak, 2009; Foti & Hajcak, 2008; MacNamra et al., 2011) or instruction to decrease subjective emotional experiences to unpleasant stimuli, the LPP is reduced (Hajcak and Nieuwenhuis, 2006; Moser et al., 2006, 2009). Other strategies to increase subjective emotional experiences to unpleasant (Hajcak and Nieuwenhuis, 2006; Moser et al., 2006, 2009) and pleasant (Krompinger et al., 2008) stimuli result in larger LPP amplitudes. The LPP is also impacted by cognitive ER strategies that shift gaze to either arousing or non-arousing areas of unpleasant stimuli, where LPP amplitudes are larger to stimuli with an arousing versus non-arousing focus (Dunning & Hajcak, 2009).

Despite this breadth of research examining the LPP in multiple contexts (passive viewing, cognitive reappraisal, and directed attention), the vast majority of these studies have been conducted with college aged students. To date, only four studies (Wood & Kisley, 2006; Kisley et al., 2007; Langeslag & van Strien, 2009) have examined the LPP in older adults using mostly passive viewing types of paradigms and only one with a cognitive reappraisal design (Langeslag & van Strien 2010). In two studies (Wood & Kisley, 2006; Kisley et al., 2007), participants were asked to categorize stimuli based on valence after passively viewing the stimuli. Though one study found that with age LPP amplitudes were increasingly reduced to unpleasant stimuli with age (Kisley et al., 2007), the other study showed that older adults did not differ in LPP amplitudes between pleasant and unpleasant stimuli (Wood & Kisley, 2006). Thus, support within this research group also finds mixed neural evidence for SST and the positivity effect in that attention to unpleasant emotion appears to be reduced with age, but a focus on pleasant stimuli was not found. Other passive viewing types of paradigms have found different results that support SST where older adults show larger LPP amplitudes to pleasant stimuli and younger adults to unpleasant stimuli (Langeslag & van Strien, 2009). Larger LPP amplitudes in this same study, for older adults only, were also associated with better memory performance. In a follow up study by Langeslag and van Strien (2010), older (60-77) and younger adults were asked to increase and decrease emotional responses to pleasant and unpleasant stimuli or to view neutral stimuli. LPP amplitudes, however, did not differ for any of the conditions between younger and older adults.

Taken together, studies examining the LPP in older samples provide some support for SST and the positivity effect with reductions in the LPP to unpleasant stimuli and larger LPP amplitudes to pleasant stimuli; however this contradicts what should be found in a bottom-up task. The one LPP and reappraisal study provides little to no evidence for the positivity effect and improved regulation with age. Moreover, questions remain as to whether the LPP during reappraisal is related to memory performance. Therefore, there are several specific components of SST that can be tested to clarify the types of tasks that may provide evidence for this theory: a) the positivity effect in terms of preferential processing of and memory for pleasant stimuli among older adults; b) better cognitive ER in older versus younger adults; and c) whether different types of antecedent focused strategies may independently capture components of SST (attentional deployment and reappraisal) d) are neural measures of attention to emotion (LPP) differentially associated with memory performance in younger versus older adults.

Taken together, fMRI and LPP cognitive ER paradigms have yet to completely clarify which types of ER strategies may best capture regulatory ability differences between younger and older adults and potential support for SST. For example, do older and younger adults differ in allocation of attention during a directed attention task between pleasant and unpleasant stimuli? Additionally, what do patterns within the LPP look like in relation to valence baseline (maintain) conditions in a reappraisal task between younger and older adults? Finally, how does the LPP in the context of a regulation task (both reappraisal and directed attention) relate to memory performance in younger and older adults? As the top-down model of Mather and Carstensen (2005) suggests evidence for the positivity effect and the impact of motivational goals of SST should be most apparent in tasks requiring cognitive control, the design of the present study serves to tease apart whether different types of cognitive ER tasks (reappraisal and directed attention) provide support for these hypotheses.

The present study also served to address several methodological concerns within the literature, namely stimulus duration, the addition of a memory task in relation to two the regulation tasks, a slightly older sample than that of previous studies and the addition of a baseline valence conditions, as well as a baseline neutral condition. We will also simultaneously examine two key cognitive ER strategies (directed attention and reappraisal) that occur at unique stages of emotional processing and patterns of neural activity in response to these strategies (measured via the LPP). First, the stimuli presented in this study were presented for 2,000 ms to examine sustained processing, rather than just early stages of emotion processing. Second, we included both younger (aged 18-26) and older (aged 65-83) adults, a much older age range than seen in previous studies (e.g. 60-77 Langeslag & van Strien, 2010; 61-65 van Reekum et al., 2007; 55-65 Opitz et al., 2012; 64-66 Urry et al., 2009; 62-64 Urry et al., 2006). Third, three types of experiments were conducted to fully evaluate SST and the positivity effect: reappraisal, directed attention, and memory recognition. Fourth, we added additional maintain or baseline conditions that included pleasant and unpleasant stimuli to evaluate the degree to which younger and older adults could increase and decrease emotional responses from a valanced baseline condition versus a neutral baseline condition.

The present study had three goals. The first goal was to determine whether the use of cognitive ER strategies differs between younger and older adults as measured by LPP amplitudes during a reappraisal task (i.e., directions to increase or decrease emotional responses). We predicted that due to the positivity effect and hypotheses of SST, older versus adults will show greater ability to use reappraisal to decrease responses to unpleasant stimuli (i.e., reduced LPP amplitudes) and increase responses to pleasant stimuli (i.e., increased LPP amplitudes). In accordance with SST and the positivity effect, older adults may focus more on pleasant stimuli and not show a strong reduction in LPP amplitudes when asked to decrease emotional responses to pleasant stimuli. Overall, an effect of condition should emerge across the sample where LPP amplitudes are larger to stimuli in the increase condition, followed by the maintain valence, and decrease conditions.

The second goal was to evaluate whether younger and older adults differ in a different type of cognitive ER strategy. A directed attention task served to control the portion of the stimulus in which participants focused their attention, either the most arousing or least arousing area of the stimulus. As previous fMRI and aging research suggests that age differences in neural activity occur between younger and older adults (Opitz et al., 2012) in mixed directed attention and reappraisal paradigms, we expected that older and younger adults may differ in how they attend to arousing and less arousing areas of pleasant and unpleasant stimuli. The directed attention task may involve some aspects of top-down processing in order to shift attention, but is a task that requires more than a passive viewing task. Thus, the directed attention task would appear to fall somewhere in between a bottom-up and top-down type of paradigm. Taking this into consideration and predictions of SST, we predicted that as younger adults are less experienced with using reappraisal as an everyday strategy, they may be more successful in using attentional focusing. This should result in larger LPP amplitudes to arousing versus non-arousing areas of emotional stimuli, particularly within unpleasant stimuli among younger adults. In addition, as older adults appear to benefit from using a combination of reappraisal and directed attention (e.g. van Reekum et al., 2007), they will show less differentiation in LPP amplitudes between arousing and less arousing attentional foci. Older adults, however, may not differ in LPP amplitudes and foci for pleasant stimuli as they may preferentially attend to arousing areas regardless of the attentional focus.

The third goal was to determine whether the hypotheses of SST related to ER and the positivity effect are correlated with LPP measures of cognitive ER, and whether patterns of associations differ between older and younger adults. It was predicted that older adults will show superior memory for pleasant stimuli, whereas younger adults will show superior memory for unpleasant stimuli within each of the cognitive ER tasks. Within the reappraisal task, stimuli in the increase condition should be remembered more than the maintain (valence) or decrease conditions. Based on top-down predictions, tasks requiring more cognitive control should result in greater differences in memory performance between younger and older adults (Mather & Carstensen, 2005). We also expect that as older adults should more adept reducing negative and increasing positive emotion, differences between age groups should emerge in memory performance. In the directed attention task memory should be best for stimuli in the arousing versus non-arousing focus conditions for the sample as a whole; however younger adults should show better memory for unpleasant arousing stimuli and older adults for pleasant arousing stimuli.

3.3 Method

3.3.1 Participants

The present study includes two age groups: 49 younger adults (aged 18 to 26: *M* = 20.51, *SD* = 2.33; 27 females) and 28 older adults (aged 65 and over: *M* = 72.60, *SD* = 6.08; 16 females). Younger adults were recruited from an introduction to psychology subject pool at Hunter College, whereas older adults were recruited using flyers and advertisements in and around New York City. Older adults were screened for cognitive deficits prior to participation, using the Mini Mental Status Exam (MMSE; Folstein et al., 1975). All older adults that were screened achieved a score of 24[2] (*M* = 28.40, *SD* = 1.33) or greater on the MMSE. Of the participants recruited for the study, nine younger adults and two older adults were excluded due to excessive artifacts and computer failure in the cognitive ER task and 11, younger adults and four older adults in the directed attention task. Thus, the final sample included 40 younger and 26 older adults for the reappraisal task and 39 younger and 22 older adults for the directed attention task. Race and ethnicity were as follows: Race and ethnicity were as follows: 17 younger, 22 older Caucasian; six younger, six older African American; 11 younger, zero older Asian; four younger and zero older Native Hawaiian or other Pacific Islander; and two younger, zero older of more than one race.

3.3.2 Stimuli and Materials

3.3.2.1 Stimuli. All stimuli were taken from the International Affective Picture System (IAPS; Lang et al., 2008). There were 175 stimuli used in the reappraisal task and 125 stimuli used in the directed attention task (see Appendix E for stimuli numbers) Pleasant stimuli included affiliative and erotic images, unpleasant stimuli included pictures depicting mutilation

[2] Only one individual scored a 24 on the MMSE. The next highest score was a 26 (only one individual), with the remaining older adults scoring a 27 or higher.

and threat, and neutral stimuli consisted of household objects, neutral faces, and neutral scenes. Additionally, 300 distractors were chosen for the memory recognition task: 175 distractors for the reappraisal task and 125 distractors for the directed attention task.

3.3.2.2 Questionnaires. Informed consent was obtained prior to all questionnaires. Participants completed demographic questionnaires prior to EEG set up.

3.3.3 Procedures

3.3.3.1 Reappraisal Task. The reappraisal task consisted of 75 unpleasant, 75 pleasant and 25 neutral stimuli for a total of 175 stimuli. Participants were asked to increase or decrease their emotional experiences to unpleasant and pleasant pictures via the use of cognitive change strategies or to simply view pleasant, unpleasant, and neutral stimuli. Prior to the start of the reappraisal task, participants were given a practice session with detailed instructions (verbal and written), as to how to go about increasing (five trials) and decreasing (five trials) emotional responses. Written instructions for this task were taken from Hajcak and colleagues (2006) For example, if instructed to decrease an emotional experience to a picture of a vicious snake, participants would be given the example that the snake was going to be captured and it will not harm anyone. The following four conditions were randomly presented and each condition was completed in its entirety before moving on to another condition: Increase- pleasant and unpleasant randomly chosen, Decrease- pleasant and unpleasant randomly chosen, Maintain- pleasant and unpleasant randomly chosen, Maintain- neutral. Participants were first presented with a screen indicating the regulation instruction (increase, decrease, or maintain) for 2000ms, followed by a fixation cross for 1000ms. The stimulus was then presented for 2000ms, followed by a prompt to rate the valence and arousal of the stimulus (Urry, 2009a; 2009b). Trials ended with a cue to “relax” for 2500ms (Figure 3.1). After two conditions were completed, the participant was prompted with a screen to take a break and to continue when they were ready.

3.3.3.2 Directed Attention Task. Fifty unpleasant and 50 pleasant stimuli, as well as 25 neutral stimuli were used. Participants were instructed to focus their gaze on the area outlined by a white box for the duration of the stimulus. In 25 of the unpleasant, and also pleasant, trials, attention was directed to an arousing area of the stimulus (outlined by a white box) whereas, the other 25 unpleasant and pleasant trials attention was directed to a less arousing area of the stimulus (Hajcak, Dunning, & Foti, 2009; Urry, 2009a). Neutral stimuli (25 stimuli) were also used in this experiment with attention directed to a neutral portion of the stimulus. All trials were randomly chosen. Each stimulus was first presented without a white box for 1000ms, followed by an inter-stimulus interval jittered between 1500 and 2000ms (Figure 3.2). The same stimulus was then presented for 2000ms with the white box directing attention to either a more arousing or less arousing area. At the end of each trial, participants rated the valence and arousal properties of the stimulus, followed by an instruction to relax for 2500ms. Trials were randomly presented in this task and participants were prompted with a break after every 50 trials. The directed attention task always followed the reappraisal task to ensure that participants would not use attentional focusing as a strategy to regulate emotion in the reappraisal task.

3.3.3.3 Memory Recognition. The memory recognition task followed the directed attention task. In order to ensure the same delay between the presentation of targets in the reappraisal task and the directed attention task, all stimuli shown in the reappraisal task along with 175 distractors were randomly presented first. A short break occurred after this portion of the memory task, followed by the direction portion of the memory task consisting of the 125 stimuli in the direction attention task and 125 distractors. All distracters were matched for valence. Each stimulus was presented for 2000ms, followed by a screen prompting a memory response. Participants were given four choices for their memory response to be made using a response box: Sure Old, Think Old, Think New, Sure New.

3.3.4 Electroencephalography (EEG) Recording and Data Reduction

EEG was recorded during the reappraisal and directed attention tasks using 64 Ag/AgCl active electrodes (BioSemi, Amsterdam, Netherlands) and ActiView software (Biosemi) sampled at 512Hz and filtered online between .1 and 100Hz. As the LPP is a broadly distributed ERP, using 64 electrodes allows for the best quantification of this ERP. Horizontal electro-oculargrams (HEOG) and vertical electro-oculargrams (VEOG) were recorded from four electrodes placed approximately 1cm to the left and right and above and below the eye. HEOG and VEOG were used offline to correct for eye movements and blinks. ERPs were generated using Brain Vision Analyzer (Version 2.0.1,GmbH, Munich, Germany). Data were filtered offline between 0.01 and 30Hz. Ocular correction was performed using Independent Component Analysis (Jung et al., 1998). The following criteria were also used to identify artifacts: Voltage steps greater than 75µV/ms, amplitudes differences between intervals greater than 105µV, amplitudes less than -120 and great than 120µV, and activity less than 0.2 µV. Prior to data analysis, EEG data was further inspected for additional artifacts (e.g. eye blinks and muscle movements). Data were then baseline corrected 200ms prior stimulus onset, segmented between 0 to 2000ms, and re-referenced offline to the average of the left and right mastoids. In addition to these filters a 60Hz notch filter was used to eliminate any 60 cycle noise for all participants. The LPP was analyzed in three time windows (early 300-800ms, middle 800-1300ms, and late 1300-2000ms) and averaged across the activity of the following electrodes for both younger and older adults: P1, Pz, and P2 for both the reappraisal and directed attention tasks. The LPP is commonly observed to be maximal at posterior electrode sites (Foti & Hajcak, 2008; Hajcak et al., 2007; Keil et al., 2002; DeCicco et al., 2012; Schupp et al., 2000). In addition, the chosen electrodes for the present study that have been used in other directed attention paradigms (Dunning & Hajcak, 2009).

3.3.5 Data Analysis

All statistical analyses were performed using SPSS (Version 19) using general linear model, independent t-test, paired samples t-test, and correlation software. When data violated assumptions of sphericity and homoscedasticity, Greenhouse-Geiser or Levene's test corrections were applied. As each of the cognitive ER paradigms included valence baseline conditions (maintain pleasant/unpleasant and non-arousing pleasant/unpleasant) in addition to a neutral baseline condition (maintain neutral and neutral non-arousing), we felt it was important to evaluate these conditions in conjunction with the regulation conditions. For each of the three repeated measures ANOVAs conducted for the reappraisal and directed attention tasks, the neutral condition was subtracted from each of the emotion conditions to control for how stimuli are generally processed. Thus, repeated measures ANOVAs were conducted for each window separately in the reappraisal task: 3(Condition: increase-neutral maintain, decrease- neutral maintain, maintain- neutral maintain) X 2(Valence: pleasant, unpleasant) X 2(Age: young, old). Three repeated measures ANOVAs were conducted again separately for each window within the directed attention test: 2(Focus: arousing- neutral non-arousing, non-arousing- neutral-non-arousing) X 2(Valence: pleasant, unpleasant) X 2(Age: young, old).

3.4 Results

3.4.1 Subjective Arousal Ratings During Regulation

To assess whether the regulation conditions in the reappraisal and directed attention tasks operated as expected (e.g. higher arousal for stimuli in the increase condition), we performed a series of repeated measures ANOVAs to provide a manipulation check.

3.4.1.1 Reappraisal Subjective Arousal Ratings

Stimuli in the increase condition should be rated to have the highest arousal, followed by the maintain valence, decrease, and finally maintain neutral. Two (one for each valence, pleasant and unpleasant) repeated measure ANOVAs 4(Condition: increase, decrease, maintain valence, maintain neutral) X 2(Age: young, old) were conducted to fully evaluate the degree to which arousal was changed as a function of the condition.

3.4.1.1.1 Pleasant

As predicted, a main effect of condition occurred $F(2.62, 168.22) = 41.44$, $p < .001$, $\eta^2 = .39$, such that the increase condition produced the highest arousal ratings, followed by the maintain pleasant, decrease pleasant, and maintain neutral [all $ts(65) > 4.90$, $ps < .001$]. The maintain pleasant condition had only slightly higher arousal ratings as compared to the decrease pleasant [at the level of a trend; $t(65) = 1.78$, $p = .08$]. There were no other significant effects of age or interaction effects.

3.4.1.1.2 Unpleasant

Within the unpleasant stimuli, predicted effects of condition did occur among the sample as a whole $F(2.53, 162.25) = 13.40$, $p = .001$, $\eta^2 = .71$. Stimuli in the increase condition again produced the greatest arousal ratings, followed by the maintain unpleasant, decrease unpleasant, and maintain neutral conditions [all $ts(65) > 2.45$, $ps < .01$]. Contrary to predictions, unpleasant stimuli were rated as more arousing by older versus younger adults $F(1, 64) = 13.40$, p .001, $\eta^2 = .17$. A Condition and Age interaction $F(3, 192) = 3.12$, $p = .02$, $\eta^2 = .04$, however, this interaction revealed that younger [all $ts(39) > 2.27$, $ps < .03$] and older [all $ts(25) > 3.05$, $ps < .01$] adults showed the same pattern of arousal ratings in paired post-hoc t-tests, with the exception of the decrease unpleasant and maintain comparison for older adults which failed to reach significance. Independent post-hoc t-tests also showed that older adults had higher arousal ratings for stimuli in the decrease unpleasant, increase unpleasant, and maintain unpleasant conditions [all $ts(64) > 2.95$, $ps < .01$]. Younger and older adults did not differ in arousal ratings for neutral stimuli. No other significant effects emerged.

3.4.1.2 Directed Attention Subjective Arousal Ratings

Arousal ratings were also analyzed within the directed attention task to determine whether manipulations of gaze direction produce changes in self-reported arousal. **An effect of focus should occur where arousing focus stimuli should produce higher arousal ratings than the non-arousing valance and neutral conditions.** Two repeated measures ANOVAs (one for each valence) were conducted: 3(Focus: arousing, non-arousing valence, non-arousing neutral) X 2(Age: young, old).

3.4.1.2.1 Pleasant

As predicted stimuli shown with an arousing focus were rated as more arousing $F(1.70, 100.39) = 36.87$, $p < .001$, $\eta^2 = .38$ than the pleasant non-arousing [$t(60) = -6.70$, $p < .001$] and neutral non-arousing [$t(60) = -7.47$, $p < .001$] stimuli. Additionally, pleasant stimuli presented with a non-arousing focus were rated higher in arousal than the neutral non-arousing [$t(60) = -2.99$, $p = .004$].

3.4.1.2.2 Unpleasant

Consistent with predictions $F(2,118) = 148.99$, $p < .001$, $\eta^2 = .71$, unpleasant stimuli with an arousing focus were rated higher in arousal as compared to the unpleasant non-arousing [$t(60) = 9.56$, $p < .001$] and neutral non-arousing stimuli [$t(60) = -16.69$, $p < .001$]. Unpleasant stimuli with a non-arousing focus were also rated as more arousing versus the neutral non-arousing stimuli [$t(60) = -7.40$, $p < .001$]. A Condition by Age interaction $F(2,118) = 3.29$, $p = .04$, $\eta^2 = .05$ revealed that older adults rated stimuli in the unpleasant arousing condition higher in arousal as compared to the younger adults [$t(59) = -2.48$, $p = .01$]. Paired post-hoc t-tests for both younger [$ts > 5.74$, $ps < .001$] and older [$ts > 4.95$, $ps < .001$] adults showed the same pattern of effects as the main effect of Focus. Overall, older adults rated stimuli as higher in arousal as compared to younger adults $F(1,59) = 3.93$, $p = .05$, $\eta^2 = .06$.

3.4.2 Descriptive Statistics

The means and standard deviations for the reappraisal and directed attention tasks appear in Table 3.1 and Table 3.2 separately for younger and older adults, divided by window and condition. Figures 3.3, 3.4, 3.5, and 3.6 also visually display the mean LPP amplitudes for young adults, older adults and the sample as a whole.

3.4.3 Reappraisal

We tested the hypothesis that older adults would show a greater ability to use reappraisal to reduce the LPP to unpleasant stimuli and increase the LPP in response to pleasant stimuli using repeated measures ANOVAs. **Overall, however, a main effect of condition should emerge where LPP amplitudes are larger in the increase condition following by the maintain valence and decrease conditions.** Three 3(Condition: increase, decrease, maintain) X 2(Valence: pleasant, unpleasant) X 2(Age: young, old) repeated measures ANOVAs were conducted separately for each window (early, middle, and late).

3.4.3.1 Early Window. As predicted LPP amplitudes differed between conditions $F(2,128) = 2.99$, $p = .05$, $\eta^2 = .04$, such that amplitudes were larger in the increase versus maintain $t(65) = 2.56$, $p = .01$ and decrease $t(65) = 2.23$, $p = .02$ conditions (Figure 3.7). A marginally significant main effect of valence occurred $F(1, 64) = 3.66$, $p = .06$, $\eta^2 = .05$, where LPP amplitudes were larger to pleasant versus unpleasant stimuli $t(65) = -2.10$, $p = .03$. Contrary to predictions there were no significant interaction effects between Condition and Age or a three-way interaction between Condition, Age and Valence. There was also no significant main effect of Age.

3.4.3.2 Middle Window. No significant effects occurred.

3.4.3.3 Late Window. No significant effects occurred.

3.4.4 Directed Attention

To test the hypothesis younger versus older adults may be more likely to use a range of ER strategies and thus may be better at using attentional deployment to change attention to emotion we conducted three repeated measures ANOVAs, one for each time window: 3(Focus: arousing- neutral non-arousing, non-arousing – neutral non-arousing) X 2(Valence: pleasant, unpleasant) X 2(Age: young, old). **We predicted that younger adults should show larger LPP amplitudes to stimuli with an arousing focus and reduced LPP amplitudes to stimuli with a non-arousing focus to unpleasant stimuli. Older adults, however, may rely on other cognitive ER strategies and show less differentiation in the LPP between arousing and non-arousing foci, particularly among pleasant stimuli. Overall, LPP amplitudes should be larger to stimuli with an arousing versus non-arousing focus.**

3.4.4.1 Early Window. A 2(Focus: arousing – neutral non-arousing, non-arousing- neutral non-arousing) X 2(Valence: pleasant, unpleasant) X 2(Age: young, old) repeated measures ANOVA showed a main effect of Focus $F(1,59) = 8.22$, $p = .0$, $\eta^2 = .12$. As predicted, LPP amplitudes were larger in arousing versus non-arousing $t(60) = 3.59$, $p = .001$ (Figure 3.8). Additionally, there was a significant interaction between Focus and Age $F(1, 59) = 7.66$, $p = .007$, $\eta^2 = .11$. Independent post-hoc t-tests showed that younger and older adults did not differ in LPP amplitudes for the arousing or non-arousing conditions. However, paired post-hoc t-tests did reveal that younger $t(38) = 4.40$, $p < .001$, but not older adults displayed larger LPP amplitudes in the arousing versus non-arousing conditions.

As predicted a three-way interaction emerged between Focus, Valence, and Age $F(1.59) = 5.62$, $p = .02$, $\eta^2 = .08$. Two post-hoc repeated measures ANOVAs were conducted to determine whether younger and older adults differed in how they attended to pleasant and unpleasant stimuli [2(Focus: arousing, non-arousing) X 2(Age: young, old). We expected for unpleasant stimuli that younger, but not younger adults would show greater differentiation in LPP amplitudes between unpleasant arousing and unpleasant non-arousing foci. The unpleasant repeated measures ANOVA, only the interaction between Focus and Age was significant $F(1,59) = 12.47$, $p = .001$, $\eta^2 = .17$. Post-hoc independent t-tests showed that older adults had larger LPP amplitudes to unpleasant non-arousing versus neutral stimuli as compared to younger adults $t(59) = -1.99$, $p = .05$. Consistent with predictions, paired post-hoc t-tests revealed that only younger adults had larger LPP amplitudes to unpleasant arousing versus unpleasant non-arousing stimuli $t(38) = 4.26$, $p < .001$ (Figure 3.9). Older adults however did not show this pattern of responding. In the pleasant post-hoc analyses we expected that older adults would show less differentiation (greater attentional preferences) between pleasant arousing and pleasant non-arousing foci. Contrary to predictions only a main effect of Focus emerged $F(1,59) = 6.98$, $p = .01$, $\eta^2 = .10$, where LPP amplitudes were larger to pleasant arousing stimuli versus pleasant non-arousing stimuli $t(60) = 2.91$, $p = .005$.

No other significant effects occurred within the early window.

3.4.4.2 Middle Window. Effects of condition within the middle window were similar to those of the early window $F(1, 59) = 8.78$, $p = .004$, $\eta^2 =.13$ where the arousing condition produced larger LPP amplitudes than the non-arousing $t(60) = 3.69$, $p < .001$. An interaction between Focus and Age also occurred within the middle window $F(1, 59) = 7.65$, $p = .008$, $\eta^2 = .11$. Independent post-hoc t-tests again showed larger LPP amplitudes in the non-arousing condition for older as compared to younger adults $t(59) = -2.14$, $p = .03$. Paired post-hoc t-tests again showed that younger adults had larger LPP amplitudes to arousing versus non-arousing stimuli $t(38) = 4.31$, $p < .001$. No significant effects occurred for older adults in these post-hoc analyses. No other significant effects occurred within the middle window.

3.4.4.3 Late Window. No significant effects emerged within the late window.

3.4.5 Reappraisal and Memory

Two 4(Condition: increase, decrease, maintain, maintain neutral) X 2(Age: young, old) repeated measures ANOVAs were conducted for each valence to test the hypothesis that older adults would remember more pleasant stimuli and younger adults more unpleasant stimuli. In addition, it was predicted that memory for stimuli in the increase

condition would produce better memory performance than the decrease condition. It is expected that interactions between Age and Condition will emerge, as we predicted that older versus younger adults would be better at reducing negative emotion and increasing positive emotion.

3.4.5.1 Unpleasant

A 4(Condition: increase unpleasant, decrease unpleasant, maintain unpleasant, maintain neutral) X 2(Age: young, old) repeated measures ANOVA showed a main effect of Age where younger adults remembered more stimuli, as compared to older adults $F(1,59) = 14.41$, $p < .001$, $\eta^2 = .19$. Contrary to predictions, a main effect of Condition $F(3, 177) = 13.53$, $p < .001$, $\eta^2 = .18$ did not show any differences in memory performance between the increase and decrease conditions; however memory for stimuli in the maintain neutral condition was better than that of the decrease unpleasant $t(61) = -4.19$, $p < .001$, increase unpleasant $t(61) = -3.79$, $p < .001$, and maintain unpleasant $t(61) = -3.45$, $p = .001$ conditions (Figure 3.10).

As predicted, there was a significant interaction between Condition and Age $F(1,59) = 3.98$, $p = .05$, $\eta^2 = .06$ (Figure 3.10). Post-hoc independent t-tests demonstrated that younger adults remembered more stimuli than older adults in the maintain unpleasant $t(25.66) = 2.80$, $p = .009$, decrease unpleasant $t(26.62) = 2.98$, $p = .006$, and increase unpleasant $t(27.11) = 3.14$, $p = .004$ conditions. Post-hoc paired t-tests revealed that younger adults remembered more stimuli in the maintain neutral condition as compared to the decrease unpleasant condition $t(38) = -2.18$, $p = .03$. Older adults, however, had better memory for the maintain neutral condition versus all three unpleasant conditions [increase: $t(21) = -4.26$, $p < .001$, decrease: $t(21) = -3.91$, $p = .001$, maintain: $t(21) = -4.04$, $p = .001$]. No other significant effects or interaction effects emerged.

3.4.5.2 Pleasant

A 4(Condition: pleasant increase, pleasant decrease, maintain pleasant, maintain neutral) X 2(Age: young, old) repeated measures ANOVA revealed a main effect of Condition $F(3,177) = 21.72$, $p < .001$, $\eta^2 = .26$, such that stimuli in the maintain neutral condition were remembered more frequently than those in the increase [$t(61) = -6.97$, $p < .001$], decrease conditions [$t(61) = -6.31$, $p < .001$], and maintain pleasant [$t(61) = -6.81$, $p < .001$] conditions (Figure 3.11). Similar to the previous analyses with unpleasant stimuli in the reappraisal task, younger adults remember more stimuli as compared to older adults $F(1,59) = 6.86$, $p = .01$, $\eta^2 = .10$.

Though an expected interaction between Condition and Age $F(3,177) = 2.82$, $p = .04$, $\eta^2 = .04$ emerged, paired post-hoc t-tests were contrary to predictions where both younger [both $t's(38) > 3.83$, $p's < .001$] and older [both $t's(21) > 4.35$, $p's < .001$] adults remembered more stimuli in the maintain neutral condition versus the increase, decrease, and maintain pleasant conditions (Figure 3.11). In addition, post-hoc independent t-tests showed that younger adults remembered more stimuli in the decrease $t(59) = 2.97$, $p = .004$ and increase $t(59) = 2.23$, $p = .02$ conditions, as compared to the older adults.

3.4.6 Directed Attention and Memory

Similar to the reappraisal and memory analyses, two repeated measures ANOVAs were conducted to **test whether the hypothesis that younger adults would show greater memory for unpleasant stimuli with arousing versus non-arousing foci**. **Within the directed**

attention task, it was expected that younger adults would have greater memory for unpleasant stimuli and older adults for pleasant stimuli. Overall, stimuli shown with an arousing focus should be remember more often than those with a non-arousing focus.

3.4.6.1. Unpleasant

As predicted, the 3(Focus: unpleasant arousing, unpleasant non-arousing, neutral non-arousing) X 2(Age: younger, older) repeated measure ANOVA showed a main effect of Focus [$F(2,132) = 14.57$, $p < .001$, $\eta^2 = .18$] (Figure 3.12), such that arousing stimuli were remembered more than stimuli with an unpleasant non-arousing focus [$t(68) = 2.67$, $p = .009$]. Additionally, neutral non-arousing focus stimuli were remembered better than the unpleasant arousing [$t(68) = 2.89$, $p = .005$] and unpleasant non-arousing focus [$t(68) = 4.44$, $p < .001$].

An expected interaction between Focus and Age [$F(2,132) = 3.93$, $p = .02$, $\eta^2 = .05$] occurred, where younger adults did demonstrate better memory performance for unpleasant stimuli: memory was best for unpleasant arousing [$t(66) = 2.54$, $p = .01$] and unpleasant non-arousing stimuli [$t(66) = 3.10$, $p = .003$] than older adults (Figure 3.12). Post-hoc paired t-tests also showed that younger and older [both *t's*(22) > 2.38, *p's* < .03] adults had better memory for stimuli in the neutral non-arousing focus condition versus the unpleasant arousing [younger at the level of a trend: [$t(44) = 1.72$, $p = .09$] and unpleasant non-arousing [younger: $t(44) = 2.58$, $p = .003$] focus conditions. Overall, however, younger adults remembered more stimuli than the older adults [$F(1,59) = 8.24$, $p = .005$, $\eta^2 = .11$].

3.4.6.2 Pleasant

As predicted a 3(Focus: arousing, non-arousing, neutral non-arousing) X 2(Age: young, old) repeated measures ANOVA revealed a main effect of Focus [$F(2,132) = 22.74$, $p < .001$, $\eta^2 = .25$] (Figure 3.13) such that stimuli in the pleasant arousing condition were remembered more than those in the pleasant non-arousing condition [$t(68) = 2.11$, $p = .03$]. Additionally, neutral non-arousing stimuli were remembered more than the pleasant arousing and pleasant non-arousing conditions [both $ts(68) > 3.28$, $ps < .003$].

A Focus by Age interaction [$F(2,132) = 9.92$, $p < .001$, $\eta^2 = .13$] (post-hoc independent t-tests) showed that contrary to predictions younger versus older adults remembered more stimuli in the pleasant arousing [$t(27.09) = 3.12$, $p = .004$] and pleasant non-arousing [$t(31.98) = 3.60$, $p = .001$] conditions (Figure 3.13). Older and younger adults did not differ, however, in memory performance for neutral non-arousing stimuli. In addition, paired post-hoc t-tests showed that younger [$t(44) = 2.89$, $p = .006$] and older [$t(22) = 4.49$, $p < .001$] adults remembered more neutral non-arousing stimuli than pleasant non-arousing stimuli. Older adults also had better memory for stimuli in the neutral non-arousing condition as compared to the pleasant arousing [$t(22) = 3.38$, $p = .003$]. Younger adults again showed better memory performance overall as compared to older adults {$F(1,59) = 14.22$, $p < .001$, $\eta^2 = .17$]. No other significant effects occurred.

3.4.7 LPP and Memory.

The third goal of the present study was to examine relations between the LPP in the context of each ER task and memory performance**. Pearson correlations were conducted to examine whether larger LPP amplitudes (increased attention and processing) would be associated with better memory performance.** As it was expected that younger and older adults may differ in how the LPP may be related to memory performance, correlations were conducted on the sample as a whole, as well as for younger and older adults separately. As effects within the LPP analyses were conducted using difference scores, the same was done for the associations between the LPP and memory performance. Tables 3.3 (reappraisal) and 3.4 (directed attention) present correlations between LPP difference scores and memory performance for the sample as a whole, younger adults, and older adults.

3.4.7.1 Reappraisal LPP and memory

As predicted, larger LPP amplitudes to unpleasant stimuli in the decrease condition relative to the maintain neutral condition were associated with better memory performance for the sample as a whole (all three windows), younger adults (all three windows) and older adults (early and middle windows). Contrary to predictions there were no associations between memory performance and LPP difference scores in the increase condition. No other significant correlations emerged (Table 3.3).

3.4.7.2 Directed Attention LPP and Memory

No significant correlations between LPP difference scores in the directed attention task and memory performance occurred (Table 3.4).

3.5 Discussion

The present study is among the first to examine age differences using the LPP during cognitive ER and the first to do so within multiple cognitive ER tasks. Consistent with predictions younger adults were successful in reducing LPP amplitudes in the directed attention task when unpleasant stimuli were shown with a non-arousing versus arousing focus. Though older adults did not show the same distinction, expected patterns in the LPP where amplitudes were larger to arousing versus non-arousing foci (relative to a neutral non-arousing focus) did occur for the sample as a whole. Anticipated changes in LPP amplitudes during the reappraisal task did emerge such that LPP amplitudes were larger in the increase versus decrease and maintain conditions (relative to a neutral maintain condition). However, contrary to predictions age differences in LPP amplitudes did not emerge in the reappraisal task. Despite a lack of differences in the LPP between younger and older adults in the reappraisal task, results are consistent with the one previous aging study using a similar reappraisal paradigm (Langeslag & van Strien, 2010). Though no differences in memory performance were found between age groups or as a function of regulation in the reappraisal task, stimuli shown with arousing foci were remembered more than those shown with valence non-arousing foci. Taken together, results are suggestive that younger and older adults may not differ in using cognitive reappraisal, but other types of cognitive ER strategies like attentional focusing could be where these two age groups differ in how they regulate emotion.

Previous research has consistently demonstrated that LPP amplitudes can be modulated with instructions to increase and decrease subjective emotional responses (e.g. Hajcak and Nieuwenhuis, 2006; Moser et al., 2006, 2009; Krompinger et al., 2008) in younger adults. The vast majority of this research has examined the LPP in relation to these instructions using unpleasant stimuli, with the exception of one study that used pleasant stimuli (Krompinger et al., 2008). Findings of the present study compliment those of Langeslag and van Strien (2010) in that age differences in LPP amplitudes did not occur between regulatory and valence conditions. In addition, we documented that LPP amplitudes were larger in the increase versus decrease and maintain conditions relative to the neutral maintain condition, also similar to Langeslag and van Strien (2010). The effects of reappraisal condition in this study within the reappraisal task were most robust within the early window (300 – 800 ms), a similar time window as other child (DeCicco et al., under review) and aging LPP research (Langeslag & van Strien, 2010). Taken together, results of the present study in conjunction with previous research, suggest that younger and older adults may not differ in how they use cognitive reappraisal to change LPP amplitudes and that this type of strategy may not be impacted by age. This is contradictory to what would be predicted by SST in that reappraisal requires cognitive control, a top-down processing task (Schiebe & Carstensen, 2010), a task that is predicted to show differences attentional preference towards pleasant stimuli between younger and older adults. In other words, motivational goals of focusing more on positive emotion and reducing negative emotion should be most apparent in this type of task in older adults.

Results within the directed attention task were expected to show age differences as SST suggests that younger adults are less likely to have the same motivational goals as older adults. Thus, younger adults may benefit more from the use of attentional focusing as compared to reappraisal. Overall, in the sample as a whole, findings were similar to that of previous studies that use attentional focusing to arousing and non-arousing areas of unpleasant stimuli (Dunning & Hajcak, 2009), such that LPP amplitudes were larger to arousing versus non-arousing stimuli (relative to the neutral non-arousing condition). As predicted, differences did emerge between younger and older adults within the unpleasant stimuli: younger showed larger LPP amplitudes to unpleasant arousing versus unpleasant non-arousing stimuli, but older adults did not show the same pattern in the LPP. In particular, older versus younger adults displayed larger LPP amplitudes to the unpleasant non-arousing condition, as compared to younger adults within early and middle windows. Findings from the directed attention task are suggestive that older adults perhaps do not use this type of cognitive ER strategy as frequently or in the same way as younger adults.

Overall, within the directed attention task, it appears that younger adults are adept in using attentional focusing to reduce negative emotion (e.g. reduced LPP amplitudes to unpleasant non-arousing versus arousing foci and lack of differences for older adults). However, results also suggest that older adults may be less flexible or not as capable of using attentional focusing as a cognitive ER strategy as their younger counterparts. For example, dot probe paradigms have demonstrated that older adults are slower to disengage from negative, but not positive facial stimuli and react to the location of a dot (Mather & Carstensen, 2003). Older adults also appear to activate prefrontal and amygdala regions in accordance with SST to reduce negative emotion in paradigms that combine both reappraisal and directed attention (van Reekum et al., 2007). Thus, results are suggestive that younger and older adults may differ in how they use bottom-up cognitive ER strategies, particularly in shifting attention away from arousing areas of unpleasant stimuli. Taken together with results from the reappraisal task, findings suggest that younger adults may be more likely to use attentional focusing as a successful cognitive ER strategy, whereas older adults could rely upon other ER strategies (e.g. situation selection, situation modification, cognitive reappraisal, or response modification). This provides some support for SST in that, as we age and improve upon our regulatory strategies with experience, we may engage more elaborate ways of regulating emotion, such as reappraisal. Attentional deployment on the other hand, may be a more useful strategy for younger adults as they are still undergoing prefrontal cortex development through emerging adulthood (Gogtay et al., 2004), a region of the brain known to facilitate successful cognitive ER.

In relation to subjective arousal ratings, expected outcomes as a function of condition occurred where arousing foci produced greater arousal ratings as compared to the valenced non-arousing and neutral non-arousing foci for both pleasant and unpleasant stimuli. Interestingly, older adults rated stimuli in the unpleasant arousing condition as more arousing than younger adults. Age differences in the rating of unpleasant stimuli were similar to that of the directed attention task, where older adults rated stimuli in each of the unpleasant regulatory conditions (increase, decrease, and maintain) as more arousing than younger adults. These findings with higher ratings of subjective arousal among unpleasant stimuli in older adults is consistent with previous work (Gavazzeni, Weins, & Fischer, 2005; Mather et al., 2004). No other age differences occurred in the rating of arousal for the cognitive reappraisal task; however ratings for pleasant and unpleasant stimuli occurred as expected such that for pleasant and unpleasant stimuli the increase condition produced the greatest arousal ratings, followed by the maintain valence, decrease, and maintain neutral conditions. Taken together with the LPP results, findings are suggestive that older adults show dissociation between brain and behavioral responses to unpleasant stimuli, where LPP amplitudes during the directed attention task did not differ between the unpleasant arousing and unpleasant non-arousing conditions, but did show expected modualtory effects in terms of subjective ratings.

SST in combination with the positivity effect and top-down hypotheses would suggest that older adults should differ in memory performance in the context of a reappraisal task, as we should improve in regulatory ability with age. However, some suggest that these effects may only occur among low arousing stimuli (Schiebe & Carstensen, 2010). In general, a variety of behavioral studies have shown that older adults remember more pleasant stimuli and younger adults more unpleasant stimuli (Charles, Mather, & Carstensen, 2003; Fernandes et al., 2008; Comblain et al., 2005). Within the reappraisal task expected effects of regulation with the increase condition producing better memory performance than the decrease condition did not occur for pleasant or unpleasant stimuli. Moreover, predictions related to regulation and age also did not emerge. Interestingly, younger and older adults showed better memory performance for stimuli that were shown in the maintain neutral condition relative to the regulation conditions (e.g. increase and decrease). Some support for the positivity effect occurred within the unpleasant stimuli of the reappraisal task, where younger adults had better memory for stimuli shown in the maintain unpleasant, decrease unpleasant, and increase unpleasant conditions, as compared to older adults. Though younger adults tend to remember more stimuli than older adults in general (Charles, Mather, & Carstensen, 2003), younger adults in the present study also had better memory overall for pleasant stimuli in the reappraisal task versus older adults. Though we did not find age differences in memory performance, other studies have also found no age difference sin emotional memory (Denburg, Buchanan, Tranel, & Adolphs, 2003). It is possible, however, that there were too many pleasant and unpleasant stimuli and too few neutral stimuli, giving both younger and older adults an advantage over remembering the neutral versus emotional stimuli.

Regulatory effects on memory performance did occur as expected in the directed attention task, were pleasant and unpleasant stimuli that were presented with an arousing focus were remembered more than those with a pleasant and unpleasant non-arousing focus. Similar to effects in the reappraisal task, neutral stimuli were remembered more than those in the unpleasant arousing, unpleasant non-arousing, pleasant arousing, and pleasant non-arousing conditions. This again could be a result of less neutral stimuli that were shown as compared to the unpleasant and pleasant stimuli in the directed attention task. Other age effects in the directed attention task suggested that although there was a significant interaction between Focus and Age, that this could have been due to the fact that younger adults remembered more stimuli (both pleasant and unpleasant) as compared to older adults. Younger adults remembered more unpleasant stimuli (both arousing and non-arousing) as compared to older adults, but both age groups remembered more neutral stimuli versus the two unpleasant directed attention foci. Contrary to predictions older adults did not remember more pleasant stimuli than younger adults. Instead younger adults remembered more in the pleasant arousing versus pleasant non-arousing conditions. Older adults only differed in memory performance for pleasant non-arousing stimuli, where their performance was worse as compared to the neutral stimuli. Behavioral memory results from the directed attention task provide further support that younger adults may be more adept and likely to be using attentional focusing as cognitive ER strategy. Despite some age differences in memory performance in the directed attention task, it is possible that neutral stimuli were remembered more frequently as there were fewer neutral stimuli (50 total between both experiments) as compared to the valence stimuli (125 pleasant and 125 unpleasant).

Few relations between LPP amplitudes and memory performance occurred for either the reappraisal or directed attention tasks. Consistent with predictions larger LPP amplitudes to stimuli in the decrease unpleasant (relative to the neutral maintain) condition were associated with better memory performance for stimuli shown in that condition. Though we expected that larger LPP amplitudes in the increase condition would be associated with better memory as well, no significant associations occurred. Results of the present study are consistent with those of the previous LPP and aging study linking larger LPP amplitudes to better memory performance in older adults (Langeslag & van Strien, 2009).

A few limitations and methodological differences should be considered when interpreting results. It is important to note that the methodology of the reappraisal task in this study differs from previous research in a few key areas. First, the present study utilized additional baseline conditions for the reappraisal task that consisted of pleasant and unpleasant stimuli presented with a maintain instruction. The primary purpose of these additional conditions was to observe whether younger and older adults were able to effectively reduce the LPP beyond this baseline valence condition, as compared a true neutral condition. By using difference scores (e.g. increase unpleasant – neutral maintain), we were able to control for individual differences in terms of basic visual processing of neutral stimuli, as previous research has also found that older and younger adults tend to differ in the magnitude of the LPP (Wood & Kisley, 2006). Second, though blocks were randomly chosen, pleasant and unpleasant stimuli were mixed within a given block (increase, decrease, maintain). This design was chosen as a way to examine the conditions under which preferential attention towards a particular type of stimulus would occur, as suggested by SST and the positivity effect. Therefore, we felt this type of design would allow a true preference in attention towards or ability to regulate emotion to a particular type of stimulus to occur, as compared to a more stringent block design. However, this mixed design could have also limited our ability to detect differences between pleasant and unpleasant stimuli. Third, the stimuli chosen for the present study have been shown to produce large to moderate LPP amplitudes (Weinberg & Hajcak, 2010). The pleasant (erotic and affiliative) and unpleasant (mutilation and threat) stimuli were chosen for this study as other types of pleasant (exciting) and unpleasant (disgusting) stimuli generate smaller LPP amplitudes (Weinberg & Hajcak, 2010). It is possible, however, that erotic stimuli may have been aversive for older adults, and limited our ability to detect preferences in attention to pleasant stimuli in the LPP. Fourth, stimuli in this study were presented for 1000 ms longer than previous LPP and aging studies (Langeslag & van Strien 2009; 2010; Wood & Kisley, 2006; Kisley et al., 2007). This type of stimulus presentation afforded the opportunity to analyze multiple stages of processing rather than rapid processing of emotional information. Although the present study differed methodologically from designs of previous aging (Langeslag & van Strien, 2010) and younger adult literature (e.g. Hajcak & Nieuwenhuis, 2006; Krompinger et al., 2008; Moser et al., 2006; 2009), we were still able to demonstrate modulation of the LPP, where amplitudes were larger in the increase versus decrease and maintain (valence) conditions relative to a neutral maintain condition. More importantly, despite these methodological differences in block presentation, they still demonstrated a lack of age effects and overall effect of regulation via the increase condition, as seen in Langeslag and van Strien (2010).

In sum, results of the present study are consistent with those of previous aging and LPP studies (Langeslag & van Strien, 2010) where age differences did not emerge within the reappraisal task. Additionally, differences that have been documented within age groups in previous LPP research have done so within less complex designs (e.g. passive viewing and passive viewing with valence categorization; Wood & Kisley, 2006; Kisley et al., 2007; Langeslag & van Strien, 2009). Taken together, results from the reappraisal and directed attention tasks suggest that younger adults may be more likely to employ attentional focusing as a regulatory strategy. The present study did not find evidence to support the top-down hypothesis that older adults show a greater ability to reduce LPP amplitudes to unpleasant stimuli on the reappraisal task (e.g. a task requiring cognitive control). Results do suggest that younger and older adults may differ in the use of a somewhat intermediary top-down cognitive ER task like attentional deployment. For example, a few passive viewing paradigms have documented age differences in the LPP (Kisley & Wood, 2006; Kisley et al., 2007; Langeslag & van Strien, 2009), but not in the context of a reappraisal task (Langeslag & van Strien, 2010). To determine whether age differences are isolated to intermediary top-down tasks, future studies should examine the LPP during a combined reappraisal and directed attention task, in conjunction with eye tracking technology to determine if age differences emerge, as seen in the fMRI literature (Optiz et al., 2012; van Reekum et al., 2007).

In addition, future research should also examine other ER strategies. For example, recent aging and ER theory has also suggested that preliminary stages of emotional processing may be where younger and older adults differ the most (Urry & Gross, 2010). The selective optimization and compensation and emotion regulation (SOC-ER) model suggests that older adults may engage more in situation selection as a strategy to compensate for a decline in cognitive function, particularly executive function related to prefrontal cortices (Urry & Gross, 2010). Younger adults, however, may use reappraisal more frequently and situation selection less frequently (Urry & Gross, 2010) as they have the cognitive resources to effectively regulate emotion. fMRI studies have been to disentangle the conditions under which younger and older adults differ in implementing reappraisal strategies; however it is also a possibility that older adults may use compensatory mechanisms (Urry & Gross, 2010; Blates & Blates, 1990) to perform the same tasks by activating other cortical networks (Gunning-Dixon et al., 2003; Tessitore et al., 2005). The SOC-ER model does suggest that a reduction in cognitive control could partially account for age-related differences in cognitive reappraisal. Thus, the SOC-ER model may be a good candidate to test top-down hypotheses. Although results of the present study do not provide support for SST or the positivity effect, and are contradictory to the top-down/bottom-up hypotheses, they do suggest that younger and older adults may differ in the types of cognitive ER strategies they may employ.

Table 3.1 Descriptive statistics for the cognitive reappraisal ask, mean LPP amplitudes for younger and older adults, as well as the sample as a whole.

		Young n = 40			Old n = 26			Total N = 66		
	Window	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
Condition										
Maintain	Unpleasant	3.78(3.46)	2.49(3.19)	-0.96(3.80)	4.35(3.44)	2.51(4.10)	0.68(5.44)	4.01(3.45)	2.50(3.55)	-0.32(4.55)
	Pleasant	4.82(4.05)	2.84(4.47)	-0.37(4.10)	4.12(4.12)	2.26(5.24)	0.01(5.75)	4.55(4.06)	2.61(4.76)	-0.22(4.87)
	Neutral	2.77(4.14)	1.34(4.32)	-1.16(4.79)	2.34(3.14)	0.19(2.61)	-1.23(3.69)	2.60(3.76)	0.89(3.76)	-1.19(4.36)
Increase	Unpleasant	4.97(3.57)	3.34(4.09)	0.34(5.52)	4.53(3.39)	2.50(4.22)	0.90(5.20)	4.80(3.48)	3.01(4.13)	0.56(5.36)
	Pleasant	5.74(4.27)	3.72(4.84)	0.90(5.37)	4.73(3.92)	2.50(4.19)	0.55(5.91)	5.34(4.14)	3.24(4.60)	0.76(5.55)
Decrease	Unpleasant	4.69(4.81)	3.17(4.40)	0.15(4.40)	3.42(3.60)	1.36(3.59)	-0.87(4.41)	4.19(4.39)	2.46(4.17)	-0.24(4.40)
	Pleasant	4.68(3.41)	3.13(3.70)	0.51(4.83)	4.33(3.10)	2.13(2.84)	0.28(3.60)	4.54(3.27)	2.74(3.40)	0.42(4.36)

Note: Standard deviations presented in parentheses. Units are in μV.

Table 3.2 Descriptive statistics for the directed attention task mean LPP amplitudes for younger and older adults, as well as the sample as a whole.

		Young n = 39			Old n = 22			Total N = 61		
	Window	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
Focus										
Arousing	Unpleasant	3.63(3.30)	0.14(3.56)	-2.75(4.51)	2.39(3.33)	1.21(3.58)	-0.66(4.06)	3.18(3.34)	0.52(3.56)	-2.00(4.44)
	Pleasant	3.80(3.33)	0.07(3.45)	-2.81(4.31)	3.51(2.99)	1.29(3.47)	0.10(3.72)	3.70(3.19)	0.51(3.48)	-1.76(4.31)
Non-Arousing	Unpleasant	1.51(3.34)	-2.56(3.58)	-4.72(4.73)	3.16(3.38)	0.99(3.23)	-0.24(3.66)	2.10(3.42)	-1.28(3.84)	-3.11(4.85)
	Pleasant	2.60(3.21)	-1.27(3.11)	-3.25(4.01)	2.69(2.79)	1.37(2.83)	-0.13(2.81)	2.63(3.04)	-0.32(3.25)	-2.12(3.90)
	Neutral	1.28(3.87)	-2.47(4.37)	-3.64(4.85)	1.19(3.60)	-1.37(3.35)	-2.00(3.50)	1.25(3.74)	-2.07(4.04)	-3.05(4.45)

Note: Standard deviations presented in parentheses. Units are in μV.

Table 3.3 Correlations between LPP difference scores in the cognitive reappraisal task and memory performance.

		Young n = 36			Old n = 20			Total N = 56		
	Window	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
Condition										
Increase	Unpleasant – Maintain Neutral	.09	.18	.04	.01	.36	.14	.16	.17	.002
	Pleasant- Maintain Neutral	-.03	-.05	.007	-.36	-.37	-.40	.17	.03	-.12
Decrease	Unpleasant- Maintain Neutral	.41*	.49*	.39*	.50*	.44*	.35	.33*	.32*	.24†
	Pleasant – Maintain Neutral	-.20	.006	.012	-.40	.05	-.27	-.02	.20	.08

*$p < .05$, † $p = .06$

Table 3.4 Correlations between LPP difference scores in the directed attention task and memory performance. There were no significant correlations.

		Young n = 36			Old n =23			Total N = 54		
	Window	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late
Focus										
Arousing	Unpleasant-Neutral	.10	-.01	-.18	.18	.01	.14	.17	.003	.06
	Pleasant-Neutral	.13	.006	-.07	.25	-.23	-.02	.18	-.07	-.09
Non-Arousing	Unpleasant-Neutral	-.004	-.11	.04	.08	-.02	-.03	-.05	-.16	-.07
	Pleasant-Neutral	.04	.07	.01	.08	-.14	.10	.04	-.09	-.02

Figure 3.1 Trial sequence for the cognitive emotion regulation task.

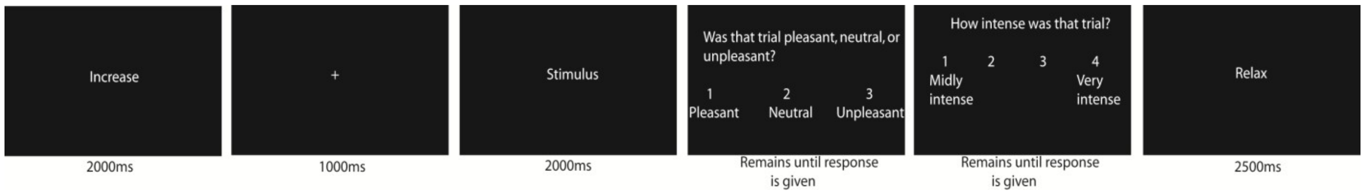


Figure 3.2 Trial sequence for the directed attention task.

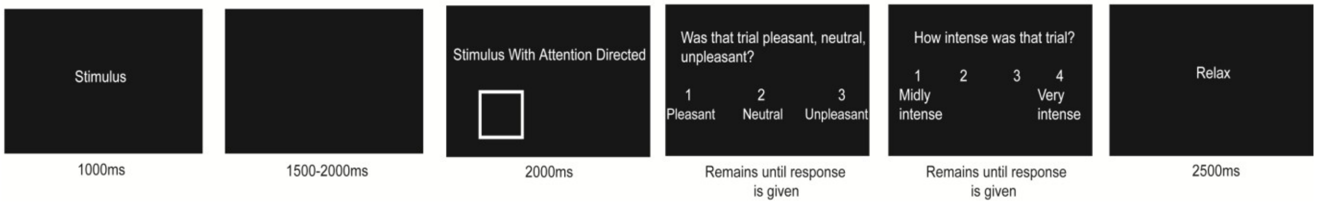


Figure 3.3 Visual depiction of mean LPP amplitudes for the cognitive reappraisal task for young and old adults.

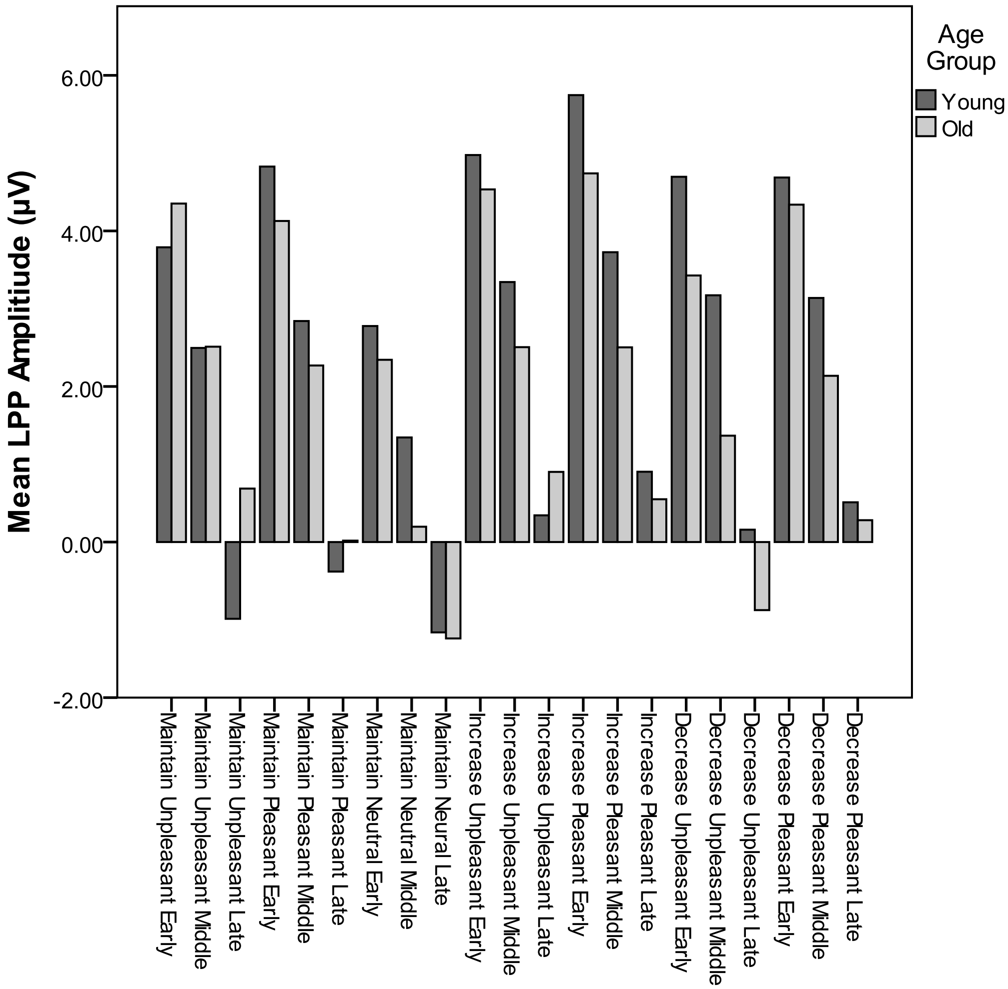


Figure 3.4 Visual depiction of mean LPP amplitudes for the cognitive reappraisal task for the sample as a whole.

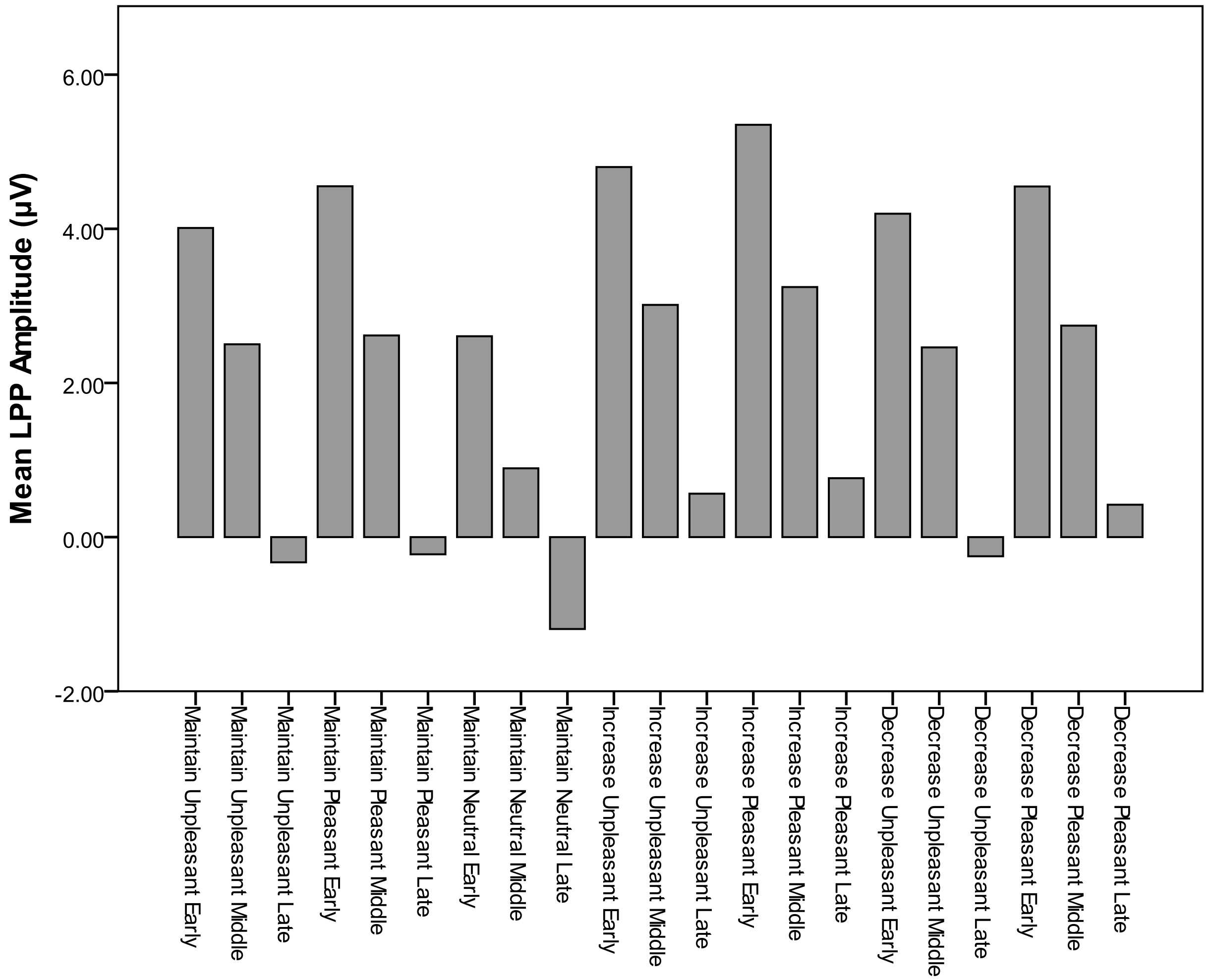


Figure 3.5 Visual depiction of mean LPP amplitudes in the directed attention task for younger and older adults.

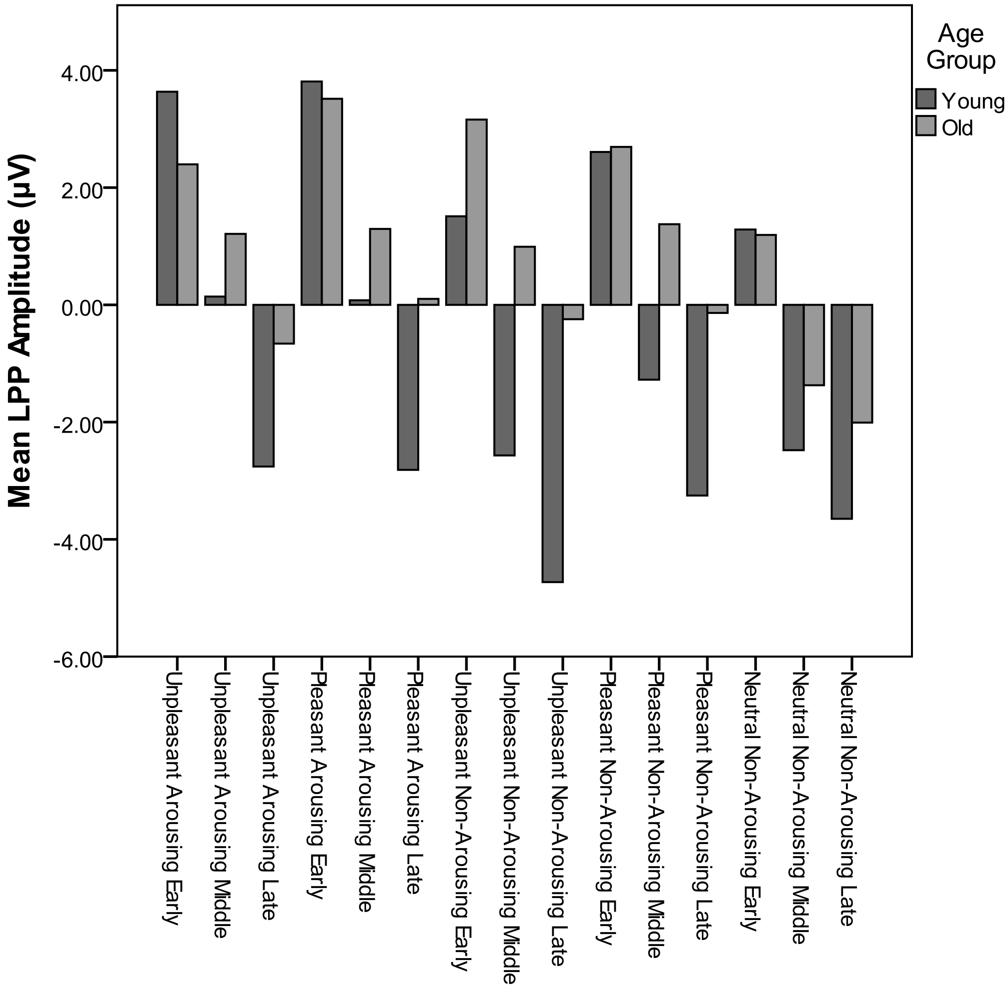


Figure 3.6 Visual Depiction of mean LPP amplitudes in the directed attention task for the sample as a whole.

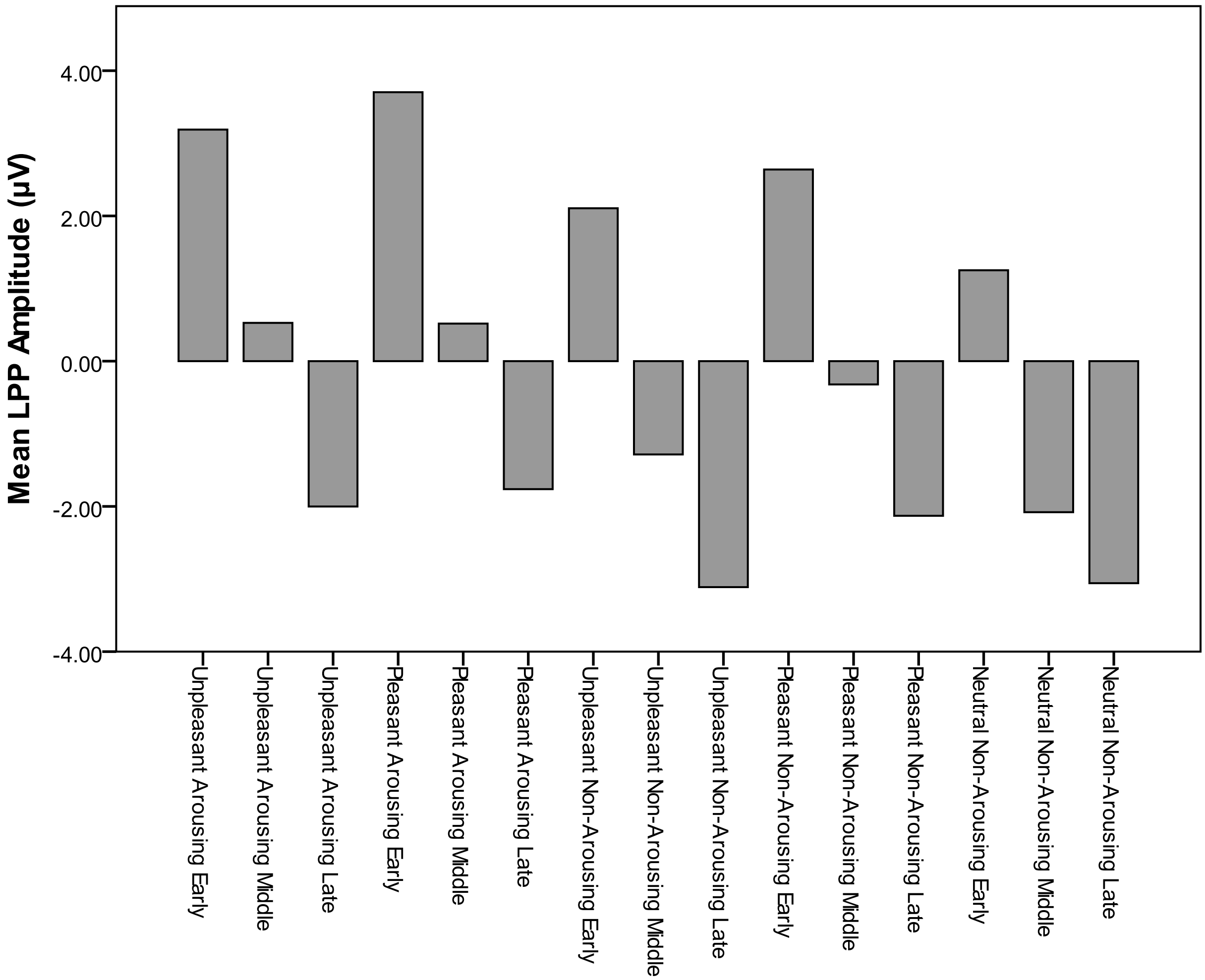


Figure 3.7 Mean LPP difference scores for the increase – maintain neutral, decrease - maintain neutral, and maintain valence - maintain neutral conditions. LPP amplitudes were larger for the increase versus decrease and maintain conditions within the early window.

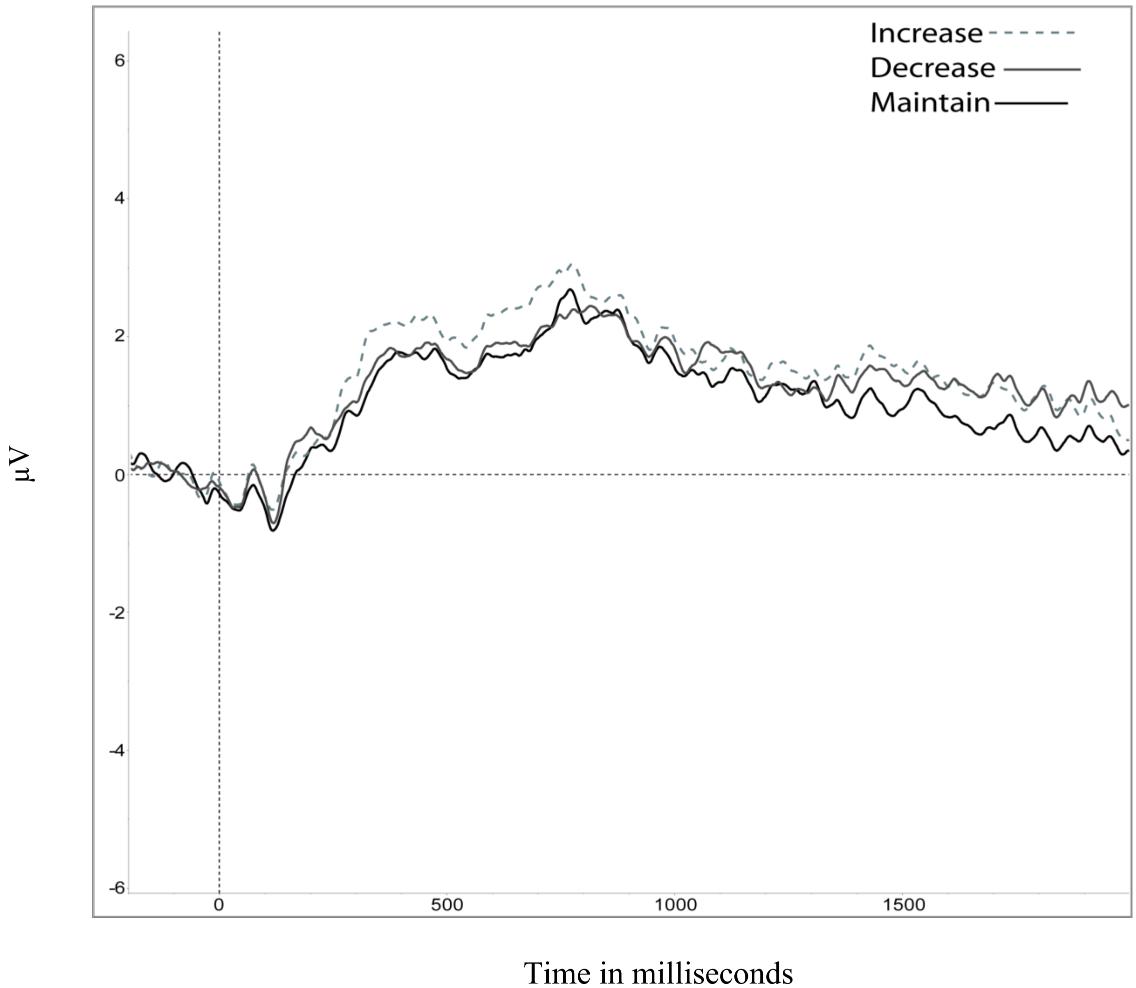


Figure 3.8 Mean LPP difference scores comparing the arousing – neutral non-arousing and non-arousing valence – neutral non-arousing conditions. LPP amplitudes were larger in the arousing versus non-arousing condition.

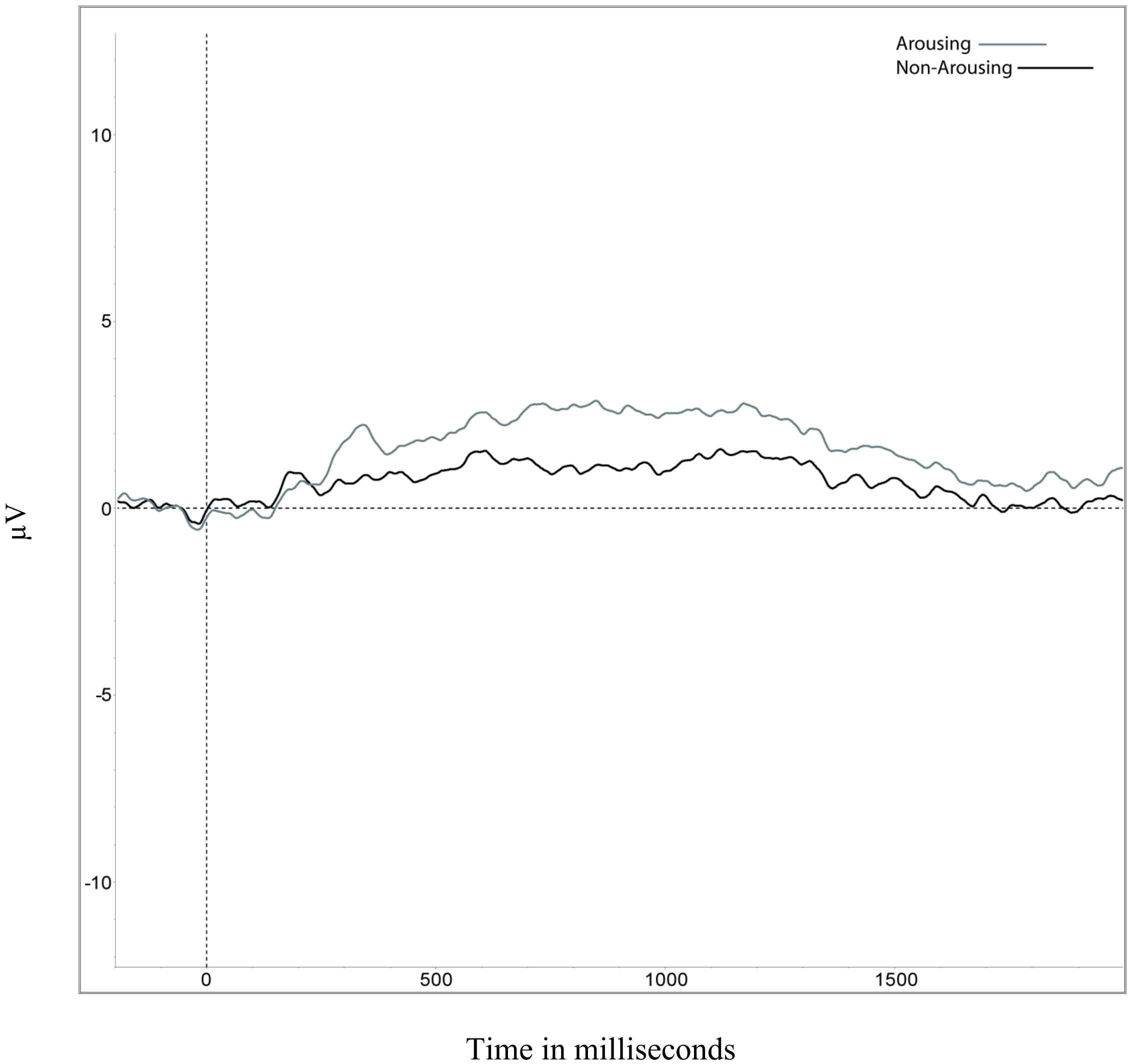


Figure 3.9 Mean LPP difference waves comparing unpleasant arousing – neutral non-arousing and unpleasant non-arousing – neutral non-arousing conditions between younger and older adults. Younger, but not older adults showed larger amplitudes to the arousing versus non-arousing focus.

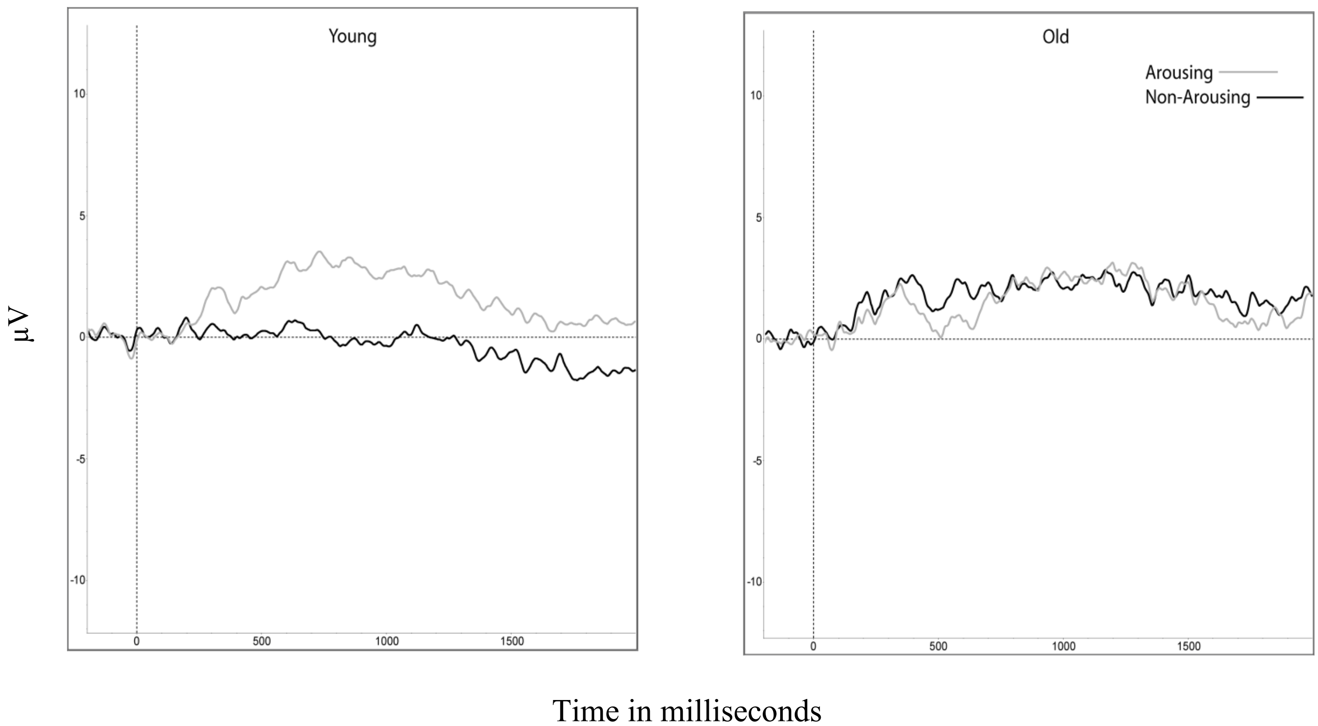
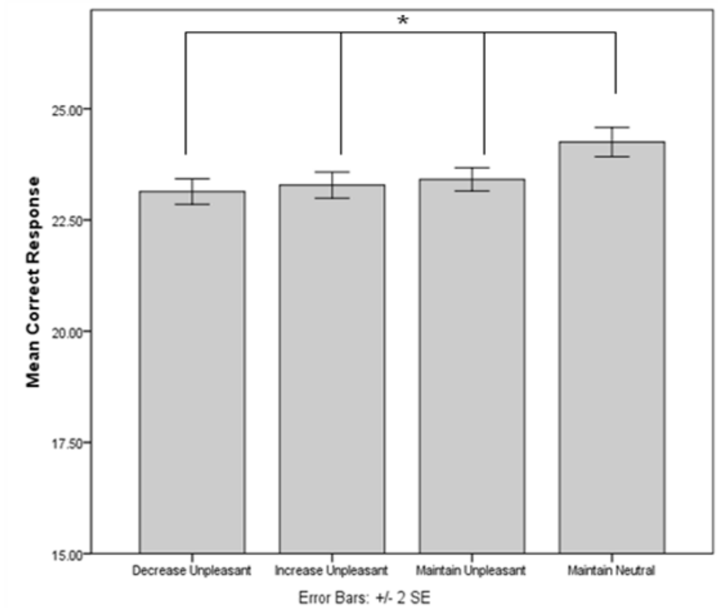


Figure 3.10 Effects of reappraisal condition on memory performance for unpleasant stimuli. Panel a: Neutral stimuli were remembered more than all unpleasant stimuli. Panel b: Younger adults have better memory overall as compared to older adults and neutral stimuli were remembered better than unpleasant stimuli.

a.



b.

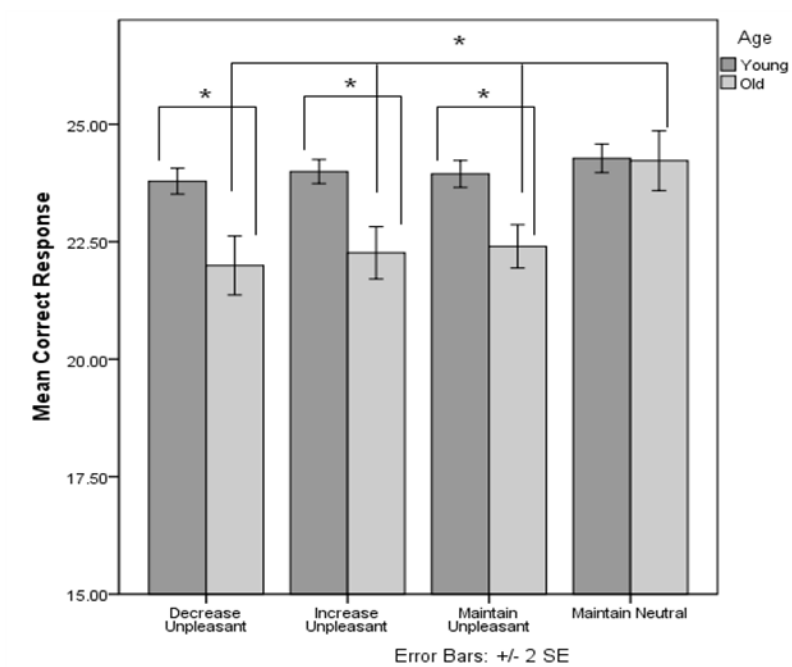
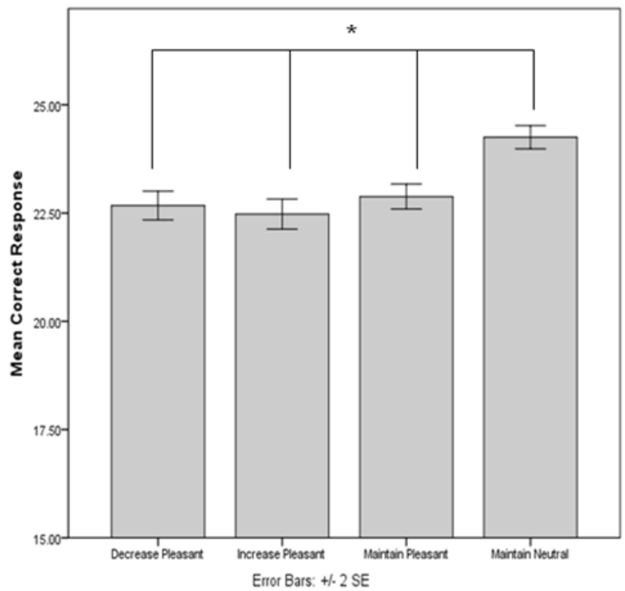


Figure 3.11 Effects of reappraisal condition on memory performance for pleasant stimuli. Panel a: Neutral stimuli were remembered more than all pleasant stimuli. Panel b: Younger adults have better memory overall as compared to older adults and neutral stimuli were remembered better than pleasant stimuli.

a.



b.

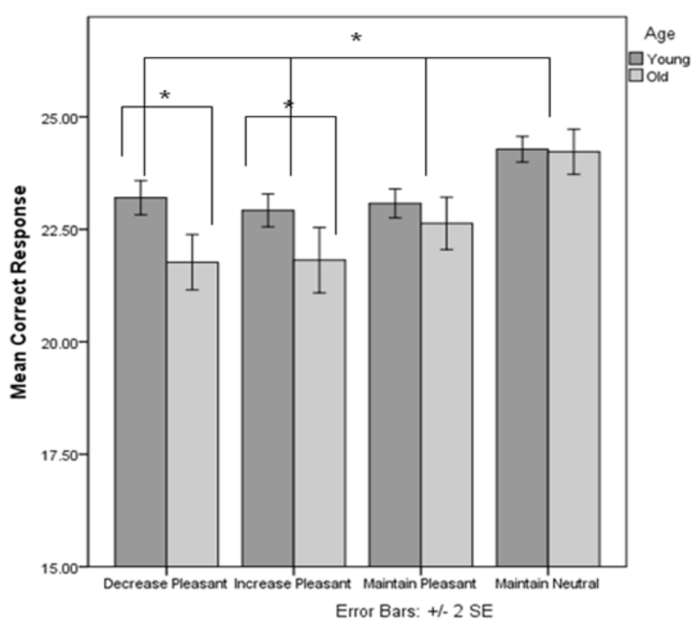
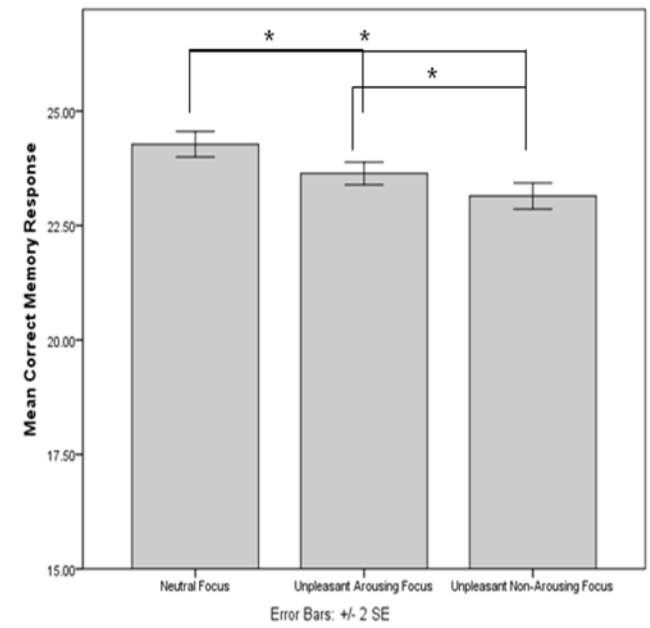


Figure 3.12 Effects of attentional gaze condition on memory performance for unpleasant stimuli. Panel a: Neutral stimuli were remembered more often than both unpleasant conditions; however the arousing condition produced better memory than the non-arousing unpleasant condition. Panel b: Younger adults have better memory for unpleasant stimuli as compared to older adults.

a.



b.

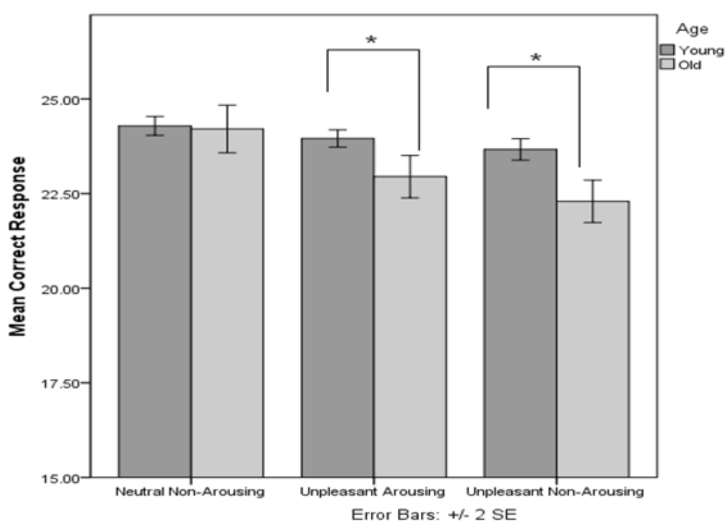
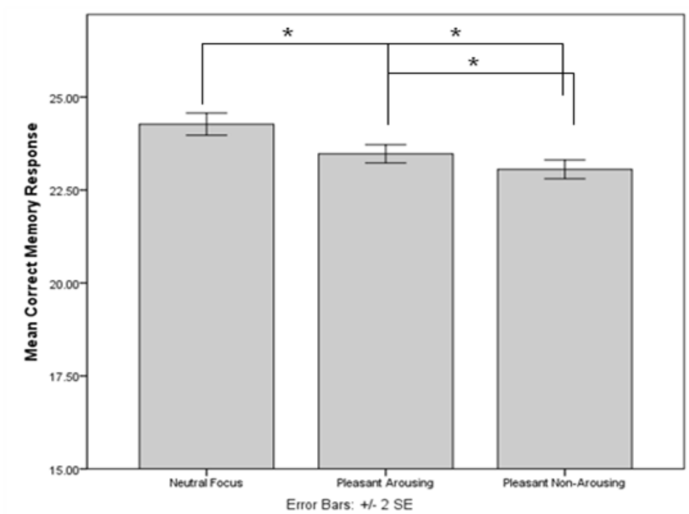
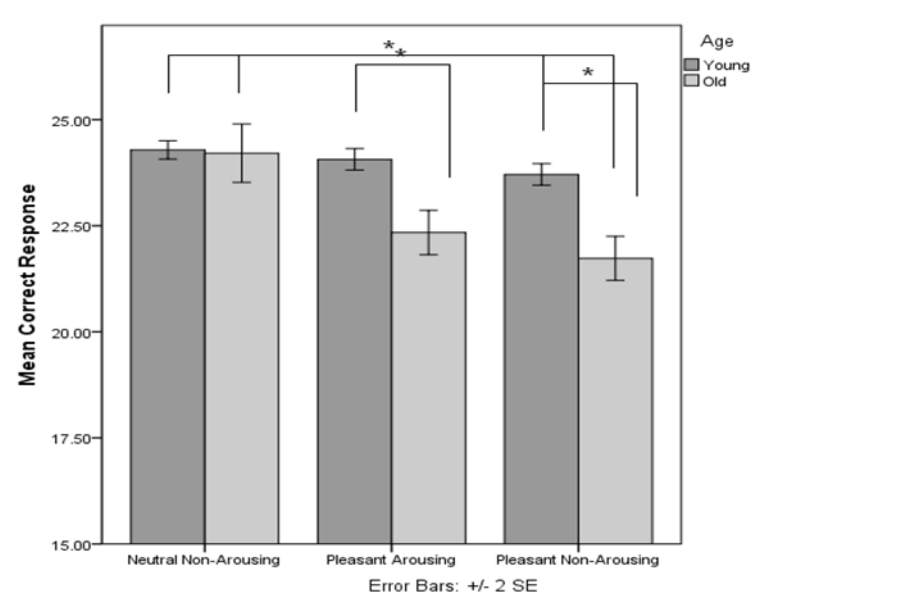


Figure 3.13 Effects of attentional gaze condition on memory performance for pleasant stimuli. Panel a: Neutral stimuli were remembered more often than both pleasant conditions; however the arousing condition produced better memory than the non-arousing pleasant condition. Panel b: Younger adults have better memory for pleasant stimuli as compared to older adults. Neutral stimuli were remembered better

a.



b.



GENERAL DISCUSSION

Two models of aging and ER informed the studies reported above, SST (Carstensen et al., 1999) and the SOC-ER (Urry & Gross, 2010) models. SST suggests that as we age we improve in our ability to reduce negative emotion (via reappraisal) and show a preferential focus on positive emotion, the positivity effect, (Carstensen et al., 1999); whereas the SOC-ER model proposes that control processes stemming from the prefrontal cortex are reduced with age, thus we tend to use other strategies to compensate for this loss (Urry & Gross, 2010). Using the LPP as a temporally sensitive measure of emotional processing and cognitive ER, we found mixed support for these hypotheses. The present research capitalizes on the excellent temporal resolution of ERPs and the sensitivity of the LPP to emotion and ER (e.g. Cuthbert et al., 2000; Hajcak & Nieuwenhuis, 2006), a target measure of attention to emotion. As few studies have examined extreme ends of the developmental continuum (e.g. DeCicco et al., 2012; Solomon et al., 2012; Kisley et al., 2007; Wood & Kisley 2006; Langeslag & van Strien, 2009; 2010) relative to college age samples, the present research adds to our continuing understanding of the LPP among other age groups.

The overarching goal of the research presented was to not only identify whether the LPP can be used as a measure of emotional processing and cognitive ER to test hypotheses of SST and the positivity effect, but also to determine at which stages of ER (passive viewing, attentional focusing or reappraisal) younger and older adults differ in how they process emotion information and their ability to reduce negative emotion. Results provide a framework for future research to examine other stages in the process model of ER (Gross & Thompson, 2007) where recent theory proposes younger and older adults may differ in the ability to regulate emotion (i.e. situation selection in the SOC-ER model; Urry & Gross, 2010).

Do younger and older adults show no differences in how they attend to pleasant and unpleasant stimuli (as measured via the LPP) during a bottom-up task? We evaluated the LPP in younger and older adults during a passive viewing task to examine whether bottom-up hypotheses could be supported during this task. In line with these predictions, results indicated that younger and older adults did not show differences in the degree to which they attended to pleasant and unpleasant stimuli. Previous research that has used the LPP to measure the positivity effect (in the context of passive viewing) has found mixed support (Langeslag & van Strien, 2009; Kisley & Wood, 2006; Kisley et al., 2007). For example, with increasing age, some studies document increased attention to pleasant stimuli (Langeslag & van Strien, 2009), whereas others find reduced attention to unpleasant stimuli (Kisley et al., 2007) and some no differences in LPP amplitudes between younger and older adults (Wood & Kisley, 2006). Taken together with previous research (Wood & Kisley, 2006), there appears to be support for this bottom-up approach in attention to emotion with age; however some questions still remain as to what type of passive viewing task or if a passive viewing task is reflective of bottom-up hypotheses.

In addition to support for bottom-up predictions, results in the passive viewing task also highlight that younger and older adults may differ in how long they attend to emotional stimuli. Older adults showed sustained LPP amplitudes up to 1,350 ms, a time frame in which younger adults showed no differences between emotional and neutral stimuli. As previous research has examined the LPP only up to 1,000 ms, our results suggest that extended periods of processing of emotional stimuli should be evaluated when examining age-related differences in the LPP. This difference in sustained processing between younger and older adults could reflect the recruitment of cognitive control processes that emerge later on. Second, stimuli used in this dissertation included highly to moderately arousing pleasant (erotic and affiliative) and unpleasant (mutilation and threat) stimuli to evaluate whether younger and older adults differ in the types of emotional stimuli they attend to. Age differences also did not emerge among the subcategories of stimuli. Taken together, results suggest that passive viewing of highly arousing stimuli support hypotheses of the bottom-up model, particularly in relatively automatic and early stages of emotional processing (e.g. early window). Future research, should also evaluate the LPP during early stages of processing among stimuli of lower arousal to examine whether support for bottom-up hypotheses emerge.

Are there age-related differences in the ability to use different types of cognitive ER strategies in younger and older adults as measured via the LPP? To evaluate how younger and older adults may use a range of ER strategies, participants completed two cognitive ER tasks: reappraisal and directed attention. To our knowledge, this is the first design that uses two types of cognitive ER tasks independently of one another in both younger and older adults. Top-down predictions in combination with SST, would suggest that older adults are better at reducing negative emotion than younger adults (Carstensen et al., 1999; Carstensen et al., 2003), perhaps via the use of reappraisal (John & Gross, 2004). Although the LPP was impacted by the types of regulation strategies where the increase condition produced larger LPP amplitudes versus the decrease and maintain valence conditions (all relative to a neutral maintain condition), age-related differences in reappraisal did not occur. Other related LPP and aging reappraisal paradigms have also found similar results across regulation conditions (e.g. larger LPP amplitudes in the increase condition), without age differences (Langeslag & van Strien, 2010). Additionally as seen in chapter one, younger adults showed larger LPP amplitudes in the increase versus decrease and view conditions in response to unpleasant stimuli. Thus, cognitive ER strategies influenced LPP in similar ways as previous LPP research across both younger samples (Hajcak & Nieuwenhuis, 2006; Moser et al., 2006; 2009; Krompinger et al., 2008; Langeslag & van Strien, 2010). In sum, our results suggest that both younger and older adults are able to use reappraisal strategies to down-regulate their attention to and experience of emotional stimuli. For results to be consistent with hypotheses of SST and the positivity effect, LPP amplitudes for older adults should have been reduced when asked to decrease emotional responses to unpleasant stimuli and larger when increasing to pleasant stimuli, as compared with younger adults.

Though age differences did not emerge in the reappraisal task, younger and older adults showed differing patterns of attention to emotion during the directed attention task. Younger adults displayed the expected changes in the LPP via the use of directed attention: smaller LPP amplitudes to unpleasant stimuli presented with a non-arousing focus as compared to unpleasant stimuli with an arousing focus (relative to neutral non-arousing stimuli). Older adults did not display this same pattern of neural activity and showed greater attention (larger LPP amplitudes) to unpleasant non-arousing stimuli in comparison to younger adults. It should also be noted that the LPP can vary greatly from individual to individual. Figure 4.1 illustrates an average waveform for 10 individual participants within the directed attention task (pleasant arousing focus).

Thus, our results suggest that differences in the ability to use cognitive ER strategies between younger and older adults may lie within attentional focusing (e.g. Opitz et al., 2012) and not necessarily the ability to reappraise (as measured via the LPP). These results partially support top-down predictions of Mather and Carstensen (2005), as older adults did not perform worse than younger adults; however to effectively support top-down predictions older adults should have demonstrated a greater ability to reduce LPP amplitudes in response to unpleasant stimuli and greater attention to pleasant stimuli. This partially supports hypotheses of SST in that older adults may become more experienced at using reappraisal with age (e.g. no differences in LPP amplitudes on the reappraisal task between younger and older adults), but they may be less likely to use other strategies like attentional focusing as a primary strategy. One explanation behind these results could be that younger adults are still developing the ability to reappraise as it requires the use of prefrontal areas that are still developing through emerging adulthood (Gogtay et al., 2004). Therefore younger adults may rely on attentional focusing more frequently than older adults, until they have more experience in using reappraisal at a later point in their lives.

How does the ability to change attention to emotion using cognitive ER tasks impact memory performance for younger and older adults? In our first study using only younger adults, increasing and decreasing emotional responses to unpleasant stimuli impacted memory performance, where stimuli in the increase and view conditions were remembered more than the decrease condition one week later. This initial study highlights that reappraisal can have an impact on emotional memory, specifically in that reducing attention to emotion via reappraisal, may change how emotional memories are encoded, consolidated, and retrieved.

In our follow-up study (Chapter 3), we built upon these initial findings and extended the methodological design by adding older adults and using pleasant, unpleasant, and neutral stimuli. No age differences however were found in memory performance in the reappraisal or directed attention tasks. As compared to the results presented in chapter one where younger adults showed differences in memory performance based on regulation condition (e.g. better memory in the increase and view versus decrease condition), the same pattern of results was not seen in the reappraisal task comparing younger and older adults. Results between these two tasks could have differed because the number of stimuli in the cognitive reappraisal and directed attention (together 300 stimuli) tasks was much greater than the study in chapter one (75 stimuli). Additionally, in chapter one, younger adults returned one week following the reappraisal task, as compared to the shorter delay for results shown in chapter three (approximately 25 minutes). It is possible that the longer delay allowed for memory consolidation to be impacted by regulation strategy much more than the memory task that occurred on the same day. Thus, the large number of stimuli and mixed valence design (inclusion of pleasant, unpleasant and neutral stimuli) could partially account for a lack of differentiation in memory performance in the reappraisal task, particularly the large number of emotional versus neutral stimuli. That is, pleasant and unpleasant stimuli mixed within the same block could reduce differentiation between the types of stimuli among older and younger adults. Some research also suggests that highly arousing stimuli are also remembered much more easily as they capture attention in a more automatic fashion, as compared to low arousal stimuli with may require participants to focus and attend more in processing the stimuli (Kensinger, 2004). Thus, as the present study used highly to moderately arousing stimuli, younger and older adults alike may have been able to remember these stimuli much more easily than if the stimuli were of lower arousal. Contrary to top-down predictions that suggest tasks that require cognitive control and are influenced by motivational goals of SST should result in differences in memory performance between younger and older adults, our reappraisal task did not produce age-related differences in memory.

Results within the directed attention task did show an added benefit in memory performance for stimuli shown with an arousing focus (for both pleasant and unpleasant stimuli) versus the non-arousing (valenced) focus. Similar to previous research, younger adults remembered more stimuli overall as compared to older adults (Charles et al., 2003); however older adults did not differ in memory performance between pleasant arousing and pleasant non-arousing stimuli. This suggests some behavioral evidence for the top-down model in that older adults did not differ in memory performance between the arousing and non-arousing conditions. That is, they may have had a preference for pleasant stimuli regardless of whether they should have been shifting their attention away from the most pleasant portion of the stimulus. Consequently, a reduction in memory for unpleasant stimuli in the directed attention task did not occur, leaving the top-down prediction in terms of memory only partially supported.

How are neural measures of attention to emotion (the LPP) related to memory performance? As the LPP reflects facilitated attention to emotional stimuli (Cuthbert et al., 2000; Schupp et al., 2000; 2004) greater attention to emotional stimuli (larger LPP amplitudes) should be associated with enhanced memory performance. In chapter one, we document that indeed larger LPP amplitudes within a sample of younger adults is associated with better memory performance for two regulation conditions: increase and decrease. Other studies have found results that support these findings as stimuli that have been previously reappraised have larger LPP amplitudes than those that have not been reappraised (MacNamara et al., 2011). Although reappraisal strategies serve to reduce attention to unpleasant stimuli (e.g. the decrease condition), the act of reappraising may require additional cognitive resources at encoding, but promote less consolidation at later on, resulting in behavioral memory performance consistent with predictions.

In chapter three comparisons between LPP reappraisal difference scores and memory performance revealed similar results as chapter one. Within the decrease condition larger LPP amplitudes, relative to the neutral maintain condition, were associated with better memory performance in younger and older adults, as well as the sample as a whole for unpleasant stimuli. This finding is consistent with results in chapter one where greater attention to unpleasant stimuli in the decrease condition was associated with better memory performance. There were no associations, however, for pleasant stimuli or the increase condition in chapter three. Taken together with results of chapter one, this suggests a dissociation between behavioral measures of memory performance and neural measures of attention to emotion at encoding, where attempts to reduce attention to emotion via reappraisal at encoding may not always yield reduced memory performance.

Do subjective arousal ratings reflect manipulations of cognitive ER? To provide a manipulation check during both of the cognitive ER tasks in chapter three, participants were asked to rate their arousal following each trial of the reappraisal and directed attention tasks. In the reappraisal task arousal was greatest for stimuli shown in the increase, followed by the maintain valence, decrease, and neutral maintain conditions for both pleasant and unpleasant stimuli. Arousal ratings were consistent with the condition in which they were shown, where arousing foci produced greater arousal ratings than the non-arousing valence and neutral non-arousing conditions for pleasant and unpleasant stimuli. Older adults, however, rated unpleasant stimuli as more arousing than younger adults in both tasks. Taken together with the lack of differences in LPP amplitudes to unpleasant stimuli (arousing versus non-arousing) in the directed attention task, this suggests that older adults may have a more difficult time shifting attention away from unpleasant stimuli.

Future Studies. As the results presented in this dissertation focus mainly on two types of cognitive ER strategies, future studies should examine additional stages of ER within the process model (Gross & Thompson, 2007). Recent aging and ER theory suggests that younger and older adults may differ in earlier stages of the process model, namely situation selection (Urry & Gross, 2010). The SOC-ER model proposes that older adults engage in situation selection as a method to regulate emotion to compensate for a loss in the ability to engage key prefrontal cortices that underlie successful reappraisal. Situation selection involves choosing a situation that will either increase or decrease the intended regulation goal (Gross & Thompson, 2007). Therefore, older adults may choose to put themselves in situations that will increase positive emotion and reduce negative emotion by either avoiding negative or increasing participation in positive emotional situations. As younger adults have greater cognitive resources to engage in cognitive reappraisal, they may be less likely to engage in situation selection as an initial regulatory strategy (Urry & Gross, 2010). Therefore, future research should systematically test whether the likelihood to engage in situation selection differs between younger and older adults and if situation selection has an impact on later reappraisal processes.

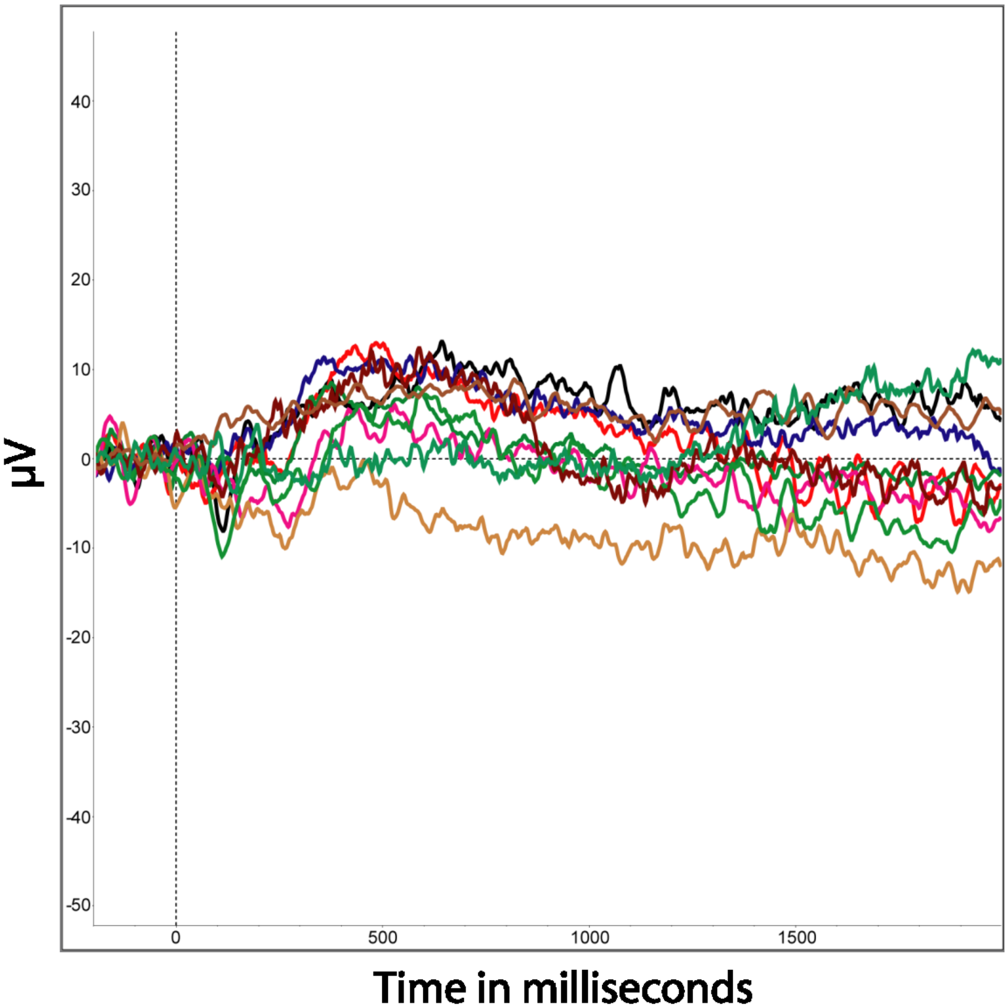
Furthermore, as differences emerged between younger and older adults in the directed attention task, future research would benefit from combining reappraisal and gaze directed attention in the same paradigm. This type of design is consistent with recent fMRI research which has found differences in the ability to down-regulate negative emotion between younger and older adults (Opitz et al., 2012). The combination of these paradigms may help to disentangle whether these two antecedent-focused strategies may account for age related differences in reappraisal and clarify differences in results between spatially and temporally sensitive neural measures. In using this type of design, it may help to clarify whether older adults may benefit from multiple antecedent-focused strategies in reducing attention to negative emotion. This design could be further improved with the addition of eye-tracking technology to confirm whether older adults do in fact have difficulty shifting gaze when the focus is on a non-arousing portion of an unpleasant stimulus.

The present study also only used highly arousing images known to produce relatively large LPP amplitudes (Weinberg & Hajcak, 2010). To have a greater understanding as to how the positivity effect and hypotheses of SST may be captured by the LPP, future research should examine not only all types of subcategories within pleasant, unpleasant, and neutral stimuli, but also cognitive ER strategies show differing patterns in the LPP within the subcategories as well. Therefore, future studies should examine these subcategories within top-down tasks that require cognitive control like reappraisal, as well as bottom-up tasks like directed attention and passive viewing. It is possible, however, that older adults may have been uncomfortable with the erotica stimuli, which could have impacted results and reduced our ability to detect preferential processing of pleasant stimuli across all three tasks. In analyzing all subcategories of emotional and neutral stimuli, this would help to clarify whether support for the positivity effect and hypotheses of SST emerges more clearly among low arousing stimuli (Kensinger, 2008) only.

An additional methodological improvement could also be made in the number of stimuli used. The number of stimuli used in the memory task was 600 (between targets and distractors for both experiments), a very large number of stimuli. As the strongest behavioral effects on memory occurred in chapter one when the total number of stimuli in the memory task was 125 (targets and distractors). Future studies should reduce the number of stimuli to optimize the effects of regulation. Additionally, the stimuli used were highly arousing and could have therefore been more memorable as compared to stimuli that are lower in arousal (Kensinger, 2004). Future research should examine the positivity effect in relation to high and low arousing images to determine whether this results in age differences both behaviorally and neurally. Within the memory recognition task, for both chapters one and three, there were not enough incorrect trials to examine whether LPP amplitudes at encoding differed between correct and incorrect trials. As some prior work with the LPP has demonstrated that previously reappraised stimuli generate larger LPP amplitudes than those that have not been reappraised (MacNamara et al., 2011), examining the differences in LPP amplitudes to correct and incorrectly remembered stimuli could yield age related differences at the time of retrieval. In other words, it could be possible that age related differences in the positivity effect may be reflected in the LPP at the time of retrieval, but not encoding.

The research presented in this dissertation has added to our understanding of the positivity effect and the hypotheses proposed by SST using a temporally sensitive measure. We have shown younger and older adults may be equally skilled at using reappraisal strategies, but could differ in how they use attentional focusing as a regulatory strategy. As much of the research that has examined the hypotheses of SST and the positivity effect have shown mixed support (Mather et al., 2004; Langeslag & van Strien, 2009; 2010; Wood & Kisley, 2006; Kisley et al., 2007; Urry et al., 2006; 2009; van Reekum et al., 2007; Opitz et al., 2012), future research should focus on these two stages and systematically vary the types of emotional stimuli (e.g. high and low arousing) used in order to fully understand how the LPP may operate during regulation between younger and older adults. As few studies examine the LPP in older age, we add to the small body of literature that examines temporally sensitive measures of attention to emotion. More importantly, this was the first study to examine multiple cognitive ER strategies within this age group and has provided insight as to how the LPP functions in older at multiple stages of processing (e.g. passive viewing, reappraisal, and attentional deployment). Findings highlight the need for future research to clarify the conditions under which younger and older adults may differ in attention to emotion, particularly between top-down and bottom-up tasks.

Figure 4.1 Average waveform for 10 participants within the directed attention task, in the pleasant arousing condition. These waveforms illustrate that the LPP can vary to a large degree across participants.



Appendix A

The picture numbers of the unpleasant pictures used in the emotion regulation task were: 1019, 1051, 1205, 1230, 1270, 1280, 1302, 1932, 2053, 2110, 2200, 2221, 2230, 2240, 2271, 2280, 2352.2, 2520, 2682, 2700, 2751, 2795, 3180, 3250, 3300, 3550.1, 5971, 6010, 6211, 6213, 6241, 6242, 6360, 6555, 6570, 6610, 6831, 6834, 6840, 6930, 7360, 7361, 8231, 8480, 9000, 9001, 9005, 9007, 9040, 9041, 9042, 9045, 9050, 9140, 9160, 9182, 9230, 9252, 9270, 9280, 9230, 9252, 9270, , 9290, 9301, 9341, 9404, 9410, 9430, 9432, 9433, 9500, 9520, 9584, 9600, 9810, 9920.

The picture numbers of the unpleasant stimuli used as distracters in the memory recognition task were: 1022, 1030, 1040, 1070, 1110, 1113, 1080, 1090, 1200, 1220, 1240, 1301, 2100, 2681, 2683, 2690, 2730, 2749, 2750, 2095, 2190, 3030, 3102, 3150, 3181, 3230, 3350, 3400, , 4233, 5120, 5130, 5940, 5972, 6000, 6190, 6200, 6210, 6230, 6250, 6260, 6314, 6315, 6350, 6415, 6561, 6571, 6800, 6836, 6900, 7920, 8010, 8060, 8232, 9006, 9090, 9101, 9190, 9181, 9220, 9320, 9331, 9401, 9405, 9409, 9411, 9420, 9440, 9471, 9472, 9561, 9570, 9582, 9594, 9621, 9635, 9830.

Appendix B

"Shortly, you will be presented with a set of images with 5 images in each set. Each image will appear on the screen for 2 seconds. Please view each image carefully. Before each set of images you will see a slide that will tell you to either VIEW, SUPPRESS, or ENHANCE the emotions you feel response to the pictures in that set. For those sets where you are asked to SUPPRESS or ENHANCE your emotions for the images, please do your best to do so AS FULLY AS POSSIBLE. For those images that you are given the instructions to VIEW, simply view them as you would naturally do so.

Here is what we mean by EHANCE, SUPPRESS, and VIEW.

When asked to ENHANCE, please do you best to AMPLIFY THE EMOTIONS EVOKED IN YOU BY THE PICTURES. AMPLIFY YOUR REACTIONS so that you feel the emotion evoked by the picture MORE STRONGLY than you would normally.

When asked to SUPPRESS, please do you best to SUPPRESS THE EMOTIONS EVOKED IN YOU BY THE PICTURES. SUPPRESS YOUR REACTIONS to the pictures so that you feel the emotion evoked by the picture LESS STRONGLY than you would normally.

When asked to VIEW, please view each image carefully and simply react as you would normally."

Appendix C

The following instructions were given to each participant prior to beginning the memory recognition task:

"Your job will be to view highly emotional images. When we say "emotional," we mean images that tend to bring out strong negative emotions. This experiment will involve images that are moderately to highly negative. Some of these images you HAVE seen before and others you HAVE NOT seen before. Your task is to determine if you HAVE or HAVE NOT seen the image before choosing one of the following responses:

1	2	3	4
SURE OLD	THINK OLD	THINK NEW	SURE NEW

If you are SURE that the image is one you have seen before, press "1." If you think the image is probably old, but are not 90 to 100% sure, then choose THINK OLD and press "2." If you are SURE it is NOT a picture that you have seen before, press "4." If you think the image is probably new, but are not 90 to 100% sure, then choose THINK NEW and press "3."

Appendix D

Pleasant: 1410, 1440, 1460, 1463, 1510, 1540, 1601, 1610, 1620, 1650, 1660, 1710, 1720, 1722, 1750, 1920, 1942, 2002, 2005, 2018, 2019, 2030, 2040, 2055.2, 2060, 2070, 2075, 2080, 2092, 2150, 2152, 2155, 2156, 2160, 2165, 2208, 2224, 2299, 2306, 2310, 2314, 2339, 2340, 2344, 2345, 2352, 2362, 2370, 2375.2, 2388, 2396, 2398, 2506, 2530, 2540, 2598, 2660, 2900.2, 4006, 4007, 4071, 4150, 4180, 4220, 4235, 4255, 4279, 4290, 4310, 4320, 4470, 4490, 4505, 4520, 4530, 4537, 4538, 4542, 4559, 4574, 4575, 4604, 4605, 4606, 4609, 4610, 4612, 4616, 4617, 4619, 4622, 4624, 4625, 4628, 4640, 4643, 4650, 4651, 4653, 4656, 4659, 4660, 4664.1, 4666, 4669, 4670, 4676, 4677, 4681, 4689, 4690, 4693, 4694, 4697, 4698, 4800, 5199, 5202, 5250, 5829, 5836, 6250.2, 8120, 8330, 8540.

Unpleasant: 1050, 1070, 1110, 1113, 1200, 1202, 1301, 2053, 2055.1, 2205, 2278, 2375.1, 2661, 2692, 2694, 2710, 2717, 2750, 2751, 2799, 2800, 3001, 3005.1, 3010, 3015, 3016, 3022, 3030, 3051, 3059, 3062, 3063, 3068, 3080, 3100, 3102, 3103, 3120, 3140, 3168, 3170, 3181, 3185, 3191, 3211, 3220, 3225, 3230, 3250, 3261, 3301, 3350, 3360, 3500, 3550.1, 3550, 4664.2, 5972, 6020, 6021, 6022, 6212, 6213, 6230, 6241, 6244, 6263, 6312, 6315, 6350, 6370, 6520, 6561, 6570.1, 6570, 6821, 6831, 6836, 6838, 6940, 8230, 8231, 8480, 8485, 9000, 9001, 9002, 9007, 9042, 9075, 9120, 9163, 9185, 9186, 9220, 9250, 9252, 9253, 9265, 9332, 9400, 9403, 9410, 9413, 9419, 9420, 9425, 9426, 9428, 9430, 9432, 9433, 9435, 9440, 9445, 9491, 9495, 9592, 9621, 9622, 9635.1, 9800, 9903, 9908, 9940.

Neutral: 2026, 2102, 2190, 2211, 2220, 2271, 2377, 2385, 2487, 2495, 2512, 2570, 2635, 2840, 2850, 2890, 5510, 5520, 6150, 7000, 7003, 7004, 7009, 7012, 7019, 7020, 7034, 7037, 7041, 7045, 7052, 7053, 7055, 7077, 7090, 7100, 7161, 7179, 7211, 7217, 7235, 7287, 7365, 7493, 7500, 7547, 7550, 7632, 7830, 7950.

Appendix E

Cognitive Reappraisal

Pleasant: 1410, 1460, 1510, 1601, 1610, 1650, 1710, 1722, 1920, 1942, 2002, 2018, 2030, 2040, 2055.2, 2060, 2075, 2092, 2152, 2155, 2160, 2208, 2299, 2306, 2314, 2339, 2344, 2352, 2362, 2375.2, 2396, 2506, 2530, 2598, 2660, 4006, 4071, 4150, 4235, 4255, 4279, 4310, 4320, 4470, 4530, 4537, 4538, 4542, 4559, 4574, 4604, 4605, 4610, 4616, 4617, 4624, 4628, 4643, 4650, 4653, 4659, 4664.1, 4669, 4676, 4681, 4689, 4693, 4697, 5199, 5202, 5250, 5829, 5836, 8120, 8330.

Unpleasant: 1050, 1070, 1113, 1200, 1301, 2205, 2661, 2692, 2717, 2750, 3001, 3005.1, 3015, 3022, 3030, 3059, 3062, 3068, 3080, 3102, 3120, 3140, 3168, 3181, 3191, 3211, 3225, 3230, 3250, 3301, 3350, 3360, 3550, 4664.2, 5972, 6020, 6022, 6212, 6230, 6241, 6244, 6312, 6315, 6370, 6520, 6561, 6570, 6821, 6831, 6836, 6940, 8230, 8480, 9002, 9042, 9120, 9163, 9185, 9220, 9250, 9252, 9332, 9403, 9410, 9413, 9419, 9420, 9425, 9428, 9430, 9445, 9491, 9495, 9622, 9908.

Neutral: 2385, 2487, 2495, 2512, 2635, 2840, 2890, 5510, 7000, 7003, 7012, 7019, 7045, 7052, 7055, 7090, 7161, 7179, 7211, 7493, 7500, 7547, 7632, 7830, 7950.

Directed Attention

Pleasant: 1440, 1463, 1540, 1620, 1660, 1720, 1750, 2005, 2019, 2070, 2080, 2150, 2156, 2165, 2224, 2310, 2340, 2345, 2370, 2388, 2398, 2540, 2900.2, 4007, 4180, 4220, 4290, 4490, 4505, 4520, 4575, 4606, 4609, 4612, 4619, 4622, 4625, 4640, 4651, 4656, 4660, 4666, 4670, 4677, 4690, 4694, 4698, 4800, 6250.2, 8540.

Unpleasant: 1110, 1202, 2053, 2055.1, 2278, 2375.1, 2694, 2710, 2751, 2799, 2800, 3010, 3016, 3051, 3063, 3100, 3103, 3170, 3185, 3220, 3261, 3500, 3550.1, 6021, 6213, 6263, 6350, 6570.1, 6838, 8231, 8485, 9000, 9001, 9007, 9075, 9186, 9253, 9265, 9400, 9426, 9432, 9433, 9435, 9440, 9592, 9621, 9635.1, 9800, 9903, 9940.

Neutral: 2026, 2102, 2190, 2211, 2220, 2271, 2377, 2570, 2850, 5520, 6150, 7004, 7009, 7020, 7034, 7037, 7041, 7053, 7077, 7100, 7217, 7235, 7287, 7365, 7550.

Memory Distractors Cognitive Reappraisal

Pleasant: 1500, 1590, 1661, 1721, 1811, 1999, 2000, 2010, 2020, 2034, 2035, 2057, 2058, 2071, 2151, 2154, 2158, 2170, 2217, 2222, 2274, 2300, 2304, 2331, 2332, 2360, 2373, 2392, 2501, 2655, 4002, 4003, 4004, 4005, 4100, 4210, 4232, 4233, 4240, 4250, 4300, 4302, 4460, 4525, 4532, 4534, 4572, 4599, 4600, 4601, 4603, 4607, 4614, 4623, 4626, 4631, 4658, 4664, 4668, 4672, 4680, 4692, 4695, 4700, 4750, 4770, 5200, 5201, 5215, 5825, 5830, 5833, 8241, 8320.

Unpleasant: 1026, 1040, 1120, 1220, 1230, 1300, 1645, 1675, 2101, 2122, 2456, 2458, 2690, 2691, 2716, 2752, 2810, 2811, 3053, 3060, 3061, 3064, 3069, 3101, 3131, 3150, 3160, 3180, 3190, 3195, 3212, 3266, 3300, 3302, 3400, 4621, 6010, 6190, 6220, 6250.1, 6314, 6360, 6510, 6560, 6570.2, 6800, 6830, 6834, 6840, 9040, 9040, 9045, 9110, 9145, 9160, 9183, 9254, 9401, 9405, 9409, 9414, 9415, 9424, 9470, 9520, 9560, 9584, 9611, 9630, 9635.2, 9901, 9904, 9909, 9910, 9926, 9941.

Neutral: 1122, 1908, 2032, 2191, 2214, 2357, 2397, 2870, 4571, 5395, 5731, 7010, 7033, 7043, 7050, 7056, 7081, 7188, 7207, 7233, 7248, 7255, 7497, 7512, 7546.

Memory Distractors Directed Attention

Pleasant: 1340, 1441, 1630, 1659, 1731, 1740, 2045, 2050, 2091, 2209, 2311, 2341, 2347, 2510, 2511, 2550, 2620, 4001, 4008, 4085, 4090, 4130, 4141, 4142, 4225, 4230, 4274, 4275, 4311, 4500, 4503, 4510, 4531, 4550, 4561, 4573, 4608, 4611, 4641, 4645, 4649, 4652, 4687, 4810, 5210, 5760, 5831, 5849, 7325, 8600.

Unpleasant: 1052, 1090, 1111, 1112, 1201, 1304, 1505, 1525, 1930, 1935, 2276, 2345.1, 2352.2, 2683, 2695, 2702, 2718, 3000, 3017, 3071, 3110, 3130, 3210, 3310, 3530, 5950, 5971, 6200, 6210, 6211, 6240, 6243, 6300, 6540, 6563, 6571, 8121, 8232, 9041, 9070, 9150, 9330, 9402, 9411, 9425, 9427, 9594, 9810, 9921, 9922.

Neutral: 2038, 2273, 2372, 2381, 2411, 2514, 2745.1, 5040, 5500, 5530, 7001, 7002, 7014, 7021, 7035, 7058, 7061, 7170, 7182, 7185, 7476, 7487, 7490, 7506, 7820.

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