Taste Dysfunction, CNS Correlates and Psychosocial Factors in Eating Disorders

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In this review we are going to explore several factors of eating disorders such as taste dysfunction, CNS correlates and psychosocial factors in order to get a better overall understanding of their contribution to anorexia nervosa, bulimia nervosa and obesity. This review aims to look at taste differences that may contribute to the development of an eating disorder or may occur because of an eating disorder. This review is also interested in looking at how different brain regions correlate with eating disorders. Understanding regions of the brain that are in relation to taste could give us a better understanding as to why individuals with eating disturbances experience differences in taste. Finally, psychosocial factors such as anxiety and body dysmorphic disorder that are often in connection with eating disorders may also help explain why individuals with eating disorders experience differences in taste. After making a connection between taste dysfunctions, CNS correlates and comorbid disorders, we will propose a treatment plan that takes these factors into consideration with the intention of providing the best fit treatment plan that will help promote a more healthy lifestyle.

Anorexia nervosa is a serious psychiatric eating disorder that is characterized by significantly low body weight due to an excessive fear of gaining weight (American Psychiatric Association [APA], 2013). It is also characterized by restricting food intake so that more energy than food consumed will be burned in a day, which leads to low body weight and BMI. The individual must have a BMI of seventeen or lower in order to be diagnosed as anorexic (APA, 2013). There are two main subtypes of anorexia nervosa, the first, restrictive anorexia, and the second, anorexia bulimia. Restrictive anorexia nervosa is characterized by displays of weight loss that are achieved by fasting, dieting or a combination of exercise and fasting for periods of time (APA, 2013). Anorexic bulimia is characterized by weight preventing habits such as self-
induced vomiting or overuse of laxatives. Consistent results of numerous studies suggest that biological factors are important contributors of the development as well as maintenance of anorexia nervosa (Brand-Gothelf et al., 2016). Social aspects such as economic status, cultural variability, and westernized promotion of weight loss programs are thought to be other important factors that may lead to the susceptibility of developing an eating disorder (Radeloff et al., 2014). Despite not exactly knowing how these disorders surface, eating disorders rank among the most common mental health issues along side of disorders such as anxiety and depression. Worldwide, anorexia nervosa is thought to occur in in 0.9 percent of the population, 0.7 percent of those being adolescent females. The most common prevalence of anorexia nervosa is among adolescent age, primarily between the ages of 12-25. The path to recovery is a long road marked with many bumps along the way. With only a recovery rate of 50 percent (Wagner et al., 2008), 30% of anorexic patients relapse, while the other 20% ultimately die of complications related to the illness, making it one of the most fatal mental illnesses (Radeloff et al., 2014). Even after recovery, due to lack of nutrition for such extended periods of time, recovered anorexic patients still experience their fair share of lingering consequences of the disorder, such as physical, mental, and social consequences (Radeloff et al., 2014).

Bulimia Nervosa is a slightly more prevalent psychiatric eating disorder, affecting 1.5 percent of the entire population (Klabunde, Acheson, Boutelle, Matthews & Kaye, 2013). The disorder is characterized by reoccurring binge eating episodes in which people consume an amount of food that is greater than what most individuals would be able to eat in a similar amount of time under the same conditions (APA, 2013). During those binge periods the individuals feel a lack of control that makes it difficult and nearly impossible for them to stop eating. The other fundamental characteristic of bulimia nervosa is reoccurring use of weight
Obesity is the most prevalent eating disorder among the others previously mentioned, affecting more than 1/3 of the adult population (Remla, Hadjidj, Ghezzaz, Moulessehoul & Aribi, 2016). In the United States alone, more than 35.5% of men and 35.8% of women struggle with obesity. Although obesity is not listed as a feeding or eating disorder in the American Psychiatric Association’s Diagnostic Statistical Manual l- 5, it is acknowledged as a food disturbance characterized by excessive food intake relative to energy expenditure therefore leading to excess body fat and a BMI of thirty or above (APA, 2013). It is not considered a mental disorder because contributing factors are in wide range of genetic, physiological, behavioral and environmental variances. Despite the fact that the American Psychiatric Association does not consider it a mental disorder, the disorder poses many mental and social problems for individuals who are obese. Perhaps more so than social consequences, the physical consequences of obesity take a detrimental toll on the body. The World Health Organization claims that excessive body fat over an extended period of time causes increased risk to heart
disease, stroke, hypertension, gallbladder disease, type II diabetes, pulmonary diseases and sleep disturbances such as sleep apnea.

Since this review aims to discuss the connection between eating disorders and taste, it is important to note that food intake is closely associated with hedonic sensations, such as liking appetitive foods or avoiding others (Oberndorfer et al., 2013). These hedonic sensations are calculated in response to food stimuli and then processed. The three main neural processing centers for liking and disliking food and therefore food consumption are the orbital frontal gyrus (OFC), insula, and striatum. The OFC is thought of as the secondary or higher order taste center that deals with emotional coding of food stimuli. It is the secondary center because first the stimulus is processed by the amygdala, and then the OFC reevaluates the rewarding properties of the stimulus in order to see if it is worth consuming or not. Another important brain region associated with eating disorders is the insula, which is thought to be the fifth lobe of the brain because of its function as well as location (Oberndorfer et al., 2013). The insula is responsible for primary taste perception. The location of the insula makes it possible to integrate body states and then make that information available to higher order processing centers such as the OFC. Therefore the insula associates bodily states with emotional experiences, which leads us to have conscious feelings. Because it is thought to decode bodily states, a bad odor for example may lead us to feel disgust, a common feeling among patients with eating disorders. The striatum is the third most common area we will discuss in this review. Afferent fibers traveling from the cortex to the striatum are not only movement related because the basal ganglia are thought to be connected to many cortical functions and aspects of cognition. Therefore the striatum is not only concerned with movement, but also with reward experiences, a very essential factor in eating disorders.
Now that we have looked at an overview of the three disorders at hand and have been presented with the three primary brain regions associated, we can look at psychosocial factors of eating disorders such as anxiety, social phobias, body dysmorphic disorder and obsessive-compulsive disorder. Most of these aspects are separate mental illnesses that are comorbid with eating disorders. In some cases it is interesting to look at if the psychosocial disturbances were present before the onset of the eating disorder or if they came about during the course of the disorder. As mentioned previously anxiety is one of the most prevalent mental illnesses; 18.1% of the population has been reported as having one type of anxiety at sometime in the span of his or her life (Godart, Flament, Lecrubier, & Jeammet, 2010). In eating disorders specifically, 75% of women who have bulimia nervosa have reported an anxiety disorder, whereas 55% of individuals with anorexia nervosa have reported one. The most common anxiety disorder is generalized anxiety disorder, which has been seen to occur in 55% of individuals with an eating disorder (Godart et al., 2010). Generalized anxiety disorder is characterized by excessive worry in which the individual finds it extremely difficult to control the worry (APA, 2013). In addition, that excessive worry is accompanied by feelings of restlessness, difficulty concentrating, unexplained fatigue, and/or sleep disturbances. The second most common anxiety disorder is social phobia, which occurs in 56% of patients with eating disorders. Social anxiety is characterized by noticeable anxiety and fear when an individual is exposed to a social situation (APA, 2013). Social situations may cause anxiety due to meeting new people; having to engage in conversation; being observed, particularly in an eating or drinking situation; or performing in front of other individuals. This social anxiety often leads individuals to avoid social situations when they can, or if they cannot, they often come up with tactics that help alleviate some of the anxiety. Another disorder that is common among patients with eating disorders is body
dysmorphic disorder, which is characterized by a preoccupation over one or more psychical characteristics that the individual believes are flawed (APA, 2013). Skin picking, mirror checking, and excessive grooming are frequent mechanisms adopted by the individual that helps them cope with the concern of his or her appearance. These behaviors and the anxiety that individuals with body dysmorphic disorder have often severely impair most social and occupational areas of life. The prevalence of body dysmorphic disorder is 1.5%, and if often comorbid with obsessive-compulsive disorder with, 66% of individuals with eating disorders additionally having both body dysmorphic disorder and obsessive-compulsive disorder (Buhlmann, McNally, Wilhelm, & Florin, 2002; Godart et al., 2010). Obsessive-compulsive disorder is a common disorder that occurs in 2.3% of people among their lifetime (Ruscio, Stein, Chiu, & Kessler, 2010). Obsessive-compulsive disorder is also often comorbid with eating disorders, having a prevalence rate of 66% (Godart et al., 2010). The disorder is characterized by obsessions and compulsions (APA, 2013). Obsessions are defined as reoccurring, persistent thoughts or images that are intrusive and unwanted and often only relieved if the individuals gives in to an action such as a compulsion. Compulsions are defined as repetitive behaviors such as checking doors or hand washing; or mental acts such as counting or repeating words that the individual feels compelled to do in response to their obsessive thoughts. Similarly to the other disorders mentioned, obsessive-compulsive disorder causes significant impairment or distress to individual’s social and occupational areas of life (APA, 2013).

In this review we provide an overview of the taste dysfunctions that occur in eating disorders, as well as look at the CNS correlates of taste to make a connection between the two. We will go more in depth about the possible correlations between eating disorders and other disorders such as social anxiety and obsessive-compulsive disorder. We will combine the
knowledge found behind taste dysfunctions, CNS correlates and comorbid psychosocial disorders in order to examine a possible connection between the three, as well as suggest a successful treatment plan.

**Taste Dysfunction and Eating Disorders**

Anorexia nervosa, bulimia nervosa and obesity all have distinct changes in taste perception that occur during the course of the individual’s eating disorder. Although patients may not recognize these taste differences in his or her everyday life, abundant research has been conducted in order to get a better understanding of taste dysfunctions in eating disorders. The most frequent changes in taste that occur predominantly have to do with overall under responsiveness or over responsiveness to stimuli, sensitivity to sweet stimuli, and changes in fat detection threshold. Previous research conducted on taste dysfunctions in anorexia nervosa suggests that patients with this disorder experience heightened sensory over - responsiveness to food stimuli as compared to people without anorexia nervosa. Sensory over responsiveness in anorexia nervosa can be applied but not limited to an increased taste perception threshold for sweet stimuli and a weakened taste reactivity to fat. On the other hand, many patients with bulimia nervosa are reported as having sensory under responsiveness. Previous research on taste and sensory response in bulimics has found that patients cannot differentiate between high calorie stimuli and low calorie stimuli, therefore they often report higher pleasantness ratings to sucrose than patients with anorexia nervosa. Research done on obese individuals has found that they have an increased responsiveness to both fat and sugar. In this section we will explore the connection between taste and eating disorders by looking at several research studies pertaining to response to sweet taste stimuli, as well as fat taste response. In addition, we will address how re-
feeding affects taste sensitivity in patients with anorexia nervosa, as well as look at how obese patient’s taste sensitivity changes after different types of diets.

*Anorexia*

Sensory modulation disorder is characterized by the integration of several abnormal sensory responses into one construct, wherein individuals cannot regulate the intensity of sensory responses that occur in every day life. Gothelf et al. (2016) conducted a study that assessed if and how sensory modulation disorder occurs in patients with anorexia nervosa or bulimia nervosa and compared those patients with healthy control participants. Two standardized questionnaires were administered, one in which participants answered questions about their disorder, which was assessing for the severity of their illness. The other questionnaire was the sensory responsiveness questionnaire (SRQ) in which patients were presented with a set of 58 everyday life scenarios and were asked to rate the intensity or aversion that was provoked by each situation. Each scenario presented was designed to have a sensory stimulus that represented an auditory, visual, gustatory, olfactory, vestibular, or somatosensory stimulus. The results of their study indicated that participants with anorexia nervosa experienced overall sensory over responsiveness for the taste/gustatory and vestibular/kinesthetic stimuli. These findings implicated that the occurrence of sensory over responsiveness may be a distinct feature of anorexia nervosa instead of malnutrition and weight reduction. An interesting speculation around this idea is that patients with anorexia nervosa have an improved recognition of tastes and therefore the ability to enjoy the pleasantness of food is reduced in sweet or high caloric food because of the fear of gaining weight. In order to further this idea, many researchers have done studies looking primarily at taste perception of sweet stimuli such as sucrose in anorexic patients.
Eiber, Berlin, Brettes, Foulon & Guelfi (2002) conducted a study on restrictive anorexia nervosa, anorexia bulimia, and bulimia nervosa patients in order to examine hedonic responses to sucrose solutions as well as fear of gaining weight in individuals with eating disorders. The study administered sucrose solutions ranging from zero to forty percent. The participants were put in either the swallow group or spit group and were then asked to rate the pleasantness of the sucrose solution on a nine-point scale. The results of the study showed that the fear of swallowing was higher among anorexic bulimic patients than anorexia nervosa and bulimia nervosa patients and that sweet taste perception was highest for the restrictive anorexic group. In addition, hedonic responses were significantly lower when the participants had to swallow the sucrose solution. For both the spit and swallow condition, participants rated 20% and 40% sucrose solutions lower than a five which was categorized as disliking the solution. The fact that hedonic responses were significantly decreased when the participant had to swallow the sucrose solution suggests that perhaps the excess fear of gaining weight is what really leads the participants to experience a decreased pleasure experience to the sweet taste. Szalay et al. (2010) conducted study on taste reactivity and hedonic responses in women with restrictive type anorexia nervosa. Presentations of concentrations were as follows: sucrose as sweet, NaCl as salty, monosodium glutamate (MSG) as umami, HCl as sour, quinine HCl (QHCl) as bitter, and orange juice as complex taste. The participants were asked to rank the exposures to the concentrations on a scale ranging from hedonically negative to hedonically positive. When compared to the control group it was determined that the anorexic group ranked sucrose, salt and umami as significantly more hedonically negative than the unpleasant, aversive tastes. These findings suggest that patients with anorexia nervosa may get less pleasure out of eating because if they cannot enjoy pleasant tasting foods they will perhaps be less motivated to eat at all.
Nozoe et al. (1994) conducted a study that looked at changes in taste responsiveness during behavior therapy for inpatients with anorexia nervosa. They conducted a taste test for each of the taste categories using refined sucrose for sweet condition, sodium hydrochloride for salty, tartrate for sour and quinine for bitter. Measures were taken on sensitivity to these taste categories at admission to treatment, one week into treatment, when food intake reached 1600kCal a day and finally at discharge. The results showed that patients began to show improvements in taste sensitivity, wherein they were responding more frequently to the stimuli, as early as the first week in treatment. Improvement in taste sensitivity to sourness and bitterness was the first significant change in taste sensitivity and did not occur until patients had begun to consume 1600kCal a day. Reaching 1600kCal a day typically ranged anywhere from 30 to 70 days depending on the severity of the disorder and motivation to recover. Sensitivity to sweet and salty tastes did not significantly improve until discharge. Delay in improvement of sweet taste sensitivity could be in connection with anorexic nervosa patients frequently admitting disliking and avoiding sugary foods. Therefore it is possible that earlier improvement in taste responsiveness is an indicator of lower resistance to therapy than those who have a slower recovery course. This notion is demonstrated in this study by patients displaying earlier improvement in taste responsiveness to both pleasant and unpleasant stimuli as well as attaining 1600kCal a day earlier than those who continue showing slower rates of improvement to taste sensitivity. Therefore, this study suggests that patients who are more motivated to recover and are willing to consume 1600kCal a day sooner than those who are not, will show enhanced improvement in taste sensitivity perception at a quicker rate than those more hesitant and less motivated to recover.
Peterson et al. (2016) conducted a study that assessed meal experiences in short term re-feeding. This study compared hunger and fullness levels, smell, and taste responses in anorexics that have severe malnutrition at admission to treatment, and after medical re-feeding occurs. Medical re-feeding occurs after periods of fasting or purging that have led the individual to the point of malnutrition. The individual is then medically re-fed in a period of time in which the individual consumes a high calorie overfeeding in order to get the individual’s weight and nutrition at a healthier level. During re-feeding patients consumed a standardized mixed meal, which consisted of 8oz. of milk and 2.2 oz. of cereal every 30-minute increment over the span of 150 minutes. The results showed that patients showed a significant change in taste perception from admission to the end of treatment. When patients were first admitted they displayed high perceptions of unpleasant taste to the standardized mixed meal, whereas when leaving treatment patients showed more normalized responses to sensory experiences such as lower perceptions of unpleasant taste. Overall, the study gathered that although patients had more normalized sensory experience responses after re-feeding, severe meal related sensory responses still occur.

Wagner et al (2015) conducted a study on sweet taste sensitivity in order to detect possible underlying sensitization and habituation in patients recovered from anorexia nervosa and bulimia. The study administered 20 trials of one of two solutions. One was made up of ten percent sucrose, while the other was sucralose (Splenda) and matched in sweetness to the sucrose. Patients underwent an fMRI while being exposed to the tastants in order to look for possible sensitization and habituation effects to sweet stimuli. The results of this study show that the recovered anorexic patients had a decreased sensitization effect for sucrose when compared to recovered bulimics and healthy controls. Therefore, recovered anorexics responded less frequently to sucrose after repeated exposure than did recovered bulimics and controls. However,
recovered anorexics showed more sensitization to sucralose. One reason that patients may respond the opposite way to sucralose, the artificial sweetener, is because they might be able to distinguish between high caloric stimuli (sucrose) and low caloric stimuli (sucralose) and therefore allow themselves to sensitize to the non-weight gain threatening artificial sweetener. This may suggest why anorexic individuals may therefore habituate to sucrose and sensitize to sucralose.

_Bulimia_

As previously mentioned in the anorexia sub-section, Gothelf et al. (2016) conducted a study to examine if sensory modulation disorder occurs in patients with anorexia nervosa, as well as bulimia nervosa and compared them with healthy control subjects. The results for bulimic patients showed that they experienced sensory under responsiveness for the intensity of the stimuli representing the different taste categories. This finding may be attributed to the idea that sensory over responsiveness is associated with over control. This would be in line with the fact that anorexics practice extreme levels of control through behaviors such as restricting. Sensory under-sensitivity may be associated with under control, and make sense in patients with bulimics because they engage in under control behavior such as binges. Also as previously mentioned, Wagner et al. (2015) conducted a study on sweet taste sensitivity to detect possible underlying sensitization and habituation in patients recovered from anorexia nervosa and bulimia. The results showed that recovered bulimics show an increased sucrose sensitization to sucrose. Because they showed increased sensitization to both solutions, it is suggested that bulimic patients do not distinguish between high calorie stimuli and low calorie stimuli, which would therefore attribute to them not being able to stop eating either during a binge episode. Franko, Wolfe & Jimerson (1993) conducted a study that aimed to test sweetness intensity and
pleasantness of sucrose solutions in concentrations ranging from zero percent to forty percent. The results showed that bulimics rated sucrose significantly more pleasant than controls. In addition, bulimics with a history of anorexia nervosa rated sucrose solutions as having lower taste pleasantness than controls. Higher pleasantness ratings to sucrose in bulimics could be due to the fact that they do not view sweet foods as much of a threat because they are more than likely to not keep those high caloric foods in their body long enough to be digested. In contrast, bulimic participants that have a prior history of anorexia nervosa may have rated sucrose pleasantness lower because of the fear of high calorie foods may persist even after the individual has received treatment for their eating disorder. In relation to the previous study, as mentioned earlier Eiber et al. (2002) later conducted a study on restrictive anorexia nervosa, anorexia nervosa bulimia nervosa and bulimia nervosa patients in order to examine hedonic responses to sucrose solutions as well as fear of gaining weight in individuals with eating disorders. The results of that study showed that taste perception threshold was increased more so than individuals with anorexia nervosa. The findings and explanation for increased taste perception of sweet stimuli are consistent with Franko (1993) study which suggests that bulimics are less concerned with high calorie content due to the fact that most often it will not actually be digested and therefore count as calories that may lead the individual to gain weight.

Obesity

Less research has been done on taste differences in obese individuals as compared to research done on anorexia nervosa and bulimia. Drewnowski, Brunzell, Sande & Iverius (1984) conducted a study that measured pleasure intensities of sweetness, fatness, and creaminess different combinations of milk, cream and sugar. Participants were presented 20 solutions and asked to rate them on four, nine point scales rating pleasure, sweetness, fat content and
carmine. The results of this study indicate that healthy control patients prefer moderate and low levels of lipid and sucrose. On the other hand, obese patients preferred a higher fat stimuli and lower sucrose intensity than controls. In addition, formally obese patients showed enhanced responsiveness to both sugar and fat when compared to obese and control patients. Obese patients showing highest preference for fat is consistent with higher fat proportions occurring in obese individuals when compared to healthy weight individuals. It makes sense that previously obese patients may have enhanced responsiveness to both sugar and fat due to the fact that in order for them to become less obese they must have had to cut down on these foods. Formerly obese patients once having to become aware of what foods had higher fat as well as higher sugar so that they could avoid those foods and lose weight may have become a automatic process to these individuals which would explain why they would have the highest responsiveness to it rather than currently obese or healthy controls. Newman, Bolhuis, Torres, and Keast (2016) conducted a much more current study on fat taste sensitivity in people with obesity. Obese patients were exposed to a six-week diet of either low fat (LF) or portion control (PC). At baseline, across the board, individuals fat taste thresholds did not differ from each other. After six weeks of being on the diet, patients fat taste thresholds were then tested again. This time both groups exposed to diets had lost weight and decreased their fat taste thresholds. The LF diet displayed a greater decrease in fat taste detection. The idea that the group exposed to a low fat diet could then better rank fat leads to the possibility that an increase in fat taste sensitivity will help obese patients achieve a healthy satiety response to dietary fat.

Each type of eating disorder being discussed in this review has quite different taste changes that occur when an eating disorder is present, and in some cases even after the participant is considered recovered. Overall, patients with anorexia nervosa experienced reduced
hedonic responses to both sucrose and fat stimuli in comparison to bulimic patients and patients with obesity. There are two takeaways that come from that, the first being that perhaps the individuals fear of gaining weight may be causing the patient to therefore categorize that food as a negative and in turn code it to be thought of as less pleasant. Another suggestion is that the taste differences that occur in patients with anorexia nervosa may causes them to have reduced pleasure when eating, which could then act as an aid in restricting food, a characteristic of anorexia nervosa. When re-fed, in most situations patients regained some taste sensitivity no matter for what taste category. However, more research is needed in order to get a better understanding of taste sensitivity that may change after long-term recovery from anorexia nervosa. In contrast to anorexic patients, bulimic patients seemed to experience sensory under responsiveness. These findings may go hand and hand with other findings that bulimics report pleasure for high levels of sucrose. It is suggested that unlike anorexics, bulimics cannot as easily tell a difference between low calorie stimuli and high calorie stimuli. Perhaps this is because bulimics are less concerned with avoidance of food because they engage in behaviors such as purging, which would not allow for those calories to be digested anyway. Studies done on obesity show that obese patients have a preference for highest fat content, which leads to the problematic consumption of higher calories and therefore more weight gain, which characterizes obesity. However, further research has found hope that healthy satiety levels may be reached if the patient is put on a diet that consists of low fat. After the low fat diet the patient is then better able to detect fat, and therefore know how to better avoid it, which could lead to a healthier lifestyle.

CNS Correlates of Eating Disorders (taste)
In this section we will explore the neural changes that occur during the course of an eating disorder that may lead to changes in taste that healthy individuals would therefore not experience. Most research done on neural pathways of eating disorders have focused on the orbital frontal gyrus (OFC), insula and striatum as they are thought to be associated with pleasantness and reward value. This section will focus mostly on those areas of the brain as well as white matter and gray matter volume. Grey matter is responsible for sensory processing of speech, emotions, vision, memory, and hearing. In addition, grey matter is responsible for a lot of the body’s muscular control. White matter is responsible for communication to and from grey areas, as well as between grey matter and the rest of the body. What matter is also responsible for dispensing hormones, controlling food intake, and the explanation of emotions. The research that this study looked at primarily found that eating disorder groups show different white and gray matter volume in the OFC when eating disorders are present. Whereas white and gray matter volume are usually decreased in individuals with current anorexia nervosa, they are most often increased in patients with bulimia. These differences in reward circuitry could distinguish between the over-controlling behavior of anorexics and under-control in bulimics that lead to the characteristics of the disorders, restriction and overconsumption. Studies conducted on recovered anorexics show that white matter and grey matter most often increase in volume after long-term recovery, suggesting that structural brain abnormalities may be reversible. Studies done on obese patients have found that whereas, anorexic patients have increased activation in the OFC, obese patients have decreased function., which may be associated with problems controlling eating. By looking at how different studies measured neural activity to taste and food stimuli, we hope to present some viable reasons for how brain circuitry contributes to different eating patterns in each of these three eating disorders.
Anorexia

Oberndorfer et al. (2013) conducted a study in order to compare ill and recovered anorexic patients, as well as currently bulimic patients. Patients underwent a fMRI in order to assess grey matter, white matter and cerebral spinal fluid in order to look at total intracranial volume. The results showed that although both eating disorder groups showed significant increased gray matter volume in the OFC (gyrus rectus), they displayed different insula responses, which may contribute to the differences between anorexia nervosa and bulimia. anorexia nervosa had increased right anter-ventral insula gray matter, while bulimics had increased left anter-ventral insula gray matter. The gyrus rectus is part of the OFC most often associated with its connection to the amygdala and cingulate and insular cortex, which are important areas for taste, reward, motivation and emotional processing. Therefore, greater or increased gyrus rectus volume is associated with stronger pleasant taste experience, which could also lead to stronger sensory experience to food stimuli, which could be overwhelming in patients with eating disturbances. The anterior ventral insula is known to be connected to the amygdala and thought to be associated with fear response, therefore altered insula volume may contribute to anxiety, a common trait in anorexia nervosa. The anorexia nervosa patients right arterial ventral insula showed more activity, whereas bulimics showed increased activity in the left arterial ventral insula. This is interesting due to the fact that the right hemisphere is associated with negative emotions and the left hemisphere is associated with positive emotions. The right anterior insula is connected to self-recognition, which could lead to the perception of patients with anorexia nervosa to have a distorted view of themselves and therefore be anxious and unwilling to engage in regular eating patterns. On the other hand, left anterior ventral insula activation is associated with fullness and gastric distention. This correlates with bulimic patients
and may offer a viable reason as to why they feel the overwhelming need to purge after consuming excess food. Frank, Shott, Hagman, & Mittal (2013) conducted a very similar study but replaced recovered anorexia nervosa individuals with adolescent anorexia nervosa individuals and compared them to adults with anorexia nervosa. The findings were relatively consistent with Oberndorfer et al. (2013). Frank et al. (2013) additionally found that left orbitofrontal cortex gyrus rectus and right insula volumes are associated with individuals with anorexia nervosa. When exposed to sucrose solutions, OFC volume negatively correlated with sweet taste pleasantness, a possible reason why food avoidance is a characteristic of anorexia nervosa. In addition, the results showed that there was increase activation in grey matter and white matter volume however a lower white matter integrity in the fornix, a finding that has been consistent in adults with anorexia nervosa. The findings that white matter integrity was lower in adolescents may indicate structural alterations in adolescents with anorexia nervosa. This points to the idea that grey matter pruning and white matter growth may indicate developmental factors that may link directly to brain alterations in anorexia nervosa.

Abundant research has been conducted on individuals recovered from anorexia nervosa. Whether it is short-term weight restoration or long-term recovery, the findings have been pretty consistent in suggesting that although white matter and grey matter may be low during the course of the illness, there is much hope that it will increase after weight restoration. Roberto et al. (2011) conducted a study in order to look at brain tissue volume changes that occur when weight gain occurred, therefore he looked at changes as the individual recovered, but could not yet be considered recovered. Prior to weight restoration, grey matter and white matter volume were significantly decreased, however after weight gain, they increased significantly. Grey matter did not fully normalize compared to healthy control participants. The findings of this study indicate
that grey matter and white matter can increase significantly following weight restoration. Further research is needed in order to get a better idea of what neural changes occur in long-term recovery of anorexia nervosa. Wagner et al. (2008) conducted a study very similar to the previously mentioned study, however the current study looked at brain tissue volumes of long term recovered (> 2 years) anorexics and bulimics and compared them with healthy individuals who have never had an eating disorder. Again patients underwent a fMRI and the results showed that grey matter, white matter and CSF were all similar in recovered anorexia nervosa, recovered bulimia nervosa, and healthy controls. Although the study conducted by Roberto et al. (2010) could not determine if structural changes would fully normalize, this study further explores the idea that structural brain abnormalities can be reversible after an extended period of long-term recovery.

Building off studies similar to the previous two, researchers have conducted more in depth studied in order to observe different taste stimuli in patients that are recovered from anorexia nervosa. Wagner et al. (2008) conducted a study that aimed to determine if neural activation in primary and secondary taste regions differed when patients were administered water and sucrose. Participants were administered the sucrose solutions and then asked to rate them for taste pleasantness. In addition, each individual underwent an fMRI. The results indicated that regardless of sugar or sucrose, a decreased response occurred in the bilateral insula. In addition, broad regions of the striatum such as the anterior cingulate cortex showed decreased response when compared with controls, however, patients recovered from anorexia nervosa did show similar responses to controls for activity of anterioventral striatum, amygdala and OFC. Also, recovered patients showed differences in correlation to pleasant taste and brain activation. Controls subjects pleasantness ratings of sucrose were positively correlated with activity in the
insula and anterior cingulate. On the other hand, patients recovered from anorexia nervosa did not show signs of positivity correlating with these regions and pleasant taste response. These findings that recovered anorexia nervosa individuals and control individuals did not show similar responses in the same regions points to the idea that patients recovered from anorexia nervosa still experience circuit wide disturbances in the brain. Still, further research is needed on long term-recovered anorexics to see if neural disturbances eventually reach more normalized neural responses similar to healthy individuals.

_Bulimia_

As mentioned earlier, Oberndorfer et al. (2013) conducted a study in order to compare brain trait alterations in anorexia nervosa and bulimia nervosa. Results indicated that both eating disorder groups showed significant increased gray matter volume in the OFC (gyrus rectus) but different insula responses, which may contribute to the differences between anorexia nervosa and bulimia nervosa. Anorexia nervosa had increased right anterior ventral insula gray matter, while bulimics had increased left anterior ventral insula gray matter. The left anterior ventral insula activation is associated with fullness and gastric distention. This relates to bulimic patients and may offer a viable reason as to why they feel the overwhelming need to purge after consuming excess food. Additionally as mentioned earlier, Wagner et al. (2008) designed an experiment looking at brain tissue volumes of long term recovered anorexics and bulimics and compared them with healthy individuals who have never had an eating disorder. Again, patients underwent a fMRI and the results showed that grey matter, white matter and CSF were all similar in recovered anorexia nervosa, recovered bulimia nervosa, and healthy controls. Although the study conducted by Roberto et al. (2010) could not determine if structural changes would fully
normalize, this study further explores the idea that structural brain abnormalities can be reversible after an extended period of long-term recovery.

Schafer, Vaitl, & Schienle (2010) were interested in looking at alterations of grey matter volume in bulimia nervosa and binge eating disorder. The participants fasted overnight, then were exposed to fMRI the following day while being exposed to pictures of high caloric food, disgust-induced pictures, and neutral pictures. The participants were then asked to rate the pleasantness of each picture. The participants underwent a fMRI and the results showed an increase in grey matter in the medial and lateral OFC as well as ventral and dorsal striatum in comparison to individuals with binge eating disorder and control subjects. The ventral striatum is not only responsible for hedonic value of stimuli and reward related cues, but also with the facilitation of behaviors that may lead to feelings of reward, such as purging after a binge. This may suggest why purging is a main characteristic of bulimia nervosa.

**Obesity**

Yokum, Ng, and Stice (2011) conducted a study that looked at the activation of OFC when individuals were presented with visual images of neutral and food stimuli. The study was conducted on adolescent girls whose weights ranged from lean to obese. The participants underwent an fMRI while being exposed to the neutral and food stimuli first at baseline, and then again a year later. The results of this study suggested that OFC positively correlated with BMI; individuals low BMI had a higher OFC response, whereas individuals with a higher BMI had a lower OFC response. These results remained the same a year later. Perhaps the reason that patients with anorexia nervosa experience higher activations in the OFC than obese patients is due to them having a higher impulse control to reward presentation. Frank et al. (2012) conducted a study with the interest of looking at the difference in brain alterations between
anorexic and obese individuals. Participants were given a taste test that exposed them to the five primary tastes, they were then asked to rank the tastes for pleasure or aversion, and then underwent a fMRI. The results of the fMRI show significant increased activation in the striatum, insula, OFC and amygdala. However, obese individuals showed less activation in those areas. These findings suggest that reduced activity in the lateral OFC may be directly associated with impulse control and reward presentation, two main characteristics of obesity. Because increased lateral OFC activation is seen in individuals with anorexia nervosa, it tends to be associated with high food intake control, whereas it would be the opposite for obese patients due to the fact that they have issues controlling consumption. Overall, the results of this study and different brain alterations between anorexia nervosa and obesity indicate that high activation in the lateral OFC may suggest that individuals have high ability to discriminate rewards, however the opposite would be true of obese patients.

In conclusion, using brain-imaging techniques such as the fMRI, has allowed researchers to look at the neural processes and structures that are involved in anorexia nervosa, bulimia nervosa and obesity. Being able to observe what brain areas are active when disorders are present as well as when certain stimuli are presented gives researchers the ability to then connect how those brain structures relate and correlate with eating disorder behavior.

**Psychosocial Factors**

In this section we will explore a few psychosocial disorders that are often comorbid with eating disorders and may contribute to the development and/or maintenance of the eating disorder. Findings from research and studies done on disorders such as generalized anxiety, social anxiety disorder, body dysmorphic disorder, obsessive-compulsive disorder, and panic disorder often suggest that individuals experience impairment to their everyday life due to the
anxiety caused by their disorders. The anxiety behind these disorders often correlates with behaviors that diminish the anxiety that they are experiencing, and perhaps that goes hand and hand with developing restriction and binging and/or purging technics.

Social Anxiety Disorder

Research on eating disorders has found that those disorders are often comorbid with at least one kind of anxiety disorder, suggesting that 83% of them meet criteria for an eating disorder and anxiety disorder at the same time. The most common comorbid disorder with eating disorders has been suggested to be social anxiety disorder, occurring in 71.4% (Godart et al., 2010) of individuals with anorexia nervosa, and 67.8% of individuals with bulimia nervosa (Laessle & Schulz, 2009).

Research conducted on social anxiety disorders and eating disorders has concluded that the two disorders go hand and hand and are often comorbid of each other. Levinson and Rodebaugh (2012) conducted a study looking at the connection between eating disorders, social anxiety, social appearance anxiety, perfectionism and fear of negative evaluation. The latter three factors were thought to be possible factors that may lead the individual to be more vulnerable to both eating disorders and social anxiety disorder. The results of their study gathered that fear of negative evaluation was only a risk factor in the development of social anxiety. In addition, they gathered that social appearance anxiety is a risk factor between both social anxiety and eating disorders. Levinson and Rodebaugh (2016) conducted a follow up study that added in a few additional factors and again looked at the relationship between social anxiety, eating disorder symptoms and factors such as fear of negative evaluation, social appearance anxiety, high standards and perfectionism. The results found that eating disorder symptoms were predicted by social appearance anxiety and perfectionism, but not the negative evaluation and high standards.
In addition, social anxiety was predicted by all four possible risk factors. Therefore the findings of this study suggest that social appearance anxiety and perfectionism are predictive symptoms that may lead individuals to be vulnerable to both eating disorders and social anxiety.

*Body Dysmorphic Disorder*

The theory underlying body dysmorphic disorder is similar to those of eating disorders, a general feeling of excessive worry of physical appearance and body dissatisfaction. Ruffolo, Phillips, Menard, Fay and Weisberg (2006) conducted a study looking at the occurrence of eating disorders in a very large sample of individuals with body dysmorphic disorder. The study found that 32.5% of body dysmorphic disorder patients had a comorbid eating disorder along with it. In the sample that the study used, 63.1% of the individuals were found to have body dysmorphic disorder before the onset of the eating disorder, with 55.5% developing it before the onset of the anorexia nervosa, and 84.6% developing it before the onset of bulimia nervosa. Therefore the findings of this study suggest that body dysmorphic disorder may be a predictor and factor of vulnerability for the individual to develop an eating disorder. Grant, Kim, and Eckert (2002) conducted a similar study and found that 94% of individuals with anorexia nervosa, developed body dysmorphic disorder before the onset of their eating disorder. This furthers the evidence that body dysmorphic disorder may be a predictor in the development of eating disorders.

*Obsessive Compulsive Disorder*

Obsessive-compulsive disorder is often found to be a comorbid disease occurring in individuals with eating disorders. In Godart et al. (2010) study, 17% of the individuals examined for different comorbid disorders, had obsessive-compulsive disorder. In the discussion the authors discussed the possibility of obsessive-compulsive disorder being a secondary factor of general and social anxiety, and therefore the most common characteristics of eating disorders
such as restricting, binging or purging could be implicated in order to reduce severity of those anxieties. Frare, Perugi, Ruffolo and Toni (2004) conducted a study looking at the relationship between obsessive-compulsive disorder and body dysmorphic disorder, two disorders that often occur comorbidly of each other. The results of their study found that generalized anxiety is often observed frequently in obsessive-compulsive disorder. Social impairment was found to be a significant hindrance in individual’s life when they had both obsessive-compulsive disorder and body dysmorphic disorder. These social impairments are thought to be brought on by anxiety about their physical appearance. Those anxieties cannot be easily diminished unless actions are made, therefore these individuals often engage in coping mechanisms such as binging and purging because they help the individual feel less anxiety over their physical appearance. Therefore this study suggests that individuals with obsessive-compulsive disorder and body dysmorphic disorder often have a higher vulnerability to developing bulimia.

Panic Disorder

Panic disorder is talked about less frequently than SAD, body dysmorphic disorder, and obsessive-compulsive disorder when in connection to comorbidity in eating disorders, but Godart et al. (2010) offered an interesting possible connection between the two in their study. Among bulimic patients, 15% of them had panic disorder, while 34% of anorexic patients had the disorder. They suggested that in particular, bulimia nervosa has clinical similarities such as sympathetic arousal that is occurring when an individual experiences a panic attack, as well as when they are in a binge eating cycle. Although panic disorder is thought to occur twice as often in anorexia nervosa rather than bulimia nervosa, more research is still needed to gain further knowledge about the connection between panic disorder and anorexia nervosa.
In conclusion, there are many psychosocial disorders that are interconnected with eating disorders and most seem to have a connection to the development and maintenance of these eating disorders. Because most of the disorders mentioned in this section have roots in anxiety or dissatisfaction of physical characteristics, it is possible that they provide individuals with a underlying vulnerability to developing eating disorders, especially when the disorders are developed before the onset of the eating disorder.

**Discussion**

After presenting information from previous research on anorexia nervosa, bulimia nervosa, and obesity we will now attempt to find existing links between taste dysfunctions, CNS correlates and comorbid disorders that each of the three eating disturbances experience. Our purpose of linking these factors to eating disturbances such as the ones discussed in this review is in effort to gain a greater understanding of the development and course of eating disorders. In addition, after taking previous research into consideration, we have provided a treatment option designed for anorexia and bulimia, as well as one for obesity. We hope that the knowledge gained from this review, as well as the proposed treatment plans will lead individuals to live a healthier lifestyle than their eating disturbances has cultivated.

As reported by several of the studies mentioned earlier, anorexia nervosa has increased responsiveness to taste stimuli, especially sweet stimuli. In addition, anorexics had a weakened taste reactivity to fat. Across the research examined in this review, it can be suggested that individuals with bulimia nervosa experience taste under responsiveness. Because anorexia nervosa is characterized by fear of gaining weight, most individuals often attempt to avoid high concentrations of sucrose because of its high caloric content. The increased white and gray matter of the OFC, a structure responsible for reward circuitry, could explain this idea of over
control in patients with anorexia nervosa. Because the OFC has decreased activity, it shows that the brain is not responding to those stimuli as a reward but instead has lower sensory experience to those stimuli, which is consistent with the behavior of patients with anorexia nervosa, because they often avoid high caloric foods. On the other hand, it was found that white matter and gray matter are increased in the OFC in patients with bulimia nervosa meaning that the individual processed those food stimuli with a higher reward value than patients with anorexia nervosa, which may help explain under control of food consumption in bulimics during a binge episode.

In addition, patients with anorexia nervosa experience increased activity in the right anterior ventral insula, an area of the brain that is responsible connecting body states to emotional experiences. The idea that there is increased activity in the right anterior ventral insula rather than the left is interesting because negative emotions are primarily processed on the right side of the brain. In contrast, bulimics show increased activity in the left anterior ventral insula, a brain region associated with positive emotions, as well as fullness. The idea that it is associated with positive emotions and increased when responding to food stimuli such as sucrose suggests that the individual is enjoying the sweet stimuli more so than an individual with anorexia nervosa, which also accounts for the finding that they cannot differentiate between high caloric content and low caloric content. The idea that the left ventral insula is increased in bulimics and associated with fullness, could account for the overwhelming need for individuals to purge after food consumption. An increase responsiveness to fat and sugar in individuals with obesity could be accounted for by decreased function in the OFC, which may suggest that the brain is not processing the food stimuli as a reward and therefore the body may feel as if it needs to consume more. This could explain the lack of controlled eating in patients with obesity.
As mentioned in the section about comorbid disorders, social appearance anxiety and perfectionism were two factors that were found to provide vulnerability to the development of both social anxiety disorder and eating disorders. The two work together because social anxiety evokes a lot of anxiety in social situations, perhaps because of how they feel about their bodies, which may lead them to develop negative behavioral mechanisms such as restriction or purging, which could easily lead to the development or maintenance of an eating disorder. Those negative behaviors may help the individual cope with their social anxiety, and perhaps may account for the reason that social anxiety disorder and eating disorders occur as comorbid so often. Similarly, body dysmorphic disorder and obsessive-compulsive disorder are very common as comorbid disorders that occur in patients that also have an eating disorder. Because body dysmorphic disorder is concerned with a perceived flaw that the individual has, this will lead the individual to want to do something about it so that anxiety can be removed from that negative thought. Obsessions and compulsions may lead to regular use of negative behaviors such as restriction, and purging, the primary components of anorexia nervosa and bulimia. Obsessive-compulsive disorder in patients with obesity may lead to overconsumption of food due to obsessions and compulsions of perhaps having to eat so many bites or number of items in each eating sitting. Panic disorder in bulimics offers an interesting suggestion that panic attacks and binge eating episodes have the same sympathetic arousal, which may lead the individual to experience more anxiety and therefore try to cope through engaging in behaviors such as purging. Therefore because each of these eating disorders seems to often have a comorbid disorder that alleviates anxiety by engaging in behaviors such as avoidance or a subsequent behavior following a trigger, if individuals learn to engage in healthy behaviors instead, their quality of life may significantly improve.
A possible treatment for anorexia nervosa and bulimia nervosa could be cognitive behavioral therapy with an emphasis on talk therapy and learned coping skills. Cognitive behavioral therapy acknowledges the notion that Skinner’s work on operant conditioning concluded that if individual’s behaviors are positively reinforced, wherein the individual receives a reward after a certain behavior; it is more likely for the behavior to occur again (Carroll, 2013). The goal of cognitive behavior therapy is to change this behavior by learning how to respond differently to getting triggered or having an urge to engage in a problem behavior. Therefore, anorexia nervosa and bulimia nervosa patients could benefit from this type of treatment because instead of restricting or purging when feeling down about oneself, the individual could learn how to change his or her thoughts and instead engage in a more healthy behavior. Another aspect often involved in cognitive behavioral therapy is learning coping skills and learned how to apply those healthy behaviors. For example, instead of restricting because an individual is feeling scared to gain weight, the individual could write down a list of things that she likes about herself and when feeling triggered, read that and remember that she is worthy of eating and needs to eat to be healthy. An patient recovering from bulimia nervosa could learn how to journal when feeling triggered instead of engage in purging after a meal, therefore instead of having those inner negative thoughts and purging to get the bad feeling out, she could write out her negative feelings instead. An emphasis on talk therapy could be crucial in helping the individual progress through cognitive behavioral therapy in ways such as helping the individual get to the root of why the disorder developed, why the individual feels the need to engage in eating disorder behaviors and learn how to sense a trigger coming on so that they can better prepare to engage in a coping skill. This type of therapy could also be applied to co – morbid obsessive-compulsive disorder symptoms in which the individual is reinforced by committing behavior such as
compulsions. Because of these components, cognitive behavioral therapy appears to be an effective potential treatment for anorexia nervosa and bulimia nervosa because it aims to disrupt the learned association between being triggered and engaging in an eating disorder behavior in order to decrease anxiety about gaining weight.

A possible treatment for obesity may be a specified diet that consists of little fat and minimal sugar. Consuming little fat and sugar would lead the individual to lose weight; therefore decreasing the individual’s BMI. Decreasing BMI would be an effective treatment for obesity because above average BMI is the main concern of the disorder. Because individuals who have recovered from obesity show increased sensitivity to sugar and fat, whereas they used to not (Drewnowski et al., 1984), we believe that once the individual decreases his or her BMI and is exposed to fat and sugar less often, the individual will then have increased sensitivity to sugar and fat and become accustomed to know not to consume it in large amounts. Therefore, if the individual maintains the diet and lifestyle, he or she should remain within normal range of BMI, and have significantly decreased health risks, therefore giving the individual a better of a more healthy life.

In conclusion, this review intended to find a connection between the proponents of taste dysfunctions and the CNS correlates related to those changes in taste experienced by patients with anorexia nervosa, bulimia nervosa and obesity. In addition, this review was interested in how co-morbid disorders such as obsessive-compulsive disorder and body dysmorphic disorder contribute the development and extended course of the eating disorders at hand. After providing previous research done on taste dysfunctions, CNS correlates, and comorbid disorders among eating disorders, I assessed how each of those are experienced differently in each eating disorder with the hopes of providing the best treatment plan for each. By following those treatment plans
and remaining motivated to recover, individuals with anorexia nervosa, bulimia nervosa or obesity will become healthier, giving them a better opportunity to live a satisfying life.
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FACTORS OF EATING DISORDERS


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