

COGNITIVE PROCESSING OF FACIAL SIZE AND VALENCE
IN DEPRESSION AND OBESITY

By

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Abstract

Prior research suggests that obesity is a risk factor for developing depression, but not all obese individuals develop depression; so what are the common factors underlying comorbid obesity and depression that may serve as markers for depression risk? Previous studies have reported the effects of obesity and negative affect on the P300 (P3) component and Thought-Shape Fusion (TSF), but prior to the present study, there has been no exploration of cognitive processing differences or similarities in comorbid depression and obesity.

This study investigated if attention bias differences exist between currently obese and depressed (Dep/O, n=16), currently obese and never depressed (ND/O, n=13), and healthy weight and never depressed (ND/HW, n=16) females when participants viewed oddball valenced target face pictures, and whether TSF scores can be used to determine correlation to depression risk.

Results showed that the ND/O group processes weight status and valence of facial stimuli more similarly to the Dep/O group than as compared to the ND/ HW participants. In contrast, with the measure of an eating-related cognitive distortion, Thought-Shape Fusion, ND/O individuals were more similar to ND/HW. Results support obesity being a risk factor for depression and support the P3 component being an objective, unbiased marker for depression risk in obese individuals. TSF scores were found to have good sensitivity and excellent specificity for classifying depression in obese individuals, indicating this self-report measure may be useful in determining depression risk in currently obese individuals. This research may highlight some useful tools for clinicians that indicate presence of cognitive risk factors for development of depression in obese individuals.

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Introduction

The Comorbid Problem of Obesity and Depression

Obesity and depression are two widespread disorders affecting individual morbidity and mortality (van Baal et al., 2008; Katon et al., 2003), in addition to impacting societal expenditures (Finkelstein et al., 2005; Stewart et al., 2003). Between 2007 and 2009, obesity (body mass index [BMI] ≥ 30 kg/m²) prevalence has been estimated to be 24.1% in Canada (Shields et al., 2011), and between 2011-2012, prevalence has been estimated to be 34.9% in the United States (Ogden et al., 2014). The prevalence of current major depressive disorder (meeting criteria for DSM-IV) has been estimated to be 4.1% (Centers for Disease Control and Prevention, 2010). High prevalence of comorbid obesity and depression has led researchers to question why the two disorders are related and whether they have a causal link.

Obesity has been shown to be associated with increased risk for depression (Johnston et al., 2004), particularly in young, obese women compared to nonobese women (Heo et al., 2005). Some research indicates obesity is related to a 21% increase in likelihood of lifetime diagnosis of depression (Simon et al., 2006), and 17-53% increase in likelihood of diagnosis of depression in women (Zhao et al., 2009). Many studies also cite obesity as a risk factor for depression (Dong et al., 2004; de Wit et al., 2010; Roberts et al., 2003). In a meta-analysis of longitudinal studies, there is also an indication that those who are depressed are at higher risk for developing obesity (Blaine et al., 2008; Goodman et al., 2002; Hasler et al., 2004), and that the relationship is potentially bidirectional such that those who are obese have a 55% increased risk of developing depression, and those who are depressed have a 58% increased risk in becoming obese (Luppino et al., 2010). While this research is primarily correlational, some basic science research in rats points to chronic consumption of high-fat foods and obesity resulting in depressotypic behavior

resulting from changes in brain reward circuitry (Sharma & Fulton, 2013). Furthermore, the results of a high fat diet appear to have long lasting effects on the hypothalamic-pituitary-adrenocortical axis (HPA), that may promote increased stress response that drives the bidirectionality of the obesity and depression comorbidity (Sharma, Fernades, Fulton, 2013). Considering these neural adaptations that the brain's circuitry endures under a high fat diet that promotes obesity, it is likely that there are additional cognitive changes that occur in obesity that may be important predictors of depression.

Investigating what cognitive similarities are present in both disorders will give more insight in understanding the comorbid conditions and how to effectively provide treatment. Additionally, exploring cognitive factors that both disorders have in common may allow researchers to predict the degree to which obesity contributes to vulnerability for depression.

Measurement of Attention Bias in Real Time

Cognitive variables such as attention biases to environmental cues and decreased inhibition can be measured through differences in biological mechanisms such as brain activity patterns; variations in brain activity patterns can be used as a biological index correlated with cognitive markers for obesity and depression.

We are interested in exploring electrophysiological similarities that underlie these comorbid disorders through the use of electroencephalography (EEG). Functional neuroimaging studies have used functional magnetic resonance imaging (fMRI), positron emission tomography (PET) or single photon emission tomography (SPET) to evaluate differences in brain activity with high spatial resolution. While EEG has lower spatial resolution, its high temporal resolution of the brain's cortical activity is an important factor when studying the temporal aspect of

processing stimuli. The positive and negative event-related potentials (ERPs), or averaged changes in EEG recording linked to an event, are useful in understanding how information is processed. The key benefit in using ERP to measure response to stimuli is that it is not subject to reporting biases, which are common in response to self-report measures. The ERPs can be used as biological indexes related to attention to indicate if there are any differences in attention correlated with depression risk in individuals who are already obese. This information may be helpful in understanding the comorbidity of obesity and depression and how individuals process cues differently.

P3 as a Measure of Attention

We are interested in understanding specific cognitive differences, such as differences in attention biases that may predict vulnerability for depression. The P300 (P3) component is a positive ERP in EEG that is most prominent at parietal electrodes (Picton, 1992; Polich and Kok, 1995). It appears between 300-600 msec after stimulus presentation (Sutton et al., 1965), and is important in evaluating attention processing (Bashore & van der Molen, 1991; Sutton, 1979). Researchers have argued (Debener, et al., 2002; Rich, et al., 2005) that the P3 amplitude can be used to assess amount of attention an individual gives to an unexpected stimulus, since it is elicited by an infrequent (low probability) stimulus through an oddball paradigm. An oddball paradigm is when low probability target stimuli are embedded with high probability non-target stimuli; the low probability target stimuli are “oddballs” and elicit the P3 wave. The reason the oddball paradigm elicits a P3 is based on the P3 being sensitive to the amount of attention that is allocated in discriminating an “oddball” target stimulus from standard frequent stimuli, such that the P3 amplitude increases as the target probability decreases (Duncan-Johnson and Donchin,

1977, 1982; Squires et al., 1976), and the P3 amplitude is inversely related to the probability of a target stimulus (Duncan-Johnson & Donchin, 1977).

P3 in Depression

EEG research investigating depression vulnerability has found clear differences in general patterns of brain activity. Greater brain activity, as defined as a greater amount of EEG activity, in the right cerebral cortex has been associated with prior depression (Henriques et al., 1990; Gotlib et al., 1998), genetic predispositions for developing depression (Bismark et al., 2010), and predisposition for future depression (Blackhart et al., 2006). In comparison to individuals with depression, those who are healthy have greater EEG activity in the left cerebral cortex (Coan et al., 2004; Thibodeau et al., 2006).

Some differences in characteristics of the P3 have already been noted in depressed individuals; for example, a common observation is that participants who are depressed generally have a lower P3 amplitude and delayed or longer P3 peak latency. Researchers have taken this P3 pattern to indicate that there is a general impairment of attention in patients with depression (Gangadhar et al., 1993; Giedke et al., 1981; Himani et al., 1999; Houston et al., 2004; Kawasaki et al., 2004; Urretavizcaya et al., 2003). Secondly, when presented with negatively valenced stimuli, currently depressed individuals show greater P3 amplitudes than previously depressed individuals and never depressed control subjects, indicating an attention bias for negative valence (Ilardi et al., 2007). This pattern is also apparent in at-risk individuals who exhibit greater attention to sad faces (Hsieh & Ko, 2004) and deficiency in attention toward happy faces (Bradley, Mogg, Falla, & Hamilton, 1998; Bradley et al., 2000). Research in childhood depression has also shown increased P3 amplitudes to be evident in children of parents who had

childhood depression (Perez-Edgar, Fox, Cohn, & Kovacs, 2006), further indicating cognitive processing differences that may be linked to depression vulnerability. Thus, general P3 attenuation and heightened P3 in response to stimuli with negative valence can be used as indexes of attention as a cognitive marker indicating depression vulnerability (Ilardi et al., 2007), where groups at risk for depression may look more similar to a currently depressed group rather than healthy group. Overall, these prior research results imply that attenuation of P3 may explain how depressed individuals often present with a decreased interest in activities they used to find exciting. Additionally, heightened P3 responses for negative information is consistent with commonly observed processing and memory biases seen in patients with depression. For example, they often see the glass as “half empty”.

Next, we should consider the P3 evidence observed for obese individuals. While less work has done with ERPs in the study of obesity, there are important parallels between these two fields of literature.

P3 in Obesity

While fMRI has been used more extensively than ERP in the study of cognitive differences in overweight and obese individuals, several ERP studies have used the P3 component to study attention bias. In a P3 study of children with obesity with and without insulin resistance, researchers found that overall P3 amplitude was significantly decreased in the obese group compared to healthy controls (Tascilar et al., 2011). In an “oddball” paradigm where subjects were presented with rare stimuli of enlarged food pictures (food dilated 25% along the horizontal axis), obese individuals had a decreased P3 amplitude compared to healthy weight controls. Additionally, a positive correlation was observed between body fat percentage and P3

amplitude in obese individuals when viewing the rare stimuli of enlarged faces (face dilated 25% along the horizontal axis) (Babiloni et al., 2009a; Babiloni et al., 2009b). Similar results showing the diminished P3 response were also observed in underweight individuals (Babiloni et al., 2011), suggesting that attention processing of food and face size differs as a function of body weight.

Measurement of Self-Reported Attention to Thoughts and Body Shape

Thought-shape fusion

While differences in the P3 amplitude provide a biological index of attention to external cues, attention to self and internalization of external cues can be measured through self-report measures of body image. Self-report of one's reflection of their body image may give an estimate of subjective ratings of attention to how food stimuli may affect body image. High levels of attention to one's body image may become cognitive distortion, which is a common occurrence in individuals with disordered eating. One type of cognitive distortion is thought-shape fusion (TSF; Shafran et al., 1999), a cognitive "error" that occurs when an individual is asked to think of certain "off-limit" foods. Individuals who exhibit high levels of TSF feel fatter, believe they have gained weight, and believe they have committed a kind of moral misconduct when they imagine eating a high-calorie or fattening food. TSF is correlated with eating disorder psychopathology (Shafran and Robinson, 2004; Radomsky et al., 2002; Coelho et al., 2008) and portion size of hedonic food individuals would serve themselves (Coelho et al., 2008). TSF can be induced in healthy weight females but not overweight females when they are asked to think about highly caloric or fattening foods and what it would be like to consume a large amount of this food (Coelho et al., 2011). These findings suggest that TSF may influence the extent to

which an individual seeks out and consumes calorie-laden or fattening foods (Coelho et al., 2008).

TSF as Self-reported Measure of Attention?

While the few studies conducted on TSF have shown that it can be an effective tool for measuring cognitive distortion, it has not yet been tested as a measure of attention. We know that there is a disparity in the salience of food stimuli between healthy weight and overweight individuals. Overweight individuals express hyperattention to food stimuli when satiated, but have decreased attention to the same stimuli when hungry (Nijs et al., 2010). This heightened interest in food stimuli when satiated may suggest that cognitive differences (among other explanations such as genetics or variations within reward system networks) are one factor that explains why food cues prompt overeating. Combined with a lower tendency toward TSF, certain individuals may be much more prone to seek out and consume calorie-laden or fattening food.

In addition to studies of differences in tendency toward TSF in different weight-status populations, there is evidence that negative affect may moderate susceptibility to TSF in healthy weight females. Low levels of negative affect seem to provide a protection against TSF, medium negative affect is associated with vulnerability for TSF, and high negative affect makes individuals especially susceptible to TSF (Coelho et al., 2010). Thus, here is another domain in which we empirically observe a clear, possibly reciprocal relationship between body weight and mood state.

The Present Study

Purpose

Comorbid obesity and depression is common; however, not all obese individuals develop depression, and not all depressed individuals develop obesity. Several questions remain, such as what common factors underlie comorbid obesity and depression, and what cognitive variables contribute to certain individuals being more prone to depression.

The literature suggests that there is sufficient support for the theory that obesity is a risk factor for developing depression. Additionally, research has shown differences in brain activity of obese individuals and overweight individuals via multiple neuroimaging modalities. Some of the cognitive factors, such as attention bias to food images, are associated with greater BMI and future weight gain, and thus provide predictive value for estimating future risk. These cognitive differences, particularly differences in attention, may be useful in understanding cognitive factors of obesity that are important in contributing to the vulnerability for depression.

The comorbidity of depression and obesity presents a bidirectional relationship posing two questions (1-“What factors in obese individuals are correlated with depression risk?” and 2-“What factors in depressed individuals are correlated with obesity risk?”). The present study will be focused on exploring the depression risk as defined by cognitive markers in obese individuals. These experiments are a part of a larger study using different experiments to investigate a variety of ERP components that may serve as biological indexes of cognitive variables, which can be used as markers of obesity that may predict depression vulnerability. While the larger study incorporates these experiments utilizing words and statements as stimuli to look at differences in response to emotional content and semantic incongruence of stimuli, the present study focuses faces as the stimuli.

The purpose of these experiments is to determine what attention bias differences and similarities are present in three groups of participants [(a) currently obese and currently depressed (Dep/O), (b) currently obese and never depressed (ND/O), or (c) healthy weight and never depressed (ND/HW)]. We will determine if differences exist between groups when participants view oddball valenced target face pictures, and whether TSF scores can be used to determine correlation to depression risk.

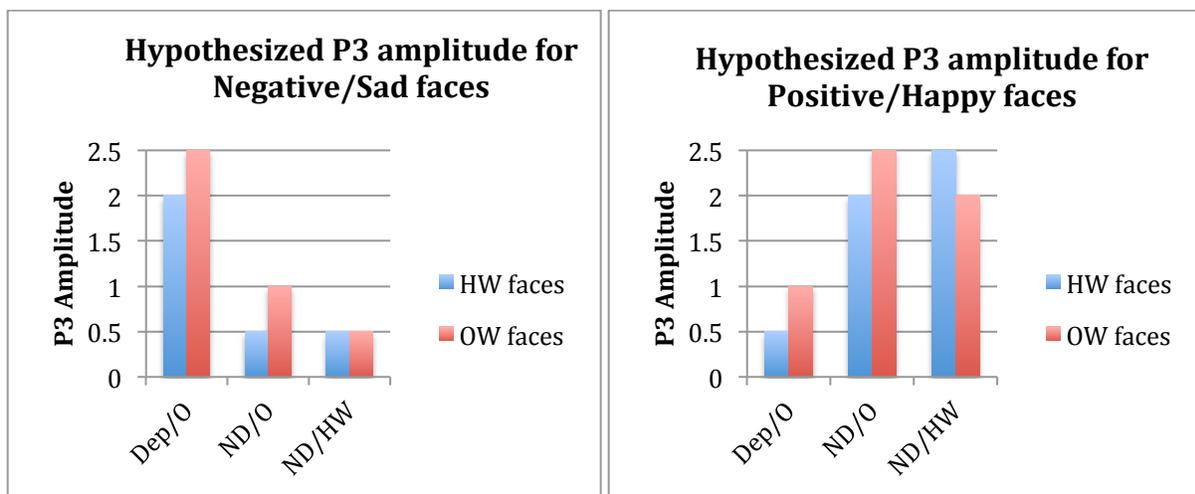
Predictions for P3

Prediction 1: Overall, we should see a two-way interaction of stimuli valence by group indicating that the Dep/O group has a decreased attentional bias for positive valence and an increased bias for negative valence. The opposite interaction is expected of ND/O and ND/HW participants: they are expected to exhibit greater bias for positively valenced stimuli, and decreased bias for negatively valenced stimuli. This is based on prior research supporting depressed individuals exhibiting general P3 attenuation and heightened P3 during negative valence when compared to never depressed controls groups (Ilardi et al., 2007).

Prediction 2: We postulate that there will be a two-way interaction of weight status by group, where both obese groups (ND/O and Dep/O) will have a heightened P3 response to all overweight faces (regardless of facial expression) compared to the ND/HW group. We base this prediction on prior findings indicating a positive correlation between body fat and amplitude of P3 in response to enlarged faces (Babiloni et al., 2009a).

Prediction 3: Additionally, we hypothesize that we should see a three-way interaction. We would also expect that within the negative faces, we would see a two-way interaction of stimuli weight status by group. Based on literature that supports heightened P3 in response to

negative valence in depressed individuals (Ilardi et al., 2007) and in response to enlarged faces with as body weight increases (Babiloni et al., 2009a), we expect that when compared to the ND/O and ND/HW, the Dep/O will have an even greater P3 response to negatively valenced, overweight faces as compared to the negative, healthy weight faces. The ND/O group will have their largest P3 amplitude to positively valenced, overweight faces, and the ND/HW group will have their largest P3 amplitude to positively valenced, healthy weight faces. Please see the figures below that illustrate these predictions.



*Figure 1a (left). Hypothesized P3 amplitude for Negative HW and OW faces.
Figure 1b (right). Hypothesized P3 amplitude for Positive HW and OW faces.*

Predictions for TSF scores

While TSF has been studied in overweight, healthy weight, and underweight individuals, and in healthy weight individuals with negative affect, it has never been studied in a population of individuals with comorbid obesity and depression. So what happens when negative affect is introduced into the equation of obesity?

Research has shown that low levels of negative affect seem to provide a protection against TSF, medium negative affect is associated with vulnerability for TSF, and high negative affect makes healthy weight individuals especially susceptible to TSF (Coelho et al., 2010). We hypothesize that negative affect influences overweight individuals in the same way, and increases vulnerability for TSF. However, overweight individuals have the heightened unconscious interest in food stimuli when satiated (Nijs et al., 2010), which would make them prone to seek calorie-laden or fattening foods. Since they are also more vulnerable to TSF induction, these individuals would also associate this food-seeking behavior with guilt and negative feelings.

In this case, we can hypothesize that Dep/O individuals will have a higher TSF score. This may be a subjective cognitive measure that distinguishes the Dep/O group from the ND/O group. TSF measure may serve as a potential future screening measure that can be used to segregate obese individuals into not-at-risk or at-risk groups for depression.

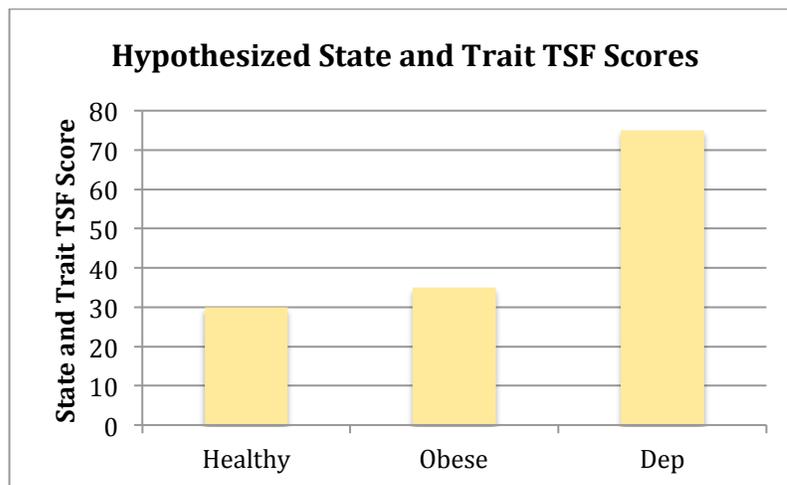


Figure 2. Hypothesized State and Trait TSF scores

Methods

Stimulus Norming Study

Purpose

The stimulus norming study allowed us to obtain normative data the face stimuli and obtain information regarding affect, weight status, and arousal intensity for our face stimuli. Responses from the norming study were used to inform the research of what stimuli were suitable for use in the main study.

Participants

The norming sample consisted of 56 total participants (30 male and 26 female). While the primary study only consisted of female participants, we included males in the normative sample so we can use the stimuli in males in the future. Participants were undergraduate student from the University of Kansas who received partial credit toward course requirements for their introductory psychology course (Psychology 104), in which they were enrolled. Participants completed the following information online before being recruited into the preliminary study: demographic and psychological prescreening measures (such as a few questions screening for depression), as well as contact information and self-report of height and weight.

Stimuli

Faces

Healthy weight face stimuli were selected from the NimStim (Mazurski et al., 1993). The face stimuli are ethnically diverse and are controlled for attractiveness by having the same actors portray expressions that are sad, happy, and neutral. Affective (sad and happy) healthy weight face stimuli were manipulated into obese faces with AlterImage®, an aesthetic simulation software commonly used in surgical and dental offices. Some affective faces that were initially

overweight or obese were manipulated to healthy weight status. Additionally, neutral face stimuli were manipulated with AlterImage® to represent a variety of weight statuses ranging from healthy weight to overweight and obese. Both unaltered faces (from the NimStim) and faces manipulated with AlterImage® were presented in E-prime®.

Participants were given a Body Image BMI scale to provide an objective sense of BMI, adapted from the original Figure Rating Scale (FRS) (Stunkard et al., 1983). The FRS is a pictorial depiction of body image, which has been correlated with self-report of BMI (Bulik et al., 2001) and has been shown to be a good index for unbiased observers judging weight status (Cardinal et al., 2006). Additionally, prior research indicates that the images are representative of certain BMI status; images 1 and 2 are considered underweight, images 3 and 4 are considered healthy weight, images 5 and 6 are considered overweight, and images 7, 8, and 9 are considered obese (Bulik et al., 2001; Hediger et al., 2005). Participants were also provided with the Self-Assessment Mankin (SAM), which is a pictorial scale used to measure affect and arousal associated with a person's response to stimuli (Bradley and Lang, 1994).

We then presented the faces to participants via E-prime, a stimulus presentation software, and asked them to rate valence (if the expression is sad, happy, or neutral); arousal they experienced when viewing the expression; and if the face looked to be healthy weight, overweight, or obese. At the end of the face rating session, each participant was given a chance to give open-ended feedback about the stimuli.

Procedure

The research laboratory has approval from the Human Subjects Committee at the University of Kansas-Lawrence to collect normative data for this study. Through the University

of Kansas's online study pre-screening site, potential participants will sign up for their preferred study session time.

When participants arrived to the scheduled study session, they were informed of what the normative study entails and provided their consent to participate.. If they consented to participate, they were seated in front of a computer that had the E-prime program, answered several self-reported demographic questions regarding their age, sex, height, and weight; then began rating the face stimuli. When the participant completed rating stimuli, they were given the opportunity to ask any questions about the purpose of the study.

Results

Participants' rating responses to the face stimuli were be compiled and averaged. A one-way analysis of variance (ANOVA) run on valence ratings of stimuli (positive, negative, neutral), and another ANOVA was run on weight ratings of stimuli (overweight, healthy weight). Valence ratings of positive, negative, and neutral stimuli were significantly different from one another [$F(4,135)=1744.14$; $p<.0001$], and weight ratings of overweight and healthy weight stimuli were significantly different from one another [$F(4,135)=92.04$; $p<.0001$]. These responses were used in deciding which stimuli to present during the main study. Resulting stimuli set consisted of 20 affective faces in each of the categories and 60 neutral faces of varying weight status.

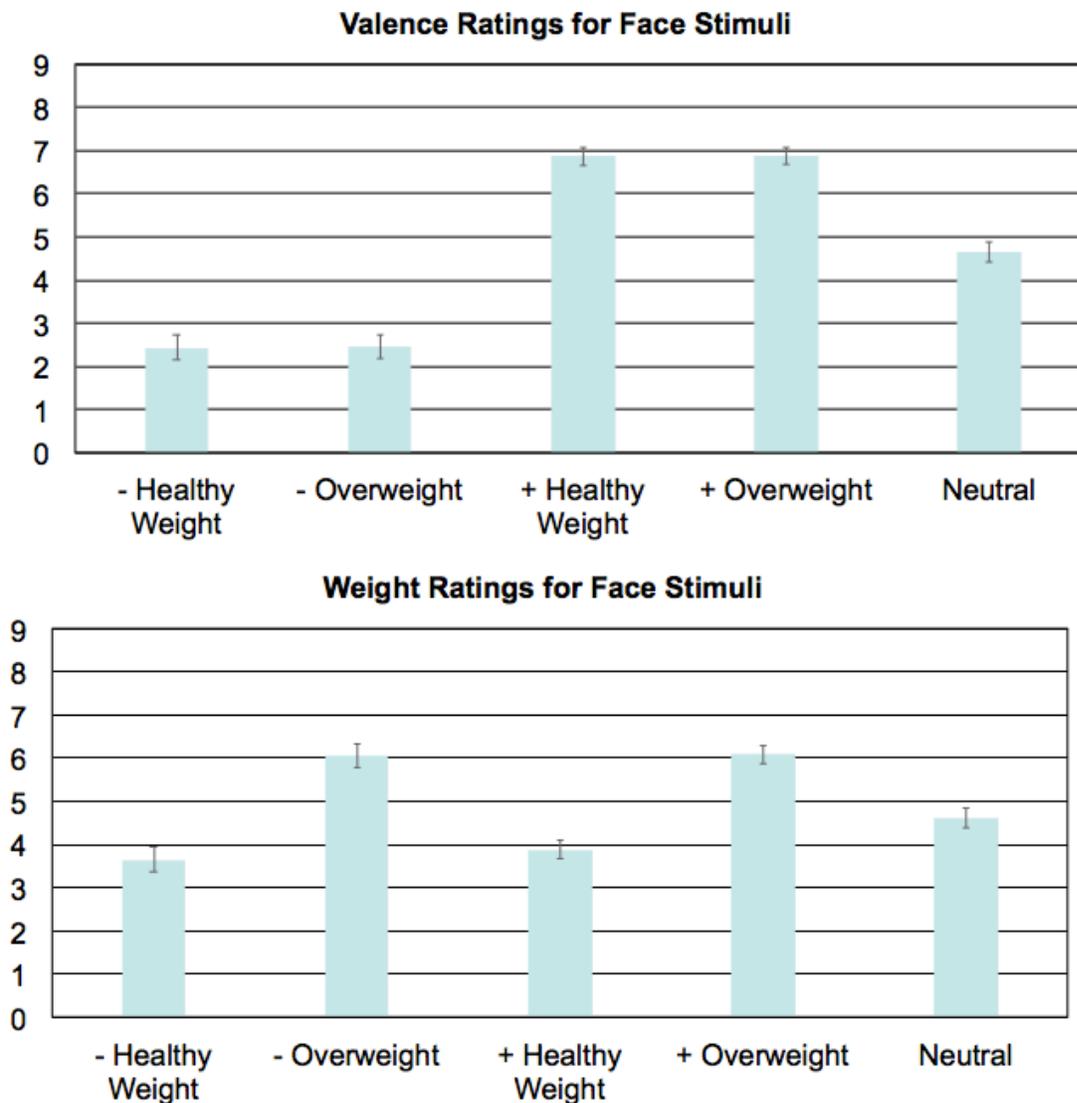


Figure 3. Mean valence and weight ratings for face stimuli in stimulus norming study

Electrophysiological Study

Participants

The sample consisted of 45 total female participants who meet criteria for one of the experimental groups: (a) currently obese and currently depressed, (b) currently obese and never depressed, or (c) healthy weight and never depressed. Height and weight measurements at the study visit were used to determine the participant's body mass index (BMI) calculation, which in

turn determined whether they were currently obese ($\text{BMI} \geq 30 \text{ kg/m}^2$) or healthy weight ($\text{BMI} 18.5\text{--}24.9 \text{ kg/m}^2$). A diagnosis of current depression was obtained through various self-report measures, as well as a clinical diagnostic interview.

Participants partially consisted of female undergraduate student volunteers from the University of Kansas who received partial credit toward course requirements for their introductory psychology course (Psychology 104). Additional participants were recruited from the community (KU Psychological Clinic, posted flyers, craigslist.com, etc.) and received up to \$50 in compensation for their travel and time (Lawrence, KS residents received up to \$25, and community members residing outside of Lawrence were eligible for an additional \$25 to compensate travel expenses, for up to \$50 total compensation).

Recruitment of participants was restricted based on the following exclusionary criteria: male, left-handed, non-native English speakers, traumatic brain injury, current or history of alcohol/drug dependence, ND/HW and ND/O: anxiety, psychiatric disorder, history of eating disorder. Potential participants were contacted by phone or email, which they provided via online screening or through contacting the investigator regarding their interest; if they were interested in participating, a session time was scheduled. Potential participants also had the opportunity to sign up for the study via KU's online research system or by contacting the investigator directly after receiving information from a flyer.

Out of the total of 77 participants who qualified via online and email screener, the following participants were excluded from the analyses: 28 participants excluded due to exclusionary criteria, 2 participants excluded due to poor data recording, and 2 participants excluded due to poor behavioral responses to task stimuli. Exclusion of these 32 participants yielded the final sample of 45 participants.

*Table 1. Descriptive characteristics of participants***Participant Characteristics (Total n=45)**

Characteristic	ND/HW	ND/O	Dep/O
	<i>n</i> = 16	<i>n</i> = 13	<i>n</i> = 16
Average Age (\pm SD)	21.69 (\pm 6.88)	19.77 (\pm 2.71)	27.13 (\pm 12.20)
BMI	21.58 (\pm 1.27)	36.01 (\pm 5.03)	37.44 (\pm 8.11)
Race			
Caucasian (n=31, 68.9%)	14 (87.5%)	6 (46.2%)	11 (68.8%)
African (n=4, 8.9%)	2 (12.5%)	0 (0%)	2 (12.5%)
Asian (n=2, 4.4%)	0 (0%)	2 (15.4%)	0 (0%)
Native American (n=1, 2.2%)	0 (0%)	1 (7.7%)	0 (0%)
Other (n=7, 15.6%)	0 (0%)	4 (30.8%)	3 (18.8%)

Study Questionnaires and Screeners*Hunger Level, Handedness, Brain Injury, Language History*

We had participants fill out a short staff-developed questionnaire upon their arrival to the study visit; it included inquiries regarding their level of hunger, handedness, any incidents involving traumatic brain injury, and language history. We noted what time of day they arrived.

Thought-Shape Fusion (TSF)

Thought-shape fusion is thought to occur when just thinking about eating forbidden foods will increase a person's estimation of their bodily shape or weight. Additionally, a person may express that they have feelings of fatness, guilt, and moral wrongdoing by just imagining the

situation. The TSF questionnaires measure cognitive distortion surrounding thoughts of eating forbidden foods. The questionnaires are a 7-item state TSF scale looking at aspects of TSF (Coelho et al., 2010) and 34-item trait TSF scale measuring tendencies toward TSF (Shafran et al., 1999).

Diagnostic Measures

Depression Measures

At the study session, participants were administered the Eating Disorders Module, Mood Module (past depression and past mania), and Anxiety Module of the in-person Structured Clinical Interview for DSM-IV-TR (SCID), which is a commonly used diagnostic exam to determine DSM-IV Axis I disorders (First et al., 2002). The 21-question self-report Beck Depression Inventory (BDI-II; Beck et al., 1996) was administered to assess for dysphoria at the beginning of the session (as defined as a score of ≥ 12 on the BDI-II).

Weight Status

Trained research staff measured the participant's height and weight using standardized protocols while participants are dressed in their street clothes (participants were asked to remove shoes and any items from their pockets). Body weight was measured to the closest 0.1 kg using a digital scale. Height was measured to the nearest 1 mm using a portable stadiometer. These values were used to calculate body mass index using the formula $BMI = [kg/m^2]$ and determined if the participant is currently obese ($BMI \geq 30 kg/m^2$) or healthy weight ($BMI 18.5-24.9 kg/m^2$).

Information Processing (Electrophysiological Measures)

Information processing during cognitive tasks was assessed through reaction times and errors. Neural activity was measured from a high-density event-related potential (ERP) mapping with information collected through electroencephalography (EEG) using a high-density, 128-channel Electrical Geodesics, Inc. system with Geodesic Sensor Nets. Electrodes were also placed around the eye to record blinks and eye movements. ERPs are the EEG variations time-locked to an event or through a specific task the person performs. These ERPs are seen as differences in response to different events. ERP amplitudes are calculated as a difference between baseline activity from a reference electrode and any activity recorded from other electrically active sites on the EEG net; they are measured through the conduction of electrical brain activity that travels through saline solution-soaked sponges on the EEG net. The net was connected to recording equipment, which amplified and recorded these EEG signals while the participant completed seven different cognitive tasks. The ERP components allowed us to measure cognitive functions in real time.

Specifically, for the following tasks, we looked at the P3 component of ERPs recorded; the P3 is a distinct positivity in EEG that appears between 300-600 msec after the stimulus is presented, and can assist us in understanding attentional bias toward cues. It is important to note that the two cognitive tasks in this specific study contribute to a larger study. Only the two tasks that concern this study will be described in detail.

P3 Face Detection Tasks (FaDTs)

The P3 Face Detection Tasks (FaDTs) consisted of two cognitive tasks that the participant completed while ERPs were measured. In this task, we measured the P3 as an index

of attentional focus for affective face stimuli. In each of the FaDTs, there were 40 different affective face stimuli presented, and 160 neutral face stimuli presented. Affective face stimuli were overweight (OW) or healthy-weight (HW). The first of the two FaDTs included 20 faces that are happy and OW, 20 faces that are happy and HW, and 160 faces that are neutral and range in weight status. The second FaDT involved presentation of 20 faces that are sad and OW, 20 faces that are sad and HW, and 160 faces that are neutral and range in weight status. Each stimulus during the task was presented on the screen for the duration of 750 msec, with fixation crosshairs presented for 1500 msec between each face stimulus. Following the presentation of the face stimulus, participants responded to the valence of the face, indicating whether the facial emotion presented was positive (happy) or neutral in the first task and negative (sad) or neutral in the second task. Ordering of face stimuli in each block of the FaDTs was random, but we kept the overall stimuli proportions the same with 80% neutral stimuli, 10% HW stimuli and 10% OW stimuli. All face stimuli were selected from the NimStim (Mazurski, 1993), and had been through a thorough norming process (described as the norming study earlier) requiring rating of affect (happy, sad, neutral), intensity of emotional arousal, and weight-status of the face.

Procedure

The study was approved by the Human Subjects Committee at the University of Kansas-Lawrence. Through the University of Kansas's online study pre-screening site or via email, participants provided their self-report of their demographic information, current height and weight, completed the PDQ, and completed select questions from the BDI-II. Potential participants were contacted by phone or email that they provided online during the pre-screening process, and if they were interested in participating, a study session time was scheduled.

Participants also had the opportunity to sign up for the study via KU's online research system.

At the study session, the participant met with the head researcher or research assistant, who then reviewed the study protocol in detail, answered any questions the participant may have had about the study and obtained written consent.

Each study session lasted approximately three hours and consisted of completing the BDI-II, measurement of height and weight, study questionnaires, screening evaluations, a clinical diagnostic interview, and EEG cognitive tasks. Measures administered before the EEG and cognitive tasks were: BDI-II, a questionnaire of handedness, brain injury, and language history; height and weight; PSQI; LSI; and SCID. If participants met criteria for one of the three study groups, they proceeded to the EEG portion of the study.

During the EEG portion of the study session, participants were seated in front of a computer monitor and were fitted with a hairnet of small sponges soaked in saline, which recorded EEG signals during cognitive task performance. Setup of applying the net, connecting it to recording equipment, and adjusting for optimal signals took about 15 minutes. Five different cognitive tasks were conducted on the computer screen; two of the tasks are part of this specific study. Two FaDTs involved the participant viewing the presentation of facial stimuli that have different emotional expressions. In the tasks that are not part of this specific study, participants viewed positive, negative, or neutral words on the computer screen; they also viewed positively or negatively valenced sentence statements. Experimental trial administration was through Eprime (Psychology Software Distribution, Pittsburgh, Pennsylvania), which also recorded trial information such as reaction time. Information from Eprime was also sent to Net Station to initiate recording of EEG data.

After the EEG portion of the experiment, participants were asked to complete the BED, TFEQ, and TSF questionnaires. At the conclusion of the study session, participants were fully debriefed, given the opportunity to ask questions about the study, and provided mental health resource information and contact information for any future questions. Payment receipts were also completed by community participants participating for compensation.

Analysis of Results

Behavioral Analyses and Criteria

We examined accuracy scores and reaction times; we only included participants with a high accuracy averaged across tasks (80%) and reaction time of greater than 100 ms. Additionally, we only included participants in the analyses if there was a minimum of 10 acceptable trials per valence condition based on acceptable impedance levels in their ERP data.

Analysis of ERP Data

All ERP data was filtered prior to segmentation and time-locked to 200 ms before the stimulus onset and 1000 ms after the stimulus onset, and a baseline correction was applied to the 200 ms period before onset of the stimulus. ERP data was analyzed within two P3 component windows, using EGI's Analysis Tools from NetStation's package (EGI, Eugene, OR) and an automated routine the lab has developed. The EEG electrode channels of interest that correspond with the P3 component consist of the EGI Geodesic Sensor Net channels 55, 61, 62, 78, and 79.

Selection of Region of Interest (ROI)

The ROI consisting of EGI Geodesic Sensor Net channels 55, 61, 62, 78, and 79 corresponding with the P3 component of interest was selected based on topographical mapping of amplitude grand averages across conditions by group. These channels were selected due to peak amplitudes centering around the region encompassed by these channels. Additionally, these channels theoretically correspond to the P3 component.

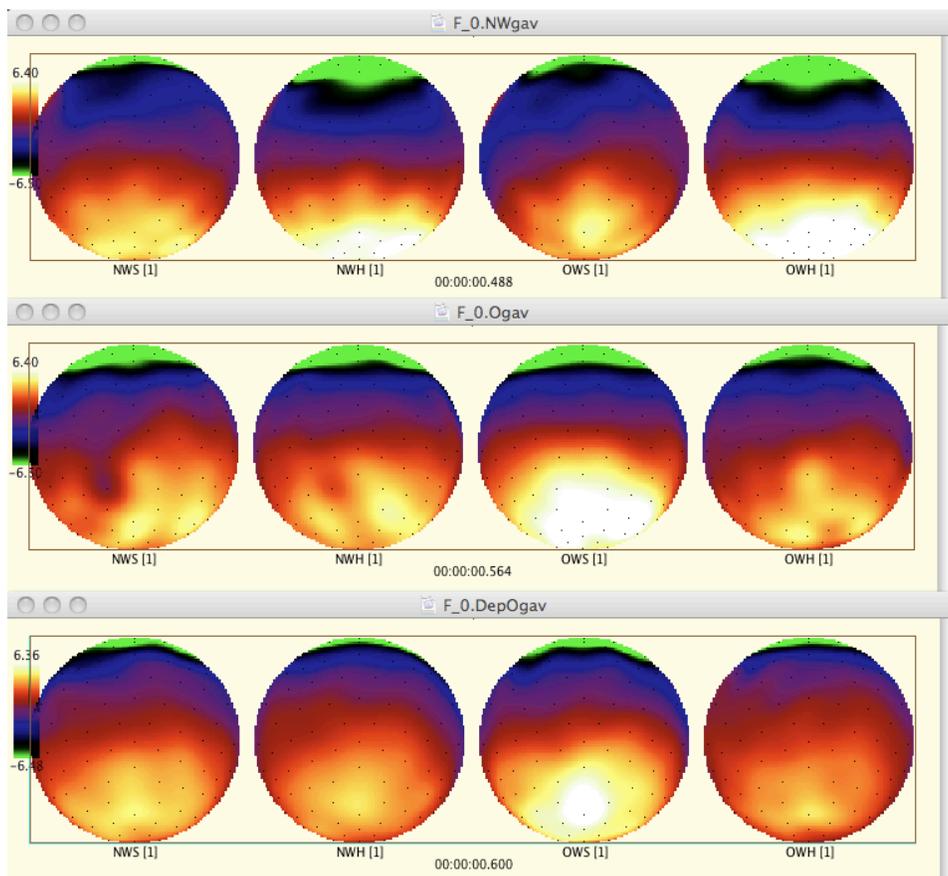


Figure 4. Topographical maps of maximal amplitudes segregated by participant group (top to bottom: ND/HW at ~250 ms, ND/O at ~350 ms, and Dep/O at ~400 ms)

Selection of Channel with Least Noise

In addition to selection of a ROI, we also opted to select a single channel with the least noise. Least noise was determined by examining mean amplitudes in the neutral condition across all subjects at each channel within the ROI (channels 55, 61, 62, 78, 79). It was determined that channel 62 had the lowest noise due to lowest mean amplitude in the neutral condition after baseline correction; this would yield difference waves (subtracting the amplitude of the neutral condition from the valenced “oddball” condition) which allows for the calculation of the typical P3 amplitude (P3 amplitude = rare amplitude – frequent amplitude).

Selection of Time Windows

Component time windows were selected by first selecting a single channel with the least noise (channel 62), and reviewing the grand average ERP resulting from each condition of valenced face stimuli (positive OW, positive NW, negative OW, and negative NW) across each group of participants (Dep/O, ND/O, ND/HW). Review of grand averages and topographical mapping across time showed a difference between peak latency to vary by participant group, such that the P3 component had a maximal peak in ND/HW participants between 250-350 ms; in the ND/O group, two distinct peaks appeared, one between 250-350 ms and one between 350-460 ms; in the Dep/O group, peak latency was less distinct, and appeared primarily between 350-450 ms. This is consistent with research showing delayed P3 amplitude and prolonged P3 latency. As a result of this difference in peak latency across subject groups, we chose to analyze ERP data within two P3 component windows (248-352 ms post stimulus onset for an “early” P3 component; 356-460 ms post stimulus onset for a “late” P3 component).

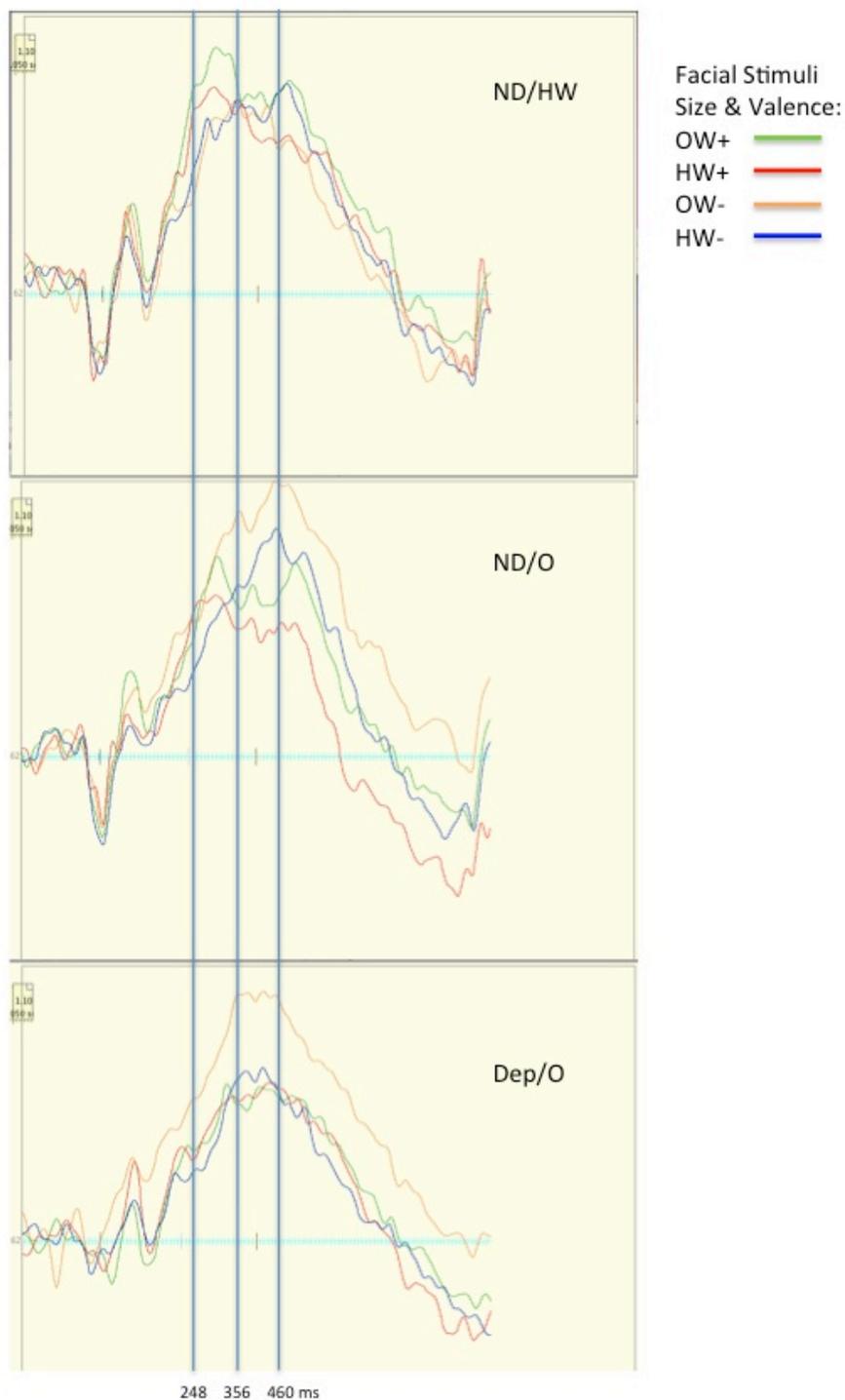


Figure 5. Grand average ERPs, averaged over single channel with least noise (Channel 62) for ND/HW (upper panel), ND/O (middle panel), Dep/O (lower panel). Line colors differentiate between stimuli weight status and valence. Component time windows indicated with vertical lines.

ERP Statistical Analysis Plan

Presence of the P3 component was first established by comparing whether “rare” conditions (“oddball”, valenced conditions) were significantly different than the “frequent” conditions (neutral condition). This was tested by running a one-sample t-test of the difference wave in both positive and negative valenced conditions (subtracting the amplitude of the neutral condition from the valenced “oddball” condition) against a test value of “0” to determine if the paradigm elicited a P3 component. This analysis was run within each selected time window (“early” P3 and “late” P3 windows) and with the mean difference wave averaged across the ROI within the time window of interest and averaged across a single channel with the least noise (channel 62).

Then we ran a 3 x 2 x 2 mixed model analysis of variance (ANOVA) for difference wave data collected during face stimuli tasks: 3 Group [obese and depressed (Dep/O), obese and not depressed (ND/O), or healthy weight and not depressed (ND/HW)] by 2 Stimuli Valence [happy, sad] by 2 Stimuli Weight Status [healthy weight, obese]. This analysis was also run within both “early” P3 and “late” P3 windows and with the mean difference wave averaged across the ROI within the time window of interest and averaged across a single channel with the least noise (channel 62).

Analysis Plan for of TSF Scores

We ran a one-way analysis of variance (ANOVA) with Tukey post hoc multiple comparisons to evaluate Trait TSF and State TSF scores across the 3 groups [obese and depressed (Dep/O), obese and not depressed (ND/O), or healthy weight and not depressed (ND/HW)]. Then we ran a discriminant analysis to predict whether obese participants

(participants in ND/O and Dep/O groups) were depressed or non-depressed. Predictor variables for the discriminant analysis were Trait TSF and State TSF.

Results

P300

Early P3

One-sample t-test of the difference wave averaged across the ROI in both positive and negative valenced conditions (subtracting the amplitude of the neutral condition from the valenced “oddball” condition) against a test value of “0” revealed a trend toward significance, $t(179)=1.65$, $p=0.100$. The same analysis completed using a difference wave approach averaged across a single channel with the least noise (channel 62) revealed a significant difference between difference wave values and the test value “0”, $t(179)=2.02$, $p=0.045$. These results indicate that the “oddball”, valenced conditions elicited a P3 component present at channel 62 within the early P3 component window, and was significantly different than the amplitude elicited from the frequent, neutral condition. Similarly, a trend toward significance was observed when the difference wave was averaged across the ROI, indicating that a P3 component was not significantly different from the response elicited by the frequent condition. Caution should thus be taken when interpreting P3 results from the ROI within the early P3 component window.

Late P3

One-sample t-test of the difference wave averaged across the ROI in both positive and negative valenced conditions (subtracting the amplitude of the neutral condition from the valenced “oddball” condition) against a test value of “0” revealed a significant difference

between difference wave values and the test value “0”, $t(179)=8.13$, $p<0.001$. The same analysis completed using a difference wave approach averaged across a single channel with the least noise (channel 62) revealed a significant difference between difference wave values and the test value “0”, $t(179)=7.41$, $p<0.001$. Thus, in the late P3 component window, results indicate that the “oddball”, valenced conditions elicited a P3 component present at both channel 62 and the ROI, and was significantly different than the amplitude elicited from the frequent, neutral condition. These analyses for the P3 ERP component indicate that we did see a reliable P3 in our experiment. Therefore, the rest of the study results are analyzed using a difference wave approach, which allows us to consider if P3 amplitude is reliably influenced by the critical individual differences of interest (obesity and depression) and the variables of face valence (happy vs. sad) and the weight status of the stimulus (healthy weight vs. overweight).

Analysis using a difference wave approach averaged across the ROI

Early P3

A 3x2x2 mixed model analysis of variance using a difference wave approach revealed the main effect of stimulus weight status (overweight, healthy weight) reflecting that all groups have greater P3 amplitudes in response to overweight facial stimuli [$F(1, 42)=4.89$, $p=0.028$]. This is evident in both Figures 6a and 6b below, where mean P3 amplitude for OW faces is greater than mean P3 amplitude NW faces in all groups. Main effect of group [$F(2, 42)=0.47$, $p=0.629$] and stimuli valence [$F(1, 42)=0.24$, $p=0.629$] were not statistically reliable. No two-way interactions were observed for Group x Stimuli Valence, Group x Stimuli Weight Status, and Stimuli Valence x Stimuli Weight Status (all F 's <2.5).

The 3-way interaction of Group x Stimuli Valence x Stimuli Weight Status was significant [$F(2, 42)=3.67, p=0.028$]. Figures 6a and 6b provide a representation of the mean amplitude seen for each of the stimulus conditions and participant samples. Examination of means show that the ND/HW group had greater mean P3 amplitudes in response to positive and overweight stimuli ($P3 = 1.14 \mu V$), as seen in Figure 6b. The ND/O and Dep/O groups had greater mean P3 amplitudes in response to negative and overweight stimuli (ND/O $P3 = 1.39 \mu V$, Dep/O $P3 = 1.74 \mu V$), which is visually depicted in Figure 6a. No other interactions were observed for Group x Stimuli Valence, Group x Stimuli Weight Status, and Stimuli Valence x Stimuli Weight Status (all F^2 's <2.5).

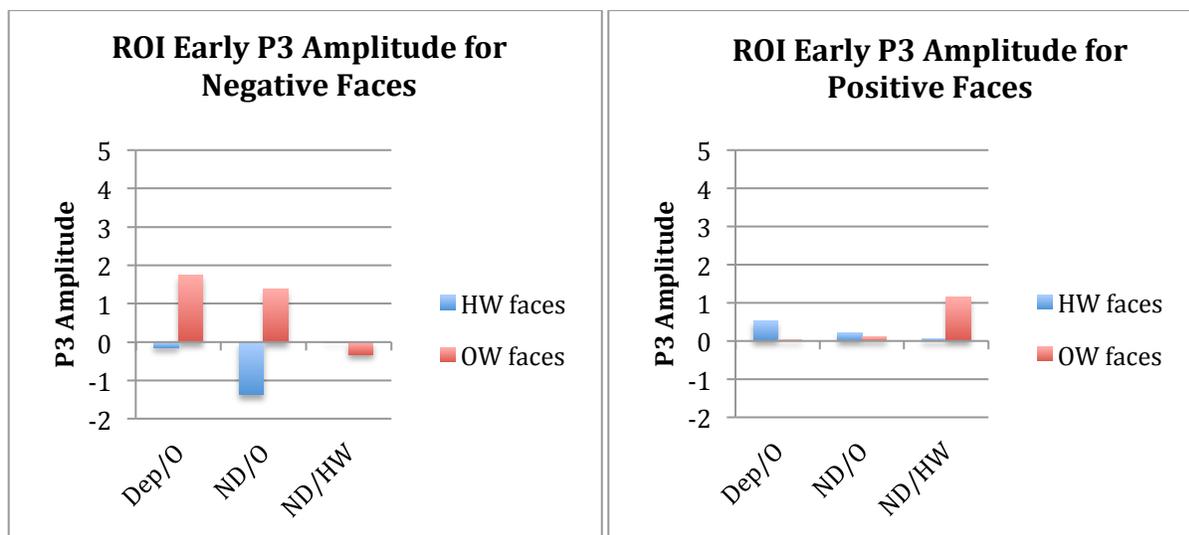


Figure 6a (left). Early window mean P3 amplitudes in response to negatively valenced faces stratified by group, with separate sets of bars for stimuli weight status.

Figure 6b (right). Early window mean P3 amplitudes in response to positively valenced faces stratified by group, with separate sets of bars for stimuli weight status.

Late P3

3x2x2 mixed model analysis of variance using a difference wave approach revealed a main effect of stimuli valence (positive vs. negative) reflecting that all groups have greater P3

amplitudes in response to negatively valenced facial stimuli [$F(1, 42)=5.30, p=0.02$]. Main effect of group [$F(2, 42)=0.598, p=.551$] and stimuli weight status [$F(1, 42)=2.11, p=0.148$] were not statistically significant. Again, no two-way interactions were observed for Group x Stimuli Valence, Group x Stimuli Weight Status, and Stimuli Valence x Stimuli Weight Status (all F 's <1).

The 3-way interaction of Group x Stimuli Valence x Stimuli Weight Status was not statistically reliable [$F(1, 42)=2.18, p=0.116$]. Examination of means show that the ND/HW group had greater P3 amplitudes in response to positive and overweight stimuli ($P3 = 2.48 \mu V$), which is evident in Figure 7b; the ND/O and Dep/O groups had higher P3 amplitudes in response to negative and overweight stimuli (ND/O $P3 = 5.04 \mu V$, Dep/O $P3 = 3.99 \mu V$), which is apparent visually in Figure 7a. These findings were consistent with the reliable findings observed for the early P3 results.

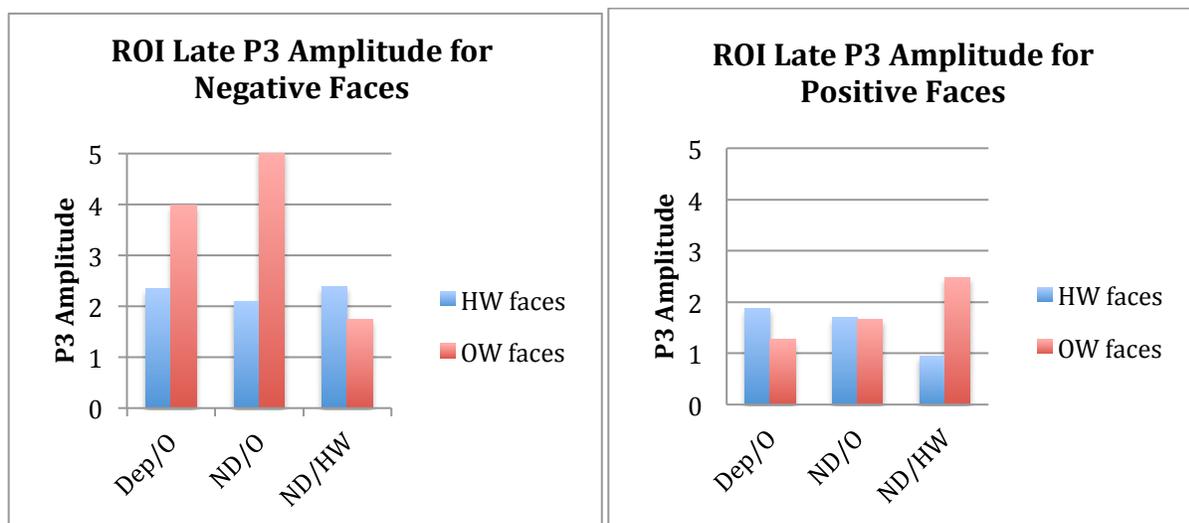


Figure 7a (left). Late window mean P3 amplitudes in response to negatively valenced faces stratified by group, with separate sets of bars for stimuli weight status.

Figure 7b (right). Late window mean P3 amplitudes in response to positively valenced faces stratified by group, with separate sets of bars for stimuli weight status.

Analysis using a difference wave approach averaged across a single electrode

Early P3

3x2x2 mixed model analysis of variance using a difference wave approach averaged across a single channel (channel 62) within the early P3 time window revealed the main effect of stimuli weight status (overweight, healthy weight) reflecting that all groups have greater P3 amplitudes in response to overweight facial stimuli [$F(1, 42)=6.23, p=0.01$]; see Figure 8a for visual representation. Main effect of group [$F(2,42)=0.12, p=0.889$] and stimuli valence [$F(1,42)=0.12, p=0.735$] were non-significant.

The 2-way interaction of Group x Stimuli Valence approached significance [$F(2, 42)=2.54, p=0.082$]. Examination of means, as depicted in Figure 8b, show that ND/HW group had greater P3 amplitudes in response to positively valenced stimuli (P3 = 1.12 μV); the ND/O and Dep/O groups had greater mean P3 amplitudes in response to negatively valenced stimuli (ND/O P3 = 0.43 μV , Dep/O P3 = 0.77 μV). No other interactions were observed for Group x Stimuli Weight Status, Stimuli Valence x Stimuli Weight Status, and Group x Stimuli Valence x Stimuli Weight Status (all F's <1.6).

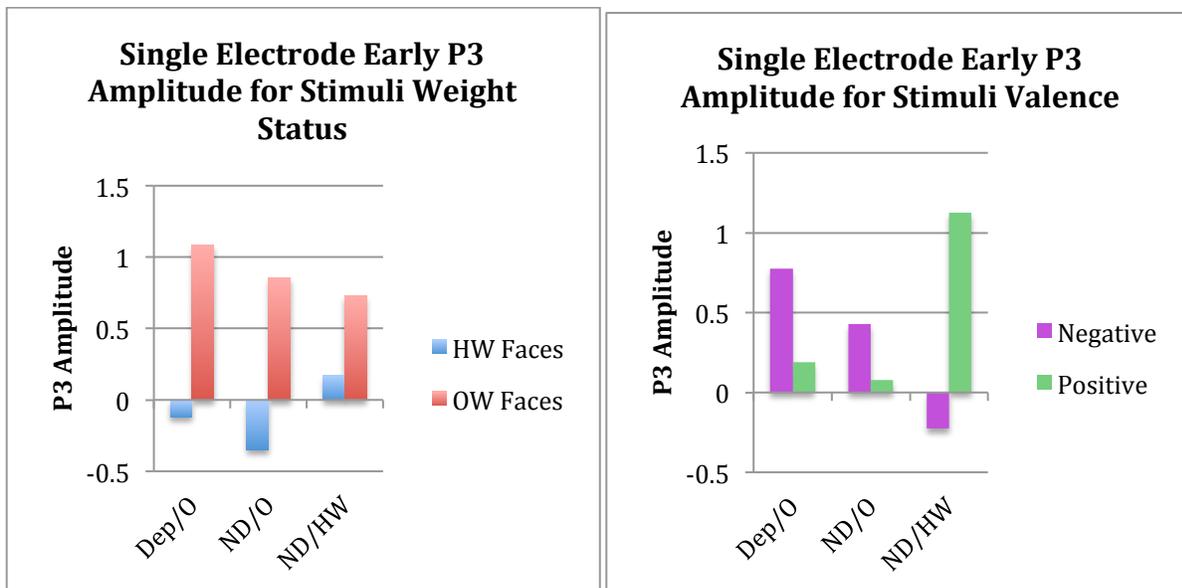


Figure 8a (left). Early window mean P3 amplitudes stratified by group, with separate sets of bars for stimuli weight status.

Figure 8b (right). Early window mean P3 amplitudes stratified by group, with separate sets of bars for stimuli valence.

Late P3

3x2x2 mixed model analysis of variance using a difference wave approach averaged at channel 62 within the late P3 time window revealed the main effect of stimuli valence (positive, negative) [$F(1, 42)=7.50, p=0.007$] reflecting that all groups have greater mean P3 amplitudes in response to negatively valenced stimuli; see Figure 9b for reference. A trend [$F(1, 42)=2.80, p=0.096$], that is displayed in Figure 9a, was also observed for the main effect of stimuli weight status (overweight, healthy weight) reflecting that all groups have a marginally greater P3 amplitudes in response to overweight facial stimuli. Main effect of group was non-significant [$F(2,42)=0.834, p=0.436$].

No interactions were observed for Group x Stimuli Valence, Group x Stimuli Weight Status, Stimuli Valence x Stimuli Weight Status, and Group x Stimuli Valence x Stimuli Weight Status (all F 's < 2).

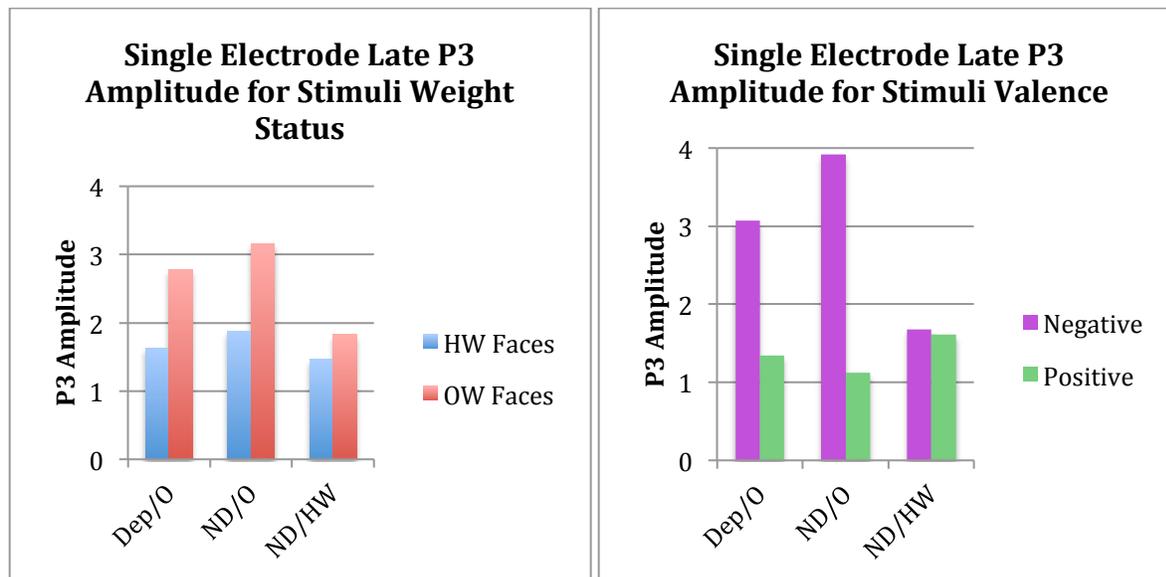


Figure 9a (left). Early window mean P3 amplitudes stratified by group, with separate sets of bars for stimuli weight status.

Figure 9b (right). Early window mean P3 amplitudes stratified by group, with separate sets of bars for stimuli valence.

TSF Scores

Analyses of Group Differences

A one-way ANOVA revealed significant differences between groups on Trait TSF scores [$F(2,44)=18.34$, $p<0.001$] and State TSF scores [$F(2,44)=23.58$, $p<0.001$]. Tukey post-hoc comparisons of the three groups' scores on the Trait TSF and State TSF indicate that the Dep/O group ($M=72.13$, 95% CI [55.98, 88.26]) scored significantly higher than the ND/HW group ($M=37.94$, 95% CI [35.49, 40.39]) and the ND/O group ($M=38.50$, 95% CI [35.12, 41.88]) at $p<0.001$ for both Trait TSF and State TSF scores. Comparisons between the ND/HW and the

ND/O groups were not statistically significant at $p < 0.05$. Visual representation of mean scores by group can be seen below in Figure 10.

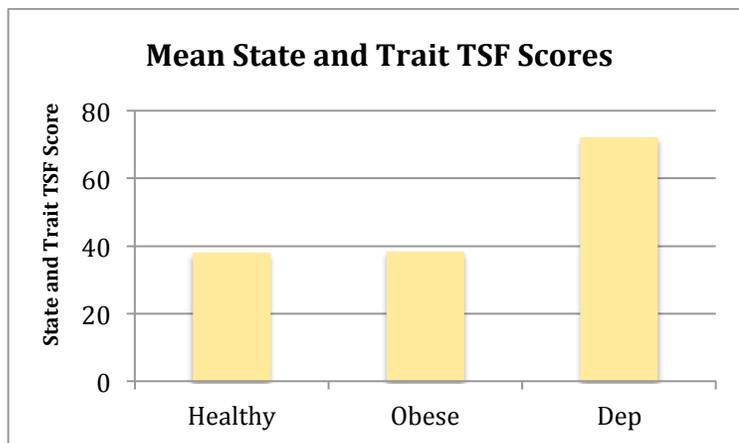


Figure 10. Mean State and Trait TSF Scores by group

Discriminant Analysis

Discriminant analysis run on obese participants (participants in ND/O and Dep/O groups) using Trait TSF and State TSF scores to determine classification as depressed or non-depressed revealed correct classification for 100% of the ND/O group and 68.8% of the Dep/O group. Discriminant score distribution can be seen in Figure 11. Classification results reveal that Trait and State TSF scores have 68.8% sensitivity and 100% specificity. This test indicates that using Trait and State TSF scores allowed for correct detection of 68.8% of obese individuals with depression, while 31.2% of obese individuals with depression went undetected; it also correctly identified all obese individuals without depression.

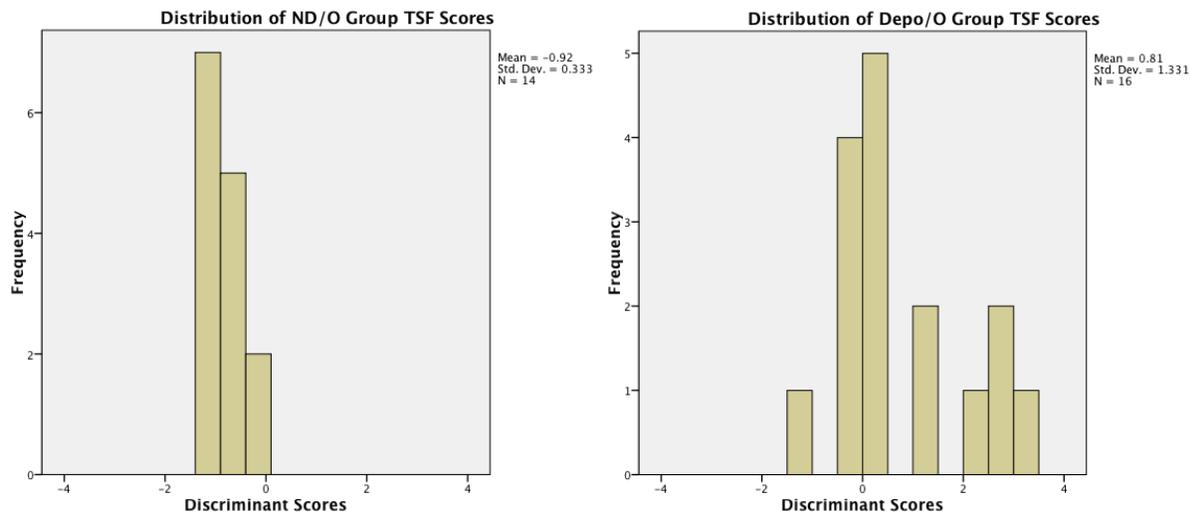


Figure 11. Frequency distribution of discriminant scores for the ND/O group (left) and Dep/O group (right)

Discussion

The purpose of this study was to determine what attention bias differences and similarities are present in three groups of participants: [(a) currently obese and currently depressed (Dep/O), (b) currently obese and never depressed (ND/O), or (c) healthy weight and never depressed (ND/HW)]. We planned to determine if attention bias differences or similarities existed by evaluating P3 component differences and similarities in response to facial images and self-report responses on State and Trait TSF questionnaires.

The present study provides support that cognitive processing of faces is different in obese individuals versus healthy weight, non-depressed individuals. Our results show that the ND/O group processes weight status and valence of facial stimuli more similarly to the Dep/O group than as compared to the ND/ HW participants. In contrast, with the measure of an eating-related cognitive distortion, thought shape fusion, ND/O individuals were more similar to ND/HW. This cognitive error appears to be present to a greater degree in Dep/O individuals and can be used to distinguish Dep/O individuals from ND/O individuals.

We found a main effect of weight, such that all groups responded more to stimuli of overweight status. All groups may have responded more to the enlarged, overweight facial stimuli due to current ideals and cultural expectations of weight and size. Cultural expectations of thinness, particularly in women have been studied for many years; models in the media have trended toward thinner standards, and diet articles have increased significantly (Garner et al., 1980, Wiseman et al., 1992). Due to this increased media exposure from various sources (online, magazines, television, radio), women have been bombarded with images and videos of healthy and thin women. Because of this increase exposure to a thinner or healthy weight ideal, it is likely that in real life, the overweight image is considered the “oddball”, infrequent stimulus. Since the P3 component is evoked by more unexpected, infrequent target stimuli, it may be possible that greater P3 amplitude by all groups in response to enlarged, overweight facial stimuli is elicited by decreased exposure to overweight individuals in the media.

Our results showed a main effect of valence, such that all groups responded more to stimuli of negative valence. A possible explanation is the “negativity bias”, phenomenon of heightened sensitivity to negatively valence information. The phenomenon has been explored in various fields, and findings suggest that negatively valenced events typically have a great impact in life (Rozin & Royzman, 2001). This idea that “Bad is stronger than good” can be applied across a broad range of psychological phenomenon (Baumeister et al., 2001), particularly in evaluative processes pertaining to valence and affect (Cacioppo & Gardner, 1999), and can have an effect on evaluative categorization and larger ERP amplitude (Ito et al., 1998).

When considering interactions of group effect on the perception of stimuli valence and weight status, we found that ND/HW individuals allocated more attentional resources to overweight, positive stimuli, while both ND/O and Dep/O group allocated more attention to

overweight, negative stimuli. This may be explained with literature pointing to amplitude of the P3 component being proportional to the amount of attention allocated to processing a stimulus (Johnson, 1988). Additionally, this allocation of attention is typically heightened when a stimulus is self-referent (Gray et al, 2004). People typically organize and process information as it pertains to the self (Rogers et al., 1977); stimuli that are particularly relevant psychologically to an individual can also promote a greater P3 amplitude, especially if they present with high emotional value to the individual (Johnston, Miller, & Burleson, 1986). We hypothesized that the Dep/O group would respond with greater attentional resources toward overweight, negative stimuli based on self-reference; overweight stimuli is more personally significant and negative valence is more emotionally relevant to this group than healthy weight or positively valenced stimuli. Our results supported this hypothesis, with the Dep/O group having an augmented P3 in response to negative, overweight stimuli. This finding provides insight into the comorbidity of depression and obesity by building upon prior research of heightened P3 in depressed individuals during presentation of negatively valenced stimuli (Ilardi et al., 2007). We had hypothesized that the ND/HW group would have the opposite result, where they would find healthy weight, positively valence stimuli most salient. Our results did support the tendency for ND/HW to have greater P3 to positive stimuli; however, we found that they displayed a greater P3 amplitude in response to overweight, positive stimuli. The increased allocation of attention to overweight faces may be due to the main effect of weight, explained by expectation of cultural norms, as discussed before. What was most surprising were results found for the 3-way interaction for the ND/O group. We hypothesized that the ND/O group would look more similar to the ND/HW group, except for their preference for overweight faces, such that they would respond with greater P3 amplitude to positively valenced, healthy weight faces. However, we found that the

ND/O group looked more similar to the Dep/O group, where a heightened P3 was present in response to negative, overweight stimuli. Our results appear to suggest support for obesity being a risk factor for depression, and support the P3 component as an objective, unbiased marker for depression risk; ND/O individuals display attention bias similarities to Dep/O individuals in the cognitive processing of facial size and valence.

Our results provided support for eating-related cognitive distortion questionnaires measuring Thought-Shape Fusion (State and Trait TSF) being a subjective cognitive measure that distinguishes the Dep/O group from the ND/O group, such that individuals in the Dep/O group score higher on the Trait and State TSF when compared to ND/O and ND/HW groups. Prior research has shown that negative affect is related to susceptibility to TSF in healthy weight individuals (Coelho et al., 2010) and can be induced in healthy weight females but not overweight females (Coelho et al., 2011). Findings from the present study expand on prior research by highlighting that negative affect is not only related to susceptibility to TSF in healthy weight females, but also currently depressed, obese females. Additionally, we found that TSF is not only a phenomenon that is present in healthy weight females, but also in obese female experiencing depression. One possibility is that when negative affect is present, like in a major depressive episode, obese individuals can also be susceptible to TSF. Similar to other cognitive “schemata” present in depression, such as “either-or rules” or “inflexible and unattainable self-expectations” (Kovacs & Beck, 1978), TSF may a maladaptive psychological pattern of thinking that predisposes obese individuals for depression when negative affect is experienced. Our results show a significant difference between the scores for the ND/O and Dep/O groups, and show that TSF scores have good sensitivity and excellent specificity for classifying depression in obese individuals. This may indicate that TSF scores may be helpful in determining depression

risk in currently obese individuals. An important next step may be to explore TSF as it relates to level of depression symptoms, or how TSF presents in obese individuals who are dysthymic.

Limitations

This investigation has several limitations that are important to consider. Categorization of weight and analyzing weight status as a factor may limit our analyses, since weight is commonly analyzed as a continuous variable in regression analyses. Though results have guided us in determining what cognitive markers of obesity may put obese individuals at risk for depression, it would be beneficial to follow up with a longitudinal study to determine if cognitive factors can truly serve as predictive markers of depression vulnerability. Since this study only included female participants, we are unable to generalize results to males. We chose female participants for the study for practical reasons, since TSF has been previously studied in only females, and there is a higher incidence of comorbid obesity and depression in females. Our population also only consisted of college undergraduates from the University of Kansas and community members from Northeastern Kansas, which may make results more difficult to generalize to more diverse populations. We only had three study groups, and lacked a healthy weight group that is diagnosed with depression. The reason for not including this particular group is because we were interested in exploring the depression risk as defined by cognitive markers in obese individuals. Additionally, due to difficulty recruiting depressed-obese individuals, the present study had a small sample size per group. Larger sample size would have aided in achieving maximal power. Similarly, if time permitted, an increased number of trials per condition in the paradigm would have likely assisted in obtaining increased ERP data per subject, also increasing power.

Future Directions

Despite the limitations this study has, it provides some important pieces of evidence toward better understanding of comorbid depression and obesity and how it arises. Prior to the present study, there has been no exploration of cognitive processing differences or similarities in healthy versus non-depressed obese versus comorbid depressed-obese individuals. This is the first study to report similarities in attentional bias between depressed and non-depressed obese individuals. Our results support obesity being a risk factor for depression and supports the P3 component being an objective, unbiased marker for depression risk in obese individuals. TSF scores were found to have good sensitivity and excellent specificity for classifying depression in obese individuals, indicating this self-report measure may be useful in determining depression risk in currently obese individuals.

Future research should aim to continue building upon findings from this study, and add to understanding of the etiology of comorbid obesity and depression. For example, while this study may provide part of the answer for how obesity is a risk factor for development of depression, in future studies, it may be beneficial to add a healthy weight and depressed group to explore how cognitive factors defining depression may predict obesity risk. This would be important in evaluating how comorbid obesity and depression may differ if obesity results from depression versus if depression results from obesity.

In this study, we found that obese individuals can also be susceptible to TSF, when experiencing depression, and there is a significant difference between how non-depressed obese versus depressed-obese individuals responded. It appears that, similar to prior findings in healthy, non-depressed females, high negative affect exacerbates vulnerability for TSF (Coelho, 2010). A potential driver behind this phenomenon may be ruminative thinking, when an

individual chooses to focus their attention on their depressive symptoms. A ruminative style of thinking (Nolen-Hoeksema, 1991) often perpetuates continued maladaptive thinking.

Additionally, ruminative thinking style appears to predict onset of major depressive symptoms (Nolen-Hoeksema, 2000). Future research looking at correlations between ruminative thinking and TSF may shed light on additional cognitive vulnerabilities that may contribute to development of depression in obese individuals.

Conclusions

When combined together, TSF scores and P3 amplitude in response to valenced stimuli may provide important information that can assist in parsing the relationship between obesity and depression. Results from the present study point to the P3 being a useful objective, unbiased marker for depression risk, and point to TSF scores being a useful clinical tool with in segregating obese individuals into not-at-risk or at-risk groups for depression. This research may highlight some useful ideas for clinical tools that indicate presence of cognitive risk factors for development of depression in obese individuals.

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Appendix A

Language and Handedness

Name _____

Phone number _____ Email address _____

Which way would you prefer us to contact you (circle one)?
 email a phone call

What hand do you use to hold a pencil when you write?
 Left Right Both

What hand do you use to throw a ball?
 Left Right Both

What hand do you use when you brush your teeth?
 Left Right Both

What hand do you use to hold the scissors when you cut paper?
 Left Right Both

Is anyone in your immediate family (mother, father, brother, sister) left handed?

What is your native language?

Do you speak any language, other than English, fluently?

Have you ever received a head trauma resulting in loss of consciousness?

Did you ever repeat a grade? If so, what grade?

What time was the last time you ate (meal, snack)?

How hungry/full are you right now? (circle one)

1	2	3	4	5
Very hungry	A bit hungry	Half full	Full	Extremely full