THE RELATIONSHIP BETWEEN BMI, SELF-ASSESSMENT OF HUNGER, AND BRAIN PROCESSING OF FOOD IMAGES

By Alexandra M. Koll

Several studies have focused on cognitive processing of food-related stimuli in response to the rising obesity rates. Previous research has examined the potential connection between brain responses to pictures of food and body mass index (BMI) using an electroencephalogram (EEG). Findings from these studies are conflicting and may be a result of differences in methodologies. The purpose of this study was to clarify and extend the knowledge about the relationship between BMI, brain activity (specifically, event-related potentials [ERPs]) elicited by food-related stimuli, and self-report of food cravings and hunger. The Late Positive Potential (LPP), the ERP of interest, was chosen as previous studies have supported its use as an index of perception of affective stimuli.

Twenty-eight participants viewed pictures of unhealthy food and office furniture while their physiological responses were recorded with an EEG. Participants also responded to several self-report questionnaires and had their height and weight collected in order to calculate their body mass index (BMI).

Self-report data of food cravings and hunger was not significantly related to BMI. Analysis of LPP amplitudes of food pictures revealed no predictable relationship with BMI. Additionally, no significant differences were found for LPP amplitudes between participants of low and high BMIs. As an extension of previous research, significant differences were found between LPP amplitudes of food pictures and LPP amplitudes of office furniture pictures, supporting the idea that the LPP is a measure of affective relevance.

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Obesity and Weight Control

Obesity is an increasingly prevalent threat to health in the U.S and around the world. As of 2012, 35.7% of Americans were obese (Flegal, Carroll, Kit, & Ogden, 2012). Surveys conducted in 2008 found that five states had an obesity prevalence of at least 30% and 32 states had rates greater than 25% (Nguyen & El-Serag, 2010). In Wisconsin, 62.8% of the population was overweight in 2012 with 26.3% being classified as obese (Centers for Disease Control and Prevention, 2012). Global data monitored by the World Health Organization (WHO) projects that at least 700 million adults will be obese by 2015, almost double the amount of 2005 (Withrow & Alter, 2011).

Obesity is linked either directly or indirectly to 280,000 deaths per year in the U.S. (Bodor, Rice, Farley, Swalm, & Rose, 2010). It has been associated with serious medical conditions such as type 2 diabetes, gallbladder disease, stroke, coronary artery disease, hypertension, several types of cancers, liver disease, and an increased risk of death (Nguyen & El-Serag, 2010; Withrow & Alter, 2011). In one study with 500,000 non-smoking U.S. participants, researchers found that compared with normal-weight patients, obese patients' risk of death was increased 2-3 fold (Nguyen & El-Serag, 2010). There are several ways to measure the weight category into which an individual may fall, one of which is body mass index (BMI).

The body mass index (BMI) is a simple and non-invasive way to determine a person's body fat percentage by calculating the ratio of their weight to their squared height (World Health Organization, 2014). Popularity for this measure began in the 1970s when an American scientist published papers describing how the BMI can evaluate levels of obesity and nutritional health (Pekar, 2011). According to the National Institute of Health (n.d.) a BMI of 18.5-24.9 is considered to be of normal weight, 25-29.9 is overweight, and a BMI above 30.0 is considered obese. In Wisconsin, which is where participants for the current study attend school, the average BMI is 26.62 ("BMI Index By State," n.d.). While this is a quick and inexpensive measure, the BMI is not appropriate for certain populations, such as athletes or the elderly, since it assumes an average body composition (Pekar, 2011). Alternatives to the BMI include underwater weighing and waste-to-hip ratio, but for epidemiological studies the BMI has been shown to be a useful tool (Pekar, 2011).

It is estimated that approximately 40-60% of adults in Western countries are trying to lose weight, with an even higher percentage among those who are overweight or obese. Despite the high number of people attempting to lose weight, obesity is still at an all time high (Teixeira et al., 2010). Additionally, within six months following the weight loss intervention, mean weight loss tends to be between six and nine percent (Puhl & Heuer, 2010). An evaluation of the effectiveness of commercial weight loss programs concluded Weight Watchers was the only program to result in an average of five percent of initial weight lost (Tsai & Wadden, 2005). In the face of existing high rates of obesity,

it is clear that more successful programs with a focus on weight loss maintenance need to be developed.

Food cravings can be thought of as "an intense desire to eat a specific a food." While the origins of these cravings are not fully understood, the strength, type, and frequency of food cravings differ with BMI (Gilhooly et al., 2007). Some of the theories for origins of cravings include biological foundations, learned appetite through reinforcement, and increased cravings with dietary monotony. Studies have shown that the most commonly craved foods include those that are high in carbohydrates and fats, such as chocolate and salty snacks (Gilhooly et al., 2007). Other studies have examined the relationship between food cravings and BMI. Franken & Muris (2005) surveyed female college students and found a significant positive relationship (r = .24) between food cravings and BMI using the Food Cravings Questionnaire-Trait (Cepeda-Benito, Gleaves, Williams, & Erath, 2000). Another study found that the portion size of craved foods (but neither frequency nor giving in to cravings) was significantly related (r = .49) to lifetime maximum BMI (Gilhooly et al., 2007). Measurements of food cravings can involve the use of questionnaires such as The Craving Questionnaire (Weingarten & Elston, 1990) and the General Food Cravings Questionnaire-Trait (G-FCQ-T; Nijs, Franken, & Muris, 2007), the latter of which will be used in the current study. These results suggest that there are several factors that can affect food cravings. Relatedly, hunger levels are also assessed by means of a visual analogue scale (VAS), which will also be used in the current study.

Factors Controlling Intake

There are many interrelated factors that impact a person's caloric intake such as culture, socioeconomic status, social situations, environmental influences, affective states, and neural (peripheral and central) mechanisms. Factors relevant to the current study are discussed below in detail.

Environmental influences. These include, among others, advertising, work schedule and food availability. It is estimated that children view roughly 40,000 food advertisements each year and 98% of these include food that is high in fat, sodium and/or sugar (Keller et al., 2012). Studies assessing the power of food advertisements with diverse populations found that these advertisements led to an increase in food intake, regardless of reported initial hunger level (Harris, Bargh, & Brownell, 2009). Further, one study reported that food intake was increased in the presence of food branding, particularly among overweight children (Keller et al., 2012). Additionally, Keller et al. (2012) found that girls ate about 100 calories more when they were given branded food versus unbranded food.

Another environmental factor affecting intake is work schedule. More than 50% of parents in the U.S. are employed and may not have the time or energy to prepare meals (Devine et al., 2009). As a result families are consuming fast food more often, much of which lacks nutritional quality. Moreover, unhealthy weight gain was two times more likely to occur for men when working long hours compared to those who work normal hours (Shields, 1999).

Food availability studies have demonstrated that those living close to convenience stores have a greater likelihood of being both overweight and obese as compared to those with greater access to supermarkets, who tend to have a lower mean BMI (Rundle et al., 2009). Fast food accessibility has also been associated with a greater likelihood of obesity, and this industry is one of the most rapidly expanding sectors of U.S. food distribution with more than 200,000 locations (Bodor et al., 2010; Rosenheck, 2008).

Affect and eating. Emotional states can affect intake. Studies have shown that in a sad state, high fat/sweet (i.e. rewarding) foods are preferred, while in a happy state dried fruit is chosen more often (Dallman, 2010). In addition, anxiety and depression can also increase intake, and it is thought that people may use food for comfort or to improve their mood (Levitan & Davis, 2010). Relatedly, stress impacts intake as approximately 80% of people report increasing (40%) or decreasing (40%) eating when under stress (Dallman, 2010). Further, those who increase food intake tend to choose foods high in fat or sugar.

Researchers have also studied the relationship between obesity and depression. One study examined the risks of depression in normal weight and obese participants (Onyike, Crum, Lee, Lyketsos, & Eaton, 2003). They found that obese individuals, compared to the normal weight participants, had one and a half times greater prevalence of depression within the last month. Moreover, individuals with a BMI of 40 or greater had the highest prevalence of depression (Onyike et al., 2003).

Neural mechanisms. Brain mechanisms of pleasure and motivation related to appetite and intake have been studied using neuroimaging techniques with humans.

Several areas in the brain have been linked to pleasure such as the orbitofrontal, anterior cingulate and insular cortices, which appear to monitor and predict the reward value of the stimulus, including food (Berridge & Kringelbach, 2013). In addition, mesocorticolimbic circuits, which include the nucleus accumbens (NAc), ventral pallidum (VP), amygdala, and mesolimbic tegmentum, are activated during motivational states, including processing of information about the reward value of a stimulus, such as different types of food (Smith, Berridge, & Aldridge, 2011).

Peripheral mechanisms. Peripheral signals play a major role in controlling food intake by monitoring nutrient and energy levels and relaying this information (via the vagus nerve and the blood stream) to relevant brain circuits.

One set of peripheral mechanisms signals hunger. The gastrointestinal system (or the stomach) releases ghrelin, a peptide hormone that has shown to be a powerful stimulator of food intake (Kojima et al., 1999; Schmid et al., 2005). Other signals come from the liver, which can detect when nutrients are low and sends the information through the hepatic branch of the vagus nerve to the brain (Novin, VanderWeele, & Rezek, 1973). Deprivation of glucose and fatty acids in the liver has been shown to stimulate hunger (Friedman, Horn, & Ji, 2005).

Peripheral mechanisms can also signal satiety. Cholecystokinin (CCK) is a peptide hormone that is secreted in response to nutrients, especially fats, and is thought to reduce ingestion (Moran, 2009) through vagus nerve connections with the hypothalamus. In addition, peptide YY (PYY) is released in the intestines in response to food intake and suppresses eating in both high-fat and low-fat diets. Two other peptide hormones, insulin

and leptin, are influential in signaling satiety and reducing food intake (Erlanson-Albertsson, 2005).

Peripheral hunger and satiety signals transmitted to the brain (via the vagus nerve and bloodstream) are then integrated, mainly by hypothalamic nuclei. The results of this integration are then processed at higher brain levels to determine ingestion patterns and amounts.

Central mechanisms. Initially, two regions of the hypothalamus were implicated in ingestive behavior and metabolism. Researchers thought the lateral hypothalamus controlled hunger and the ventromedial hypothalamus controlled satiety (Anand & Brobeck, 1951; Teitelbaum & Stellar, 1954) Subsequently, it has been shown that other nuclei are involved as well.

Ghrelin from the stomach travels to the brain and binds to receptors in the arcuate nucleus and activates neuropeptide Y (NPY) & agouti-related peptide (AGRP) neurons (Van den Top, Lee, Whyment, Blanks, & Spanswick, 2004). NPY is secreted in a pathway that directly projects to two orexigenic hormones produced by the lateral hypothalamus, melanin-concentrating hormone (MCH) and orexin, both of which stimulate appetite (Broberger, De Lecea, Sutcliffe, & Hökfelt, 1998; Clark, Kalra, Crowley, & Kalra, 1984; Elias et al., 1998b). When NPY levels are increased by food deprivation (Sahu, Kalra, & Kalra, 1988), MCH and orexin levels are also increased and appear to stimulate intake. Endocannabinoids can also promote food intake by increasing the release of MCH and orexin (Di Marzo & Matias, 2005).

Leptin, an appetite-suppressing hormone, targets the arcuate nucleus and inhibits NPY neurons, therefore decreasing the release of MCH and orexin. PYY acts in the same way, targeting the arcuate nucleus and suppresses release of NPY resulting in a decrease of food intake (Glaum et al., 1996; Jobst, Enriori, & Cowley, 2004).

In addition to the environmental and neural underpinnings of ingestion, it is also important to understand cognitive mechanisms related to processing of eating-related stimuli.

Cognitive Processing and Food

Several cognitive measures have been used to study different aspects of the mental processing of food stimuli. These include measuring attention via eye-tracking, the Stroop task (processing time), functional magnetic resonance imaging (fMRI), and electroencephalography (EEG).

Eye tracking and attention. Nijs, Muris, Euser, and Franken (2010a) assessed attentional biases and food consumption with normal weight and overweight/obese females who were randomly assigned to either a hunger or satiety condition. Eye movements of participants were recorded in response to image pairs consisting of high-calorie snack foods (chocolate, donuts, etc.) and office items (stapler, paperclips etc.). The hungry overweight/obese group tended to have a greater fixation bias to the high-calorie snack foods than the normal weight group. The overweight/obese group also ate significantly more snack food compared to the normal weight group but only in the

hunger condition. Overall, the results suggest that when hungry, overweight/obese individuals display an increased sensitivity to food stimuli (Nijs et al., 2010a).

Graham, Hoover, Ceballos, and Komogortsev (2011) also examined fixation biases to different kinds of food images in participants of varying BMIs by tracking their eye movements. Participants in this study viewed pairs of images from two of the following three categories: high-calorie savory foods (bacon cheeseburger, fried chicken meal etc.), high-calorie sweet foods (chocolate cake, ice cream etc.), and low-calorie foods (fruit, veggie wrap etc.). Total fixation time (average amount of time per trials spent fixating on a particular image in the pair) for each category was analyzed to create an index of maintained fixation and revealed no significant differences for the three categories of food images. However, the low BMI group showed an orienting bias toward high-calorie sweet items, while the high BMI group did not show this type of bias for any food type. The results are opposite from the prediction that people with high BMIs would have increased fixation biases for food stimuli and the researchers suggest that it may be a reflection of negative attitudes towards high calorie foods in overweight individuals (Graham et al., 2011).

Another study (Werthmann et al., 2011) compared BMI groups (overweight/obese females and normal weight females) using eye-tracking measures to assess attentional biases using highly palatable food items (i.e. high in fat) and musical instruments as image pairs. Additionally, food consumption was compared between during a taste test. The overweight/obese group directed their initial fixation more often to the food item than the non-food item when compared to the normal weight group, and this initial

fixation was shorter for the obese/overweight group (although total time spent viewing the two stimuli did not differ). Further, this group ate significantly more of the snack food than the healthy weight group. These results suggest that the overweight/obese group's initial attention bias to the food item may be related to higher intake during the taste test compared to the normal weight group (Werthmann et al., 2011).

The Stroop task. The Stroop Task is used to assess biases in processing of food stimuli. In this paradigm, participants must name, as quickly as possible, the color of the word that appears. In the food Stroop Task, words are those of different kinds of food and neutral items. A longer reaction time in response to the food words is considered to represent an information-processing bias (Phelan et al., 2011). Calitri, Pothos, Tapper, Brunstrom, and Rogers (2010) used the food Stroop Task to see if these attentional biases could predict changes in BMI over a one-year period in first year college students. Stimuli consisted of 10 healthy (spinach, apples etc.) and 10 unhealthy food words (chips, pizza etc.) and 20 "office" words (desk, calculator etc.) presented in the colors red, blue, green, and yellow. The researchers found that a bias for the unhealthy food words was associated with a one-year increase in BMI while a bias for healthy food words was associated with a one-year decrease in BMI.

Phelan et al. (2011) also used the food Stroop Task with participants who were normal weight, obese, or who were currently normal weight and had lost more than 30 pounds at some time in their life (weight loss maintainers). This food Stroop Task consisted of three subtests: one with neutral non-food words, one with common low-calorie food words, and one with common high-calorie food words. Results indicated that

the weight loss maintainer group had a significantly slower reaction time for high-calorie food words than the normal and obese weight groups but no significant differences in reaction time were observed for low-calorie or neutral non-food words. The longer reaction times may be indicative of emotional distraction from the desired or craved stimuli or increased attention to food stimuli due to dietary restriction. Further, the findings indicate that cognitive responses of weight loss maintainers differ from those of normal weight and obese participants.

Altogether, these eye-tracking and Stroop findings highlight the importance of cognitive biases in processing of eating-relevant stimuli. Calitri et al. (2010) conclude that if cognitive biases can be reduced, by cognitive-style interventions or some other means, then possibly BMI and obesity rates could also be reduced.

Functional magnetic resonance imaging. Studies of food motivation and processing have used functional magnetic resonance imaging (fMRI) to look at activation of the brain following exposure to food stimuli. Holsen et al. (2005) studied normal weight children and adolescents in an attempt to identify the normal neural circuitry of food motivation. Participants completed two scanning sessions: one after fasting for four hours (pre-meal) and one immediately after eating a small meal (post-meal). Pictures presented were those of food, animals, and blurred control pictures (for low-level baseline comparison). Analyses revealed that in the pre-meal condition, there was greater activation in the orbitofrontal cortex (OFC) and medial frontal cortex (MFC) to food pictures than non-food pictures, which suggests that these areas may play an important role in food motivation while in a fasting state (Holsen et al., 2005). As mentioned

previously, PYY is a peptide hormone that suppresses intake and research has shown that increased levels of PYY result in decreased activation of the OFC (Batterham et al., 2007). Martin et al. (2010) used the same paradigm with obese and normal weight adults and found that the obese group had greater responses for food pictures in both pre-meal and post-meal conditions in the prefrontal and limbic regions, areas which have been strongly linked to motivational processing (Martin et al., 2010).

EEG. Electroencephalogram (EEG) is used to record responses to stimuli by measuring the electrical activity of the brain. EEG typically records both patterns of wave activity distinguished by their frequency and amplitudes (alpha, beta, gamma, theta and delta waves) and event-related potentials (ERP) (used in the current study), which are the specific neural responses associated with particular events (Luck, 2005). Two ERP components are generally measured: amplitude and latency (Coles & Rugg, 1995). Amplitude can be defined as the difference in voltage between the pre-stimulus baseline and the largest peak of the post-stimulus ERP (Polich & Kok, 1995). Latency is the time from stimulus presentation to the point of maximum amplitude.

The P300 is one of the most widely used ERPs to study attention allocation and immediate memory (Polich & Kok, 1995). This ERP is a positive deflection with a latency of approximately 300ms that has a maximum amplitude over the parietal/central area. The amplitude of the P300 depends in part on the novelty of the stimulus; the more novel the event, the larger the positive amplitude (Coles & Rugg, 1995). Another ERP, the late positive potential (LPP), which is the electrophysiological focus of the current study, has been used to examine motivational systems (Pastor et al., 2008). The latency

window of this ERP can range from 400-800 ms after stimulus onset with larger positivity over centro-parietal areas (Schupp et al., 2000; Pastor et al., 2008). Both the P300 and LPP have been used to study brain responses to pictures of food in individuals of different weights and/or BMIs.

P300 and food stimuli. Nijs, Franken, and Muris (2009) recorded P300 amplitudes after showing food-related stimuli to high and low external eaters. External eating is the tendency to eat when exposed to food-related cues (Nijs et al., 2009) and it was hypothesized that high external eaters would show a larger P300 amplitude in response to food stimuli. Participants for this study were selected based on their scores on the External Eating subscale of the Dutch Eating Behavior Questionnaire (DEBQ; Strein van, Frijters, Bergers, & Defares, 1986). The P300 was chosen because it is assumed to reflect allocated attention to relevant cues. Before starting the EEG session, participants completed self-report questionnaires to assess pre-test food craving and affect. Brain responses were then recorded while viewing pictures of babies, food items (chocolate, fries, etc.), and neutral pictures (stapler, scissors etc.). Post-test food craving was then reported again. These ratings were significantly positively correlated with P300 amplitudes. It was also found that high external eaters had larger P300 amplitudes in response to food pictures compared to low external eaters, leading Nijs et al. (2009) to suggest that high external eaters have stronger craving responses to food-related stimuli and may be more likely to overeat.

Further, Nijs et al. (2010a) investigated processing biases in normal weight and overweight/obese females with the P300. During the EEG recording session, pictures of

food (chocolate, donut etc.) and office items (staper, paperclips etc.) were presented along with pleasant pictures of babies (as controls). Results indicated that (contrary to their hypothesis) an enlarged P300 amplitude was observed in both groups when comparing food and office picture ERPs (Nijs et al., 2010a).

Nijs, Franken, and Muris (2010b) conducted another study measuring the P200 (an attention-related ERP occurring approximately 200 ms post-stimulus) and the P300 with obese and normal weight adults. Participants first reported pre-test food craving and affect. Afterwards, a food-related Stroop task was completed while measuring brain responses. During this task, food (cheese, cookie etc.) and office-related words (tape, printer etc.) were presented and participants were instructed to press the button that corresponded to the font color of the word as quickly as possible. Analyses revealed that P200 amplitudes after food words were larger for the obese group compared to the normal weight group. No such group differences were found for the P300 as larger amplitudes were observed in both groups (Nijs et al., 2010b). These results suggest that in an early stage of processing (as the P200 appears prior to the P300 in the EEG record) the obese participants were already allocating more attention to food-related stimuli, but in a later stage of processing this bias is comparable among BMI groups.

While the P300 provides information specifically about allocation of attentional resources, the LPP is thought to reflect intrinsic motivation and may be a more adequate measure for studying processing of food-related stimuli.

LPP and food stimuli. Nijs, Franken, and Muris (2008) examined brain responses to high-caloric foods (French fries, chocolate etc.) and office items (paperclips,

stapler etc.) in normal and obese participants. Specifically, the researchers were interested in the P300 and the LPP amplitude differences between the two groups. Participants first completed questionnaires assessing their food cravings (General Food Cravings Questionnaire-State; G-FCQ-S) and hunger (VAS Hunger), what they last ate, and their height and weight. They then completed a modified Stroop task (results reported separately in Nijs et al., 2010b), following which ERPs for each food and office item picture were recorded. Afterwards, participants completed a visual analogue scale to assess the arousability and valence of each picture along with the G-FCQ-S and VAS Hunger scales. ERP amplitudes for the P300 and LPP did not differ between groups, though significant positive correlations were found between the P300 and LPP, and between the P300 and hunger (Nijs et al., 2008). These results suggest that the obese and normal weight participants processed the stimuli in a similar manner. It may be that the food cravings and hunger questionnaire cued the participants as to what the researchers were studying or adding another component (the modified Stroop task) affected the ERP results.

Another study (Stockburger, Schmälzle, Flaisch, Bublatzky, & Schupp, 2009) assessed the relationship between food deprivation and processing of food pictures with the LPP. Healthy male and female participants completed both food deprived (for 24 hours) and satiated (followed normal eating habits) conditions one week apart. Each testing session consisted of participants freely viewing pictures of appetizing main dishes, flowers, and pleasant, unpleasant, and neutral stimuli while recording ERPs. The food deprivation condition resulted in significantly enhanced positive amplitudes to food cues

as indexed by the LPP compared to the satiated state. It is important to note that these results were recorded while there was no task (i.e. attentional) involved, suggesting that motivational regulation (reflected by the LPP) is involuntary (Stockburger et al., 2009).

Blechert, Feige, Hajcak, and Tuschen-Caffier (2010) studied cue reactivity to high-caloric foods to determine in which conditions responses would be enhanced. They did this by manipulating the availability of the food that was presented during EEG recording. During the first block (passive) of EEG recording, participants viewed food pictures (fast food, sweets, deserts) along with pleasant, neutral and unpleasant pictures. In the second block, the same pictures were presented but participants were told they would have to eat some of the items later. Participants for this study were chosen on the basis of their score on the Restraint Scale (Dinkel, Berth, Exner, Rief, & Balck, 2005), a measure that assesses balance between desire for food and efforts to resist the desire, and separated into restrained and unrestrained eaters. Analyses showed that both the restrained and unrestrained eaters had comparable LPP amplitudes to food pictures in the passive viewing block. However, during the block in which food was available, restrained eaters' LPP amplitudes were smaller compared to their amplitudes in the passive viewing block, suggesting that cognitive control was exerted in response to food cues and that different types of eaters may use different mechanisms when confronted with food-related stimuli (Blechert et al., 2010).

Lastly, Svaldi, Tuschen-Caffier, Peyk, and Blechert (2010) measured the LPP and Slow Positive Wave (SPW – an index of sustained attention) in response to food pictures, but using different types of food items. There were two groups of participants: the first

met the DSM criteria for Binge Eating Disorder (BED) and the second who were overweight without a diagnosis of BED. They rated their feelings of hunger, food craving, and emotion before viewing the pictures of food. In the viewing session, participants saw food pictures of both high-caloric (i.e. high in fat and sugar) and low-caloric foods (fruits, vegetables etc.) while ERPs were recorded, following which they rated each picture on palatability and forbiddance. The amplitudes for both the LPP and SPW were larger in the BED group compared to the "healthy overweight" controls, indicating a strong appetitive response for BED participants (Svaldi et al., 2010).

Methodological Issues

After reviewing the relevant literature, it is clear that the ERP data are inconsistent regarding attentional biases of food-related stimuli in overweight/obese individuals. This may in part be due to the methodological differences. The following have been cited by researchers as possible factors contributing to the inconsistencies: food deprivation level, self-report biases, time of day the session was conducted, gender of participants, matching of control stimuli, and distinction between overweight and obese participants (Nijs & Franken, 2012). The results of the current study will be interpreted in the context of the previous research.

Proposed Study

Goals. The proposed study will examine the relationship between BMI, ERPs, and self-report of food cravings and hunger. The ERP of interest is the LPP, which occurs 400-800ms after stimulus onset.

Definition of variables. Two independent variables will be used: (1.) photo type (high-calorie foods and office furniture) and (2.) BMI (quasi-independent; low to normal L/N and overweight to obese O/O). Several variables will be measured: (1.) hunger ratings via a Visual Analogue Scale for Hunger (VAS Hunger); (2.) food craving from the Preoccupation with Food subscale General Food Cravings Questionnaire-Trait (G-FCQ-T); (3.) mean LPP amplitude; (4) valence and arousability of stimuli with a VAS for Valence and Arousal (VAS Valence and VAS Arousal).

Hypotheses:

1. Scores on the Preoccupation with Food subscale of the G-FCQ-T will be significantly higher for the high BMI group compared to the low BMI group.
2. LPP amplitudes for food pictures will be significantly positively correlated with BMI.
3. LPP amplitudes for office furniture pictures will not be significantly correlated with BMI.
4. LPP amplitudes will be significantly larger for food pictures than for office furniture pictures.
5. LPP amplitudes for food pictures will be significantly larger for the high BMI group compared to the low BMI group.

6. LPP amplitudes for office furniture pictures will not significantly differ between the two BMI groups.

Methods

Participants

Twenty-eight participants (16 females and 12 males {19-52 years old}; mean = 23.46 years, *SD* = 1.26) were recruited from the SONA system at the University of Wisconsin Oshkosh. Participants were non-smokers with normal or corrected to normal vision (with contacts) and normal hearing. Ninety-six percent were Caucasian, 82% were right-handed, and none reported a history of mental illness. All participants received course credits or extra credit for their participation.

Materials

Self-report questionnaires. Three separate questionnaires were used to gather data about hunger status, valence of stimuli, and craving for food.

Visual analogue scales (VAS). In order to assess subjective hunger states of participants, a visual analogue scale (VAS Hunger; Appendix A) was used. Participants were asked four questions regarding their current state of satiety and subsequently indicated their response by placing a vertical line on a 10-point scale (Murano, Talcott, Hernandez, Wan, & Gearing, n.d.). An additional VAS (VAS valence and arousal; Appendix B) was used to rate the valence (0 = very unpleasant, 9 = very pleasant) and arousability (0 = not at all arousing, 9 = very arousing) of each food and office furniture picture.

General food cravings questionnaire-trait (G-FCQ-T). To evaluate food craving, participants completed the Preoccupation with Food subscale of the Trait version of the G-FCQ (Cepeda-Benito et al., 2000; Nijs, Franken, & Muris, 2007; Appendix C). This subscale contains six items that measure obsession with thinking about food and eating. Chronbach's α for the complete scale is .90 (Nijs et al., 2007).

Stimuli. Two types of pictures (gathered from the internet) were shown to the participants: unhealthy foods (e.g. cake, pizza, ice cream) and office furniture (e.g. desk, chair, lamp), the latter of which served as affectively neutral stimuli (see Appendix D for examples). Both categories contained 20 pictures and were standardized for length, height, and background luminance. In each phase of the study every picture had a duration of 1500ms and the inter-stimulus interval was 2000ms.

The pictures were presented using E-Prime (Psychology Software Tools Inc., Pittsburgh, PA) running on a 17-inch Hewlett-Packard monitor with a resolution of 1024 x 768 pixels. The participants were seated approximately 60 cm from the monitor.

Electroencephalography (EEG) equipment. The EEG data were recorded with the Biopac MP150 (©BIOPAC Systems, Inc.) system and AcqKnowledge (AcqKnowledge® 4.2.0) software package, running on a Macintosh computer (Apple Inc.®). An EEG cap (Electro-Cap International, touch proof, CAP100C, with electrodes in the international 10/20 montage) was used to collect the ERP data.

Procedure

Figure 1 shows the general procedure for all participants. All testing sessions occurred between 12:00 and 5:00 PM. When registering for a session participants were instructed to remove all jewelry, including piercings & studs and refrain from eating or drinking (water was allowed) for one hour before the scheduled session in order to have all participants in a comparable hunger state. The subscale of the GFCQ-T was completed when the participants registered on SONA. The participants first read and signed the informed consent form (Appendix E) and the researcher addressed any questions or concerns after which the experiment began.

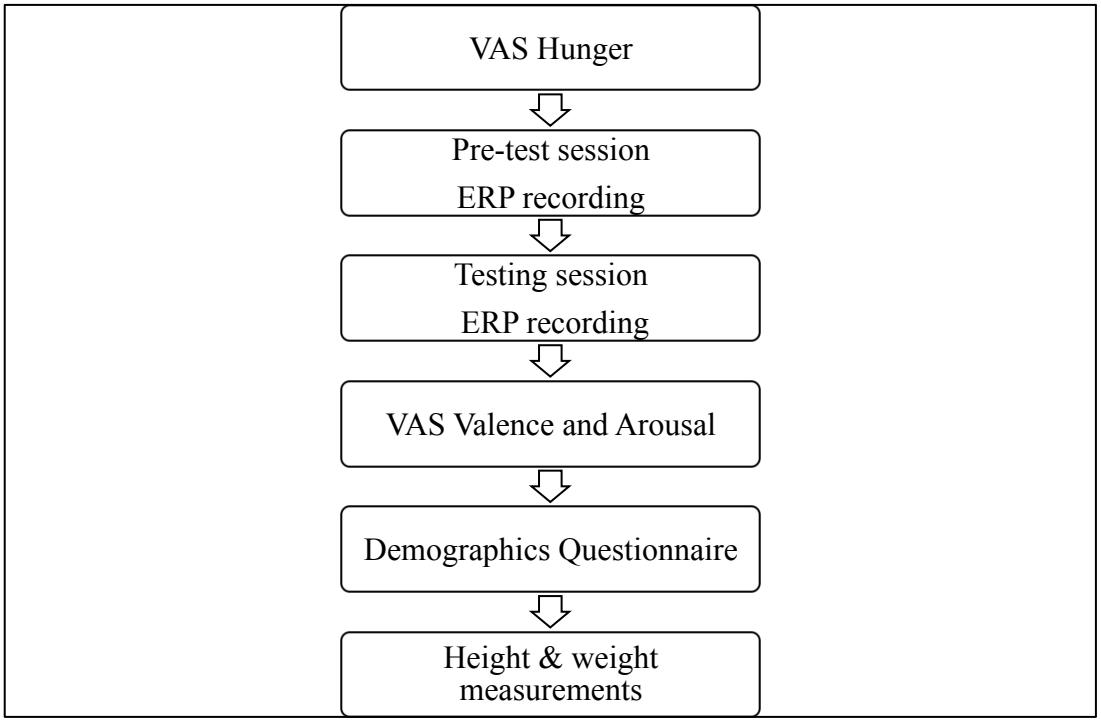


Figure 1. Flowchart of procedure.

Participants first completed the VAS for Hunger in order to obtain baseline hunger scores. The participants were then fitted with the EEG cap.

Due to differences in head sizes, the researcher measured the circumference of the participant's skull from the naison to the inion for fitting of the appropriate EEG cap (refer to figure 2 and 3) which was available in three sizes: small (50-54cm); medium (54-58cm) and large (58-62cm). The EEG cap was then placed on the participant's head and properly adjusted: after having anchored it down to a chest strap and holding it in place with two adhesive discs (corresponding to FP1 and FP2) on the forehead, electrode CZ (see figure 3) was positioned at the junction of halfway between the ears and halfway between the nasion and inion (see figure 2).

The scalp under each electrode of interest (P3, P4, PZ, CZ) was then gently abraded with a blunt-end needle and each electrode was filled with Signa electrode gel (GEL101). Electrode CZ was used as the reference electrode, and the ground electrode was placed on the middle of the forehead below the EEG cap. Vertical eye movements (EOG) were recorded via 4mm electrodes - one each above and below the right eye. The EEG and EOG activity were filtered with a bandpass of 0.1-35 Hz at a sampling rate of 625 Hz, and with a gain of 20,000. Impedance of less than 5KΩ (Checktrode UFI model 1089ES; see figure 5) was required for each electrode before recording. Impedance was checked again at the end of the procedure to ensure that electrode recording integrity had remained consistent throughout the recording session.

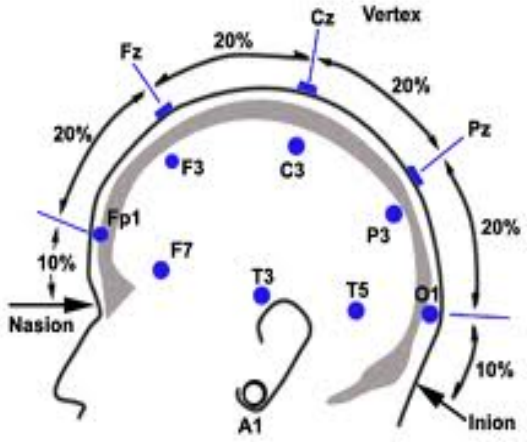


Figure 2. Nasion & Inion

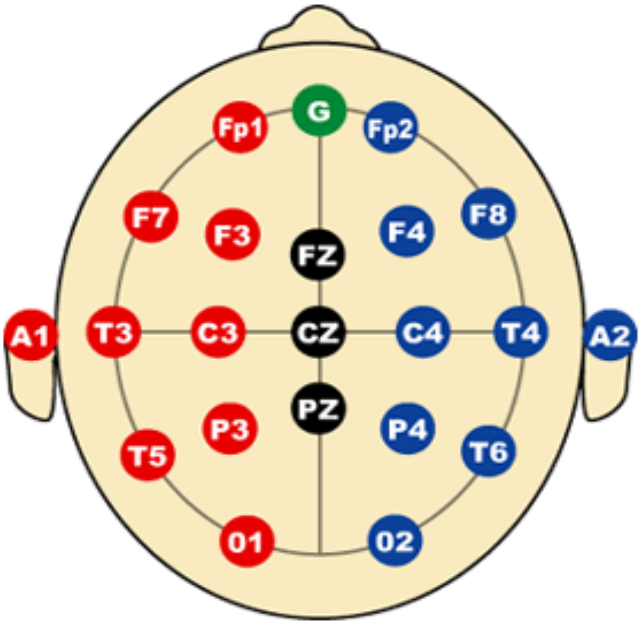


Figure 3. Electrodes of interest: P3, P4, PZ

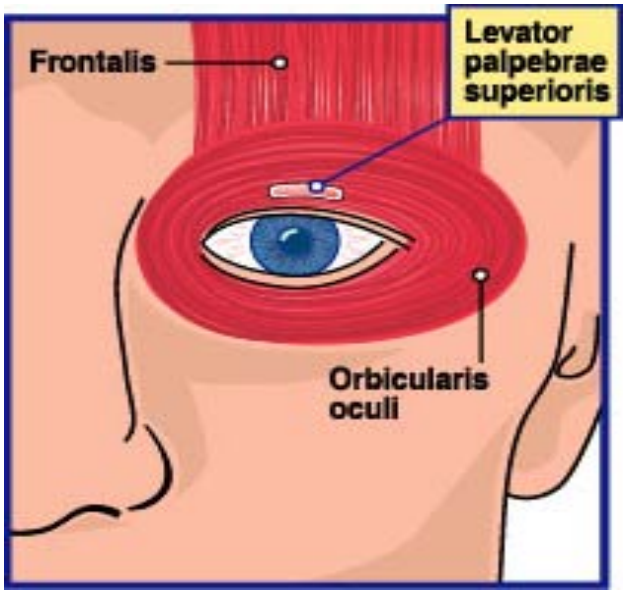


Figure 4. Eye and eye-lid muscles involved in blinking and other eye-movements, of importance in the measurement of EOG.

Figure 5. Checktrode box used to ensure proper operation of EEG equipment.

Pre-test session. Participants underwent a pre-test session to (1) check for proper functioning of the EEG recording system and (2) familiarize them with the procedure that would occur during the testing session. Fifteen pictures of neutral items (tools) were presented two times each for a total of 30 trials and a total viewing time of 1.75 minutes. Participants were instructed to pay attention to the pictures as they would evaluate them afterwards.

Testing session – EEG. Participants were again reminded to pay attention to the pictures as they would be evaluating them afterwards. Pictures were presented in semi-random order such that no more than two pictures of the same category were shown consecutively. All 40 pictures were presented four times for a total of 160 trials and a total viewing time of 9.33 minutes while EEG (and EOG) data were collected. A fixation cross appeared on the screen for the duration of each interstimulus interval (2000ms) and stimulus onset was marked on the EEG timescale using a five volt pulse sent from the stimulus presentation computer (via E-prime) through a parallel port to the EEG recording computer.

Testing session – VAS valence and arousal ratings. Participants then viewed the pictures again but this time rated each food and office furniture picture for valence and arousability. After the viewing session was completed, and following the final impedance check, participants were detached from the EEG electrodes.

BMI and additional data. Participants then completed the demographics questionnaire (Appendix F) and reported what and when they last ate. Finally, the

researcher collected height and weight data from the participants with a tape measure and digital scale in order to calculate their BMI.

After data collection was completed, participants read the debriefing form (Appendix G) and the researcher answered any questions and thanked the participant for their time.

Data Preparation

Screening of EEG data. Following data collection, offline EOG artifact removal was performed (using Acq EOG artifact removal tool). Based on previous research, the LPP was quantified as the mean amplitude during 400-800ms after stimulus presentation (LPP time window). For each trial, mean amplitude for the 200ms before stimulus onset (baseline) was then subtracted from the mean amplitude from 400-800ms post-stimulus (LPP time window) amplitude to arrive at the final LPP amplitude for that trial. LPP amplitudes were calculated in this way (per participant) for all 160 trials from each electrode (P3, P4, and PZ) for both picture types. For each participant the final LPP amplitudes (400-800ms post - 200ms pre) were then averaged separately for food and office furniture pictures such that each participant ended up with one LPP mean amplitude for food pictures and one LPP mean amplitude for office furniture pictures. These amplitudes were then subjected to the analyses described below.

Statistical analyses. The scale for weighing participants was inaccurate for the first two participants, so their self-reported weights from SONA were used to calculate their BMIs. The remaining participants' BMIs were calculated from weights measured at

the time of the study. BMI groups were separated using the classifications specified by the National Institute of Health (n.d.): BMIs 24.9 and below were categorized as low to normal (L/N) and BMIs 25.0 and above were categorized as overweight to obese (O/O). This resulted in two groups of 14. In addition, as the BMI cutoff for the L/N and O/O groups is somewhat arbitrary (though based on established standards for BMI categorization), and with the rationale that any relationship between BMI and ERPs would most likely be revealed by looking at the extremes (low and high) of the sample distribution, participants with the seven highest and seven lowest BMIs were selected to create two BMI sub-groups (low: 17.1-20.9; and high: 29.8-34.2; N=14) which were used for ERP comparisons. Data from both sets of participants (N=28 and N=14) were subjected to the following analyses.

Independent t-tests were conducted to determine if the L/N groups differed significantly for (1) BMI, (2) VAS Hunger ratings, (3) valence and arousal ratings and (4) total scores on the G-FCQ-T (hypothesis 1).

Two Pearson r's were used to establish the degree and direction of any relationship between (1) BMI and VAS Hunger scores to determine if the VAS Hunger would be used as a covariate in other analyses and (2) items on the VAS Hunger.

Dependent t-tests were done to determine if ratings were significantly different for food and office furniture pictures on (1) the VAS Valence and (2) the VAS Arousal.

Further, for the High and Low BMI subgroups (N-14), ERP data (from each electrode individually and from the combined "cluster" of all three electrodes) were subjected to the following analyses.

Pearson r's determined (1) the relationship between food LPP amplitudes and BMI and (2) the relationship between office furniture LPP amplitudes and BMI (hypotheses 2 and 3).

Dependent t-tests were conducted to see if LPP amplitudes were significantly different for food and office furniture pictures (hypothesis 4).

Lastly, independent t-tests were conducted to determine if LPP amplitudes differed significantly between the subgroups for (1) food pictures and (2) office furniture pictures (hypotheses 5 and 6).

Results

BMI Analyses

When groups were segregated into low to normal (L/N) and overweight to obese (O/O), the mean BMI for L/N was 21.02 (*SD* = 2.14) and the mean for O/O was 29.76 (*SD* = 3.05). An independent t-test revealed that these differences were statistically significant, $t(26) = -8.76$, $p < .001$. Further, a second independent t-test was done for the seven low (*M* = 19.19, *SD* = 1.25) and seven high (*M* = 32.36, *SD* = 1.80) BMIs which resulted in significant differences between the two groups, $t(12) = -15.87$, $p < .001$.

Questionnaire Analyses

VAS hunger. Independent t-tests revealed no significant group differences for any items on the VAS Hunger for both sets of participants (N = 28 and N = 14). Means and standard deviations are presented in Table 1.

Table 1. *Means and Standard Deviations of VAS Hunger Scores.*

	Low to Normal			Overweight to Obese		
	N	*M*	*SD*	*N*	*M*	*SD*
1. How hungry do you feel	14 (7)	4.21 (4.00)	2.25 (2.31)	14 (7)	4.18 (3.57)	2.57 (2.07)
2. How full do you feel	14 (7)	5.00 (5.14)	2.30 (2.67)	14 (7)	4.61 (4.79)	1.89 (2.23)
3. How satisfied do you feel	14 (7)	5.50 (5.00)	1.79 (1.53)	14 (7)	4.46 (4.79)	1.88 (2.16)
4. How much do you think you can eat right now	14 (7)	4.89 (4.50)	1.93 (1.38)	14 (7)	5.21 (4.57)	1.99 (2.01)

Note. ERP subset data is in parentheses. Maximum possible VAS Hunger score = 10

Correlational analyses revealed that VAS Hunger scores for all items were not significantly related to BMI for data when including all 28 participants or when using the ERP subset's BMIs. As such, VAS Hunger scores were not used as a covariate in subsequent analyses.

Pearson r's were calculated for items on the VAS Hunger. As expected, 'how hungry do you feel' was negatively correlated with 'how full do you feel' ($r(28) = -.60$, $p = .001$), and positively correlated with 'how much do you think you can eat right now' ($r(28) = .81$, $p < .001$). Although not significant, 'how hungry do you feel' and 'how satisfied do you feel' were correlated in the expected direction ($r(28) = -.32$, $p = .10$) as other factors likely affect satisfaction, not just hunger levels. Significant correlations were found for 'how full do you feel' with (a) 'how satisfied do you feel' ($r(28) = .57$, $p = .002$) and (b) 'how much do you think you can eat now' ($r(28) = -.52$, $p = .005$). Additionally, 'how satisfied do you feel' was negatively correlated with 'how much do you think you can eat now' ($r(28) = -.42$, $p = .03$). The general pattern was the same for the ERP subsets although only two of the six correlations were statistically significant. 'How full do you feel' was positively correlated with 'how satisfied do you feel' ($r(14) = .69$, $p = .007$), and 'how hungry do you feel' was positively correlated with 'how much do you think you can eat now' ($r(14) = .78$, $p = .001$).

VAS valence and arousal. As a manipulation check, two separate paired-samples t-tests were run on the valence and arousal ratings between the food and office items. As expected, food pictures were rated significantly more pleasant ($M = 5.82$, $SD = 1.41$) than

office furniture pictures (M = 3.95, SD = 1.39), $t(27) = 5.47$, $p < .001$, and food pictures were rated as significantly more arousing (M = 4.93, SD = 1.46) than office furniture pictures (M = 2.31, SD = 1.28), $t(27) = 7.00$, $p < .001$. A similar pattern of results was found for the ERP subset. Food pictures were rated more pleasant (M = 5.78, SD = 1.62) than office furniture pictures (M = 4.17, SD = 1.42), $t(13) = 2.55$, $p = .02$, and food pictures were rated more arousing (M = 4.92, SD = 1.42) than office furniture pictures (M = 2.65, SD = 1.38), $t(13) = 3.39$, $p = .005$. Figure 6 shows VAS valence and arousal ratings across groups.

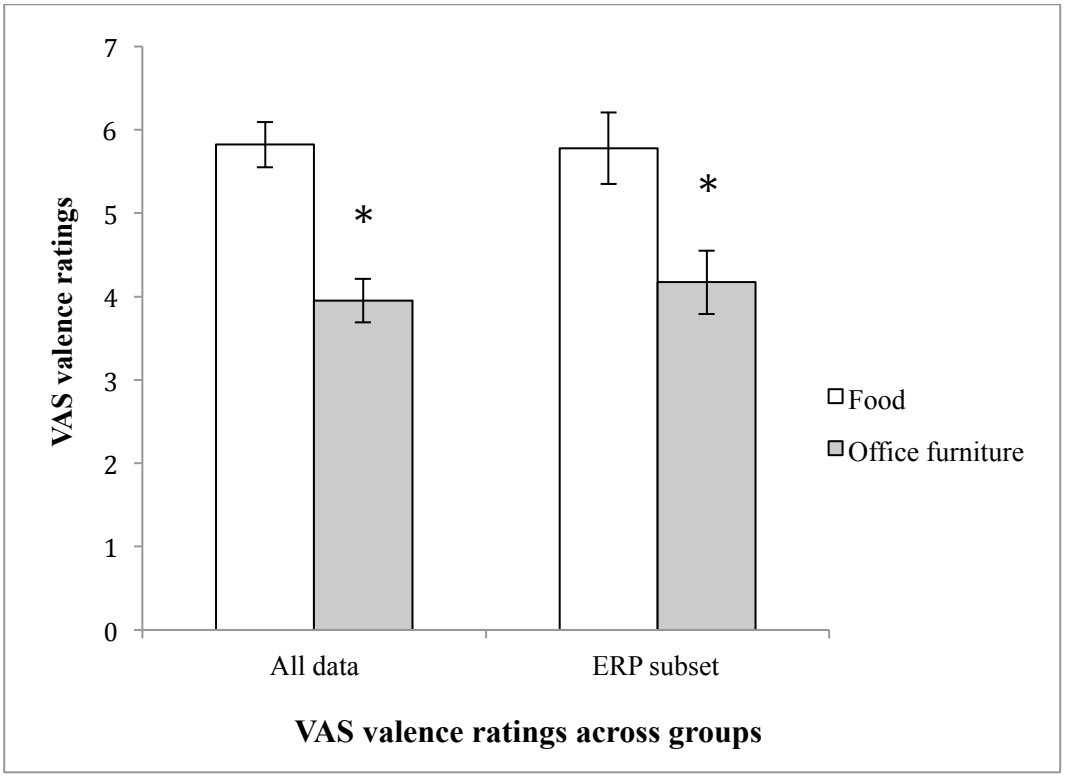


Figure 6a. VAS ratings for valence across groups. (*$p < .05$)

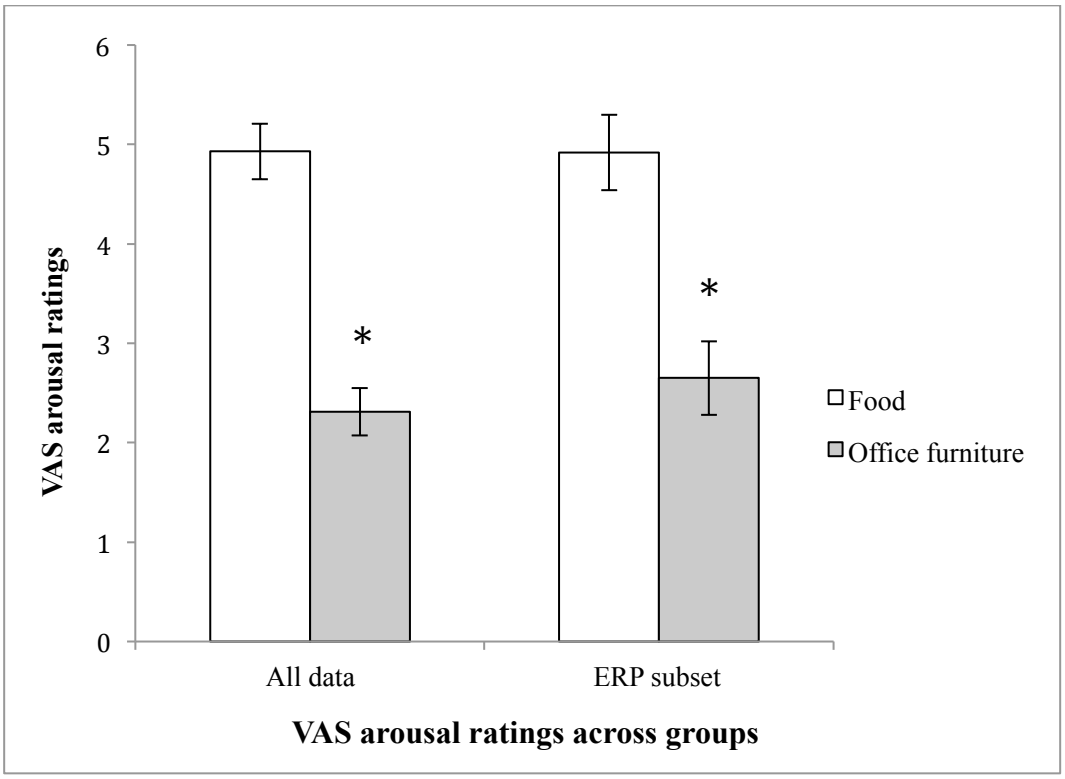


Figure 6b. VAS ratings for arousal across groups. (*$p < .05$)

Independent t-tests revealed that valence ratings on the VAS for food pictures were not significantly different for the L/N ($M = 5.95$, $SD = 1.54$) and O/O groups ($M = 5.69$, $SD = 1.31$), $t(26) = .47$, $p = .64$. No differences were found for valence ratings on the VAS for office pictures either for the L/N ($M = 3.83$, $SD = 1.56$) and O/O groups ($M = 4.07$, $SE = 1.23$), $t(26) = -.47$, $p = .65$. There were no significant differences found for arousal ratings for the L/N ($M = 5.35$, $SD = 1.36$) and O/O ($M = 4.51$, $SD = 1.48$) groups on the VAS for food, $t(26) = 1.57$, $p = .13$, or for office furniture pictures between the L/N ($M = 1.99$, $SD = 1.41$) and O/O ($M = 2.64$, $SD = 1.09$) groups, $t(26) = -1.35$, $p = .19$. When examining the data with the ERP subset, again, no significant differences for valence ratings of food pictures were found between the low ($M = 5.82$, $SD = 1.81$) and

high (M = 5.74, SD = 1.56) BMI groups, $t(12) = .09$, $p = .93$, or for office furniture picture ratings (low: M = 4.13, SD = 1.86; high: M = 4.21, SD = .93), $t(12) = -.11$, $p = .92$. Food picture ratings for arousal were also not significantly different between the low (M = 5.12, SD = 1.61) and high (M = 4.71, SD = 1.29) BMI groups $t(12) = .52$, $p = .61$, or for office furniture picture arousal ratings (low: M = 2.02, SD = 1.66; high: M = 3.29, SD = .65), $t(12) = -1.88$, $p = .09$.

G-FCQ-T. An independent t-test revealed no significant differences for total scores on the subscale of the G-FCQ-T between the L/N (M = 13.75 SD = 5.66) and O/O (M = 15.75, SD = 6.92) groups, $t(22) = -.78$, $p = .45$. No differences were found for total scores for the ERP subset either for the low (M = 10.67, SD = 2.66) and high (M = 14.00, SD = 6.93) BMI groups, $t(10) = -1.10$, $p = .30$.

EEG Analyses

Correlations were run between individual electrode mean LPP amplitudes and BMI (low and high BMI subgroups combined) and between the cluster (average of P3, P4, and PZ) and BMI for both food and office furniture pictures. Results are presented in Table 2.

Table 2. *Pearson Correlations for Food and Office Mean LPP Amplitudes and BMI.*

	P3	P4	PZ	Cluster
Food pictures	-.158	.204	-.008	-.031
Office pictures	-.259	.173	-.037	-.133

Note. Correlations were not statistically significant.

Paired samples t-tests were run on individual electrode mean amplitudes and the cluster for food and office furniture pictures. No significant differences were found between food picture (M = 1.69, SD = 1.83) and office furniture picture mean LPP amplitudes (M = 1.09, SD = 1.62) at PZ, $t(13) = 1.72$, $p = .11$. However, significant differences were found for both P3 and P4. Mean amplitudes for food pictures (M = .49, SD = 3.36) were significantly larger than office furniture picture mean amplitudes (M = -.21, SD = 3.36) at P3, $t(13) = 3.19$, $p = .007$, and at P4 (food: M = 1.75, SD = 1.91; office furniture: M = 1.04, SD = 1.98), $t(13) = 3.10$, $p = .008$. Results for the cluster between food and office furniture pictures also revealed a significant difference. Food picture mean amplitudes (M = 1.31, SD = 1.66) were significantly larger than office furniture mean amplitudes (M = .64, SD = 1.47), $t(13) = 2.79$, $p = .02$. Figure 7 shows LPP mean amplitudes for both individual electrodes and the cluster by picture type.

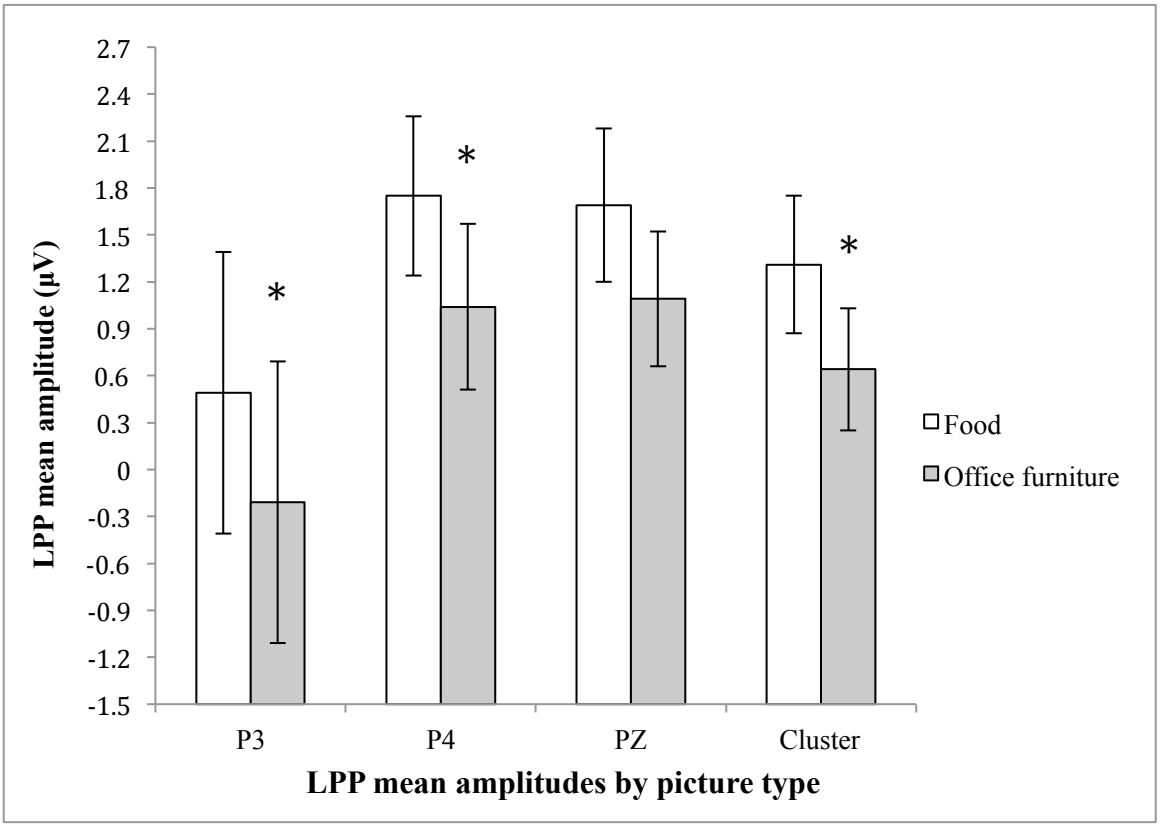


Figure 7. LPP mean amplitudes for all individual electrodes and the cluster for food and office furniture pictures. (*p < .05)

Independent t-tests looking for LPP amplitude differences between the high and low BMI groups for the individual electrodes and the cluster revealed no significant differences between BMI groups. Results are reported in Table 3.

Table 3. *Means and Standard Deviations of LPP Mean Amplitudes by BMI Group.*

	P3	P4	PZ	Cluster
Food pictures (low BMI)	1.19(1.83)	1.49(1.72)	1.89(2.38)	1.52(1.70)
Food pictures (high BMI)	-0.21(4.47)	2.01(2.19)	1.49(1.21)	1.09(1.73)
Office pictures (low BMI)	0.79(1.78)	0.85(0.94)	1.31(1.67)	0.98(1.24)
Office pictures (high BMI)	-1.21(4.36)	1.24(2.74)	0.88(1.68)	0.30(1.70)

Note. Standard deviations are in parentheses.

Discussion

This study investigated the relationship between BMI, self-assessment of hunger and cravings, and brain activity (ERP) related to the processing of food and affectively neutral (office furniture) images. LPP mean amplitudes for food pictures were analyzed for any significant differences between subsets of the low and high BMI groups. Additionally, self-report data for the VAS Hunger, VAS Valence and Arousal, and G-FCQ-T were also examined to look for differences between the stimulus types, the two groups and any relationship with BMI.

BMI

The division of the participants at both levels (full sample of 28 and ERP subset of 14) into L/N (and low BMI) and O/O (and high BMI) used the established standard for BMI designation and resulted in groups whose BMIs differed significantly from each other (L/N vs. O/O and low BMI vs. high BMI). Despite this, the distribution of BMIs within our sample is multi-modal rather than bell-shaped and is not positively skewed as has been modeled for state and US populations (Penman & Johnson, 2006). While this may raise questions as to representativeness, the sample mean BMI (25.39) is close to the mean BMI of Wisconsin (26.62). Further, the segregation into subgroups resulted in low and high BMI groups whose means were more than two standard deviations (SD of entire sample of 28) apart in an attempt to create highly disparate BMI groups with the goal of

revealing any relationships between BMI and hunger reports or ERPs. While this did not have the desired effect in that several hypothesized differences were not found, the small sample sizes may be a contributing factor. These results are discussed in more detail below.

Self-Report Questionnaires

VAS hunger. Scores on the VAS Hunger did not differ between the L/N and O/O BMI groups (or subgroups) and were not related to participants' BMIs. This common baseline level of huger state helped control for potentially different levels of hunger-related motivation that might have impacted both the perception of the food stimuli and any accompanying neurological events. Our participants were instructed not to eat at least 1 hour prior to the testing session, and similar instructions to not eat for the few hours before the start of a testing session resulted in a similar lack of differences in hunger levels between restrained and unrestrained eaters (Blechert, 2010). However, and particularly relevant to the high and low BMI groups used here, when Nijs et al. (2008) instructed normal weight and obese participants to refrain from eating two hours prior to the start of a study, subjective hunger levels in the normal participants were higher at both the pre- and post-test ratings. Controlling for pre-testing hunger levels was integral to the current study, but in future it may also be valuable to collect post-testing hunger ratings as the viewing of food pictures may instigate appetitive processes (both cognitive and physiological) leading to differentially increased feelings of hunger in people with different BMIs.

Correlational analyses of the four VAS Hunger items revealed relationships in the expected directions. For example, the question 'how hungry do you feel' was positively correlated with 'how much do you think you can eat right now' and negatively correlated with 'how full do you feel' (significantly) and 'how satisfied do you feel' (non-significantly). An examination of the VAS Hunger means for the L/N and O/O groups shows essentially identical hunger ratings in both groups, but lower scores on the fullness and satisfaction ratings in the O/O group along with higher ratings on how much food could be eaten at that time. Thus, the relationship of satisfaction-to-how-much is opposite in the two groups, with relatively higher satisfaction ratings compared to how- much ratings in the L/N group and lower satisfaction ratings relative to how-much ratings in the O/O group. The directions of these differences provide some evidence for opposite perceptions that link satisfaction to future food intake, particulary in terms of portion size or total amount eaten. The degree to which this satisfaction is related to obesity or being overweight remains to be determined. For example, Ello-Martin, Ledikwe, and Rolls (2005) report that even with increased intake in the form of larger portions, people don't report they feel fuller or respond to the increased intake by decreasing subsequent intake.

VAS valence and arousal. As predicted, food pictures were rated significantly more pleasant and arousing than office furniture pictures. However, there were no differences on ratings between the L/N and O/O BMI groups (or subgroups). This is in line with previous research (Nijs et al., 2008) which found no group differences on a similar task. A factor that could have impacted valence and arousal ratings is hunger levels as Stockburger et al. (2009) found that participants who were food deprived for 24

hours rated food pictures significantly more pleasant and arousing than satiated participants (self reports of hunger in food-deprived participants were significantly higher than those from the satiated group). Ratings for flower pictures did not differ based on the experimental condition (Stockburger et al., 2009). However, we found no differences in hunger levels while still finding significant differences in arousal and valence ratings of food vs. non-food stimuli. Thus, it may be that hunger alone is not sufficient to create differences in the affective processing of food vs. non-food stimuli, but is only one of the contributing factors, though BMI does not appear to be one of these factors.

G-FCQ-T. Contrary to the hypothesis that craving scores would be significantly higher for the O/O group compared to the L/N group (and for the high BMI group compared to the low BMI group), no group differences were found for the total subscale score on the G-FCQ-T. Previous research on trait cravings has been conflicting. Franken & Muris (2005) found a significant positive relationship between BMI and scores on the Food-Cravings Questionnaire with 99 participants (FCQ-T; Cepeda-Benito et al., 2000). Conversely Graham et al. (2011) found no differences between the high and low BMI groups on the Revised Food-Cravings Questionnaire trait version. Sample sizes for the present study (N = 28) and for that of Graham et al.'s (2011; N = 36) were relatively small, which may account for some of the differences in the findings.

While the trait version of the G-FCQ is theoretically designed to measure a relatively stable characteristic (or trait) related to craving for food, internal (hunger level, for example) and external (time of day; if the participant were alone or with others) factors at the time of completing the survey likely impacted the scores, perhaps obscuring

any differences in trait craving related to BMI, especially in the high and low BMI subgroups**.** Additionally, all of the items in the G-FCQ-T subscale are coded in the same direction and this may suppress self-assessments of high ratings as these may appear socially undesirable, especially to those with higher BMIs. Perhaps including these items as part of another instrument or interspersed within a series of demographic and other questions would help counter the obvious intent of the six items on the G-FCQ-T.

EEG Data

As predicted (hypothesis 4), LPP amplitudes for the food pictures were significantly larger than those for office furniture pictures at P3, P4, and the posterior cluster but not at PZ. In fact, the results for PZ are in line with previous research where Blechert et al. (2010) found no significant differences between food and neutral items for the LPP at PZ. Previous research examining the LPP with two posterior clusters of electrodes had comparable results. Nijs et al., (2008) found significant differences for food and office item LPP mean amplitudes at the left posterior cluster (P1, P3, P5, P7, P9, PO3, PO7, and O1), and right posterior cluster (P2, P4, P6, P8, P10, PO4, PO8, and O2) but found no significant differences between hemispheres, and they did not examine LPPs at PZ.

The larger LPP mean amplitudes for food pictures fits with previous research that looked to see if brain processing is modulated by emotional (pleasant and unpleasant) stimuli (and in comparison to neutral stimuli). Schupp et al. (2000) found that LPP amplitudes were significantly larger in response to both pleasant and unpleasant pictures

compared to neutral pictures at parietal electrode sites (PZ, P3, and P4). Another study also found that LPP amplitudes were larger for affective stimuli than neutral stimuli (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). Moreover, LPP amplitudes in this study were positively correlated (r = .73) with arousal ratings: the higher the rating the larger the LPP amplitude (Cuthbert et al., 2000). The food pictures used in the current study fall into the affective stimuli category, as evidenced by significantly larger (68% larger for the cluster) LPP mean amplitudes and higher VAS valence and arousal ratings for food compared to office furniture pictures.

The lack of significant correlations between LPP mean amplitude and BMI for food or office furniture pictures for individual electrodes and the posterior cluster is also in agreement with previous results from patients with BED and "healthy overweight" controls (Svaldi et al, 2010). Although our participants do not match with the BED patients, some of the O/O participants would be considered overweight but not necessarily unhealthy (we did not perform a general health screening; one of the participants reported being diabetic). However, of the seven high BMI participants for whom we examined LPP data, only one was below the cutoff for a categorization of obese and then barely so (at 29.8). If in fact there were some linear relationship between BMI and LPP amplitude, it would likely be evident at the extreme ends of the BMI scale, both of which we examined. One could hypothesize that processing of the affective value of food stimuli (and its neurological correlates, such as the LPP) would be most accentuated (or non-prominent) at these poles (high and low ends respectively) of the BMI scale if indeed BMI were strongly related to such processing. Our prediction along

those lines (hypothesis 5) was not supported, though, as LPP amplitudes for food pictures were not higher in the high BMI group compared to the low BMI group for the individual electrodes or the posterior cluster. Further, LPP amplitudes for office furniture pictures were not significantly different for the two groups for the posterior cluster and individual electrodes. Thus, although the LPP amplitudes reflect a strong difference of processing of affective and neutral stimuli, this processing does not appear to interact with BMI.

Conclusions and Future Directions

Overall, the data from the current study are both in agreement with and differ from previous studies. We confirm results that reported no predictable relationship between BMI and ERPs, specifically the LPP, as well as between BMI and processing of food pictures. The larger LPP amplitudes produced by the food as compared to the office furniture pictures also are aligned with prior results and support the concept of the LPP as a neural event associated with affective processing. To further investigate the LPP in the context of food stimuli, and to determine more completely what impact, if any, BMI may have on this ERP, additional studies could focus on another aspect of food-related affect such as craving. For example, it is possible that, by priming participants of different BMIs for craving, valence and arousal perceptions of food pictures will be differentially activated and accompanied by differential brain activity. Other BMI-related studies could examine the effects on ERPs of manipulating levels of motivation to eat by using a pre-test eating session or different lengths of fasting prior to testing combined with a range of healthy and unhealthy foods as stimuli. It is possible that as motivation to eat increases,

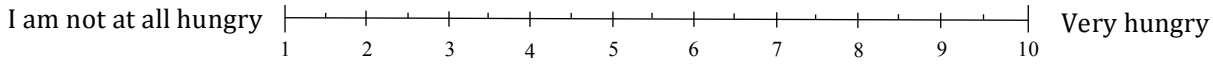
food becomes increasingly salient and hedonically attractive, and further that this effect may vary with different types of food.

APPENDIX A

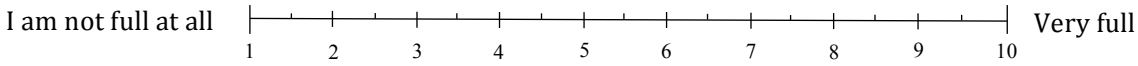
VAS Hunger

Please respond to the following questions by placing a vertical line on the scale

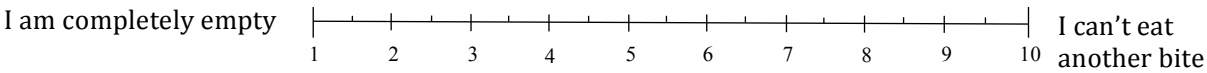
1. How hungry do you feel?



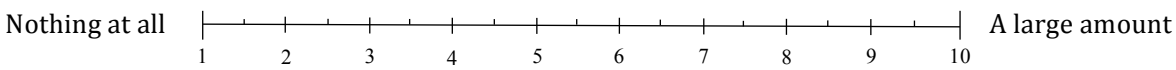
2. How full do you feel?



3. How satisfied do you feel?



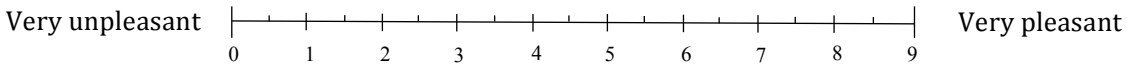
4. How much do you think you can eat now?



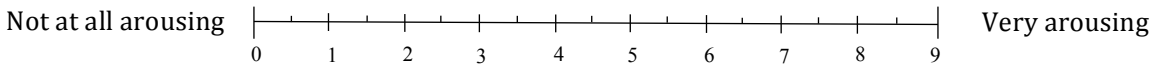
APPENDIX B

VAS Valence and Arousal

Please rate this picture from very unpleasant to very pleasant by typing the number that corresponds with your rating. Then press enter to continue.



Please rate this picture from not at all arousing to very arousing by typing the number that corresponds with your rating. Then press enter to continue.



APPENDIX C

GFCQ-T Subscale

Directions: Please indicate the extent to which the item would be *generally* true for you. Use the following scale from 1 to 6 for your responses.

1	2	3	4	5	6
Never/Not Applicable	Rarely	Sometimes	Often	Usually	Always

_____ 1. I feel like I have food on my mind all the time
_____ 2. I can't stop thinking about eating no matter how hard I try
_____ 3. I find myself preoccupied with food
_____ 4. If I am craving something, thoughts of eating it consume me
_____ 5. Food cravings invariably make me think of ways to get what I want to eat
_____ 6. I spend a lot of time thinking about whatever it is I will eat next

APPENDIX D

Stimuli Examples


MONDAINE
SBB CFF FFS
OFFICIAL RAILWAYS CLOCK DESIGN

Appendix E

Informed Consent

Informed Consent Form

You are invited to participate in a study conducted by the University of Wisconsin Oshkosh. We are studying the relationship between viewing pictures of different types and brain wave patterns using an electroencephalogram (EEG). You were selected as a possible participant in this study because you met the guidelines required by this study.

If you decide to participate, the study should take 45 minutes to one hour.

Any information that is obtained with this study will remain confidential. The information you provide will be used for the completion of the study only. By signing the consent form you agree to provide us with information to enhance the progress of our study.

If you feel uncomfortable or unable to complete the study for other reasons at any point, you are free to withdraw your consent and to discontinue participation at any time without penalty. Also, research credit will still be given to you despite incomplete participation. We cannot guarantee that you will receive any direct benefits from this study. The Institutional Review Board (IRB) has reviewed and approved the present research to be conducted.

If you have any questions, please ask the experimenter. If you have any future questions please contact Dr. James Koch. Email: kochj@uwosh.edu. Phone number: (920) 424-2303.

By providing your signature, you have decided to participate in the present study having read the information provided above. Please read all information prior to signing.

Printed Name	Signature	Date
_____	_____	_____

In addition, please read the following information about the procedures in this study and provide your signature at the bottom.

A. For this experiment, the following conditions will be in place:
1. All data collected will be confidential and anonymous. No participants' names will appear in any subsequent presentation or publication involving any of this data. Data will be stored in a locked file cabinet in CF20, the office of Dr. Jim Koch.
2. I acknowledge that once I start the experiment, I can withdraw at any time without negative consequences, and I acknowledge that I will not receive credit for research participation for only listening to the instructions.
3. During the experiment, any questions I have will be answered immediately and clearly.

4. Upon completion of or withdrawal from the experiment, I will be fully debriefed about the nature of the experiment.
5. I agree not to discuss the procedures, intent or results of this experiment with any person. All data will be available upon request at the completion of the entire experiment.
6. I have been informed and recognize that there are no known short- or long-term medical risks associated with participation in this experiment.
7. I agree to remove and keep possession of all jewelry or other items that might interfere with data collection. I agree that at no point in the experiment will any researcher be in possession of any of my personal items.

B. During this experiment, the following are necessary parts of the procedure:
1. wearing an EEG recording cap containing recording electrodes and attaching electrodes to near your right eye and applying electrode conductance gel underneath all electrodes.
2. if necessary, a slight abrading of any spot under the electrodes to enhance the signal; this is done by rubbing gently with a scrubbing sponge . Mild and temporary skin reactions to the conductive gel have been noted in a small percentage of participants in previous studies. There are no medical risks associated with this portion of the procedure.
3. making a temporary mark on your forehead with a washable marker
4. fitting yourself with a stability strap looped under the armpits and anchoring it to the EEG cap
5. a slight abrading of any spot under an EEG electrode to enhance the signal; this is done by inserting a blunt end syringe in the electrode hole, squeezing in some conducting gel, and wiggling the syringe back & forth in the electrode hole while the blunt end of the syringe is in contact with the skin. There are no medical risks associated with this portion of the procedure.
6. height and weight data will be collected with a scale and tape measure.
7. The entire experiment will take 45-60 minutes.

C. You will receive the following information/instructions during the study:
The relationship between viewing pictures of different types and brain wave patterns. This type of information is important when researching individual differences in perception of visual stimuli.

To start, you will be connected to a biomoitor used to collect physiological signals: electroencephalograms (EEG) and electrooculograms (EOG). Once hook up is complete, recording of EEG & EOG signals will start.

You will be seeing pictures on a computer screen, during and following which recordings will be taken. You will also complete a couple of questionnaires. These will not be timed; please make sure that you complete all parts of the study to the best of your ability.

D. General Information

Your participation in this study is voluntary and you may decline further involvement at any time. You may also request that your data not be used and/or be destroyed.

Information on all participants is confidential and will be recorded and kept in an anonymous manner. At no time will your name or other identifying information be used in conjunction with your responses in this study. The information provided will also not be distributed and will remain in the sole custody of myself, the principal investigator.

Once the study is complete, we will be happy to give you the results. In the meantime, if you have any questions, please contact: James Koch, Ph.D., kochj@uwosh.edu or (920) 424-2303. If you have a complaint about your treatment as a participant in this study, please call or write: Chair, Institutional Review Board For Protection of Human Participants, c/o Grants Office, UW Oshkosh, Oshkosh, WI 54901, (920) 424-1415; although the chairperson may ask for your name, all complaints are kept in confidence.

I acknowledge that I have read, understood and agreed to the procedures listed above. I am satisfied that I am proceeding with this experiment with full knowledge of the intentions and procedures involved. I understand that my participation in this study is strictly voluntary.

Printed Name	Signature	Date
_____	_____	_____

APPENDIX F

Demographics Questionnaire

Please provide the following information.
Place and X next to your choice or fill in the requested information.

1. What is your gender?
Male _____
Female _____
Other (specify if desired) _____

2. What is your age? _____

3. What year are you in school?
Freshman _____
Sophomore _____
Junior _____
Senior _____

4. What is your ethnicity?
Caucasian _____
African American _____
Asian _____
Hispanic/Latino _____
Native American _____
Other (specify if desired) _____

5. Which is your dominant hand? Right _____ Left _____ Neither _____

6. Please check those questions to which you answer yes (leave the others blank).

- ☐ Have you been diagnosed with a psychiatric or mental illness within the last month?
- ☐ Do you excessively use alcohol?
- ☐ Do you have a history of drug abuse?
- ☐ Have you participated in a weight loss intervention within the last three months?
- ☐ Are you currently taking any medications?
  If yes, please list: _____

7. Please provide the following information as accurately and detailed as possible:

At what time did you last eat? _____ AM or PM (circle the appropriate choice)

Please list what you had to eat at this time

_____

APPENDIX G

Debriefing Statement

Debriefing Statement

Thank you for participating in this study. The purpose of this form is to provide you more in-depth information about this study. After reading it, any further questions you have will be answered.

This study was designed to examine the relationship between body mass index (BMI), brain activity, and self-report of food cravings and hunger.

The scientific background for this study included similar studies demonstrating the LPP (in parietal region), an event related potential signal is often used as an index of motivation. It is for this reason that we look at the brain activity in the parietal region.

You were connected to a Biomonitor to provide specific physiological signals, which are produced naturally by the nervous system's reactions to perceived stimuli, in this case pictures of unhealthy foods and office furniture. The physiological signals collected are naturally-occurring EEG patterns, in this case event related potentials (ERPs) are time-locked to the event taking the waveform created reflects your responses.

The EOG data will be subtracted from the EEG data to control for artifacts in the EEG data produced by eye movements during reading.

No individual data will ever be presented or published. All data will be published as group data only. It is important to stress that you do not reveal the goal of this study to other potential participants, so that data remains original and uncontaminated.

If you have any concerns about this study, you may speak with Dr. Jim Koch at kochj@uwosh.edu. He, as well the researcher involved, will be more than happy to talk with you about any concerns you may have.

Again, thank you very much for your participation. We value the time and energy you spent in this study and it is our hope that the data you have provided will help us to better understand human psychology.

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