2012

The Neural Correlates of Emotion Regulation

Brandy Nicole Tiernan
Iowa State University

The neural correlates of emotion regulation: An ERP investigation

BY

BRANDY NICOLE TIERNAN

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Psychology

Program of Study Committee:
Robert West, Major Professor
Jason Chan
Carolyn Cutrona
Veronica Dark
Alison Morris

Iowa State University

Ames, Iowa

2012

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

I attribute the completion of this project to the support of my advisor, friends, family, and husband. I am appreciative and grateful for the guidance provided by my committee members, and all of the advice and help I received from peers and colleagues. I would like to express gratitude to my major professor, Dr. Robert West, for his direction and guidance on this project; in addition to other projects I have had the privilege of being a part of as a student in his laboratory. I would like to sincerely thank Drs. Sharon Mutter, Martin Bink, Veronica Dark, Alison Morris, and Jason Chan for their advice over the years, reading my work, guiding my research, and assisting with the development of my knowledge and love of cognitive psychology. I would also like to extend a special thank you to Dr. Carolyn Cutrona for serving as a member of my committee at the final defense at the last moment– you were a great addition and I appreciate your perspective and contribution to this project. All of you have provided some sort of guidance or mentorship that has been instrumental in my growth, both personally and professionally -- and for that, I thank you. Thanks also to all of the former and current members of the Temporal Dynamics of Attention and Memory Lab. My friends and co-workers in this lab offered some much needed comic relief and entertainment in the most stressful of times. Thank you all for listening, helping, and supporting.

Finally, and most importantly, I'd like to thank my husband Benjamin and my son Ezra. Ben, your unconditional love, support, patience, and encouragement are undeniably the reason I was able to find the steam to keep going when I felt like I had nothing left to give. I've been saying for the past four years "if you love me now, just wait until I finish graduate school." That time is finally here! Thank you for tolerating my tears and bad moods. Thank you for supporting my ambition. I am excited for our adventures to come. Ezra, I learn something new about life from you every day. You make me want to be the best person I can be. I cannot tell you "I love you" enough. Everything I do, I do it for you. Thank you for helping me "be present", fueling my drive, and giving me purpose.

ABSTRACT

Antecedent-focused strategies of emotion regulation involve modifying thoughts shortly after an emotional stimulus is encountered. Cognitive reappraisal and distraction represent two forms of antecedent-focused emotion regulation. The current study used event-related brain potentials (ERPs) to examine whether regulation interacts with the content of emotional information (Experiment 1), the neural correlates of these two forms of emotion regulation and their effectiveness in decreasing negative emotion (Experiment 2 and 3), the pattern of neural recruitment during regulation (Experiment 1, 2, and 3), and role of working memory and metacognition in regulation (Experiment 3). In each experiment, individuals were asked to first view an emotional picture, then, based on a cue, continue to think about the picture, reappraise the picture, or use a form of distraction (i.e., either self-directed or experimenter directed) to deploy attention away from the picture. Differences in neural activity were found in all three experiments. In Experiment 1, the LPP was reduced in amplitude for reappraisal trials relative to attend trials for violent picture content. In Experiment 2, the LPP was reduced in amplitude for reappraise trials, relative to attend trials. In contrast, there was little difference in the amplitude of the LPP between distract and attend trials. Experiment 3 failed to establish an association between working memory capacity and emotion regulation, or metacognition and emotion regulation. Together, these data highlight the neural correlates of successful emotion regulation and directions for future research.

CHAPTER 1.

OVERVIEW OF DISSERTATION

An unexpected meeting with one's boss is rarely met without anxiety. The walk to his office would be long and riddled with nervous thoughts. Depending on your line of thinking, apprehension could easily transform into fear, which would be expressed through feelings, thoughts, and physiological changes (e.g., rapidly beating heart, dilated pupils, sweaty palms). Before making the last turn down the hallway, you decide that it's unnecessary to worry about the meeting given that your performance has been above company expectations. After pausing, taking a deep breath, and wiping the visible sweat away, you may feel much more at ease about approaching the boss's office and attending the meeting.

As demonstrated by the above example, emotion regulation allows an individual to cope with conflict. It is also a valuable tool used to promote socialization and functionality in numerous environments. People engage in a variety of strategies to regulate emotion. Given that various strategies exist, some individuals may be more adept at using one over another. Additionally, individual differences in learning and information processing can shape the strategies one utilizes and how successful one is at regulation. In this dissertation, I provide an overview of the processes involved in emotion regulation (e.g., emotion and appraisal), emotion regulation strategies, how differences in cognition contribute to regulation, and the purpose and goals of the current experiments.

Emotions play a large role in behavior and decision-making. In order to understand emotion regulation, it is necessary to consider the nature of, and

processes underlying emotion. Emotions enable one to determine their priorities evaluate their relationships and assess the psychological states of others. Emotions are elicited by social and environmental stimuli, are internal, observable, and physiological and expressed through our posture, facial expressions, the way we talk, and our body language. In the first two sections of the introduction, I define and evaluate emotion based on prominent theories in the literature, and then review the evidence for emotion regulation. Emotion regulation refers to how people regulate their emotions through behavioral and physiological alterations (Gross, 1998). To eliminate the ambiguity of term, this section identifies the processes supporting regulation, reviews the time course and dynamics involved in regulating, and discusses various forms of regulation and strategies.

In the following section, I discuss the role of working memory and metacognition in successful emotion regulation. The nature of emotion regulation can be automatic or controlled - which is largely dependent on the goals of the individual. Working memory supports the maintenance, updating, and shifting of information to guide selection of an appropriate response when the current one is contextually in-appropriate (Ilkowska & Engle, 2010). It could be argued that the ability to control what is attended to in an emotional situation is largely influenced by working memory (Barrett, Tugade, & Engle, 2004). Much like working memory, metacognition, or knowledge regarding one's ability to perform various cognitive tasks (Moses & Baird, 1999), supports the planning, evaluation, and monitoring of strategies used to achieve a goal. Metacognitive insight may help inform how an individual evaluates and performs a task.

In the last section, I discuss the use of event related brain potentials as a method to study emotion and emotion regulation. I briefly review six ERP components (P1, N1, P200, EPN, P3, LPP) and how they can be used to understand the automatic and controlled nature of emotion. There is evidence to suggest that specific forms of regulation are effective at modulating the neural response to emotionally negative images. For instance, cognitive reappraisal has been shown to modulate the neural response to unpleasant pictures (Hajcak & Nieuwenhuis, 2006), and distraction, or directing attention to less arousing features of negative image also been shown to effective (Dunning & Hajcak, 2009). To extend the findings of previous studies, Experiment 1 used ERPs to examine the effects of picture content on cognitive reappraisal and neural recruitment during regulation. Regulation may vary by content, and I was able to examine whether subjects engaged in differential processes for each regulation condition. Experiment 2 was an extension of the first experiment to evaluate the effectiveness of reappraisal and distraction in direct comparison to one another. The goals of Experiment 3 were to: a) explore the nature of the differences found between attending to a negative image, using reappraisal, or attentional deployment (i.e., distraction), and b) investigate the role of cognition, specifically working memory and metacognition on successful regulation.

CHAPTER 2.

LITERATURE REVIEW

Emotion

Defining Emotion

Emotion is a psychological concept that is somewhat difficult to define. Both scientists and laymen use the term often; however, the question “what is emotion” rarely generates the same answer. One standard definition in the literature is that emotion is a psychological state that reflects the integration of three distinct but interrelated features: physiological responses, overt behaviors, and conscious feelings (Gross, 1998). Physiological responses associated with emotion may include changes in heart rate, increased perspiration, and increased respiration (Gross & Thompson, 2007; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Examples of overt and observable behaviors are facial expressions, vocal tone, and posture. The conscious feelings are the subjective experiences of sadness, joy, fear, anger, etc. (Gross & Thompson, 2007). For instance, if one feels as if another person has treated him unfairly, he might squint his eyes, clinch his jaws, lower his voice, experience increased heart rate, and overtly label this feeling as anger.

Another definition considers the functional and adaptive nature of emotion, where various components are synchronized and integrated to create an overarching feeling or psychological state (Scherer, 1984; Scherer, 1987). These components are: cognitive (information processing), neurophysiological (system regulation between the central nervous system, autonomic nervous system, and neuroendocrine system), motivational (preparation and direction of action), motor

expression (action involving the somatic nervous system), and subjective feelings (monitoring of internal state and environment interaction through the central nervous system; Scherer, 1987; Scherer, 2004). Emotion is a change in the state of the central nervous, endocrine, autonomic, and somatic systems in response to an external or internal stimulus relevant to the individual. The significance of an event is evaluated when something occurs that triggers a change in one the systems (Scherer, 1987). The event can be severe weather, the behavior of the individual, or the behavior of other people. Whatever the stimulus or event, it is linked to our needs, goals, values, and/or wellbeing.

According to Klaus Scherer (2005), emotions are short-lived and connected to a specific event, either internal (e.g., ones own behavior, thoughts, or images) or external (e.g., dog barking, baby crying, thunderstorm). The consequences of the eliciting event must be relevant to the person – people become emotional about things they care about. The appraisal of relevance can be intrinsic (e.g., related to self) or extrinsic (e.g., related to other). An intrinsic evaluation focuses on the goals of the person based on generic or learned preferences. Changes occur in the bodily state of the organism, which prepares them to make an appropriate response to the eliciting event. The response generated by the organism corresponds to the appraisal and probable/assumed consequences of the event. Depending on the appraisal, the current goals of the individual are interrupted by emotion-related changes in the bodily systems, enabling one to form new plans, rethink interactions, and re-set goals.

Appraisal Theories of Emotion

Most appraisal theories suggest that emotions are comprised of interpretations of perceptions. These interpretations are a product of the central and peripheral nervous systems, and are means for adaptation (Lazarus, 1991; Scherer, 1999; Clore & Ortony, 2000; Roseman, 2001; Scherer, 2001; Scherer et al., 2001). In order for adaptation to occur, the individual must be motivated to change their thoughts or environment. Emotions serve as motivators that enable us to understand and extract meaning from situations (Ellsworth & Scherer, 2003). Appraisal theories connect emotion to cognitive processes concerning evaluation, meaning, attribution, and coping, and are motivated by: 1) the idea that thought and emotion are inseparable, 2) emotions are dependent on appraisal processes (judging events), and 3) the notion that different people can experience different emotions to the same event (Clore & Ortony, 2000; Cornelius, 2000; Ellsworth & Scherer, 2003); for example, failing a test may make one student feel anger and another feel shame and sadness.

Arnold (1960), an early influence behind the appraisal approach, concluded that emotions are a product of appraisal (e.g., individual's assessment of the situation familiarity, valence, and value) and attributions related to the causes of events (Frijda, 1986; Scherer, 1999; Smith & Ellsworth, 1985). Appraisal enables an organism to act appropriately based on the surrounding environment (Cornelius, 1996; Cornelius, 2000; Frijda, 1986). Cognitive appraisal theories insist that every emotion is linked to a particular pattern of appraisal and when the appraisal changes, the emotion changes along with it (Ellsworth & Scherer, 2003; Lazarus,

1993). Whether appraisal is conscious or unconscious, an individual assesses the valence of an event, how it aligns with their current goals, the familiarity of the situation, and the effects of their potential reactions (Smith & Ellsworth, 1985). Emotions often unfold in a variable manner to particular situations and events. The significance of an emotional event depends upon an individual's goals and coping abilities (Lazarus, 1993; Scherer & Ceschi, 1997), which shapes the emotional response.

The primary tenet of appraisal theories is that an individual's interpretation of a situation is what evokes emotion (Barrett, 2006; Frijda, 1988). A classic example of this is found in Schachter and Singer's (1962) experiment where they explored the role of cognition and physiological states of arousal on the differentiation of emotion, and found that arousal can take place without a noted cause. When an individual becomes aroused, they are motivated to explain the source, cause, and features of their arousal, which then leads to an emotional state. Schachter and Singer injected subjects with epinephrine to induce arousal, or with a placebo (saline solution) to cause no physiological change. They told some subjects injected with epinephrine (informed) to expect an increase in arousal; all other participants were ignorant to the effects of the injection (e.g., no experimentally provided explanation for bodily state), or misinformed (e.g., informed of side effects unrelated to the drug, such as itchiness or numbness). Subjects were placed in a highly arousing situation after the epinephrine became effective – a confederate was present and acted in either a euphoric or angry manner. Those who received the shot of epinephrine and were ignorant or misinformed about the arousal reported feeling emotions similar to the

confederate. Those who received the placebo or were in the epinephrine-informed condition were less susceptible to the rousing behavior of the confederate. In sum, those who experienced unexplained arousal looked for an explanation from the environment – cognitive appraisal determined the reported state. The data from Schachter and Singer (1962) experiment suggest that cognition may differentiate an emotional experience, and these results have greatly influenced emotion theorists.

Cognitive appraisal theories insist that emotion is linked to a particular pattern of appraisal and when the appraisal changes, the emotion changes along with it (Scherer, 1999; Scherer et al., 2001). Whether an appraisal is quickly derived (e.g., driven by prior knowledge) or carefully considered, an individual assesses the valence of an event, how it aligns with their current goals, the familiarity of the situation, and the effects of their potential reactions. For instance, Scherer and Ceschi (1997) videotaped travelers who reported their luggage as lost in a large airport. The investigators from the baggage claim office gathered information regarding the travelers' appraisal of the situation. The emotional reaction to the experience varied – the more an event was viewed as a goal obstruction, the more likely the individual was to display emotions of anger or worry. In contrast, those who did not view the experience as a goal obstruction were more likely to express feelings of indifference or good humor. The take home message from appraisal theories would be that emotions do not often unfold in an invariable manner to particular situations and events. The significance of an emotional event depends entirely an individual's goals and coping abilities. Appraisal theories assume that one's interpretation of a situation can trigger preexisting properties of emotion. The

cognitive interpretation of an object, event, or stimulus enables flexibility in the emotional response (Lazarus, 1991; Roseman, 1991; Roseman, 2001; Scherer, 2005).

Emotion Regulation

The Modal Model of Emotion

To discuss emotion regulation, it is necessary to first outline the 'modal model' of emotion (Figure 1). The 'modal model' of emotion, commonly used to define and study emotion, suggests that emotions are the result of person-situation interactions, which involve attention, provide meaning, and elicit a behavioral and/or physiological response (Gross & Thompson, 2007). The first element of the model is the psychologically relevant situation-at-hand, which is commonly external and physical, but can also be internal. From here, the situation is attended to which then leads the individual to make an appraisal, or assess the situation's familiarity, valence, value, or relevance (Ellsworth & Scherer, 2003). Appraisals are generally followed by an emotional response. The following emotional response is observed or realized in changes in an individual's experience, behavior, and physiology (Mauss et al., 2005; Scherer, 2004). Moreover, emotional responses can often have an effect on the initial situation, hence the arrow from response to situation in Figure 1. For example, a husband and wife are having a heated discussion and the wife starts to cry in response to something her husband says, thus, changing the nature of the situation. Her tears drive him to comfort her and apologize – a new response that will again,

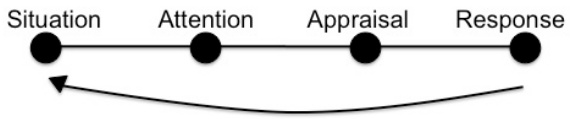

Figure 1. The 'modal model' of emotion

transform the situation. This situation to response cycle will continue as long as one of the two individuals in the example is provoked. The nature of emotion is recursive and a change in the environment, or alteration of a particular instance of an emotion, will influence subsequent emotions (Gross & Thompson, 2007).

Defining Emotion Regulation

The term emotion regulation refers to how emotional responses regulate behavior and physiology or to how emotional responses are regulated by behavior and physiology (Gross & Thompson, 2007). As mentioned in the previous section, emotional responses are produced and coordinated by changes in bodily systems (e.g., central nervous system, etc.) in response to internal or external stimuli; therefore, to differentiate between the functions of emotion and emotion regulation, the second use of the term (i.e., emotions are regulated by behavior) is preferred. Through emotion regulation, the emotion one feels, when it is felt, and/or how it is expressed is influenced by altering the intensity or duration of the behavioral, experiential, and physiological aspects of the emotional response (Gross, 2007; McRae & Gross, 2009).

Emotion regulation is somewhat closely related to the construct of affect regulation (e.g., mood regulation, coping, defense mechanisms). However, emotion regulation is distinct from the mentioned process because it specifically targets emotion and no other form of “affect” (e.g., stress responses, emotions, moods, motivational impulses, such as sex and hunger; Scherer, 1984; Gross & Thompson, 2007). Emotion regulation can be automatic or controlled, and is goal dependent. Therefore, regulation may weaken, enhance, or sustain a particular emotion, and

can change the degree to which bodily systems correspond as emotions take place (e.g., internally thinking angry thoughts, experiencing increase heart rate, yet suppressing the urge to grimace, frown, or shout). Emotion regulation can be intrinsic or extrinsic. Self-regulated emotion is known as intrinsic emotion regulation (Thompson, 1991) and is generally studied in adults (Gross & Thompson, 2007). Extrinsic emotion regulation is involved in the development of appropriate regulatory skills (e.g., often by a parent). Researchers primarily examine this form of regulation in infants and small children. Extrinsic factors include the way in which caregivers help shape and the support emotional responses of a child (Fox & Calkins, 2003).

Emotion regulation can be used to enhance and/or impede both positive and negative emotions (Gross, Richards, & John, 2006; Gross & Thompson, 2007). For instance, in an interview study conducted by Gross, Richards, and John (2006) college students reported down regulating negative emotions through behavioral and experiential means, such as changing the way they thought about the situation, or surrounding themselves with friends, or spending time with romantic partners. Emotion regulation can also involve increasing emotion to prolong its effects (e.g., telling everyone about a prospective interview; Langston, 1994). Regulation strategies can be situation dependent (Gross, 2008; Gross & Thompson, 2007). For example, it may be advantageous to down-regulate negative emotion if one's manager reprimands her for something she did not do in order refrain from saying something that will result in losing her job. In contrast, if while attending a funeral one receives a text message informing him of a hefty inheritance he will receive from

the deceased, it may also be advantageous to remain calm and suppress his excitement until the service has ended.

The Process Model of Emotion Regulation

The 'modal model' of emotion provides a foundation for the major points in the emotion generative process and the way in which an emotional response is shaped and delivered (McRae & Gross, 2009). The Process Model of Emotion Regulation (Figure 2; Gross, 1998) redraws the 'modal model' and emphasizes five points at which regulation can take place. Each point represents a broad family of emotion regulation strategies: situation selection, situation modification, attentional deployment, cognitive change, and response modulation. Each family provides a framework that is useful for identifying and understanding the underlying mechanisms, causes, and consequences of emotion regulation (McRae & Gross, 2009).

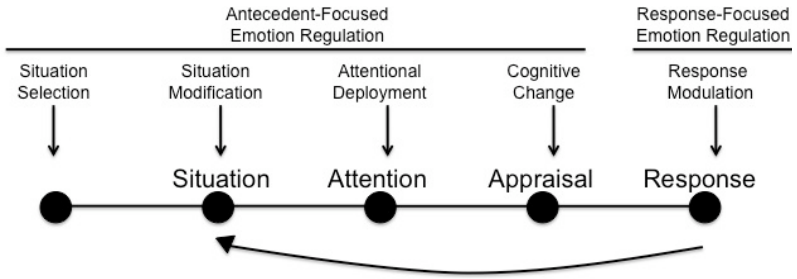

Figure 2. A Process Model of Emotion Regulation that highlights five regulation strategies.

These five families fall under two higher order categories: antecedent-focused emotion regulation and response-focused emotion regulation (Gross, 1998; Gross & Munoz, 1995; Gross & Thompson, 2007). Antecedent-focused regulation refers to the manipulation of the input to the emotion system (before an event occurs) and strategies we use before behaviors and response tendencies have been fully activated or affect our behavioral responses. An example of antecedent-focused

emotion regulation is seeing an exam as an opportunity to learn more about the content of a course, rather than a test of your intelligence, self-worth, or a pass-fail experience. Response-focused regulation refers to the manipulation of output of the emotion system (after an event has occurred; Gross, 1998). Response-focused strategies are typically utilized once a response tendency has already been produced (Gross, 2001; Gross, 2002). An example of response-focused emotion regulation would be smiling when one receives a disappointing gift (Richards & Gross, 2000), or keeping a straight face in an anxiety provoking or frustrating situation. Antecedent-focused regulation includes situation selection, situational modification, attentional deployment, and cognitive change. Response-focused regulation includes response modulation.

An individual may use situation selection or situation modification to preemptively modify a situation (Gross, 1998; Gross & Thompson, 2007). Situation selection involves forming an expectation about the emotional consequences of a situation that might occur in the future, and shaping one's behavior to achieve emotional goals associated with the desired outcome of that situation. Situation selection involves managing the short-term effects of emotion by considering the potential long-term effects (Gross, 1998). An example would be changing a route to work to avoid traffic, if traffic was a substantial source of stress and frustration. Situation modification involves changing various aspects of one's external environment to meet emotional goals (Gross, 1998). For example, if one becomes more anxious on airplanes in window seats, it would be advantageous to pre-select an aisle seat at the time the ticket is purchased.

Unlike the previous forms of regulation, attentional deployment entails altering or regulating emotions without manipulating the external environment. Attentional deployment occurs when attention is directed away from a stimulus, toward a non-emotional aspect of a stimulus, or toward another stimulus altogether, to influence one's emotional state. Such manipulations of attention are known as rumination (repeatedly focusing internally on one's feelings or the consequences of a particular situation), distraction (focusing on different aspects of a situation, attending to something unrelated to the situation, or shifting internal focus) and concentration (controlled focus and attention to a situation; Gross, 1998, Gross & Thompson, 2007). For instance, if the anxious airplane passenger is rerouted onto a different plane without an opportunity to switch seats, she might choose to avoid discomfort by thinking about something different or focusing deeply on reading material while traveling.

Cognitive change involves altering the way in which the emotional significance of situation is evaluated (Gross, 1998); cognitive reappraisal, one form of cognitive change, involves changing one's appraisal of the affective meaning of a stimulus, situation, or event (McRae et al., 2010). Reappraisal can be used to down-regulate a negative emotional response, and reframe the situation in terms that decrease emotional reactivity (Giuliani & Gross, 2009; McRae et al., 2008). Consider, once again, the anxious traveler from the previous two examples. Instead of becoming angry when she finds out that her flight has been rerouted due to technical and mechanical issues, she chooses to remind herself how pleased she is

that the airline conducts routine safety checks and is thankful that she will eventually arrive at her destination safe and sound.

Response modulation is the final effort to change the potential outcome of an emotional response by attempting to directly change the physiological, experiential, or behavioral response (Gross & Thompson, 2007). Food, drugs (legal and illicit), exercise, and relaxation (e.g., meditation) are often used to modify an emotional experience. Manipulating or changing an emotionally expressive behavior is also a way to modulate a response (e.g., suppressing anger). Say the anxious traveler is waiting to receive her new ticket for the rerouted flight and another person somehow intersects and receives service from the counter attendants before she does. Although she is upset and angry about what has just happened, she can override her urge to scowl or yell at the person who cut the line.

Emotion Regulation Strategies: Reappraisal and Distraction

As described previously, the goal of emotion regulation, to adapt or adjust one's emotion, can be accomplished through different strategies. Previous literature categorizes these strategies based on the target of regulation (Lazarus & Folkman, 1984), the implementation of regulation, engagement or disengagement from emotion (Parkinson & Totterdell, 1999), and, as discussed in the previous section, the timing and impact of particular regulation strategies within the emotion-generative process (Gross, 1998).

Two emotion regulation strategies that have received a substantial amount of attention in the literature are cognitive reappraisal and distraction, a form of attentional deployment (Goldin, McRae, Ramel, & Gross, 2006; Krompinger, Moser,

& Simons, 2008; McRae et al., 2010; Mauss et al., 2007; Ray et al., 2005; Rusting & Nolen-Hoeksema, 1998; Sheppes & Meiran 2007). As previously mentioned, reappraisal falls under the family of cognitive change, and involves changing the initial appraisal of a situation to adjust its emotional significance (Gross & Thompson, 2007), or changing the meaning of a situation or event to modify its emotional effect (Gross & Thompson, 2007).

Evidence from both behavioral (Gross, 1998; Richards & Gross, 2000; Gross & John, 2003) and physiological (Jackson, Malmstadt, Larson, & Davidson, 2000; Ochsner, Bunge, Gross, & Gabrieli, 2002; Ochsner, Ray, Cooper, Robertson, Chopra, S., Gabrieli, & Gross, 2004; Hajcak & Nieuwehuis, 2006; Ray, McRae, Ochsner, & Gross, 2010) studies has shown that reappraisal decreases negative affect. For example, asking participants to reappraise unpleasant films leads to a decrease in negative emotion (Gross, 1998). Ochsner, Bunge, Gross, and Gabrieli (2002) found that reappraisal influences the affective salience and significance of a stimulus. Reappraisal is also more effective in complex situations. Stemmler (1997) found that participants who used reappraisal in stressful interpersonal interactions showed decreases in blood pressure and heart rates compared to those who did not use a strategy. Hajcak and Nieuwenhuis (2006) examined the neural correlates of emotion regulation, specifically whether cognitive reappraisal could modulate the neural response, specifically the late positive potential (LPP), to negative emotional stimuli. The LPP is an index of arousal and is sensitive to both positive and negative images, rather than neutral images. In their experiment, participants viewed unpleasant photographs and were asked to either reinterpret or alter their feelings

about the picture so that it was less negative, or attend (control condition) to the picture without altering their initial interpretation. Hajcak and Nieuwenhuis (2006) found that amplitude of the LPP greater in amplitude for attend trials than reappraisal trials, thus suggesting that the neural response was modulated by cognitive reappraisal.

Distraction falls under the family of attentional deployment, or how attention is directed in a situation to influence an emotional response. Distraction focuses attention on nonemotional aspects of a situation or diverts attention from the event altogether, and has been shown to be effective for reducing negative thoughts (Fennell & Teasdale, 1984), feelings (Rusting, 1998), anger (Gerin, Davidson, Christenfeld, Goyal, & Schwartz, 2006; Rusting, 1998), and stress (Bennett, Phelps, Brain, Hood, & Gray, 2007). Removing attention from provocative or threatening stimuli enables coping in stressful situations (Boden & Baumeister, 1997). Distraction may also involve an internal shift in focus, where one recalls memories or thoughts that are inconsistent with the aversive stimulus at hand (Fraley & Shaver, 1997, Gross & Thompson, 2007, Josephson, Singer, & Salovey, 1996).

Components of Successful Emotion Regulation

Working Memory

Regulation is inherently intertwined in physiological and behavioral changes that underlie emotion. According to Scherer (2005), emotion is activated, supported, and regulated by the synchronization of several systems related to stimulus evaluation, planning, decision-making, and motor expression. Therefore, it is reasonable to assume that working memory (WM) is an aspect of emotion

regulation. WM supports the regulation of thought and responses by actively maintaining information pertinent to a goal while subsequently manipulating to-be-processed information (Engle, Kane, & Tuholski, 1999). The WM system is capable of maintaining memory traces while simultaneously processing information, facing distractions, allocating resources, and managing shifts in attention when conflict arises (Hasher & Zacks, 1988; Cowan, 2001; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, 2002; Long & Prat, 2002). Working memory capacity is measured as the number of items recalled when a task requires one to process and manipulate goal relevant information in the presence of distractions (Engle, 2001).

Research on individual differences in WMC has generally focused on its relationship to attentional and cognitive control tasks. Several tasks have been used to measure WMC, all of which examine the number of items that can be recalled in a complex task. An example directly relevant to this dissertation would be the Operation Span (OSPAN) Task, in which a subject performs a memory test while performing mathematical equations (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005). The better a person encodes and recalls target words (goal-relevant information) while also having to solve math problems (distraction /irrelevant information), the higher the WMC. When administering the OSPAN task a simple math equation and a word appear on the computer screen (Is (2*2) – 3= 2? Hat). The subject reads the equation aloud, provides an answer to the problem (aloud), and finally reads the word next the equation aloud. The experimenter proceeds to another screen presenting the next equation and word. The pairs are presented in sets (about 3 per set). Once the last equation-word pair of a set has been presented,

the subject must recall the words from that set in the order they appeared. WMC is quantified by the number of words correctly recalled within a set.

WM has been linked to tasks that call for controlled, rather than automatic responses (Kane & Engle, 2003), the ability to shift visual focus away from salient stimuli (Kane, Bleckley, Conway, & Engle, 2001), and ignoring irrelevant information in a dichotic listening task (Conway, Cowan, & Bunting, 2001). Each requires goal relevant processing in the face of competing response tendencies and/or distractions. There is limited research examining the role of WMC in emotional processes and responses, and most of the research tends to focus on the influence of emotional states (e.g., positive and negative moods, anxiety, stress) on WM tasks. Mather and Knight (2005) found that engaging in goal directed behavior during an emotion task may modify the affective experience. More specifically, the authors found that older subjects with high scores on measures of cognitive control also showed a stronger tendency to exhibit the positivity effect (e.g., remembering more positive items than negative items than older adults with lower scores on cognitive control measures). In a follow up study, Mather and Knight manipulated attention during picture encoding, and found that older adults who devoted full attention to the stimuli showed the positivity effect, remembering more positive images than negative images, in contrast with their younger counterparts. On the other hand, when attention was divided, the recall of younger adults was not affected, yet older adults recalled more negative images. The results suggest that older adults depend on attentional resources to focus on positive over negative information. Thus, older adults are more successful at implementing goal directed

behavior when their attention is not distracted. Other research has focused on the extent to which emotional stimuli influences WM in the inhibition of processing irrelevant information. For instance, Kuhl and Kazen (1999) found that color word interference was eliminated after exposure to positive words when compared to negative and neutral words.

A goal in most tasks both in the laboratory and daily life is self-regulation. Self-regulation enables us to manipulate and alter our behavior in a way that will guide subsequent actions and thoughts (Schmeichel, 2007). WM is necessary to guide processing of perceptual and contextual information (Gyurak, Goodkind, Madan, Kramer, Miller, & Levenson, 2009). In order to self-regulate behavior and keep information active in WM, one must monitor his behavior to allocate attention towards achieving a goal (Ilkowska & Engle, 2010). There may be important links between individual differences in WMC and successful self-regulation. For instance, one function of self-regulation is flexibility (e.g., the ability to switch back and forth between different strategies; Gyurak et al., 2009; Hoffman, Friese, Schmeichel, & Baddley, 2011; Ilkowska & Engle, 2010), which is necessary for competence on numerous tasks and in many situations, such as implementing rules for emotional expression and monitoring emotional responses (Gyurak et al., 2009). Unfortunately, flexibility opens the door to multiple options, which may lead to conflict (Gyurak et al., 2009). Monitoring for the presence of conflict is necessary in order to select the optimal response among competing goals. Moreover, processing conflict can often carry affective consequences (Schmeichel, 2007). It is important to understand the role of working memory in emotion, in addition to the role of emotion when resolving

conflict. Emotion adds value to a situation and enables an individual to take into account situational factors and internal information that is subjectively relevant (Gross, 1998; Van Dillen & Koole, 2007; Koole, Van Dillen, & Sheppes, 2011).

Emotion regulation requires an individual to alter an initial or automatic emotional response under a variety of circumstances. Individual differences in WMC may influence ones ability to successfully regulate. Therefore, producing an emotional state congruent with the demands of the situation should be easier for those with high WMC because they are better able to plan and monitor their behavior in complex and novel situations (Lepine, Barrouillet, & Camos, 2005). For instance, in novel situations, those with high WMC are more likely to use social norms or prior personal beliefs as rules to regulate their behavior by deriving an evaluation based on available information (Barrett et al., 2004; Smith & DeCoster, 2000; Wilson & Brekke, 1994). This idea is consistent with previous findings where subjects with high WMC made fewer errors than individuals with low WMC on the Stroop task when the proportion of incongruent trials was low, suggesting that those with high WMC were better able to ignore irrelevant distractions (Kane and Engle, 2003). Furthermore, those higher in WMC show enhanced performance when the situation uses a rule to steer behavior (Barrett et al., 2004). For instance, Schmeichel, Volokhov, and Demaree (2008) showed participants emotionally evocative stimuli and asked them to maintain a neutral expression. The authors found that working memory capacity predicted adequate emotion expression suppression. Schmeichel and Demaree (2010) examined the manner in which working memory capacity contributes to emotion regulation strategies and found that

participants with higher working memory capacity: a) report decreased negative affect when faced with negative information and, b) spontaneously and successfully down regulated their emotional response to unpleasant information.

It is entirely possible that emotion influences thought and behavior by influencing how cognition *controls* behavior. Emotion regulation processes are goal directed, and function to modify the duration and intensity of physiological, behavioral, and experiential responses (Gross & Thompson, 2007). For the purposes of this dissertation, successful emotion regulation would depend on the ability to execute an appropriate response once faced with an unexpected and/or evocative stimulus or event (Gyurak et al., 2009).

Metacognitive Awareness

Metacognition is knowledge of or beliefs about one's cognitive system, factors affecting that system, the regulation and awareness of one's current state, and appraisal of the significance of current thoughts and memories (Wells, 1995; Moses & Baird, 1999). Metacognition is involved in the planning, evaluation, monitoring, and application of strategies, and cognitive functioning (Brown, 1987; Fernandez-Duque, Baird, & Posner, 2000; Spada, Nikcevic, Moneta, Wells, 2008). Examples of metacognition include understanding that one should rehearsing a phone number to commit it to memory, or knowing what types of cognitive tasks you perform best (e.g. "I am great at math equations, but horrible at remembering words"). Metacognition contributes to the coordination of conflict resolution, inhibition, and resource allocation (Fernandez-Duque, et al., 2000). Currently, no published research has examined the relationship between individual differences in metacognition and

successful emotion regulation. Much of metacognitive research has focused on learning, education, and development in naturalistic settings (Thompson, 1994; Fernandez-Duque et al., 2000). In this dissertation, I am interested in whether those with high metacognitive insight are more skilled at emotion regulation than those with low metacognitive insight.

We rely on metacognition for daily tasks that involve decision-making, strategy use and selection, and performance of non-routine and/or novel activities (Norman & Shallice, 1986; Fernandez-Duque et al., 2000). For this reason, metacogniton may also be involved in emotional control and regulation. For example, response criterion can be shifted by valenced (positive or negative) feedback (Derryberry, 1991). Fernandez-Duque (1999) found that using a valenced cue during a task reduced errors and increased accuracy, even when subjects felt the cue was uninformative. Moreover, individuals use internal speech to control their affective responses.

Metacognition is implicated in the ability to change one's goals (e.g., deciding to focus on something new altogether) and to change one's thoughts (e.g., focusing on another aspect or a stimulus, or changing the way one thinks about the stimulus; Farb et al., 2010). When regulating emotion, one must have an awareness of the situation, and knowledge of what strategies to employ to dampen unwanted feelings and thoughts (Davis, Levine, Lench, & Quas, 2010; Farb et al., 2010). This requires an individual to monitor their history of success or failure with previous regulation attempts, the knack to accurately detect and identify strength and weaknesses, and adjust behavior accordingly (Diamond & Aspinwall, 2003).

The Electrophysiology of Emotion

As described in previous sections, emotions are physiological, experiential, and behavioral responses to personally relevant internal and external stimuli (Gross & Thompson, 2007). Many studies have used event related brain potentials (ERPs) to examine the time course of emotion/affect, as well as to investigate what strategies may modulate responses to emotional information (Bradley & Lang, 2000; Olofsson, Nordin, Sequerira, & Polich, 2008). Research assumes that emotional responses are rooted in personal relevance or motivational states (Bradley, 2000; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Davidson, 1993). Generally, emotion influences a number of components of ERPs reflected at different stages of processing. (Bradley, Codispoti, Cuthbert, & Lang, 2001; Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006). These ERPs are: the P1 and N1, the P200, the EPN (N200), the P3, and the Late Positive Potential (LPP). This section provides an overview of the latency and the way in which emotional stimuli influence each component. The topography and timing of these ERPs is consistent despite the variability of stimulus onset, the type of task and task demands, and the number of presentations (Hajcak, MacNamara, & Olvet, 2010).

Studying emotion in the laboratory is challenging, as it remains difficult to emulate real-world interactions between stimuli and individuals. Most paradigms and designs use pictures (e.g., items from the International Affective Picture Set (IAPS); Lang, Bradley, & Cuthbert, 2005) that elicit changes in attention and arousal. Pictures are effective stimuli despite the fact that a picture stimulus is not a real and, in the case of unpleasant stimuli, not an imminent or potential threat. Previous

investigations have noted that valence (pleasant/unpleasant) and arousal (high/low) might elicit different changes in amplitude in response to pictures, and most often, valence effects are observed earlier (100 – 200 milliseconds) than arousal effects (200 – 1000 milliseconds; Codispoti, Ferrari, & Bradley, 2007; Olofsson & Polich, 2007; Olofsson, Nordin, Sequeira, & Polich, 2008). These effects are observed during passive viewing, and on active tasks (Olofsson et al., 2008).

P1 and N1

The P1 and N1 are two early visual components elicited between 100 milliseconds and 150 milliseconds (Keil, Bradley, Hauk, Rockstroh, Elbert, & Lang, 2002; Olofsson & Polich, 2007) generally observed at the parietal-occipital and occipital regions of the scalp. Often, the P1 and N1 are elicited for stimuli with affective content compared to neutral content (Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004; Holmes, Nielsen, & Green, 2008).

The P1 is a positive deflection appearing between 100 milliseconds and 130 milliseconds following picture onset (Oloffson & Polich, 2007). Some report enhanced P1 amplitude for emotional images at occipital and/or frontal regions of the scalp (Delplanque et al., 2004; Holmes et al., 2008). Other research reports a reduction in amplitude for emotional images (Delplanque et al., 2004). The nature of task demands may account for variation in the effect of emotion on the P1 across studies. For instance, studies using categorization tasks report a larger P1 for positive and negative stimuli than neutral stimuli (Delplanque et al., 2004). On the other hand, there is no effect of emotion in studies that use passive viewing paradigms (Weinberg & Hajcak, 2010).

The N1 peaks around 130 milliseconds after stimulus onset (Keil, Muller, Gruber, Wienbruch, Stolarova, & Elbert, 2001), is greater in amplitude for valenced compared to neutral stimuli, sensitive to positive and negative stimuli, (Keil et al., 2001), and reflects early visual processing of emotional content (Keil et al., 2001; Weinberg & Hajcak, 2010).

The P200 and the Early Posterior Negativity (EPN)

The P200 is observed approximately 180 milliseconds after stimulus onset and is sensitive to target stimuli with low probability (Luck & Hillyard, 1994; Olofsson et al., 2008). The EPN begins around 200 milliseconds and ends between 300 and 325 milliseconds. The P200 and EPN are sensitive to highly arousing valenced stimuli, and typically observed at the central parietal and parietal regions of the scalp. There appear to lateral differences between the P200 and EPN. More specifically, the EPN has been observed more often over the right hemisphere than the left (Schupp, Junghofer, Weike, & Hamm, 2003). Previous research has found that although this component is sensitive to valence, it is more sensitive to negative stimuli than positive stimuli (Schupp et al., 2003). The P200 and EPN are an index of selective attention to specific stimulus features (e.g., valence) and stimulus evaluation (Codispoti, Ferrari, Junghofer, & Schupp, 2006; Oloffson & Polich, 2007), which allows an individual to gather information for further processing. In summary, the P200 and EPN are sensitive to emotional content (Bradley, Hamby, Loew, & Lang, 2007).

The P3

The P3 is a well known and widely reported waveform found between 300 milliseconds and 500 milliseconds after stimulus onset (Luck, 2005; Polich, 2007) and is observed at the central and parietal regions of the scalp. The P300 is sensitive to motivationally relevant stimuli and is an index of: 1) stimulus categorization (e.g., primarily seen in oddball tasks; Polich, 2007), 2) probability of stimulus occurrence (e.g. Duncan-Johnson & Donchin, 1977), and 3) allocation of attention or cognitive resources consumed by one aspect of a task (e.g. Duncan-Johnson & Donchin, 1977). The P300 elicited in nonaffective tasks is similar in timing and topography for emotion tasks (Cacioppo, Crites, Berntson, & Coles, 1993). Evidence from previous research suggests that emotional stimuli automatically seize our attention (Bradley, 2009; Bradley & Lang, 2000). For instance, positive and negative pictures are viewed longer than neutral pictures; therefore, emotional stimuli are natural targets. Unlike the EPN, modulations of the P3 are similar for emotional stimuli and nonemotional stimuli, depending on the manipulation. For instance, the P300 is not enhanced for unattended positive and negative images in comparison to neutral images or unattended nonaffective targets (MacNamara & Hajcak, 2009).

The Late Positive Potential (LPP)

The late positive potential (LPP) is a positive, slow waveform beginning around 300 milliseconds after stimulus onset and ending around approximately 1000 - 2000 milliseconds. The LPP is located at the midline of the central parietal and parietal regions of the scalp. The LPP is greater in amplitude for positive and

negative stimuli compared to neutral stimuli and is an index for sustained attention and arousal (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hajcak, et al., 2010; Hajcak & Nieuwenhuis, 2006; Schupp et al., 2003). For instance, in one study where subjects passively viewed positive, negative, and neutral pictures, the LPP was greater in amplitude for emotional pictures than neutral pictures, however, the LPP did not differ between positive and negative pictures. These findings suggest that this component is sensitive the intensity of the stimulus, and not valence (Hajcak & Nieuwenhuis, 2006).

The amplitude of the LPP is associated with subjective arousal ratings and the presentation of motivationally significant stimuli (Cuthbert et al., 2000; Weinberg & Hajcak, 2010). Previous research has found increases in amplitude for pictures depicting threat, violence, mutilations, and erotica (Briggs & Martin, 2009; Weinberg & Hajcak, 2010). Furthermore, modulation of the LPP is stable and not susceptible to habituation (Codispoti et al., 2007; Hajcak et al., 2010; Olofsson & Polich, 2007). For instance, Codispoti, Ferrari, and Bradley (2007) measured examined variability of the LPP for multiple stimulus presentations of positive, negative, and neutral images. The authors found that the amplitude of the LPP was attenuated by stimulus repetition; however, modulation related to affective pictures remained stable. This suggests that although attention for affective images might have declined over trial repetitions, sensitivity to motivationally salient images does not decrease. As previously mentioned, emotional images are automatic targets. The authors also concluded that their results were not due to fatigue because novel pictures reintstated the amplitude of the LPP. Other techniques (e.g., heart rate, facial

electromyography, galvanic skin response) used to measure emotion show habituation after repeated presentations (Bradley, Lang, & Cuthbert, 1993; Codispoti et al., 2007). These findings indicate that the LPP is modulated by stimulus intensity and personal/motivational relevance.

Emotion Regulation and the LPP

Cognitive reappraisal (e.g., reinterpreting an emotional stimulus) has been found to decrease the intensity of a response to an emotionally evocative event without impacting other nervous system and/or cognitive functions (Gross, 2002; Hajcak & Nieuwenhuis, 2006; Hajcak et al., 2010; Richards & Gross, 2000). For example, asking subjects to decrease the intensity of their emotional response, or using more directive instructions such as reinterpreting an emotional stimulus as something less negative, has been shown to reduce the amplitude of the LPP (Hajcak & Nieuwenhuis, 2006; Moser, Hajcak, Bukay, & Simons, 2006). Measures of distraction, such as concurrent task difficulty, do not reduce the modulation of the LPP (Hajcak, Dunning, & Foti, 2007), but there is evidence that redirecting attention can. For instance, Dunning and Hajcak (2009) found that when attention was directed to a less emotional part of a negative picture, the LPP was reduced compared to when attention was directed to view a more emotional aspect of the picture.

CHAPTER 3.

EXPERIMENT 1: THE EFFECTS OF PICTURE CONTENT ON COGNITIVE REAPPRAISAL

The ability to influence and manipulate how we experience and express emotion is known as emotion regulation (Gross, 2007; McRae et al., 2010). Emotion regulation refers to intrinsic processes used to decrease the experiential, behavioral, or physiological characteristics of negative emotions (e.g., fear, anger, sadness, frustration, etc.), by initiating, maintaining, and/or increasing positive emotions after an emotionally evocative event (Gross, 2008; Mauss et al, 2005). Individuals actively regulate their emotions on a regular basis and the successful regulation of emotion is important for psychological well-being and social adjustment (Gross & John, 2003; Krompinger et al., 2008; McRae et al., 2010). Emotion regulation processes are said to differ in when and how they influence the emotion generative process (Goldin et al. 2006). Emotion regulation can be intentional or routine, and consistent, conscious or unconscious. The onset, duration, quality, and magnitude can change based on the initiated regulatory response (Hajcak & Nieuwenhuis, 2006; Gross, 2007; McRae et al., 2008).

In an effort to expand the findings of Hajcak and Nieuwenhuis (2006), an ERP experiment was conducted to examine the effects of picture content on reappraisal ability and neural recruitment. The purpose of the current experiment was threefold: the first goal was to investigate whether the results of Hajcak and Nieuwenhuis (2006) could be replicated for different picture content. Using the same experimental design, the LPP was measured on attend and reappraise trials for pictures depicting

grief/loss, violence, and mutilations. A comparison of the LPP for each picture type allowed us to determine whether the ability to reappraise depends on the specific content presented. It was expected that reappraisal would modulate the neural response for all pictures, regardless of content. Second, ERPs were used to investigate differences in neural recruitment during regulation for all content areas. It was hypothesized there should be differences in neural processing content influences reappraisal ability. In addition, there should also be sustained neural activity during regulation. Lastly, after each trial, participants rated the intensity of their emotional responses. These ratings were used to examine behavioral differences between the attend and reappraisal conditions for picture content. It was hypothesized that emotional intensity ratings would be higher on attend trials relative to reappraisal trials, and vary by picture content.

EXPERIMENT 1 METHOD

Participants

Thirty-six Iowa State University undergraduates (mean age = 20.22, range = 18-33) were recruited through the Department of Psychology research sign-up system (SONA) and received course credit for their participation. The sample included 15 males and 21 females, and all were right-handed. Data for 4 individuals were excluded from the analyses due to high levels of movement artifact in the electroencephalogram (EEG). The university's institutional review board approved the experiment and informed consent was obtained from all participants prior to testing.

Materials

Emotion regulation task. The stimuli for this task were selected from the IAPS (Lang et al., 2005). For the purposes of the task, only negative pictures with similar arousal ratings were used (Table 1).

Table 1.
IAPS mean valence and arousal ratings by picture content.

	Arousal	Valence
Grief/Loss	5.09 (.67)	2.48 (.53)
Mutilations	6.40 (.64)	1.80 (.32)
Violence	6.23 (.50)	2.37 (.33)

A total of 90 pictures[1] were selected and each image contained one or more people. Pictures were 512 by 384 pixels and presented on a white background. All stimuli were presented using E-Prime 1.2 Software (Psychology Software Tools, Pittsburgh, PA).

Design

The research design was a 3 (picture content: violence, mutilations, grief/loss) x 2 (regulation: attend, reappraise) factorial with picture type and regulation strategy as within-subject variables. There were three blocks of 30 trials, one block for each picture type (violence, mutilations, grief/loss). Within each block, a picture was paired with one of two regulation strategies (attend or reappraise). The trial list within each block contained 15 attend trials and 15 reappraise trials. The list was counterbalanced between subjects so that each picture was displayed with each

[1] 2053, 2095, 2141, 2205, 2276, 2278, 2352.2, 2399, 2455, 2683, 2700, 2703, 2799, 2800, 2900, 3000, 3005.1, 3010, 3016, 3017, 3030, 3051, 3053, 3060, 3061, 3062, 3063, 3064, 3068, 3069, 3071, 3080, 3100, 3101, 3102, 3110, 3120, 3130, 3150, 3168, 3170, 3215, 3216, 3220, 3225, 3230, 3261, 3266, 3300, 3350, 3500, 3530, 6021, 6212, 6213, 6243, 6250, 6311, 6312, 6313, 6315, 6350, 6360, 6530, 6540, 6550, 6560, 6571, 6821, 6831, 9040, 9041, 9050, 9220, 9250, 9252, 9253, 9254, 9331, 9415, 9420, 9421, 9423, 9424, 9425, 9427, 9428, 9433, 9435, 9530

regulation strategy. A practice block containing 9 trials (4 attend, 5 reappraise) was constructed that included stimuli that were not used in the experimental blocks. The practice block was the same for all subjects.

Procedure

Participants were tested individually in a session lasting approximately 2 hours. All testing was conducted in the Temporal Dynamics of Attention and Memory Laboratory at Iowa State University. Upon arrival, participants were given an overview of the session, completed informed consent procedures and psychometric measures, and were then fitted with an Electro-Cap (Electro-cap International, Eaton, OH). Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971).

Participants were seated in front of a computer with a 17-inch monitor at a distance of 41 inches from the screen. They were told that they would see several pictures on the screen. Depending on the cue, their task was to either attend to, or reappraise, the picture. If the cue was “attend”, the participant was instructed to think about the picture displayed. If the cue was “reappraise”, the participant was instructed to reinterpret the picture in a more positive manner. Once the regulation phase was complete, the picture was displayed a second time and participants rated the intensity of their emotional response to the picture on a four-point scale (weak to strong) with their index and middle fingers (see Figure 3 for trial sequence). The ‘v’, ‘b’, ‘n’, and ‘m’ key were

Figure 3. Task structure for Experiment 1.

used for responses, with ‘v’ being weak and ‘m’ being strong. A practice block was presented to familiarize participants with the task before presenting the experimental trials. For the practice trials only, participants were instructed to state their reappraisal aloud so that the experimenter could judge whether participants understood the task.

On each trial, the word “VIEW” was presented for 1000 milliseconds to indicate a new picture was about to appear. The picture was then presented for 1000 milliseconds, and then the regulation cue (“ATTEND”, “REAPPRAISE”) appeared and remained on the screen for 4500 milliseconds. A blank white screen was presented for 500 milliseconds followed by the second presentation of the picture, which remained on the screen for 2000 milliseconds. Afterward, participants rated the intensity of their emotional response to the image. Participants were given the opportunity to take a break between blocks. After task completion, the Electro-cap was removed, and individuals were debriefed and thanked for their participation in the experiment.

Electrophysiological Recording and Analysis

The electroencephalogram (EEG, bandpass .02–150 Hz, digitized at 500 Hz, gain 1,000, 16-bit A/D conversion) was recorded from an array of 68 tin electrodes that were sewn into an Electro-cap (Electro-cap International, Eaton, OH) or affixed to the skin with an adhesive patch. The Electro-cap was interfaced to a DBPA-1 (Sensorium Inc., Charlotte, VT) amplifier and digitizer. Vertical and horizontal eye movements were recorded from four electrodes placed below or beside the eyes. During recording, all electrodes were referenced to electrode Cz.

For data analysis, the electrodes were re-referenced to an average reference (Picton et al., 2000). Considerable alpha activity was observed in a number of participants, therefore a .1 to 8 Hz zero-phase-shift bandpass filter was applied to the EEG data before averaging. Ocular artifacts associated with blinks and saccades were corrected by hand using the ocular artifact correction filter within the EMSE software (Source Signal Imaging, San Diego). Trials contaminated by other artifacts (peak-to peak deflections greater than 100 μV) were rejected before averaging. ERP epochs included data for responses where response time was less than 5000 milliseconds. The ERP epoch included -200 milliseconds of prestimulus activity to 1000 milliseconds of poststimulus activity for the first presentation of the picture, -200 milliseconds of prestimulus activity to 3000 milliseconds of poststimulus activity for the cue-locked data, and -200 milliseconds of prestimulus activity to 2000 milliseconds of poststimulus activity for the second presentation of the picture. We averaged to 3000 milliseconds instead of 4500 milliseconds for the cue-locked data to ensure stable averages for the waveforms.

ERPs were averaged by picture content and regulation type. The effect of picture content on the P3 at the first presentation of the picture, LPP at the first and second presentation of the picture, and slow wave activity during regulation was examined in the analyses. These analyses included measures of mean amplitude in a set of ANOVAs using the Huynh–Feldt (Huynh & Feldt, 1976) corrected degrees of freedom when necessary. For the first presentation of the picture, the amplitude of the P3 was measured as mean voltage between 400 milliseconds and 600 milliseconds at electrode Pz, and the LPP was measured as mean voltage between

600 milliseconds and 800 milliseconds at electrode CPz. For the grief/loss cue-locked data, slow wave activity was measured as mean voltage in two epochs (1000 milliseconds – 2000 milliseconds and 2000 milliseconds – 3000 milliseconds) at electrodes F9, F7, F5, F3, POz, and Oz. For the mutilation cue-locked data, slow wave activity was measured as mean voltage in two epochs (1000 milliseconds – 2000 milliseconds and 2000 milliseconds – 3000 milliseconds) at electrodes F5 and F3. For the violence cue-locked data, slow wave activity was measured as mean voltage in two epochs (1000 milliseconds – 2000 milliseconds and 2000 milliseconds – 3000 milliseconds) at electrodes AF3, AF4, Ft9, F7, F5, PO1, POz, and PO2. For the second presentation of the picture, the LPP was measured as mean voltage between 500 and 1000 milliseconds at electrodes CPz and POz.

EXPERIMENT 1 RESULTS

Behavioral Data

The effects of picture content and regulation on emotional intensity ratings were examined in a 3 (picture content: grief/loss, mutilations, violence) x 2 (regulation: attend, reappraise) ANOVA (Table 2).

Table 2.
Means and standard deviations for emotional intensity ratings for content by regulation.

	Grief/Loss	Mutilations	Violence
Attend	2.30 (.60)	3.13 (.59)	2.79 (.63)
Reappraise	1.95 (.59)	2.65 (.75)	2.25 (.61)

The analysis revealed a significant main effect of picture content, $F(2, 62) = 32.29$, $p = .001$, $\eta_p^2 = .53$, with ratings being higher for mutilations than for grief, $F(1, 31) =$

45.69, p = .001, η_p^2 = .60, and for violence, F(1, 31) = 18.80, p = .001, η_p^2 = .38, and higher for violence than for grief, F(1, 31) = 32.39, p = .001, η_p^2 = .51. There was a significant main effect of regulation, F(1, 31) = 22.51, p = .001, η_p^2 = .42, as emotional intensity ratings were lower on regulation trials than on attend trials. The picture content x regulation interaction was not significant, F(2, 62) = 1.41, p = .251, η_p^2 = .04.

Electrophysiological Data

First presentation of the picture. Grand-averaged ERPs recorded at Pz and CPz, elicited by grief/loss, mutilation, and violent images are presented in Figure 4. These electrodes portray the effect of picture content on the P3 and LPP components. The effect of picture content on the P3 was examined between 400 and 600 milliseconds in a one-way ANOVA at electrode Pz. There was a significant main effect of picture content, F (2, 62) = 10.13, p = .001, η_p^2 = .25, ϵ = .91, with the amplitude of the P3 being greater for pictures depicting mutilations than violence, F (1, 31) = 13.52, p = .001, η_p^2 = .30, or grief/loss, F (1, 31) = 12.35, p = .001, η_p^2 = .29, and no significant differences between grief/loss and violence pictures, F < 1.00.The effect of picture content on the LPP was examined between 600 and 800 milliseconds in a one-way ANOVA at electrode CPz. As revealed in

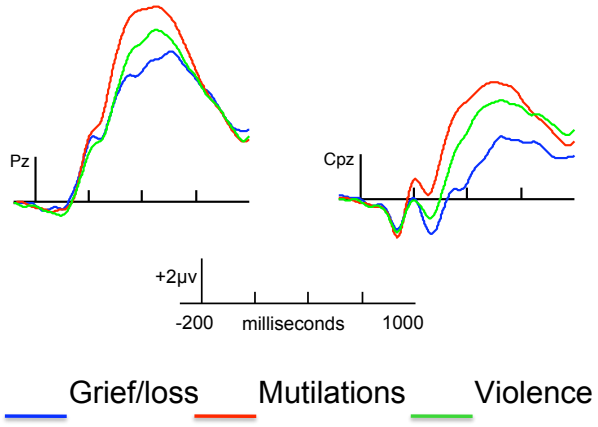

Figure 4. Grand averaged ERPs at electrodes Pz and CPz at the first presentation of the picture.

Figure 4, there was a significant main effect of picture content, F (2, 62) = 9.82, p = .001, η_p^2 = .24, ϵ = .89, with the amplitude of the LPP being greater for mutilations than for grief/loss pictures, F (1, 31) = 14.01, p = .001, η_p^2 = .31, and greater for violence than grief loss pictures, F (1, 31) = 16.96, p = .001, η_p^2 = .35. The difference between mutilations and violence pictures was not significant, F (1, 31) = 1.15, p = .292, η_p^2 = .04.

Cue-locked data. The time course and topographic differences in neural recruitment for picture content are portrayed in Figures 5 and 6. In Figure 5, there are differences in the topography of slow wave activity for the three picture types. Therefore, analyses for the cue-locked data are described separately for each content area. To examine and best determine the latency of the effects, we divided the 3-second epoch into two separate time frames (1000 – 2000 milliseconds and 2000 – 3000 milliseconds). Mean voltages are presented in Table 3.

Table 3.
Mean voltages and standard error for cue-locked slow wave activity by picture content and regulation.

	Grief/Loss		Mutilations		Violence	
1000 – 2000 ms	Attend	Reappraise	Attend	Reappraise	Attend	Reappraise
Left Frontal	2.56 (.87)	4.34 (.57)	2.05 (.83)	4.19 (.55)		
Parietal-Occipital	-2.96 (.81)	-4.56 (.73)			-4.40 (.91)	-6.50 (.61)
2000 – 3000 ms						
Anterior Frontal					1.15 (.83)	3.06 (.95)
Left Frontal			1.12 (.59)	3.31 (.69)	2.41 (1.28)	4.86 (.82)
Parietal-Occipital	-1.88 (69)	-2.83 (.70)			-3.21 (.98)	-5.56 (.74)

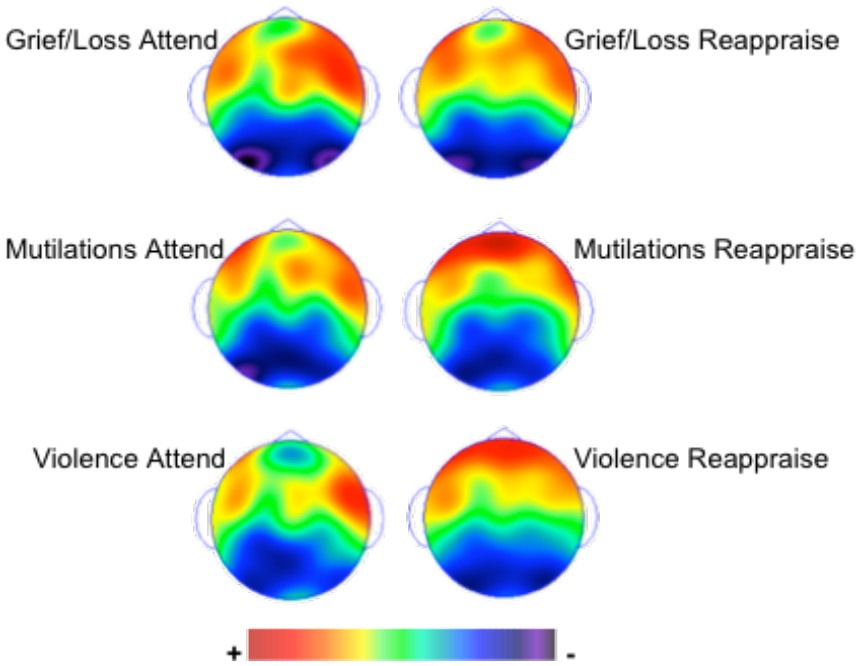

Figure 5. Topography maps demonstrating slow wave activity during the cue locked period for each picture type at 1000 milliseconds.

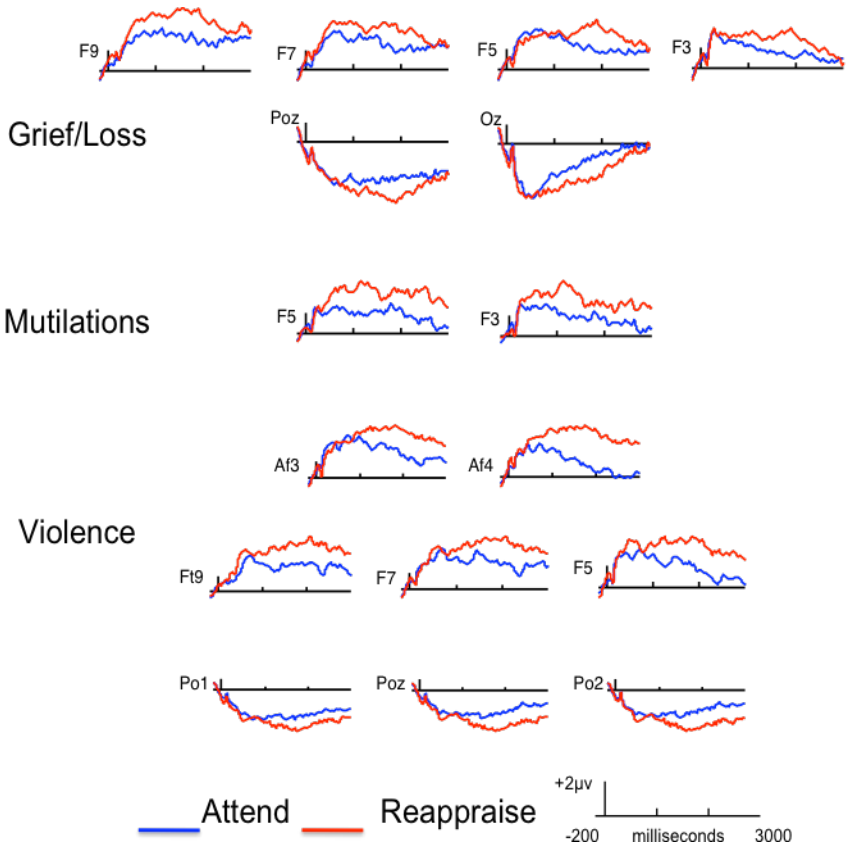

Figure 6. Grand averaged ERPs for the cue locked data. Select electrodes portraying slow wave activity for each condition.

Grief/loss. For the grief/loss data, a slow wave began around 1000 milliseconds after cue onset and appeared to be more strongly expressed over the left frontal region and persisted until 2000 milliseconds. Over the parietal-occipital region, slow wave activity began around 1000 milliseconds after cue onset and persisted until 2000 milliseconds, where the mean amplitude of the reappraise condition was more negative than the attend condition.

Slow wave activity over the left frontal region reflected greater positivity for the reappraise condition relative to the attend condition between 1000 and 2000 milliseconds. This effect was examined in a 2 (regulation) x 4 (electrode: F9, F7, F5, F3) ANOVA (Figure 6). In this analysis, the main effect of regulation was significant, F (1, 31) = 4.14, p = .05, η_p^2 = .12, where the mean amplitude of the reappraise condition, M = 4.34 μV, SE = .57, was more positive than the attend condition, M = 2.57 μV, SE = .87. Slow wave activity over the parietal-occipital region of the scalp reflected greater negativity for the reappraise condition relative to the attend condition (Figure 6) and was examined in a set of 2 (regulation) x 2 (electrode: POz, Oz) ANOVAs that included two epochs (1000 milliseconds – 2000 milliseconds and 2000 milliseconds – 3000 milliseconds). In this analysis, there was a significant main effect of regulation in the first epoch, F (1, 31) = 6.91, p = .01, η_p^2 = .18, where the mean amplitude for the reappraise condition was more negative, M = -4.56 μV, SE = .73, than the attend condition, M = -2.96 μV, SE = .81. The main effect of regulation was marginally significant in the second epoch, F (1, 31) = 3.40, p = .07, η_p^2 = .10, where the mean amplitude for the reappraise condition continued to be more negative, M = -2.83 μV, SE = .70, than the attend condition, M = -1.88 μV, SE =.69.

Mutilations. For the mutilation data, a slow wave began around 1000 milliseconds after cue onset and appeared to be more strongly expressed over the left frontal region and persisted until 3000 milliseconds. Slow wave activity over the left frontal region reflected greater positivity for the reappraise condition relative to the attend condition (Figure 6). This effect was examined in a set of 2 (regulation) x 2 (electrode: F5, F3) ANOVAs that included two epochs (1000 milliseconds – 2000 milliseconds and 2000 milliseconds – 3000 milliseconds). The main effect of regulation was significant in the first epoch, F (1, 31) = 9.01, p = .01, η_p^2 = .22, where the mean amplitude for the reappraise condition was more positive, M = 4.19 μV, SE = .55, than the attend condition, M = 2.05 μV, SE = .83, and a significant main effect of regulation in the second epoch, F (1, 31) = 7.89, p = .01, η_p^2 = .20, where the mean amplitude for the reappraise condition was more positive, M = 3.31 μV, SE = .69, than the attend condition, M = 1.12 μV, SE =.59.

Violence. For the violence data, a slow wave began around 2000 milliseconds after cue onset and appeared to be more strongly expressed over the anterior frontal region and persisted until 3000 milliseconds. Over the left frontal region, slow wave activity began around 2000 milliseconds after cue onset and persisted until 3000 milliseconds. Slow wave activity was observed over the parietal-occipital region and began 1000 milliseconds after stimulus onset and persisted for 3000 milliseconds.

At two anterior frontal electrodes, slow wave activity reflected greater positivity for the reappraise condition relative to the attend condition between 2000 and 3000 milliseconds (Figure 6). This effect was examined in a 2 (regulation) x 2 (electrode: AF3, AF4) ANOVA. In this analysis, the main effect of regulation was

marginally significant, F (1, 31) = 3.90, p = .06, η_p^2 = .11, where the mean amplitude for the reappraise condition was more positive, M = 3.06 μV, SE =.95, than the attend condition, M = 1.15 μV, SE =.83. Greater positivity over the left frontal region of the scalp for the reappraise condition relative to the attend condition between 2000 and 3000 milliseconds (Figure 6) was examined in a 2 (regulation) x 3 (electrode: Ft9, F7, F5) ANOVA. In this analysis, there was a marginally significant main effect of regulation, F (1, 31) = 3.79, p = .06, η_p^2 = .11, where the mean amplitude for the reappraise condition was more positive, M = 4.86 μV, SE =.82, than the attend condition, M = 2.41 μV, SE =1.28. Slow wave activity over the parietal-occipital region that reflected greater negativity for the reappraise condition relative to the attend condition (Figure 6) was examined in a set of 2 (regulation) x 3 (electrode: PO1, POz, PO2) ANOVAs that included two epochs (1000 – 2000 milliseconds, 2000 – 3000 milliseconds). In this analysis, the main effect of regulation was significant in the first epoch, F (1, 31) = 6.34, p = .02, η_p^2 = .17, where the mean amplitude for the reappraise condition was more negative, M = -6.50 μV, SE = .61, than the attend condition, M = -4.40 μV, SE = .91 and was also significant in the second epoch, F (1, 31) = 4.38, p = .05, η_p^2 = .12, where the mean amplitude for the reappraise condition was more negative, M = -5.56 μV, SE = .74, than the attend condition, M = -3.21 μV, SE =.98.

Second presentation of the picture. The amplitude of the LPP was greatest in amplitude over the central-parietal and parietal-occipital regions of the scalp between 500 and 1000 milliseconds after stimulus onset for pictures depicting violence. Also for violent pictures, a frontal slow wave began around 500

milliseconds after stimulus onset and persisted until 1000 milliseconds. The LPP for picture content is portrayed at electrodes CPz and POz in Figure 7. The effects of picture content and regulation on the LPP were examined between 500 and 1000 milliseconds in a 2 (regulation) x 2 (electrode: Cpz, POz) ANOVA separately for picture content. The main effect of regulation was significant for pictures depicting violence, F (1, 31) = 4.90, p = .03 η_p^2 = .137, where the amplitude of the LPP was

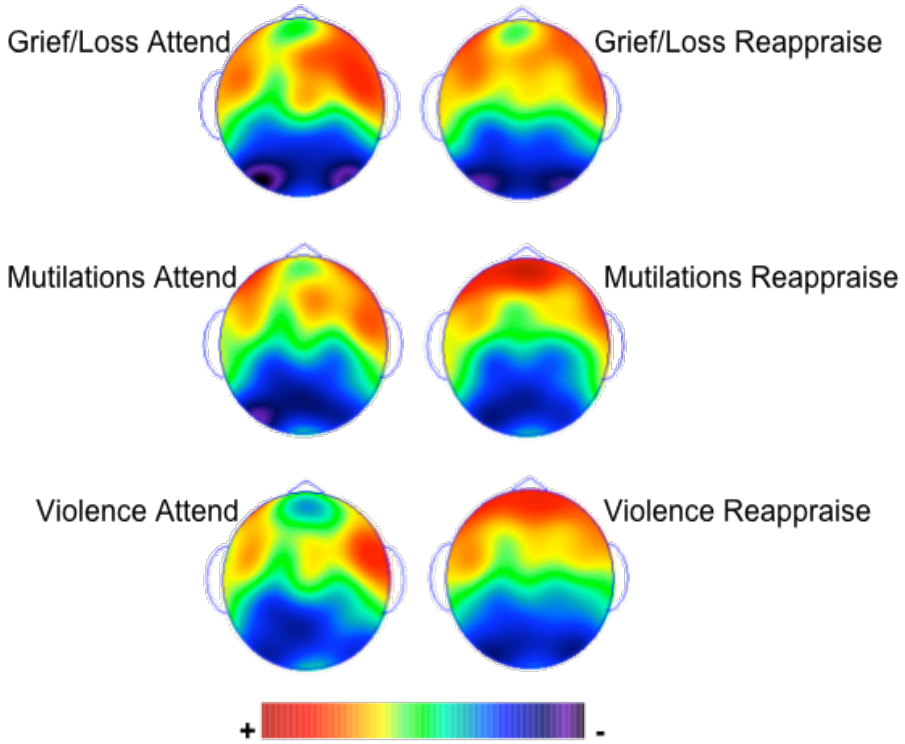

Figure 7. Grand averaged ERPs for the second presentation of the picture for each content area.

greater for attend trials, M = 2.60 μV, SE = .55, than reappraise trials, M = 1.55 μV, SE = .41.The main effect of regulation was not significant for pictures depicting grief/loss, F (1, 31) = 2.96, p = .09, η_p^2 = .04, or for pictures depicting mutilations, F (1, 31) = 1.05, p = .31, η_p^2 = .03. At the same time as the LPP (500 milliseconds – 1000 milliseconds), greater negativity was observed over the left and right frontal

regions of the scalp for the attend condition relative to the reappraise condition (Figure 7). This was examined for each picture content in a 2 (regulation) x 2 (hemisphere) x 2 (electrode: F10, FT10, F9, FT9) ANOVA. In this analysis, a significant main effect of regulation was found for pictures depicting violence, F (1, 31) = 4.87, p = .03 η_p^2 = .04, where the mean amplitude of the attend trials was more negative, M = -3.30 μV, SE = .50, than the amplitude for reappraise trials, M = -1.97 μV, SE = .50. The main effect of regulation was not significant for pictures depicting grief/loss, F (1, 31) = 1.32, p = .26, η_p^2 = .04, or for pictures depicting mutilations, F < 1.00.

EXPERIMENT 1 DISCUSSION

This experiment was designed to examine the influence of emotional content on self-reports of emotion regulation and the neural correlates of reappraisal. This investigation was grounded in previous work demonstrating that reappraisal modulates the neural response to unpleasant images (Hajcak & Nieuwenhuis, 2006) and conceptually motivated by the idea that affective picture processing is sensitive to picture content (Weinberg & Hajcak, 2010). Behaviorally, it was found that self-reported ability to reappraise did not vary significantly by picture content. In contrast, the neural correlates of reappraisal were indeed sensitive to picture content, and there were differences in neural recruitment during regulation between content areas.

Behavioral Data

The self-report data revealed that the intensity of the emotional response was highest for pictures depicting mutilations and lowest for those depicting grief and

loss. For each content area, emotional intensity ratings were lower on regulation trials than on attend trials. Together, these findings suggest that reappraisal appears to successfully dampen the response to negative images regardless of picture content. This is consistent with previous studies demonstrating that reappraisal reduces the impact of negative responses to unpleasant stimuli (Gross, 1998; Gross, 2002; Gross & Thompson, 2007) and that reappraisal is an effective strategy for maintaining well-being and positive feelings (Gross & John, 2003; Ochsner & Gross, 2007).

Electrophysiological Data

At the first presentation of the picture, the P3 was enhanced for pictures depicting mutilations relative to pictures depicting violence or grief and loss. This finding suggests that although all of the pictures were matched for valence and arousal, images of mutilations may be more motivationally relevant in comparison to other unpleasant stimuli. Greater attentional resources are allocated to stimuli (e.g., human mutilations or sex) that portray images or information with high motivational significance (e.g., survival; Briggs & Martin, 2008; Briggs & Martin, 2009; Lang et al., 1997). Moreover, the amplitude of the LPP was greater for pictures depicting mutilations and violence, than for those depicting grief and loss. The amplitude of the LPP did not differ between pictures of mutilations and violence. This finding is consistent with previous work demonstrating that the LPP is sensitive to emotionally salient images and motivational significance (Cuthbert et al., 2000; Hajcak & Nieuwenhuis, 2006; Keil et al., 2002; Lang et al., 1997; Schupp et al., 2000).

The ERP data for the second presentation of the picture is in line with previous evidence demonstrating that reappraisal modulates the neural response to negative emotionally evocative stimuli. Content effects were found for unpleasant stimuli. For violent pictures, we were able to replicate the effect previously shown by Hajcak and Nieuwenhuis (2006), confirming that reappraisal is associated with a reduction of the amplitude of the LPP. In addition, the timing of the effects was consistent, with slow wave activity continuing throughout the duration of stimulus presentation. It was expected that reappraisal would modulate the emotional response to mutilation pictures, given the P3 at the first presentation of the picture; however, an effect was not observed at the second presentation of the picture. It may be that subjects found pictures of mutilations difficult to reappraise. It is much more difficult to put a positive spin on a picture of a mutilated body, then say, a picture of a man holding a gun a to his head. For instance, when reappraising the violent image, one could say the man was talked out of pulling the trigger, or the gun was not real. No effect of reappraisal was found for pictures depicting grief and loss. Undergraduate students may not identify with this category, which would make these images less evocative or not salient enough to trigger a response that would later be sensitive to regulation. This particular finding would suggest that using relevant and arousing images is necessary to replicate effects previously reported by Hajcak and Nieuwenhuis (2006).

A novel set of findings reflected the systematic differences in neural recruitment during the cue period related to active regulation while subjects attended to or reappraised the pictures. The analyses revealed that neural recruitment varies

by picture content. For pictures depicting grief and loss and mutilations, the analyses revealed slow wave activity modulated by reappraisal beginning around 1000 milliseconds after cue onset and lasting up to 3000 milliseconds. Similar slow wave activity was found for pictures depicting violence beginning around 2000 milliseconds after cue onset and lasting for at least 1000 milliseconds. For all three content areas, slow wave activity was observed over the left frontal region of the scalp for the reappraisal condition. For grief and loss pictures, slow wave activity over parietal-occipital regions of the scalp was observed, and for violence pictures, slow wave activity was observed over the anterior frontal region of the scalp for the reappraisal condition. The duration of these effects suggests that regulation is a controlled process associated with sustained neural activity. The differential recruitment between the attend condition and reappraise condition supports the notion that the two processes are distinct, and that subjects engaged in different types of processes during the task. Unfortunately, neural recruitment during regulation did not map directly onto reappraisal ability (second presentation of the picture), as seen in pictures depicting grief and loss, and mutilations. This finding indicates that effective regulation is sensitive to picture content.

In summary, the self-report data indicate that reappraisal decreases the emotional intensity of the picture for all content areas, and the cue-locked data reveals differential recruitment for regulation. However, these effects do not correspond with the ERP data at the second presentation of the picture. In addition, the ERP data for the first presentation of the picture did not correspond with data at the second presentation of the picture for mutilation images, but did for violent

images. These data extend work related to cognitive reappraisal, revealing effects of content on successful regulation. Given that the analyses related to the cue-locked data and regulation revealed that different regions are recruited to support reappraisal by content area, it may be interesting to parse the data based on self-reported ratings for each content area for high and low self-rated reappraisal ability to examine possible differences in neural recruitment during regulation, and at the second presentation of the picture.

CHAPTER 4.

EXPERIMENT 2: AN EXAMINATION OF REGULATION STRATEGY ON ERPs

As previously mentioned, cognitive reappraisal involves reinterpreting an emotional situation or event as less unpleasant than the initial appraisal (Gross, 1998; McRae et al., 2008; Sheppes & Meiran, 2008; Giuliani & Gross, 2009; McRae et al., 2010). Another commonly used form of antecedent-focused emotion regulation is distraction, a regulation strategy used to divert ones attention away from an unpleasant stimulus or situation and shift focus onto something neutral or non-provoking (Sheppes & Meiran, 2008). One form of regulation alters the way we *interpret* a stimulus (reappraisal), and the other alters the way we *attend* to a stimulus or its initial representation (distraction; McRae et al., 2010).

Distraction requires the use of selective attention to decrease or diminish a response to an emotional event, stimulus, or situation, so that highly evocative aspects are not evaluated or attended to (McRae et al., 2010). Evidence has shown that distraction is effective for reducing unpleasant thoughts, anger, stress, frustration, and other negative affective responses (Bennett et al., 2007; Gerin, et al., 2006; Rusting, 1998).

The purpose of Experiment 2 was to evaluate the neural correlates of reappraisal and distraction side by side. In contrast to Experiment 1, a “distract” condition was used in addition to the attend and reappraise conditions, where participants were instructed to focus on a non-emotional aspect of the presented stimuli or think of something positive, unrelated to the picture. We compared the amplitude of the LPP for attend, reappraise, and distract conditions to examine the

nature of the two regulation conditions. It was expected that both strategies (reappraise and distract) would be effective for down-regulation of unpleasant stimuli. Furthermore, differences in neural recruitment were explored between reappraise and distract conditions during regulation. It was hypothesized that systematic differences in scalp topography and amplitude would be observed in the cue-locked data for all three conditions. There were three possibilities for this data: a) there would be differential recruitment for all three conditions (attend ≠ distract ≠ reappraise), b) a regulation effect (attend ≠ distract = reappraise), or c) distinct effects for one of the three conditions. Again, participants were asked to rate the intensity of their emotional response to each picture. For the sef-report data, lower emotional intensity ratings were expected for all pictures on reappraise and distract trials, relative to attend trials.

EXPERIMENT 2 METHOD

Participants

Twenty-seven Iowa State University undergraduates (mean age = 20.64, range = 17-31) were recruited through the Department of Psychology research sign-up system (SONA) and received course credit for their participation. The sample included 14 males and 13 females, and all were right-handed individuals. Two subjects were excluded from the analyses due to excessive eye movements and other artifacts. The university's institutional review board approved the experiment and informed consent was obtained from all participants prior to testing.

Materials

Emotion regulation task. The stimuli for this task were selected from the IAPS (Lang, et al., 2005). A total of 60 pictures[2] from Experiment 1 (violence and mutilations) were selected and each image contained one or more people. Pictures were 512 by 384 pixels and presented on a white background. All stimuli were presented using E-Prime 1.2 Software (Psychology Software Tools, Pittsburgh, PA).

Design

The research design was a one-way ANOVA examining regulation strategy (attend, reappraise, distract) as a within-subject variable. There were two blocks of trials, consisting of 30 pictures. On each trial, a randomly selected picture was paired with one of three regulation strategies (attend, reappraise, or distract). One block consisted of 15 attend trials and 15 reappraise trials, and the other block consisted of 15 attend trials and 15 distract trials. The list was counterbalanced between subjects so that each picture was displayed with each regulation strategy. A practice block containing 9 trials (3 attend, 3 reappraise, and 3 distract) was constructed to include stimuli that were not used in the experimental blocks. The practice block was the same for all subjects.

Procedure

Participants were tested individually in a session lasting approximately 2 hours. All testing was conducted in the Temporal Dynamics of Attention and Memory

[2] 2352.2, 2683, 3000, 3010, 3016, 3017, 3030, 3051, 3053, 3060, 3061, 3062, 3063, 3064, 3068, 3069, 3071, 3080, 3100, 3101, 3102, 3110, 3120, 3130, 3150, 3168, 3170, 3215, 3225, 3261, 3266, 3500, 3530, 6021, 6212, 6213, 6243, 6250, 6312, 6313, 6315, 6350, 6360, 6530, 6540, 6550, 6560, 6571, 6821, 6831, 9252, 9253, 9254, 9420, 9423, 9424, 9425, 9427, 9428, 9433

Laboratory at Iowa State University. Upon arrival, participants were given an overview of the session, completed informed consent procedures, and psychometric measures then fitted with an Electro-Cap (Electro-cap International, Eaton, OH) before completing the emotion regulation task. Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971).

Participants were seated in front of a computer with a 17-inch monitor at a distance of 41 inches from the screen. They were told that they would see several pictures on the screen. Depending on the cue, their task was to attend to, reappraise, or distract their attention from the picture. If the cue was “attend”, then the participant was instructed to think about the picture displayed. If the cue was “reappraise”, the participant was instructed to reinterpret the picture in a more positive manner. If the cue was “distract” the participant was instructed to think of something positive or focus on some non-emotional aspect of the picture. Once the regulation phase was complete, the picture was displayed a second time and participants rated the intensity of their emotional response to the picture on a four-point scale (weak to strong) with their index and middle fingers. We used the ‘v’, ‘b’, ‘n’, and ‘m’ keys, with ‘v’ being weak and ‘m’ being strong. A practice block was presented to familiarize participants with the task before presenting the experimental trials. For the practice trials only, participants were instructed to state their reappraisal aloud so that the experimenter could judge whether participants understood the task.

On each trial, the word “VIEW” was presented for 1000 milliseconds to indicate a new picture was about to appear. The picture was then presented for

1000 milliseconds, and then the regulation cue (“ATTEND”, “REAPPRAISE”, “DISTRACT”) appeared and remained on the screen for 4500 milliseconds. A blank white screen was presented for 500 milliseconds followed by the second presentation of the picture, which remained on the screen for 2000 milliseconds. Afterward, participants rated the intensity of their emotional response to the image. Participants were given the opportunity to take a break between blocks. After task completion, the Electro-cap was removed, and individuals were debriefed and thanked for their participation in the experiment.

Electrophysiological Recording and Analysis

For data analysis, the electrodes were re-referenced to an average reference (Picton et al., 2000). Considerable alpha activity was observed in a number of participants, therefore a .1 to 8 Hz zero-phase-shift bandpass filter was applied to the EEG data before averaging. Ocular artifacts associated with blinks and saccades were corrected by hand using the ocular artifact correction filter within the EMSE software (Source Signal Imaging, San Diego). Trials contaminated by other artifacts (peak-to peak deflections greater than 100 μV) were rejected before averaging. ERP epochs included data for responses where response time was less than 5000 milliseconds. The ERP epochs included -200 milliseconds of prestimulus activity to 3000 milliseconds of poststimulus activity for the cue-locked data, and -200 milliseconds of prestimulus activity to 2000 milliseconds of poststimulus activity for the second presentation of the picture. We averaged to 3000 milliseconds instead of 4500 milliseconds for the cue-locked data to ensure stable averages for the waveforms.

ERPs were averaged by regulation. The effect of regulation on the LPP at the second presentation of the picture, and slow wave activity during regulation was examined in the analyses. These analyses included measures of mean amplitude in a set of ANOVAs using the Huynh–Feldt (Huynh & Feldt, 1976) corrected degrees of freedom when necessary. For the cue-locked data, slow wave activity was measured as mean voltage between 1000 milliseconds and 2000 milliseconds at electrodes T7, C5, T8, and C6, and between 2000 milliseconds and 3000 milliseconds at electrodes FP1, FPz, and FP2. Slow wave activity was also measured for two epochs (1000 milliseconds – 2000 milliseconds and 2000 milliseconds – 3000 milliseconds) at electrodes TP7, CP5, CP3. For the second presentation of the picture, the LPP was measured as mean voltage between 500 and 600 milliseconds at electrode CPz.

EXPERIMENT 2 RESULTS

Behavioral Data

The effects of picture content and regulation on emotional intensity ratings were examined in a one-way ANOVA with regulation (attend, reappraise, distract) as a within subjects variable (Table 4). The analysis revealed a significant main effect of regulation, $F(2, 48) = 19.40$, $p = .001$, $\eta_p^2 = .45$, with the emotional intensity rating being higher for attend than reappraise, $F(1, 24) = 30.60$, $p = .001$, $\eta_p^2 = .56$, or distract, $F(1, 24) = 17.41$, $p = .001$, $\eta_p^2 = .42$, and no differences between distract and reappraisal, $F(1, 24) = 1.34$, $p = .26$, $\eta_p^2 = .05$.

Table 4.
Means and standard deviations for emotional intensity ratings by regulation.

Attend	3.14 (.07)
Distract	2.68 (.11)
Reappraise	2.60 (.11)

Electrophysiological Data

First presentation of the picture. In Experiment 2, the data were analyzed by regulation type (attend, reappraise, distract). We collapsed the data across picture content because: a) the images of mutilations and violence were intermixed within a block, and b) there were too few trials to examine content differences.

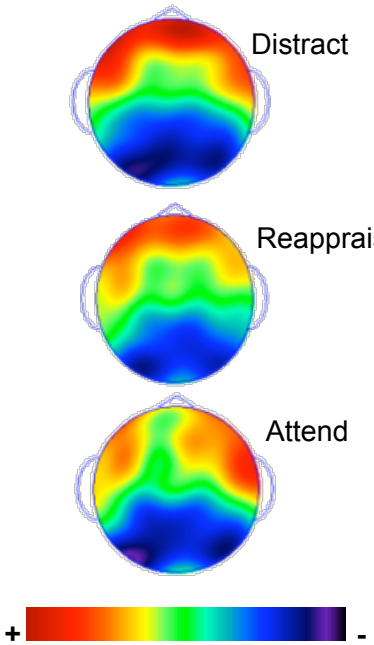

Figure 8. Topography maps demonstrating slow wave activity during the cue locked period for each condition at 1000 milliseconds.

Cue-locked data. The time course and topography of slow wave activity during regulation are portrayed in Figures 8 and 9. The data revealed two different modulations of the ERPs that distinguish neural activity for the distract condition from neural activity elicited by the attend and reappraise conditions. In the first modulation, approximately 2000 milliseconds after stimulus onset, slow wave activity emerged over the frontal polar region, distinguishing the distract condition from the attend and reappraise condition. In the second modulation, a similar effect was observed over the left central parietal region beginning around 1000 milliseconds after stimulus onset and

persisting until 3000 milliseconds, distinguishing the distract condition from the attend and reappraise condition. Another effect of distract was observed over the left central region of the scalp beginning around 1000 milliseconds after stimulus onset and persisting until 2000 milliseconds. During the same time frame over the right central region, slow wave activity distinguished the reappraise condition from the distract and attend conditions. Mean voltages are listed in Table 5.

Table 5.
Mean voltages and standard error for cue-locked slow wave activity by regulation.

	Attend	Distract	Reappraise
1000 – 2000 ms			
Left Central	1.23 (.50)	.26 (.54)	1.88 (.69)
Right Central	1.78 (.37)	1.38 (.41)	.001 (.52)
Left Central-Parietal	-1.14 (.47)	-2.02 (.43)	-.66 (.49)
2000 – 3000 ms			
Frontal Polar	1.30 (1.22)	4.06 (1.17)	3.07 (1.08)
Left Central Parietal	-1.09 (.50)	-1.93 (.45)	-.57 (.39)

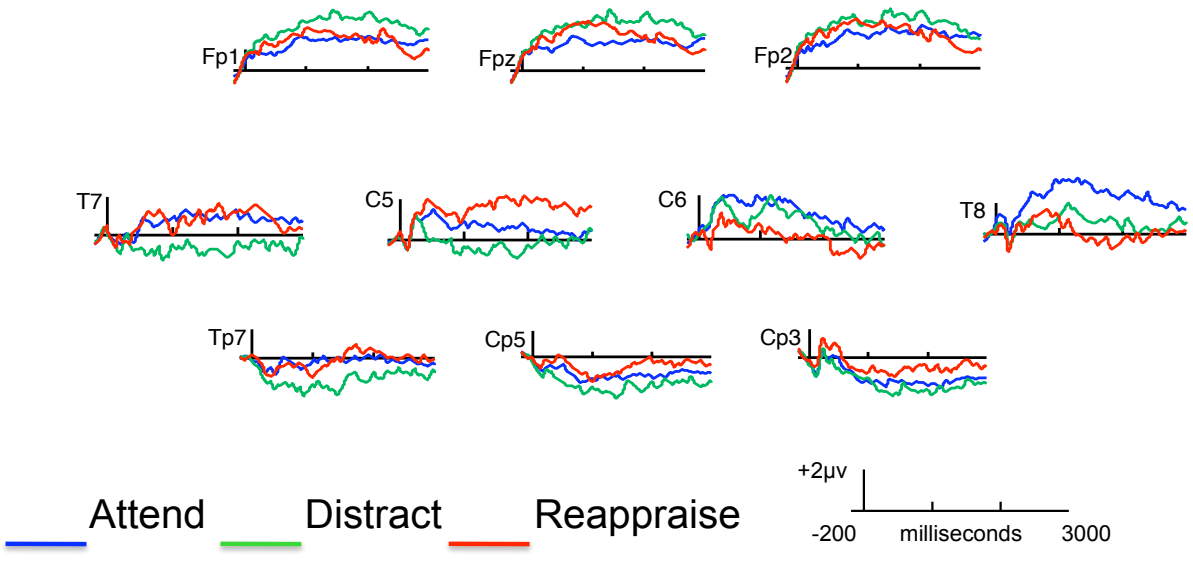

Figure 9. Grand averaged ERPs for the cue locked data. Select electrodes portraying slow wave activity for each condition.

The effects of the distract condition on slow wave activity expressed over the frontal polar region of the scalp between 2000 milliseconds and 3000 milliseconds were examined in a 3 (regulation) x 3 (electrode: FP1, FPz, FP2) ANOVA (Figure 9). A marginally significant main effect of regulation was found, F (2, 48) = 2.87, p = .06, η_p^2 = .11, ϵ = 1.00, with the amplitude of the distract condition (M = 4.06 μV, SE = 1.17), being greater than the attend condition (M = 1.30 μV, SE = 1.22), F (1, 24) = 7.08, p = .01, η_p^2 = .23, and the reappraise condition (M = 3.07 μV, SE = 1.08), F < 1.00. Over the left central parietal region of the scalp the distract condition was more negative than attend and reappraise conditions. This effect was explored in a 3 (regulation) x 3 (electrode: TP7, CP5, CP3) ANOVA in two epochs (1000 – 2000 milliseconds, 2000 – 3000 milliseconds; Figure 9). For the first epoch, a significant main effect of regulation was found, F (2, 48) = 5.77, p = .001, η_p^2 = .19, ϵ = 1.00, where the amplitude of the distract condition (M = -2.02 μV, SE = .43) was more negative than the reappraise condition (M = -.66 μV, SE = .49), F (1, 24) = 9.53, p = .01, η_p^2 = .28, and the attend condition (M = -1.14 μV, SE = .47), F (1, 24) = 7.03, p = .01, η_p^2 = .23. There was also a significant main effect of regulation for the second epoch, F (2, 48) = 4.70, p = .01, η_p^2 = .16, ϵ = 1.00, where the amplitude of the distract condition (M = -1.93 μV, SE = .45) was more negative than the reappraise condition (M = -.57 μV, SE = .39), F (1, 24) = 7.71, p = .01, η_p^2 = .24, and the attend condition (M = -1.09 μV, SE = .50), F (1, 24) = 6.40, p = .02, η_p^2 = .21.

Two effects emerged over the central region of the scalp between 1000 and 2000 milliseconds. Over the left central region, ERPs for the distract condition more negative than the attend and reappraise conditions. In contrast, ERPs for the attend

and distract conditions were more positive than the reappraise condition over the right central region. These effects were examined in a 2 (hemisphere) x 3 (regulation) x 2 (electrode: T7, C5, T8, C6) ANOVA (Figure 9). In this analysis, there was a significant main effect of regulation, F (2, 48) = 3.68, p = .03, η_p^2 = .13, ϵ = .99, which was qualified by a significant hemisphere x regulation interaction, F (2, 48) = 7.16, p = .002, η_p^2 = .23, ϵ = 1.00. Over the left hemisphere, the amplitude of the distract condition (M = .26 μV, SE = .54) was lower than the attend condition (M = 1.23 μV, SE = .50), F (1, 24) = 3.81, p = .06, η_p^2 = .14, and the reappraise condition (M = 1.88 μV, SE = .69), F (1, 24) = 10.43, p = .004, η_p^2 = .303. Over the right hemisphere, the attend condition (M = 1.78 μV, SE = .37) was greater in amplitude than the reappraise condition (M = .001 μV, SE = .52), F (1, 24) = 9.19, p = .006, η_p^2 = .28, and the distract condition (M = 1.38 μV, SE = .41) was greater in amplitude than the reappraise condition, F (1, 24) = 7.77, p = .01, η_p^2 = .25. Together, these findings reflect sustained mental processing associated with using different regulation strategies. Consistent with our predictions, slow wave activity differentiated neural activity for the distract and the reappraise conditions.

Second presentation of the picture. The amplitude of the LPP was greatest in amplitude over the central-parietal region of the scalp between 500 and 600 milliseconds after stimulus onset, distinguishing the reappraise condition from the attend and distract conditions. At central parietal electrode CPz, the attend and distract conditions were greater in amplitude than the reappraise condition. We examined the LPP between 500 and 600 milliseconds in a one-way ANOVA at electrode CPz (Figure 10). In this analysis, the main effect of regulation was

significant, F (2, 48) = 3.17, p = .05, η_p^2 = .12, ϵ = 1.00, where the amplitude of the attend condition was greater than the reappraise condition, F (1, 24) = 5.19, p = .03, η_p^2 = .18, and the amplitude of distract condition was greater than the reappraise condition, F (1, 24) = 3.16, p = .08, η_p^2 = .12. No significant difference was found between the attend and distract condition, F < 1.00. The findings are in line with previous reports demonstrating that reappraisal modulates the neural response to unpleasant stimuli, and also suggest that distraction may not be an effective regulation strategy.

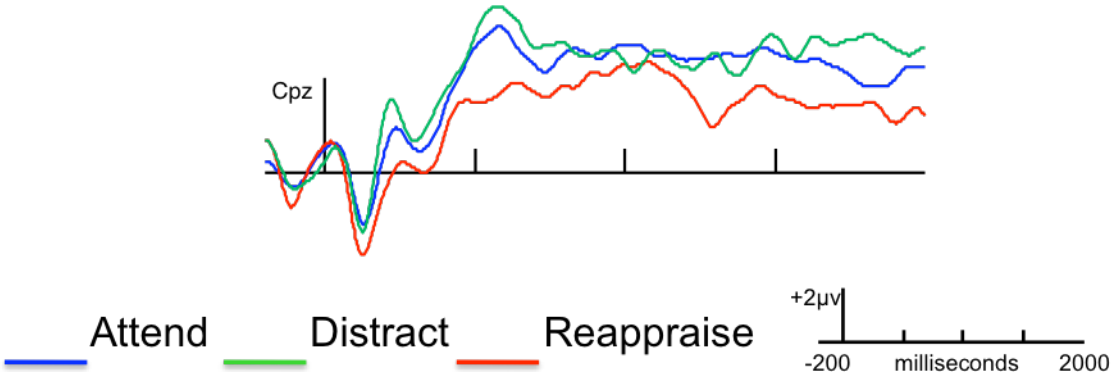

Figure 00. Grand averaged ERPs at electrode CPz.

EXPERIMENT 2 DISCUSSION

Experiment 2 was designed to examine whether distraction would modulate the LPP in the same manner as reappraisal. Behaviorally, it appeared as if reappraisal and distract were both effective means of regulation. Physiologically, we were able to replicate the effect for reappraisal at the second presentation of the picture as demonstrated in Experiment 1 and Hajcak and Niewenhuis (2006) for reappraisal, but did not find the same effect for distraction. Differential neural recruitment during regulation was found for reappraisal and distraction.

Behavioral Data

The behavioral data showed that self-reported emotional intensity ratings were higher for the attend condition for both picture types than for reappraise and distract. No differences were found between the reappraise and distract conditions, suggesting that these two conditions may be successful at decreasing the emotional response.

Electrophysiological Data

At the second presentation of the picture, we found the reappraisal modulated the amplitude of the LPP, as seen in the previous experiment. In contrast, distract did not modulate the neural response to negative images. No differences were found between the attend and distract conditions, which suggests that focusing on a non-emotional aspect of the picture may be as maladaptive as directly focusing on the picture itself. The effects in the second experiment were weaker than those presented in Experiment 1, or in previous electrophysiological investigations of reappraisal on the LPP (Hajcak & Niewenhuis, 2006). It is possible that increasing the number of stimuli presented would have produced stronger effects.

Neural recruitment for active regulation was examined during the cue period for attend, reappraise, and distract trials and systematic differences were found between the conditions. Two effects emerged. The first effect distinguished the reappraise condition from the attend and distract conditions. Over the right central region of the scalp, attend and distract were greater in amplitude than the reappraise condition. The second effect distinguished the distract condition from the attend and reappraise conditions. During regulation there was slow wave activity for the distract

condition that differed from the other two conditions over the frontal-polar, central parietal, and the left central region of the scalp. The timing of this slow wave activity mimics that observed in Experiment 1, each lasting over a second. This slow wave activity further indicates that regulation involves extended processing most likely related to the attentional resources devoted to performing the task.

In this experiment, there were discrepancies between the self-report data and the ERP data, as also seen in Experiment 1. Participants reported lower intensity ratings for both forms of regulation. This, however, was not the case for the ERP data, as there were no differences between the attend and distract conditions at the second presentation of the picture. This result is likely due to demand characteristics. Participants were aware that using distraction and reappraisal should both alter/dampen the emotional response. The cue-locked data distinguished the distract condition from the reappraise and attend conditions, and distinguished the reappraise condition from the distract and attend conditions, yet at the second presentation of the picture, distract overlapped with attend. It may be that participants were still somehow focusing on an emotional aspect of the picture. In the future, it might be helpful to use more specific instructions to direct attention away from the emotional content of the images (Dunning & Hajcak, 2009).

CHAPTER 5.

EXPERIMENT 3 INTRODUCTION

The primary goal of Experiment 3 was to extend the findings of the Experiments 1 and 2 and directly compare reappraisal and distraction given that previous research has demonstrated that both of these strategies result in the decrease of self-reported negative emotion (McRae et al., 2010; Ochsner & Gross, 2005; Sheppes & Meiran, 2007). Based on the findings from Experiment 2, it is assumed that reappraisal would be more effective at modulating the neural response to negative images. Another goal of this experiment was to explore the link between successful regulation (as provided by the electrophysiology and self-reported ratings) and their metacognitive awareness of this success. Finally, WMC was examined to determine the role of control processes in successful regulation.

Research has shown that engaging in mindful, or unemotional self-observation and self-regulatory cognition can prove useful in reducing emotional reactivity to negative information (Farb et al., 2010; Schmeichel & Demaree, 2010). Individuals who are particularly skilled at performing the regulation task and high in self-monitoring ability might have an advantage over those who are low in self-monitoring ability. Moreover, WMC might facilitate self-monitoring and regulatory ability. WM represents one's capacity to hold goal relevant information in mind, while simultaneously processing information, facing distractions, and managing shifts in attention (Conway et al., 2002; Conway et al., 2005). Previous investigations have found that WMC predicts emotion suppression (Schmeichel et al., 2008) and increased ability to spontaneously and successfully down regulate negative emotion

(Schmeichel & Demaree, 2010). The idea is that those who are adept at focusing on a single stream of information will not only display skilled performance on purely cognitive tasks, but emotional tasks as well (Hoffman, Gschwendner, Friese, Wiers, & Schmitt, 2008; Schmeichel & Demaree, 2010).

In Experiment 3, participants viewed negative images and were instructed to attend to, reappraise, or judge the colorfulness of each picture. The color-rating task was used to ensure that participants refrained from focusing on emotional aspects of the picture. Depending on the previous cue, participants were then instructed to rate the intensity of their emotional response ('weak' to 'strong') to the picture or rate the colorfulness ('least colorful' to 'most colorful') of the picture. After reappraise trials, they rated their regulation ability ('low' to 'high'). We expected to replicate the findings of Hajcak and Nieuwenhuis (2006) and compare the LPP for regulation trials and color-rating trials. It was also expected that using distraction, such as rating each picture for colorfulness, would not be as effective as reappraisal in modulating the neural response to negative stimuli, given the findings of Experiment 2. Moreover, differences in neural recruitment were examined between each condition.

Individual differences in regulation ability based on working memory capacity (OSPAN) and metacognitive success (i.e., subjective ratings provided after each trial) were examined to further investigate the relationship between brain and behavior. It was hypothesized that individuals with high WMC would show increased ability to reappraise compared to those with low WMC on reappraise trials. Therefore, those with high WMC should show greater amplitude differences between attend and reappraise trials than those with low WMC. In the previous two

experiments, the self-report data did not map on to the electrophysiological findings. In this experiment, we explored whether metacognitive ratings correlated with modulations in the ERPs related to reappraisal, and expected that self-monitoring ratings would be associated with reappraisal success.

EXPERIMENT 3 METHOD

Participants

Seventy-two Iowa State University undergraduates (mean age = 19, range = 18 - 25) were recruited through the Department of Psychology research sign-up system (SONA) and received course credit for their participation. The sample included 38 males and 34 females, and 58 were right handed, 6 were left handed, and 8 were ambidextrous. 7 subjects were excluded from the analyses due to excessive eye movements and other artifacts. The university's institutional review board approved the experiment and informed consent was obtained from all participants prior to testing.

Materials

Operation span task (OSPAN). The stimuli were presented in light gray, Arial 16-point font, and presented on a black background using E-Prime 1.2. Software (Psychology Software Tools, Pittsburgh, PA).

Emotion regulation task. The stimuli for this task were selected from the IAPS (Lang, et al., 2005). A total of 120[3] pictures were selected and each image

---

3063, 3064, 3068, 3069, 3071, 3080, 3100, 3101, 3102, 3110, 3120, 3130, 3150, 3168, 3170, 3215, 3225, 3261, 3266, 9253, 2055.1, 2981, 3015. 3140, 3302, 3400, 9042, 9405, 9410, 9921, 3250, 7361, 2053, 2095, 2141, 2205, 2276, 2278, 2399, 2455, 2700, 2703, 2799, 2800, 2900, 3005.1, 3216, 3220, 3230, 3300, 3350, 6311, 9040, 9041, 9050, 9220, 9250, 9331, 9415, 9421, 9435, 9530, 2710, 2717, 2751, 3160, 3301, 9006, 9007, 9419, 9429, 9432, 9901, 9903, 2352.2. 2683, 3500, 3530, 6021, 6212, 6213, 6243, 6250, 6312, 6313, 6315, 6350, 6360, 6530, 6540, 6550, 6560, 6571, 6821, 6831, 9252, 9254, 9420, 9423, 9424, 9425, 9427, 9428, 9433, 2688, 2730, 2811, 3180, 9810, 6834, 6838, 9400, 9635.1, 9800, 6211, 2694

contained one or more people. Pictures were 512 by 384 pixels and presented on a white background. All stimuli were presented using E-Prime 1.2 Software.

Design

The research design was a one-way ANOVA with trial-type (attend, reappraise, color) as within-subject variables. There were three blocks with 40 trials, and the same picture category presented within each block (i.e., grief/loss, violence, mutilations). On each trial, a randomly selected picture was paired with one of three cues (attend, reappraise, color). The list was counterbalanced between subjects so that each picture was displayed with each trial-type. A practice block containing 9 trials (3 attend, 3 reappraise, and 3 color) was constructed to include stimuli not used in the experimental blocks. The practice block was the same for all subjects.

Procedure

Participants were tested individually in a session lasting approximately 2 hours. All testing was conducted in the Temporal Dynamics of Attention and Memory Laboratory at Iowa State University. Upon arrival, participants were given an overview of the session, completed informed consent procedures, and psychometric measures then fitted with an Electro-Cap before completing the emotion regulation task. Data from the OSPAN task is presented in Table 6. In this task, participants were presented with a set of mathematical operations followed by a one-syllable noun (e.g., IS 6 / 3 + 1 = 6? BIRD). The participant was required to read the statement aloud, indicate its correctness, and remember the word for later recall. Subject performance was in an expected range on these measures. Handedness was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971).

Table 6.
Participant characteristics (n =65).

Automated Operation SPAN (OSPAN)	Mean (SD)
Total Score	*55.42 (12.97)*
Absolute Score	*40.31 (17.19)*
Math Errors	*6.06 (4.18)*

Participants were seated in front of a computer with a 17-inch monitor at a distance of 41 inches from the screen. First, they completed the OSPAN task. Following the OSPAN task, participants completed the emotion regulation task. They were told that they would see several pictures on the screen. Depending on the cue, their task was to attend to, reappraise, or judge the colorfulness of each picture. If the cue was "attend", the participant was instructed to think about the picture displayed. If the cue was "reappraise", the participant was instructed to reinterpret the picture in a more positive manner. If the cue was "color" the participant was instructed to judge the colorfulness of each image.

Once the regulation phase was complete, the picture was displayed a second time. Participants rated the intensity of their emotional response to the picture on a four-point scale using the keys 'v', 'b', 'n', and 'm', with 'v' being weak and 'm' being strong. After this, participants rated their regulation ability on a four-point scale using the keys 'v', 'b', 'n', and 'm', with 'v' being low and 'm' being high (See Figure 11 for an example of the task structure). A practice block was presented to familiarize

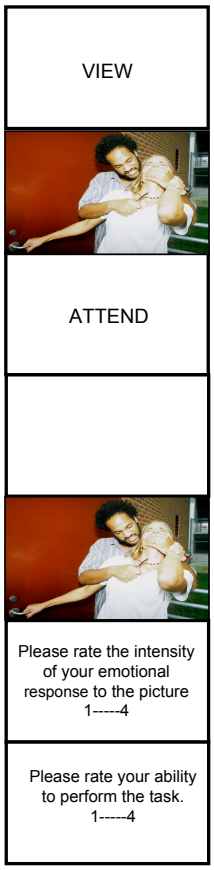

Figure 11. Task Structure for Experiment 3

participants with the task before presenting the experimental trials. For the practice trials only, participants were instructed to state their reappraisal aloud so that the experimenter can judge whether participants understood the task.

On each trial, the word “VIEW” was presented for 1000 milliseconds to indicate a new picture is about to appear. The picture was presented for 1000 milliseconds, and then the cue (“ATTEND”, “REAPPRAISE”, or “COLOR”) appeared and remained on the screen for 4500 milliseconds. A blank white screen was presented for 500 milliseconds followed by the second presentation of the picture, which remained on the screen for 2000 milliseconds. Afterward, participants rated the intensity of their emotional response to the image, and their ability to perform the task. Participants were given the opportunity to take a break between blocks. After task completion, the Electro-cap was removed, and individuals were debriefed and thanked for their participation in the experiment.

Electrophysiological Recording and Analysis

For data analysis, the electrodes were re-referenced to an average reference (Picton et al., 2000). Considerable alpha activity was observed in a number of participants, therefore a .1 to 8 Hz zero-phase-shift bandpass filter was applied to the EEG data before averaging. Ocular artifacts associated with blinks and saccades were corrected by hand using the EMSE software (Source Signal Imaging, San Diego). Trials contaminated by other artifacts (peak-to peak deflections greater than 100 μV) were rejected before averaging. ERP epochs included data for responses where response time was less than 5000 milliseconds. The ERP epoch included -200 milliseconds of prestimulus activity to 3000 milliseconds of poststimulus activity

for the cue-locked data, and -200 milliseconds of prestimulus activity to 2000 milliseconds of poststimulus activity for the second presentation of the picture. We averaged to 3000 milliseconds instead of 4500 milliseconds for the cue-locked data to ensure stable averages for the waveforms.

ERPs were averaged by regulation. Differences in mean amplitude between the three trial-types were considered in a set of ANOVAs using the Huynh–Feldt (Huynh & Feldt, 1976) corrected degrees of freedom when necessary. For data at the second presentation of the picture, the amplitude of the P3 was quantified as mean voltage at electrodes CPz, Pz, and POz 200 – 400 milliseconds after stimulus onset. The amplitude of the LPP was quantified as mean voltage at electrode CPz 600 – 1400 milliseconds after stimulus onset and measured in 4 separate epochs (i.e., 600 – 800 milliseconds, 800 – 1000 milliseconds, 1000 – 1200 milliseconds, 1200 -1400 milliseconds). The P3 and LPP electrode locations and epochs were selected on the basis of the results of the previous two experiments, and prior studies examining the ERP correlates of emotion regulation (Hajcak & Nieuwenhuis, 2006) and affective picture processing (Oloffson et al., 2008). Frontal central slow wave activity was examined at electrodes FC1, FCz, and FC2 200 – 600 milliseconds after stimulus onset and measured in two separate epochs (200 – 400 milliseconds and 400 – 600 milliseconds). For the cue-locked data, activity was measured as mean voltage between 300 and 500 milliseconds at electrodes F4, F3, Fz, F2, F1, F9, FT9, F10, and FT10, between 500 and 1000 milliseconds at electrodes F9, FT9, F10, and FT10, between 1000 and 2000 milliseconds at

electrodes F4, F3, Fz, F2, and F1, and between 1500 and 2000 milliseconds at electrodes P1, Pz, P2, PO1, POz, and PO2.

For the metacognitive cue-locked data activity was measured as mean voltage between 500 and 800 milliseconds at electrodes F6, F8, and F10, between 500 and 1000 milliseconds at electrodes F5, F7, F9, P1, Pz, and P2, between 1000 and 1800 milliseconds at electrodes F5, F7, and F9, between 1000 and 2000 milliseconds at electrodes FP1, FPz, FP2, FC1, FCz, FC2, O1, Oz, and O2, and between 1500 and 1800 milliseconds at electrodes CP1, CPz, and CP2. For metacognitive data at the second presentation of the picture activity was measured between 300 and 600 milliseconds at electrodes FP1, FPz, FP2, CP1, CPz, and CP2, between 600 and 1000 milliseconds at electrodes FP1, FPz, FP2, CP1, CPz, and CP2, and between 400 and 2000 milliseconds at electrodes F6, F8, F10, F5, F7, PO1, POz, and PO2.

For the WMC cue-locked data activity was measured between 500 and 1000 milliseconds at electrodes F5, F6, F7, F8, F9, FT9, F10, FT10, T7, T8, PO1, POz, and PO2, and between 1000 and 2500 milliseconds at electrodes PO1, POz, and PO2. For WMC data at the second presentation of the picture activity was measured between 350 and 500 milliseconds at electrodes F1, Fz, and F2, between 350 and 1000 milliseconds at electrodes Pz and Oz, and between 1000 and 2000 milliseconds at electrodes F1, Fz, and F2. Activity related to metacognition and WMC reflect novel findings and electrodes were selected for the analyses represented locations where there appeared to be differences in amplitude between the trials.

EXPERIMENT 3 RESULTS

Behavioral Data

Participants rated the intensity of their emotional response for each image. The effects of regulation strategy on emotional intensity ratings were examined in a one-way ANOVA (regulation strategy: attend, reappraise, color-rating; Table 7). The analysis revealed a significant main effect of regulation strategy, F (2, 128) = 115.34 p = .001, η_p^2 = .64, emotional intensity ratings were higher for attend than for reappraise, F (1, 64) = 178.74, p = .001, and color-rating, F (1, 64) = 116.99, p = .001, and lower for reappraise than color-rating, F (1, 64) = 13.27, p =.001. These findings suggest that reappraisal and/or rating the colorfulness of the picture successfully down regulate negative emotions elicited by negative images.

Table 7.
Means and standard deviations for emotional intensity ratings and metacognitive ratings by regulation strategy.

	Emotional Intensity	Metacognitive Ratings
Attend	3.21 (.61)	2.85 (.68)
Reappraise	2.50 (.58)	3.07 (.63)
Color-rating	2.67 (.60)	3.11 (.60)

Participants rated how successful they were at performing the regulation task (i.e., attend, reappraise, or color-rating). The effects of regulation strategy on metacognitive ratings were examined in a one-way ANOVA (regulation strategy: attend, reappraise, color-rating; Table 7). The analysis revealed a significant main effect of regulation, F (2, 128) = 13.13, p = .001, η_p^2 = .17, subjects reported being less successful at performing the attend task than the reappraise task, F (1, 64) = 10.95, p = .002, and color-rating task F (1, 64) = 19.63, p = .001, and no significant

differences between success in performing the reappraise task and the color-rating task, F (1, 64) = 1.62, p =.21. The findings reveal that subjects, based on their perceptions, were more successful at performing the reappraise and color-rating task, and less successful at attending to the image.

Electrophysiological Data

Cue-Locked Data. The time course and topography of the ERPs elicited during regulation is portrayed in Figures 12 and 13. The data reveal three different modulations of the ERPs that varied by regulation strategy. The first modulation appeared to distinguish neural activity for the reappraise trials from neural activity elicited by attend trials and color-rating trials. For these data, activity over the midline-frontal and lateral-frontal regions of the scalp appeared to distinguish reappraise trials from attend trials and color-rating trials between 300 and 500 milliseconds. Beginning around 1000 milliseconds over the midline-frontal region, slow wave activity appeared to distinguish the reappraise trials from attend trials and color-rating trials. Over the parietal-occipital region of the scalp distinguishing reappraise trials from attend trials and color-rating trials, slow wave activity began around 1500 milliseconds after stimulus onset and persisted until 2000 milliseconds. The second modulation appeared to distinguish neural activity for attend trials from neural activity elicited for reappraise and color-rating trials. Between 500 and 1000 milliseconds, slow wave activity over the lateral-frontal region of the scalp appeared to distinguish attend trials from the color-rating and reappraise trials. The final modulation appeared to distinguish neural activity for each trial-type from one

another over the parietal region of the scalp beginning around 1500 milliseconds and persisting until 2000 milliseconds. Mean voltages are presented in Table 8.

Table 8.
Mean voltages and standard error for cue-locked activity by epoch and regulation.

	Attend	Reappraise	Color
300 – 500 ms	M (SD)	M (SD)	M (SD)
Midline-Frontal	3.15 (.26)	3.68 (.28)	3.22 (.29)
Lateral-Frontal	2.17 (.29)	1.80 (.32)	2.72 (.28)
500 – 1000 ms			
Lateral-Frontal	3.73 (.35)	3.01 (.37)	3.14 (.34)
1000 – 2000 ms			
Midline-Frontal	2.45 (.35)	3.68 (.34)	2.72 (.35)
1500 – 2000 ms			
Parietal	-2.47 (.35)	-3.32 (.37)	-2.92 (.36)
Parietal-Occipital	-3.78 (.49)	-4.90 (.49)	-4.12 (.45)

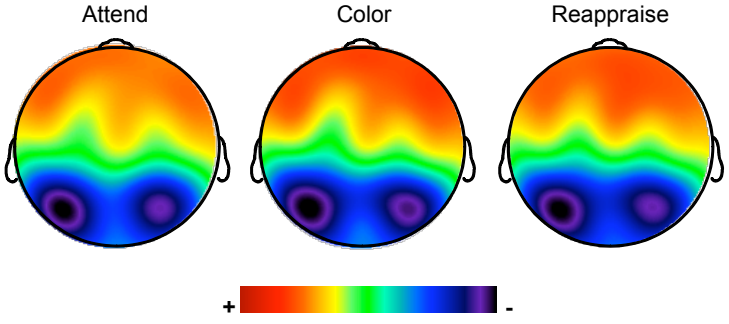

Figure 12. Topography maps demonstrating neural activity during the cue locked period for attend, color, and reappraise trials at 1000 milliseconds.

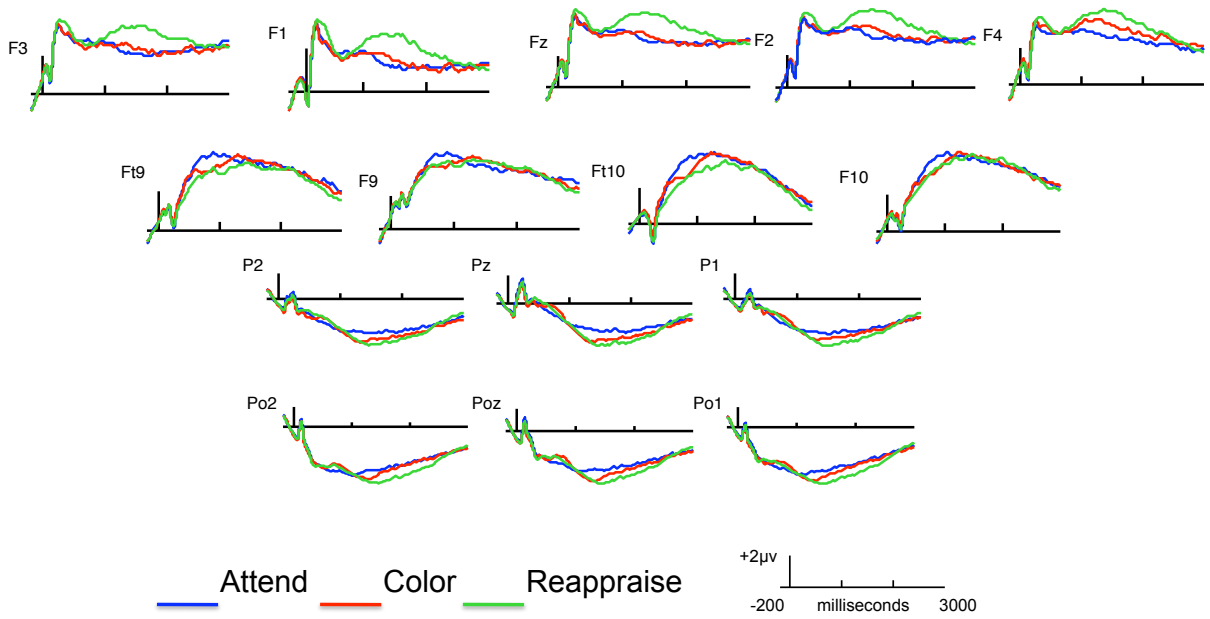

Figure 13. Grand Averaged ERPs for the cue locked data. Select electrodes portraying neural activity for each condition.

Reappraise distinct from Attend and Color-rating. Over the midline-frontal region of the scalp, the amplitude of reappraise trials appeared to be greater than the amplitude of attend and color-rating trials. This effect was examined in a 3 (regulation strategy) x 5 (electrode: F4, F3, Fz, F2, F1) ANOVA (Figure 13). In this analysis, there was a significant main effect of regulation strategy, F (2, 128) = 5.90, p = .004, η_p^2= .09, ϵ = 1.00, where the amplitude of reappraise trials (M = 3.68 μV, SE = .28) was greater than attend trials (M = 3.15 μV, SE = .26), F (1, 64) = 9.32, p = .003, η_p^2 = .13, and color-rating trials (M = 3.22 μV, SE = .29), F (1, 64) = 8.46, p = .005, η_p^2= .12, with no significant difference between the attend and color-rating trials, F < 1.00. During the same time frame over the lateral frontal region of the scalp, the amplitude of the attend and color-rating trials appeared to be greater than reappraise trials. This effect was examined in a 2 (hemisphere) x 3 (regulation strategy) x 2 (electrode: F9, FT9, F10, FT10) ANOVA (Figure 13). There was a

significant main effect of regulation strategy, F (2, 128) = 3.95, p = .02, η_p^2= .06, ϵ = 1.00, where the amplitude of reappraise trials (M = 1.80 μV, SE = .32) was lower than attend trials *(*M = 2.17 μV, SE = .29), F (1, 64) = 4.60, p = .04, η_p^2 = .07, and color-rating trials (M = 2.72 μV, SE = .28), F (1, 64) = 7.15, p = .01, η_p^2 = .10. There were no significant differences between the attend and color-rating trials, F < 1.00.

Approximately 1000 milliseconds after stimulus onset, slow wave activity over the midline-frontal region of the scalp reflecting greater positivity for reappraise trials relative to the other two trial-types was examined in a 3 (regulation strategy) x 5 (electrode: F4, F3, Fz, F2, F1) ANOVA (Figure 13). There was a significant main effect of regulation strategy, F (2, 128) = 18.17, p = .001, η_p^2 = .22, ϵ = 1.00, where the amplitude of reappraise trials (M = 3.68 μV, SE = .34) was greater than attend trials (M = 2.45 μV, SE = .35), F (1, 64) = 31.10, p = .001, η_p^2 = .33, and color-rating trials (M = 2.72 μV, SE = .35), F (1, 64) = 18.99, p = .001, η_p^2 = .23. No significant difference was found between attend trials and color-rating trials, F (1, 64) = 1.78, p = .19, η_p^2 = .03. Lastly, between 1500 and 2000 milliseconds over the parietal-occipital region of the scalp, the amplitude of the reappraise trials was more negative than attend and color-rating trials. This effect was examined in a 3 (regulation strategy) x 3 (electrode: PO1, POz, PO2) ANOVA (Figure 13). There was a significant main effect of regulation strategy, F (2, 128) = 12.05, p = .001, η_p^2 = .16, ϵ = 1.00, where the amplitude of reappraise trials (M = -4.90 μV, SE = .49) was more negative than attend trials (M = -3.78 μV, SE = .49), F (1, 64) = 19.47, p = .001, η_p^2 = .23, and color-rating trials (M = -4.12 μV, SE = .45), F (1, 64) = 9.69, p = .003, η_p^2 = .13. The difference between attend and color-rating trials was marginally

significant, F (1, 64) = 3.10, p = .08, η_p^2 = .05. The results of these analyses may indicate that reappraisal is associated with differential neural activity that extends across time and may involve frontal and posterior neural generators.

Attend distinct from Reappraise and Color-rating. Over the lateral-frontal region of the scalp between 500 and 1000 milliseconds, the mean amplitude of attend trials was greater than the color-rating and reappraise trials. The effect of attend trials on neural activity was examined in a 2 (hemisphere) x 3 (regulation strategy) x 2 (electrode: FT10, F10, FT9, F9) ANOVA (Figure 13). There was a significant main effect of regulation strategy, F (2, 128) = 7.41, p = .001, η_p^2 = .10, ϵ = 1.00, where the amplitude of attend trials (M = 3.73 μV, SE = .35) was greater than reappraise trials (M = 3.01 μV, SE = .37), F (1, 64) = 11.63, p = .001, ηp^2 = .15, and color-rating trials (M = 3.14 μV, SE = .34), F (1, 64) = 9.59, p = .003, η_p^2 = .13. No significant difference was found between color-rating and reappraise trials, F < 1.00. These results may indicate that slow wave activity over the lateral frontal region was sensitive to processes involved in ruminating over an image, rather processes related to regulation.

All trials different. Neural activity was distinguished for each trial-type over the parietal region of the scalp between 1500 milliseconds and 2000 milliseconds and examined in a 3 (regulation strategy) x 3 (electrode: P1, Pz, P2) ANOVA (Figure 13). There was a significant main effect of regulation strategy, F (2, 128) = 8.12, p = .001, η_p^2= .11, ϵ = 1.00, where the amplitude of reappraise trials (M = -3.32 μV, SE = .37) was more negative than attend trials (M = -2.47 μV, SE = .35), F (1, 64) = 14.52, p = .001, η_p^2 = .19, and color-rating trials (M = -2.92 μV, SE = .36) was more

negative than attend trials, F (1, 64) = 5.85, p = .02, η_p^2 = .08. A marginally significant difference was found between reappraise and color-rating trials, F (1, 64) = 3.21, p = .08, η_p^2 = .05. These findings may indicate that differential neural recruitment over the parietal region was required to perform each of these tasks.

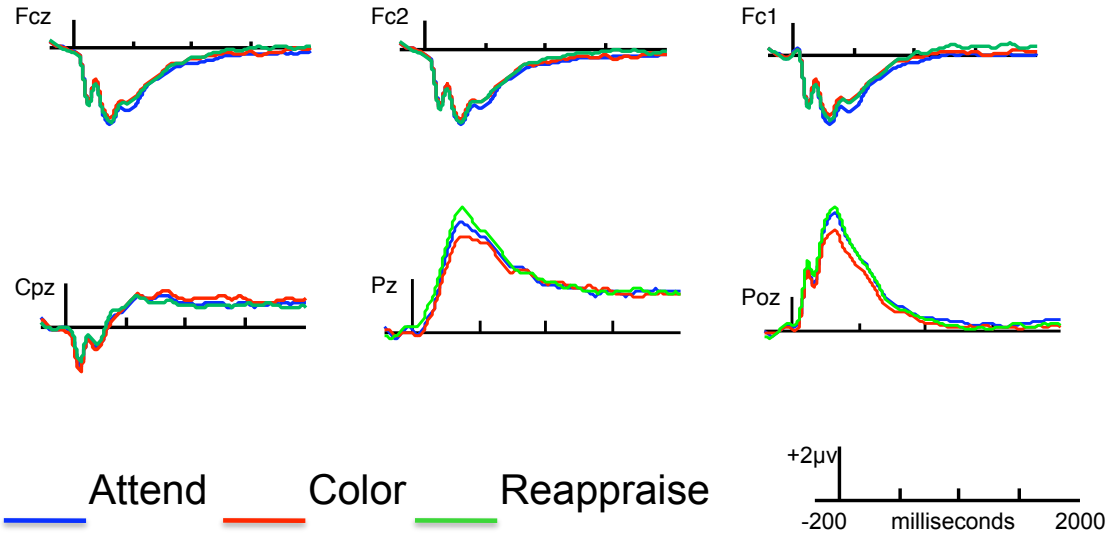

Figure 14. Grand averaged ERPs at the second presentation of the picture for each trial type.

Second presentation of the picture. Grand-averaged ERPs recorded at electrodes CPz, Pz, and POz are presented in Figure 14. These electrodes portray the effect of regulation on the P3 and the LPP components. The effect of regulation strategy on the P3 (between 200 and 400 milliseconds) was examined in a 3 (electrode: CPz, Pz, POz) x 3 (regulation strategy) ANOVA (Figure 14). There was a significant main effect of regulation strategy, F (2, 128) = 11.24, p = .001, η_p^2 = .15, ϵ = 1.00, which was qualified by an electrode x regulation strategy interaction, F (4, 256) = 12.32, p = .001, η_p^2 = .16, ϵ = 1.00. The main effect of regulation strategy was not significant at electrode CPz, F (2, 128) = 2.43, p = .09, η_p^2 = .04. There was a significant main effect of regulation strategy at electrode Pz, F (2, 128) = 11.24, p

= .001, η_p^2 = .15, ϵ = 1.00, where the amplitude of reappraise trials (*M* = 3.78 *μV*, *SE* = .38) was greater than attend trials (*M* = 3.37 *μV*, *SE* = .35), *F* (1, 64) = 4.73, *p* = .03, η_p^2 = .07, and color-rating trials (*M* = 2.92 *μV*, *SE* = .34), *F* (1, 64) = 30.10, *p* = .001, η_p^2 = .32. Also, the amplitude of the attend trials was greater than color-rating trials, *F* (1, 64) = 5.23, *p* = .03, η_p^2 = .08. There was a significant main effect of regulation strategy at electrode POz, *F* (2, 128) = 16.39, *p* = .001, η_p^2 = .20, ϵ = 1.00, where the amplitude of reappraise trials (*M* = 6.45 *μV*, *SE* = .53) was greater than color-rating trials (*M* = 5.28 *μV*, *SE* = .50), *F* (1, 64) = 33.84, *p* = .001, η_p^2 = .35, and the amplitude of the attend trials (*M* = 6.14 *μV*, *SE* = .51) was greater than color-rating trials, *F* (1, 64) = 17.24, *p* = .001, η_p^2 = .21. There was no significant difference between the attend and reappraise trials, *F* (1, 64) = 1.88, *p* = .18, η_p^2 = .03. These findings indicate that attending to and/or reappraising were ineffective means of down-regulation, relative to rating the colorfulness of the picture, and this effect may also reflect the allocation of cognitive resources used to meet the demands of the task.

The data revealed slow wave activity distinguishing the three trial-types that persisted for the majority of the 2-second epoch. To better understand these effects, the data were analyzed in 200 millisecond increments. The effect of regulation on the LPP was examined at electrode CPz at four different time frames in a 4 (epoch: 600-800 milliseconds, 800-1000 milliseconds, 1000-1200 milliseconds, 1200-1400 milliseconds) x 3 (regulation strategy) ANOVA (Figure 14). The main effect of regulation strategy was not significant, *F* (2, 128) = 1.96, *p* = .001, η_p^2 = .03, ϵ = 1.00. We did not replicate the effects found in the previous two experiments or those

found in Hajcak & Nieuwenhuis (2006). These findings may suggest that amplitude of the reappraise LPP in previous experiments is influenced by factors outside of the reappraisal instructions.

Activity related to attend trials reflected greater negativity over the frontal-central region of the scalp, relative to the color-rating and reappraise trials. This modulation emerged around 200 milliseconds after the second presentation of the picture and persisted until about 600 milliseconds. The data was analyzed for two different time frames (200 – 400 milliseconds and 400 – 600 milliseconds) to best determine the latency of the effects. Color-rating trials appeared to be less negative than attend and reappraise trials between 200 and 400 milliseconds. This effect was examined in a 3 (regulation strategy) x 3 (electrode: FC1, FCz, FC2) ANOVA (Figure 14). There was a significant main effect of regulation strategy, F (2, 128) = 4.65, p = .01, η_p^2 = .07, ϵ = 1.00, where the amplitude the color-rating trials (M = -3.86 μV, SE = .31) was less negative than the attend trials (M = -4.28 μV, SE = .31), F (1, 64) = 10.47, p = .002, η_p^2 = .14. The difference between the color-rating and reappraise trials (M = -4.13 μV, SE = .30), was marginally significant, F (1, 64) = 3.18, p = .08, η_p^2 = .05. No significant difference was found between attend and reappraise trials, F (1, 64) = 1.24, p = .27, η_p^2 = .02. Attend trials appeared to be more negative than color-rating and reappraise trials between 400 and 600 milliseconds. This effect was examined in a 3 (regulation strategy) x 3 (electrode: FC1, FCz, FC2) ANOVA (Figure 14). There was a significant main effect of regulation strategy, F (2, 128) = 6.82, p = .002, η_p^2 = .10, ϵ = 1.00, where attend trials (M = -3.68 μV, SE = .28) were more negative than color-rating trials (M = -3.16 μV, SE = .29), F (1, 64) = 12.51, p = .001,

η_p^2 = .16, and reappraise trials (*M* = -3.23 *μV*, *SE* = .26), *F* (1, 64) = 9.52, *p* = .003, η_p^2 = .13. No significant difference was found between color-rating and reappraise trials, *F* < 1.00. Consistent with findings from previous studies, attenuation of the color-rating and reappraise trials relative to attend trials may indicate that rating the colorfulness of the picture or successfully reappraising the picture may reduce the perceived emotional intensity of the negative image (Moser et al., 2006, Hajcak & Nieuwenhuis, 2006).

Metacognitive Electrophysiological Data

We were interested in how trial-type (e.g., attend or reappraise in response to negative stimuli) influenced ratings of metacognitive success, which rating ranged from 1 (e.g., low ability to perform the task) to 4 (e.g., high ability to perform the task). Median metacognitive ratings by regulation strategy were calculated for each subject before analyzing the data. High success trials were trials above the median rating for each regulation strategy, and low success trials were trials below or equal to the median rating for each regulation strategy. Only subjects with variability in ratings were included in the metacognitive analyses (N = 29). These data have not been previously examined in the literature; thus, the analyses of these ERPs are highly exploratory and reflect novel findings.

Cue-Locked Data. The time course and topography of the ERPs for regulation and metacognitive success are portrayed in Figures 15 and 16. Three effects seemed to emerge from the data during the cue-locked period. The first effect appeared to distinguish high success at reappraising negative images from all other trials. For these data, activity over the right frontal region of the scalp

distinguished high reappraisal success trials from all other trial-types between 500 and 800 milliseconds. Over the parietal region between 500 and 1000 milliseconds, high reappraisal success trials appeared to be distinguished from the other three trial-types. Over the frontal-central region of the scalp between 1000 and 2000 milliseconds, slow wave activity appeared to distinguish high reappraisal success trials from all other trial-types. The second effect appeared to distinguish low success to attend to negative images from all other trials. Activity over the left frontal region of the scalp between 500 and 1000 milliseconds appeared to distinguish low attend success trials from all other trial-types. Lastly, the third effect appeared to distinguish high success to attend to negative images from all other trials. For these data, activity over the frontal-polar region of the scalp between 1000 and 2000 milliseconds distinguished high attend success trials from all other trials. Over the left frontal region of the scalp slow wave activity between 1000 and 1800 milliseconds appeared to distinguish high attend success trials from all other trial-types. Activity over the central-parietal region of the scalp between 1500 and 1800 milliseconds appeared to distinguish high attend success trials from all other trial-types.

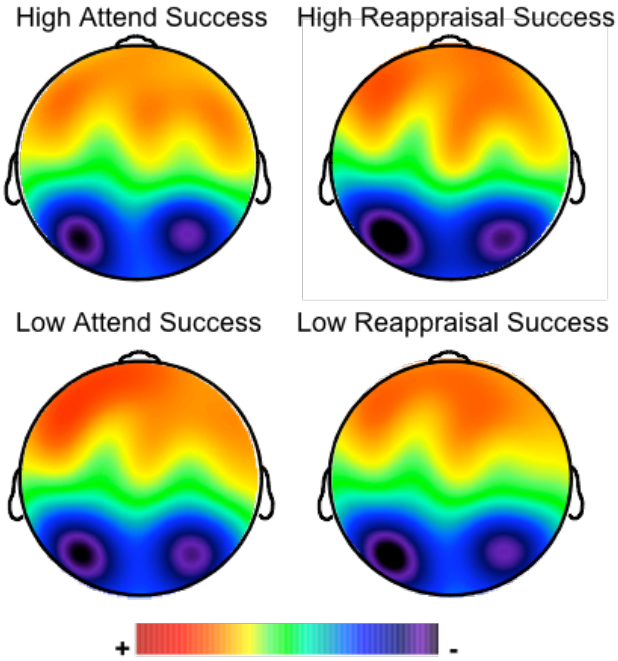

Figure 15. Topography maps demonstrating neural activity during the cue locked period for metacognitive trials at 1000 milliseconds.

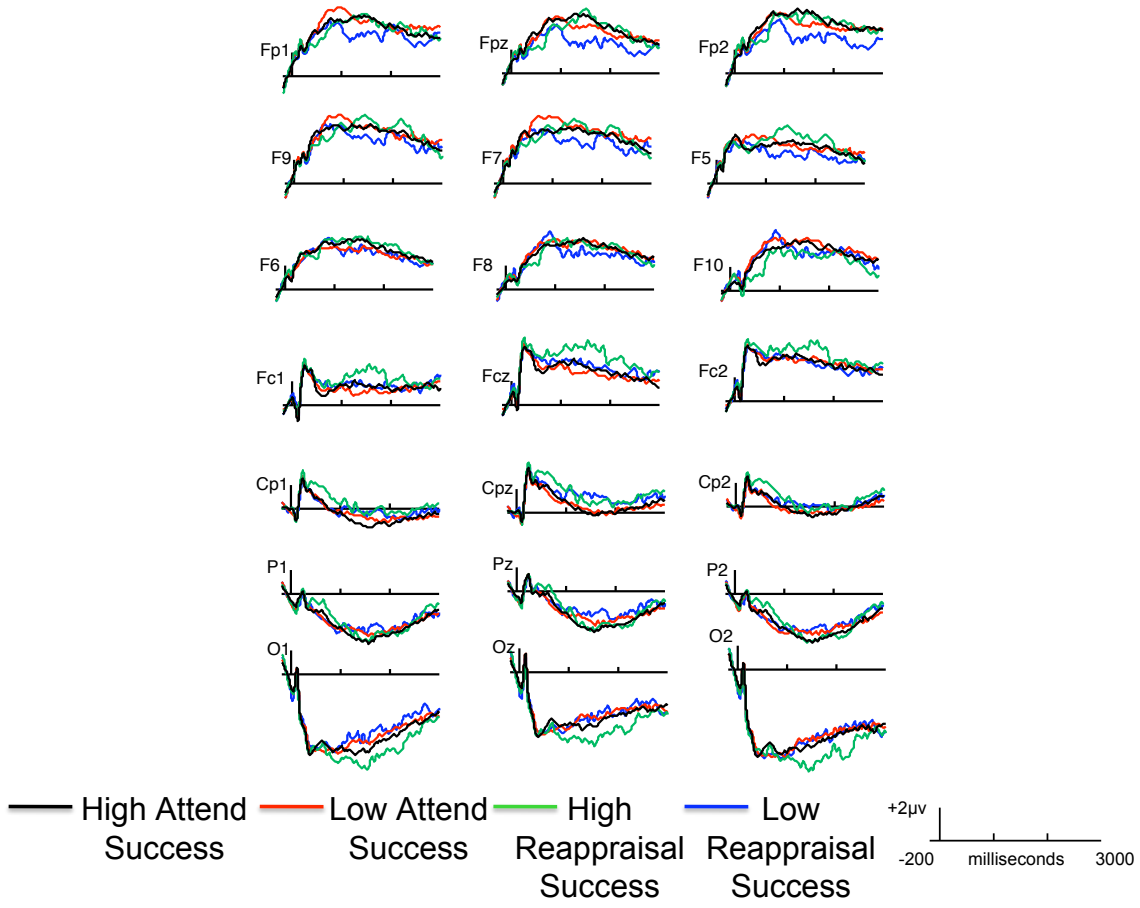

Figure 16. Grand averaged ERPs for the metacognitive cue locked data. Select electrodes portraying neural activity for each trial type.

***High reappraisal success distinct from all other trials*.** The effect of reappraisal success over the right frontal region of the scalp between 500 and 800 milliseconds was examined in a 2 (regulation strategy: attend, reappraise) x 2 (metacognition: low vs. high success) x 3 (electrode: F6, F8, F10) ANOVA (Figure 16). No significant main effect of metacognition was found, $F < 1.00$. There was a significant main effect of regulation strategy, F (1, 28) = 4.04, p = .05, η_p^2 = .13, ϵ = 1.00, where attend trials (M = 3.56 μV, SE = .55) were more positive than reappraise

trials (M = 2.90 μV, SE = .67). The effect of reappraisal success over the parietal region of the scalp between 500 and 1000 milliseconds was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: P1, Pz, P2) ANOVA (Figure 16). No significant main effect of metacognition was found, F (1, 28) = 2.03, p = .17, η_p^2 = .07, ϵ = 1.00. There was a significant main effect of regulation strategy, F (1, 28) = 4.20, p = .05, η_p^2 = .13, ϵ = 1.00, where attend trials (M = -2.06 μV, SE = .55) were more negative than reappraise trials (M = -1.44 μV, SE = .63). It appears that slow wave activity during this time frame was more sensitive to processes related directly to regulation strategy, rather than successful performance of the regulation task.

Between 1000 and 2000 milliseconds slow wave activity over the frontal-central region for high reappraisal success trials appeared to be more positive in amplitude than the other three trial types. This effect was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: FC1, FCz, FC2) ANOVA (Figure 16). There was a significant main effect of regulation strategy, F (1, 28) = 4.24, p = .05, η_p^2 = .13, ϵ = 1.00, where the amplitude of reappraise trials (M = 3.34 μV, SE = .58) was greater than attend trials (M = 2.58 μV, SE = .58), and a significant main effect of metacognition, F (1, 28) = 5.48, p = .03, η_p^2 = .16, ϵ = 1.00, where the amplitude of the high success trials (M = 3.35 μV, SE = .62) was greater than the low success trials (M = 2.57 μV, SE = .51). These findings may indicate that the frontal-central region is involved in processes related to reappraisal and to successful performance. Between 1000 and 2000 milliseconds over the occipital region of the scalp, slow wave activity for high reappraisal success trials was more negative than the other

three trial types. This effect was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: O1, Oz, O2) ANOVA (Figure 16). A marginally significant regulation strategy x metacognition interaction was found, F (1, 28) = 3.23, p = .08, η_p^2 = .10, ϵ = 1.00, where the amplitude of high reappraisal success trials (M = -6.74 μV, SE = .80) was more negative than low reappraisal success trials (M = -5.55 μV, SE = .72), F (1, 28) = 5.33, p = .03, η_p^2 = .16, ϵ = 1.00, high attend success trials (M = -4.96 μV, SE = .71), F (1, 28) = 7.24, p = .01, η_p^2 = .21, ϵ = 1.00, and low attend success trials (M = -5.06 μV, SE = .74), F (1, 28) = 8.34, p = .01, η_p^2 = .23, ϵ = 1.00. Altogether, it appears as if slow wave activity over the frontal and occipital regions of the scalp may be sensitive to processes generally involved in metacognitive success.

Low attend success distinct from all other trials. Over the left frontal region of the scalp between 500 and 1000 milliseconds, slow wave activity was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: F5, F7, F9) ANOVA (Figure 16). No significant main effect was found for regulation strategy, F (1, 28) = 1.77, p = .19, η_p^2 = .06, ϵ = 1.00, or metacognition, F (1, 28) = 1.68, p = .21, η_p^2 = .06, ϵ = 1.00.

***High attend success distinct from all other trials*.** Over the frontal-polar region of the scalp between 1000 and 2000 milliseconds, slow wave activity for high attend success trials appeared to be lower in amplitude than the other three trial types. This effect was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: FP1, FPz, FP2) ANOVA (Figure 16). No significant main effect was found for regulation strategy, F (1, 28) = 2.83, p = .10, η_p^2 = .09, ϵ = 1.00, or

metacognition, F (1, 28) = 1.94, p = .18, η_p^2 = .07, ϵ = 1.00. The results this analysis indicate that neural recruitment over the frontal-polar region of the scalp during this time frame was not influenced by regulation strategy or metacognitive success.

Over the left frontal region of the scalp between 1000 and 1800 milliseconds, slow wave activity for high attend success trials appeared to be lower in amplitude than the other three trial types. This effect was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: F5, F7, F9) ANOVA (Figure 16). There was a significant interaction between regulation strategy and metacognition, F (1, 28) = 5.93, p = .02, η_p^2 = .18, ϵ = 1.00. The amplitude of high attend success trials (M = 3.26 μV, SE = .53) differed between the low attend success trials (M = 4.37 μV, SE = .51), F (1, 28) = 5.93, p = .02, η_p^2 = .18, ϵ = 1.00, and high reappraisal success trials (M = 4.75 μV, SE = .53), F (1, 28) = 5.72, p = .02, η_p^2 = .17, ϵ = 1.00, but did not differ for low reappraisal success trials (M = 4.19 μV, SE = .54), F (1, 28) = 2.07, p = .16, η_p^2 = .07, ϵ = 1.00. This interaction reflects the fact that high attend success trials and low reappraisal success trials may be qualitatively similar.

Over the central parietal region of the scalp between 1500 and 1800 milliseconds, slow wave activity for the high attend success trials appeared to be more positive in amplitude than the low attend success and low reappraisal success trials. This effect was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: CP1, CPz, CP2) ANOVA (Figure 16). The main effect of regulation strategy was not significant, F < 1.00. There was a significant main effect of metacognition, F (1, 28) = 8.91, p = .006, η_p^2 = .24, ϵ = 1.00, where the amplitude of high success trials (M = .25 μV, SE = .46) was more positive than low success trials

(*M* = -.66 *μV*, *SE* = .45). These results may suggest an effect of categorization between high success and low success for metacognition.

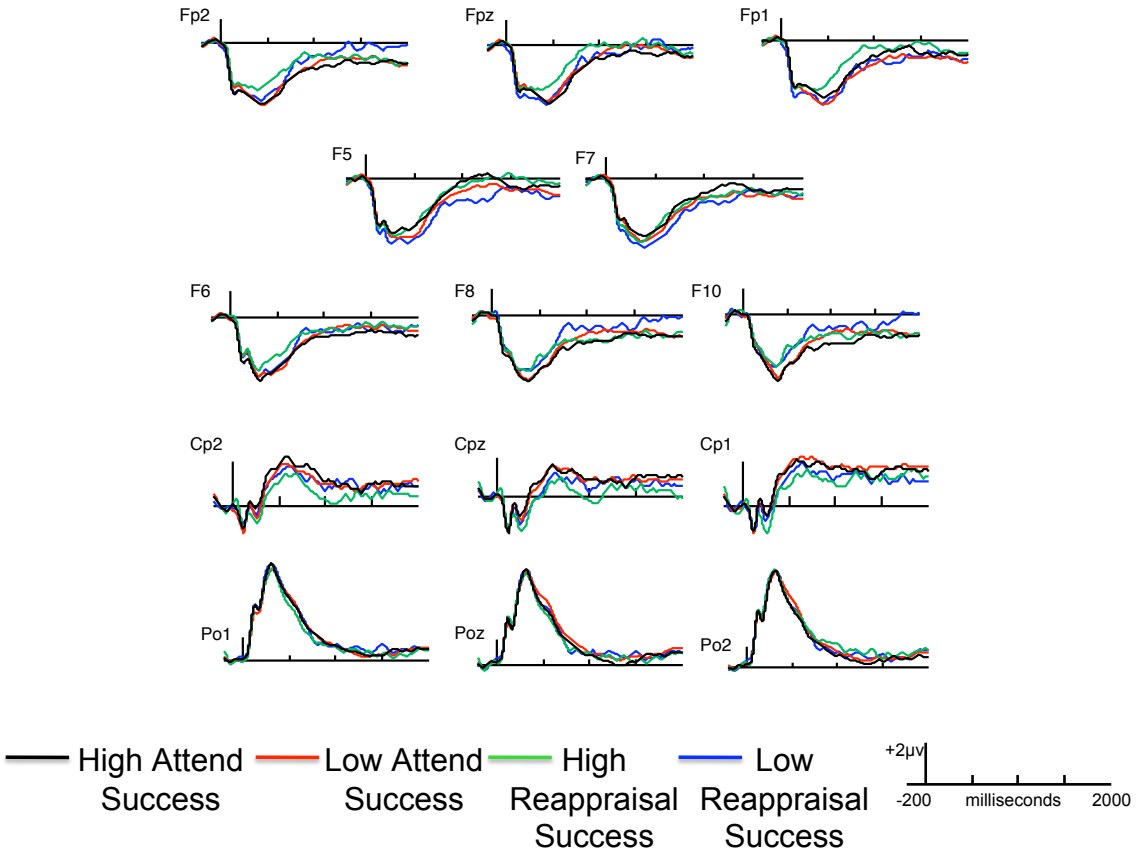

Figure 17. Grand averaged ERPs for the metacognitive data at the second presentation of the picture for each trial-type.

Second Presentation of the Picture. Grand-averaged ERPs recorded at the second presentation of the picture for high and low success are presented in Figure 17. The electrodes selected for the analyses of the ERPs represented locations where the effects appeared to be maximal in amplitude. A measure of mean amplitude was used to quantify the modulation of the ERPs. Upon visual inspection of the data, over the frontal-polar region of the scalp between 300 and 600 milliseconds, high reappraisal success trials appeared to be distinct from all other trials. Between 600 and 1000 milliseconds, high reappraisal success trials were

distinguished from all other trials over the frontal-polar region of the scalp. During this same time frame, a similar pattern was observed over the central-parietal region of the scalp. Differential slow wave activity over the right and left frontal regions between 400 and 2000 milliseconds distinguished high reappraisal success trials from all other trials. Over the parietal-occipital region of the scalp between 400 and 2000 milliseconds, high reappraisal success trials were distinguished from all other trials.

This effect of regulation on metacognitive success over the frontal-polar region between 300 and 600 milliseconds was examined in a 2 (regulation strategy: attend, reappraise) x 2 (metacognition: low vs. high success) x 3 (electrode: FP1, FPz, FP2) ANOVA (Figure 17). No significant main effect was found for regulation strategy, F (1, 28) = 1.93, p = .18, η_p^2 = .06, ϵ = 1.00, or metacognition, F (1, 28) = 1.74, p = .20, η_p^2 = .06, ϵ = 1.00. A similar effect was observed over the central-parietal region of the scalp between 300 and 600 milliseconds, and examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: CP1, CPz, CP2) ANOVA (Figure 17). No significant main effect was found for regulation strategy, F < 1.00, or metacognition, F (1, 28) = 2.44, p = .13, η_p^2 = .08, ϵ = 1.00. The results this analysis indicate that neural recruitment in the frontal-polar and central-parietal regions of the scalp during this time frame were not influenced by regulation strategy or metacognitive success.

Over the frontal-polar region of the scalp between 600 and 1000 milliseconds, the effect of regulation and metacognitive success was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: FP1, FPz, FP2) ANOVA (Figure 17). No

significant main effect was found for regulation strategy, F (1, 28) = 1.58, p = .22, η_p^2 = .05, ϵ = 1.00, or metacognition, F (1, 28) = 2.20, p = .15, η_p^2 = .07, ϵ = 1.00. Over the central parietal region of the scalp between 600 and 1000 milliseconds the effect of regulation and metacognition was examined in a 2 (regulation strategy) x 2 (metacognition) x 3(electrode: CP1, CPz, CP2) ANOVA (Figure 17). No significant main effect was found for regulation strategy, F <1.00, or metacognition, F (1, 28) = 2.02, p = .17, η_p^2 = .07, ϵ = 1.00. The results this analysis indicate that neural recruitment in the frontal-polar and central-parietal regions of the scalp during this time frame were not influenced by regulation strategy or metacognitive success.

The effect of regulation and metacognition over the right frontal region of the scalp between 400 and 2000 milliseconds was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: F6, F8, F10) ANOVA (Figure 17). No significant main effect was found for regulation strategy, F (1, 28) = 2.36, p = .14, η_p^2 = .08, ϵ = 1.00, or metacognition, F (1, 28) = 1.73, p = .20, η_p^2 = .06, ϵ = 1.00. During the same epoch over the left frontal region, the effect of regulation and metacognition was examined in a 2 (regulation strategy) x 2 (metacognition) x 2 (electrode: F5, F7) ANOVA (Figure 17). No significant main effect of metacognition was found, F < 1.00. A significant main effect was found for regulation strategy, F (1, 28) = 6.25, p = .02, η_p^2 = .18, ϵ = 1.00, where the amplitude of the attend trials (M = -2.17 μV, SE =.48) was more negative than the reappraise trials (M = -1.46 μV, SE =.49). It appears from these analyses that the left frontal region of the scalp was more sensitive to differences in regulation strategy. Lastly, the effect of regulation and metacognition over the parietal-occipital region of the scalp between 400 and 2000 milliseconds

was examined in a 2 (regulation strategy) x 2 (metacognition) x 3 (electrode: PO1, POz, PO2) ANOVA (Figure 17). No significant main effect was found for regulation strategy, $F < 1.00$, or metacognition, $F < 1.00$. The results this analysis indicate that neural recruitment in the parietal-occipital region of the scalp during this time frame was not influenced by regulation strategy or metacognitive success.

Working Memory Electrophysiological Data.

The automated OSPAN task provides an absolute score based on the total number correct for perfectly recalled set. A total score is also calculated based on the number of trials reported in the correct position regardless of whether the trial is considered perfect. If the subject committed 12 or more math errors (e.g., less than 85% correct on the math portion) we did not use their OPSAN data. This criterion was based on the parameters specified in the instructions for the task. Descriptive statistics for OSPAN are given in Table 8. Out of the 65 subjects, 59 subjects had valid OSPAN score, and 39 were included in the analyses. We used a percentile ranking to divide subjects into high, medium, and low WMC groups. Only high and Low WMC were considered in the data analyses. The electrodes selected for the analyses of modulation of the ERPs for both the cue-locked data and data for the second presentation of the picture represented locations where the amplitude of the effects appeared to be different for each group. A measure of mean amplitude was used to quantify the modulation of the ERPs. Again, these data have not been previously examined in the literature; thus, the analyses of these ERPs are highly exploratory. No significant WMC x regulation interactions were found in any of the analyses.

Cue-Locked Data. The time course and topography of the ERPs for regulation strategy and WMC are portrayed in Figures 18 and 19. Over the frontal region of the scalp there appeared to differences in regulation based on hemisphere for each group. Over the right frontal between 500 and 1000 milliseconds, attend trials appeared to be distinguished from color-rating and reappraise trials for those with high WMC, and no differences between three trial-types for those with low WMC. Over the left frontal region of the scalp between 500 and 1000 milliseconds, reappraise trials appeared to be distinguished from the attend and color-rating trials for those with high WMC, and attend trials were distinguished from color-rating and reappraise trials for those with low WMC. Differential slow wave activity for each group also emerged over the frontal-temporal region of the scalp. Over the right hemisphere between 500 and 1000 milliseconds, attend trials was distinguished from color-rating and reappraise trials for those with high WMC, and with no distinctions between the trial-types for those with low WMC. During the same time frame over the left hemisphere, reappraise trials were distinguished from attend and color-rating trials for those with high WMC, and attend trials were distinguished

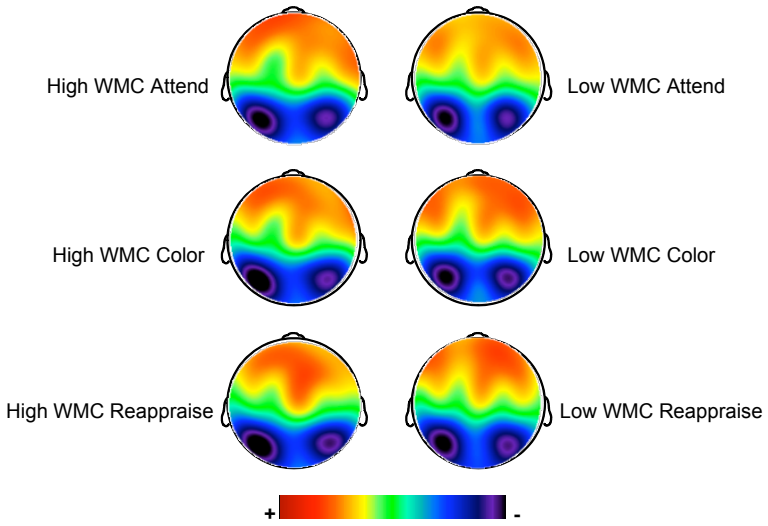

Figure 18. Topography maps demonstrating neural activity during the cue locked period for each trial-type by WMC at 1000 milliseconds.

from color-rating and reappraise trials for those with low WMC. Over the parietal-occipital region a slow wave began around 500 milliseconds and persisted until 1000 milliseconds. For those with high WMC, attend trials were distinguished from color-rating and reappraise trials. Between 1000 and 2500 milliseconds reappraise trials were distinguished from attend and color-rating trials for those with high WMC.

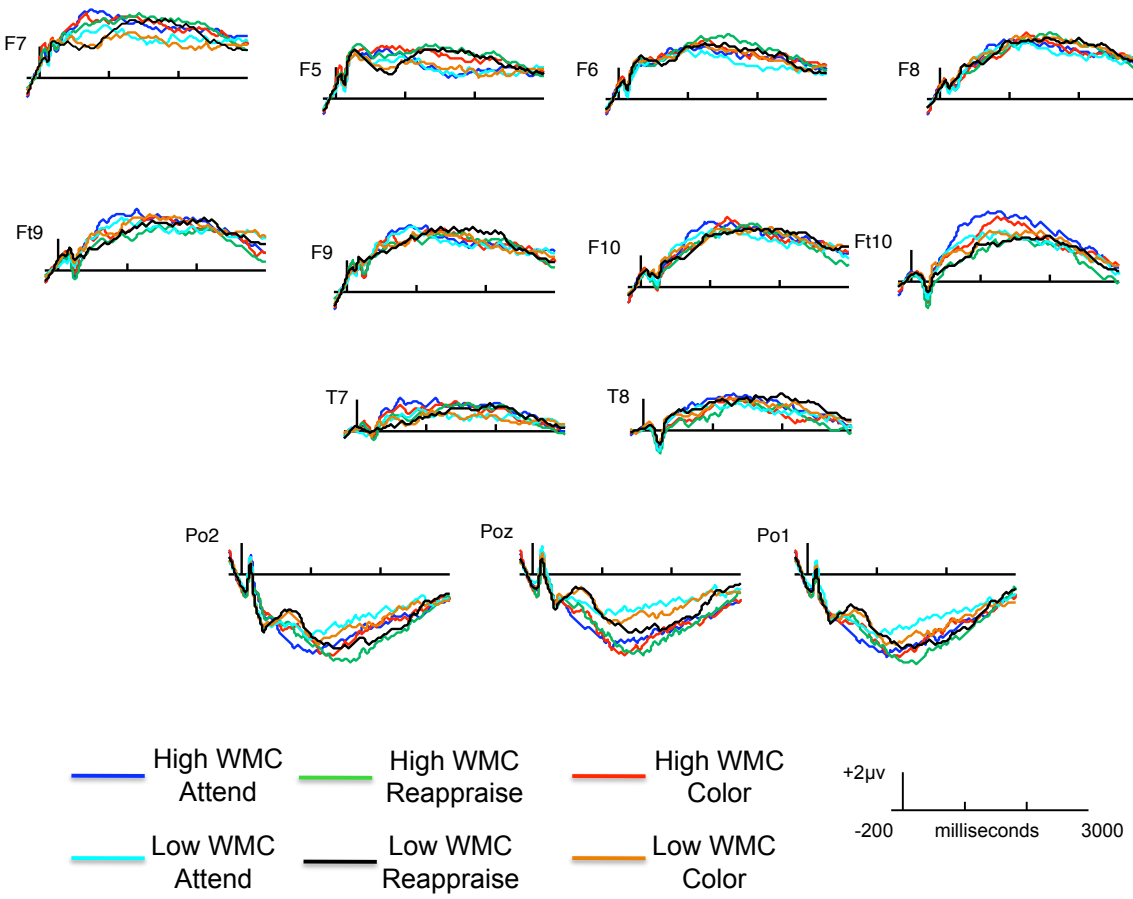

Figure 19. Grand averaged ERPs for the cue locked data by WMC. Select electrodes portraying neural activity for each trial-type.

Upon visual inspection of the data, group differences appeared to emerge over the frontal region of the scalp. For individuals with high WMC, between 500 and 1000 milliseconds, attend trials appeared to be distinct over the right hemisphere, whereas reappraise trials were more distinct over the left hemisphere. For those with

low WMC, there appeared to be no differences between the three trial-types over the right hemisphere, whereas attend trials appeared to be distinct over the left hemisphere. The effects of WMC on slow wave activity during regulation were examined in a 2 (WMC: high, low) x 2 (hemisphere) x 3 (regulation strategy) x 2 (electrode: F5, F6, F7, F8) ANOVA (Figure 19). In this analysis, the main effect of WMC was not significant, $F < 1.00$, and the main effect of regulation strategy was not significant, $F(2, 74) = 1.53$, $p = .22$, $\eta_p^2 = .04$, $\epsilon = 1.00$.

During this same time frame group differences appeared to emerge over the frontal-temporal region of the scalp. For individuals with high WMC, it appeared as if attend trials were distinct from color-rating and reappraise trials over the right hemisphere, whereas reappraise trials were distinct from attend and color-rating trials over the left hemisphere. For those with low WMC, no differences were visually observed between the three trial-types over the right hemisphere, however, attend trials were distinct from color-rating and reappraise trials over the left hemisphere. This effect was examined in a 2 (WMC: high, low) x 2 (hemisphere) x 3 (regulation strategy) x 3 (electrode: F9, FT9, F10, FT10, T7, T8) ANOVA (Figure 19). In this analysis, the main effect of WMC was not significant, $F < 1.00$, and the main effect of regulation strategy was not significant, $F < 1.00$.

Beginning around 500 milliseconds after cue onset and lasting until 1000 milliseconds over the parietal-occipital region of the scalp, attend trials appeared to be more negative than the reappraise and color-rating trials in individuals with high WMC. This effect was examined in a 2 (WMC: high, low) x 3 (regulation strategy) x 3 (electrode: PO1, POz, PO2) ANOVA (Figure 19). In this analysis, the main effect of

WMC was not significant, $F < 1.00$. There was a significant main effect of regulation strategy, F (2, 74) = 3.80, p = .03, η_p^2 = .09, where the amplitude of the attend trials (M = -3.50 μV, SE =.59) was more negative than the color-rating (M = -2.88 μV, SE =.59), F (1, 38) = 5.32, p = .03, η_p^2 = .13, or reappraise trials (M = -2.78 μV, SE =.58), F (1, 38) = 6.33, p = .02, η_p^2 = .15. There was no significant difference between color-rating trials and reappraise trials, $F < 1.00$. These findings indicate differential neural activity between attending and regulating. For those with high WMC, beginning around 1000 milliseconds and lasting until 2500 milliseconds, the reappraise trials appeared to be more negative relative to the attend and color-rating trials. This effect was examined in a 2 (WMC: high, low) X 3 (regulation strategy) x 3 (electrode: PO1, POz, PO2) ANOVA (Figure 19). The main effect of WMC was not significant, $F < 1.00$. There was a significant main effect of regulation strategy, F (2, 74) = 4.74, p = .01, η_p^2 = .11, where the amplitude of reappraise trials (M = -4.14 μV, SE =.52) was more negative than attend (M = -3.21 μV, SE =.55), F (1, 38) = 8.04, p = .01, η_p^2 = .18, and color-rating trials (M = -3.53 μV, SE =.52), F (1, 38) = 3.30, p = .07, η_p^2 = .08. There was no significant difference between the attend trials and color-rating trials, F (1, 38) = 1.64, p = .21, η_p^2 = .04. These findings indicate differential neural activity related to using reappraisal as a regulation strategy.

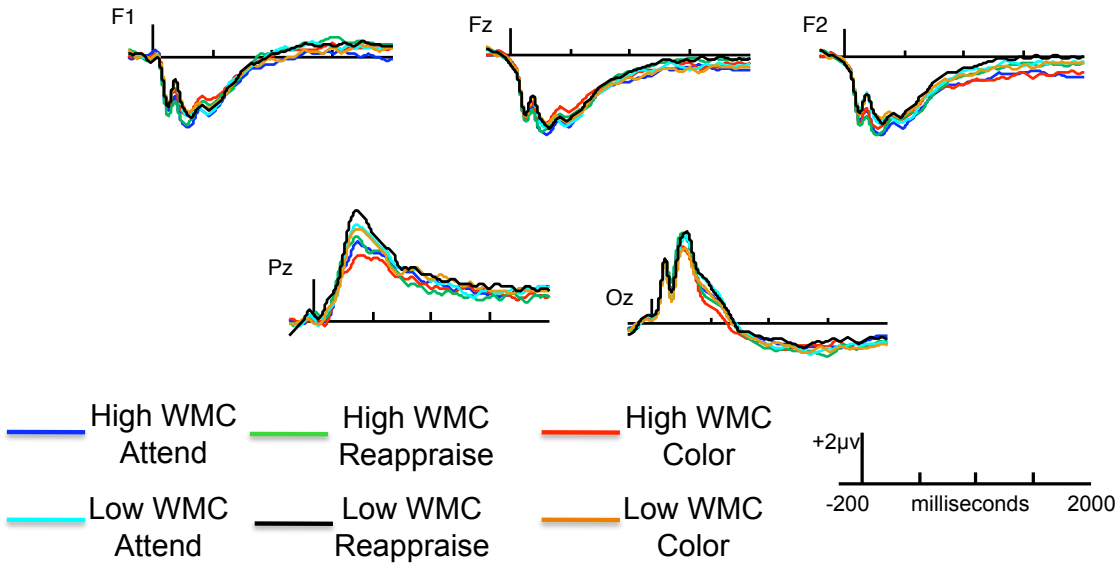

Figure 20. Grand averaged ERPs at the second presentation of the picture by WMC. Select electrodes portraying neural activity for each trial type.

Second Presentation of the Picture. In these data, between 350 and 500 milliseconds over the frontal region of the scalp, attend trials appeared to be distinguished from the color-rating and reappraise trials for those with high WMC. Over the same region around 1000 milliseconds, color-rating trials were distinguished from reappraise trials for those with low WMC, whereas attend trials were distinguished from reappraise trials for those with high WMC. Beginning around 350 milliseconds over the parietal-occipital and occipital region of the scalp and persisting until 1000, slow wave activity for the attend trials were distinguished from the color-rating and reappraise trials for those with high WMC.

For those with high WMC, the amplitude of the attend trials appeared to be more negative over the frontal region of the scalp between 350 and 550 milliseconds. This effect was examined in a 2 (WMC: high, low) x 3 (regulation strategy) x 3 (electrode: F1, Fz, F2) ANOVA (Figure 20). The main effect of WMC

was not significant, $F < 1.00$. There was a significant main effect of regulation strategy, F (2, 74) = 3.87, p = .03, η_p^2 = .10, where the amplitude of attend trials (M = -4.45 μV, SE =.40) was more negative than color-rating trials (M = -3.88 μV, SE =.46), F (1, 38) = 8.56, p = .006, η_p^2 = .18, and reappraise trials (M = -4.03 μV, SE =.39), F (1, 38) = 4.25, p = .05, η_p^2 = .10. No significant difference was found between the color-rating and reappraise trials, $F < 1.00$. Over the same region of the scalp between 1000 and 2000 milliseconds, color-rating trials appeared to be more negative in amplitude than reappraise trials for those with low WMC. On the contrary, attend trials appeared to be more negative in amplitude than the reappraise trials for those with high WMC. This effect was examined in a 2 (WMC: high, low) x 3 (regulation) x 3 (electrode: F1, Fz, F2) ANOVA (Figure 20). The main effect of WMC was not significant, $F < 1.00$. There was a significant main effect of regulation strategy, F (2, 74) = 3.61, p = .03, η_p^2 = .09, where the amplitude of attend trials (M = -.60 μV, SE =.30) was more negative than reappraise trials (M = -.13 μV, SE =.32), F (1, 38) = 6.21, p = .02, η_p^2 = .14, and the amplitude of the color-rating trials (M = -60 μV, SE =.31) was more negative than reappraise trials, F (1, 38) = 5.01, p = .03, η_p^2 = .12. No significant difference was found between the attend and color-rating trials, $F < 1.00$. Together, these findings may indicate that they frontal region of the scalp is involved in the successful down regulation of emotional evocative stimuli.

For those with low WMC, the reappraise trials appeared to be greater in amplitude than the color-rating and attend trials over the parietal-occipital and occipital region of the scalp between 350 and 1000 milliseconds. For those with high

WMC, attend trials appeared to be greater in amplitude than the color-rating and reappraise trials. This effect was examined in a 2 (WMC: high, low) x 2 (electrode: Pz, Oz) x 3 (regulation strategy) ANOVA (Figure 20). The main effect of WMC was not significant, $F < 1.00$, nor was the main effect of regulation strategy, $F(2, 74) = 1.99$, $p = .14$, $\eta_p^2 = .05$.

EXPERIMENT 3 DISCUSSION

The purpose of Experiment 3 was to further examine the neural correlates of emotion regulation by directly comparing two cognitive regulation strategies (e.g., reappraisal and distraction – rating the colorfulness of the picture), and to address discrepancies found in Experiments 1 and 2 between emotional intensity ratings and the electrophysiological data by examining metacognitive ratings based on regulation success. The present study also examined the association between WMC and emotion regulation. It was hypothesized that reappraisal would be associated with a reduction in the amplitude of the LPP for the second presentation of the picture, and the LPP would be greater in amplitude on trials where subjects were instructed to attend to an image or rate the colorfulness of the picture (i.e., distraction; Hajcak & Nieuwenhuis, 2006; Dunning & Hajcak, 2009). Contrary to the previous two experiments, reappraisal did not result in a reduction of the amplitude of the LPP. It was also expected that metacognitive success ratings would correlate with the ERP data, with the LPP being attenuated for high reappraisal success trials in comparison to all other trial-types. While the means for the data were in the hypothesized direction, the interaction between metacognitive success and regulation was not significant for the LPP. Finally, it was hypothesized that the

difference in the amplitude of the LPP between attend and reappraise trials would be greater for those with high WMC than for those with low WMC (MacNamara, Ferri & Hajcak, 2011) and that the modulation of the LPP for reappraisal would begin sooner after stimulus onset for those with high WMC than for those with low WMC. The means for these data were also in the hypothesized direction, however, the association between WMC and regulation was not significant.

Behavioral Data

The self-report data were consistent with the previous two experiments in that emotional intensity ratings were lower for reappraisal and color-rating trials than for attend trials. This finding is consistent with data from previous investigations examining reappraisal and distraction (Gross, 1998; Jackson et al., 2000; Ochsner et al., 2004, Hajcak & Nieuwehuis, 2006). In addition, subjects reported being better able to perform the reappraisal task and color-rating task than they were at attending to the images. The behavioral findings suggest that these two forms of regulation were effective at dampening the subjective experience of emotion to negative images. However, as seen in the prior two experiments, the ERP data diverged from the behavioral findings.

Electrophysiological Data

Cue-Locked Data. Consistent with Experiments 1 and 2, the cue-locked data revealed differential ERPs for each of the regulation strategies. One modulation distinguished reappraisal trials from attend and color-rating trials, and was associated with activity over both the frontal and posterior regions of the scalp. The second modulation distinguished attend trials from regulation trials and was

associated with activity over the lateral-frontal region(s) of the scalp. Effects revealed during the cue-locked epoch were not associated with WMC. Given that WMC has predicted successful regulation in previous investigations (Schmeichel & Demaree, 2010), this outcome was not expected.

Second Presentation of the Picture. The P3 was elicited between 200 and 400 milliseconds at the second presentation of the picture, where the mean amplitude was greater for attend trials and reappraisal trials, than for color-rating trials. Assuming the P3 reflects the allocation of attention to self-relevant stimuli (Donchin & Coles, 1988; Gray, Ambady, Lowenthal, & Deldin, 2004; Johnston et al., 1986), these findings could reflect the aftermath of maintaining attention to a negative/evocative image or manipulating information when performing the reappraisal task. A more deliberate investigation on the effects of regulation on the P3 would need to be conducted to make any founded conclusions.

In addition to the P3, rating the color (i.e., distraction) was associated with a reduction in the amplitude of activity over the frontal-central region of the scalp, which suggests that this strategy was effective at modulating the neural response to negative images. This finding is in line with previous investigations demonstrating that the frontal regions are involved in distraction (Mayer et al., 2007; McRae et al., 2010), and that using distraction as a regulation strategy may result in decreased amygdala activation because individuals neglect to process the emotional aspects of a stimulus (McRae et al., 2010).

Contrary to what was expected based on the previous two experiments and other findings in the literature (Cuthbert et al., 2000; Weinberg & Hajcak, 2010),

neither the reappraisal task nor the color task resulted in a reduction in the amplitude of the LPP relative to the attend condition. Moreover, subject's emotional intensity ratings did not map on to the ERP data from the second presentation of the picture. This finding is surprising, as Hajcak and Nieuwenhuis (2006) found a positive correlation between the amplitude of the LPP and ratings of emotional intensity, along with a reduction in the amplitude of the LPP for reappraisal trials at the second presentation of the picture. There are a few possibilities that might provide an explanation for the discrepancy between the self-report ratings and the ERP data. First, it is possible that the regulation effects were dampened due to the increased number of trials. In Hajcak and Nieuwenhuis, subjects were asked to generate a reappraisal on 20 trials, as opposed to generating a reappraisal for 42 trials in addition to another regulation task (i.e. rating the colorfulness of the picture). Second, generating a reappraisal could have been cognitively taxing; thus, the failure to find a reduction in the amplitude of the LPP at the second presentation of the picture may be due to mental fatigue. Finally, in Experiment 1 modulations in the LPP were sensitive to the nature of the content to-be-regulated, so collapsing across content in the current study may have masked any significant effects.

Metacognitive Data.

Cue-Locked Data. The metacognitive cue-locked ERP data revealed that successful performance of each task was generally associated with activity over the frontal and central-parietal regions of the scalp. These findings may indicate that subjects engaged in active control processes to perform the reappraisal task and the attend task, and possibly demonstrate that different neural structures support the

demands related to each of these tasks (Braver, Cohen, & Barch, 2002; Gray, 2001; Gray, Braver, & Raichle, 2002).

Second Presentation of the Picture. To better understand the discrepancy between the self-report data and ERP data from the Experiments 1 and 2, subjects were asked to provide metacognitive ratings evaluating their success at performing the regulation task. It was expected that self-monitoring would be associated with ERPs that differentiate successful regulation from unsuccessful regulation. Over the occipital region of the scalp, the amplitude of high reappraisal success trials was reduced relative to all other trial-types, when subjects reported being capable of effectively performing the reappraisal task. It appears that the perception of successful task performance may modulate ERPs to negative stimuli, and these findings suggest that activity over the occipital region of the scalp may be another index of reappraisal. There was also a reduction in amplitude for reappraisal trials relative to attend trials over the left frontal region of the scalp indicating that reappraisal may impact stimulus processing related to down-regulation. The topography of this regulation effect seems to be consistent with previous work regarding lateralization of emotional categorization and task demands (Schupp et al., 2000).

The lack of strong results for the metacognitive data may be due to the fact that over half of the subjects were eliminated from the analyses because there was no variability in their metacognitive success ratings. The absence of variability may reflect poor metacognitive skills. Perhaps subjects lacked knowledge concerning their cognitive processes related to the regulation of emotion. The lack of variability

may also be a result of subjects not performing the task, or poor task design. In the future, it would be useful to ask subjects to complete a formal measure assessing their general metacognitive knowledge, in addition to making metacognitive ratings during the task. It may also be advantageous to take the metacognitive success rating at the end of the regulation epoch, rather than at the second presentation of the picture.

Working Memory Data. WMC was not associated with regulation strategy in any of the analyses. The amplitude of the ERPs were sensitive to regulation for both the cue-locked data and data locked to the second presentation of the picture, yet these effects were not moderated by WMC. The present study employed the OSPAN task to place subjects into low and high WMC groups, rather than testing and recruiting subjects based on their scores. It is possible that if extreme groups were used then an association may have been revealed between reappraisal-induced modulation of the waveforms and WMC. Given that cognitive control has been implicated an important factor in emotion regulation by previous investigations (Carver, Sutton, & Scheier, 2000; Gray, Braver, & Raichle, 2002; Gray, 2004), it would be advantageous to entertain the idea of examining extreme WMC groups with this paradigm in the future. It would also be beneficial to obtain more than one measure of WMC. The current study used only one measure of WMC due to time constraints related to data collection.

CHAPTER 6.

GENERAL DISCUSSION

The purpose of the dissertation was to examine the neural correlates of different forms of emotion regulation and how these are related to picture content, metacognition, and WMC. Experiment 1 revealed that successful reappraisal varied by the content of the pictures. Specifically, reappraisal-induced modulation of the LPP was found for pictures depicting violence, but not those depicting mutilations or grief and loss. Experiment 2 established that distraction did not modulate the LPP and appeared to be a less effective means of regulation in comparison to reappraisal. Experiment 3 compared the effects of reappraisal and distraction on the LPP, and was also designed to understand the nature of cognitive control in successful regulation and the relationship between self-monitoring and successful regulation. Together, the data from these three experiments leads to the suggestion that reappraisal modulates the neural response to negative stimuli under specific conditions; however, further research is required before making definitive conclusions about the influence of WMC and metacognition on regulation success.

Behavioral Data

The self-report data were consistent across all three experiments, with emotional intensity ratings being higher on attend trials than on regulation trials. Thus, it appears as if reappraisal and distraction decreased the experience of negative emotion. This finding is in line with other studies demonstrating that reappraisal and distraction are effective regulation strategies (Gross, 1998; Gross, 2002; Nolen-Hoeksema & Morrow, 1993; McRae et al., 2010).

One concern regarding the self-report findings is that the decrease in emotional intensity ratings for reappraisal and distraction may have resulted from demand characteristics due to the failure to find significant effects of the LPP in the electrophysiological data at the second picture presentation. Essentially, the instructions for the task in all three experiments indicate the way participants should feel. If subjects are aware that these two conditions should decrease the intensity of their emotionally response for the purposes of the experiment, they may be making a response that is congruent with the demands and expectations of the experiment. For instance, if the task instructions direct participants to focus on a “non-emotional” aspect of an image, this would imply that the image is emotional in and of itself. Therefore, the participant may assume that emotional intensity ratings should be lower when the cue associated with this instruction appears.

The discrepancy between the self-report data and the ERPs might have been a result of fatigue related to performing the regulation task. This is based on two assumptions. First, fatigue might have been a factor due to the increased number of regulation trials. There were 126 trials in Experiment 3, and 90 trials in Experiment 1, in comparison to 40 trials in Hajcak and Nieuwenhuis’s (2006) experiment. Second, the timing of the effects for the cue-locked data in Experiment 3 did not persist as long as the effects found in Experiments 1 and 2, which would suggest a change in the amount of time spent regulating, or attempting to regulate. It could be suggested that habituation influenced the modulation of the LPP rather than fatigue. However, if this were the case then one would expect differences between the two conditions at the first presentation of the picture (i.e., before the presentation of the cue).

Furthermore, habituation to the negative stimuli likely does not explain the lack of regulation-induced modulation of the LPP, as the current study and previous investigations have demonstrated a) no differences between the attend and reappraise conditions at the first presentation of the picture, and b) the sustained presence of the LPP through multiple presentations of affective stimuli (Codispoti, Ferrari, & Bradley, 2007; Ferrari, Bradley, Codispoti, & Lang, 2010; Hajcak & Nieuwenhuis, 2006, Hajcak, MacNamara, & Olvet, 2010).

Second Presentation of the Picture

The current study used reappraisal and distraction to explore how effective these strategies were at down-regulating the emotional response to negative information. The findings of Hajcak and Nieuwenhuis (2006) were replicated in Experiments 1 and 2, where reappraisal modulated the neural response to negative images following regulation. In Experiment 2, the LPP for distraction trials was greater in amplitude than the LPP for attend trials, suggesting that self-directed distraction (e.g., focus on a non-emotional aspect of the image) was an ineffective regulation strategy from relative to reappraisal. This finding is in line with previous studies demonstrating that distraction is less effective at reducing the emotional response to negative stimuli than reappraisal (McRae et al., 2010; McRae, Misra, Prasad, Pereira, & Gross, 2011; Sheppes & Meiran, 2007). Although using reappraisal was successful for modulating the LPP, the reappraisal effect was not as robust in Experiment 2. In Experiment 1 only violent pictures were associated with the reappraisal-induced modulation of the LPP. Therefore, it is possible the

dampened reappraisal effect demonstrated in Experiment 2 was a result of collapsing across content for mutilations and violent pictures.

As mentioned above, the reappraisal effect on the LPP at the second picture presentation was observed in Experiment 1, but only for violent pictures. This finding suggests that violent pictures might be responsible for the reappraisal effect shown in the Hajcak and Nieuwenhuis (2006). For instance, Experiment 1 in the current study revealed that, at the first presentation of the picture, the LPP was greater in amplitude for pictures depicting violence and mutilations, that for those depicting grief and loss; however, the LPP for reappraise trials was only lower in amplitude that attend trials for violent pictures. Also, greater attention is allocated to personally relevant / motivationally significant images (Cuthbert et al., 2000; Gray et al., 2004; Schupp et al., 2000; i.e., mutilations and violence) and that the reappraisal effect was observed on trials that were likely less difficult to reappraise (i.e., violence). These findings lead to the conclusion that the ability to generate a reappraisal with ease and self-relevant pictures are two conditions that may be necessary to observe the reappraisal effect on the LPP. In Hajcak and Nieuwenhuis, 21 of the 40 negative images used could be considered self-relevant, or motivationally significant due to threatening content (e.g., a picture of a dog bearing it's teeth and preparing to attack, the barrel of a gun pointed at the computer screen, or a man holding a knife up to a woman's neck). Also, 18 of the 40 negative images used by Hajcak and Nieuwenhuis were categorized as violent pictures in the current study. Appraisals are generally more accessible for self-relevant information, making them easier to manipulate and change, as required during reappraisal (McRae et al., 2011). If

reappraisals are easier to generate for self-relevant images, then collapsing across picture content may be one reason why the reappraisal effect on the LPP was not observed in Experiments 2 and 3.

The reappraisal effect on the LPP in Experiment 2 was short lived (100 milliseconds in the middle of the epoch); however, in Hajcak and Nieuwenhuis (2006) the LPP for reappraisal trials began around 200 milliseconds after stimulus onset and lasted for the remained of the epoch. This finding may suggest a potential cost associated with switching between regulation strategies during the task (i.e., attend, reappraise, distraction). The argument for this idea is based on the process model of emotion regulation (Gross, 1998). Reappraisal is considered an antecedent-focused regulation strategy, meaning that it is employed early in the emotion trajectory before an emotional response is generated, which minimizes the challenge of inhibiting the initial emotional response (Gross, 1998; Gross, 2001; Sheppes, et al., 2009). However, if attempts to change an emotion are delayed, the reappraisal task could be difficult to perform because it would involve overriding an established interpretation of the picture. As shown in previous studies (Sheppes & Meiran, 2008), delayed reappraisal may tax self-regulation resources in a manner similar to interference effects observed in the Stroop task (Sheppes & Meiran, 2008; Sheppes et al., 2009; Vohs & Schmeichel, 2003). There may have been a cost associated with switching between three different regulation tasks, where subjects initiated and applied the regulation technique later in the process. In Experiment 2, this may have delayed the reappraisal effect and decreased its effectiveness at modulating the neural response (Sheppes & Meiran, 2007).

Regulation induced modulation of the LPP was not found in Experiment 3. The increased number of trials may have contributed to this result. As previously mentioned, there were 126 trials, 84 of which were regulation trials. Thus, participants were asked to meet different regulation goals on a randomized, trial-by-trial basis, all while being presented with evocative negative images. Subjects might have found it relatively difficult to repeatedly generate reappraisals that could effectively decrease negative emotion, which has been reported as difficult by other investigators (Ochsner et al., 2004).

In Experiment 3, I expected that cognitive processes related to self-regulation would be involved in the successful regulation of emotion. If cognitive control is indeed involved in emotional control, then WMC should pay a role in the effective regulation of emotion (Gray, 2004). The OSPAN task was used to assess individual differences in WMC in Experiment 3. No significant difference was found in the ERP data between individuals with high and low spans. Although the data at the second presentation of the picture was sensitive to regulation, these effects were not moderated by WMC. It is possible that utilizing an extreme-group design to maximize the influence of individual differences would reveal an association between emotion regulation and WMC.

Metacognitive success ratings were also used to assess whether self-monitoring would be associated with successful regulation. It appeared as if successful task performance was associated with ERPs of negative stimuli, however, these effects were marginal. The process of reappraisal involves many steps such as examining the emotional situation, generating a number of appraisals,

selecting and maintaining the appraisal and monitoring the success related to cognitive change. With that said, subjects may have found it difficult to accurately monitor their ability to regulate after making multiple decisions beforehand. Assessing metacogntive success immediately after regulation could result in more robust effects.

Cue-Locked Data

A novel contribution of this dissertation was the examination of the ERPs during the cue-locked period (i.e., during active regulation). Activity was found in all three experiments during the cue-locked epoch that differentiated attend, reappraise, and distraction trials. Experiment 1 revealed differential slow wave activity related to content, and Experiment 2 revealed differential slow wave activity related to regulation strategy. Experiment 3 revealed differential activity related to regulation, and for the metacognitive data, differential neural activity was related to regulation success. Slow wave activity observed in Experiments 1 and 2 suggest that emotion regulation is related to active control processes (Gray, 2004; Gray & Braver, 2002), similar to slow wave ERPs found in cognitive control experiments (West, 2003). These modulations of the ERPs may also be neural indices of each regulation strategy. As demonstrated in Experiments 1 and 2, slow wave activity over the frontal and right central regions of the scalp appears to be an index of reappraisal. This finding complements previous fMRI investigations demonstrating activity in the medial prefrontal cortex regions and dorsolateral prefrontal cortex regions when decreasing negative emotion (Goldin et al., 2008; Ochsner et al., 2002; Ochsner et al., 2004; Phan, Fitzgerald, Nathan, Moore, Unde, & Tancer, 2005; Schaefer et al.,

2002). In addition, slow wave activity over the central-parietal and parietal regions of the scalp appear to be indices of distraction, which is in line with evidence suggesting that distraction depends more on parietal regions involved in the control of attention (McRae et al., 2010).

It is interesting, however, that although differential neural activity was exhibited during active regulation, findings were mixed for all three experiments at the second picture presentation. For instance, there was no effect of reappraise at the second presentation of picture for content areas outside of violence for Experiment 1, no effect of distraction for Experiment 2, and no effect of reappraisal and color for Experiment 3. If subjects are indeed performing the regulation task during this epoch, then the assumption is there should be significant differences in the modulation of the ERPs. Given that reappraisal does not modulate the LPP under a variety of conditions (e.g., for content areas outside of violence, or a reappraisal and distraction task with a high number of trials) it appears that strategies or processes implemented during this time frame were ineffective.

Limitations and Future Directions

There were a couple of limitations of this study. First, pictures depicting mutilations and grief or loss were used in Experiments 2 and 3, after findings from Experiment 1 revealed that reappraisal was ineffective for these two content areas. This would imply that self-relevant images might be required to observe effects of regulation on reappraisal similar to those found in Hajcak and Nieuwenhuis (2006). A second limitation was the limited stimulus set (IAPS; Lang et al., 2008) used to evaluate each content area. The IAPS was developed to provide a normative set of

emotional stimuli rated on arousal (e.g., high and low) and valance (e.g., positive and negative). Although the IAPS is a large picture set that includes a wide range of evocative stimuli, the photographs have not been placed into distinct and tested categories. It is possible there could be different results if clear, tested, and unambiguous categories existed within the IAPS.

In future studies, it could be helpful include trials where subjects are asked to increase negative emotion, in addition to decreasing negative emotion on others to tackle potential demand characteristics in the self-report data (Jackson et al., 2000; Ochsner et al., 2004; Urry, 2009). Modulation in the ERPs found for increasing and decreasing emotion would suggest that different reappraisals focused on different outcomes also modulate the subjective experience of emotion (Sheppes & Meiran, 2007; Urry, 2009). Another possibility is that these data legitimately indicate the subjective emotional experience and are not completely driven by demand characteristics. Measuring the subjective experience of the emotion throughout the epoch could help address this issue.

Based on the results from the current study, there is a need to further examine the way in which picture content interacts with other manipulations associated with emotion regulation. For instance, the data for Experiment 3 was collected in 3 blocks and each block consisted of the same picture type (e.g., grief/loss, mutilations, violence). If violent images drive the reappraise-induced modulation of the LPP, as suggested above, it would be beneficial in the future to remove all other content areas from the dataset. It would also be interesting to

analyze the data with content as a between subjects variable to see there are any meaningful differences between the three conditions.

Conclusion

The work of this dissertation was designed to examine the behavioral effects and neural correlates of two emotion regulation strategies: reappraisal and distraction. Data from the current study provided support for the idea that emotion regulation and its associated ERP components are modulated by content (i.e., the information to-be-regulated) and number of stimuli. Experiment 1 demonstrated a relationship between picture content and modulation of the LPP. Experiment 2 revealed that self-directed distraction was less effective than reappraisal in decreasing the neural response to negative images. Experiment 3 failed to establish an association between emotion regulation and WMC, or emotion regulation and metacognition. A novel contribution of this dissertation would be indices of active regulation strategies that correspond with existing fMRI data. These indices were determined by examining modulations in the ERPs during the cue-locked period for all three experiments. Together, the results from this study indicate that reappraisal and distraction are supported by control processes similar to those employed by attentional or cognitive control tasks. Also, each reappraisal is effective under certain conditions; for instance, the information to be regulated should have personal relevance or motivational significance. In conclusion, identifying the context(s) in which changing or ignoring emotional information is most effective will inevitably enhance our understanding of emotion regulation.

APPENDIX A. INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT YOUNGER ADULT

Title of Study: **Emotion Regulation and Cognitive Control**
Investigators: Robert West, PhD, Associate Professor of Psychology
Brandy Tiernan, MA, Graduate Student in Psychology
Kira Bailey, MS, Graduate Student in Psychology

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION --

The purpose of this study is to examine the brain processes that are involved in attention and emotion. You are eligible to participate in this project as part of the Department of Psychology Research Participation Pool. As noted on your course syllabus, participation in experiments is one of the available options for acquiring experimental credit in your psychology course.

DESCRIPTION OF PROCEDURES --

You will be asked to perform tasks that tap into attention and emotion while we record EEG (brain waves) from your scalp. In order to record the EEG you will wear a cap that contains the electrodes. In each of the electrodes we will place a small quantity of conductive gel. This gel is water based and is easy to wash out of your hair at the end of the study. The tasks will be presented on a computer. In task 1, you will be asked to count the number of digits on the screen. In tasks 2 and 3, you will be asked to view pictures of scenes and rate the emotional content. The scenes will be similar to the sample pictures. You will also complete 5 questionnaires and 2 rating scales. These scales measure handedness, demographic information, and aspects of mood and personality. The entire experiment should take less 2 hours.

RISKS --

There are no known risks associated with performing the computer tasks. Stimuli will be letter strings (XXXX), numbers, or pictures like those you saw in the sample pictures. Some of the stimuli may be mildly offensive, but not more so than those presented in the sample pictures. There is a slight risk of developing a headache while wearing the Electro-cap. This goes away after the cap is removed. If this occurs during the study let us know and we can take steps to eliminate the discomfort. There is also a slight risk related to the transmission of pathogens (bacteria or viruses) related to wearing the Electro-cap. This risk of transmission is greatly reduced by disinfecting the caps following use with a medical grade disinfectant.

BENEFITS --

The knowledge gained in the study will not directly benefit you. This knowledge will extend our understanding of the brain processes that support attention and emotion regulation.

ALTERNATIVES TO PARTICIPATION --

Alternatives other than research participation for earning research/extra credit are described in your course syllabus.

COSTS AND COMPENSATION --

No monetary costs or compensation are associated with this project. You are participating as part of the Psychology Research Participation Pool. You will earn 3 credits for your participation.

PARTICIPANT RIGHTS --

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time without penalty or loss of benefits.

CONFIDENTIALITY –

Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information. We are required by the University IRB to keep a copy of the informed consent.

To ensure confidentiality to the extent permitted by law, the following measures will be taken: The electronic data will be stored on a password-protected computer that is in the experimenters' laboratory. Only the investigators have access to this computer. The consent form will be separated from the other data following the completion of data collection and maintained in a locked file cabinet sot that there is no way to link the identity of the individual to the written or electronic data. The data collected in this research may be used for educational or scientific purposes and may be presented a scientific meetings or published in professional journals. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS --

You are encouraged to ask questions at any time during this study. At the end of the study, you will be debriefed. For further information about the study, please contact Dr. Robert West, Science I Room 492, 294-3950, rwest@iastate.edu or Brandy Tiernan, MA, Science I Room 9, brandyj@iastate.edu.

If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, 1138 Pearson Hall, Iowa State University, Ames, Iowa 50011.

****

PARTICIPANT SIGNATURE --

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You may receive a copy of the signed and dated written informed consent prior to your participation in the study.

Participant's Name (printed) _____

_____ _____

(Participant's Signature) (Date)

INVESTIGATOR STATEMENT --

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.

_____ _____

(Signature of Person Obtaining Informed Consent) (Date)

APPENDIX B. BRIEF HANDEDNESS INVENTORY

Participant ID#: _____

Have you ever had any tendency to left-handedness? YES NO

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

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

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

	Right	**Left**
1. Writing	_____	_____
2. Drawing	_____	_____
3. Throwing	_____	_____
4. Scissors	_____	_____
5. Toothbrush	_____	_____
6. Knife (without fork)	_____	_____
7. Spoon	_____	_____
8. Broom (upper hand)	_____	_____
9. Striking Match (match)	_____	_____
10. Opening Box	_____	_____
	_____	_____

REFERENCES

Arnold, M. (1960). *Emotion and personality.* NY: Columbia University Press.

Barrett, L. (2006). Solving the emotion paradox: categorization and the experience of emotion. *Personality and Social Psychology Review, 10(1),* 20-46.

Barrett, L., Tugade, M., & Engle, R. (2004). Individual differences in working memory capacity and dual-process theories of the mind. *Psychological Bulletin, 130,* 553–573.

Bennett, P., Phelps, C., Brain, K., Hood, K., & Gray, J. (2007). A randomized controlled trial of a brief self-help coping intervention designed to reduce distress when awaiting genetic risk information. *Journal of Psychosomatic Research, 63*, 59–64.

Boden, J., & Baumeister, R. (1997). Repressive coping: Distraction using pleasant Thoughts and memories. *Journal of Personality and Social Psychology, 73,* 45-62.

Bradley, M. (2000). Emotion and motivation. In J.T. Cacioppo, L.G. Tassinary, & G.G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 602–642). New York: Cambridge University Press.

Bradley, M. (2009). Natural selective attention: Orienting and emotion. *Psychophysiology, 46,* 1–11.

Bradley, M., Codispoti, M., Sabatinelli, D., & Lang, P. (2001). Emotion and motivation: II. Sex differences in picture processing. *Emotion, 1,* 300–319.

Bradley, M., Hamby, S., Loew, A., & Lang, P. (2007). Brain potentials in perception: Picture complexity and emotional arousal. *Psychophysiology, 44,* 364–373.

Bradley, M., & Lang, P. (2000). Measuring emotion: Behavior, feeling, and physiology. In R. Lane & L. Nadel (Eds.), *Cognitive neuroscience of emotion* (pp. 242-276). NY: Oxford University Press

Bradley, M., Lang, P., & Cuthbert, B. (1993). Emotion, novelty, and the startle reflex: Habituation in humans. *Behavioral Neuroscience, 107,* 970–980.

Braver, T., Cohen, J., & Barch, D. (2002). The role of the prefrontal cortex in normal and disordered cognitive control: A cognitive neuroscience perspective. In D.T. Stuss & R.T.Knight (Eds.), Principles of frontal lobe function (pp. 428–448). Oxford, England: Oxford University Press.

Briggs, K., & Martin, F. (2008). Target processing is facilitated by motivationally relevant cues. *Biological Psychology, 78*, 29–42.

Briggs, K., & Martin, F. (2009). Affective picture processing and motivational relevance: Arousal and valence effects on ERPs in an oddball task. *International Journal of Psychophysiology, 72*, 299 –306

Brown, A. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, motivation, and understanding* (pp. 65-116). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Cacioppo, J., Crites, S., Berntson, G., & Coles, M. (1993). If attitudes affect how stimuli are processed, should they not affect the event-related brain potential? *Psychological Science, 4,* 108–112.

Carver, C., Sutton, S., & Scheier, M. (2000). Action, emotion, and personality: Emerging conceptual integration. *Personality and Social Psychology Bulletin,*

26, 741–751.

Clore, G., & Ortony, A. (2000). Cognition in emotion: Always, sometimes, or never? In L. Nadel, R. Lane, & G. Ahern (Eds.), *The cognitive neuroscience of emotion* (pp. 24 - 61). NY: Oxford University Press.

Codispoti, M., Ferrari, V., & Bradley, M. (2007). Repetition and ERPs: Distinguishing early and late processes in affective picture perception. *Journal of Cognitive Neuroscience,19,* 577–586.

Codispoti, M., Ferrari, V., Junghöfer, M., Schupp, H. (2006). The categorization of natural scenes: brain attention networks revealed by dense sensor ERPs. *Neuroimage, 31*, 881–890.

Conway, A., Cowan, N., & Bunting, M. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review, 8*, 331–335.

Conway, A., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. (2002). latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence, 30*, 163-183.

Conway, A., Kane, M., Bunting, M., Hambrick, D., Wilhelm, O., & Engle, R. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review, 12,* 769 –786.

Cornelius, R. (1996). *The science of emotion. Research and tradition in the psychology of emotion.* NJ: Prentice-Hall.

Cornelius, R. (2000). Theoretical approaches to emotion. In: Proceedings of the

ISCA Workshop on Speech and Emotion, 3–10.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24,* 87–185.

Cuthbert, B., Schupp, H., Bradley, M., Birbaumer, N., & Lang, P. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology, 52*, 95–111.

Davidson, R. (1993). Cerebral asymmetry and emotion: Conceptual and methodological conundrums. *Cognition and Emotion, 7*, 115-138.

Davidson, R., Ekman, P., Saron, C., Senulis, J., & Friesen, W. (1990). Approach – withdrawal and cerebral asymmetry: Emotional expression and brain physiology. *Journal of Personality and Social Psychology, 58,* 330–341.

Davis, E., Levine, L., Lench, H., & Quas, J. (2010). Metacognitive emotion regulation: children's awareness that changing thoughts and goals can alleviate negative emotions. *Emotion, 10(4),* 498-510.

Delplanque, S., Lavoie, M., Hot, P., Silvert, L., & Sequeira, H. (2004). Modulation of cognitive processing by emotional valence studied through event-related potentials in humans. *Neuroscience Letters, 365*, 1-4.

Derryberry, D. (1991). The immediate effects of positive and negative feedback signals. *Journal of Personality and Social Psychology, 61*, 267–278.

Diamond, L., & Aspinwall, L. (2003). Emotion regulation across the lifespan: An integrative approach emphasizing self-regulation, positive affect, and dyadic processes. *Motivation and Emotion, 27,* 125-156.

Donchin, E., & Coles, M. (1988). Is the P300 component a manifestation of cognitive

updating? *The Behavioral and Brain Sciences, 11,* 357–427.

Duncan-Johnson, C., & Donchin, E. (1977). On quantifying surprise: The variation of event-related potentials with subjective probability. *Psychophysiology, 14,* 456–467.

Dunning, J., & Hajcak, G. (2009). See no evil: Directing visual attention within unpleasant images modulates the electrocortical response. *Psychophysiology, 46*, 28 –33.

Ellsworth, P., & Scherer, K. (2003). Appraisal processes in emotion. In R. Davidson, K. Scherer, & H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 572 – 595). NY: Oxford University Press.

Engle, R. (2001). What is working memory capacity? In H. L. Roediger, J. S. Nairne, I. Neath, & A. M. Suprenant (Eds.), *The nature of remembering: Essays in honor of Robert G. Crowder* (pp. 297–314). Washington, DC: American Psychological Association.

Engle, R. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11*, 19 –23.

Engle, R., Kane, M., & Tuholski, S. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 102 -134). New York: Cambridge University Press.

Farb, N., Anderson, A., Mayberg, H., Bean, J., McKeon, D., Segal, Z., 2010. Minding one's emotions: mindfulness training alters the neural expression of sadness.

Emotion,*10*, 25–33.

Fennell, M., & Teasdale, J. (1984). Effects of distraction on thinking and affect in depressed patients. *British Journal of Clinical Psychology, 23*, 65-66.

Fernandez-Duque, D. (1999). *Automatic processing of object identity, location, and valence information.* Unpublished doctoral dissertation, University of Oregon.

Fernandez-Duque, D., Baird, J. A., & Posner, M. I. (2000). Executive attention and metacognitive regulation. *Consciousness & Cognition, 9*, 288-307.

Fernandez-Duque, D., Baird, J. A., & Posner, M. I. (2000). Attention and awareness in self-regulation. *Consciousness & Cognition, 9,* 324-326.

Ferrari, V., Bradley, M., Codispoti, M., & Lang, P. (2010). Detecting novelty and significance. *Journal of Cognitive Neuroscience, 22*, 404–411.

Fox, N. & Calkins, S. (2003) The development of self-control of emotions: Intrinsic and extrinsic influences. *Motivation and Emotion, 27,* 7-26.

Fraley, R., & Shaver, P. (1997). Adult attachment and the suppression of unwanted thoughts. *Journal Of Personality and Social Psychology, 73*, 1080–1091.

Frijda, N. (1986). *The emotions*. London: Cambridge University Press.

Frijda, N. (1988). The laws of emotion. *American Psychologist, 43,* 349-358.

Garnefski, N., Kraaij, V., & Spinhoven, P. (2002). C*ERQ: Manual for the use of the Cognitive Emotion Regulation Questionnaire.* Leiderdorp, the Netherlands: DATEC.

Gerin, W., Davidson, K., Christenfeld, N., Goyal, T., & Schwartz, J. (2006). The role of angry rumination and distraction in blood pressure recovery from emotional arousal. *Psychosomatic Medicine, 68,* 64–72.

Goldin, P., McRae, K., Ramel, W., & Gross, J. (2008). The neural bases of emotion regulation: Reappraisal and suppression of negative emotion. *Biological Psychiatry, 63*, 577–586.

Gray, J. (2001). Emotional modulation of cognitive control: Approach-withdrawal states double-dissociate spatial from verbal two-back task performance. *Journal of Experimental Psychology: General, 130,* 436–452

Gray, J. (2004). Integration of emotion and cognitive control. *Current Directions in Psychological Science, 13,* 46-48.

Gray, H., Ambady, N., Lowenthal, W., & Deldin, P. (2004). P300 as an index of attention to self-relevant stimuli. *Journal of Experimental Social Psychology, 40,* 216–224.

Gray, J. & Braver, T. (2002). Personality predicts working memory related activation in the caudal anterior cingulate cortex. *Cognitive, Affective, & Behavioral Neuroscience, 2*, 64–75.

Gray, J., Braver, T., & Raichle, M. (2002). Integration of emotion and cognition in the lateral prefrontal cortex. *Proceedings of the National Academy of Sciences, USA, 99,* 4115–4120.

Gross, J. (1998a). Antecedent- and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology, 74,* 224–237.

Gross, J. (1998b). The emerging field of emotion regulation: An integrative review. *Review of General Psychology, 2,* 271-299.

Gross, J. (2001). Emotion regulation in adulthood: Timing is everything. *Current*

Directions in Psychological Science, 10, 214 – 219.

Gross, J. (2002). Emotion regulation: Affective, cognitive, and social consequences. Psychophysiology, 39(3), 281 - 291.

Gross, J. (Ed.). (2007). *Handbook of emotion regulation.* New York: Guilford Press.

Gross, J. (2008). Emotion regulation. In M. Lewis, J. Haviland-Jones, and L. F. Barrett (Eds), *Handbook of Emotion, 3rd edition* (pp. 497-512). New York: Guilford Press.

Gross, J., & John, O. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships and wellbeing. *Journal of Personality and Social Psychology, 85,* 328 –362.

Gross, J., & Munoz, R. (1995). Emotion regulation and mental health. *Clinical Psychology: Science and Practice, 2*, 151–164.

Gross, J., & John, O. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85,* 348–362.

Gross, J., Richards, J., & John, O. (2006). Emotion regulation in everyday life. In D. K. Snyder, J. Simpson, & J. N. Hughes (Eds.), *Emotion Regulation in Couples and Families: Pathways to Dysfunction and Health* (pp. 13–35). Washington, DC: American Psychological Association.

Gross, J., & Thompson, R. (2007). Emotion regulation: Conceptual foundations. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 3-24). New York: Guilford Press.

Giuliani, N., & Gross, J. (2009). Reappraisal. In: Sander, D., Scherer, K.R. (Eds.),

Oxford Companion to the Affective Sciences. Oxford University Press, New York, NY.

Gyurak, A., Goodkind, M., Madan, A., Kramer, J., Miller, B., & Levenson, R. (2009). Do tests of executive functioning predict ability to down regulate emotions spontaneously and when instructed to suppress? *Cognitive, Affective, and Behavioral Neuroscience, 9,* 144 –152.

Hajcak, G., Dunning, J., & Foti, D. (2007). Neural response to emotional pictures is unaffected by concurrent task difficulty: An event-related potential study. *Behavioral Neuroscience, 121,* 1156 –1162.

Hajcak, G., MacNamara, A., & Olvet, D. (2010). Event-related potentials, emotion, and emotion regulation: An integrative review. Developmental Neuropsychology, 35(2), 129–155.

Hajcak, G., & Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective, & Behavioral Neuroscience, 6 (4),* 291–297.

Harmon-Jones, E., Lueck, L., Fearn, M., & Harmon-Jones, C. (2006). The effect of personal relevance and approach-related action expectation on relative left frontal cortical activity. *Psychological Science, 17,* 434–440.

Hasher, L., & Zacks, R. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 22, pp. 193-225). San Diego: Academic Press.

Hoffman, W., Gschwendner, T., Friese, M., Wiers, R., & Schmitt, M. (2008). Working

memory capacity and self-regulatory behavior: Toward an individual differences perspective on behavior determination by automatic versus controlled processes. *Journal of Personality and Social Psychology, 95 (4)*, 962-977.

Hofmann, W., Friese, M., Schmeichel, B., & Baddeley, A. (2011). Working memory and self-regulation. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of self regulation: Research, theory, and application* (2nd ed.) (pp. 204-225). New York: Guilford Press.

Holmes, A., Nielsen, M., & Green, S. (2008). Effects of anxiety on the processing of fearful and happy faces: An event-related potential study. *Biological Psychology, 77(2),* 159-173.

Huynh, H. & Feldt, L. (1976). Estimation of the box correction for degrees of freedom from sample data in the randomized block and split plot designs. *Journal of Educational Statistics, 1,* 69-82.

Ilkowska, M., & Engle, R. (2010). Working memory capacity and self-regulation. In: R.H. Hoyle (Ed.), *Handbook of personality and self-regulation* (pp. 265-290). Willey Blackwell.

Jackson, D., Malmstadt, J., Larson, C., & Davidson, R. (2000). Suppression and enhancement of emotional responses to unpleasant pictures. *Psychophysiology, 37,* 515–522.

Johnston, V., Miller, D., & Burleson, M. (1986). Multiple P300s to emotional stimuli and their theoretical significance. *Psychophysiology, 23,* 684–694.

Josephson, B., Singer, J., & Salovey, P. (1996). Mood regulation and memory:

Repairing sad moods with happy memories. *Cognition and Emotion, 10*, 437–444.

Kane, M. J., Bleckley, M. K., Conway, A. R. A., & Engle, R. W. (2001). A controlled attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130*, 169 –183.

Kane, M., & Engle, R. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132,* 47-70.

Keil, A., Bradley, M. M., Hauk, O., Rockstroh, B., Elbert, T., & Lang, P. J. (2002). Large scale neural correlates of affective picture processing. *Psychophysiology, 39*, 641 – 649.

Keil, A., Müller, M., Gruber, T., Stolarova, M., Wienbruch, C., & Elbert, T. (2001). Effects of emotional arousal in the cerebral hemispheres: A study of oscillatory brain activity and event-related potentials. *Clinical Neurophysiology, 112,* 2057–2068.

Koole, S., van Dillen, L., & Sheppes, G. (2011). The self-regulation of emotion. In K. D.Vohs, R. F. Baumeister, K. D. Vohs, R. F. Baumeister (Eds.), *Handbook of self-regulation: Research, theory, and applications* (2nd ed.) (pp. 22-40). New York, NY, US: Guilford Press.

Krompinger, J., Moser, J., & Simons, R. (2008). Modulations of the electrophysiological response to pleasant stimuli by cognitive reappraisal. *Emotion, 8,* 132–137.

Kuhl, J., & Kazen, M. (1999). Volitional facilitation of difficult intentions: Joint activation of intention memory and positive affect removes Stroop interference. *Journal of Experimental Psychology: General, 128,* 382-399.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons, & M. T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97–135). Hillsdale NJ: Erlbaum.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). International affective picture system (IAPS): Technical manual and affective ratings. Gainesville: University of Florida, Center for Research in Psychophysiology.

Langston, C. (1994). Capitalizing on and coping with daily life events: Expressive responses to positive events. *Journal of Personality and Social Psychology, 67,* 1112 - 1125.

Lazarus, R. (1991). Progress on a cognitive-motivational-relational theory of emotion. *American Psychologist, 46,* 819 - 834.

Lazarus, R. (1993). From psychological stress to the emotions: a history of changing outlooks. *Annual Review of Psychology, 44,* 1-21.

Lazarus, R., & Folkman, S. (1984b). Stress, appraisal, and coping. New York: Springer. Lépine, R., Barrouillet, P., & Camos, V. (2005). What makes working memory spans so predictive of high-level cognition? *Psychonomic Bulletin & Review, 12,* 165-170.

Long, D., & Prat, C. (2002). Working memory and Stroop interference: An individual differences investigation. *Memory & Cognition, 30*(2), 294-301.

Luck, S. (2005). *An introduction to the event-related potential technique.* Cambridge, MA: The MIT Press.

Luck, S., & Hillyard, S. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology, 31*, 291-308.

MacNamara, A., Ferri, J., & Hajcak, G. (2011). Working memory load reduces the late positive potential and this effect is attenuated with increasing anxiety. *Cognitive, Affective, and Behavioral Neuroscience, 11(3)*, 321-331.

MacNamara, A., Foti, D., & Hajcak, G. (2009). Tell me about it: Neural activity elicited by emotional stimuli and preceding descriptions. *Emotion, 9(4),* 531-543.

Mather, M., & Knight, M. (2005). Goal-directed memory: The role of cognitive control in older adults' emotional memory. *Psychology and Aging, 20,* 554–570.

Mauss, I., Levenson, R., McCarter, L., Wilhelm, F., & Gross, J. (2005). The tie that binds? Coherence among emotion experience, behavior, and autonomic physiology. *Emotion, 5,* 175-190.

Mauss, I., Bunge, S., & Gross, J. (2007). Automatic emotion regulation. *Social and Personality Psychology Compass, 1*, 146-167.

Mayer, J., Bittner, R., Nikolic, D., Bledowski, C., Goebel, R., & Linden, D. (2007). Common neural substrates for visual working memory and attention. *Neuroimage, 36,* 441–453.

McRae, K., & Gross, J. (2009). Emotion regulation. In D. Sander & K. Scherer (Eds.), *Oxford companion to the affective sciences*. New York, NY: Oxford University Press.

McRae, K., Hughes, B., Chopra, S., Gabrieli, J., Gross, J., & Ochsner, K. (2010). The neural bases of distraction and reappraisal. *Journal of Cognitive Neuroscience, 22(2),* 248 – 262.

McRae, K., Misra, S., Prasad, A., Pereira, S., & Gross, J. (2011). Bottom-up and top down emotion generation: Implications for emotion regulation. *Social, Cognitive & Affective Neuroscience, 7(3),* 253-262.

McRae, K., Ochsner, K., Mauss, I., Gabrieli, J., & Gross, J. (2008). Gender differences in emotion regulation: An fMRI study of cognitive reappraisal. *Group Processes and Intergroup Relations, 11,* 143–162.

Moses, L., & Baird, J. (1999). Metacognition. In R. Wilson (Ed.), *Encyclopedia of cognitive neuroscience*. Cambridge, MA: MIT Press.

Moser, J., Hajcak, G., Bukay, E., & Simons, R. (2006). Intentional regulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology, 43*, 292–296.

Nolen-Hoeksema, S., & Morrow, J. (1993). Effects of rumination and distraction on naturally occurring depressed mood. *Cognition and Emotion, 7,* 561-570.

Norman, W., & Shallice, T. (1986). Attention to action. In: Davidson, R., Schwartz, G., & Shapiro, D., (Eds)., *Consciousness and self regulation: Advances in research and theory*, vol. 4. (pp. 1-18). New York: Plenum.

Ochsner, K., & Gross, J. (2007). The neural architecture of emotion regulation. In: Gross, J.J., & Buck, R. (Eds)., *The Handbook of Emotion Regulation* (pp. 87–109). New York: Guilford Press.

Ochsner, K., Bunge, S., Gross, J., & Gabrieli, J. (2002). Rethinking feelings: An fMRI

study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience, 14*, 1215 –1229.

Ochsner, K., Ray, R., Cooper, J., Robertson, E., Chopra, S., Gabrieli, J., et al. (2004). For better or for worse: Neural systems supporting the cognitive down and up regulation of negative emotion. *Neuroimage, 23,* 483–499.

Oldfield, R. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*, 97–113.

Olofsson, J., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology, 77,* 247–265.

Olofsson, J., & Polich, J. (2007). Affective visual event-related potentials: Arousal, repetition, and time-on-task. *Biological Psychology, 75,* 101–108.

Parkinson, B., & Totterdell, P. (1999). Classifying affect-regulation strategies. *Cognition and Emotion, 13,* 277–303.

Phan, K., Fitzgerald, D., Nathan, P., Moore, G., Uhde, T., & Tancer, M. (2005). Neural substrates for voluntary suppression of negative affect: A functional magnetic resonance imaging study. *Biological Psychiatry, 57,* 210-219.

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118*, 2128–2148.

Ray, R., Ochsner, K., Cooper, J., Robertson, E., Gabrieli, J., & Gross, J. (2005). Individual differences in trait rumination and the neural systems supporting cognitive reappraisal. *Cognitive, Affective & Behavioral Neuroscience, 5,* 156–168.

Ray, R., McRae, K., Ochsner, K., & Gross, J. (2010). Cognitive reappraisal of negative affect: Converging evidence from EMG and self-report. *Emotion, 10,* 587–592.

Richards, J., & Gross, J. (2000). Emotion regulation and memory: The cognitive costs of keeping one's cool. *Journal of Personality and Social Psychology, 79,* 410–424.

Roseman, I. (2001). A model of appraisal in the emotion system: Integrating theory, research, and applications. In K. Scherer, A. Schorr, & T. Johnstone (Eds.), *Appraisal processes in emotion: Theory, methods, and research* (pp. 68–91). NY: Oxford University Press.

Roseman, I. (1991). Appraisal determinants of discrete emotions. *Cognition and Emotion, 5,* 161–200.

Rusting, C. (1998). Personality, mood, and cognitive processing of emotional information: Three conceptual frameworks. *Psychological Bulletin, 124*, 165–196.

Rusting, C., & Nolen-Hoeksema, S. (1998). Regulating responses to anger: Effects of rumination and distraction on angry mood. *Journal of Personality and Social Psychology, 74*, 790-803.

Schachter, S. & Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review, 69,* 379–399.

Schaefer, S., Jackson, D., Davidson, R., Aguirre, G., Kimberg, D., & Thompson-Schill, S. (2002). Modulation of amygdala activity by the conscious regulation of negative emotion. *Journal of Cognitive Neuroscience, 14,* 913–921.

Scherer, K. (1984). On the nature and function of emotion: A component process approach. In K.R. Scherer & P.E. Ekman (Eds.), *Approaches to emotion* (pp. 293-317). Hillsdale, NJ: Erlbaum.

Scherer, K. (1987). Toward a Dynamic Theory of Emotion: The Component Process Model of Affective States. *Geneva Studies in Emotion and Communication*, 1, 1–98.

Scherer, K. (2004b). Feelings Integrate the Central Representation of Appraisal-Driven Response Organization in Emotion. In A.S.R. Manstead, N.H. Frijda and A.H.Fischer (Eds), *Feelings and Emotions: The Amsterdam Symposium* (pp. 136–57), Cambridge: Cambridge University Press.

Scherer, K. (2005). What are emotions? And how can they be measured? *Social Science Information, 44,* 693 - 727.

Scherer, K. (1999). Appraisal theories. In T. Dalgleish & M. Power (Eds.) *Handbook of cognition and emotion* (pp. 637-63). Chichester, UK: Wiley.

Scherer, K. (2001). Appraisal considered as a process of multi-level sequential checking. In K. Scherer, A. Schorr, & T. Johnstone (Eds.), *Appraisal processes in emotion: Theory, methods, research* (pp. 92–120). NY: Oxford University Press.

Scherer, K., & Ceschi, G. (1997). Lost luggage emotion: A field study of emotion-antecedent appraisal. *Motivation and Emotion, 21,* 211–235.

Scherer, K., Schorr, A., & Johnstone, T. (Eds.). (2001). *Appraisal processes in emotion: Theory, methods, research.* NY: Oxford University Press.

Schmeichel, B. (2007). Attention control, memory updating, and emotion regulation

temporarily reduce the capacity for executive control. *Journal of Experimental Psychology: General, 136*, 241-255.

Schmeichel, B., & Demaree. H. (2010). Working memory capacity and spontaneous emotion regulation: High capacity predicts self-enhancement in response to negative feedback. *Emotion, 10(5),* 739-744.

Schmeichel, B., Volokhov, R., & Demaree, H. (2008). Working memory capacity and the self-regulation of emotional expression and experience. *Journal of Personality and Social Psychology, 95*, 1526-1540.

Schupp, H., Cuthbert, B., Bradley, M., Cacioppo, J., Ito, T., & Lang, P. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology, 37,* 257–261.

Schupp, H., Junghöfer, M., Weike, A., & Hamm, A. (2003a). Attention and emotion: An ERP analysis of facilitated emotional stimulus processing. *Neuroreport, 14*, 1107-1110.

Schupp, H., Junghöfer, M., Weike, A., & Hamm, A. (2003b). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science, 14,* 7–13.

Sheppes, G., Catran, E., & Meiran, N. (2009). Reappraisal (but not distraction) is going to make you seat: Physiological evidence for self control effort. *International Journal of Psychophysiology, 71*, 91-96.

Sheppes, G., & Meiran, N. (2007). Better late than never? On the dynamics of online regulation of sadness using distraction and cognitive reappraisal. *Personality & Social Psychology Bulletin, 33,* 1518–1532.

Sheppes, G., & Meiran, N. (2008). There is no such thing as a free lunch: Divergent

cognitive costs for online reappraisal and distraction. *Emotion, 8,* 870-874.

Smith, E., & DeCoster, J. (2000). Dual-process models in social and cognitive psychology: Conceptual integration and links to underlying memory systems. *Personality and Social Psychology Review, 4,* 108 –131.

Smith, C., & Ellsworth, P. (1985). Patterns of cognitive appraisal in emotion. *Journal of Personality and Social Psychology, 48,* 813 - 838.

Spada, M., Nikčević, A., Moneta, G., & Wells, A. (2008). Metacognition, perceived stress, and negative emotion. *Personality and Individual Differences, 44(5),* 1172-1181.

Stemmler, G. (1997). Selective activation of traits: Boundary conditions for the activation of anger. *Personality and Individual Differences, 22,* 213 – 233.

Thompson, R. (1991). Emotional regulation and emotional development. *Educational Psychology Review, 3,* 269-307.

Thompson, R. (1994). Emotion regulation: A theme in search of definition. In N.A. Fox (Ed.), *The development of emotion regulation: Biological and behavioral considerations. Monographs of the Society for Research in Child Development, 59,* 25-52.

Urry, H. (2009). Using reappraisal to regulate unpleasant emotional episodes: Goals and timing matter. *Emotion, 9,* 782-797.

Van Dillen, L., & Koole, S. (2007). Clearing the mind: A working memory model of distraction from negative emotion. *Emotion, 7,* 715 - 723.

Vohs, K., & Schmeichel, B. (2003). Self-regulation and the extended now: Controlling the self alters the subjective experience of time. *Journal of*

Personality and Social Psychology, 85, 217-230.

Weinberg, A., & Hajcak, G. (2010). Beyond good and evil: Implications of examining electrocortical activity elicited by specific picture content. *Emotion, 10(6),* 767-782.

Wells, A. (1995). Meta-cognition and worry: A cognitive model of generalized anxiety disorder. *Behavioural and Cognitive Psychotherapy, 23,* 301–320.

West, R. (2003). Neural correlates of cognitive control and conflict detection in the Stroop and digit-location tasks. *Neuropsychologia, 41,* 1122–1135.

Wilson, T., & Brekke, N. (1994). Mental contamination and mental correction: Unwanted influences on judgments and evaluations. *Psychological Bulletin, 116*, 117-142.