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Attentional Sub-Processes Involved with Emotional Eating

Gregory Denke
gdenke@uno.edu

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Gregory Denke

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Abstract

Emotional eating behavior is characterized by eating a large amount of calorie dense sweet and/or high fat foods in an attempt to control, cope with, or avoid negative emotions. Numerous factors are likely to contribute to emotional eating behavior, including attentional factors, such as rumination and avoidance coping. Rumination based emotional eating (attention focused on negative stimuli while mindlessly eating) is often utilized to improve mood while dwelling on problems. However, for those inclined to escape/avoid troublesome thoughts, another type of emotional-eating pattern may be used. By focusing attention on food, emotional eating is believed to distract individuals from negative emotions. However, along with avoiding distressing thoughts, a strong attentional focus on food may also lead to diminished attention resources and subsequently the missing of self-preserving thoughts (e.g. dietary restraint or satiety). While Denke & Lamm (2015) explored neural mechanisms underlying rumination based emotional eating, to the best of our knowledge, no one has investigated the neural correlates underlying avoidance based emotional eating. This study examined how attentional sub-processes contribute to emotional eating behavior among female participants in a task designed to explore escape type emotional-eating behavior. Dense-array EEG and a version of the canonical attentional blink task were used to ascertain the neural correlates underlying the attentional sub-processes and how attentional activation differs for emotional eaters vs. non-emotional eaters. Findings do not support the food fixation escape type emotional-eater hypothesis, but do indicate task validity.

Emotional-eating, Event Related Potential, Dense Array EEG, Attentional Blink

Introduction

1.1 Prevalence and implications of emotional eating

Eating as a means to deal with the stress associated with negative emotions is a widespread, maladaptive, emotion regulation/coping behavior that is a momentary fix at best and it often leads to additional problems. According to the American Psychological Association's (2014) *Stress in America* survey, 38 percent of adults reported that they had engaged in stress eating within the past month, with 49 percent of them doing it weekly. In general, eating disorders are more prevalent in women than in men (Fairburn & Harrison, 2003; Hudson, Hiripi, Pope, & Kessler, 2007; Woodside et al., 2001), and two studies found binge-eating prevalence was 3.3% among women and .8% among men (Kinzl, Traweger, Trefalt, Mangweth, & Biebl, 1999a; Kinzl et al., 1999b). Striegel-Moore and colleagues (2009) also found women to be significantly more likely than men to report binge eating and a loss of control while eating. Though this behavior is a means to deal with negative emotions, rather than eliminating problems, it typically results in additional distress. Emotional eaters often feel guilty about their eating behavior, sluggish, and feel bad about their physiques immediately after emotional eating episodes (APA, 2014). Additionally, emotional eating can lead to a clinical level of dysfunction, (i.e. binge-eating disorder, BED; Masheb & Grilo, 2006; Stice, Presnell, & Spangler, 2002). While not the focus of the current study, the next section will briefly outline binge-eating disorder and how it relates to emotional eating.

1.1.1 Binge-Eating Disorder

According to the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5), binge-eating disorder (BED) is defined as the recurrence of binge-eating episodes, or a high frequency of binge-eating. A binge-eating episode is characterized by eating a greater amount than most in a discrete amount of time, feeling a loss of control over the binge-eating, and the presence of three of the following criteria. Eating more rapidly than normal, eating until uncomfortably full and feeling self-disgust, eating large quantities of food when not physically hungry and/or eating alone due to embarrassment and/or guilt or depression after binge-eating (APA, 2013). Beyond the presence of a diagnosis, the primary difference between binge-eating and emotional eating appears to be the sense of a loss of control associated with binge eating (Pollert et al., 2013). However, the presence of negative emotions is pervasive in both forms of maladaptive eating behaviors (APA, 2013; Konttinen, Männistö, Sarlio-Lähteenkorva, Silventoinen, & Haukkala, 2010).

There have been numerous studies that have shown binge-eating episodes to be triggered by emotion (Arnow, Kenardy, & Agras, 1995; Chua, Touyz, & Hill, 2004; Elmore & De Castro, 1990; Grange, Gorin, Catley & Stone, 2001; Greeno, Wing, & Shiffman, 2000; Grilo, Shiffman, & Carter-Campbell, 1994; Heatherton & Baumeister, 1991; Masheb et al., 2006; Waters, Hill, & Waller, 2001). Lingswiler and colleagues (1989) found stress and negative moods to be precursors to binge-eating episodes. While, Greeno et al. (2000) found that non-BED women who emotionally eat tend to experience worse mood than non-BED women who do not engage in emotional eating, Chua and colleagues (2004) found an effect of mood on amount of food eaten for obese binge-eaters. Interestingly, negative affect has been found to be an antecedent for binge-eating episodes for obese women with and without BED (Grange et al., 2001). It appears that negative emotions are the primary antecedent for binge-eating behavior for those with clinical diagnoses (i.e. BED) as well as those without. Overconsumption of food to combat negative emotions is maladaptive and may lead to other problems. Though by no means the only route, emotional eating behavior (both within and outside of the context of BED) is a contributing factor for weight gain and obesity (Croker, Cooke, & Wardle, 2011; Geliebter & Aversa, 2003).

1.1.2 Obesity

However, there are numerous factors that cause this unbalanced calorie consumption/calorie use relationship. According to the Centers for Disease Control (CDC, 2012) genes, metabolism, behavior, and environment are all implicated as causes of obesity. Among these factors, emotional eating behavior plays a significant role (CDC, 2012). Emotional eating can foster obesity in a non-clinical manner, by promoting a maladaptive relationship with eating/food, or through progression into the sense of loss of control over the behavior, (i.e. a clinical diagnosis of BED). Indeed, Lowe and Fisher, (1983) found emotional eating to be prevalent among obese participants, while many other studies have also found this connection between emotional eating behavior and obesity (e.g. Ganley, 1989; Hill, Weaver, & Blundell, 1991; Torres & Nowson, 2007). Subsequently, emotional eating behavior is a maladaptive behavior which contributes to the obesity epidemic.

Emotional eating entails a sense of guilt over the eating behavior, it may progress into BED, and it ultimately may contribute to obesity. Given the negative implications that come with this maladaptive behavior, this investigation will address emotional eating. More specifically, the current study will use neurophysiological measures to decompose factors contributing to emotional eating behavior. However, first I am going to describe emotional eating behavior and discuss contributing factors. Second, I will outline a cognitive process that may contribute to emotional eating behavior. Lastly, I am going to explore this cognitive process to investigate what specific neural mechanisms underlie emotional eating behavior.

1.2 Etiology of emotional eating tendencies

Emotional eating is an umbrella term which can be used to describe a variety of eating behaviors. In general, emotional eating is simply eating in the context of feeling either positive or negative emotions (Geliebter et al., 2003; Macht, Haupt, & Salewsky, 2004). However, in terms of dysfunctional eating behavior, most define emotional eating (also known as stress eating) in terms of negative emotions (Konttinen et al., 2010; van Strien & Oosterveld, 2008; Van Strien et al., 2013) with some adding specified food choice to the criteria (Lyman, 1982; Macht, 1999; Macht, Roth, & Ellgring, 2002). Indeed, emotional eaters have been found to eat significantly more in the context of negative emotion compared to positive emotion (Van Strien et al., 2013) regardless of internal state of hunger or satiety (Van Strien, Frijters, Roosen, Knuiman-Hijl, & Defares, 1985). Therefore, for the sake of the current study, I will use the terms emotional eating and stress eating interchangeably and define them as eating a large amount of calorie dense sweet and/or high fat foods in an attempt to control, cope with, or avoid negative emotions. To start I will decompose this definition to explore why emotional eaters prefer these calorie dense foods and why they choose eating as a way to cope with negative emotions.

1.2.1 Food choice

A major part of the problem with emotional eating is the food choices that go along with this behavior. Emotions and food choice interact with each other, with emotional state being manipulated by particular food types, and food choice being influenced by emotional state (Dallman et al., 2003; Gibson, 2006; Pecoraro, Reyes, Gomez, Bhargava, & Dallman, 2004). Emotional eaters are not combating their emotions with carrot sticks and rice cakes. Instead, studies find that emotional eating increases the consumption of sweet and high-fat foods in particular (Gibson, 2006; Macht, 2008; Oliver, Wardle, & Gibson, 2000; Roberts, 2008; Wallis

& Hetherington, 2004). This is a problem because it is these characteristics of the food choice that leaves emotional eaters feeling worse off than before and can lead to obesity. In other words, if emotional eaters chose to eat fruit and vegetables during an episode, it would not lead to feelings of guilt and/or obesity. Various biological and behavioral factors may predispose an individual's emotional eating of energy dense, high-fat and sweet foods. A few key influences in the emotional eating-food choice relationship are outlined.

Refined grains, fats, and sweets are inexpensive and easily obtained, they are energy dense, and they taste good (Putnam, Allshouse, & Kantor, 2002). Moreover, foods that combine sugar and fat (e.g. cookies, cakes, and ice cream) have universal appeal (Drewnowski, 1997; Drewnowski & Greenwood, 1983), due to their ability to quickly increase energy levels (Drewnowski, 2000; Prentice, 1998) and elevate mood (Avena, Rada, & Hoebel, 2009; Drewnowski, Krahn, Demitrack, Nairn, & Gosnell, 1992; Parker, Parker, & Brotchie, 2006; Wurtman, 1987). Nearly everyone has an appreciation for sweet/fatty foods (Yanovski, 2003). However, emotional eaters have learned to pair these foods with negative emotions in an attempt to feel better (Blissett, Haycraft, & Farrow, 2010).

Utilizing the pleasing nature of particular food types in an attempt to modify mood is known as reward-based feeding behavior (Berthoud, 2004). This behavior is influenced through endogenous opioid neuropeptides (Doyle, Berridge, & Gosnell, 1993; Mercer & D Holder, 1997), increased dopamine levels (Hernandez & Hoebel, 1988; Volkow et al., 2002), and cognitive emotional processing within the mesolimbic pathway (Cota, Barrera, & Seeley, 2006; Saper, Chou, & Elmquist, 2002; Zheng & Berthoud, 2007). Importantly, this reward-based feeding that helps drive emotional eating behavior is often motivated by cues that are associated with the food (Cason et al., 2010; Perelló & Zigman, 2012), like negative emotions. However, the tendency to eat when presented with negative emotions is by no means a universal behavior. In fact, while around 40 percent of people increase their consumption during stressful periods, about 20 percent of people do not change their eating behavior, and 40 percent show a decrease in eating (Gibson, 2006). Moreover, this food/emotion relationship is learned, and often it is learned through feeding practices (Blissett et al., 2010; Hurley, Cross, & Hughes, 2011).

1.2.2 Pairing food with emotion

Feeding practices, such as over restriction, using food as reward, or using food to regulate emotions, can lead to emotional eating (Birch & Fisher, 1998; Puhl & Schwartz, 2003; Stifter, Anzman-Frasca, Birch, & Voegtline, 2011) that persists into adulthood (Brunstrom, Mitchell, & Baguley, 2005; Puhl et al., 2003). Interesting, different eating practices may influence maladaptive eating behaviors in unique ways. A food/reward relationship may result from high calorie sweet/fatty foods (e.g. ice cream or cake) being given as rewards for successes, (e.g. good grades or high performance in various activities; Birch, Zimmerman, & Hind, 1980; Benton, 2004). While this pairing teaches an individual that unhealthy food is used for reward, it also introduces an unhealthy food/positive emotion association. This pairing may lead to emotional eating in a tangential manner referred to affect regulation focused coping or eating expectancies (i.e. unhealthy foods may be used to combat negative emotions through increased positive emotions; Hohlstein, Smith, & Atlas, 1998; Simmons, Smith, & Hill, 2002). Conversely, the pairing of food with negative emotions is perhaps a more direct path toward long term emotional eating behavior. Pairing unhealthy food with negative emotions is learned through the direct association of food with negative emotions (Blackburn, Johnston, Blampied, Popp, & Kallen, 2006). For example, when an individual has a bad day at school or work, they may seek out sweet or salty foods to distract them from thinking about their day while also elevating their mood. This avoidance coping behavior teaches that high calorie, sweet/fatty foods, can be utilized to distract from negative thoughts and modulate negative emotions (Paxton & Diggens, 1997). Consequently, both unhealthy food/positive emotion and unhealthy food/negative emotion coupling can lead to maladaptive emotion regulation/coping strategies, (i.e. emotional eating behavior).

1.2.3 Emotion regulation strategy

Emotional eating may improve mood, reduce anxiety, and distract people from negative emotions (Elmore et al., 1990). However, this behavior reflects an inappropriate response to emotional situations (Heatherton, Herman, & Polivy, 1991), or in other words, a deficiency of emotion regulation abilities or coping strategies. The previous section highlighted the pairing of unhealthy foods with either positive or negative emotions as two antecedents for emotional eating behavior. These pairings may lead to at least two different ways of utilizing eating behavior to regulate/cope with negative emotions: 1) rumination (Nolen-Hoeksema, Stice, Wade, & Bohon, 2007; Rawal, Park, & Williams, 2010) and 2) avoidance coping (See Figure 1;

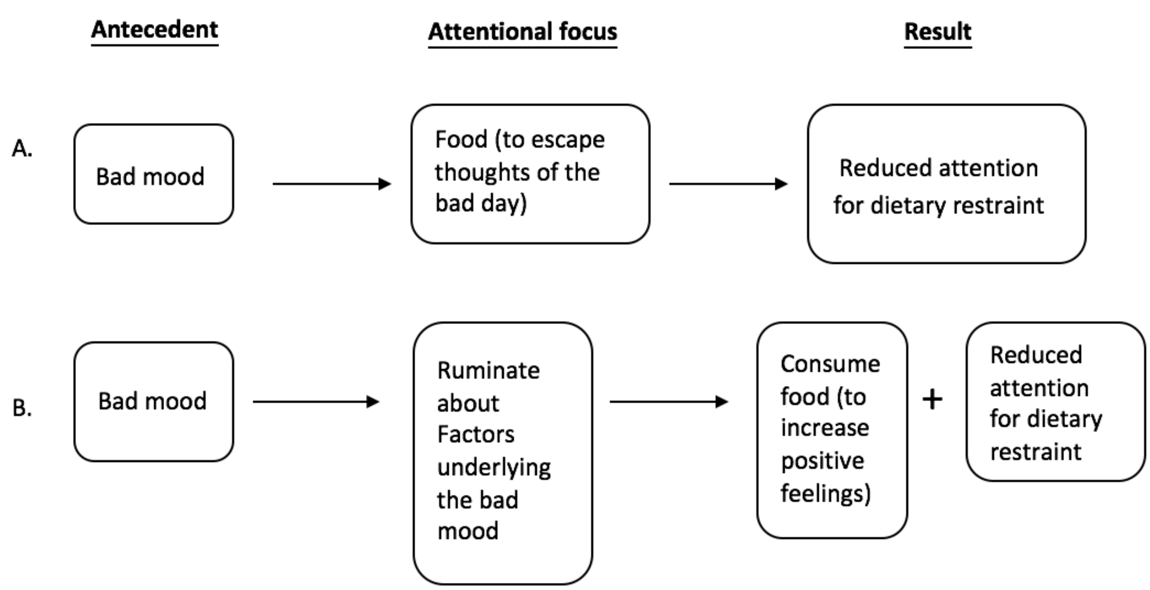

Figure 1: Depiction of escape based emotional-eating (A) and rumination based emotional-eating (B).

Blackburn et al., 2006; Heatherton & Baumeister, 1991; Paxton et al., 1997). Though at opposite ends of the coping style spectrum, rumination and avoidance coping styles have been found to be utilized more frequently by individuals diagnosed with eating disorders when compared to those without eating disorders when faced with negative emotions (Troop, Holbrey, & Treasure, 1998).

Nolen-Hoeksema et al. (2007) found that negative mood induced rumination predicted the onset of binge eating episodes. It may be that this emotional-eating/rumination relationship is based on elevating one's mood while still dwelling on negative subject matter. Wedig and Nock (2010) proposed that emotional eaters overeat in response to negative emotions, because it relieves them from aversive mood states and increases positive emotions (i.e. affect regulation focused coping). Studies have found support for this theory, showing increased eating in normal-weight and obese emotional eaters to be associated with increased positive emotions in the context of negative affect (Macht & Mueller, 2007; Oliver et al., 2000). Additionally, using event related potentials (ERPs), Denke and Lamm (2015) explored the neural basis of negative attention bias in a population of self-described emotional eaters. Specifically, during incorrect trials, they found less P2 activation in emotional-eaters vs. non-emotional eaters following the presentation of negative images. The P2 is associated with attention orienting and this result suggests that emotional-eaters may get attentionally stuck on negative stimuli resulting in inadequate attentional resources for later stimuli. They also found increased N2 activation during negative trials that result in an erroneous response (Denke & Lamm, 2015). N2 activation is associated with cognitive conflict suggesting that when stuck on negative images, emotional-eaters show an increase in cognitive conflict when pertinent new information is presented. Their findings suggest a particular pattern of neural dysregulation may contribute to ruminating type emotional eaters getting attentionally "stuck" on negative stimuli. Given that avoidance coping has also been associated with emotional eating behavior, the current study explores if this emotion regulation strategy shows similar cortical patterns of activation that contribute to emotional eaters getting attentionally stuck on food stimuli.

An escape/avoidance focused coping style (e.g. Aldao, Nolen-Hoeksema, & Schweizer, 2010; Endler & Parker, 1994; Heatherton et al., 1991) may be used, in order to reduce the discomfort associated with negative emotions by avoiding thoughts of them. Endler and colleagues (1994) refer to avoidance coping as escaping from negative emotions by distraction through either social means (e.g. talking with a friend) or by focusing attention on another task (e.g. eating). Indeed, the APA (2014) reported that thirty three percent of adults who report stress eating use it as a way to distract themselves from negative thoughts and feelings. Unfortunately, both of these emotion regulation/coping strategies (rumination/affect regulation focused and escape/avoidance focused) are considered maladaptive; they do not eliminate the negative emotions and often lead to additional distress (Seiffge-Krenke, 2004; Wenzlaff & Wegner, 2000).

These emotion regulation strategies differ in that one attempts to cope with negative emotions by increasing positive emotions while dwelling/ruminating on negativity, while the other attempts to avoid/escape any thoughts of negativity altogether. However, in terms of emotional eating, this is where the differences may end. The target of emotional eating behavior may be distinct for affect regulation focused eaters compared to avoidance/escape focused ones, but the behavior is the same. Whether to increase positive emotions or avoid negative ones, emotional eaters ultimately wind up focusing a large amount of attention on stimuli (negative events or food). Though it may temporarily increase mood, this focused allocation of attention may also interfere with the ability to attend to any other thoughts (i.e. dietary restraint). While the attentional neuromechanisms underlying rumination that contribute to emotional eating behavior have been explored by Denke and Lamm (2015), to the best of our knowledge, no study has unpacked the attentional neuromechanisms underlying avoidance coping and how these contribute to emotional eating behavior. In line with the Denke and Lamm (2015) study, the current study will use ERPs to unpack the attentional mechanisms underlying avoidance coping and explore if emotional eaters apply these mechanisms differently than non-emotional eaters.

1.3 Avoidance Coping and Cognitive Narrowing

Given that a negative emotional state has been implicated as a primary trigger for emotional eating episodes (Waters et al., 2001), often interfering with cognitive control over eating behavior (Engelberg, Steiger, Gauvin, & Wonderlich, 2007), it may be that emotional eating results in part from an attempt to improve or avoid negative feelings. Heatherton and colleagues (1991) explored the phenomena, cognitive narrowing, which is used by emotional eaters as an attentional escape from emotional distress. Used to eliminate upsetting thoughts from consciousness and improve mood, cognitive narrowing refers to focused attention on the immediate present. Narrowing attention disengages normal inhibitions against eating by focusing exclusively on one stimulus (Heatherton et al., 1991). Thus, in the context of negative emotion, emotional eaters may focus solely on food (cognitive narrowing) to improve their mood and/or avoid thinking about negative events. However, this cognitive narrowing may also prevent individuals from thinking about their ongoing dietary restraint plans thereby facilitating emotional eating episodes.

1.3.1 Attention mechanisms involved with cognitive narrowing

Understanding how narrowing attention onto food stimuli to cope with negative events may be the key to understanding emotional eating behavior. However, since overall attentional processing is comprised of numerous attentional sub-processes, it may be that only some attentional sub-processes are dysfunctional in the context of emotional eating behavior. While it is well known that overarching attentional processes, such as cognitive narrowing, contribute to emotional eating behavior (e.g., Heatherton et al., 1991), to the best of our knowledge, the specific attentional sub-processes underlying these attentional biases that contribute to avoidance coping have not been explored. The current study used ERPs to characterize the sub-processes of attention to decompose the mechanistic chronology underlying attentional deficits contributing to avoidance copying and thus emotional-eating behavior. Specifically, I explored three attentional ERPs, the P2, N2, and P3, that have been associated with three corresponding attentional sub-processes: orientating, executive control, and the processing of stimuli in working memory (Baddeley, 1992; Engle, 2002; Posner et al., 1971). These ERPs were measured in the context of a task that requires attentional control. The current task is a modified version of the task used by Denke and Lamm (2015). In the task used by Denke and Lamm (2015), participants were presented a string of emotionally salient negative images or relatively neutral images and required to “search” for a key stimulus, thus applying attentional control in either negative or neutral contexts. That task was thought to emulate our ability to apply attentional control while focusing our attention on negative events, i.e., ruminating. The current task is similar to the Denke and Lamm (2015) task in that it presents participants with a string of images, specifically, images designed to induce sad emotions. However, this task also presents participants with images of delicious looking food or similarly shaped and colored neutral (non-food) images. Thus, I explore if emotional eaters vs. non-emotional eaters differ in how they allocate their attentional resources to food images and how this differential allocation impacts downstream attentional resources. This task has been designed to emulate avoidance coping by presenting food images and exploring how these impact downstream attentional resources. In line with the Denke and Lamm (2015) study, I will outline how the P2, N2, and P3 might contribute to emotional eating behavior.

1.3.1a Attention orienting (P2)

Orientating is the act of directing attention toward a particular stimulus (Posner et al., 1971) and it has been found to correspond to activation in the intraparietal cortex and superior frontal cortex (Corbetta & Shulman, 2002). The P2, an ERP evoked around 200 ms after stimulus onset, has been linked with attentional orienting (e.g., Huang & Luo, 2006), with increased P2 activation representing increased attentional orientating (Kanske, Plitschka, & Kotz, 2011). Kranczioch, Debener, and Engel (2003) found P2 activation at frontal and central midline areas with the greatest activation found at the frontal midline area. Furthermore, Denke and Lamm (2015) found decreased P2 activation among emotional-eaters for target stimuli that followed negative stimuli. This was believed to be the result of attention sticking to the negative stimuli causing a reduction in orienting ability. In the context of emotional eating as a means to avoid negative emotions, individuals would orient toward food stimuli, away from negative stimuli. Therefore, increased P2 activation for food stimuli and decreased P2 activation for subsequent stimuli, in the context of predominant negative stimuli, may be a key factor for emotional eating behavior.

1.3.1b Executive control of attention (N2)

The executive control of attention may be an error detection and correction mechanism triggered in the context of cognitive conflict and has been associated with anterior cingulate cortex activation (Bush, Luu, & Posner, 2000; Fan et al., 2005), a brain region routinely associated with conflict monitoring (Kerns et al., 2004). This attentional sub-process may be measured by examining N2 activation, a mediofrontal ERP component peaking roughly 200-400 ms after stimulus onset, since this ERP component has been shown to reflect conflict monitoring (Donkers & van Boxtel, 2004). Furthermore, the N2 seems to evoke emotional information processing (Lamm, Pine, & Fox, 2013; Lamm, White, McDermott, & Fox, 2012; Lewis et al., 2006). Lewis and colleagues (2006) found emotion-related changes in N2 activation within a go/no-go task designed to induce negative emotion. Additionally, Lamm, White, McDermott, and Fox (2012) found greater N2 activation in response to emotional stimuli in comparison to neutral stimuli. Thus, N2 activation is increased in the context of negative emotion/negative events. Forestell, Dickter, and Young, (2012) and Dickter, Forestell, Hammett, and Young (2014) used EEG ERPs to explore alcohol, rather than food, as a means of escaping negative mood. They found an increase in N2 activation in escape drinkers vs. non-escape drinkers when viewing images of people drinking alcohol. Their findings, that escape drinking was associated with attentional biases to active alcohol cues during attention processing, support the notion that the type of stimuli (e.g. alcohol or food) used to escape negativity, will cause a detectable neural attention bias. Additionally, Denke and Lamm (2015) also found an increase in N2 activation for emotional-eaters vs. non-emotional eaters in erroneous trials containing negative images. Because N2 activation represents neural resources recruited to modulate cognitive conflict and is influenced by emotional stimuli, emotional eaters may focus excessive attentional neural resources on one event (food stimuli) and are not able to recruit enough N2 activation to facilitate cognitive awareness of subsequent events. Thus, insufficient N2 activation may contribute to emotional eating behavior.

1.3.1c Stimuli processing in working memory (P3)

The last ERP component that was examined was the P3, which has been associated with information processing (e.g., Kranczioch, Debener & Engel, 2003), and thus may be a neural marker of affective attentional processing. The P3 is the largest cognitive ERP, peaks at roughly 300 ms after stimulus onset, reaches maximum amplitude at central-parietal midline sites, and is generally evoked by infrequent occurring stimuli (Pritchard, 1981). This component has been linked with processing of information in working memory and reduced P3 activation may be a marker of information not making it to working memory (Kranczioch et al., 2003). Detected stimuli have been found to show an enhanced P3 while missed stimuli show little or no P3 (Kranczioch et al., 2003; Ritter & Vaughn, 1969). Hillyard, Squires, Bauer, and Lindsay (1971) found a relationship between P3 amplitude and stimuli detection accuracy. More specifically, larger P3 amplitudes corresponded with increased likelihood that stimuli would be accurately detected. Furthermore, Hillyard, Hink, Schwent, and Picton (1973) found that when attention is highly focused on a particular task, additional stimuli that would usually elicit a P3 do not elicit a response. For emotional eaters, a small P3 may indicate ineffective stimulus processing in working memory. Therefore, in the context of negative emotion, emotional eaters may focus their attention on the food stimuli in order to cope with the negative stimuli. Consequently, they may not process additional stimulus information effectively in working memory, and this would lead to attentional unawareness.

1.4 Attentional blink

In this study, I examined the sub-processes of attention that contribute to emotional eating behavior in the context of a task that allows for the measurement of neural activation both when salient cues are encoded and missed. When an individual focuses a large amount of their attentional resources on a particular item, there is an increased likelihood that a subsequent item will not be recognized (Raymond, Shapiro, & Arnell, 1992). This phenomenon, referred to as an attentional blink, is believed to be the result of using a large amount of attentional resources for the processing of one stimulus, resulting in an inadequate amount of resources left to process a subsequent stimulus. An attentional blink can be reliably measured using a standard rapid serial visual presentation (RSVP) task (Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Raymond et al., 1992; Shapiro, Raymond, & Arnell, 1997; Vogel, Luck, & Shapiro, 1998). Thus, I utilized an RSVP task to elicit an attentional blink to explore cognitive narrowing as a means to cope with negative emotion.

In short, emotional eating behavior may occur because of attentional deficits brought about by cognitive narrowing-induced attentional blinks. It is important to note, that in this study, I used a laboratory environment to emulate real-world emotion induced cognitive narrowing leading to attentional blinks. While this is a useful approach to decomposing the attentional mechanisms contributing to emotional eating behavior, it is likely not as salient as real-world emotions. Thus, the current project likely has a much smaller temporal scale than might be found for real world emotion-induced eating. In the next section, I depict specific hypotheses for each attentional sub-process and the corresponding ERP component.

1.5 Hypotheses

This task used food and neutral images to ascertain if food images, embedded within streams of sad images, would differentially affect attentional sub-processes for emotional eaters compared to non-emotional eaters. Subsequently, compared with neutral images, food images were expected to affect the attentional sub-processes of emotional eaters differently than non-emotional eaters. Moreover, since we had two overarching questions, we structured the hypotheses section into two subsections. The two overarching questions were: 1) how does each of the attentional sub-process ERP activation contribute to accurate vs. inaccurate responding (Accuracy differences), and 2) how do emotional eaters differ from non-emotional eaters (Group differences), in the amount of neural resources required for effective attentional processing and in behavioral performance in an emotional context. Therefore, the two subsections are: Accuracy (dependent variables being ERPs) and Group differences (dependent variables being ERPs and performance accuracy). Furthermore, within each subsection, we outline specific hypotheses for each ERP component.

1.5.1 Accurate vs. inaccurate responding

1.51.a Accuracy (P2). An increase in P2 activation has been linked with effective orientating (Delplanque, Lavoie, Hot, Silvert, & Sequeira, 2004). In an attentional blink task, Denke and Lamm (2015) found a decrease in P2 activation for stimuli that were not detected, compared to those that were detected, in both neutral and negative trials. In the context of the attentional blink paradigm, P2 activation represents the neural activation underlying attentional orientation or lack of attentional orientation toward stimuli. In other words, are there sufficient attentional resources available to orient attention away from food stimuli and towards subsequent stimuli or have attentional resources been maxed out by the food stimuli? Based on this argument, we expected increased P2 activation for subsequent stimuli for accurate trials compared to inaccurate trials (blinked trials), in both the sad and neutral conditions.

1.5.1.b Accuracy (N2). N2 activation has been shown to increase as more cognitive resources are recruited (Van Veen & Carter, 2002). Denke and Lamm (2015) found increased (more negative) N2 activation for incorrect T2 detection trials, when compared with correct T2 detection trials in negative and neutral trials. Therefore, in general, we expected increased activation for more challenging trials. In the context of the attentional blink paradigm, N2 activation represents the attentional conflict between two competing stimuli (i.e., the food stimuli and subsequent stimuli). Namely, do attentional resources allocated to the food stimuli override subsequent stimuli or are attentional resources sufficient to allow for the subsequent stimuli to be noticed? Based on this argument, we predicted increased N2 activation for the subsequent stimuli, in inaccurate trials, when compared with accurate trials (i.e., blinked trials), for both neutral and sad conditions.

1.5.1.c Accuracy (P3). P3 activation is linked with the processing of information in working memory, with increased activation for detected stimuli and little or no P3 for missed stimuli (Ritter et al., 1969). In the context of the attentional blink paradigm, P3 activation represents subsequent information making it into working memory and thus allowing it to be noticed, or does the attention allotted toward food stimuli cause subsequent stimuli to be missed? Using an attentional blink paradigm, Denke and Lamm (2015) found increased P3 activation for correct T2 detection trials, when compared with incorrect T2 detection trials, in both neutral and negative conditions. Based on this argument, we expected increased P3 activation for stimuli following the neutral and food images, in accurate trials, when compared with inaccurate trials (i.e., blinked trials), for both sad and neutral conditions.

1.5.2 Group

1.5.2.a Group (P2). As outlined by Heatherton et al. (1991), emotional eaters show attentional narrowing in the context of negative events. Additionally, emotional eating behavior has been associated with an attempt to avoid/escape from negative emotions (Aldao et al., 2010; Endler et al., 1994; Heatherton et al., 1991). Thus, in the context of negative emotion, emotional eaters may have difficulty orienting away from their chosen escape stimuli (i.e., food) and towards subsequent events. Similarly, Denke and Lamm (2015) found trend level group difference for incorrect T2 detection trials in the negative condition, with emotional-eaters showing decreased

P2 activation compared to non-emotional eaters. Therefore, in trials with food stimuli, we expected emotional eaters to show decreased P2 activation for subsequent stimuli, compared to non-emotional eaters, and consequently show decreased performance accuracy in these trials.

1.5.2.b Group (N2). If emotional eaters have difficulty orienting away from food stimuli (i.e., escape mechanism) when in an environment filled with negative stimuli (see P2 hypothesis), they may experience attentional conflict between focusing on the food stimuli and focusing on subsequent stimuli. This increased conflict might contribute to inaccurate responding. Indeed, Denke and Lamm (2015) found more N2 activation for emotional-eaters than non-emotional eaters in negative erroneous trials. Therefore, along with decreased performance accuracy, we predicted increased (i.e., more negative) N2 activation for emotional eaters compared to non-emotional eaters for blinked food trials.

1.5.2.c Group (P3). Because in the context of negative emotion, emotional eaters may be affected more by food stimuli than non-emotional eaters (Bohon, Stice, & Spoor, 2009) preventing them from orienting away from food stimuli (see P2 hypothesis) and increasing the amount of attentional conflict resources used (see N2 hypothesis), it may be that emotional eaters have difficulty processing subsequent information in working memory leading to inaccurate responding. Therefore, we expected emotional eaters to show decreased P3 activation for subsequent stimuli, compared to non-emotional eaters, for food trials that are blinked. This decrease in activation was also predicted to manifest as a decrease in performance accuracy.

Method

2.1 Participants

Participants were female undergraduate students (N = 62) who attended the University of New Orleans. From this group, 29 participants were found to be non-emotional eaters (mean age 23) and 33 were found to be emotional eaters (mean age 21). Thirteen participants who did not have sufficient number of trials to generate an ERP, due to artifacts or poor performance, were excluded from the analysis (N = 49). Excluded participants did not significantly differ from included participants in emotional eating behavior, $\chi^2(1, N = 62) = 3.33$, $p = .07$, racial category, $\chi^2(2, N = 62) = 3.52$, $p = .17$, age, $t(60) = 1.03$, $p = .49$, or days since their last period, $t(49) = -1.28$, $p = .37$. All participants had normal or corrected-to-normal vision, a hair style that was conducive to EEG data collection procedures, and were free of current psychiatric diagnoses. Additionally, participants completed pre-screening questionnaires to access their level of emotional eating behavior. Participants who were found to have emotional eating tendencies (i.e. those with a mean score 1SD above 2.31 which was 2.97 on prescreening questionnaires; threshold value determined by a previous Denke & Lamm, 2015 study) and those not showing such tendencies (i.e. those with a mean score 1SD below 2.31 which was 1.65 on prescreening questionnaires) were asked to further participate in the lab portion of the study. Participants were recruited through undergraduate classes and earned course credit for their participation. This study received IRB approval from the University of New Orleans.

2.2 Measures

<u>2.2.1 Emotional eating behavior.</u> An emotional eating behavior composite score (established during prescreening) was generated for each participant by averaging the standardized scores for the Dutch Eating Behavior Questionnaire (DEBQ) and Emotional Eating Scale (EES) measures.

Dichotomizing the emotional eating behavior composite measure generated emotional eating behavior groups. This measure was used to comprise the groups outlined above.

2.2.1a Dutch Eating Behavior Questionnaire (DEBQ) is a measure of eating behavior (Van Strien, Frijters, Bergers, & Defares, 1986). The DEBQ consists of three subscales: emotional eating, restraint, and externality scales, for a total of 33 items answered on a 5-point Likert scale ranging from "never" to "very often" (Van Strien et al., 1986). Only the 13 items from the emotional eating subscale (α = .93) were used in the present investigation. The emotional eating subscale addresses eating behavior in the context of emotion with questions such as, do you have the desire to eat when you are depressed or discouraged (M = 2.99, SD = .78). Other studies have composed eating groups with this measure using lower eating scores (M = 1.99, SD = .66; Chao et al., 2016; Van Strien, Konttinen, Homberg, Engels, & Winkens, 2016).

2.2.1b Emotional Eating Scale (EES) is a measure of emotional eating behavior (Arnow et al., 1995). The EES consists of 25 mood descriptions (α = .88) answered on a 5-point Likert scale ranging from "no desire to eat" to "an overwhelming urge to eat" (Arnow et al., 1995). After reading the mood description (e.g. irritated), participants indicate what their usual desire to eat level would be (M= 2.49, SD = .60). Other studies have shown similar groupings of emotional eaters vs control (M = 2.23, SD = .83; e.g. Goldbacher et al., 2012; Koball, Meers, Storfer-Isser, Domoff, & Musher-Eizenman, 2012; Schneider et al., 2012).

2.2.2 Debriefing Questionnaire is a questionnaire used to ascertain if (after completion of the task) the participant feels disturbed by the images utilized in the paradigm and if they would like to talk with someone about their feelings. No participants indicated concerns.

2.2.3 Task. Raymond and colleagues (1992) introduced the term attentional blink (AB), a psychological construct in which attention is momentarily inaccessible due to the processing of previous information. When two targets are to be identified among non-target distractors most individuals show an AB in reporting the second target. Correct identification of the first target (T1) impedes the detection of a second target (T2) that appears within 500 ms of T1 (Chun & Potter, 1995; Raymond et al, 1992). The failure to report a T2 is believed to happen because a large amount of attentional resources have been allocated to T1 (Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006). The attentional blink is believed to be induced when salient stimuli cause a focus of attention (Shapiro et al., 2006). Moreover, Olivers and Nieuwenhuis, (2005) found that the size of an attentional blink is determined by an individual's psychological state and that a strong focus on T1 promotes the attentional blink. Shapiro and colleagues (2006) found that performance on T2 could be predicted from the amount of resources used in the processing of T1; more resources used for T1 equated to larger blink magnitude for T2. EEG and fMRI studies have shown reduced activity in the frontoparietal cortex when T2 cannot be reported, even though both targets activate early visual areas (Sergent, Baillet, & Dehaene, 2005; Kranczioch, Debener, Schwarzbach, Goebel, & Engel, 2005; Williams, Visser, Cunnington, & Mattingley, 2008). However, these studies did not use emotionally salient images. Most, Chun, Widders, and Zald (2005) found negative T1s to cause greater deficits in T2 processing than neutral T1s. However, the study was only behavioral and did not examine associated neural correlates. Furthermore, Denke and Lamm (2015) also found negative T1s to cause greater deficits in T2 processing, along with differences in associated ERP amplitudes, in emotional eaters compared with non-emotional eaters. However, this study used negative and neutral T1 images within streams of neutral distractor images to explore if attentional rumination might contribute to emotional eating behavior (see part B of Figure 1). The current study, on the other hand, uses food and neutral T1 images within streams of negative images to explore if avoidance coping might contribute to emotional eating behavior (see part A of Figure 1). Currently, no studies have explored the link between attentional blinks and emotional eating behavior in this manner.

For the current task (Figure 2), participants began with a 10-trial practice session with instructions emphasizing that T1 will be framed in yellow or red and T2 will follow the picture with the yellow or red frame (T1). Following the practice task, participants played the actual task. The task consisted of 4 blocks of 126 trials each. Between each block of the task, participants were instructed to stretch and blink their eyes in order to get comfortable and ready

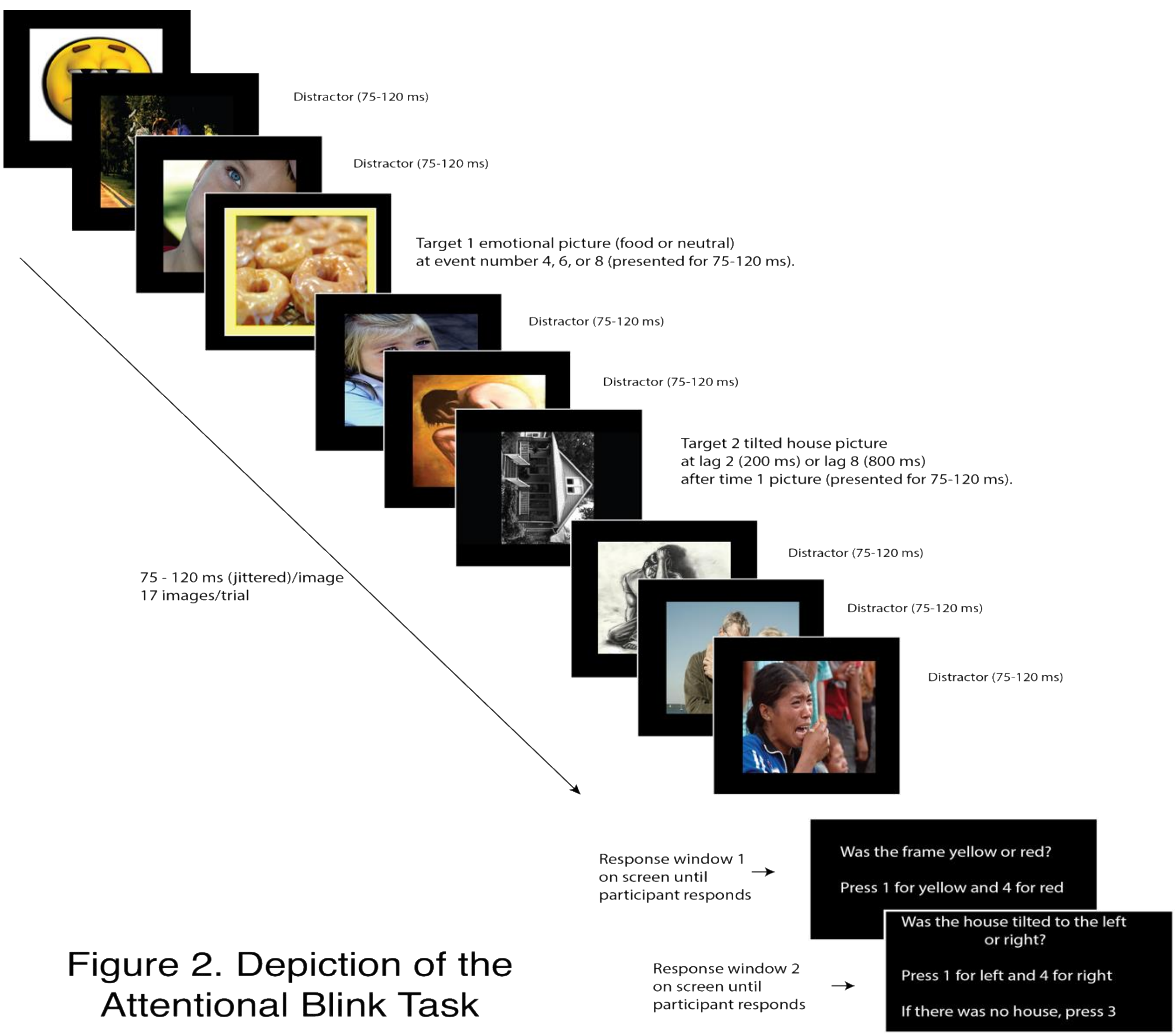

Figure 2. Depiction of the Attentional Blink Task

to proceed with the next block.

Stimuli were primarily color photographs, with only the T2 images being black and white photographs: 62 T1 images framed in yellow (31 food T1 images and 31 neutral T1 images), 62 T1 images framed in red (31 food T1 images and 31 neutral T1 images), 400 sad distractor images (each used randomly 4 times), and 102 T2 images (black and white house photos, 50 tilted 90º to the left and 50 tilted 90º to the right) all presented on a 34-cm wide x 27 cm high LCD monitor. I also include 22 trials where no T2 image was presented to make missed T2 trials a true option and thereby prevent random responding when T2 was not observed. Sad pictures were drawn from publicly available sources and rated by university students (N = 223). House and food pictures were drawn from publicly available sources and some house photos were taken by the researchers. Neutral pictures were drawn from the International Affective System (IAPS; Lang, Bradley, & Cuthbert). Negative distractor pictures were of sad or dreary looking people (e.g. a person crying), animals, or landscapes (e.g. a rainy day). T1 food pictures were of high calorie, sweet (e.g. cupcake) or savory (e.g. pizza), foods. T1 neutral pictures were of inanimate objects (e.g. a chair). Trials consisted of a rapid serial visual presentation (RSVP) stream of 17 images, presented for 75-120 ms, and jittered trial-by-trial to aid in ERP processing. Depending on the trial, T1 was presented as the 4th, 6th, or 8th stimulus. T2 was presented either two or eight pictures after the T1 (lag 2 and lag 8).

At the end of each trial, participants first answered what color frame was seen (question #1) by pressing either “1” if T1 had a yellow frame or “4” if it had a red frame. Then, participants pressed either “1” for a house tilted left, “4” for a house tilted to the right or “3” if no house was seen (question #2). To prevent participants from looking at their hands to indicate the correct button, which would lead to EEG eye artifact, a large fuzzy sticker that could easily be identified by touch alone marked button 3.

This task was adapted from a previous version by the current author (Denke & Lamm, 2015) and loosely based on the task used by Most and colleagues (2005), but differs in many ways. The task previously used by the current author used black and white photos throughout the task, to avoid the possibility of participants reacting to potential color salience differences rather than the difference between T1 images. The current task used color images throughout so that food images appeared more realistic, but analyses were within condition in order to avoid color salience issues. Also, the negative images in the previous task were primarily threatening in nature and not sad, this study used sad images. While the previous task used neutral and negative T1 images in the context of neutral distractor images, we used food and neutral T1 images in the context of negative distractor images, to better emulate the context of real-world emotional eating (i.e. to surround the participant with sad images in the hope of inducing a sad mood). Additionally, previous research suggests that requiring participants to behaviorally respond to the T1 increases the attentional conflict between T1 and a subsequent T2, thus the attentional blink is increased (Giesbrecht, Sy, & Lewis, 2009). The previous task used a yellow frame to distinguish T1 from the distracter images, and encourage participants to pay attention to the T1 images. The current task furthered this process of highlighting T1 by using 2 frame colors (yellow and red), and by having the participants indicate behaviorally which frame color was used (response #1).

2.3 Procedure

After obtaining written consent, height, weight, and head circumference measurements were taken and questionnaires were started. Participants completed four questionnaires in the EEG testing room while an electrode sensor net was prepared. Following completion of the questionnaires, participants were seated 67 cm from a computer monitor and an electrode sensor net was applied. Instructions on how to do the task were given and participants completed a practice block of 10 trials, which were identical to the actual task. When proficiency was shown on the practice block (less than 3 incorrect trials), participants moved on to perform the actual task. The task took approximately forty-five minutes to complete. After completion of the task, the EEG net was removed and participants completed the debriefing questionnaire.

2.4 EEG data collection and analysis

EEG was recorded using a 128-channel Geodesic Sensor Net and sampled at 250 Hz, using EGI software (Net Station; Electrical Geodesic, Inc., Eugene, OR). Data acquisition was started after all impedances for all EEG channels are reduced to below 50 kΩ. All channels were referenced to Cz (channel 129) during recording and were later re-referenced against an average reference corrected for the polar average reference effect (PARE correction; Junghoefer, Elbert, Tucker, & Braun, 1999). Data were filtered using a FIR bandpass filter with a lowpass frequency of 50 Hz and a highpass frequency of .3 Hz. Data were artifacted to remove ocular artifacts and to interpolate all other artifacts. P2, N2, and P3 data were time-locked to the T2 and baseline corrected for 200 ms before T2 onset. Datum from trials with correct T2 detection and trials in which T2 was erroneously not detected were analyzed for Lag 2 trials. All ERP and behavioral data that showed values greater or less then 3SD from the mean were modified to reflect exactly 3 SDs from the mean (outlier correction) thereby preventing statistical analyses from being skewed by outliers.

2.5 Data analyses

To increase the potential emotional salience of the sad images and to make food images appear more appealing, the current study used color images. To ascertain if food images and neutral images were processed similarly, a previous study (n = 36) was conducted using the same task except that T1 (food and neutral) images were scrambled (pixels comprising an image were randomized) and therefore the content of the images were not identifiable. However, the salience levels of the images were still the same. I was hoping to show that food and neutral T1 images were similarly salient in color and that only the content information was different. However, I found significant condition (food, neutral) differences in this preliminary study for the N2 component, $F(1,36) = 27.38$, $p < .001$, therefore, in the current study, I cannot compare food and neutral conditions. Thus, analyses for the current study consisted of 6 mixed design ANOVAs computed separately for each condition (negative and neutral) and each ERP component (P2, N2, P3). Analyses were conducted separately for each ERP component rather than for each hypothesis to avoid redundancy of analysis. More specifically, the mixed design ANOVA can show results for all hypotheses (accuracy and group) for one ERP component. For both conditions, within each ANOVA Group (emotional eaters vs. non-emotional eaters) was a between subject factor and Accuracy (correct T2 detection vs. incorrect T2 detection) was a within subject factor.

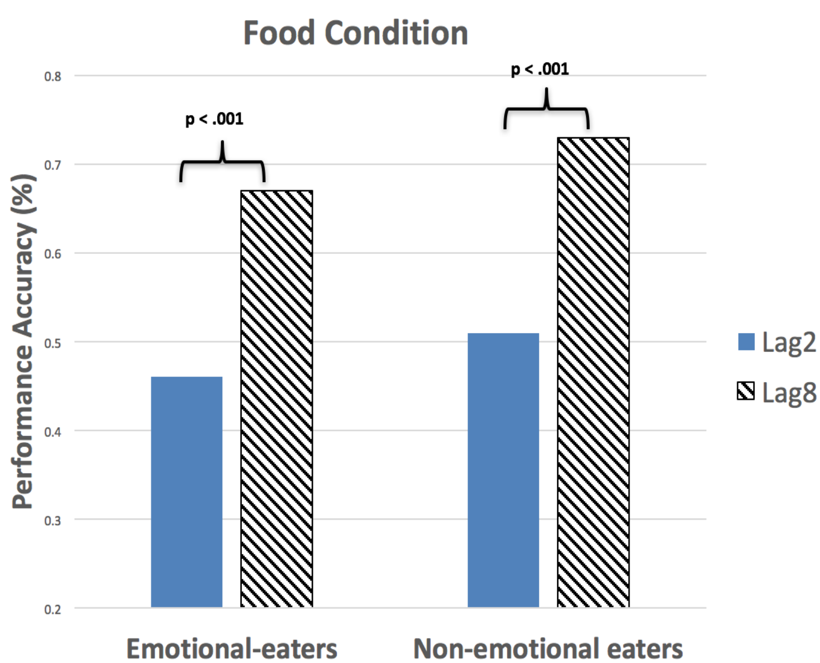

Figure 3: Bar graph showing reduced accuracy in lag 2 trials vs. lag 8 trials, in the food condition, for both Emotional-eaters and Non-emotional eaters.

Results

3.1 Accuracy

A 2 (lag; lag 2 vs. lag 8) x 2 (group; emotional eaters vs. non-emotional eaters) mixed design ANOVA on performance accuracy was computed separately for each condition (Food and Neutral). Findings showed a main effect for lag in both the neutral condition F(1, 47) = 199.5, $p < .001$, $\eta^2 = .809$, and the Food condition, F(1, 47) = 236.0, $p < .001$, $\eta^2 = .83$, with decreased performance accuracy for lag 2 trials when compared with lag 8 trials (see figures 3 and 4). Given that the attentional blink has been shown to appear between 200 and 500 ms after T1 (Raymond et al, 1992), the fact that we found decreased accuracy for lag 2 trials compared to lag 8 trials indicates that the task was administered correctly.

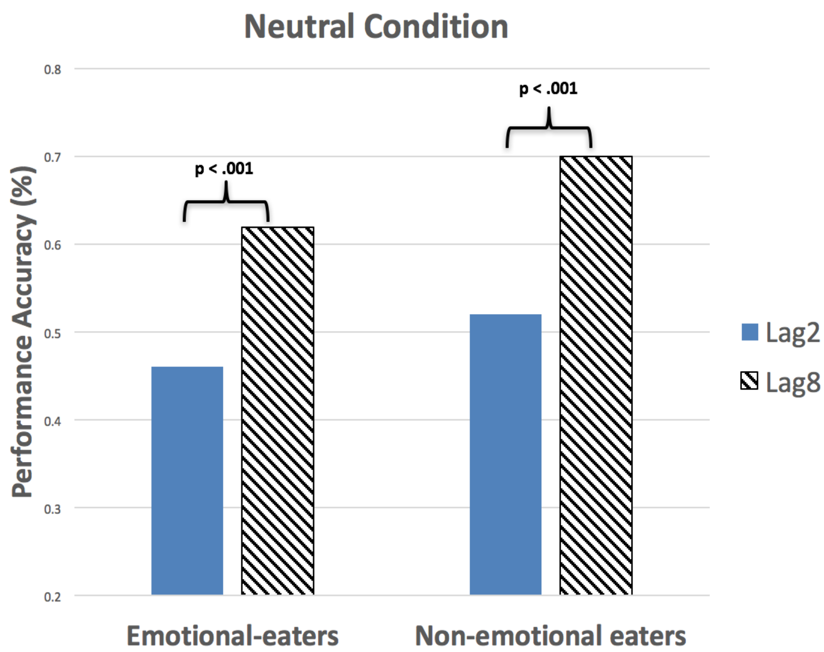

Figure 4: Bar graph showing reduced accuracy in lag 2 trials vs. lag 8 trials, in the Neutral condition, for both Emotional-eaters and Non-emotional eaters.

3.2 P2 Data Analysis

A 2 (trial type; correct T2 detection vs. incorrect T2 detection) x 2 (group; emotional eaters vs. non-emotional eaters) mixed design ANOVA on P2 activation was computed

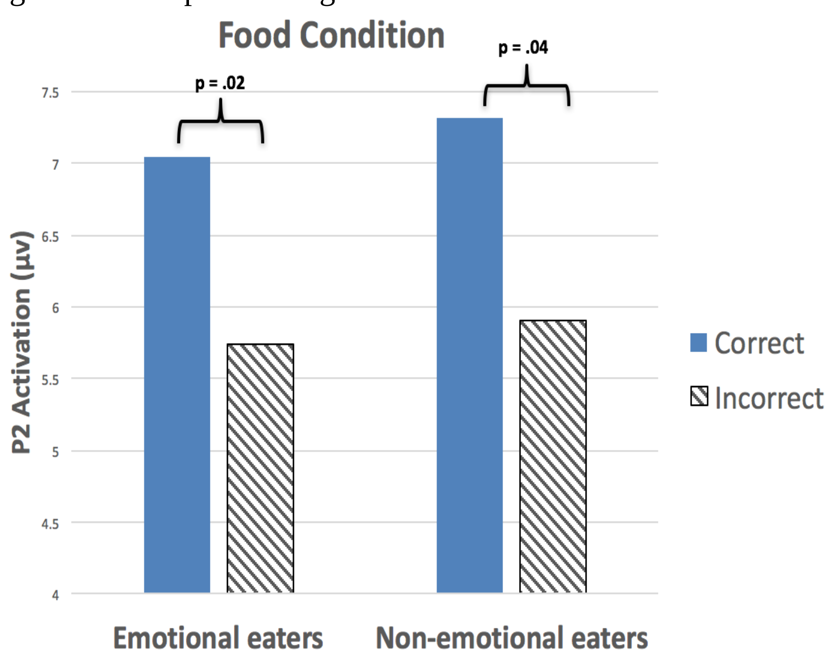

Figure 5: (Electrode VREF) Bar graph showing increased P2 activation for correct T2 detection trials vs. incorrect T2 detection trials, in the Food condition, for both emotional-eaters and non-emotional eaters.

separately for each condition (Food and Neutral). Findings did not show a main effect of group, F(1,46) = .09 p = .76, η^2 = .002, or a trial type x group interaction, F(1,46) = .051, p = .88, η^2 = .02, as hypothesized. Though, as hypothesized (see hypothesis 1.1.a), findings did show a main effect for trial type in both the food condition, F(1, 46) = 10.02, *p* = .003, η^2 = .18, and the neutral condition, F(1, 46) = 26.50, *p* < .001, η^2 = .37, with increased P2 activation during trials in which T2 was accurately detected vs. trials in which T2 was not accurately detected (see figures 5 and 6).

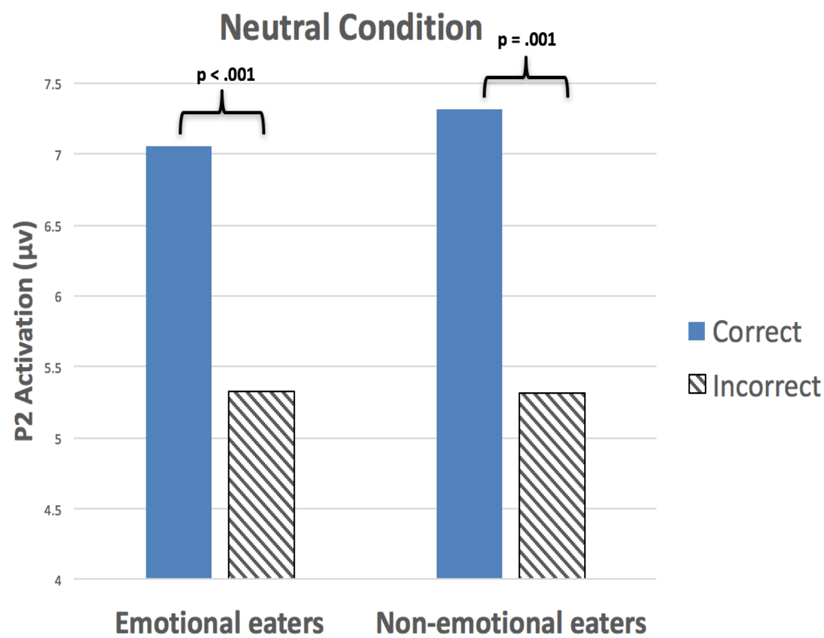

Figure 6: (Electrode VREF) Bar graph showing increased P2 activation for correct T2 detection trials vs. incorrect T2 detection trials, in the Neutral condition, for both emotional-eaters and non-emotional eaters.

3.3 N2 Data Analysis

A 2 (trial type; correct T2 detection vs. incorrect T2 detection) x 2 (group; emotional eaters vs. non-emotional eaters) mixed design ANOVA on N2 activation was computed separately for both conditions (Food and Neutral). Findings did

Figure 7: (Electrode VREF) Bar graph showing increased (more negative) N2 activation, for incorrect T2 detection trials vs. correct T2 detection trials, for both emotional-eaters and non-emotional eaters in the Food condition.

not show a main effect of group, F(1,46) = .91, p = .35, η^2 = .02, or trial type x group interaction, F(1,46) = 4.94, p = .38, η^2 = .02, as hypothesized. However, as hypothesized (see hypothesis 1.1.b), findings did show a main effect of trial type in both the Food condition, F(1, 46) = 24.15, $p < .001$, η^2 = .34, and the neutral condition, F(1, 46) = 14.08, $p < .001$, η^2 = .23, with increased N2 activation during trials in which T2 was not accurately detected vs. trials in which T2 was accurately detected (see figures 7 and 8).

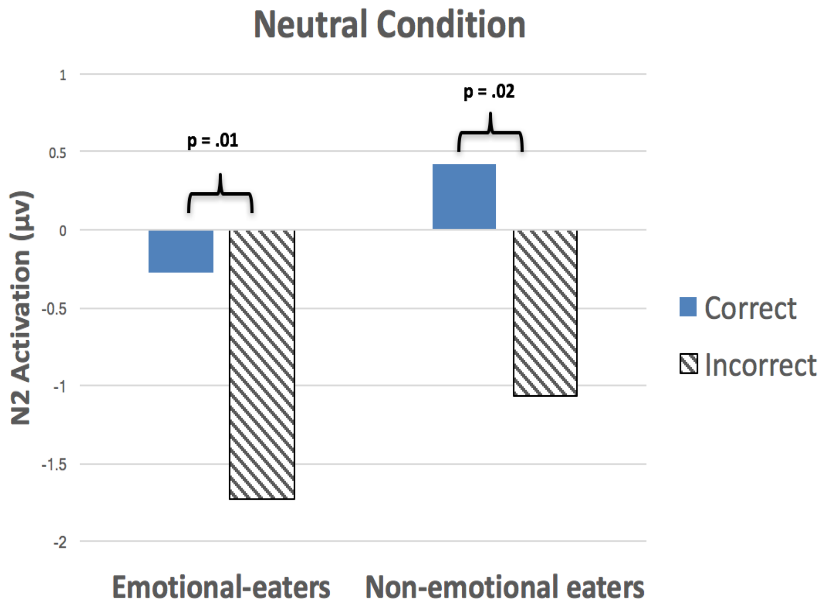

Figure 8: (Electrode VREF) Bar graph showing increased (more negative) N2 activation, for incorrect T2 detection trials vs. correct T2 detection trials, for both emotional-eaters and non-emotional eaters in the Neutral condition.

3.4 P3 Data Analysis

A 2 (trial type; correct T2 detection vs. incorrect T2 detection) x 2 (group; emotional eaters vs. non-emotional eaters) mixed model repeated-measures ANOVA was computed for both conditions (Food and Neutral). Findings did not reveal a main effect of group, F(1,46) = .02, p

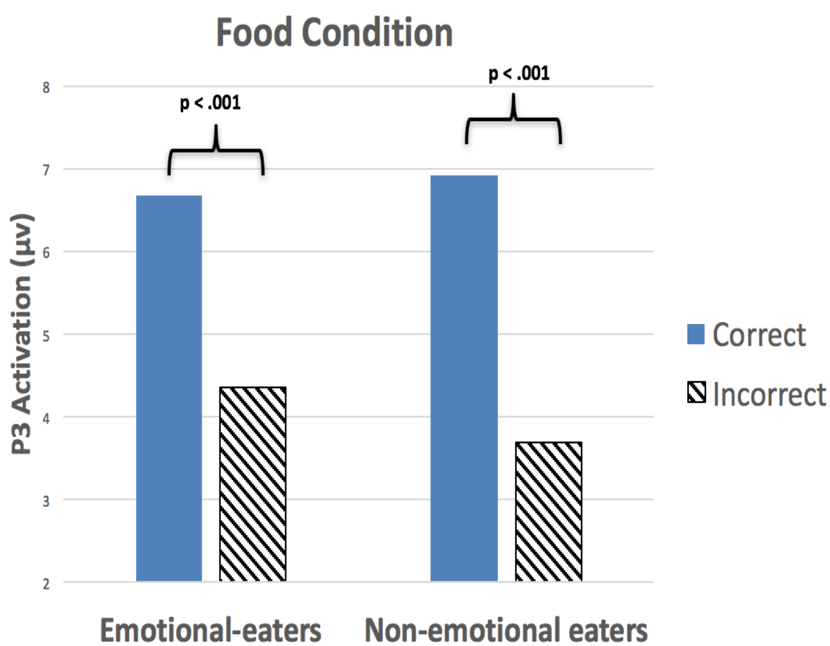

Figure 9: (Electrode VREF) Bar graph showing increased P3 activation for correct T2 detection trials vs. incorrect T2 detection trials, in the Food condition, for both emotional-eaters and non-emotional eaters.

= .89, η^2 = .00, or a trial type x group interaction, F(1,46) = 1.26, p = .268, η^2 = .03, as was hypothesized. Findings did show, as hypothesized (see hypothesis 1.1.c), a main effect of trial type in both the food condition, $F(1, 46) = 46.16$, $p < .001$, $\eta^2 = .50$, and the neutral condition, $F(1, 46) = 59.16$, $p < .001$, $\eta^2 = .56$, with increased P3 activation during trials in which T2 was accurately detected vs. trials in which T2 was not accurately detected (see figures 9 and 10).

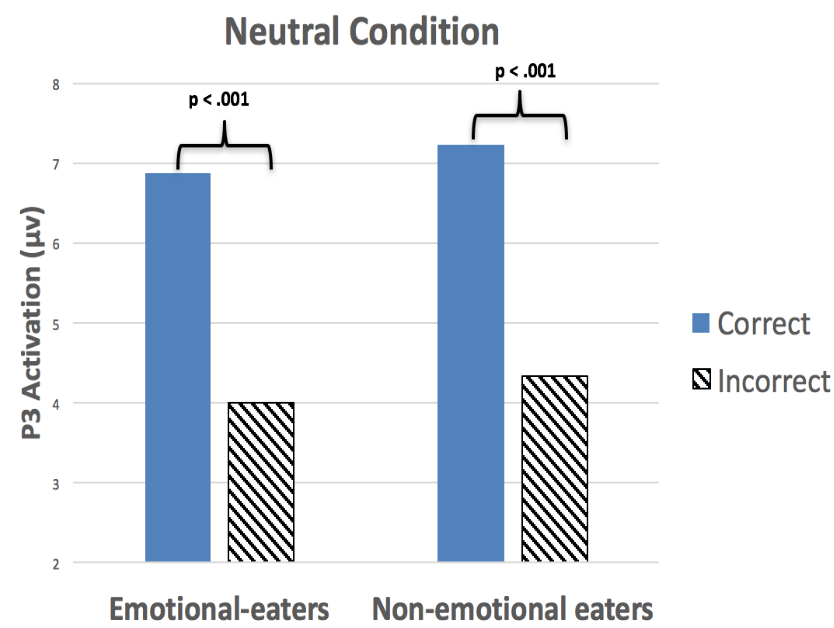

Figure 10: (Electrode VREF) Bar graph showing increased P3 activation for correct T2 detection trials vs. incorrect T2 detection trials, in the Neutral condition, for both emotional-eaters and non-emotional eaters.

4.0 Discussion

The current study decomposes attentional deficit that may contributing to emotional-eating behavior by analyzing three ERP components (P2, N2, and P3) measured in the context of an attentional blink task. These ERP components have been associated with attention orienting (P2), cognitive conflict (N2), and context updating in working memory (P3; Carretié et al., 2001; Delplanque et al., 2004; Donkers et al., 2004; Kanske et al., 2011; van Wouwe et al., 2009; Woodman, 2010). Denke and Lamm (2015) also measured these ERP components to examine attentional deficits that underlie emotional-eating; however, they examined rumination based emotional eating. Within rumination based emotional eating attention is focused on negative stimuli (ruminate about) while people consume unhealthy food to increase positive feelings (Nolen-Hoeksema, Stice, Wade, & Bohon, 2007; Rawal, Park, & Williams, 2010). But, because attention is focused on the negative stimuli, a person likely lacks the attentional resources to effectively process the quantity and type of food being ingested. However, Denke and Lamm (2015) did not assess avoidance based emotional eating. Avoidance based emotional eating involves focused attention on food consumption in order to avoid negative thoughts (Blackburn et al., 2006; Heatherton & Baumeister, 1991; Paxton et al., 1997). Because attention is focused on the qualities of the food, e.g., taste, attention is likely not focused on the quantity and type of food being ingested. The current study used ERPs to assess attentional mechanisms underlie avoidance based emotional-eating.

Before discussing potential causes for my non-significant emotional eating group differences, to better understand what these results might mean, I am first going to discuss ERP difference contributing to correct and incorrect responses. Attentional blinks are believed to result from the large amount of attentional resources used to focus on particular stimuli, which interferes with attending to temporally close subsequent stimuli (Raymond et al., 1992). Furthermore, missed stimuli show reduced P3 activation compared to correctly perceived stimuli, which Kranczioch and colleagues (2003) interpret to reflect "blinked" information not entering working. The current study found similar differences between accurate and inaccurate responses for all 3 ERP components: P2, N2, and P3. Consistent with the previous literature, I found decreased activation for P2 and P3 components in trials where T2 was "blinked" compared to trials in which T2 was accurately detected. For N2 activation, I found more negative activation for inaccurate T2 detection trials than accurately detected trials. Additionally, a key component of the canonical attentional blink task is that trials in which T2 comes shortly after T1 (roughly 200 to 500 ms) performance accuracy is worse than for trials in which there is a much larger gap in time (roughly 800 ms) between T1 and T2. Again, my results are in line with this component of the attentional blink task. Together, these behavioral and ERP results suggest that I administered the attentional blink task correctly and that my non-significant group differences cannot be due to errors in our attentional blink method.

In the previous study, emotional-eaters were found to have reduced P2 activation compared to non-emotional eaters for erroneous T2 detection trials in the negative condition (Denke & Lamm, 2015). Given that elevated P2 activation has been associated with better attentional orientating (Kanske, Plitschka, & Kotz, 2011), the reduced P2 activation suggest that emotional-eaters get attentionally stuck on negative stimuli. Emotional-eaters getting attentionally stuck on negative stimuli falls in line with rumination based emotional-eating (see part B of Figure 1). In the current study, I focused on avoidance based emotional-eating, hypothesizing that food images would also induce attentional sticking and result in reduced P2 activation for subsequent stimuli. However, I did not find these predicted group differences. It is not clear why I did not find these predicted results; however, it might be in part due to differential levels of hunger.

While numerous studies have found attention biases for food stimuli (Castellanos et al., 2009; Graham, Hoover, Ceballos, & Komogortsev, 2011; Kakoschke, Kemps, & Tiggemann, 2014; Werthmann et al., 2011; Yokum, Ng, & Stice, 2011) as well as differential responses to food images among individuals with abnormal eating behaviors when compared with controls (Blechert, Feige, & Tuschen-Caffier, 2010; Nijs, Franken, & Muris, 2009; Svaldi, Tuschen-Caffier, Peyk, & Blechert, 2010), other studies have found this food attention bias to be independent of abnormal eating behavior (Loeber et al., 2012; Werthmann et al., 2013). It may be that food attention biases are heavily influenced by an individual’s current state. A variety of studies have found food attention bias to be heavily influenced by hunger level (Green & Rogers, 1993; Hollitt, Kemps, Tiggemann, Smeets, & Mills, 2010; Mogg, Bradley, Hyare, & Lee, 1998), with hungry participants orientating their attention faster to food related cues. The current study did not ask participants to rate their hunger levels or ask about amount of time since their last meal. Thus, it may be that any group differences in the propensity to orient toward attention food images and away from sad images was negated by undisclosed hunger levels. Future studies should ascertain participant hunger level at the time of the task in order to reduce this confounding effect.

Furthermore, in the previous study (Denke & Lamm, 2015), emotional-eaters were found to have significantly greater N2 activation (more negative), compared with non-emotional eaters, in trials containing negative T1 images, when T2 was present but not detected. Given that more negative N2 activation has been associated with emotional stimuli compared to less emotional stimuli (Lamm, et al., 2013; Lamm, et al., 2012; Lewis, et al., 2006), these results suggest that emotional eaters may have been more affected by negative stimuli than non-emotional eaters. Moreover, this elevated neural response to the emotional stimuli may have resulted in increased conflict between negative images and subsequent images and thus caused the subsequent images to be missed. This pattern of results and the use of negative stimuli is in line with a rumination based emotional-eating hypothesis (see part B of Figure 1). After modifying the task, requiring participants to focus on food images (avoidant based emotional-eating), I hypothesized similar group differences as found by Denke and Lamm (2015). More specifically, I thought emotional-eaters compared with non-emotional eaters, would allocate too much attentional resources to the food image and therefore cause elevated conflict (more negative N2) between the memory of the food image and the subsequent stimuli (See part A of Figure 1). However, I did not find these group differences.

As outlined above, it may be that variation in levels of hunger introduced methodological noise into the analysis and therefore prevented me from finding group differences in emotional eating behavior. Given that hunger levels might have impacted the “stickiness” of participants attention to the food images, it would then also have influenced the downstream amount of conflict between the food images and the subsequent image, to which the participant was required to respond. Thus, the fact that I did not measure levels of hunger could also explains the non-significant group differences in N2 activation.

Additionally, attention bias to food stimuli has also been strongly linked to external eating behavior (i.e. eating in response to external cues; Brignell, Griffiths, Bradley, & Mogg, 2009; Hou et al., 2011; Johansson, Ghaderi, & Andersson, 2004; Newman, O’Connor, & Conner, 2008), as well as restrained eating behavior (i.e. individuals undergoing dietary restraint measures; Brooks, Prince, Stahl, Campbell, & Treasure, 2011; Hollitt et al., 2010). The current study did not probe participant’s predisposition for external eating or any dietary restraint measures undertaken by them. Consequently, it could be that our non-emotional eating group was comprised of individuals predisposed to external eating behavior or individuals who were undergoing dietary restraint measures during the time of their participation. Future studies will need to fully ascertain participant’s hunger state, external eating predispositions, as well as any dietary restraint measures that they may be employing.

The current study also examined P3 activation, which has been associated with information processing within working memory, i.e., increased activation found for detected stimuli and little or no P3 activation found for missed stimuli (Kranczioch et al., 2003; Ritter & Vaughn, 1969). More specifically, Kranczioch et al., (2003) found that in the context of the attentional blink paradigm, P3 activation may represent information making it into working memory. Both the Denke and Lamm (2015) and the current study, did not find an emotional eating behavior group difference in P3 activation, suggesting that for both emotional eaters and non-emotional eaters similar amounts of information are processed in working memory. Since the P3 unfolds after both the P2 and N2, it may be that variance introduced by factors, such as level of hunger and current dietary practices, may have “washed out” any potential group differences in P3 activation and performance accuracy.

In addition to not adequately measuring state problems, e.g., level of hunger, as outlined above, the non-significant group difference results may have also been caused by some task related factors. Overall, given that Denke and Lamm (2015) found group differences in emotional eating behavior using a very similar attentional blink task, our non-significant group differences are not likely due to task insensitivity. However, some of the modifications in the task I designed to emulate avoidance based emotional eating behavior may have been problematic. It may be that my food images were not enticing enough to capture the emotional-eating groups attention, or perhaps the sad images were not affective in inducing the sullen mood associated with emotional-eating. Furthermore, because I did not pre-screen for type of emotional eater, it may also be that our sample did not include enough emotional eaters who apply an avoidance coping style of emotion regulation. Thus, future research should include both the attentional blink paradigms used in this study and the one used by Denke and Lamm (2015) in one research study. This would allow researchers to explore if emotional eaters who use an avoidance copying emotion regulation style evoke different attentional deficits than emotional eaters who use a rumination style. Additionally, future research should ascertain the hunger state of participants at the time of participation along with other eating associated behaviors that my influence food attention biases.

Along with the previously mentioned state and task issues, differences in temperament and coping strategies used by participants may have also been a factor for not finding the group differences that I had hypothesized. Such variations among participants may have added a large amount of variance to our groups. This variance could result in a large amount of noise interfering with signal detection and consequently an inability to find significance. Future research should include temperament and coping strategy measures in order to control for this variance

5.0 Limitations

There are limitations to the current study. In the current study, I am using a laboratory environment to emulate real world emotion-induced emotional-eating. While this is a useful approach to decomposing the attentional mechanisms contributing to emotional-eating behavior, it is likely not as salient as real-world emotions.

Second, my food images were two dimensional odorless stimuli which are very scaled down representations of the real thing. Attention is directed through a variety of means (sight, sound, thought, smell, tactile) and focused attention to food is heavily influenced by more than just sight (Lawless, 1991). The use of two-dimensional food images in place of real food is of major concern. Food captures attention in a variety of ways, so limiting it to visual attention is most likely a substantial limitation.

Third, in an attempt to evoke negative emotion within our participants, the majority of images that I utilized (distractor images) depicted gloomy environments (e.g. rainy days or funeral scenes) or sad people (e.g. people crying). Though images may help to induce moods, it may be that my images were not salient enough to induce the saddened state that I was looking for. Given that I cannot induce the level of emotional arousal, as might be realistic in the real world (e.g., breakup of a relationship or loss of a job), due to ethical considerations, I can only speculate that the attentional neuromechanistic chronometry revealed in the current study is similar to what might be expected for real world levels of emotional arousal.

Fourth, though my participants were screened using emotional-eating questionnaires, the questionnaires did not indicate emotional-eating type. As has been previously discussed, emotional-eaters may come in two distinct forms (rumination based and avoidant based). It may be that my participants were primarily rumination type emotional-eaters and consequently not affected by the food images to the extent that avoidant type emotional-eaters may be.

Fifth, my participants were not asked about current hunger state, external eating behavior, or dietary restraint measures in place at the time of the study. All of these factors can contribute to food attention bias and subsequently could contaminate group differences.

6.0 Conclusion

Emotional-eating is a maladaptive coping behavior that may manifest in a variety of ways including rumination-based or avoidance-based styles. The neural underpinnings of rumination based emotional-eating were previously explored by Denke &Lamm, 2015, measuring P2, N2, and P3 amplitudes with results suggesting that attentional deficits may underlying that style of emotional-eating. The current study explored these same ERP components in a similar paradigm designed to capture avoidance based emotional-eating but did not find significant group differences. Future studies should use both versions of the attentional blink task to emulate both rumination-based and avoidance-based emotional eating styles in one sample, thereby controlling for state-level noise, i.e., levels would be equal for both tasks. Future studies should also incorporate additional questionnaires to systematically ascertain any food attention bias factors beyond emotional-eating behavior that may influence participants engagement with the task. Additionally, future studies should consider pairing additional sensory stimuli (e.g. food aromas) with food images, in order to heighten the attention capturing effects of food images.

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Vita

The author was born in Rapid City, South Dakota. He obtained his Bachelor's degree in psychology from the University of Southern Maine in 2012. He joined the University of New Orleans psychology graduate program to pursue a PhD in Biopsychology, and became a member of Professor Connie Lamm's research group in 2012.