# EYE TRACKING FOOD CUES IN SUBJECTS WHO ARE OVERWEIGHT/OBESE, WEIGHT LOSS MAINTAINERS, AND NORMAL WEIGHT

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# ABSTRACT

Eye Tracking Food Cues in Subjects Who Are Overweight/Obese, Weight Loss Maintainers, and Normal Weight

Carrie Ann Petro

Adult obesity is associated with increased morbidity and mortality. Increasing success in weight loss maintenance will decrease the prevalence of overweight and obesity, and therefore help control the adverse health effects of excess weight. Much is known about the behavioral characteristics of successful long-term weight loss maintenance, but less is known about the cognitive processes behind weight loss maintenance. The purposes of this study were to (1) identify differences in visual attention to high-energy dense foods between individuals who are normal weight, weight loss maintainers, and overweight/obese in a high-risk (food-buffet) situation; (2) to evaluate differences in food choices from a food buffet between weight status groups; (3) to analyze correlations between food attention and food choice across weight status groups. No significant differences were found between groups with respect to food attention or food choice. Overall, findings from this study may have been limited by methodology, technology, and sample size. Future research is needed to better understand the interaction of cognitive processes and weight loss maintenance.

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# 1 Introduction

## 1.1 Statement of the Problem

Adult obesity is associated with increased morbidity and mortality (US Department of Health and Human Services, 2001) and is increasing in prevalence in the United States (US Department of Health and Human Services). Increasing success in weight loss maintenance will decrease the prevalence of overweight and obesity, and thus help control the adverse health effects of excess weight. Successful long-term weight loss maintenance involves a complex interaction between biological factors (de Luis, Aller, Conde, Izaola, Sagrado, et al., 2013; Zhang, Qi, Zhang, Smith, Hu, et al., 2012; Qi, Bray, Smith, Hu, Sacks, et al., 2011; Qi, Bray, Hu, Sacks and Qi, 2012; Ahima, 2008; Leidy, Gardner, Frye, Snook, Schuchert, et al. 2004; Leidy et al., 2007; Soenen, Martens, Hochstenback-Waelen, Lemmons and Westerterp-Plantenga, 2012), environmental factors (Guthrie, Lin and Frazao, 2002; Wansink, 2004; Wansink and Cheney, 2005; Wansink, 1996; Wansink, van Ittersum and Painter, 2006), and behavioral factors such as increased physical activity, decreased caloric intake, decreased intake of energy dense foods (Bell, Castellanos, Pelkman, Thorwart & Rolls, 1998), and regular self-monitoring (Phelan, Roberts, Lang and Wing, 2007; Phelan et al., 2010; Klem, Wing, McGuire, Seagle & Hill, 1997; Shick, Wing, Klem, McGuire, Hill, et al., 1998; Phelan, Liu, Gorin, Lowe, Hogan et al., 2009; Wing and Phelan, 2005). Long-term weight loss maintainers practice these weight-control behaviors more often than always-normal weight individuals, but less is known about the cognitive processes behind weight loss maintenance.

Exploring cognitive responses to different food cues can help us to identify variances in cognitive processes between different weight status groups, possibly providing insight to new weight loss maintenance strategies, or perhaps weight gain prevention strategies, that involve cognitive therapies. Most cognitive studies use food words or pictures to assess an individual's relationship with and reaction to food. In an analysis using the Stroop Color-Word interference test, Phelan et al. (2010) showed increased cognitive interference in weight loss maintainers compared to normal weight and obese subjects, suggesting increased attention and conscious attention to food cues and food related situations. Another study analyzed changes in activity in the P300 wave using electroencephalography (Nijs et al., 2010), which is related to conscious attention allocation (Nijs et al., 2010). They compared normal weight individuals to overweight/obese individuals under conditions of hunger and satiety. A difference between the two weight status groups was found in the hunger condition: a bias toward food pictures was present in hungry normal weight individuals, but it was not present in hungry obese individuals; that is, increased activity was recorded for the P300 wave on the EEG. The disappearance of a significant bias between food and neutral pictures in hungry obese women suggests an intentional effort to suppress attention to food-related cues. However, it is hard to infer much about food avoidance strategies with the measures used in this study, also showing the need for further investigation in cognitive differences in response to food between weight status groups. While differences in cognition and attentional processes have been found between weight loss maintainers, normal weight, and overweight/obese individuals, studies have lacked objective measurements of attention and examination of responses to real food cues, as opposed to food pictures.

Eye tracking technology is an evolving field in which eye movements can be recorded and analyzed with regard to human processing of visual information (Mele and Federici, 2012). It has been used to explore eye movements in response to advertisements (Kessels and Ruiter, 2012; Gidlöf, Holmberg and Sandberg, 2012), product labels (van Herpen and van Trijp, 2011), and reading habits and techniques (Kunze et al., 2013). Recent research has linked eye movement data to cognitive and attentional activity (Gog, Jaradzka, Scheiter, Gerjets & Paas, 2009; Benedek, Jauk, Beaty, Fink, Koschutig et al., 2016), suggesting that gaze fixation and duration may be indicative of attentional processes in the brain.

Eye tracking technology has not been extensively used to analyze visual attention to food cues, and the innovative, portable design of the current eye-tracking device provides the opportunity to leave the lab and analyze subjects in a real life situation with real food. Gaining insight to cognitive processes in response to real food cues will expand our understanding of overweight/obesity and weight control, which is crucial for developing successful obesity interventions. It may also offer the opportunity for new and innovative weight loss maintenance strategies involving the deliberate redirection of attention to attempt to recondition the brain's response to certain foods or food situations.

**1.2 Statement of Purpose**

The primary purpose of this study was to identify differences in visual attention to high-energy dense foods between individuals who are overweight/obese, weight loss maintainers, and normal weight in a high-risk (food-buffet) situation. A secondary purpose was to evaluate possible discrepancies between food attention and food choice across weight status groups. The final purpose was to identify mediators (dietary restraint, dietary disinhibition, hunger and cravings) and moderators (gender, age, education) of differences in gaze fixation and food choice between weight status groups.

### 1.3 Research Hypotheses

*Aim 1:* To identify differences in visual attention to high-energy dense foods between individuals who are overweight obese, weight loss maintainers, and normal weight in a high-risk (food-buffet) situation.

*Hypothesis 1:* In a high-risk food buffet situation, individuals who are overweight/obese and those who are weight loss maintainers will accumulate a greater total gaze duration on high-energy density foods versus low-energy density foods, as a percent of total time spent gazing at food, compared to individuals who are normal weight.

*Aim 2:* To analyze possible discrepancies between food attention and food choice across weight status groups.

*Hypothesis 2:* In a high-risk food buffet situation, individuals who are weight loss maintainers will demonstrate the greatest discrepancy between food attention and food selection. Specifically, individuals who are weight loss maintainers will show more attention to high-energy dense foods relative to the total number of high-energy dense foods selected at the buffet compared with individuals who are normal weight and individuals who are overweight/obese. A discrepancy ratio between food attention and food choice will be defined as percent high-energy dense food fixation divided by percent high-energy dense foods chosen. Thus, this ratio will be larger for individuals who are weight loss maintainers compared with individuals who are normal weight and those who are overweight/obese.

*Aim 3:* To identify mediators (dietary restraint, dietary disinhibition, hunger and cravings) and moderators (gender, age, education) of differences in gaze fixation duration and food choice between weight status groups.

**1.4 Significance**

This study was the first to analyze eye movements and visual attention in response to real food cues in a real life setting between varying weight status groups. To our knowledge, this was also the first study to use the SMI Eye Tracking Glasses 2.0 device to infer cognitive activity in response to real food cues in a real life setting. The results of this study have the potential to expand the literature on cognitive differences between individuals who are overweight obese, weight loss maintainers, and normal weight, thus expanding our understanding of overweight and obesity, enabling development of better weight loss interventions that may include cognitive therapies. Understanding attentional processes surrounding food may offer novel targets for treatment. Some research has shown that purposefully changing or redirecting an individual's attention changes automated thought processes (Gog, Jaradzka, Scheiter, Gerjets & Paas, 2009). If attention to food cues is related to weight control success, purposeful attention or redirection strategies could be incorporated into treatment to alter cue reactivity and improve weight loss interventions or weight loss maintenance strategies.

**1.5 Definition of Terms**

<u>Weight loss maintenance:</u> Wing and Hill (2001) proposed that an individual who intentionally lost 10% or more of their maximum body weight and have kept it off for at least one year be considered a "successful weight loss maintainer." That being said, a

participant in the weight loss maintainer (WLM) group must have had a BMI>25 at some point in their life, must have lost ≥10% of their maximum body weight, and have kept it off for at least one year.

Normal weight: A participant in the normal weight (NW) group must have a BMI between 18.5-25, with no history of overweight or obesity (BMI>25). They must also be weight stable (±15 lbs) for at least two years.

Overweight/obese: A participant in the overweight/obese (OW/OB) group must have an adult history of overweight or obesity (BMI>25), currently have a BMI>25, and have been weight stable (±15 lbs) for at least two years.

Energy density of food: According to a study by Bell et al. (1998), the energy density of foods is calculated as kcals per gram of food (kcal/g). Foods were divided into three groups, based on mean values of energy density of foods: "high" (1.34 kcal/g), "medium" (1.17kcal/g), or "low" (1.02kcal/g). For the purposes of the present study, only two energy density classifications were desired; thus a high-energy density (HED) food was any food with an energy density greater than the mean energy density of the "medium" classification in the Bell study, and a low-energy density (LED) food was any food with an energy density less than the mean energy density of the "medium" classification in the Bell study. That is to say, an HED food has ≥1.17kcal/g, and an LED food has <1.17kcal/g.

Area of Interest (AOI): Within the BeGaze analysis software, an AOI is created to help to define which areas will be included or excluded from analysis. AOIs in this study were HED foods and LED foods.

Fixation: The state when the eye remains still over a period of time, quantified in milliseconds. Gaze duration was calculated as the sum of all fixations that fall within an AOI.

Percent HED food gaze duration: Quantified as the total amount of time spent looking at HED foods divided by the total time spent surveying food.

Percent HED food choice: Quantified as the total amount of HED foods chosen divided by the total number of foods available.

Discrepancy Ratio: Calculated as the quotient of percent HED gaze duration and percent HED food choice.

Dietary restraint: An individual's intent and capability to restrict caloric intake (Allison, 1995). Disinhibition: The inability to control intake and the tendency to overeat (Stunkard & Messick, 1985).

Perceived Hunger: Refers to the subjective sense of hunger (Allison, 1995).

The Three Factor Eating Questionnaire (TFEQ): Used to assess Dietary Restraint, Disinhibition, and Perceived Hunger (Stunkard & Messick, 1985).

The Food Craving Inventory (FCI): Measures cravings for foods in four categories: High Fats, Sweets, Carbohydrates/Starches, and Fast Food Fats, which comprise the higher order construct of "food craving" (White et al., 2001).

**1.6 Delimitations**

The primary recruitment efforts were held off the researcher's university campus in order to ensure a broad range of subjects and to be able to generalize results beyond a college population. Since there were two appointments necessary in San Luis Obispo, subjects were only recruited from San Luis Obispo and Santa Barbara counties to keep subjects' travel distances reasonable. The criterion for weight loss maintainers defining a 10% reduction in weight, and keeping it off for one year, was chosen based on other studies that have used this definition of weight loss maintainers (Wing and Phelan, 2005; Wing and Hill, 2001), and thus we can compare our study results. The HomeTown Buffet restaurant was chosen because it offered a variety of food types, as opposed to a buffet restaurant that specializes in one food type, such as Chinese or Indian food. Food choice was assessed without regard to amount served or amount consumed because this study aimed to investigate possible correlations between visual attention and type (rather than quantity) of food choice.

**1.7 Limitations**

Maintaining a fully stocked buffet was not within our control. For some subjects, some buffet dishes were full, and others near empty. This possibly impacted whether participants chose a certain food or not. Additionally, some subjects may not have been used to eating in a food buffet and thus may have altered their behavior from normal eating routines; that is, it is possible that food choice may have been different due to increased food availability presented by a food buffet (Wansink, 2004). The eye tracking glasses may also have imposed feelings of embarrassment, which may have potentially altered their food choices. Lastly, this technology had never previously been used for food cognition studies in the weight groups under investigation, nor has it been used in a dynamic situation (i.e.: walking through the food buffet) in which subjects were in motion during data collection; thus, application, reliability and validity could differ.

# 2 Literature Review

## 2.1 Obesity

Obesity is a major health concern in the United States (US Department of Health and Human Services). Approximately two thirds of adults are overweight, and one third classify as obese (Ogden, Carroll, Kit & Flegal, 2012). Adult obesity is associated with increased morbidity and mortality (US Department of Health and Human Services, 2001); therefore, reducing overweight and obesity could improve the overall health of the nation. There are many strategies to promote successful weight loss, however, maintaining weight loss is difficult, and is typically perceived as difficult to achieve. In a recent meta-analysis, Ohsiek and Williams (2010) found that just 20-26% of individuals are able to maintain a ten percent reduction in body weight for at least two years. Biological, environmental, and behavioral factors have been implicated as facilitating or derailing long-term weight control. The extent to which successful weight loss maintenance is under individual control remains an active area of debate, as reviewed below. The review briefly discusses biological determinants of weight control and then covers behavioral and environmental factors in greater detail, as they are addressed in the current study.

## 2.2 Correlates of Weight Change and Maintenance

**2.2.1 Biological Factors.** Biological factors, including genetic factors (de Luis, Aller, Conde, Izaola, Sagrado, et al., 2013; Zhang, Qi, Zhang, Smith, Hu, et al., 2012; Qi, Bray, Smith, Hu, Sacks, et al., 2011; Qi, Bray, Hu, Sacks and Qi, 2012), changes in hormones (Ahima, 2008; Leidy, Gardner, Frye, Snook, Schuchert, et al. 2004; Leidy et al., 2007), and declines in resting metabolic rate (RMR) (Soenen, Martens, Hochstenback-Waelen, Lemmons and Westerterp-Plantenga, 2012) may undermine success in long-term weight control.

***2.2.1.1 Genetic Factors.*** With the emergence of genome-wide association studies, researchers have been able to begin to identify certain genes that may play a role in dictating success, or lack thereof, in weight loss and weight loss maintenance. For example, genes such as insulin receptor substrate 1 (IRS1) and glucose-dependent insulinotropic polypeptide receptor (GIPR) have been found to have a relationship between differential genotype expression and weight loss success, but not long-term weight loss maintenance (Qi et al., 2011; Qi et al., 2012). Other obesity related genes such as MC4R have been associated with long-term weight loss, but not with losing larger amounts of weight (Verhoef, Camps, Bouwman, Mariman and Westerterp, 2014). Some studies have shown that the obesity-associated gene (FTO) is differentially expressed in different individuals, and this difference in genotype expression is correlated with weight loss success, but not weight loss maintenance (Verhoef, Camps, Bouwman, Mariman and Westerterp, 2014; de Luis et al., 2013; Zhang et al., 2012), however results are varied and inconclusive (Matsuo, Nakata, Murotake, Hotta, Tanaka, 2012; de Luis, Aller, Izaola, de la Fuente, Conde, et al., 2012; Grau, Hansen, Holst, Astrup, Saris, 2009). Genetics seem to contribute to weight loss and weight control, however further research is needed in this area to more fully understand its role.

***2.2.1.2 Appetitive factors***. Several appetite hormones have been shown to change in response to weight loss and may predict subsequent weight regain. For example, leptin, a satiety hormone, has been shown to significantly decrease following weight loss (Ahima, 2008). This may be a contributing cause of weight regain, as low levels of leptin stimulate food intake. Ghrelin, a meal-initiating hormone, has also been studied following weight loss. Higher levels of ghrelin are typically recorded after weight loss, which may also be a contributing cause of weight regain, as high levels of ghrelin stimulate food intake (Leidy et al. 2004; Leidy et al., 2007). These findings suggest that hormonal alterations may play a part in complicating efforts to maintain weight loss.

***2.2.1.3 Changes in resting metabolic rate***. Another reason weight control may be difficult to achieve is the possibility of compensatory metabolic processes that resist altered body weight maintenance (Soenen et al., 2012; Leidy et al., 2004). Decreased overall energy expenditure could negatively affect energy balance and increase the likelihood of weight regain. For example, resting energy expenditure (REE) has been noted to significantly drop during weight loss, and remain depressed during weight loss maintenance (Soenen et al., 2012). Shorter-term studies have similarly reported significant declines in RMR associated with both weight loss and weight loss maintenance (Leidy et al., 2004; Leibel, Rosenbaum, Hirsch, 1995). The implications of long-term depression of RMR during long-term weight control is however still equivocal. Other studies have found no significant relationship between reduced RMR and reduced weight, after controlling for decreased fat mass and increased respiratory quotient (Wyatt, Grunwalk, Seagle, Klem, McGuire, et al., 1999). The overall decrease in REE may contribute to difficulty maintaining weight loss because of the decrease in daily caloric expenditure, however long term effects require further investigation.

***2.2.1.4 Changes in brain activity***. Researchers have also begun “mapping the brain” to identify whether alterations in brain functioning might also limit success at long-term weight control. Different areas of the brain have increased responsiveness to food stimulation (DelParigi, Chen, Salbe, et al., 2004; delParigi, Chen, Salbe et al., 2007; McCaffery, Haley, Sweet, et al., 2009, Sweet, Hassenstab, McCaffery, Raynor and Bond et al., 2012). One study examined brain response to real food cues in nine different brain areas (Sweet et al., 2012). Of particular note in their results was that successful weight loss maintainers exhibited significantly higher reactivity in the left putamen, which was been associated with food reward (DelParigi et al., 2004; Schur, Kleinhans, Goldberg et al., 2009), and in IFG, which was been associated with inhibitory control (DelParigi et al., 2004; Swick, Ashley, Turken, et al., 2008), compared to normal weight and obese subjects (Sweet et al., 2012). These results suggest that weight loss maintainers may exhibit a greater food reward response, countered by a greater inhibitory response. This may have important implications for the current study with respect to understanding cognitive differences between weight status groups. It is possible that this pattern of responses may correlate with their weight loss success, and perhaps cognitive therapies that aim to increase inhibitory responses to food may be helpful in increasing weight loss maintenance success.

Taken together, these findings indicate that biological factors might explain, in part, the low prevalence of long-term successful weight control, however environmental and behavioral factors interact with biological factors, and are also implicated in the obesity epidemic. These factors may be more directly modifiable.

**2.2.2 Environmental Factors.** Food cues are ever-present in today's society. The number of restaurants available to consumers is constantly increasing (NPD 2012 Recount), as well as the frequency with which people eat at restaurants (Guthrie, Lin and Frazao, 2002). Restaurants pose particularly high-risk situations for eating, due to increased portion size, food availability, and convenience (Wansink, 2004). Many studies have shown that consumption increases along with increases in food availability, serving plate size, serving utensil size, and portion sizes (Wansink, 2004, Wansink, van Ittersum and Painter, 2006)

Restaurants, and especially buffets, create extremely high-risk environments for food over consumption. Studies of buffet eating have shown increased consumption at food buffets, especially when eating with friends or family (Hetherington, Anderson, Norton and Newson, 2006). A positive relationship has also been demonstrated between increased consumption and increased BMI at buffet meals (Martins Rodrigues, Pacheco da Costa Proenca, Calvo, Fiates, 2012), as well as a strong correlation between available food and amount consumed (Levitsky and Youn, 2004). Coupled with the fact that people tend to eat everything they serve themselves (Wansink and Cheney, 2005; Wansink, 1996), proliferation of restaurants and buffet dining are significant contributors to increased consumption (Wansink, 2004).

**2.2.3 Behavioral Factors.** A variety of behavioral changes are associated with weight loss and weight loss maintenance, most notably increased physical activity, and increased dietary restriction and monitoring. A large resource that has identified several behavioral factors linked with successful weight control is the National Weight Control Registry (NWCR). Findings from the NWCR have described the physical activity, dietary, and behavioral habits associated with long-term weight control. Moreover, researchers have further studied effects of modifying behavioral factors to promote long-term success.

***2.2.3.1 Physical activity.*** Overall, findings from the NWCR (www.nwcr.ws) and other studies suggest that weight loss maintainers participate in higher levels of physical activity, both in duration and intensity (Klem, Wing, McGuire, Seagle & Hill, 1997; Phelan, Roberts, Lang and Wing, 2007). It has also been shown that the degree of successful weight loss maintenance correlates with amount of physical activity (Jakicic, 2008). However, mechanisms linking physical activity to successful weight maintenance are poorly understood. Higher physical activity may alter certain appetite hormones (Hagobian, Yamashiro, Hinkel-Lipsker, Streder, Evero, et al., 2013), cause changes in food reward regions of the brain (Evero, Hackett, Clark, Phelan and Hagobian, 2012), or even decrease food intake (Hagobian, Yamashiro, Hinkel-Lipsker, Streder, Evero, et al., 2013), but this area is not fully understood and is another area in need of further research.

***2.2.3.2 Caloric Restriction.*** Clearly, caloric restriction is necessary for weight loss (Wing and Hill, 2001; Klem, Wing, McGuire, Seagle and Hill, 1997; Holden, Darga, Olsen, Stettner & Ardito et al., 1992; Shick, Wing, Klem, McGuire, Hill, et al., 1998; Phelan, Liu, Gorin, Lowe, Hogan et al., 2009; Wing and Phelan, 2005; Soeliman and Azadbakht, 2014). Overweight/obese people eat more than normal weight individuals or weight loss maintainers (Phelan et al., 2009; Klem et al., 1997). To promote weight loss, most programs encourage a restriction of about 500 kcal/day, which typically results in a 10% reduction in weight over six months (National Institutes of Health, 1998). Studies have shown that weight loss is achieved through calorie restriction (Wing and Hill, 2001; Klem et al., 1997; Phelan et al., 2009; Wing and Phelan, 2005), and weight loss is better maintained with a continued restricted-calorie diet (Holden et al., 1992; Soeliman and

Azadbakht, 2014). In addition to calorie restriction, a variety of other dietary factors influence consumption, including dietary restraint and disinhibition.

***2.2.3.3 Dietary Restraint.*** While calorie restriction differentiates weight loss maintainers from obese and normal weight individuals, dietary restraint is also a noticeably different characteristic in weight loss maintainers (Pratt and Wardle, 2012; Phelan, Lang, Jordan & Wing; 2009). Restrained eating refers to a person's conscious control over food intake and a tendency to eat less than they desire (Allison, 1995). In a recent review by John, Pratt and Wardle (2012), dietary restraint was inversely related to BMI in overweight/obese individuals, yet had no real association in normal weight subjects. Additionally, Phelan et al. (2009), noted that weight loss maintainers scored significantly higher on the Eating Inventory, which assesses dietary restraint. Questions on this survey inquire about behaviors such as counting calories and consciously controlling food intake. This study also noted that weight loss maintainers ate significantly fewer high-fat foods, more low-fat foods, eat out less often, and tended to keep more fruits and vegetables in the home, further supporting conscious control of intake as a favorable method for successful weight loss maintenance.

***2.2.3.4 Dietary Disinhibition***. Maintaining caloric restriction in the face of eternal food cues has shown to be problematic. Individuals who fail to control intake will score high on assessments of disinhibition. Disinhibition refers to the inability to control intake and the tendency to overeat. Weight loss maintainers have lower dietary disinhibition scores compared to overweight/obese subjects (Phelan et al., 2009), suggesting a better ability to control overeating in weight loss maintainers. Dietary disinhibition tends to decrease during weight loss treatment, but data have shown that subsequent increases in disinhibition are linked to weight regain over time (NWCR.com), and that disinhibition scores are a significant predictor of weight regain after weight loss efforts (Teixeira, Silva, Coutinho, Palmiera, Mata et al., 2010); that is, the higher the disinhibition score following weight loss, the lower the success rate at keeping it off. Additionally, disinhibition scores tend to be lower in individuals consciously trying to lose weight or maintain weight, compared to individuals not trying to lose weight. (Viera, Silva, Mata, Coutinho, Santos et al., 2013). The extent to which disinhibition is under conscious control or is biologically determined is unclear, however the level of disinhibition seems to be inversely related to success of weight loss maintenance.

**2.2.4 Appetitive Factors**. While food intake behaviors are clearly associated with weight loss maintenance, many factors can influence food intake and the ability to control food intake. Appetite, or the desire to eat, is controlled by a highly complex system involving neural and endocrine signaling (Berthoud and Morrison, 2008). However, there is an interaction between excessive environmental food cues and hedonic systems that promote overeating and can override these biological appetite control systems.

***2.2.4.1 Hunger***. One reason why people may have trouble maintaining weight loss is that they may experience increased somatic cues linked with hunger. Hunger refers to a physiological need state, in part reflecting blood glucose levels and stomach volume expansion (Piech, Lewis, Parkinson, Owen, Roberts et al., 2009). Hunger is strongly associated with increased food intake. In a recent review, Sadoul, Schuring, Mela and Peters (2013) concluded that higher ratings of hunger lead to higher caloric intake at the subsequent meal. However, the physiological need for food is not the only aspect influencing food intake.

***2.2.4.2 Craving***. While cravings are not necessarily related to hunger, they do play a part in regulating food intake. Craving is generally defined as an intense desire to eat a specific food (Kozlowski and Wilkinson, 1987). Studies have shown that food cravings are positively and strongly correlated with BMI (Batra, Das, Salinardi, Robinson, Saltzman et al., 2013; Gilhooly, Das, Golden, McCrory, Dallal, et al., 2007), overconsumption (Forman, Hoffman, McGrath, Herbert, Brandsma, et al., 2006), and unsuccessful weight loss (Fabbricatore, Imperatori, Contardi, Tamburello and Innamoarti, 2013). However, changes in craving directly after weight loss and during weight loss maintenance are varied. Some studies show a decrease in cravings following weight loss (Batra et al., 2013; Jakubowicz, Froy, Wainstein, & Boaz, 2012), others show an elevation in cravings following weight loss (Jakubowicz, Froy, Wainstein, & Boaz, 2012).

Cravings are also best assessed in a real food situation. In a 2013 study by Ledoux, Nguyen, Bakos-Block, and Bordnick, food cravings were assessed in fifty-five non-dieting normal weight subjects. Subjects were exposed to virtual reality neutral cues, food pictures, virtual reality food cues, and real food cues. Cravings were measured subjectively by self-report, as well as objectively by magnitude of salivation. Results showed that cravings were highest when exposed to real foods, and lowest when exposed to neutral cues. There was no significant difference in food cravings produced by virtual reality food cues compared to food pictures. This provides evidence toward the importance of using real food cues in studies involving food, hence offering support for our methodology in the current study to use real food.

Pertaining to weight loss maintenance, a decreased craving score has been associated with increased success in long-term weight loss (Jakubowicz, Froy, Wainstein,

& Boaz, 2012; Fabbricatore et al, 2013; Gilhooly, Das, Golden, McCrory, Dallal, 2007). It has also been shown that perhaps intensity or frequency of cravings do not directly effect weight loss maintenance, however the frequency with which an individual gives into cravings and the portion size consumed of that craving may be more directly linked (Gilhooly, et al., 2007), therefore strategies to consciously control craving portion size and frequency of giving into cravings may be a more important area of emphasis in weight loss maintenance programs. While craving scores may be linked to successful weight loss and weight control, additional factors such as diet composition or behavioral strategies may be important components to consider. More research in this area is needed to assess the effects of craving on long-term weight control.

**2.2.5 Cognitive Factors.** While behavioral differences can be more easily recorded and analyzed, cognitive differences between different weight status groups are less studied. Food pictures or food words are often used in cognitive studies involving food and individuals' relationship with and reaction to food (Phelan, Hassenstab, McCaffery, Sweet, Raynor, et al., 2009; Nijs, Muris, Euser and Franken, 2010).

Phelan et al. (2009), used a Stroop Food Interference test to measure cognitive interference from food-related cues in weight loss maintainers, normal weight, and obese individuals. Their hypothesis that weight loss maintainers would have the highest amounts of cognitive interference with high-calorie foods (indicated by the slowest reaction times to these words) was confirmed. Significantly longer reaction times to higher calorie food words were recorded in the weight loss maintainers group, compared to obese and normal weight individuals. This suggests a difference in cognitive response to high calorie foods in weight loss maintainers, perhaps due to increased efforts to monitor or limit these types of foods. These results provide evidence for a difference in cognitive activity between weight loss maintainers, normal weight, and obese individuals, most importantly that weight loss maintainers had the highest cognitive response to food cues; the current study will offer further investigation with real food, which will provide more information and understanding about real-world settings.

Attention has been assessed in response to food pictures, and recorded with electroencephalography (EEG). One study analyzed EEG results on the amplitude of P300, which reflects electrophysiological activity related to conscious attention allocation (Nijs, et al., 2010). They compared normal weight individuals to overweight/obese individuals under conditions of hunger and satiety. Researchers found a significant bias toward food pictures in both conditions for normal weight subjects, as well as a bias toward food pictures in satiated obese individuals; but the bias toward food pictures was not present in hungry obese individuals. The disappearance of a significant bias between food and neutral pictures in hungry obese women potentially suggests an intentional effort to suppress attention of food-related cues, or a lack of a reaction to food cues. However, it is hard to infer much about food avoidance strategies with the measures used in this study, also showing the need for further investigation in cognitive differences in response to food between weight status groups. Further investigation on differences in cognitive activity between weight status groups using real foods, not food pictures, is necessary. The current study aims to add to the literature regarding cognitive differences between weight status groups using real food in a real-world food consumption setting (i.e.: buffet meal). Moreover, an innovative measure of cognitive functioning is now available in the form of eye tracking devices.

## 2.3 Eye Tracking Methodology

A relatively new and evolving method to measure attentional focus is the use of eye tracking devices. Eye tracking technology is a growing field in which eye movements can be recorded, and those recordings can be analyzed with regard to human processing of visual information (Mele and Federici, 2012). It has been used to explore eye movements in response to advertisements (Kessels and Ruiter, 2012; Gidlöf, Holmberg and Sandberg, 2012), product labels (van Herpen and van Trijp, 2011), and reading habits and techniques (Kunze et al., 2013). It has been used in limited amounts of studies to analyze visual attention to food cues (Werthmann, Roefs, Nederkoorn and Jansen, 2013; Nijs, Muris, Euser and Franken, 2010; Castellanos, Charoneau, Dietrich, Park, and Bradley et al., 2009), yet many of these studies do not use real food or real life situations.

A handful of studies have used eye-tracking devices with food images or with just one type of food. Food pictures attract more visual focus than do neutral pictures (Werthmann, et al., 2013; Nijs, et al., 2010; Castellanos, et al., 2009), but some have failed to find any difference in attention between weight status groups (Nijs et al., 2010). For example, one study compared overweight/obese subjects to normal weight subjects under differing hunger conditions (Nijs et al., 2010). They analyzed differences in attention for food-related stimuli and food intake between overweight/obese and normal weight women under conditions of hunger or satiety (2010). They analyzed gaze direction and duration using the Tobii Eye Tracker 2150. For the eye-tracking procedure, fifteen pairs of high-calorie foods and neutral pictures (i.e: office supplies) were displayed. Ten additional pairs of neutral items (tools), without a food object, were also displayed as fillers (although these filler data were discarded). This study found no significant differences in eye movements between groups. All had a similar bias toward the food pictures, which was significantly larger in hunger conditions for both overweight/obese and normal weight groups. They did find that the attentional bias toward food items was largest in overweight/obese individuals, however this value only approached significance. This study offers useful methodology for assessing attentional focus to food cues. The present study will use real food cues, as well as utilize newer eye tracking technology, as the Tobii Eye Tracker 2150 is now obsolete.

Another study using eye-tracking technology found that normal weight subjects tended to focus more on food images in the fasted state compared to fed state, whereas obese subjects focused more attention on food images regardless of feeding condition (Castellanos, et al., 2009). They concluded that the continued bias toward food cues even in a fed state in obese subjects suggests some sort of dysregulation in the food reward system (Castellanos, et al., 2009). This imbalance in the food reward system may be helpful in understanding becoming or staying overweight or obese. Further research on attentional focus with real food in a real life situation will allow us to better understand the cognitive factors that enable some but not others to succeed at long term weight control.

**2.4 Theoretical explanation of attentional biases in weight control.**

Theories of information processing may provide useful insight into differences in attentional bias to food cues among normal weight, overweight/obese, and weight loss maintainers. The Elaboration Likelihood Model (ELM) (Petty and Cacioppo, 1986) can help to explain the anticipated differences in eye movements between normal weight, overweight/obese and weight loss maintainers. This model states that information influences an individual via a process of cognitive elaboration, that is, the recipient evaluates new information and forms a judgment about its use (Petty and Cacioppo, 1986). Since weight loss maintainers spend a larger proportion of time on weight control behaviors, these things can be deemed important to them and could perhaps cause an inherent change in cognitive response to food cues.

Social Cognitive Theory (SCT) explains that people's behaviors can be influenced and regulated by a complex interaction between personal factors, behavior, and the environment (Bandura, 2004). This could help explain the success of weight control behaviors using constructs such as self-efficacy, behavioral capability, and outcome expectation. The basis of this theory may be one possible explanation for the ability of weight loss maintainers to adjust their dietary and physical activity behaviors and patterns, in addition to an increased sense of self-efficacy and goal-orientation in the ability to resist food cues. SCT may therefore be helpful in explaining anticipated differences in food choices among different weight status groups.

### 2.5 Rationale for the Current Study

The obesity epidemic is severe and biological factors may make it difficult to succeed at weight control. Those that are successful at long-term weight control exhibit increased restriction of food intake and/or maintain higher levels of physical activity. Ongoing monitoring and management of the obesogenic environment also appears characteristic of successful weight control. Emergent research examining cognitive factors related to food cues suggest that differences in attentional processes may also characterize successful weight control. However, existing research examining attentional processes is limited by use of food images or food words rather than real food. The current study will use the SMI Eye Tracking Glasses 2.0 device to explore the differences in eye movements between normal weight, weight loss maintainers, and overweight/obese individuals when placed in a high-risk food buffet situation. The use of the eye-tracking device will provide objective measurements for attention to real food, in a real life situation. Additionally, subject food choices will be recorded and analyzed to give insight to relative differences in food selection in relation to attentional focus to food between weight status groups. The results of this study will help to reveal whether cognitive processes (i.e., eye movements in response to food cues) are significantly different between normal weight, weight loss maintainers, and overweight/obese individuals, as well as to investigate congruence of behavioral tendencies (i.e., food choice) with attentional focus. Learning about differences in attention may offer insight into possible psychological treatments and techniques involving changing or altering attention to change brain activity (i.e.: thoughts or implicit attitude). Furthering our understanding of the characteristics and tendencies of a successful weight loss maintainer can help to better design interventions for weight loss and weight loss maintenance.

# 3 Methods

## 3.1 Overview

The current study was a cross-sectional, three-group design that assessed differences in eye movements and food choices at a food buffet in adult men and women. Subjects were recruited to fill one of the three groups: 1) Normal Weight (NW), 2) Overweight/Obese (OW/OB), and 3) Weight Loss Maintainers (WLM). Dietary restraint, dietary disinhibition, perceived appetite, and food cravings were assessed before the buffet appointment. The SMI Eye Tracking 2.0 device was used to record eye movements, including gaze fixation (i.e., what food the subject is looking at) and fixation duration (i.e., how long the subject looks at a particular food). The SMI Eye Tracking 2.0 device was calibrated for each subject prior to entering the food buffet. Subjects attended visits alone. After calibration, the subjects entered the food buffet and served themselves a meal. Subsequent analysis investigated potential differences in attentional focus to food types and for possible relationships between food attention and food choice.

## 3.2 Subjects

Participants in San Luis Obispo County and Santa Barbara County were recruited via convenience sampling. An email was sent to the Compass Health Employee email list with details about the study and information of how to participate. Flyers were also posted throughout the community requesting participation.

**3.2.1 Inclusion criteria.** Subjects had to be between 18 and 65 years of age; younger subjects were excluded because they could have different nutritional needs and influences on food intake, such as peer influence (Salvy, 2010) or family/parental influence (Roos, Lehto, Ray, 2012). For older adults, research has shown that food intake generally declines with age, due to changes in hormones, taste, smell, and digestive function (Morley, 2001). For the overweight/obese (OW/OB) group, a participant had to have an adult history of OW/OB, be currently OW/OB (BMI≥25), and report being weight stable (±15 lbs) for at least two years (NHLBI.NIH.gov). For the Weight Loss Maintainers (WLM) group, a participant had to be OW/OB (BMI≥25) at some point in their life, report having lost ≥10% of maximum body weight, and keeping off a loss of ≥10% maximum body weight for at least one year (Wing and Hill, 2001). A 10% reduction in weight loss was chosen because intentionally losing this much weight is associated with a variety of health benefits (Blackburn, 1995; Stevens, Obarzanek, Cook, et al., 2001; Goldstein, 1992; Solomon, Manson, 1997; Moore, Visioni, Wilson, et al., 2000), compared to losing smaller amounts of weight. Additionally, the NWCR uses this criterion for WLM in many of their studies, thus making our results suitable for comparison. For the normal weight (NW) group, a participant had to be NW (BMI between 18.5-25), with no history of overweight or obesity (BMI≥25). They also had to be weight stable (±15 lbs) for at least two years (NHLBI.NIH.gov).

Recruitment for each group continued until the target (10 per group) was reached. Recruiting these separate weight status groups gave the opportunity to assess differences between individuals who were OW/OB, NW, or WLM.

**3.2.2 Exclusion criteria.** Individuals with eyeglasses were not eligible, as the frame of the glasses can impede the camera on the eye-tracking device. Contact lenses, however, did not pose a problem. Individuals who were underweight (BMI<18) were not a focus of this study as underweight individuals could have different factors influencing food intake (Geliebter & Aversa, 2003). Smoking has been shown to reduce appetite and food intake (Battig, Kos, Hasenfratz, 1994; Duffy, Hall, 1988), therefore, smokers were also excluded. Individuals with eating disorders, food allergies, food restrictions or aversions (either for medical or personal reasons), smell aversions, or those who are taking medications that impact appetite were also excluded. These criteria ensured that food choices were not influenced by dietary disorders, dietary restrictions, lifestyle choices, or medications. Each of these were assessed by self-report from the participant.

**3.3 Institutional Review Board Approval**

The California Polytechnic State University Institutional Review Board approved this study. Subjects received a free lunch meal as well as a $20 incentive for participation. The free lunch meal and the monetary incentive were information that was included in recruitment efforts.

**3.4 Initial Deception of Study Purpose to Subjects**

To lessen the potential of subjects altering their eye behavior during their buffet appointment, the researcher informed potential subjects (in both advertising and during the screening process) that the study was examining the effects of restaurant aesthetics, ambience, lighting and layout on the dining experience and meal satisfaction (Ryu & Han, 2011). After the buffet appointment, subjects were debriefed on the true purpose of the study, and all questions were answered.

**3.5 Phone Screening**

After interested subjects contacted the researcher, there was a phone screening to discuss the study and to ensure all inclusion criteria were met. Within this phone screening, the researcher included a self-report of height, weight, highest weight, and recent weight changes (within the last two years) to have a baseline on which group to assign the subject.

**3.6 Orientation Meeting**

After the phone screening, eligible subjects scheduled and attended an initial appointment on the 2nd floor of the Kinesiology Tower, Building 43A, at Cal Poly State University, San Luis Obispo. During this meeting, the researcher explained the study, procedures, risks, and benefits in detail. The researcher obtained informed consent from the interested subjects. Subjects' questionnaire packet was distributed. This packet included a demographics and weight history questionnaire, a Three Factor Eating Questionnaire and a Food Craving Inventory, as described in the measures section. Subjects were asked to complete the packet, to answer each question honestly and to the best of their ability, and the researcher answered any questions they had. The researcher performed a baseline assessment to record height and weight. Taking these measurements confirmed eligibility with respect to weight and determined weight group. The subject then scheduled the buffet appointment with the researcher.

Subjects were asked to arrive at the buffet appointment alone, as research has shown that eating with friends or family can influence food choice (Higgs, 2014). Additionally, subjects were notified that childcare would not be offered for the duration of the buffet appointment; the researcher did not have the personnel or the budget to provide a service like this.

Subjects were asked to reschedule their buffet appointment if they became ill. To ensure similarity in appetite between subjects, a four-hour fast was required prior to the buffet appointment. Moreover, subjects were asked to refrain from moderate to vigorous physical activity the day of their appointment, anytime before their buffet appointment, as research has shown that physical activity can affect food intake (Hagobian, Yamashiro, Hinkel-Lipsker, Streder, Evero, et al., 2013).

The researcher informed the subject that they would receive a reminder message the day prior to the buffet appointment.

**3.7 Reminder Message**

One day prior to the subject's scheduled buffet appointment, the researcher made a phone call, sent a text message, or sent an email reminder to the subject. The subject determined the method of the reminder message at the orientation meeting. If they did not answer the phone call, a voice mail was left. If they needed to reschedule, the buffet appointment was rescheduled.

**3.8 Buffet Protocol**

Data collection took place at the HomeTown Buffet, in San Luis Obispo, CA. This buffet offered a variety of foods, including but not limited to salad items, vegetables, fruits, soups, beef, chicken, pork, potatoes, pasta, rice, beans, desserts, and various non-alcoholic beverages. It was arranged in a multi-station set-up of buffet options, allowing customers to walk from station to station to choose different food types

After arriving, subjects were greeted by the researcher just outside the entrance of the restaurant. All but one subject arrived alone as requested (one subject brought her significant other; he waited outside, and then came in when the researcher retrieved him). The researcher and the subject then entered the restaurant and proceeded to a table in the far corner of the restaurant that the researcher selected prior to the subjects' arrival. The subject was then asked to sit down. The researcher asked subjects to self-report whether or not they were feeling ill; subjects were to be rescheduled if they were sick. No subjects reported feeling sick during this study, thus no subjects were rescheduled due to illness. The researcher asked the subject to report on all food and beverage consumed prior to the meeting; those who were not fasted for four hours were to be rescheduled. No subject reported eating or drinking anything less than four hours prior to the buffet appointment, thus no subjects were rescheduled due to unsuccessful fasting. Lastly, subjects were also asked to self-report whether they exercised that morning; those who participated in moderate to vigorous exercise were to be rescheduled. No subject reported participating in moderate to vigorous exercise that morning, thus no subjects were rescheduled due to participating in exercise. Subjects then had the opportunity to use the restroom prior to putting on the glasses.

The researcher put the SMI Eye Tracking 2.0 glasses device onto the subject and secured them to their head. The glasses were approximately six inches wide and had no lens. There were two available nose rests that had been developed to fit most noses (SMI.com).

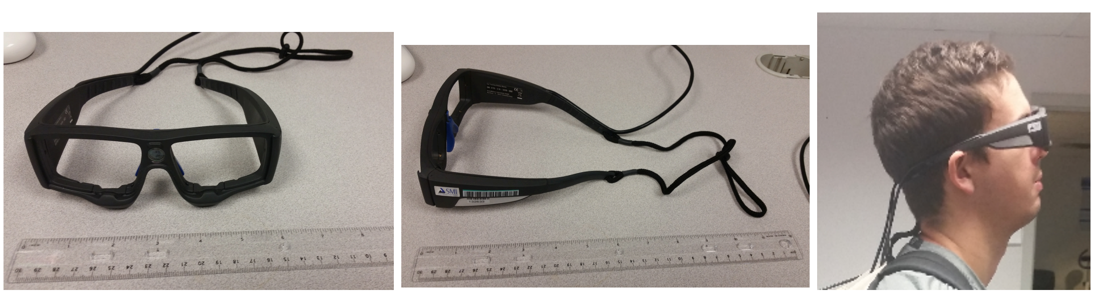

Figure 1. Eye Tracking Device Placement on Subject

The subject was asked if they were comfortable. If they were not, the researcher made necessary adjustments. Once the glasses were comfortably placed on the subject and secured, the researcher proceeded to perform a three-point calibration. The subject was asked to look at a predetermined noticeable object in their field of view at a distance approximately one and a half meters away. The researcher positioned the crosshairs of the mouse cursor over the gaze cursor and right clicked. The subject was asked to keep their head still and to shift their gaze horizontally to the right to another predetermined object approximately one and a half meters away. The researcher positioned the crosshairs of the mouse cursor over the gaze cursor and right clicked. The subject was again asked to keep their head still and to shift their gaze vertically downward to another predetermined object approximately one and a half meters away. The researcher positioned the crosshairs of the mouse cursor over the gaze cursor and right clicked. The calibration was then complete. The computer was placed in a drawstring backpack, and the researcher helped the subject put the backpack on the subject's back. The backpack with the computer inside weighed five pounds.


Figure 2. Computer and Drawstring Backpack Visual

Subjects were instructed to pretend they were not wearing the glasses, and to enter the buffet and serve themselves a lunch meal; the researcher informed the subject that there were regular customers present, and to just proceed as they normally would in a buffet if they were not wearing the glasses. The subject was asked to choose all desired food in one buffet trip, as they were not required to wear the glasses while eating, and recalibration of the glasses would have been required once they were removed.

### 3.9 Measures

**3.9.1 Eye tracking.** In 2012, SensoMotoric Instruments (SMI) released a new gaze-tracking device, the SMI Eye Tracking 2.0 glasses device, which was designed to be fully mobile, non-invasive, and used like a common pair of glasses. The glasses weighed 75 grams. The glasses provided reliable binocular eye-tracking data, complete with an HD scene camera (resolution 1,280 x 960 pixels) for optimal recording quality. The SMI Eye Tracking 2.0 glasses device, recording unit, and the SMI iView software were used to record subject data at the buffet, including gaze fixation (to which AOI the subject is visually attending) and fixation duration (amount of time spent looking at an AOI, in milliseconds). The SMI BeGaze software allowed for complex analysis of specific AOIs at the buffet. Foods were categorized into HED food and LED food categories, which comprised these AOIs. Each video was individually analyzed for visual attention to HED and LED foods. The researcher created each AOI and adjusted its location on the screen as the subject's field of vision changed throughout the duration of the buffet visit. The video was advanced by fractions of a second to ensure accurate placement of the AOIs throughout the analysis of the recording. Using this software, we were able to quantify total gaze duration on specific food types using the quantitative output data from the BeGaze program.

**3.9.2 Food Classification.** Previous research has indicated that low energy dense food diets may be more important in weight loss and control (Bell, Castellanos, Pelkman, Thorwart, Rolls, 1997). Thus, the AOIs created were based on energy density, specifically number of kilocalories per gram of food; menu items were divided into high-energy density (HED) foods and low-energy density (LED) foods. The nutritional content of each food offered was obtained from the company website (http://www.hometownbuffet.com/menus/nutritional-information), which provided the number of calories per serving of food. Energy density was defined as number of calories per gram. See Table 1 for the list of these foods and the nutritional information provided by HomeTown Buffet. The table shows foods available at the buffet during the buffet appointments, however not every food listed was available every day.

Table 1. List of Foods and Calculated Energy Density (kcal/g)

| LED food | Energy Density (kcal/g) |
|---|---|
| Beef gravy | 0.91 |
| Beets | 0.60 |
| Black beans | 0.94 |
| Broccoli, raw | 0.5 |
| Broccoli, steamed | 0.29 |
| Carrots, raw | 0.63 |
| Carrots, steamed | 0.47 |
| Cherry tomato | 0.29 |
| Coleslaw | 1.00 |
| Cucumber | 0.13 |
| Garbanzo beans | 0.67 |
| Gelatin | 0.57 |
| Green beans | 0.18 |
| Ground beef | 0.88 |
| Honeydew melon | 0.40 |
| Hot sauce | 0.00 |
| Jalapeño pepper | 0.18 |
| Kidney beans | 0.67 |
| Lemon | 0.25 |
| Lettuce, iceberg | 0.00 |
| Macaroni and cheese | 1.10 |
| Mixed greens | 0.11 |
| Mushrooms | 0.20 |

Table 1., continued List of Foods and Calculated Energy Density (kcal/g)

| LED food | Energy Density (kcal/g) |
|---|---|
| Olives | 1.00 |
| Onion, green | 0.33 |
| Peaches | 0.67 |
| Pineapple | 0.45 |
| Potatoes, mashed | 0.64 |
| Ranch dressing (fat free) | 1.00 |
| Red onion | 0.33 |
| Salad, cucumber tomato | 0.30 |
| Salsa, pico de gallo | 0.30 |
| Soup, chicken noodle | 0.65 |
| Soup, minestrone | 0.48 |
| Spaghetti | 0.85 |
| Spinach | 0.11 |
| Strawberries | 0.35 |
| Tomato | 0.33 |
| Vinegar, balsamic | 0.89 |
| Vinegar, red wine | 0.19 |

| HED food | Energy Density (kcal/g) |
|---|---|
| Bacon bits | 3.57 |
| Baked beans | 1.53 |
| Banana cream pie | 2.00 |
| Bread pudding | 1.80 |
| Brownie | 3.57 |
| Butter | 7.00 |
| Carrot cake | 3.75 |
| Cheese, feta | 2.75 |
| Cheese, shredded cheddar | 4.00 |
| Cheese sauce | 1.41 |
| Cheesecake | 2.67 |
| Chicken, BBQ baked | 1.88 |
| Chicken, fried | 2.34 |
| Chicken, teriyaki | 4.00 |
| Chocolate chip cookie | 5.00 |
| Chocolate cream pie | 2.00 |
| Chocolate mousse | 1.33 |
| Cocktail sauce | 2.00 |
| Cornbread | 3.20 |
| Cornbread, jalapeño | 3.20 |
| Crispy noodles | 4.29 |
| Croutons | 5.00 |
| Dinner roll | 3.42 |
| Dressing, Balsamic, creamy | 4.00 |
| Dressing, Bleu cheese | 5.00 |

Table 1., continued List of Foods and Calculated Energy Density (kcal/g)

| HED food | Energy Density (kcal/g) |
|---|---|
| Dressing, French | 4.33 |
| Dressing, Italian | 4.00 |
| Dressing, Italian, creamy | 4.00 |
| Dressing, Ranch | 4.67 |
| Dressing, thousand island | 4.00 |
| Egg, hard-boiled | 1.33 |
| Fish, baked | 1.61 |
| French fries | 2.83 |
| Fudge sundae | 3.02 |
| Ham | 1.41 |
| Ice cream, soft serve | 1.49 |
| Kielbasa | 1.88 |
| Lemon cream pie | 2.66 |
| Marble cake | 3.17 |
| Mexican rice | 1.29 |
| Okra, fried | 2.59 |
| Quesadilla | 2.24 |
| Pizza | 2.27 |
| Pot roast | 1.18 |
| Pudding, chocolate | 1.33 |
| Raisins | 3.33 |
| Rice crispy treat | 3.75 |
| Roast beef | 1.50 |
| Salad, broccoli bacon | 1.80 |
| Salad, potato | 1.41 |
| Salad, seafood | 2.64 |
| Saltine cracker | 4.38 |
| Sirloin and potatoes | 1.46 |
| Sour cream | 2.08 |
| Sunflower seeds | 6.36 |
| Taco shell | 4.55 |
| Tartar sauce | 5.00 |
| Tortilla chips | 5.00 |
| Turkey | 1.18 |
| White rice | 1.29 |

LED food = energy density < 1.17 kcal/g; HED food = energy density ≥ 1.17 kcal/g

### 3.9.3 Anthropometrics.

***3.9.3.1 Height.*** Subject height was recorded to the nearest quarter of an inch using a wall-mounted stadiometer. The subject turned their back to the wall, stood up straight, head straight forward, with their heels, buttocks, shoulders and head against the wall. The stadiometer headpiece was lowered to firmly touch the subject's head, the subject was instructed to take a deep breath, and then height was recorded to the nearest quarter of an inch (CDC.com).

***3.9.3.2 Weight.*** Subject weight was recorded with a Detecto Scale. To calibrate and balance the scale, both poises were moved to zero, and the balance screw was turned to the right or left until the scale balanced (detecto.com). The subject then stepped on, and the poises were moved to the appropriate position that made the scale balance (detecto.com). Weight was recorded to the nearest tenth of a kilogram.

**3.9.4 Questionnaires.** In order to assess various appetite factors associated with food intake, a variety of questionnaires were administered.

***3.9.4.1 Demographics and weight history.*** Subjects were asked to provide basic demographic information including age, gender, education level, and marital status. They were also asked to self-report their maximum adult weight and the month and year they last weighed that maximum weight (Wyatt, Grunwald, Mosca, Klem, Wing, et al., 2001).

***3.9.4.2 Food cravings.*** The Food Craving Inventory (FCI) questionnaire was administered to examine food cravings. It measures cravings for foods in four categories: High Fats, Sweets, Carbohydrates/Starches, and Fast Food Fats, which comprise the higher order construct of "food craving" (White, Whisenhunt, Williamson, Netemeyer, 2001). The FCI has been found to be a valid and reliable measure of both general and specific food cravings (White et al., 2001). The FCI can be used in research related to overeating, binge eating, obesity, and/or food cravings (White et al., 2001).

***3.9.4.3 Restraint and Disinhibition.*** In order to assess dietary restraint and dietary disinhibition, the Eating Inventory was administered (Stunkard and Messick, 1985), and is a validated quantitative questionnaire (Angle, Engblom, Eriksson, et al., 2009; O'Neil, Currey, Hirsch, et al., 1979). It was developed over a series of administering questionnaires, analyzing, and revising the questions (Stunkard and Messick, 1985), and has been used in a variety of studies assessing weight loss maintenance (Sciamanna, Kiernan, Rolls, et al., 2011; Phelan, et al., 2009; French, Jeffery, Murray, 1999; Nothwehr, Dennis, Wu, 2007).

***3.9.4.4 Visual Analog Scale (VAS)-Hunger.*** In order to control appetite and perceived hunger, subjects were asked to complete a four-hour fast prior to attending their buffet appointment, and hunger was assessed using the VAS for hunger. The reliability and validity of this measure has been tested and established (Flint, Raben, Blundell & Astrup, 2000).

## 3.10 Statistical Analysis

SPSS version 22 by IBM Corporation was used for data analysis. Group differences in demographic characteristics were examined using independent t-tests for continuous measures and chi-square tests for categorical measures. An ANOVA was used to compare percent HED fixation time, as well as the ratio between percent HED fixation time and total percent HED food choice (discrepancy ratio), and differences in questionnaire measures (dietary restraint, dietary disinhibition, appetite, and food cravings). General linear models were used to compare group differences in HED fixation time, independent of demographic covariates, restraint, disinhibition, appetite, and cravings. General Linear Models were also used to examine the role of potential modifiers (age, gender, education, marital status) and mediators (restraint, dis) in explaining relationships between group status and %HED fixation time.

### 3.11 Sample Size Calculation

The power calculation and sample size for this study was based on a study by Phelan, Hassenstab, McCaffery, Sweet, Raynor, et al., 2010 that found a significant increase in reaction time to food-related words in WLM vs NW ($p<0.05$; mean reaction time in WLM = 885msec, SD = 17.6msec; mean reaction time in NW = 834msec, SD = 15.8msec). Using a similar effect size, a sample size of 30 had 91.2% power to detect a significant increase in visual fixation and fixation duration on high-fat foods in WLM vs NW, using an $\alpha = 0.05$.

# 4 Results

## 4.1 Participants

Thirty-eight people responded to email and flyers. Of those, two could not be contacted. Six were ineligible for the following reasons: two people were smokers, three were not weight stable, and one had a history of an eating disorder. Thirty subjects met inclusion criteria and provided informed consent for study participation. Participants completed all aspects of the study, but some technical difficulties occurred during the video recording for two of the NW subjects and one WLM; thus, eye movement data for these three subjects were lost.

Participants were 10 overweight/obese, 10 weight loss maintainers, and 10 normal weight individuals. Demographic information and survey data were collected on all 30 subjects; twenty-five (83.33%) of the subjects were non-Hispanic white, two (6.7%) of the subjects were Native American, two (6.7%) of the subjects were Pacific Islander, and one (3.3%) was Latino. The mean age of the sample was 33.8 years (SD=13.4), and 50% were female. Seventeen (56.7%) of the subjects were single, eight (26.7%) were married, and five (16.7%) were divorced. There were significant group differences in BMI ($F=12.8$, $p<0.001$), with WLM and NW having lower BMIs than OW/OB. Differences in weight only approached significance ($F=3.27$, $p=0.053$). No significant group differences were found on age ($F=0.75$, $p=0.48$), sex ($F=0.37$, $p=0.69$), education ($F=0.09$, $p=0.91$), ethnicity ($F=1.0$, $p=0.38$), or marital status ($F=0.75$, $p=0.48$). Demographic information is summarized in Table 2.

Table 2: Descriptive Characteristics of the sample

| Variable | Overall | OW/OB | WLM | NW | p |
|---|---|---|---|---|---|
| **N** | 30 | 10 | 10 | 10 | |
| **Age (years)** | 33.8±13.4 | 31.7±10.6 | 38.1±16 | 31.7±13.3 | 0.481 |
| **Sex (% female)** | 50% | 60% | 50% | 40% | 0.694 |
| **Weight (kg)** | 78.2±13.3 | 86.4±9.3 | 73.9±16.9 | 74.4±9.4 | 0.053 |
| **BMI** | 25.6±3.7 | 29.2±2.7 | 24.2±3.6 | 23.4±1.6 | <0.001* |
| **Highest Wt (kg)** | 85.7±15.5 | 89.6±9.9 | 89.5±21.8 | 77.9±10 | 0.154 |
| **Education** | | | | | |
| *College Educated* | 83.33% | 80% | 90% | 80% | 0.913 |
| **Ethnicity** | | | | | 0.383 |
| *Native American* | 6.67% | 10% | 10% | 0% | |
| *Non-Hispanic White* | 83.33% | 70% | 90% | 90% | |
| *Pacific Islander* | 6.67% | 10% | 0% | 10% | |
| *Latino* | 3.33% | 10% | 0% | 10% | |
| **Marital Status** | | | | | 0.481 |
| *Single* | 56.67% | 50% | 50% | 70% | |
| *Married* | 26.67% | 40% | 20% | 20% | |
| *Divorced* | 16.67% | 10% | 30% | 10% | |

p-values are from ANOVA analysis.
* = significant

### 4.2 Group differences in visual attention to high vs. low-energy dense foods

The primary hypothesis was that, in a high-risk food buffet situation, weight loss maintainers and obese individuals would accumulate a greater total gaze duration on high-energy density foods versus low-energy density foods, as a percent of total time spent gazing at food, compared to normal weight individuals. Percent HED fixation time was calculated as the amount of time spent looking at HED foods (in milliseconds) divided by the total time spent looking at available foods (HED and LED; in milliseconds), multiplied by 100.

As a percentage of total time, OW/OB, WLM, and NW spent 71.9%, 68.5% and 63.8% of time fixated on HED foods (Table 3). While OW/OB spent more time fixated on HED foods, these differences were not statistically significant. Specifically, ANOVA analysis demonstrated no significant differences between groups with regard to visual attention to HED foods (F[2,24]=0.68, p=0.52). Similarly, no significant group differences were observed in time spent fixated on LED foods. As a percentage of total fixation time, OW/OB, WLM, and NW 28.1%, 31.5%, and 36.2% of time fixated on LED foods. ANOVA analysis demonstrated no significant differences between groups with regard to visual attention to LED foods (F[2,24]=0.68, p=0.52). GLM analyses that adjusted for gender, age, sex, BMI, and hunger did not alter these results. These data are presented in Table 3.

**4.3 Discrepancies between food attention and food choice across groups.**

The secondary hypothesis was that WLM would have higher attention to HED foods but fewer HED food selections. On average, OW/OB, WLM, and NW chose 14.3%, 16.2%, and 12.4%, of HED foods, as a percent of total foods available at the buffet, which ranged from 88 to 96 total foods each day. ANOVA analysis demonstrated no significant differences between groups with regard to percentage of HED foods selected (F[2,24]=0.48, p =0.62). A discrepancy ratio was calculated as percent HED fixation time divided by percent HED choices. ANOVA analysis demonstrated no significant differences in the discrepancy ratio between groups (F[2,24]=0.50, p=0.61). These data are presented in Table 3.

Table 3. Visual Attention to food*

| | NW | WLM | OW/OB | F | p |
|---|---|---|---|---|---|
| %HED fixation time[1] | 63.8±16.2 | 68.5±11.9 | 71.9±15.8 | 0.68 | 0.52 |
| %LED fixation time[2] | 36.2±16.2 | 31.5±11.9 | 28.1±15.8 | 0.68 | 0.52 |
| % HED food choice[3] | 12.4±3.5 | 15.3±7.9 | 13.5±6.4 | 0.48 | 0.62 |
| Discrepancy Ratio[4] | 9.39±3.5 | 9.58±5.2 | 11.60±6.5 | 0.50 | 0.61 |

p-values are from ANOVA analysis
1: %HED fixation time = time in milliseconds fixated on HED foods divided by total time spent fixated on all foods (HED and LED), multiplied by 100; shown as a percent
2: %LED fixation time - time in milliseconds fixated on LED foods divided by total time spent fixated on foods (HED and LED), multiplied by 100; shown as a percentage.
3: % HED food choice = # HED food choices divided by total number of available foods (HED and LED), multiplied by 100; shown as a percent; parentheses show total number HED choice/total number of available foods)
4: Discrepancy Ratio = (mean % HED fixation time) / (mean % HED food choice)
%HED fixation time = time in milliseconds fixated on HED foods divided by total time spent fixated on foods (HED and LED), multiplied by 100; shown as a percentage

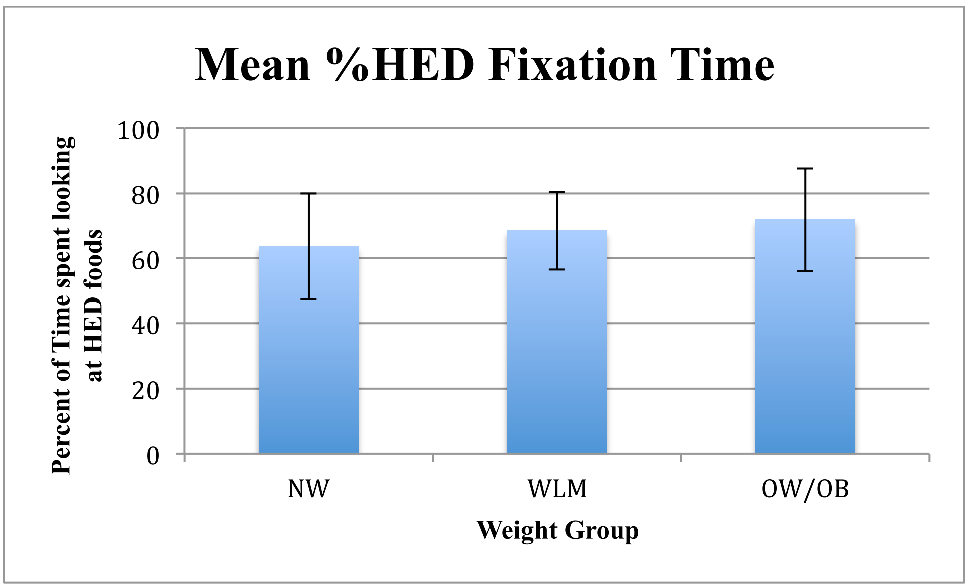


Figure 3. Mean Percent HED Fixation Time

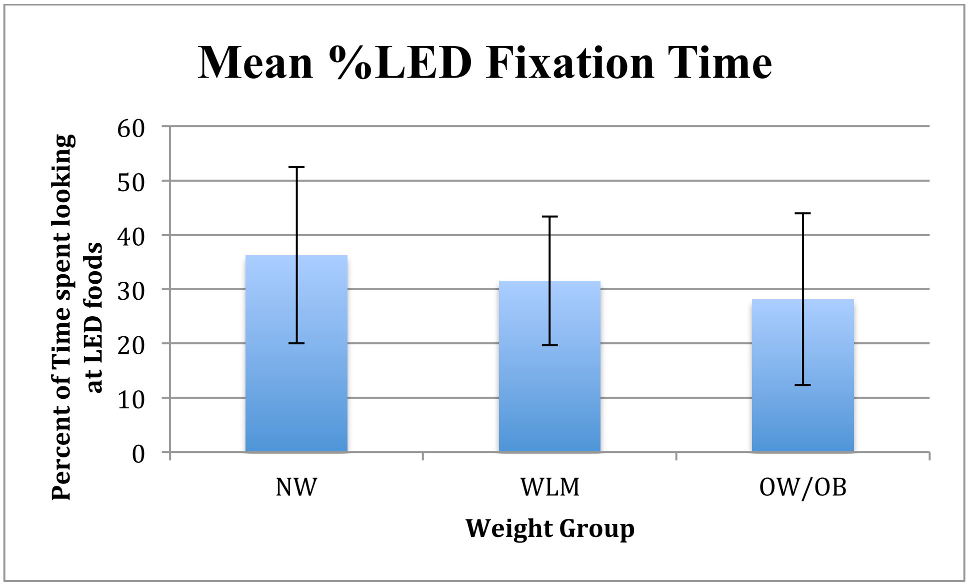

Figure 4. Mean Percent LED Fixation Time

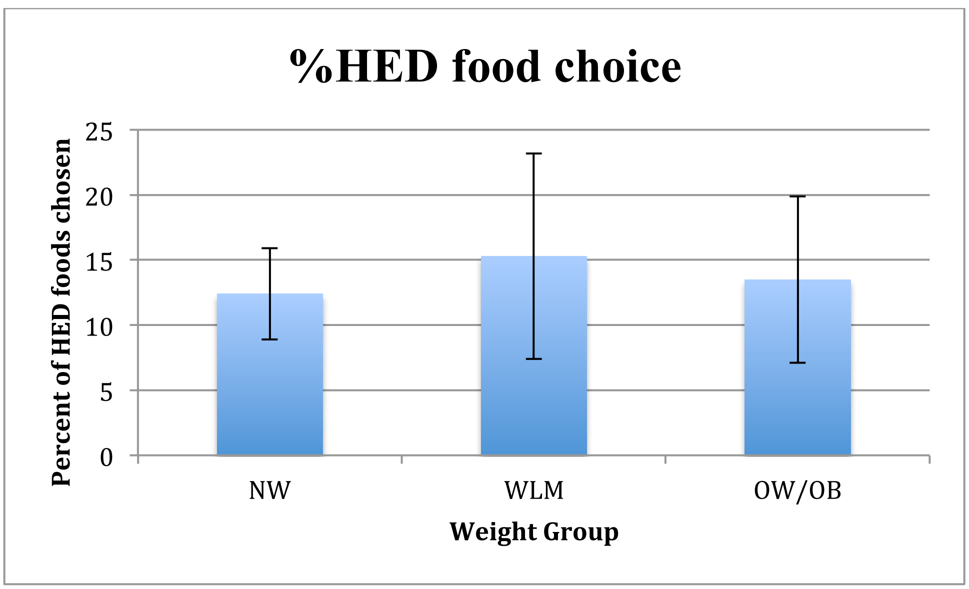

Figure 5. Percent HED Food Choice

#### *4.3.1 Appetite and Eating Behaviors*

A third aim was to identify mediators (dietary restraint, dietary disinhibition, appetite and cravings) and moderators (gender, age, education) of differences in gaze fixation and food choice between weight status groups. There were no significant effects between group statuses, the proposed mediators (restraint, craving, disinhibition, hunger) and visual attention to HED foods. Also, as shown in Table 2, there were no significant group differences in dietary restraint (F=0.139, p=0.871) or disinhibition (F=0.793, p=0.464), with OW/OB, WLM, and NW scoring on average 9.2, 9.33 and 8.88 on restraint, and, 8.2, 7.67 and 9.13 on disinhibition, respectively. Also, there were no significant differences in pre-meal appetite scores as demonstrated by the VAS for appetite: hunger (F=0.229, p=0.797), fullness (F=0.044, p=0.957), desire to eat (F=1.658, p=0.209), and prospective food consumption (F=0.805, p=0.458) measures. OW/OB, WLM and NW all displayed high levels of hunger (75.8, 74.1, and 71.2 respectively), high levels of desire to eat (82.2, 82.5, and 74.4 respectively), and high levels of prospective food consumption (65.4, 73.7, and 70 respectively). Low levels of fullness were noted in all three groups (14.3, 15.7, and 15.3 for OW/OB, WLM, and NW). No significant group differences were observed in cravings as demonstrated by the FCI, which measures cravings in high fats (F=0.64, p=0.534), sweets (F=0.24, p= 0.789), carbohydrates (F=1.567, p=0.23) or fast food fats (F=1.31, p=0.29). These data are presented in Table 4.

Table 4. Appetitive Factors

| **Variable** | **OW/OB** | **WLM** | **NW** | **F** | **p** |
|---|---|---|---|---|---|
| **VAS** | | | | | |
| *Hunger* | 75.8 | 74.1 | 71.2 | 0.23 | 0.80 |
| *Fullness* | 14.3 | 15.7 | 15.3 | 0.04 | 0.96 |
| *Desire to eat* | 82.2 | 82.5 | 74.4 | 1.66 | 0.21 |
| *Prospective Food Consumption* | 65.4 | 73.7 | 70.0 | 0.80 | 0.46 |
| **Restraint** | 9.2 | 9.33 | 8.88 | 0.14 | 0.87 |
| **Disinhibition** | 8.2 | 7.67 | 9.13 | 0.79 | 0.46 |
| **Cravings** | | | | | |
| *High-fats* | 16 | 18.4 | 18.9 | 0.64 | 0.534 |
| Sweets | 20 | 18.2 | 18.5 | 0.24 | 0.789 |
| Carbs | 16.6 | 16.8 | 20.4 | 1.57 | 0.23 |
| Fast-food fats | 11.1 | 10 | 12.4 | 1.31 | 0.29 |

p-values are from ANOVA analysis

## 5 Discussion

The present study is the first to use eye-tracking technology to examine differences in eye movements and visual attention in response to real food in a food buffet situation. Contrary to the primary hypothesis, findings indicated no significant differences in visual attention to HED foods vs. LED foods in a buffet situation between OW/OB, WLM, and NW individuals after adjusting for several potential confounds that could influence gaze fixation. Although visual inspection of mean values indicated that OW/OB spent a greater percentage of time looking at HED foods, followed by WLM and NW, these differences were not statistically significant.

There are several potential explanations for these findings. It is possible that these groups did not differ in visual attention to food cues in a buffet situation. While other work has shown support for there being cognitive differences in WLM vs NW and OW/OB (Phelan et al., 2009), that work used the Stroop task to measure the extent to which these groups differed in being "distracted" by HED foods. Some studies measuring attentional focus to food cues using eye-tracking methodology have shown no significant differences in attention between NW and OW groups (Nijs et al., 2010, Brignell, Griffiths, Bradley, and Mogg, 2009; Calitri, Pothos, Tapper, Brunstrom and Rogers, 2010). The current study's findings were more consistent with these latter studies, but included a WLM group and real food cues. Future research should include multiple attentional measures, such as pupil dilation and EEG activity; maybe these groups differ in some, but not other attentional processes.

Some studies have shown that a condition of hunger can elevate attentional bias to food cues (Mogg, Bradley, Hyre and Lee, 1998; Loeber, Grosshans, Herpertz, Kiefer, Herpertz, 2013), or even eliminate differences in cognitive response to food cues among weight status groups (Brignell, Griffiths, Bradley, and Mogg, 2009; Calitri, Pothos, Tapper, Brunstrom and Rogers, 2010). Since all three groups in the present study exhibited similar, high levels of hunger, it is possible that the hunger condition influenced all three groups to have similarly heightened levels of attentional focus on HED foods.

It is also possible that social desirability could have influenced the study's results. Social desirability refers to an individual's tendency to behave or respond in a manner consistent with societal norms or beliefs (Edwards, 1953; Herbert, Ma, Clemow, Ockene, Saperia, et al., 1997). Literature suggests that individuals of varying weight statuses and weight histories may be differentially affected by social desirability. For example, higher levels of social desirability are associated with less success in weight loss programs and higher BMI (Carels, R., Cacciapaglia, H., Rydin, S., Douglass, O., & Harper, J., 2006). Furthermore, individuals with higher BMIs tend to underreport weight when asked to self-report it (Taylor, A., Grande, E., Gill, T., Chittleborough, C., Wilson, D., et al., 2006). It is possible that wearing glasses in a food situation could have differentially affected the behaviors of OW/OB and WLM, who may be more conscious of social norms surrounding food than individuals of NW.  OW/OB and WLM may be more self-conscious of food gaze and food selections, possibly altering naturalistic visual attention and food choice behaviors.

It may be that differences in weight status were more attributable to behavioral or biological characteristics than cognitive factors. Indeed, prior research has shown WLM vs. OW/OB differ in physical activity habits (Klem, Wing, McGuire, Seagle & Hill, 1997; Phelan, Roberts, Lang, and Wing, 2007; Phelan, Liu, Gorin, Lowe, Hogan, Fava &

Wing, 2009), dietary monitoring habits (Wing and Hill, 2001; Klem et al., 1997), and genetic factors (de Luis et al., 2013, Qi t al., 2011). Future research that includes biological, physical activity, diet, and attention measures are needed to examine relative importance of these factors in predicting weight status.

It is also possible that group differences in cognition exist but that differences are smaller than anticipated. The current study was powered based on a study by Phelan, Hassenstab, McCaffery, Sweet, Raynor, et al., 2010 that found a significant increase in Stroop test reaction time to food-related words in WLM vs NW (WLM = 885msec vs NW = 834msec,). Using a similar effect size, a sample size of 30 yielded 91.2% power to detect a significant increase in visual fixation and fixation duration on high-fat foods in WLM vs NW. In the current study, data from three subjects were unavailable from 1 WLM and 2 NW because of technical problems with the computer, which may have reduced power to detect differences. Also, as noted, attentional processes in a food buffet situation used in the current study might have differed from those elicited in the Stroop study. In a post-hoc power calculation, assuming a mean %HED fixation time of 63.8±16.2% for NW, 68.5±15.8% for WLM, and 71.9±11.9% for OW/OB, an appropriate sample size to give 79.4% power would be 60 subjects per group (N=180).

Methodological difficulties could also have reduced ability to detect differences in visual attention to HED foods that may exist across the groups. The BeGaze analysis software offered some leniency in how an Area of Interest (i.e.: an HED food or an LED food) was defined, leaving room for user interpretation and human error. For example, the AOI manually created by the researcher around the food may have been designated slightly outside the container for one subject, but slightly inside the container for another. Figures 6 and 7 demonstrate this.

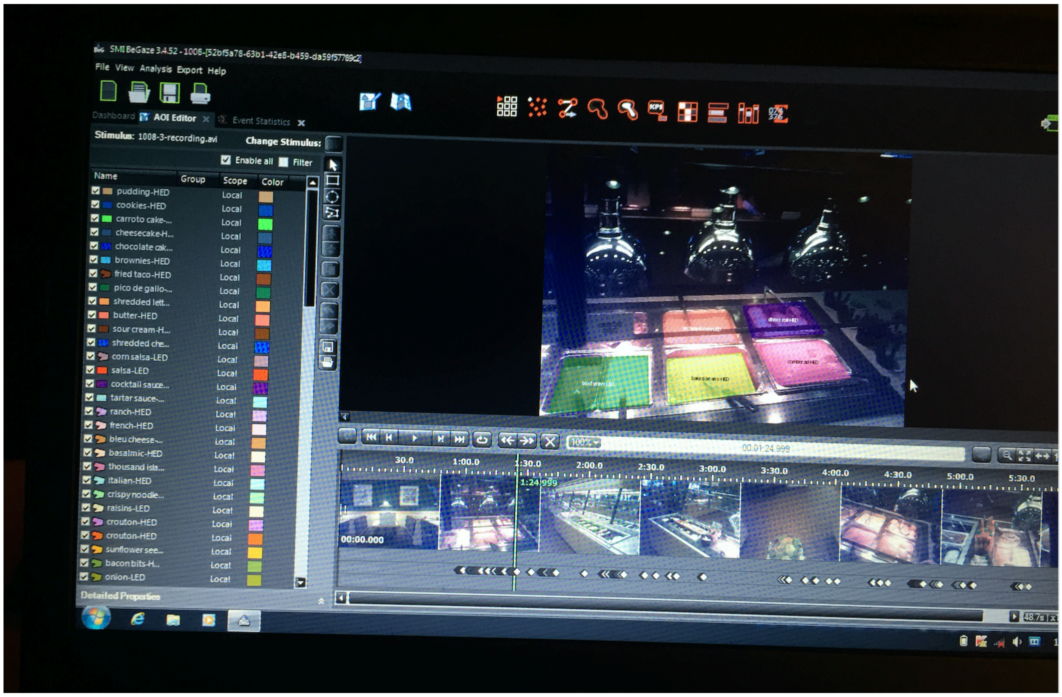

Figure 6. AOI Positioned Inside

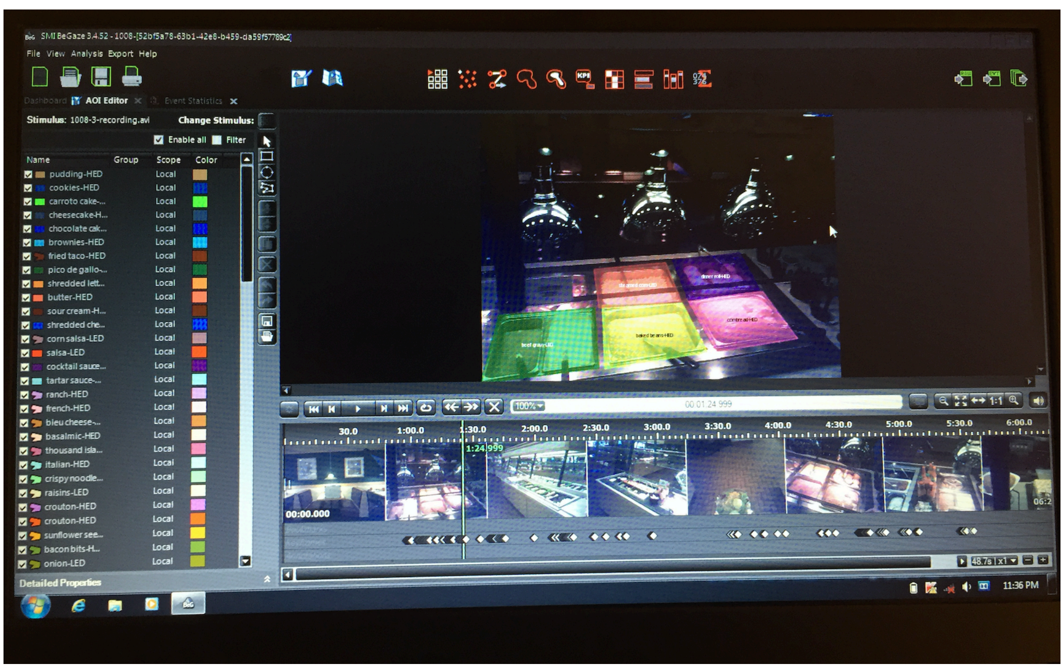

Figure 7. AOI Positioned Outside

Slight differences in the size of the AOI may have had a large overall effect on how often the gaze cursor fell into the AOI, thereby altering amount of time spent fixated on that AOI.

Some subjects spent more time looking at the food label positioned above the food, rather than looking at the food itself. This was not represented in the AOIs, which were created around the food containers, not on the food labels. Additionally, subjects may have slightly moved or touched the glasses during the buffet selection process, which could have compromised the calibration, and thus adversely affected the ability of the software system to accurately record eye movement data.

An interesting part of the data output involved the total time spent looking at foods. All groups on average spent 9.81 seconds looking at HED foods, 5.13 seconds looking at LED, and 14.9 seconds total fixated on foods at the buffet. Considering that subject buffet videos lasted anywhere from 3 minutes 32 seconds to 12 minutes 51 seconds, the total amount of time spent fixated on AOIs (i.e.: the total amount of time spent looking at foods) was surprisingly low. A fixation was defined in the software as the period of time when the eye was still, or the period of time that occurred between two saccades (SMI BeGaze Manual, version 3.3). A saccade was defined as the rapid change of gaze location (SMI BeGaze Manual, version 3.3). The software used a complex algorithm to calculate the occurrences of saccades and fixations. However, the reference manual indicated that the current algorithms might not be well suited to detect fixations on moving targets (SMI BeGaze Manual, version 3.3). While the targets in the current study were stationary (i.e.: the food containers were stationary), the subject was not stationary (body movement and head movement were almost completely constant).

Furthermore, the position of the food containers with respect to the subject was such that subjects needed to look downward to view them. The SMI Eye Tracking 2.0 glasses may not have detected fixations as efficiently with possible obstruction from the subject's eyelid, or less accurate algorithmic calculations due to the subject not looking directly forward at AOI's (SMI BeGaze Manual, version 3.3). These limitations might have significantly affected the ability of the software to capture and/or calculate all fixations that occurred and thus the ability to formulate accurate and/or complete fixation data on the defined AOI's.

Furthermore, the current study did not control the availability of the buffet foods. While this did allow for a more realistic situation, it compromised our ability to ensure equal amounts, locations, and types of food available on all days at the buffet. However, the proportion of HED and LED foods available at the buffet were very similar across days (51-54 HED foods available and 37-40 LED foods available), which offered consistency throughout data collection.

**5.1 Discrepancies in attention vs. food selection**

Interestingly, the three groups did not significantly differ in number of selections of HED vs. LED foods, as research has shown that BMI and intake of higher energy density foods are positively correlated (Savage, Marini, & Birch, 2008; Ledikwe, Blanck, Kettel, Serdula, Seymour et al., 2006; Raynor, Van Wlleghan, Bachman, Looney, Phelan et al., 2011; Saquib, Natarajan, Rock, Flatt, Madlensky et al., 2008). Also, OW/OB tend to serve themselves more than NW in a food buffet situation (Martins Rodrigues, Pacheco da Costa Proenca, Calvo, Fiates, 2012). It could be that group differences existed in total daily food intake, or amounts of HED/LED foods eaten over the course of the day, but total daily intake was not measured in the current study. Also, it is possible that while subjects in all groups served themselves the same number of HED and LED foods, the portions varied. This, too, was not measured in the current study, limiting conclusions that can be drawn.

**5.2 Differences in cognition and visual attention**

While previous research has exhibited differences in brain activity between weight status groups in response to food cues in a lab (DelParigi at al., 2004; Schur et al., 2009; Swick et al., 2008; Sweet et al., 2012), there have been no studies that have tested brain activity during a buffet visit with high food availability. This is likely because it would be inconvenient, invasive, and impractical to put subjects in a non-laboratory setting and record brain activity. This is another reason to explore the connection between eye movement data and brain activity, so that eye tracking may be used in more realistic settings such as a restaurant buffet, as it is less invasive and more practical.

While previous studies have revealed mixed results regarding visual attention to food cues among weight status groups (Castellanos et al., 2009; Werthmann et al., 2013; Nijs et al., 2010), it is possible that high food availability at the buffet masked or eliminated potential differences in visual attention. Learning more about how visual attention influences brain activity, we can perhaps develop strategies that purposefully alter visual attention, which would in turn change brain activity, perhaps offering a new and innovative avenue for changing thought and/or behavior. The possible strategies would have yet to be developed and explored.

## 5.3 Appetite and Eating Behavior

Several covariates were measured that were hypothesized to potentially affect visual attention. However, inclusion in our models did not alter results. As planned, all subjects were asked to complete a four-hour fast before attending the buffet meal; we successfully controlled for appetite before the meal across all subjects, as there were no differences in pre-meal appetite scores as demonstrated by the VAS for appetite.

The groups did not significantly differ in restraint, which is a measure of a person's conscious control over food intake and a tendency to eat less than they desire (Allison, 1995). This is surprising in light of prior research, which indicates that WLM usually exhibit significantly higher levels of dietary restraint (Phelan et al., 2009, Teixeira et al., 2012). The scores in this study were 9.33 in WLM, which is much lower than prior work in WLM. For example, Phelan et al. (2009) showed WLM restraint scores of 14.7, and Teixeira et al. (2010) noted WLM restraint scores of 15. Similarly, disinhibition scores showed no significant differences between groups, which is also in contrast to prior research (Phelan et al., 2009, Teixeira et al., 2010). Disinhibition scores were 7.67 for WLM in the present study, which is higher than prior work (Phelan et al., 2009; Teixera et al., 2010). Reasons for differences could be that the sample of WLM in the proposed study was different than WLM in other research. Larger sample sizes are needed to have more generalizable results.

## 5.4 Future Research

Several avenues for future investigation remain to be explored. A larger sample size may be necessary both to have stronger representation of WLM and to detect smaller differences that may exist. For example, the study by Phelan et al., (2010) used a sample size of 48, and Nijs et al., (2010) used 66 subjects. It is likely that a larger sample size may reveal potential differences. While having subjects in a natural environment is a strength of this study, future studies may want to exercise better control over the food in order to provide consistent food availability and choices for every subject. The container in which food is presented and the amount of food available in that container has been shown to impact consumption of that food (Chandon & Wansink, 2002; Sobal & Wansink, 2007). If the food is more visible and more easily obtainable, data suggest that this promotes and increases consumption (Chandon & Wansink, 2002).

While a limitation of this study acknowledged that the glasses could potentially alter behavior, future research may have subjects attend the food buffet twice, once with the glasses and once without, in order to compare behavioral choices at the buffet within subjects.

Future research utilizing eye-tracking technology should consider the constraints of the software technology used. It is possible that the usability of the BeGaze software may compromise the accuracy of the data outputs. Cognitive differences may very well still be existent between these weight groups, however the sample size may need to be larger in order to detect the postulated differences.

Other responses such as pupil diameter may also offer insight into cognitive differences between these weight status groups. For example, recent research has linked pupil diameter to activity of the locus coeruleus (LC), which is a region of the brain associated with attention (Benarroch, 2009; Nieuwenhuis, De Gues, Aston-Jones, 2010; Rajkowski, Jubiak, Aston-Jones, 1993). Heightened LC neural activity has been tightly linked with attentional state and pupil diameter (Hong, Walz, & Sajda, 2014). It is possible that pupillary responses are more directly connected to cognitive activity, and may be a better inference of brain activity than simply duration of gaze fixation on objects.

Regarding the potential for Social Cognitive Theory to help explain differences in food choices between weight status groups, it is also likely that SCT may help explain the lack of differences found between groups in the present study. SCT acknowledges that the environment can influence individuals' behaviors. It is likely a food buffet situation may be an uncommon situation for most participants in this study, thus the environment of high food availability and accessibility may have had a larger effect on subject behavior than individual factors.

**5.5 Conclusions and Implications**

Although this study yielded null findings, eye-tracking technology should not be ruled out as a method to explore attentional focus and brain activity. We have yet to define whether eye-trackers can be used as a proxy for brain studies, or whether eye movement data is measuring something completely different. This technology is new and constantly developing, and has the potential to replace more sophisticated equipment that may be more expensive, more invasive, and less practical. Exploring eye movement data in conjunction with EEG data may be a possible next step to learn more about the connection between visual attention and brain activity.

While findings suggest no significant group differences in visual attention to HED foods and HED food choice, these results should be interpreted with caution. Limitations in sample size, methodology, and technology could underlie these results. More research is warranted to examine the role of attention processes in weight management.

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