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The Neurobiological Correlates of Savoring

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ABSTRACT

Personality traits pertaining to positive emotion may be a key factor in deriving vitality from our lives. Positive affectivity refers to one's disposition to experience intense and frequent episodes of positive affect, while savoring capacity refer to one's ability to regulate positive affect. Both traits have been positively associated with happiness, self-esteem, prosocial behaviors, improved health outcomes, as well as attenuated depressive symptomatology and neuroticism. The late positive potential (LPP) is an electroencephalography (EEG) component that is theorized to index a visual cortical/amygdala pathway that is involved in evaluating the affective salience of stimuli. LPP is sensitive to the emotional content of stimuli, as well as how these stimuli are appraised. Research examining the neural time course of affective processing has long utilized the International Affective Picture System (IAPS). The Open Affective Standardized Image Set (OASIS) is an up-to-date and open access stimulus set that may improve upon some shortcomings of the IAPS. Thus, the present study evaluated the following hypotheses: a) enhanced LPP is evoked by positive and negative compared to neutral OASIS images, b) participants' LPP evoked by passively watching positive images will vary based on levels of positive affectivity and c) participants' LPP in response to increasing emotional intensity to positive images will vary based on levels of savoring capacity. As predicted, results showed enhanced LPP in response to positive and negative OASIS stimuli, indicating that the OASIS may be an advantageous replacement stimulus set for the IAPS in future psychophysiological research. However, in the present study, positive affectivity and savoring

capacity did not moderate the relationship between passively viewing positive images/increasing emotional intensity in response to positive images and LPP activity. The present study brings much needed attention to positive emotion and its neurobiological correlates. This work is critical to developing neuroscience-informed clinical interventions for those with psychological and physiological disorders, as well as uncovering the biological implementations of well-being.

CHAPTER ONE

REVIEW OF THE RELEVANT LITERATURE

Positive Affectivity Influences Well-Being

Affective theories of mood and anxiety disorders have posited that low positive affectivity is a

specific risk factor for depression (Clark & Watson, 1991; Kendall et al., 2015; Lewinsohn &

Graf, 1973; Raes, Smets, Nelis, & Schoofs, 2012; Watson et al., 1995) and culprit for

exacerbated course of depressive symptomatology (Clark & Watson, 1991; Davidson, 1998;

Watson, Stasik, Ellickson-Larew, & Stanton, 2015). While high negative affectivity may be a

more general indicator of distress that is observed across depressive and anxiety disorders, as

well as other psychopathology types, positive affectivity reflects a tendency to experience

intense and frequent episodes of pleasant moods (Watson, 2002), such as happiness, interest,

energy, and self-assurance (Mineka, Watson, & Clark, 1998; Watson & Naragon-Gainey, 2010),

and has been associated with increased social activities (Watson & Clark, 1984). Negative

affectivity refers to a tendency to experience negative moods, such as fear, anger, sadness, and

guilt (Mineka et al., 1998) and is often associated with somatic symptoms and increased levels of

psychopathology (Watson & Clark, 1984). Indeed, research has shown that individuals with

depression report reduced mood shifting in response to positive film clips, as well as an

attenuated startle response (theorized to be an indicator of emotional reactivity) to positive and

negative film clips (Kaviani et al., 2004). Positive and negative affectivity are theorized to

represent stable individual differences indicative of one's disposition to experience positive and

negative affect (i.e., transient emotional experiences) respectively. To this extent, positive affectivity and negative affectivity are closely associated with highly stable personality traits such as extraversion and neuroticism, correspondingly (Costa & McCrae, 1980; Warr, Barter, & Brownbridge, 1983). Even major life events that influence well-being and affect only have short-term effects, and there is a tendency to revert back to baseline levels of positive affectivity following these rare events (Suh, Diener, & Fujita, 1996; Watson, 2002). With regard to depression, the frequency of positive life events alone does not appear to modify depression symptoms (Needles & Abramson, 1990). Rather, the relationship between positive events and depression symptomatology is likely modulated by individual differences ranging from cognitive style (Needles & Abramson, 1990) to neurobiological factors (Watson, 2002) that influence the interpretation and/or experience of positive events.

Positive affectivity may be a key variable influencing overall well-being, and strong links have been found between positive affectivity and health (Cohen & Pressman, 2006). In the famous nun study, Danner, Snowdon, & Friesen (2001) demonstrated a strong inverse relationship between positive emotional content written in personal autobiographies (e.g., "emotion sentences" coded for affective states such as happiness, love, gratefulness, etc.) and mortality, above and beyond the influence of negative emotional content. Other studies also indicate that positive affectivity is related to lower rates of strokes among the elderly (Ostir, Markides, Peek, & Goodwin, 2001). Those reporting a greater tendency to experience positive affect also may have increased resilience to the common cold, even after accounting for the effects associated with negative affect (Cohen, Doyle, Turner, Alper, & Skoner, 2003). Research has shown that those suffering from life-threatening disease with decent prospects of survival

(e.g., AIDS, coronary heart disease, early-stage breast cancer) show an association between positive affectivity and improved health outcomes (Pressman & Cohen, 2005). Higher levels of positive affectivity have also been associated with improved sleep quality, more exercise, and lower levels of the stress hormones epinephrine, norepinephrine, and cortisol (Cohen & Pressman, 2006). Additionally, PA has been hypothesized to increase levels of hormones and neurotransmitters, such as oxytocin and growth hormone, as well as endogenous opioids (Pressman & Cohen, 2005). PA also promotes prosocial behavior, empathy, forming closer relationships, and larger social networks (Morelli, Rameson, & Lieberman, 2014; M. Stewart, Craig, MacPherson, & Alexander, 2001), which are factors that positively impact overall health outcomes (Cacioppo et al., 2002; Cohen & Pressman, 2006).

Neural Correlates of Positive Affectivity

Although higher levels of positive affectivity have been implicated in promoting well-being, relatively little research has been dedicated to studying associated neural correlates. Advancing the neuroscientific understanding of state and trait positive affect has the potential to facilitate the development of intervention strategies that promote well-being for individuals with psychological and medical disorders. Research has indicated that individuals self-described as happy tend to exhibit more left prefrontal cortical brain activity during resting state, while those endorsing dysphoria show greater right anterior frontal activity (Davidson, 1992; Tomarken & Keener, 1998). Left prefrontal cortex (LPFC) activity is theorized to be related to the mesolimbic dopaminergic system, which is involved in subjective experiences of positive affect and reward-seeking (Burgdorf & Panksepp, 2006; Depue & Collins, 1999; Depue, Luciana, Arbisi, Collins, & Leon, 1994) and marked by an asymmetric concentration of projections in the left frontal

region. Related, research has indicated that dopaminergic activity is uniquely associated with positive affectivity (Depue et al., 1994).

Research investigating neural responses to affective stimuli using functional magnetic resonance imaging (fMRI) indicates enhanced blood-oxygenation-level-dependent (BOLD) changes predominately in the right occipital cortex (i.e., fusiform cortex, lateral occipital cortex, & medial parietal cortex; Bradley et al., 2003), as well as the amygdala and visual cortex (Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005) in response to affective (pleasant and unpleasant) compared to neutral images. These BOLD signal changes are correlated with emotional arousal ratings of affective stimuli, irrespective of valence. Indeed, the greatest changes in brain activity are observed for highly arousing stimuli, such as mutilations, erotica, and threat, compared to neutral objects (Bradley & Lang, 2007).

Researchers have posited that individuals who self-report higher levels of positive affectivity may gain more pleasure and exhibit more responsivity to positive stimuli (Gross, Sutton, & Ketelaar, 1998; Rusting & Larsen, 1997; Tomarken & Keener, 1998). Previous research investigating the relationship between the personality traits and response to emotional stimuli examined extraversion and neuroticism. Extraversion is defined as a personality trait associated with sociability, warmth, involvement with people, social participation, activity, and contributes to one's enjoyment and satisfaction of life (Costa & McCrae, 1980). Neuroticism is associated with proneness to guilt, anxiety, psychosomatic concerns, worry, and may predispose one to suffer more from one's misfortunes (Costa & McCrae, 1980).

Gross and colleagues (1998) observed a positive relationship between extraversion and increases in state positive affect after viewing a positive film clip. No relationship was found

between extraversion and changes in state negative affect after viewing a negative film clip (Gross et al., 1998). Thus, those reporting higher positive affectivity may be deriving more pleasure from positive stimuli, which is consistent with reports of more frequent and intense episodes from those endorsing higher levels of positive affectivity (Watson, 2002). These results are also in line with the notion that low levels of extraversion and neuroticism do not appear to reduce unpleasantness of adverse circumstances and diminish joy, respectively (Costa & McCrae, 1980). Overall, this suggests that extraversion and neuroticism may have distinct effects on relatively dissociable affective systems.

A study by Canli and colleagues (2001) investigated the relationship between stable personality traits (extraversion and neuroticism) and neural activation in response to positive and negative emotional stimuli. Extraversion scores correlated with brain activation in response to positive (relative to negative) pictures in bilateral cortical (frontal and temporal) and subcortical (e.g., amygdala, dorsal striatum) regions. Neuroticism, on the other hand, correlated with brain activation to negative (relative to positive) images in left temporal and frontal lobes (Canli et al., 2001). No correlations were found between extraversion and neural activation in response to negative (relative to positive) pictures (Canli et al., 2001). This study suggests that personality traits are associated with variability in brain reactivity to emotional stimuli (Canli et al., 2001). Another related study found that left amygdala activation in response to happy faces was positively correlated with extraversion scores (Canli, Sivers, Whitefield, Gotlib, & Gabrieli, 2002). These data are consistent with behavioral accounts demonstrating an association between positive emotional reactivity and extraversion (Gross & John, 1995). Positive affectivity is highly correlated with extraversion (Costa & McCrae, 1980; Warr et al., 1983) and positive

affectivity is also marked by more intense episodes of positive affect (Watson, 2002). Thus, it can be hypothesized that those with higher levels of positive affectivity may exhibit similar neural affective responsivity.

While neuroscience research has identified some key structures associated with positive affectivity, the neural time course of affective processing associated with positive affectivity has yet to be explored. fMRI methodology has advanced the identification of specific subcortical structures involved in emotion, but its low temporal resolution precludes it from being an effective method of measuring neural time course (Kim, Richter, & Uğurbil, 1997). In contrast, electroencephalography (EEG) allows for the analysis of event-related potentials (ERPs) that facilitate assessment of neural responses to affective stimuli with millisecond temporal resolution (Olofsson, Nordin, Sequeira, & Polich, 2008). This is important considering that the rapid processing of emotional stimuli is characteristic of emotional responsivity (Olofsson et al., 2008) and the perception of threatening/arousing events is enabled by a rapid processing pathway that recruits thalamus and amygdala (LeDoux, 2000). Developing a better understanding of the temporal course of ERPs evoked by affective stimuli will advance knowledge regarding affective processing. (Batty & Taylor, 2003; Codispoti, Ferrari, & Bradley, 2007; Schupp, Flaisch, Stockburger, & Junghöfer, 2006; Schupp, Stockburger, et al., 2006; Smith, Dolan, & Rugg, 2004).

Affective neuroscience research utilizing EEG has implicated the late positive potential (LPP), a sustained positive slow wave observed starting as early as 300 ms following stimuli onset, as an established index of evaluative congruency, valence, and arousal in response to visual stimuli (Olofsson et al., 2008). Research has consistently shown that LPP activity over the

centroparietal cortex are augmented in the presence of unpleasant and pleasant compared to neutral images (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Keil et al., 2002; Olofsson et al., 2008; Schupp, Markus, Weike, & Hamm, 2003). LPP activity is most pronounced for images that are rated as highly arousing (Bradley & Lang, 2007). As such, LPP has been theorized to reflect activation of a brain network engaged in processing affective visual stimuli, including subcortical structures, particularly the amygdala (Bradley & Lang, 2007; Cuthbert et al., 2000; Keil et al., 2002; Olofsson et al., 2008; Schupp et al., 2003). Indeed, there is considerable input and output connections connecting the visual cortex to amygdaloid nuclei in primates (Amaral, Price, Pitkanen, & Carmichel, 1992).

LPP is theorized to index a visual cortical/amygdala pathway that is involved in evaluating the affective salience of stimuli (Sabatinelli, Lang, Keil, & Bradley, 2007). Several subcortical structures indirectly contribute to the scalp-recorded LPP component, and the extrastriate occipital, inferior temporal, and medial parietal cortex seem to be critical for the observation of LPP (Sabatinelli et al., 2007). LPP may index early processes associated with the salience network (SN) characterized by functional magnetic resonance imaging (fMRI) research. The SN refers to a network of brain regions of the medial wall of the frontal lobe, such as the anterior cingulate cortex and the presupplementary motor area, and the anterior insula (Beckmann, DeLuca, Devlin, & Smith, 2005; Seeley et al., 2007; Sridharan, Levitin, & Menon, 2008) and is theorized to be important in assessing importance of internal and external stimuli in order to guide behavior (Seeley et al., 2007). Nodes within the SN independently track feelings of pleasure and displeasure, as well as feelings of arousal in response to feelings of happiness, sadness, and fear (Barrett & Satpute, 2013; Wilson-Mendenhall, Barrett, & Barsalou, 2013).

In Cuthbert and colleague's (2000) seminal study of LPP in response to affective stimuli, participants' peripheral physiology and self-reports in response to emotional images were analyzed. One of the main goals of the aforementioned study was to ascertain whether LPPs in response to affective images loaded on the same factors as other established measures of emotional arousal (i.e., affective ratings, facial muscle change, heart rate, & skin conductance). Results indicated LPP activity is enhanced in response to affective images (pleasant and unpleasant) and reduced or absent for neutral stimuli (Cuthbert et al., 2000). Results also indicated a two-factor solution in a principal components analysis, a valence factor and arousal factor. Participant valence ratings, facial muscle change, and heart rate peaks loaded on the valence factor while arousal ratings, average ERP activity (over 400-1000 ms), skin conductance response, interest ratings, and viewing time loaded on a second arousal factor (Cuthbert et al., 2000). In summary, this study showed that LPP activity are selectively augmented in response to arousing emotional images and these activity positively covary with participant reports of emotional arousal (Cuthbert et al., 2000). This finding of LPP being augmented following pleasant and unpleasant versus unpleasant stimuli has been replicated in a number of other studies (Dillon, Cooper, Grent-'t-Jong, Woldorff, & LaBar, 2006; Foti & Hajcak, 2008; Hajcak, Dunning, & Foti, 2007; Hajcak, Moser, & Simons, 2006; Hajcak & Nieuwenhuis, 2006; Hajcak & Olvet, 2008; Moser, Hajcak, Bukay, & Simons, 2006; Schupp et al., 2000, 2003).

Much of the aforementioned research has utilized the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008). The IAPS is a set of color pictures that span a range of semantic categories, and valence/arousal ratings derived from a normative sample are provided for each image. The IAPS was developed to provide a standardized stimulus set of

emotional images to facilitate the comparison of results across different studies, and enhance replication across research groups (Bradley & Lang, 2007). IAPS images are rated with respect to valence (negative-to-positive) and arousal (low-to-high) on a nine-point visual analogue scale. The IAPS has been used in a number of studies investigating neural correlates of affective processing and emotion regulation (e.g., Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006; Hajcak & Olvet, 2008; Keil et al., 2002; Kim & Hamann, 2007; Moser, Hajcak, Bukay, & Simons, 2006; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp, Markus, Weike, & Hamm, 2003).

While the IAPS is one of the most used stimuli sets in behavioral research (Kurdi, Lozano, & Banaji, 2017) and it has advanced affective science, many images in the IAPS are subject to copyright restrictions that preclude their use in online research (Kurdi et al., 2017). Furthermore, the copyright agreement that accompanies the stimuli set states that users cannot place any of the images on computer-accessible websites. This may not have been an issue when the IAPS were created in pre-Internet search times, but this poses considerable restraint on increasing reliance on online samples in behavioral research that make data collection from large and diverse samples faster, less costly, and more efficient (Berinsky, Huber, & Lenz, 2012; Buhrmester, Kwang, & Gosling, 2011; Kraut et al., 2004; Mason & Suri, 2012; Paolacci, Chandler, & Ipeirotis, 2010). Given these advantages, it is hardly surprising that hundreds of online studies are conducted daily, with more and more by the day (Krantz, 2015). Thus, there is an increasing demand for images with standardized valence and arousal ratings for behavioral researchers to use in online contexts. Kurdi, Lazano, and Banaji (2015) heeded this call with the Open Affective Standardized Image Set (OASIS). The OASIS is a collection of 900 high quality

images collected from open-access online sources depicting a range of categories (people, animals, objects, & scenes). The OASIS was normed on valence and arousal ratings collected from a diverse sample recruited through Amazon's Mechanical Turk (Kurdi et al., 2015). To the end of fulfilling Dr. Lang and Dr. Bradley's vision of providing researchers experimental control in the selection of stimuli and facilitating comparison of results and replication across different studies, the present study will utilize OASIS stimuli in lieu of the IAPS.

Replicating previous research on the neural time course of affective processing of emotional stimuli, it is expected that OASIS stimuli that are rated as more emotionally arousing will be associated with enhanced LPP activity for both positive and negative images compared to neutral images. Furthermore, given that a) positive affectivity is associated with greater frequency and intensity of positive affect, b) LPP is an established index of emotional arousal, and c) past research has indicated that neural responsivity to positive affective stimuli is correlated with extraversion, it is expected that higher self-reported positive affectivity will be associated with larger LPP activity in response to positive OASIS stimuli.

Emotion Regulation and Savoring

Healthy emotion regulation abilities are integral to well-being (Gross, 1998b; Gross & Muñoz, 1995; Koole, 2009; Sapolsky, 2007). Emotion regulation generally refers to individuals' attempts to influence their emotional states (Carl, Soskin, Kerns, & Barlow, 2013). Broadly, emotion regulation refers to modulation of positive and negative emotional states that are emotionally arousing (Koole, 2009). This also includes attenuating upsetting, or enhancing positive, aspects of a situation (Gross, 1998a). Poor emotion regulation strategies are associated with reduced social functioning, such as avoidance of close relationships, few positive relationships, and

disinclination to share emotions with others (Gross & John, 2003), as well as lower self-esteem and life satisfaction (Gross, 1998b, 2002; Koole, 2009). Poor emotion regulation is also associated with bullying and victimization among youth (Walcott & Landau, 2004), physical ailments such as hypertension and coronary heart disease (Hinton, Hofmann, Pollack, & Otto, 2009; Jorgensen, Johnson, Kolodziej, & Schreer, 1996), exacerbated cortisol reactivity to stressors (Wirtz et al., 2006), and attenuated cognitive functioning (Gross, 2002; Keenan, 2000).

Gross and Levenson (1993) were among the first to empirically study the influence of emotion regulation on physiological responses. This seminal study found differences in heart rate variability, skin conductance, and finger temperature between participants that suppressed emotional behavior (i.e., participants were instructed, "to behave so that someone watching you would not know that you are feeling anything at all.") in response to neutral and disgusting films and participants that passively watched them. Participants were also asked to indicate their emotional responses to the film by using an inventory consisting of 16 terms (e.g., anger, confusion, happiness, etc.) and rating the greatest amount of each emotion, or affective state, felt during a given film. Despite differences in physiological variability between the suppress and passive watch groups, no differences in self-reported emotion were observed (Gross & Levenson, 1993). This suggests that suppressing negative emotion may result in some reduction of expressive behavior (e.g., facial movement) and physiological arousal, but subjective experience of negatively-valenced stimuli may be no less distressing than if one did not suppress emotion (Gross & Levenson, 1993).

A related study found that participants who used an antecedent-focused emotion regulation strategy (reappraisal) while viewing a negatively-valenced film reported less

subjective negative emotional response than those instructed to use a response-focused emotion regulation strategy (suppression) or passively watch (Gross, 1998a). Reappraisal and suppression strategies successfully led to decreases in behavioral signs of emotion, measured by coding participants' behavioral responses (i.e., facial behavioral and upper body movement) in response to the films, but reappraisal was not associated with elevations in physiological responses (i.e., finger pulse activity, finger temperature, skin conductance, & heart rate). Emotional suppression, on the other hand, led to increases in physiological response on several indices (Gross, 1998a). Overall, results suggest that antecedent-focused emotion regulation strategies are a more effective means of experiencing less negative emotional states and, similar to response-focused strategies, successfully decrease behavioral reactions. This, coupled with augmented physiological responses associated with response-focused strategies, may suggest that antecedent-focused emotion regulation is a more effective, or adaptive, means of regulating one's emotions (Gross, 1998a; Gross & John, 2003). These findings also support the association between adverse health consequences and maladaptive emotion regulation strategies, as habitual suppression of emotion may be correlated with chronically elevated physiological arousal (Gross, 1998a; Hinton et al., 2009; Jorgensen et al., 1996).

While emotion regulation is often associated with decreasing negative emotion, it also pertains to increasing positive emotion, or savoring. Savoring refers to an awareness of positive experiences and the use of positive emotion regulation strategies to enhance and extend positive feelings that are derived from those experiences (Bryant, 2003; Bryant, 1989; Bryant, Chadwick, & Kluwe, 2011; Bryant & Veroff, 2007; Smith & Bryant, 2017). People initiate savoring responses in reaction to a positive event or affect as a way to maintain, intensify, or prolong the

initial positive experience (Bryant & Veroff, 2007). The original conceptual formulation of savoring (Bryant & Veroff, 2007) is predicated on the assumption that people typically initiate savoring responses in reaction to positive events or affect, which people regulate through cognitive or behavioral strategies. Chronically low levels or infrequency of positive affectivity would be expected to reduce savoring responses, which over time would lower self-evaluations of savoring ability. While savoring, one may reminisce about past positive experiences, focus on ongoing positive experiences as they occur, or anticipate the enjoyments of future positive experiences (Bryant & Veroff, 2007). Regardless of the temporal focus, savoring processes regulate positive emotions in the present moment.

Savoring is associated with a number of positive outcomes. Research has indicated that those with a greater capacity to savor possess increased life satisfaction, affective intensity, and self-esteem (Bryant, Chadwick, & Kluwe, 2011). Past research has also revealed that savoring is related to present happiness, total percent of time feeling happy versus sad, extraversion, optimism, and self-esteem. Furthermore, savoring is negatively associated with depression, neuroticism, and hopelessness (Bryant, 2003; Eisner, Johnson, & Carver, 2009; Hou et al., 2016; Ramsey & Gentzler, 2014; Smith & Hollinger-Smith, 2015). A separate study found that savoring the moment is related to higher life satisfaction, subjective happiness, and overall higher levels of positive affect (Hurley & Kwon, 2007). Other research has similarly revealed that savoring was strongly related to higher levels of present happiness, higher self-esteem, and lower reported levels of depression (Bryant, 2003). Furthermore, increased savoring capacity is associated with pain resilience (Thong et al., 2017). In sum, savoring may be a key mechanism in deriving vitality from our lives.

Savoring may have the potential to improve treatment of depression. Common treatments for depression include cognitive behavioral therapy (CBT), antidepressant medication, or a combination of them (Price & Drevets, 2010). Regrettably, 45-65% of those with depression undergoing CBT do not achieve remission (DeRubeis et al., 2005). This leaves considerable room for improvement that may be fulfilled by integrating savoring into treatment. Indeed, greater savoring beliefs are correlated with lower levels of depressive symptoms (Bryant, 2003; Eisner, Johnson, & Carver, 2009; Hou et al., 2016; Ramsey & Gentzler, 2014; Smith & Hollinger-Smith, 2015). A more thorough understanding of the mechanisms of savoring, may pave the way for improving treatments for depression. Intervention studies aimed at enhancing savoring capacity show that enriching any three of the three temporal domains of the savoring (reminiscing, savoring the moment, or anticipating) is associated with greater life satisfaction, increased frequency and intensity of positive affect, and decreased negative affect (for a review, see Smith, Harrison, Kurtz, & Bryant, 2014). Given that savoring is strongly associated with a number of positive outcomes and may improve current treatment methods for mental illness, further research is needed, particularly regarding its neural correlates.

Neural Correlates of Emotion Regulation

A substantial body of research has been dedicated to emotion regulation in an effort to understand its neural correlates. fMRI research has identified specific brain structures implicated in emotion regulation processes. A general pattern of findings from this research is an association between reappraisal of negative emotional stimuli and 1) activation of the dorsal anterior cingulate cortex (ACC) and prefrontal cortex (PFC) systems that are implicated in the selection and use of reappraisal strategies and 2) increases, decreases, or maintenance of activity

in the amygdala or insula that is in accordance with the goal of reappraisal (Beauregard, Lévesque, & Bourgouin, 2001; Lévesque et al., 2003; Ochsner et al., 2004; Ochsner, Bunge, Gross, & Gabrieli, 2002; Phan et al., 2005; Schaefer et al., 2002). For example, Ochsner et al. (2004) analyzed brain structures correlated with reappraisal of negative images (to increase or decrease emotional significance of the image) via fMRI. Both up and down regulation strategies were associated with increased PFC and ACC activity, while amygdala activity increased or decreased in line with the regulatory goal (Ochsner et al., 2004). Another study conducted by Beauregard, Lévesque, and Bourgouin (2001) similarly found that volitional inhibition of emotional arousal in response to erotic stimuli was associated with increased PFC and ACC activity and decreased amygdala activation compared to passively watching viewing stimuli.

Neuroscience research on emotion regulation has almost exclusively focused on negative emotion, with relatively little attention paid to savoring. There are numerous benefits associated with the capacity to increase positive emotion (e.g., Bryant, 2003; Eisner, Johnson, & Carver, 2009; Hou et al., 2016; Ramsey & Gentzler, 2014; Smith, Harrison, Kurtz, & Bryant, 2014; Smith & Hollinger-Smith, 2015). A more refined understanding of its neural correlates will be instrumental in devising neuroscience-informed clinical interventions aimed at increased savoring capacity. One of the few studies that probed the neural correlates of positive emotion regulation examined fMRI BOLD response while participants increased and decreased emotional intensity in response to positive and negative images (Kim & Hamann, 2007). Consistent with previous research, results of the study indicated that volitional emotion regulation modulated amygdala activity in both regulation conditions for positive and negative stimuli compared to watch conditions. More specifically, increasing emotional intensity showed a positive

relationship in activation between the amygdala and structures (e.g., ACC and PFC) implicated in cognitive control. On the other hand, decreasing emotional intensity changed the direction of the relationship, with greater activation of cognitive control regions being related to attenuated amygdala activity (Kim & Hamann, 2007).

The aforementioned studies have focused primarily on identifying specific brain regions involved in emotion regulation, but very little is known about the processing stages, or neural time course, of emotion regulation. The manner in which emotional responses unfold over time are a function of regulatory goals and attentional allocation (Hajcak, Dunning, Foti, & Weinberg, 2007). fMRI gives insight to this process in the form of a static portrait. However, tracking how neural activation unfolds and changes over time is essential in better characterizing the process of emotion regulation and delineating which structures activate concomitantly with reactive and regulatory processes and (Hajcak, Dunning, Foti, et al., 2007). To this end, EEG is an ideal method to use since its measures near-instantaneous activity of cortical activation (Hajcak, Dunning, Foti, et al., 2007)

As previously mentioned, LPP is theorized to index a visual cortical/amygdala pathway that is involved in evaluating the affective salience of stimuli (Sabatinelli, Lang, Keil, & Bradley, 2006). Thus, it could be reasonably hypothesized that the aforementioned fMRI research would translate to modulation of LPP signals dependent on the appraisal of emotional stimuli. Research has supported this claim. One study conducted by Foti & Hajcak (2008) examined changes in LPP activity when negative images were preceded by more or less negative descriptions. When unpleasant pictures were explained more neutrally, resulting LPP activity were reduced compared to unpleasant pictures that were described negatively (Foti & Hajcak, 2008). In a

similar vein, one study compared LPP activity in affective and non-affective appraisal conditions of emotional stimuli. In the non-affective condition, participants were instructed to report the number of people were in each image. During affective conditions, participants rated images as pleasant or unpleasant. Compared to the affective condition, LPP was reliably reduced in the non-affective condition for positive and negative stimuli (Hajcak et al., 2006). Collectively, these studies illustrate that LPP is not only sensitive to the emotional content of stimuli, but also how the stimuli are appraised.

These aforementioned studies have indeed illustrated that LPP activity can be modulated, but what of more deliberate regulation strategies akin to savoring? Moser et al. (2006) asked participants to deliberately suppress or enhance emotional intensity in response to high arousing negative and neutral images. A passive viewing, or "watch" condition was also included. Participants' LPP activity were significantly smaller when suppressing emotional response to negative images compared to passively watching them. A notable finding of this study was that there were no observed differences in LPP between passive watch and enhance conditions. The authors attribute this to a number of factors, one of which was the utilization of only unpleasant images. Using pleasant images, they argue, may produce an augmented LPP in the enhance condition.

In response, Krompinger, Moser, and Simons (2008) analyzed LPP signals in response to increasing and decreasing emotional responses to, as well as passively watching, positive images. Results indicated increased LPP signals in response to passively watching positive stimuli compared to neutral stimuli. Furthermore, LPP signals were attenuated when participants were instructed to suppress emotional response vs. passively watch. However, no significant

differences were found for the enhance condition (Krompinger, Moser, & Simons, 2008). The authors noted several limitations of this experiment, such as a relatively short stimulus duration compared to other studies (500 vs. 2000-6000 ms) that successfully captured emotional enhancement of affective stimuli (Kim & Hamann, 2007; Ochsner et al., 2004). Furthermore, this study did not collect self-report trait data. Considering that past research has found correlations between personality trait measures and neural activation in response to emotional stimuli (Canli et al., 2002; Canli et al., 2001), a trait measure specifically measuring the regulation of positive emotion (i.e., savoring beliefs) may explain additional variance that is not being accounted for. Given the inconsistent findings regarding the enhancement of emotional arousal in response to positive stimuli, further research is warranted.

Moser and colleagues (2006) make the important observation that LPP is affected by intentional regulation strategies and that, "...LPP may also be a viable dependent measure of the interaction between cognitive and affective processing" (Moser et al., 2006). Savoring is a type of emotion regulation, and thus may be related to structures implicated in metacognition (e.g., ACC and PFC). Since a) LPP may be an indicator of this cognitive-affective interaction, b) LPP is an index of emotional arousal, and c) savoring is an emotion regulation strategy associated with increased emotional arousal in response to positive affect/events, it is hypothesized that the relationship between increasing emotional arousal in response to positive images and LPP will be dependent on one's capacity to savor. More specifically, LPP may be modulated when increasing emotional intensity in response to positive stimuli and that this relationship is expected to be moderated by savoring capacity.

The Present Study

Past research utilizing EEG has indicated that higher arousal in response to stimuli yields augmented LPP signals (Cuthbert et al., 2000; Hajcak & Nieuwenhuis, 2006; Schupp et al., 2000; Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011; Tritt, Peterson, Page-Gould, & Inzlicht, 2016) Increasing emotional intensity results in enhanced amygdala activity and structures related to cognitive control (Kim & Hamann, 2007). fMRI research has demonstrated that personality trait ratings (extraversion and neuroticism) correlate with neural responsivity to affective stimuli (Canli et al., 2001; Canli et al., 2002). Given that positive affectivity and extraversion are associated with more positive emotional arousal, it was hypothesized that the relationship between LPP signals and viewing positive stimuli will be dependent upon levels of positive affectivity. LPP is theorized to be indicative of an interaction between amygdala and cognitive control structures (Moser et al., 2006). Furthermore, savoring capacity is positively associated with affect intensity and is indicative of one's ability to bolster positive emotion (Bryant, 2003). Thus, savoring may be related to activation of neural structures associated with cognitive control. Therefore, higher self-report ratings of one's capacity to savor were expected to moderate the relationship between LPP signals and increased emotional intensity in response to positive stimuli. The primary aims and hypotheses of the present study were as follows:

Study Hypotheses.

The present study had two primary objectives. The ***first objective*** of the proposed study was to investigate the relationship between highly arousing affective vs. neutral OASIS stimuli and parietal cortical activity (LPP). It was hypothesized that a) highly arousing positive vs. neutral OASIS stimuli would be associated with greater LPP activity (***Hypothesis 1a***; Figure 1)

and b) highly arousing negative vs. neutral OASIS stimuli would be associated with greater LPP

activity (**Hypothesis 1b**; Figure 1).

Figure 1. Conceptual figure with viewing condition of affective (positive and negative) vs. neutral stimuli as the predictor and LPP activity as the outcome variable.
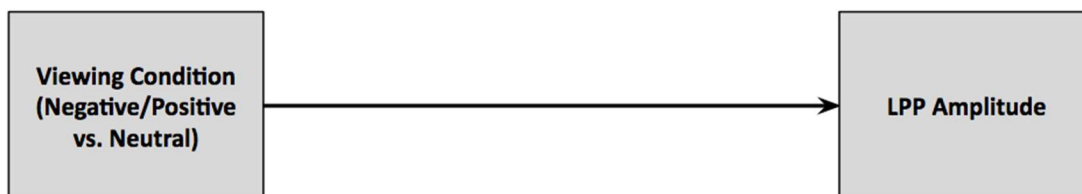
The **second objective** was to examine the relationship between personality traits

pertaining to positive emotion and LPP activity. It was predicted that a) positive affectivity

would moderate the relationship between watching positive images and LPP activity (**Hypothesis**

2a; Figure 2) and b) savoring capacity would moderate the relationship between increasing

emotional intensity in response to positive images and LPP activity (**Hypothesis 2b**; Figure 3).

Figure 2. Conceptual figure with positive affectivity as the moderator of the relationship between passively watching positive stimuli and LPP activity.
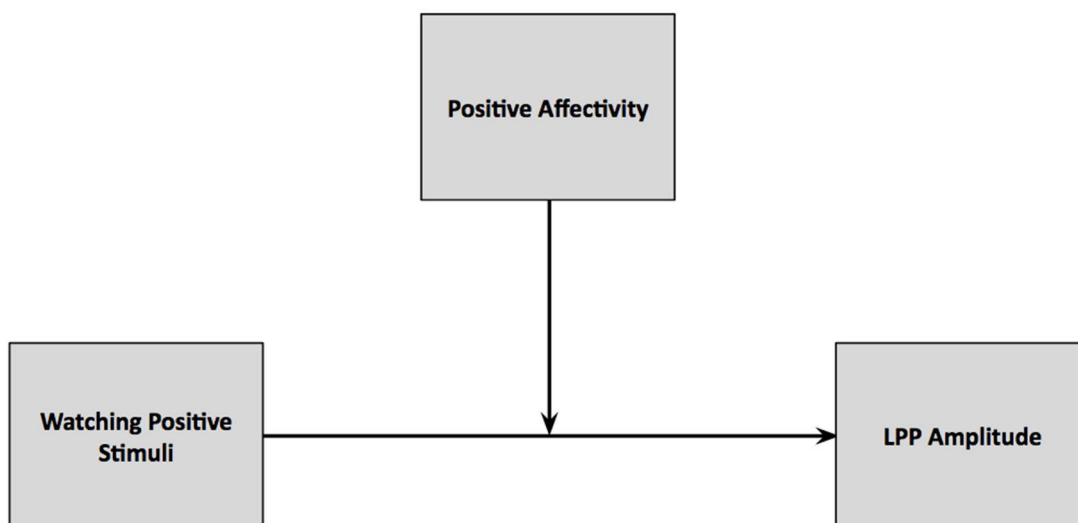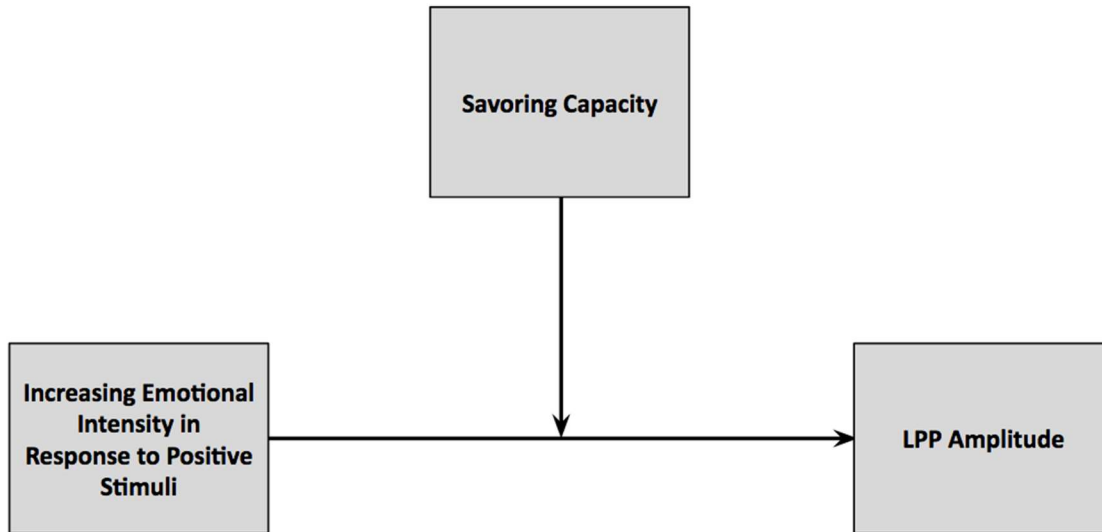
Figure 3. Conceptual figure with savoring capacity as the moderator of the relationship between increasing emotional intensity in response to positive stimuli and LPP activity.

CHAPTER TWO

METHOD

Participants

54 participants were recruited for the study, 48 of which were included in analyses ($n = 27$

women, $n = 2$ non-binary). Six participants were excluded due to insufficient number of valid

EEG task trials. Participants ranged in age from 18-29 ($M = 19.78$ years, $SD = 2.03$). The sample

was 69.6% Caucasian, 17.4% Asian, 2.1% Black or African American, and 8.7% Biracial (2.1%

declined to answer); 10.9% reported that they were Hispanic/Latino and 89.1% were not

Hispanic/Latino. The study was approved by the Institutional Review Board and informed

consent was provided to all participants prior to beginning the experiment.

Materials and Procedure

Participants were asked to complete the trait Positive and Negative Affect Schedule (PANAS;

Watson, Clark, & Tellegen, 1988) to assess for positive affectivity ($\alpha = .86$). At the beginning

and end of the experiment, participants were also asked to complete the state PANAS in order to

assess state affect changes over the course of the experiment ($\alpha = .86$; Watson et al., 1988).

Participants also completed the Savoring Beliefs Inventory (SBI; Bryant, 2009). The SBI

measures the perception of one's ability to feel pleasure through anticipating positive outcomes

($\alpha = .87$), savoring positive moments ($\alpha = .83$), and reminiscing about past positive events ($\alpha =$

.86; Bryant, 2009). Only the momentary savoring subscale was used in the following analyses, as

this temporal domain was most relevant to the present hypotheses and experimental paradigm.

64-channel high-density electroencephalography (EEG) data were recorded while participants viewed seven blocks of 40 images (280 total trials). The study used 120 different Open Affective Standardized Image Set (OASIS) images (Kurdi et al., 2017). 40 of the images were positive, 40 were neutral, and 40 were negative. Previous research has shown that 40 trials is sufficient to evoke a reliable late positive potential (LPP) component (Foti & Hajcak, 2008; Hajcak et al., 2006; Hajcak & Nieuwenhuis, 2006; Hajcak & Olvet, 2008). The mean normative valence ratings (on a scale of one to seven) were 5.71, 4.09, and 2.18 for positive, neutral, and negative pictures, respectively. The mean normative arousal ratings (on a scale of one to seven) were 4.46, 1.99, and 4.52, for positive, neutral, and negative pictures, respectively. Though previous studies have used the IAPS, these means are similar to those reported in other LPP studies (Cuthbert et al., 2000; Foti, Hajcak, & Dien, 2009; Hajcak & Nieuwenhuis, 2006; Keil et al., 2002; Schupp et al., 2003).

Each block represented an experimental regulation condition: increase (positive/negative), decrease (positive/negative), and watch (positive/negative/neutral). During the increase condition, participants were instructed to appraise the picture in a way that will intensify the emotion that is elicited by looking at it. During the decrease condition, participants were asked to reduce the intensity of the emotion that is elicited by looking at the picture. When prompted to watch, participants were asked to view the picture as they would naturally. The passive "watch" blocks served as baseline conditions for LPP component analyses (Hajcak & Nieuwenhuis, 2006). A block design was selected for the proposed study because valenced images outnumber the neutral images two-to-one. The relatively rare neutral stimuli may produce a P3 if intermixed with valenced stimuli in the same block (Schupp et al., 2000).

Additionally, LPP signal is increased for stimuli that are percieved as incongruent within a given affective context. Thus, a neutral stimulus displayed in a series of emotional stimuli would likely evoke an enahnced LPP activity, thus decreasing effect size (Schupp et al., 2000).

First, participants completed three practice trials that consisted of 10 not used during the actual task (Hajcak & Nieuwenhuis, 2006). Particpants were instructed to increase or decrease emotional arousal in response to a mixture of positive and negative images, respectively. Participants were also asked to watch a third practice trial comprised of positive, negative, and neutral images. Stimuli were presented in random order. Prior to each practice trial, participants were provided with instructions on how to regulate (increase/decrease) their affective response to the stimuli, or to simply view the stimuli (Moser et al., 2006). Participants were shown which regulation strategy to engage in (increase, decrease, or watch) at the start of each experimental block. Once the participant was ready, an OASIS stimulus appeared for 2000 ms (Foti et al., 2009; Hajcak & Olvet, 2008). Following stimulus offset, a blank screen appeared for 500 ms followed by a fixation cross for 1500 ms ($\pm$ 250 ms) for a total inter-stimulus interval (ISI) of 1750 - 2250 ms. This interval is identical to other studies utilizing the IAPS and investigating LPP (Dunning & Hajcak, 2009; Hajcak, Dunning, & Foti, 2009). Stimuli within each block were presented in random order. Each block was separated by a break and presented in random order. After each experimental block, valence and arousal ratings were collected using a seven-point likert scale and the same instructions used in Kurdi, Lozano, and Banaji's (2017) norming study of the OASIS stimuli set. Furthermore, difficulty ratings on a seven-point likert scale were also obtained.

Apparatus and Physiological Recording

Scalp EEG was measured while participants completed an emotion regulation task. Participants were seated in a comfortable chair, approximately 24 inches from a 24-inch LCD monitor in a quiet, dimly lit room. Participants were monitored by a task administrator in a nearby room and received task instructions by intercom. EEG data were recorded using a Biosemi Active2 EEG system. A custom-designed Falk Minow 64-channel cap with equidistantly spaced BioSemi active Ag and AgCl electrodes was used for data collection. CMS/DRL was placed near the vertex, and two electrodes were located on the mastoid bones. After placement of the electrode cap, electrode positions were digitized. An additional electrode was placed on the inferior edge of the orbit of each eye to monitor vertical eye movements; nearby electrodes in the cap (lateral to each eye) monitored horizontal eye movements. Data was recorded with a band pass of $0 - 104$ Hz at a sampling rate of 512 Hz.

The following EEG data processing steps were implemented in Brain Electrical Source Analysis software (BESA; Scherg & Berg, 1990). EEG data were re-referenced to the average activity of the mastoid electrodes (Hajcak et al., 2006; Hajcak & Nieuwenhuis, 2006) and digitally filtered with a half-power amplifier bandpass at 0.01–30 Hz, with a cutoff attenuation of 12 dB/octave. Muscle (e.g., eye blink, eye movement) and other artifacts were removed and/or corrected via implementing automatic algorithms in BESA. Stimulus-locked averages were calculated to ascertain LPP. The data were baseline-adjusted by subtracting the average activity for 200 milliseconds (Hajcak et al., 2006) before stimulus onset. LPP activity was calculated as the average activity in the 300 – 800 ms window at Pz, P1, P2 and CPz electrode sites. The scoring window and sites were selected based upon the existing literature as well as visual

inspection of the data to determine where LPP activity was maximal in the present sample. The selected scoring window and electrode sites were similar to other studies investigating LPP in similar contexts (Hajcak et al., 2006; Hajcak & Nieuwenhuis, 2006; Moser et al., 2006).

The experiment was computer-administered, using E-Prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) in order to manipulate the timing and presentation of stimuli. All stimuli were presented in color and occupied the entirety of the 21-inch monitor. The viewing distance was approximately 24 in. and occupied 25°of the vertical visual angle and 30° horizontally (Cuthbert et al., 2000; Hajcak & Nieuwenhuis, 2006).

CHAPTER THREE

RESULTS

Hypothesis Testing

Objective 1.

The first objective of the proposed study was to investigate the relationship between highly arousing affective vs. neutral stimuli from the OASIS and parietal cortical activity (LPP). Data below a skewness statistic of 1.0 were considered normally distributed. No variables of interest violated this threshold. Participants without valid EEG data were excluded from the following analyses ($n = 6$). No other data were missing from variables of interest.

All analyses were run in R version 3.5.0 (R Core Team, 2018). Multilevel modeling (MLM) analyses were conducted using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015). Means and standard deviations of LPP activity and participant ratings (arousal, valence, and difficulty) were calculated for each of the experimental blocks (see Table 1). In order to evaluate whether the experimental blocks varied on arousal and valence, a repeated measures analysis of variance yielded significant variation among image blocks for arousal ($F(6, 270) = 25.02$, $p < .001$) and valence ($F(6, 270) = 80.43$, $p < .001$) ratings. Tukey's HSD test was used to calculate comparisons across all blocks for arousal (see Table 2) and valence (see Table 3) ratings using the psycho package (Makowski, 2018). Pearson correlations were run among psychological and physiological variables across the sample. Significant correlations were found between several variables (see Table 4). Means and standard deviations of between-subjects

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variables (savoring the moment, trait positive affect, and state positive affect) were also derived

(see Table 4).

Table 1. Descriptive Statistics Among LPP Activity and Self-Reported Arousal,
Valence, and Difficulty Ratings for each Image Block

Block	Mean LPP Activity (µv) (SD)	Mean Arousal Rating (SD)	Mean Valence Rating (SD)	Mean Difficulty Rating (SD)
Negative Decrease	3.21(3.10)	3.89(1.37)	2.96(0.99)	3.87(1.69)
Negative Increase	3.61(3.53)	4.74(1.34)	2.57(1.09)	3.24(1.51)
Negative Watch	2.52(3.71)	3.78(1.36)	3.09(0.96)	1.93(0.98)
Neutral Watch	0.31(2.57)	2.46(1.46)	4.07(0.44)	1.80(1.34)
Positive Decrease	1.74(2.72)	2.78(1.15)	4.00(0.70)	3.17(1.64)
Positive Increase	2.29(2.90)	4.17(1.34)	5.46(0.72)	2.67(1.33)
Positive Watch	1.64(3.05)	3.04(1.26)	4.46(0.69)	1.67(1.08)

Table 2. Comparisons among Arousal Rating Means of each Block

Contrast	Difference	*t*	*p*
Negative Decrease – Negative Increase	-0.85	-3.67	.005
Neg Decrease – Negative Watch	0.11	0.47	.999
Negative Decrease – Neutral Watch	1.43	6.20	<.001
Negative Decrease – Positive Decrease	1.11	4.79	<.001
Negative Decrease – Positive Increase	-0.28	-1.22	.885
Negative Decrease – Positive Watch	0.85	3.67	.005
Negative Increase – Negative Watch	0.96	4.14	<.001
Negative Increase – Neutral Watch	2.28	9.87	<.001
Negative Increase – Positive Decrease	1.96	8.46	<.001
Negative Increase – Positive Increase	0.57	2.44	0.185
Negative Increase – Positive Watch	1.70	7.33	<.001
Negative Watch – Neutral Watch	1.33	5.73	<.001
Negative Watch – Positive Decrease	1.00	4.32	<.001
Negative Watch – Positive Increase	-0.39	-1.69	.622
Negative Watch – Positive Watch	0.74	3.20	.026
Neutral Watch – Positive Decrease	-0.33	-1.41	.796
Neutral Watch – Positive Increase	-1.72	-7.43	<.001
Neutral Watch – Positive Watch	-0.59	-2.54	.150
Positive Decrease – Positive Increase	-1.39	-6.02	<.001
Positive Decrease – Positive Watch	-0.26	-1.13	.919
Positive Increase – Positive Watch	1.13	4.89	<.001

Note. Tukey's HSD test used to adjust for multiple comparisons.

Table 3. Comparisons among Valence Rating Means of each Block

Contrast	Difference	t	p
Negative Decrease – Negative Increase	0.39	2.48	0.173
Neg Decrease – Negative Watch	-0.13	-0.83	0.982
Negative Decrease – Neutral Watch	-1.11	-7.01	<.001
Negative Decrease – Positive Decrease	-1.04	-6.6	<.001
Negative Decrease – Positive Increase	-2.5	-15.81	<.001
Negative Decrease – Positive Watch	-1.5	-9.49	<.001
Negative Increase – Negative Watch	-0.52	-3.3	0.019
Negative Increase – Neutral Watch	-1.5	-9.49	<.001
Negative Increase – Positive Decrease	-1.43	-9.08	<.001
Negative Increase – Positive Increase	-2.89	-18.29	<.001
Negative Increase – Positive Watch	-1.89	-11.96	<.001
Negative Watch – Neutral Watch	-0.98	-6.19	<.001
Negative Watch – Positive Decrease	-0.91	-5.78	<.001
Negative Watch – Positive Increase	-2.37	-14.99	<.001
Negative Watch – Positive Watch	-1.37	-8.66	<.001
Neutral Watch – Positive Decrease	0.07	0.41	0.999
Neutral Watch – Positive Increase	-1.39	-8.8	<.001
Neutral Watch – Positive Watch	-0.39	-2.48	0.173
Positive Decrease – Positive Increase	-1.46	-9.21	<.001
Positive Decrease – Positive Watch	-0.46	-2.89	0.063
Positive Increase – Positive Watch	1	6.33	<.001

Note. Tukey's HSD test used to adjust for multiple comparisons.

Table 4. Means, standard deviations, and correlations

Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. PW LPP	1.64	3.05																
2. PW ARO	3.04	1.26	.01															
3. PW VAL	4.46	0.69	-.10	.26														
4. PI LPP	2.29	2.90	.73*	-.03	-.18													
5. PI ARO	4.17	1.34	.04	.51*	.08	-.04												
6. PI VAL	5.46	0.72	.11	.25	.06	.02	.54*											
7. NgW LPP	2.52	3.71	.68*	-.17	.14	.61*	-.12	.17										
8. NgW ARO	3.78	1.36	.04	.21	.20	.02	.18	.06	.12									
9. NgW VAL	3.09	0.96	-.14	.27	.01	-.15	-.08	-.09	-.28	-.51*								
10. NuW LPP	0.31	2.57	.67*	.02	-.10	.47*	-.08	-.06	.40*	.14	-.10							
11. NuW ARO	2.46	1.46	-.00	.53*	-.08	-.07	.24	-.03	-.27	.05	.34*	.10						
12. NuW VAL	4.07	0.44	-.15	.07	.12	-.09	-.32*	-.23	-.12	.24	.30*	-.13	.09					
13. T_PA	31.76	6.55	-.06	.36*	.49*	-.05	.17	.09	-.05	.09	.14	-.14	.21	-.03				
14. S_PA	27.59	7.25	-.12	.46*	.36*	-.14	-.00	.13	-.17	.23	.22	.03	.25	.20	.45*			
15. ANT	5.46	0.97	-.03	.19	.21	.01	.11	.04	-.02	.14	.16	-.03	-.07	.17	.52*	.30*		
16. StM	4.90	1.01	-.22	.24	.09	-.14	.11	.03	-.30*	.17	.14	-.18	.22	.11	.58*	.27	.50*	
17. REM	5.56	0.91	-.05	.31*	.12	.02	.22	.06	-.18	-.07	.31*	-.08	.15	.11	.29	.07	.35*	.62*

Note. * *p* < .05. *M* and *SD* are used to represent mean and standard deviation, respectively. PW = Positive Watch, PI = Positive Increase, NgW = Negative Watch, NuW = Neutral Watch, ARO = Arousal, VAL = Valence, T_PA = Positive Affectivity, S_PA = Positive Affect, ANT = Anticipating, StM = Savoring the Moment, REM = Reminiscing

Before testing primary hypotheses, a null model was run to assess whether the grouping variable (participant) differed on the outcome variable (parietal cortical activity) and to estimate the degree of nonindependence in the sample. An intraclass-correlation indicated that that 56% of the total variance in LPP activity is accounted for by differences between participants' average LPP activity. This necessitates an analytical technique, such as MLM, that accounts for non-independence. Semi-partial R^2 was calculated for model parameters to estimate relative variance explained by each predictor (Edwards, Muller, Wolfinger, Qaqish, & Schabenberger, 2008; Tritt et al., 2016).

Hypotheses 1a & 1b. MLM with variance components covariance matrices to estimate random intercepts and slopes for each participant was used to test whether increased LPP activity is associated with passively viewing highly arousing affective compared to neutral OASIS stimuli. Dummy-coded block (within subjects: neutral watch block as reference level) and mean-centered valence (within subjects) variables were included in the omnibus model to predict LPP activity while accounting for the variance attributed to the how positive or negative participants rated each block. A main effect of block type upon LPP activity was found (positive watch; $b = 1.38$, $SE = .39$, $t(244.96) = 3.52$, $p < .001.$, $R^2 = .03$; negative watch; $b = 2.12$, $SE = .42$, $t(249.05) = 5.10$, $p < .001$, $R^2 = .06$). These findings indicate that passively viewing affective (positive and negative) compared to neutral OASIS images is associated with enhanced LPP activity (see Figure 4).

Figure 4. ERP waveforms averaged across Pz, P1, P2 and CPz electrode sites for negative, positive, and neutral stimuli in the passive viewing block. Bold vertical axes indicate brain activity from 300 to 800 ms.
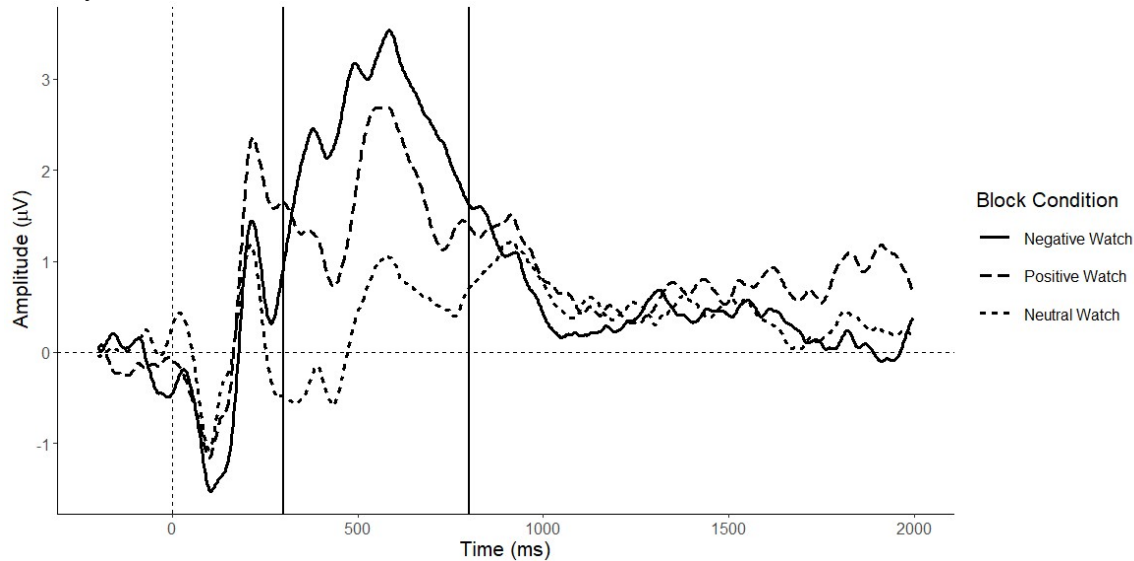

Objective 2.

The second objective was to examine the relationship between personality traits pertaining to positive emotion (i.e., positive affectivity and savoring capacity) and parietal cortical activity.

Hypothesis 2a. MLM with variance components covariance matrices to estimate random intercepts and slopes for each participant was used to test if the relationship between LPP activity and passively viewing positive images versus neutral images varied as a function of trait positive affect. Dummy-coded block (within subjects: neutral watch block as reference level), mean-centered difficulty rating (within subjects), mean-centered trait positive affect (between subjects), and mean-centered state positive affect (between subjects) variables were included in the omnibus model. An interaction term between block and trait positive affect variables was also added to probe for a conditional relationship between block and LPP activity as a function of trait positive affect while accounting for the variance attributed to the how difficult

participants rated each block and their state positive affect. Results did not indicate a significant interaction between viewing condition and positive affectivity in predicting LPP activity ($b =$ 0.03, $SE = .06$, $t(262.81) = 0.50$, $p = .620.$, $R^2 < .01$).

Hypothesis 2b. MLM with variance components covariance matrices to estimate random intercepts and slopes for each participant was used to test if the relationship between parietal cortical activity and increasing emotional intensity in response to positive images versus passively watching positive images (see Figure 5) varied as a function of momentary savoring capacity. Dummy-coded block (within subjects: positive watch block as reference level), mean-centered difficulty rating (within subjects), mean-centered savoring capacity (between subjects), and mean-centered trait positive affect (between subjects) variables were included in the omnibus model. An interaction term between the block and savoring capacity variables was added to probe for a conditional relationship between block and LPP activity as a function of momentary savoring capacity while accounting for the variance attributed to the how difficult participants rated each block and their trait positive affect. Results did not indicate a significant interaction between viewing condition and savoring capacity in predicting LPP activity ($b =$ 0.30, $SE = .39$, $t(262.79) = 0.76$, $p = .445$, $R^2 < .01$).

Figure 5. ERP waveforms averaged across Pz, P1, P2 and CPz electrode sites for positive stimuli in the passive viewing and increase blocks. Bold vertical axes indicate brain activity from 300 to 800 ms.
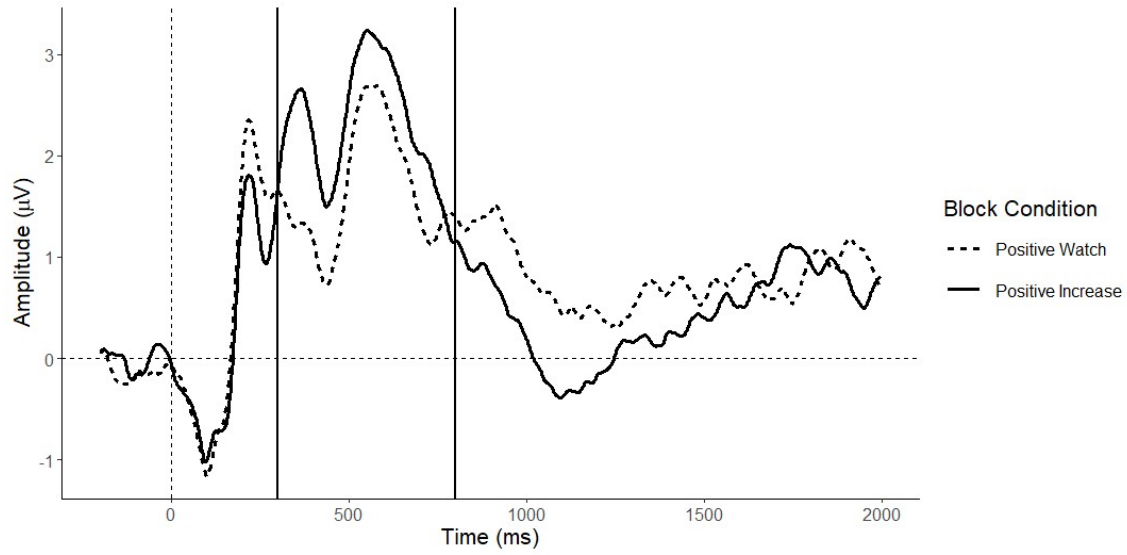
CHAPTER FOUR

DISCUSSION

The present study sought to explore the OASIS as an alternative to the IAPS in psychophysiological research as well the role of personality traits in neural affective processing. This research will help introduce more up-to-date and open access materials in affective neuroscience research and devise neuroscience-informed clinical interventions to enhance positive emotion. We found that, similar to the IAPS, highly arousing positive and negative OASIS stimuli elicited augmented LPP activity. Furthermore, positive affectivity and capacity to savor the moment did not influence the relationship between passively viewing and increasing emotional intensity in response to positive images, respectively.

Results suggest that highly arousing positive and negative images are correlated with enhanced parietal cortical activity. This is a common finding in research investigating the neural time course of affective processing with the IAPS (Cuthbert et al., 2000; Hajcak, Dunning, & Foti, 2007; Hajcak et al., 2009; Krompinger et al., 2008; Moser et al., 2006; Schupp et al., 2000; Tritt et al., 2016). Participant rating scales in the present study indicated that passively viewing positive and negative image blocks were associated with more arousal when compared to neutral images. Passively watching negative images was associated with higher arousal ratings when compared to positive images. Passively viewing negative images was associated with valence scores that were significantly lower than neutral images, yet the difference between positive and neutral images was not significant. This suggests that negatively-valenced stimuli may have

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more profound effects on state manipulations of emotion than positively-valenced stimuli. Notably, these behavioral ratings did not correlate with LPP activity. This may be attributed to the fact that participant ratings likely reflect state manipulations at the end of each block while LPP may reflect arousal and/or valence in response to each image. Overall, these findings lend support to the OASIS image set being used in subsequent psychophysiological studies investigating the neural time course of affective processing. The OASIS also has several advantages over the IAPS. More specifically, it is up-to-date, spans a number of semantic categories, and is open access (Kurdi et al., 2017).

Evidence of conditional relationships between regulating one's emotion in response to affective images and LPP activity as a function of personality traits pertaining to positive emotion was not found. This is a departure from earlier fMRI research investigating correlations between neural activation in response to pleasant stimuli/happy faces and the personality trait of extraversion (Canli et al., 2002; Canli et al., 2001). This discrepancy could be due to different methods. Canli et al. (2001, 2002) utilized fMRI and presented five blocks of four pictures that were presented for 7.5 seconds each while the present study used EEG and utilized seven blocks of 40 image blocks that were presented for two seconds each. fMRI does not have the temporal resolution necessary to analyze timing in the 0 – 3000 ms time window as the present study did. Thus, it is possible that different components were being analyzed in Canli et al. (2001, 2002) and the present study. Furthermore, Canli et al. (2001) limited their sample to only women on the grounds that, "…they are more likely to report intense emotional experiences (Shields, 1991) and because they show more physiological reactivity in concordance with valence judgments than men (Lang, Greenwald, Bradley, & Hamm, 1993)." In contrast, the present study recruited

participants regardless of gender in order produce more generalizable findings. Additionally, different statistical analyses were utilized in the present study compared to those reported in Canli et al. (2002, 2003). Though the language used in Canli et al. (2003) suggests a moderation analysis: "…given that amygdala activation to positive emotional scenes varies *as a function* of this trait…" (p. 1), closer inspection indicates that correlations between z scores for voxels in fMRI slices and personality traits were reported. This technique necessitates multiple statistical tests, inflating type-I error, and is unable to account for variance attributed to other variables. True moderation analyses, as performed in the present study, are tested in a single regression model that allows one to statistically control for effects of other variables.

There are several other noteworthy aspects of the present study. Psychology is in the midst of a "replicability crisis," suggesting that a majority of published findings in the field may be false (Baker, 2015). This is compounded by instances of scientific misconduct (Stroebe, Postmes, & Spears, 2012), unwillingness to share data for re-analyses (Wicherts, Bakker, & Molenaar, 2011), and questionable statistical practices (Simmons, Nelson, & Simonsohn, 2011). It is incumbent upon psychological researchers to resolve these problems. To this end, hypotheses of the present study were preregistered with the Center for Open Science (link: https://osf.io/p5ba9/). Furthermore, all data and R code used for data management, analyses, and ERP visualizations are publicly available so that others may independently replicate reported results. This study is also notable for the analytical technique utilized to test main hypotheses (MLM). MLM improves upon the most commonly used technique in ERP research, repeated measures analysis of variance, in several ways: 1) MLM accepts categorical and continuous predictors, 2) researchers can use partial data in MLM analyses, and 3) more complex models

can be specified using MLM. Lastly, previous studies utilizing affective stimuli and EEG utilized an experimental design that randomly presents images of intermixed valence (positive, negative, and neutral). LPP is sensitive to intrinsic affective properties of stimuli picture *and* the local affective context in which the picture is presented (Schupp et al., 2000). There may be overlap between neural responsivity to incongruency and psychophysiological components of interest related to a behavioral task (e.g., increasing or decreasing emotional intensity) in these randomized designs. This may introduce extraneous variance not germane to the question at hand. The present study rectifies this methodological issue by utilizing a block design where no images were presented in an affectively incongruent context. The present study contributes to the field beyond its findings through its transparency as well as its methodological and statistical rigor.

Despite the strengths and novelty of this experiment, there are limitations. The psychophysiological data collected are cross-sectional and causation cannot be inferred. While we have done our best to adhere to open science principles, software used for EEG reduction is closed source (BESA; Scherg & Berg, 1990). While we are unable to share materials or code that can replicate our data reduction analyses, we have provided step-by-step instructions that were used for data reduction. Lastly, the present study's exclusionary criteria (only recruited participants who were right-handed, not color-blind, and learned English as a first language) and reliance on a convenience sample mostly comprised of Caucasian college students limits ability to generalize findings to a more diverse population. Future research should investigate the neural correlates of positive emotion regulation in more diverse samples. Much research on this topic

(the present study included) relies on convenience samples (e.g., Hajcak & Nieuwenhuis, 2006; Kim & Hamann, 2007; Moser et al., 2006).

Research indicates that past adverse experiences may contribute to one's capacity to savor present events (Croft, Dunn, & Quoidbach, 2014). An interesting future line of inquiry may examine if past experiences predict certain patterns of neural activity in response to emotional stimuli. Additionally, research indicates that psychopathology influences emotion regulation and salience of emotional stimuli (Ehring, Tuschen-Caffier, Schnülle, Fischer, & Gross, 2010; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Hamilton & Gotlib, 2008; Joormann & Gotlib, 2010; Joormann & Vanderlind, 2014). Future research should investigate how depression and anxiety influence neural activity in response to passively viewing and regulating one's emotion in response to affective stimuli.

It may be that the LPP is not capturing the mechanism most relevant to savoring or positive affectivity. Thus, future research should consider utilizing different EEG methods. For example, source analysis is able to identify subcortical neural source generators of EEG activity. Considering that savoring is a form of emotion regulation, it may be related to structures implicated in metacognition, such as the ACC. Another method to consider is time-frequency analysis, which is able to simultaneously measure signals in time and frequency domains. Frontal EEG alpha band frequency asymmetry has been observed at rest in those with depression (Gotlib, 1998; Keune, Bostanov, Hautzinger, & Kotchoubey, 2013; Stewart, Coan, Towers, & Allen, 2011; Thibodeau, Jorgensen, & Kim, 2006), and research has also shown correlations between reductions of frontal alpha band EEG frequency and decreased depression symptomatology (Zotev et al., 2016). Considering that low positive affectivity is theorized to be

a specific risk factor for depression (Clark & Watson, 1991; Kendall et al., 2015; Lewinsohn & Graf, 1973; Raes et al., 2012; Watson et al., 1995) and related to exacerbated depressive symptomatology (Clark & Watson, 1991; Davidson, 1998; Watson et al., 2015), it may be associated with less left frontal EEG alpha-band frequency.

This is one of the first studies to examine the neural time course of affective processing using the OASIS. Results indicate that it is an appropriate replacement for the IAPS. Future researchers would be wise to utilize the OASIS in order to facilitate comparison of results across studies and capitalize on its high quality, open access, and up-to-date stimuli. Results of the present study did not support the hypotheses that positive affectivity and capacity to savor the moment alter the relationship between passively viewing and increasing emotional intensity in response to positive images, respectively. However, future aims have been identified based on these findings, such as examining the role that past experiences/psychopathology play in neural affective processing, recruiting a more diverse sample, and utilizing different EEG methods (e.g., source analysis, time frequency analysis) to study how the neural time course of affective processing interacts with positive affectivity and savoring capacity. The study is limited by its use of cross-sectional data, precluding causal inference, and a sample predominately comprised of Caucasian college students, which limits generalizability of findings. Regardless of these limitations, the present study sets standards for open science practice, statistical analyses, and methods for future research in affective neuroscience. The present study brings attention to the often-neglected study of positive emotion and its neural correlates. Past research on affective processing has overwhelmingly focused on negative emotion. This work is useful for mitigating the effects of unpleasant emotion but may not benefit individuals in need of bolstered levels of

positive emotion. Uncovering the biological implementations of positive emotion will be crucial for developing therapeutic and pharmacological interventions for those suffering from psychological and physiological ailments. It may also bring us a step closer to harnessing the mechanisms of well-being

REFERENCE LIST

Amaral, D. G., Price, J. L., Pitkanen, A., & Carmichel, S. T. (1992). Anatomical organization of the primate amygdaloid complex. In *The amygdala: Neurobiological aspects of emotion, attention, and mental dysfunction* (pp. 1–66). New York: Wiley.

Baker, M. (2015). Over half of psychology studies fail reproducibility test. *Nature News*. https://doi.org/10.1038/nature.2015.18248

Barrett, L. F., & Satpute, A. B. (2013). Large-scale brain networks in affective and social neuroscience: towards an integrative functional architecture of the brain. *Current Opinion in Neurobiology*, *23*(3), 361–372. https://doi.org/10.1016/j.conb.2012.12.012

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Batty, M., & Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Cognitive Brain Research*, *17*(3), 613–620. http://dx.doi.org/10.1016/S0926-6410(03)00174-5

Beauregard, M., Lévesque, J., & Bourgouin, P. (2001). Neural correlates of conscious self-regulation of emotion. *The Journal of Neuroscience*, *21*(18), 6993–7000. http://dx.doi.org/10.1523/JNEUROSCI.21-18-j0001.2001

Beckmann, C. F., DeLuca, M., Devlin, J. T., & Smith, S. M. (2005). Investigations into resting-state connectivity using independent component analysis. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1457), 1001–1013. https://doi.org/10.1098/rstb.2005.1634

Berinsky, A. J., Huber, G. A., & Lenz, G. S. (2012). Evaluating online labor markets for experimental research: Amazon. com's Mechanical Turk. *Political Analysis*, *20*(3), 351–368. http://dx.doi.org/10.1093/pan/mpr057

Bradley, M. M., & Lang, P. J. (2007). The International Affective Picture System (IAPS) in the study of emotion and attention. In *Handbook of Emotion Elicitation and Assessment* (pp. 29–46). New York: Oxford University Press.

Bradley, M. M., Sabatinelli, D., Lang, P. J., Fitzsimmons, J. R., King, W., & Desai, P. (2003). Activation of the visual cortex in motivated attention. *Behavioral Neuroscience*, *117*(2), 369–380. https://doi.org/10.1037/0735-7044.117.2.369

Bryant, F. B. (1989). A four-factor model of perceived control: Avoiding, coping, obtaining, and savoring. *Journal of Personality*, *57*(4), 773–797. http://dx.doi.org/10.1111/j.1467-6494.1989.tb00494.x

Bryant, F. B. (2003). Savoring Beliefs Inventory (SBI): A scale for measuring beliefs about savouring. *Journal of Mental Health*, *12*(2), 175–196. https://doi.org/10.1080/0963823031000103489

Bryant, F. B., Chadwick, E. D., & Kluwe, K. (2011). Understanding the processes that regulate positive emotional experience: Unsolved problems and future directions for theory and research on savoring. *International Journal of Wellbeing*, *1*(1). https://doi.org/10.5502/ijw.v1i1.18

Bryant, F. B., & Veroff, J. (2007). *Savoring: A new model of positive experience.* Mahwah, New Jersey: Lawrence Erlbaum Associates Publishers.

Buhrmester, M., Kwang, T., & Gosling, S. D. (2011). Amazon's mechanical turk: A new source of inexpensive, yet high-quality, data? *Perspectives on Psychological Science*, *6*(1), 3–5. https://doi.org/10.1177/1745691610393980

Burgdorf, J., & Panksepp, J. (2006). The neurobiology of positive emotions. *Neuroscience & Biobehavioral Reviews*, *30*(2), 173–187. https://doi.org/10.1016/j.neubiorev.2005.06.001

Cacioppo, J. T., Hawkley, L. C., Crawford, L. E., Ernst, J. M., Burleson, M. H., Kowalewski, R. B., … Berntson, G. G. (2002). Loneliness and health: Potential mechanisms. *Psychosomatic Medicine*, *64*(3), 407–417. http://dx.doi.org/10.1097/00006842-200205000-00005

Canli, T., Sivers, H., Whitefield, S. L., Gotlib, I. H., & Gabrieli, J. D. E. (2002). Amygdala response to happy faces as a function of extraversion. *Science*, *296*, 2191–2193. http://dx.doi.org/10.1126/science.1068749

Canli, T., Zhao, Z., Desmond, J. E., Kang, E., Gross, J., & Gabrieli, J. D. E. (2001). An fMRI study of personality influences on brain reactivity to emotional stimuli. *Behavioral Neuroscience*, *115*(1), 33–42. https://doi.org/10.1037//0735-7044.115.1.33

Carl, J. R., Soskin, D. P., Kerns, C., & Barlow, D. H. (2013). Positive emotion regulation in emotional disorders: A theoretical review. *Clinical Psychology Review*, *33*(3), 343–360. https://doi.org/10.1016/j.cpr.2013.01.003

Clark, L. A., & Watson, D. (1991). Tripartite model of anxiety and depression: Psychometric evidence and taxonomic implications. *American Psychological Association*, *100(3)*, 316–336. http://dx.doi.org/10.1037/0021-843X.100.3.316

Codispoti, M., Ferrari, V., & Bradley, M. M. (2007). Repetition and event-related potentials: Distinguishing early and late processes in affective picture perception. *Journal of Cognitive Neuroscience*, *19*(4), 577–586. http://dx.doi.org/10.1162/jocn.2007.19.4.577

Cohen, S., Doyle, W. J., Turner, R. B., Alper, C. M., & Skoner, D. P. (2003). Emotional style and susceptibility to the common cold. *Psychosomatic Medicine*, *65*(4), 652–657. https://doi.org/10.1097/01.PSY.0000077508.57784.DA

Cohen, S., & Pressman, S. D. (2006). Positive affect and health. *Current Directions in Psychological Science*, *15*(3), 122–125. https://doi.org/10.1111/j.0963-7214.2006.00420.x

Costa, P. T., & McCrae, R. R. (1980). Influence of extraversion and neuroticism on subjective well-being: Happy and unhappy people. *Journal of Personality and Social Psychology*, *38*(4), 668–678. https://doi.org/10.1037/0022-3514.38.4.668

Croft, A., Dunn, E. W., & Quoidbach, J. (2014). From tribulations to appreciation: Experiencing adversity in the past predicts greater savoring in the present. *Social Psychological and Personality Science*, *5*(5), 511–516. https://doi.org/10.1177/1948550613512510

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P. J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology*, *52*(2), 95–111. http://dx.doi.org/10.1016/S0301-0511(99)00044-7

Danner, D. D., Snowdon, D. A., & Friesen, W. V. (2001). Positive emotions in early life and longevity: Findings from the nun study. *Journal of Personality and Social Psychology*, 80(5), 804-813. 10.1037//0022-3514.80.5.804

Davidson, R. J. (1992). Anterior asymmetry and the nature of emotion. *Brain and Cognition*, *20*, 125–151. https://doi.org/10.1016/0278-2626(92)90065-T

Davidson, R. J. (1998). Affective style and affective disorders: Perspectives from affective neuroscience. *Cognition and Emotion*, *12 (3)*, 307–330. http://dx.doi.org/10.1080/026999398379628

Depue, R. A., & Collins, P. F. (1999). Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences*, *22*(3), 491–517. http://dx.doi.org/10.1017/S0140525X99002046

Depue, R. A., Luciana, M., Arbisi, P., Collins, P., & Leon, A. (1994). Dopamine and the structure of personality: Relation of agonist-induced dopamine activity to positive

emotionality. *Journal of Personality and Social Psychology*, *67*(3), 485–498. https://doi.org/10.1037//0022-3514.67.3.485

DeRubeis, R. J., Hollon, S. D., Amsterdam, J. D., Shelton, R. C., Young, P. R., Salomon, R. M., ... & Gallop, R. (2005). Cognitive therapy vs medications in the treatment of moderate to severe depression. Archives of general psychiatry, 62(4), 409-416. 10.1001/archpsyc.62.4.409

Dillon, D. G., Cooper, J. J., Grent-'t-Jong, T., Woldorff, M. G., & LaBar, K. S. (2006). Dissociation of event-related potentials indexing arousal and semantic cohesion during emotional word encoding. *Brain and Cognition*, *62*(1), 43–57. https://doi.org/10.1016/j.bandc.2006.03.008

Dunning, J. P., & Hajcak, G. (2009). See no evil: Directing visual attention within unpleasant images modulates the electrocortical response. *Psychophysiology*, *46*(1), 28–33. http://dx.doi.org/10.1111/j.1469-8986.2008.00723.x

Edwards, L. J., Muller, K. E., Wolfinger, R. D., Qaqish, B. F., & Schabenberger, O. (2008). An R2 Statistic for fixed effects in the linear mixed model. *Statistics in Medicine*, *27*(29), 6137–6157. https://doi.org/10.1002/sim.3429

Ehring, T., Tuschen-Caffier, B., Schnülle, J., Fischer, S., & Gross, J. J. (2010). Emotion regulation and vulnerability to depression: Spontaneous versus instructed use of emotion suppression and reappraisal. *Emotion*, *10*(4), 563–572. https://doi.org/10.1037/a0019010

Eisner, L. R., Johnson, S. L., & Carver, C. S. (2009). Positive affect regulation in anxiety disorders. *Journal of Anxiety Disorders*, *23*(5), 645–649. https://doi.org/10.1016/j.janxdis.2009.02.001

Foti, D., & Hajcak, G. (2008). Deconstructing reappraisal: Descriptions preceding arousing pictures modulate the subsequent neural response. *Journal of Cognitive Neuroscience*, *20*(6), 977–988. http://dx.doi.org/10.1162/jocn.2008.20066

Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures: Evidence from temporal-spatial PCA. *Psychophysiology*, *46*(3), 521–530. http://dx.doi.org/10.1111/j.1469-8986.2009.00796.x

Gotlib, I. H. (1998). EEG alpha asymmetry, depression, and cognitive functioning. *Cognition & Emotion*, *12*(3), 449–478. https://doi.org/10.1080/026999398379673

Gotlib, I. H., Krasnoperova, E., Yue, D. N., & Joormann, J. (2004). Attentional biases for negative interpersonal stimuli in clinical depression. *Journal of Abnormal Psychology*, *113*(1), 127–135. https://doi.org/10.1037/0021-843X.113.1.121

Gross, J. J. (1998a). Antecedent-and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology*, *74*(1), 224–237. http://dx.doi.org/10.1037/0022-3514.74.1.224

Gross, J. J. (1998b). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2*(3), 271. http://dx.doi.org/10.1037/1089-2680.2.3.271

Gross, J. J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*(3), 281–291. http://dx.doi.org/10.1017/S0048577201393198

Gross, J. J., & John, O. P. (1995). Facets of emotional expressivity: Three self-report factors and their correlates. *Personality and Individual Differences*, *19*, 55–568. http://dx.doi.org/10.1016/0191-8869(95)00055-B

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, *85*(2), 348–362. https://doi.org/10.1037/0022-3514.85.2.348

Gross, J. J., & Levenson, R. W. (1993). Emotional suppression: Physiology, self-report, and expressive behavior. *Journal of Personality and Social Psychology*, *64*(6), 970. http://dx.doi.org/10.1037/0022-3514.64.6.970

Gross, J. J., & Muñoz, R. F. (1995). Emotion regulation and mental health. *Clinical Psychology: Science and Practice*, *2*(2), 151–164. http://dx.doi.org/10.1111/j.1468-2850.1995.tb00036.x

Gross, J. J., Sutton, S. K., & Ketelaar, T. (1998). Relations between affect and personality: Support for the affect-level and affective-reactivity views. *Personality and Social Psychology Bulletin*, *24*(3), 279–288. http://dx.doi.org/10.1177/0146167298243005

Hajcak, G., Dunning, J. P., & Foti, D. (2007). Neural response to emotional pictures is unaffected by concurrent task difficulty: An event-related potential study. *Behavioral Neuroscience*, *121*(6), 1156. http://dx.doi.org/10.1037/0735-7044.121.6.1156

Hajcak, G., Dunning, J. P., & Foti, D. (2009). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology*, *120*(3), 505–510. https://doi.org/10.1016/j.clinph.2008.11.028

Hajcak, G., Dunning, J. P., Foti, D., & Weinberg, A. (2007). Temporal dynamics of emotion regulation. In *Handbook of Emotion Regulation* (2nd ed., pp. 43–57). New York: Guilford Press.

Hajcak, G., Moser, J. S., & Simons, R. F. (2006). Attending to affect: Appraisal strategies modulate the electrocortical response to arousing pictures. *Emotion*, *6*(3), 517. http://dx.doi.org/10.1037/1528-3542.6.3.517

Hajcak, G., & Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective, & Behavioral Neuroscience*, *6*(4), 291–297. http://dx.doi.org/10.3758/CABN.6.4.291

Hajcak, G., & Olvet, D. M. (2008). The persistence of attention to emotion: Brain potentials during and after picture presentation. *Emotion*, *8*(2), 250. http://dx.doi.org/10.1037/1528-3542.8.2.250

Hamilton, J. P., & Gotlib, I. H. (2008). Neural substrates of increased memory sensitivity for negative stimuli in major depression. *Biological Psychiatry*, *63*(12), 1155–1162. https://doi.org/10.1016/j.biopsych.2007.12.015

Hinton, D. E., Hofmann, S. G., Pollack, M. H., & Otto, M. W. (2009). Mechanisms of efficacy of CBT for cambodian refugees with PTSD: Improvement in emotion regulation and orthostatic blood pressure response. *CNS Neuroscience & Therapeutics*, *15*(3), 255–263. https://doi.org/10.1111/j.1755-5949.2009.00100.x

Hou, W. K., Lau, K. M., Ng, S. M., Cheng, A. C. K., Shum, T. C. Y., Cheng, S. T., & Cheung, H. Y. S. (2016). Savoring moderates the association between cancer-specific physical symptoms and depressive symptoms. *Psycho-Oncology*, *26*(2), 231–238. https://doi.org/10.1002/pon.4114

Joormann, J., & Gotlib, I. H. (2010). Emotion regulation in depression: Relation to cognitive inhibition. *Cognition and Emotion*, *24*(2), 281–298. http://dx.doi.org/10.1080/02699930903407948

Joormann, J., & Vanderlind, W. M. (2014). Emotion regulation in depression: The role of biased cognition and reduced cognitive control. *Clinical Psychological Science*, *2*(4), 402–421. https://doi.org/10.1177/2167702614536163

Jorgensen, R. S., Johnson, B. T., Kolodziej, M. E., & Schreer, G. E. (1996). Elevated blood pressure and personality: A meta-analytic review. *Psychological Bulletin*, *120*(2), 293–320. https://doi.org/10.1037//0033-2909.120.2.293

Kaviani, H., Gray, J. A., Checkley, S. A., Raven, P. W., Wilson, G. D., & Kumari, V. (2004). Affective modulation of the startle response in depression: Influence of the severity of depression, anhedonia, and anxiety. *Journal of Affective Disorders*, *83*(1), 21–31. https://doi.org/10.1016/j.jad.2004.04.007

Keenan, K. (2000). Emotion dysregulation as a risk factor for child psychopathology. *Clinical Psychology: Science and Practice*, *7*(4), 418–434. http://dx.doi.org/10.1093/clipsy.7.4.418

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*(5), 641–649. http://dx.doi.org/10.1111/1469-8986.3950641

Kendall, A. D., Zinbarg, R. E., Mineka, S., Bobova, L., Prenoveau, J. M., Revelle, W., & Craske, M. G. (2015). Prospective associations of low positive emotionality with first onsets of depressive and anxiety disorders: Results from a 10-wave latent trait-state modeling study. *Journal of Abnormal Psychology*, *124*(4), 933–943. https://doi.org/10.1037/abn0000105

Keune, P. M., Bostanov, V., Hautzinger, M., & Kotchoubey, B. (2013). Approaching dysphoric mood: State-effects of mindfulness meditation on frontal brain asymmetry. *Biological Psychology*, *93*(1), 105–113. https://doi.org/10.1016/j.biopsycho.2013.01.016

Kim, S. G., Richter, W., & Uğurbil, K. (1997). Limitations of temporal resolution in functional MRI. *Magnetic Resonance in Medicine*, *37*(4), 631–636. http://dx.doi.org/10.1002/mrm.1910370427

Kim, S. H., & Hamann, S. (2007). Neural correlates of positive and negative emotion regulation. *Journal of Cognitive Neuroscience*, *19*(5), 776–798.

Koole, S. L. (2009). The psychology of emotion regulation: An integrative review. *Cognition and Emotion*, *23*(1), 4–41. http://dx.doi.org/10.1080/02699930802619031

Krantz, J. H. (2015). Psychological research on the net. Retrieved October 20, 2017, from https://psych.hanover.edu/research/exponnet.html

Kraut, R., Olson, J., Banaji, M., Bruckman, A., Cohen, J., & Couper, M. (2004). Psychological research online: Report of board of scientific affairs' advisory group on the conduct of research on the internet. *American Psychologist*, *59*(2), 105–117. https://doi.org/10.1037/0003-066X.59.2.105

Krompinger, J. W., Moser, J. S., & Simons, R. F. (2008). Modulations of the electrophysiological response to pleasant stimuli by cognitive reappraisal. *Emotion*, *8*(1), 132–137. https://doi.org/10.1037/1528-3542.8.1.132

Kurdi, B., Lozano, S., & Banaji, M. R. (2017). Introducing the Open Affective Standardized Image Set (OASIS). *Behavior Research Methods*, *49*(2), 457–470. https://doi.org/10.3758/s13428-016-0715-3

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). International Affective Picture System (IAPS): Affective ratings of pictures and instruction manual. *Technical Report A-8*.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, *23*(1), 155–184. http://dx.doi.org/10.1146/annurev.neuro.23.1.155

Lévesque, J., Eugène, F., Joanette, Y., Paquette, V., Mensour, B., Beaudoin, G., … Beauregard, M. (2003). Neural circuitry underlying voluntary suppression of sadness. *Biological Psychiatry*, *53*(6), 502–510. http://dx.doi.org/10.1016/S0006-3223(02)01817-6

Lewinsohn, P. M., & Graf, M. (1973). Pleasant activities and depression. *Journal of Consulting and Clinical Psychology*, *41*(2), 261–268. http://dx.doi.org/10.1037/h0035142

Makowski, D. (2018). The psycho package: An efficient and publishing-oriented workflow for psychological science. *The Journal of Open Source Software*, *3*(22), 470. https://doi.org/10.21105/joss.00470

Mason, W., & Suri, S. (2012). Conducting behavioral research on Amazon's Mechanical Turk. *Behavior Research Methods*, *44*(1), 1–23. https://doi.org/10.3758/s13428-011-0124-6

Mineka, S., Watson, D., & Clark, L. A. (1998). Comorbidity of anxiety and unipolar mood disorders. *Annual Review of Psychology*, *49*(1), 377–412. http://dx.doi.org/10.1146/annurev.psych.49.1.377

Morelli, S. A., Rameson, L. T., & Lieberman, M. D. (2014). The neural components of empathy: Predicting daily prosocial behavior. *Social Cognitive and Affective Neuroscience*, *9*(1), 39–47. https://doi.org/10.1093/scan/nss088

Moser, J. S., Hajcak, G., Bukay, E., & Simons, R. F. (2006). Intentional modulation of emotional responding to unpleasant pictures: An ERP study. *Psychophysiology*, *43*(3), 292–296. https://doi.org/10.1111/j.1469-8986.2006.00402.x

Needles, D. J., & Abramson, L. Y. (1990). Positive life events, attributional style, and hopefulness: Testing a model of recovery from depression. *Journal of Abnormal Psychology*, *99*(2), 156–165. http://dx.doi.org/10.1037/0021-843X.99.2.156

Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. (2002). Rethinking feelings: An FMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience*, *14*(8), 1215–1229. http://dx.doi.org/10.1162/089892902760807212

Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D. E., & Gross, J. J. (2004). For better or for worse: Neural systems supporting the cognitive down- and up-regulation of negative emotion. *NeuroImage*, *23*(2), 483–499. https://doi.org/10.1016/j.neuroimage.2004.06.030

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology*, *77*(3), 247–265. https://doi.org/10.1016/j.biopsycho.2007.11.006

Ostir, G. V., Markides, K. S., Peek, M. K., & Goodwin, J. S. (2001). The association between emotional well-being and the incidence of stroke in older adults. *Psychosomatic Medicine*, *63*(2), 210–215. https://doi.org/10.1097/00006842-200103000-00003

Paolacci, G., Chandler, J., & Ipeirotis, P. G. (2010). Running experiments on amazon mechanical turk. *Judgment and Decision Making*, *5*, 411–419.

Phan, K. L., Fitzgerald, D. A., Nathan, P. J., Moore, G. J., Uhde, T. W., & Tancer, M. E. (2005). Neural substrates for voluntary suppression of negative affect: A functional magnetic resonance imaging study. *Biological Psychiatry*, *57*(3), 210–219. https://doi.org/10.1016/j.biopsych.2004.10.030

Pressman, S. D., & Cohen, S. (2005). Does positive affect influence health? *Psychological Bulletin*, *131*, 925–971. http://dx.doi.org/10.1037/0033-2909.131.6.925

Price, J. L., & Drevets, W. C. (2010). Neurocircuitry of mood disorders. *Neuropsychopharmacology*, 35(1), 192-216. 10.1038/npp.2009.104

R Core Team. (2018). R: A language and environment for statistical computing. (Version 3.5.0). Vienna, Austria: R Foundation for Statistical Computing.

Raes, F., Smets, J., Nelis, S., & Schoofs, H. (2012). Dampening of positive affect prospectively predicts depressive symptoms in non-clinical samples. *Cognition & Emotion*, *26*(1), 75–82. https://doi.org/10.1080/02699931.2011.555474

Ramsey, M. A., & Gentzler, A. L. (2014). Age differences in subjective well-being across adulthood: The roles of savoring and future time perspective. *The International Journal of Aging and Human Development*, *78*(1), 3–22. https://doi.org/10.2190/AG.78.1.b

Rusting, C. L., & Larsen, R. J. (1997). Extraversion, neuroticism, and suceptibility to positive and negative affect: A test of two theoretical models. *Personality and Individual Differences*, *22*, 607–612. https://doi.org/10.1016/S0191-8869(96)00246-2

Sabatinelli, D., Lang, P. J., Keil, A., & Bradley, M. M. (2007). Emotional perception: Correlation of functional MRI and event-related potentials. *Cerebral Cortex*, *17*(5), 1085–1091. https://doi.org/10.1093/cercor/bhl017

Sabatinelli, D., Bradley, M. M., Fitzsimmons, J. R., & Lang, P. J. (2005). Parallel amygdala and inferotemporal activation reflect emotional intensity and fear relevance. *NeuroImage*, *24*(4), 1265–1270. https://doi.org/10.1016/j.neuroimage.2004.12.015

Sapolsky, R. M. (2007). Stress, stress-related disease, and emotional regulation. In *Handbook of emotion regulation*. New York: Guilford Press.

Schaefer, S. M., Jackson, D. C., Davidson, R. J., Aguirre, G. K., Kimberg, D. Y., & Thompson-Schill, S. L. (2002). Modulation of amygdalar activity by the conscious regulation of negative emotion. *Journal of Cognitive Neuroscience*, *14*(6), 913–921. http://dx.doi.org/10.1162/089892902760191135

Scherg, M., & Berg, P. (1990). BESA—Brain electric source analysis handbook. *Munich: Max-Planck Institute for Psychiatry*.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). E-Prime user's guide. Psychology Software Tools Incorporated.

Schupp, H. T., Cuthbert, B. N., Bradley, M. M., Cacioppo, J. T., Ito, T., & Lang, P. J. (2000). Affective picture processing: The late positive potential is modulated by motivational relevance. *Psychophysiology*, *37*(2), 257–261. http://dx.doi.org/10.1111/1469-8986.3720257

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: Event-related brain potential studies. *Progress in Brain Research*, *156*, 31–51. http://dx.doi.org/10.1016/S0079-6123(06)56002-9

Schupp, H. T., Markus, J., Weike, A. I., & Hamm, A. O. (2003). Emotional facilitation of sensory processing in the visual cortex. *Psychological Science*, *14*(1), 7–13. http://dx.doi.org/10.1111/1467-9280.01411

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2006). Stimulus novelty and emotion perception: The near absence of habituation in the visual cortex. *Neuroreport*, *17*(4), 365–369. http://dx.doi.org/10.1097/01.wnr.0000203355.88061.c6

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., … Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *Journal of Neuroscience*, *27*(9), 2349–2356. https://doi.org/10.1523/JNEUROSCI.5587-06.2007

Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2011). False-positive psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science*, *22*(11), 1359–1366. https://doi.org/10.1177/0956797611417632

Smith, A. P., Dolan, R. J., & Rugg, M. D. (2004). Event-related potential correlates of the retrieval of emotional and nonemotional context. *Journal of Cognitive Neuroscience*, *16*(5), 760–775. http://dx.doi.org/10.1162/089892904970816

Smith J.L., Bryant F.B. (2017) Savoring and well-being: Mapping the cognitive-emotional terrain of the happy mind. In Robinson M. & Eid M. (eds) The happy mind: Cognitive contributions to well-being (pp. 139-156). Springer, Cham.

Smith, J. L., Harrison, P. R., Kurtz, J. L., & Bryant, F. B. (2014). Nurturing the capacity to savor: Interventions to enhance the enjoyment of positive experiences. In *The Wiley Blackwell Handbook of Positive Psychological Interventions* (pp. 42–65). John Wiley & Sons. Retrieved from https://doi.org/10.1002/9781118315927.ch3

Smith, J. L., & Hollinger-Smith, L. (2015). Savoring, resilience, and psychological well-being in older adults. *Aging & Mental Health*, *19*(3), 192–200. http://dx.doi.org/10.1080/13607863.2014.986647

Sridharan, D., Levitin, D. J., & Menon, V. (2008). A critical role for the right fronto-insular cortex in switching between central-executive and default-mode networks. *Proceedings of the National Academy of Sciences*, *105*(34), 12569–12574. https://doi.org/10.1073/pnas.0800005105

Stewart, J. L., Coan, J. A., Towers, D. N., & Allen, J. J. B. (2011). Frontal EEG asymmetry during emotional challenge differentiates individuals with and without lifetime major depressive disorder. *Journal of Affective Disorders*, *129*(1–3), 167–174. https://doi.org/10.1016/j.jad.2010.08.029

Stewart, M., Craig, D., MacPherson, K., & Alexander, S. (2001). Promoting positive affect and diminishing loneliness of widowed seniors through a support intervention. *Public Health Nursing*, *18*(1), 54–63. http://dx.doi.org/10.1046/j.1525-1446.2001.00054.x

Stroebe, W., Postmes, T., & Spears, R. (2012). Scientific misconduct and the myth of self-correction in science. *Perspectives on Psychological Science*, *7*(6), 670–688. https://doi.org/10.1177/1745691612460687

Suh, E., Diener, E., & Fujita, F. (1996). Events and subjective well-being: Only recent events matter. *Journal of Personality and Social Psychology*, *70*(5), 1091. http://dx.doi.org/10.1037/0022-3514.70.5.1091

Thibodeau, R., Jorgensen, R. S., & Kim, S. (2006). Depression, anxiety, and resting frontal EEG asymmetry: A meta-analytic review. *Journal of Abnormal Psychology*, *115*(4), 715–729. https://doi.org/10.1037/0021-843X.115.4.715

Thiruchselvam, R., Blechert, J., Sheppes, G., Rydstrom, A., & Gross, J. J. (2011). The temporal dynamics of emotion regulation: An EEG study of distraction and reappraisal. *Biological Psychology*, *87*(1), 84–92. https://doi.org/10.1016/j.biopsycho.2011.02.009

Thong, I. S., Tan, G., & Jensen, M. P. (2017). The buffering role of positive affect on the association between pain intensity and pain related outcomes. *Scandinavian Journal of Pain*, 14, 91-97. 10.1016/j.sjpain.2016.09.008

Tomarken, A. J., & Keener, A. D. (1998). Frontal brain asymmetry and depression: A self-regulatory perspective. *Cognition & Emotion*, *12*(3), 387–420. https://doi.org/10.1080/026999398379655

Tritt, S. M., Peterson, J. B., Page-Gould, E., & Inzlicht, M. (2016). Ideological reactivity: Political conservatism and brain responsivity to emotional and neutral stimuli. *Emotion*, *16*(8), 1172–1185. https://doi.org/10.1037/emo0000150

Walcott, C. M., & Landau, S. (2004). The relation between disinhibition and emotion regulation in boys with attention deficit hyperactivity disorder. *Journal of Clinical Child and Adolescent Psychology*, *33*(4), 772–782. http://dx.doi.org/10.1207/s15374424jccp3304_12

Warr, P. B., Barter, J., & Brownbridge, G. (1983). On the independence of positive and negative affect. *Journal of Personality and Social Psychology*, *44*(3), 644–651. http://dx.doi.org/10.1037/0022-3514.44.3.644

Watson, D. (2009). Positive affectivity. In C. R. Snyder & S. J. Lopez (Eds.), *Oxford Handbook of Positive Psychology* (2nd ed., pp. 106–119). Oxford University Press.

Watson, D., & Clark, L. A. (1984). Negative affectivity: The disposition to experience aversive emotional states. *Psychological Bulletin*, *96*, 465–490. http://dx.doi.org/10.1037/0033-2909.96.3.465

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063. http://dx.doi.org/10.1037/0022-3514.54.6.1063

Watson, D., & Naragon-Gainey, K. (2010). On the specificity of positive emotional dysfunction in psychopathology: Evidence from the mood and anxiety disorders and schizophrenia/schizotypy. *Clinical Psychology Review*, *30*(7), 839–848. https://doi.org/10.1016/j.cpr.2009.11.002

Watson, D., Stasik, S. M., Ellickson-Larew, S., & Stanton, K. (2015). Extraversion and psychopathology: A facet-level analysis. *Journal of Abnormal Psychology*, *124*(2), 432–446. https://doi.org/10.1037/abn0000051

Watson, D., Weber, K., Assenheimer, J. S., Clark, L. A., Strauss, M. E., & McCormick, R. A. (1995). Testing a tripartite model: I. Evaluating the convergent and discriminant validity of anxiety and depression symptom scales. *Journal of Abnormal Psychology*, *104*(1), 3–14. http://dx.doi.org/10.1037/0021-843X.104.1.3

Wicherts, J. M., Bakker, M., & Molenaar, D. (2011). Willingness to share research data is related to the strength of the evidence and the quality of reporting of statistical results. *PLoS ONE*, *6*(11), e26828. https://doi.org/10.1371/journal.pone.0026828

Wilson-Mendenhall, C. D., Barrett, L. F., & Barsalou, L. W. (2013). Neural evidence that human emotions share core affective properties. *Psychological Science*, *24*(6), 947–956. https://doi.org/10.1177/0956797612464242

Wirtz, P. H., von Känel, R., Mohiyeddini, C., Emini, L., Ruedisueli, K., Groessbauer, S., & Ehlert, U. (2006). Low social support and poor emotional regulation are associated with increased stress hormone reactivity to mental stress in systemic hypertension. *The Journal of Clinical Endocrinology & Metabolism*, *91*(10), 3857–3865. https://doi.org/10.1210/jc.2005-2586

Zotev, V., Yuan, H., Misaki, M., Phillips, R., Young, K. D., Feldner, M. T., & Bodurka, J. (2016). Correlation between amygdala BOLD activity and frontal EEG asymmetry

during real-time fMRI neurofeedback training in patients with depression. *NeuroImage: Clinical*, *11*, 224–238. https://doi.org/10.1016/j.nicl.2016.02.003

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