

STRESS, CUES, AND MOTIVATION FOR FOOD: USING ADDICTIONS MODELS TO
UNDERSTAND DYSREGULATED EATING

by

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ABSTRACT

Eating patterns that lead to overconsumption of high fat, high sugar (HFHS) foods share similar features with addictive behaviors. Thus, application of addiction paradigms and analytical methods, such as stress inductions, cue reactivity and behavioral economic assessments of reinforcing value, to the study of motivation for HFHS food consumption is promising means of understanding overconsumption. To date, no studies have investigated the interaction of stress and environmental cues on subjective craving and the relative reinforcing value of HFHS foods (RRV_{food}), the focus of the current study. The study used a mixed factorial design (Mood Induction: Neutral, Stress; Cues: Neutral, Food) with repeated measures on time (Baseline, Post-Mood Induction, Post-Cue Exposure). Participants ($N=133$) were adults recruited from the community who denied symptoms of eating disorders and endorsed liking of HFHS snacks. The primary dependent variables were subjective craving and RRV_{food} . Negative and positive affect, heart rate and blood pressure, the amount of food consumed, and latency to first bite were also examined. Participants in the Stress Induction condition reported the expected increase in negative affect and decrease in positive affect, but no change in craving or RRV_{food} . Exposure to food cues significantly increased participants' subjective craving and RRV_{food} . A significant

interaction of stress and cues, was not present. Participants did not differ on how many calories they consumed based on exposure to stress or food cues, but those exposed to food cues tended to start eating faster. This study highlights the utility of using RRV_{food} to further characterize food motivation above and beyond craving. It also suggests that stress does not generally influence food motivation and may only be relevant in clinical groups or individuals with certain motivational profiles.

INDEX WORDS: Eating Behaviors; Behavioral Economics; Cue Reactivity; Stress; Craving.

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DEDICATION

To Szymon,

For relentless support and confidence in me

Dla Rodziców

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CHAPTER 1

INTRODUCTION

Overconsumption of high fat and high sugar (HFHS) foods substantially contributes to obesity and associated health problems (Corsica, 2010; Davis & Carter, 2009; Gold, Frost-Pineda, & Jacobs, 2003; Liu, von Deneen, Kobeissy, & Gold, 2010; Gearhardt, Phil, & Corbin, 2011). The World Health Organization (WHO) identified obesity as a “global epidemic,” with 34% of U.S. adults obese in 2007 (Flegal, Carroll, Ogden, & Curtin, 2010). The risk of a number of adverse health consequences increases as an individual reaches the Body Mass Index (BMI) of 30 or above (the cut-off for obesity; National Institutes of Health Heart, Lung and Blood Institute [NHLBI], 1998), including heart disease, Type II diabetes, and osteoarthritis (NHLBI, 1998). Similarly, a diet high in fat and sugar is implicated in a number of major Western diseases, such as ischemic heart disease, stroke, some cancers, and Type II diabetes (McGinnis & Foege, 1993; WHO, 2003). Diets high in sugar and fat along with physical inactivity are estimated to cause up to half a million deaths annually in the U.S. due to cancer, cardiovascular disease, and diabetes (Jacobson & Brownell, 2000; McGinnis & Foege, 1993). Despite these health consequences, the availability of foods high in fat and sugar per capita has increased at least 20% since 1977, in part due to increased density of fast food restaurants or increases in sugar added to processed foods (Drewnowski, 2003; Lustig, Schmidt, & Brindis, 2012). Excessive availability and consumption of fast food and snacks has been implicated in increased energy density in the U.S. diet (Zizza, Siega-

Riz, & Popkin, 2001). Thus, overconsumption of HFHS snack food is associated with significant health costs to society.

Some researchers have proposed that dysregulated consumption of HFHS foods is akin to addiction, as eating patterns that lead to overconsumption and drug addiction have many similar features (Davis & Carter, 2009; Volkow & Wise, 2005). Individuals with substance use disorders and those who over consume HFHS foods report increased craving for their preferred substance in response to relevant cues (Davis & Carter, 2009; Volkow & Wise, 2005). Hyperactivity of the limbic system is associated with response to environmental cues and excessive consumption of HFHS foods as well as drugs of abuse (Gearhardt et al., 2011; Volkow & O'Brien, 2007; Volkow & Wise, 2005; Wang, Volkow, Thanos, & Fowler, 2009). Classical and operant conditioning mechanisms are associated with the development and maintenance of the overconsumption of both drugs and food (Volkow & Wise, 2005). Animal studies have indicates that removal of palatable food substances causes withdrawal-like symptoms and stress, which are alleviated when those foods are reinstated (for a review see Volkow & Wise, 2005; Wise, 2004). HFHS foods and drugs are used to regulate emotional states and cope with stress (Epel, Lapidus, McEwen, & Brownell, 2001; Sinha, 2007). Finally, it can be argued that both behaviors are associated with chronic relapse and moderate long-term treatment gains (Gearhardt et al., 2011; Volkow & Wise, 2005). Therefore, applying paradigms used in addiction research to the study of HFHS food consumption has the potential to inform our understanding of the motivational processes that influence overconsumption.

The Role of Environmental Cues in Addictive Behaviors

Craving is one mechanism that may be associated with overconsumption of HFHS foods (Lafay et al., 2001; Martin, O'Neil, Tollefson, Greenway, & White, 2008). The concept of craving has been extensively discussed in the addiction literature. Craving is subjective in that it refers to the unique experience of an individual, emotional in that the experience of craving is characterized by anticipation of pleasurable substance, and motivational in that it elicits substance-seeking behavior (Tiffany & Wray, 2009; Tiffany, 1990). Craving theories also assert that craving episodes are typically situation-specific, which in turn is explained by classical conditioning where cues typically paired with the substance of preference elicit a craving (Ludwig, Wikler, & Stark, 1974; Tiffany & Conklin, 2000).

One laboratory paradigm that has been extensively used to study the use of drugs, tobacco, and alcohol to investigate craving is the cue-reactivity paradigm in which individuals are exposed to visual cues of their preferred substance (Carter & Tiffany, 1999; Niaura et al., 1988; Perkins, 2009). The cue-reactivity paradigms are grounded in classical conditioning theory (Tiffany, 1995), with drug-related stimuli (e.g., environmental context, drug paraphernalia) putatively becoming conditioned stimuli, which in turn elicit conditioned responses, including subjective craving. Numerous studies support the proposition that classical conditioning plays a role in the etiology and maintenance of drug-seeking appetitive behavior patterns (Drobes, Saladin, & Tiffany, 2001; Hyman, 2005; Niaura et al., 1988; Redish, Jensen, & Johnson, 2008). Recent reviews based on studies in this area support the importance of cue-elicited craving in motivation for consumption of substances such as alcohol and tobacco (MacKillop &

Monti, 2007; Robbins, Ersche, & Everitt, 2008). In a meta-analysis of human laboratory studies using cue-reactivity paradigms in addiction research, Carter and Tiffany (1999) found that, on the whole, participants displayed an increase in heart rate and in sweat gland activity when exposed to drug-related cues. Participants also reported significant increases in subjective self-reported craving (Carter & Tiffany, 1999). The findings of their analysis indicate that exposure to external drug-related stimuli (e.g., beer cans, needles, *in vivo* exposure to drug itself) on the whole results in increased drug craving and physiological reactivity (Carter & Tiffany, 1999), in contrast to earlier studies which often found contradictory associations between craving and physiological reactivity (for review, see Niaura et al., 1988).

Research has indicated that environmental cues play a similar role in food consumption. Exposure to visual and olfactory food cues elicits a physiological reaction (also known as cephalic phase responses) in healthy weight individuals marked by changes in gastric activity, heart rate, blood pressure, and salivation (Jansen, 1998; Nederkoorn, Smulders, & Jansen, 2000; Wardle, 1990). These changes are presumed to prepare the body for consumption and digestion, and occur in response to learned associations between cues that signal food and resulting consumption (Jansen, 1998). Some studies indicated positive associations between these physiological changes and craving, and between craving and food intake (Jansen, 1998; Martin et al., 2008; Nederkoorn et al., 2000). Presentation of food in a laboratory setting elicits craving for food compared to neutral cues (Sobik, Hutchison, & Craighead, 2005). In turn, cravings for specific foods have been found to be associated with increased consumption of these food items compared to others in a laboratory study (Martin et al., 2008). Thus, it appears

that food cues elicit cravings and preliminary results suggest that cravings for food are associated with increased food consumption.

The Role of Stress in Overconsumption

Since the initial investigations in the stress field, researchers have attempted to establish a satisfactory definition of stress (Mason, 1968, 1971; Selye, 1936, 1937, 1975). Levine and Ursin (1991) offer a comprehensive theoretical framework for understanding this phenomenon. They postulate that stress responses to physical and psychological stimuli are determined by interpretation of an individual to effectively cope with the situation, but also by a myriad of other factors such as social context, social status, genetic factors, gender, among others. The biological sequelae of a distressing experience appear to involve the hypothalamic-pituitary axis (HPA) which, when activated, stimulates secretion of the corticotropin-releasing hormone which in turn triggers the release of cortisol in the adrenal gland (Kudielka & Kirschbaum, 2007). A distressing experience is also likely to result in the activation of the sympathetic nervous system which results in increased heart rate and blood pressure (Kudielka & Kirschbaum, 2007).

The most common methods for eliciting psychosocial stress in the laboratory involve either performance of various challenging tasks (non-personalized) or being exposed to personally salient stressful material. The Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993) has several variations which generally include a speech task, a social interaction task, or a mental arithmetic task, or a combination of these three tasks. TSST has been shown to generally elicit the expected subjective and physiological reactions (Dickerson & Kemeny, 2004).

Another type of stress induction is the personalized guided imagery procedure (Sinha, 2011; Sinha, 2001) based on Lang's theory, which posits that emotional imagery activates the same physiological, subjective, and behavioral responses as an emotionally stressful experience in real life (Lang, Kozak, Miller, Levin, & McLean, 1980; Lang, 1977, 1979). Grounded in information processing theory, it postulates that emotions are represented as networks of nodes in the memory, hence an activation of any node causes a cascade of activation of the entire network (Lang et al., 1980; Lang, 1977, 1979). As studies on anxiety disorders have found that emotional imagery does indeed elicit the expected physiological and subjective responses in a laboratory settings (e.g., Cook, Melamed, Cuthbert, McNeil, & Lang, 1988; McNeil, Vrana, Melamed, Cuthbert, & Lang, 1993; Miller, Levin, Kozak, & Cook, 1987), it became an established paradigm for studying stress reactions based on a personalized emotional experience. In this paradigm, individuals are instructed to imagine and re-experience an emotional situation based on their recent personal experience. Guided imagery technique appears to be generally effective in eliciting subjective distress and the expected physiological reactions (Sinha, 2011).

The link between exposure to stress or negative emotional states and drug use (either continued use or relapse) is abundantly documented (e.g., Bradley, Phillips, Green, & Gossop, 1989; Litman, Eiser, Rawson, & Oppenheim, 1977; Ludwig et al., 1974; Sinha, 2001a). The basis for this has been addressed by several theoretical accounts. For example, Baumeister has argued that coping with stress and other negative emotions requires exertion of self-control, which may result in poorer self-control performance even after the aversive experience has ended (Baumeister & Heatherton,

1996; Muraven & Baumeister, 2000). Similarly, Lowenstein (1996) proposed that exposure to both acute and chronic stress increases the salience of a preferred substance, and hence craving, for the substance. Metcalfe and Mischel (1999) advanced a model of cool and hot processing of stimuli that influences decision-making. As emotion increases, the focus shifts from the cool (i.e., one concerned with cognitive processing, complex spatial-temporal representations, etc.) to the hot (i.e., one specialized for quick emotional responding) system (Metcalfe & Mischel, 1999). As such, exposure to acute and chronic stress may lead to systematic depletion of impulse control abilities, making people more likely to behave impulsively, e.g., relapse into smoking or abuse drugs, among other things. Thus, negative emotional states have been implicated in impulsive and compulsive drug-seeking behaviors as they are purported to decrease self-control and increase the salience of environmental cues. Similarly, both stress or negative emotions and environmental cues, may increase the desire for and consumption of HFHS foods.

Many individuals report increased consumption in response to stressful situations (Adam & Epel, 2007; Epel et al., 2001). Studies that examined the cortisol levels in response to emotional arousal found that cortisol reactivity was related to overconsumption following a stressful experience (Epel et al., 2001; Newman, O'Connor, & Conner, 2007). Epel and colleagues (2001) found that total calories consumed following a TSST induction was significantly related to cortisol levels in a sample of women, regardless of their weight status (BMI status ranged from normal weight to obese). Additionally, women with a high cortisol reaction in response to TSST had a preference for sweet high-fat foods compared to women who had a lower cortisol reaction (Epel et al., 2001). An ecological momentary assessment (EMA) study found

that for women who have higher cortisol reactions, the total number of calories consumed was significantly related to a total number of daily hassles that they experienced, which was not the case for women with low cortisol reactions (Newman et al., 2007). The mean BMI in this sample was 23.34 (SD=3.62) indicating healthy weight status. Based on these studies, it appears that cortisol reactivity influences the amount and type of food consumed in response to stress, in individuals with a range of BMIs.

Studies have also examined self-reported subjective distress and its relationship to food consumption. One study using the TSST found that the total number of calories consumed was positively related to self-reported subjective distress in normal-weight, overweight, and obese women, regardless of their weight status (Epel et al., 2001). In another study, healthy, non-obese participants were asked to prepare a speech on a controversial topic and anticipated delivering it in front of a live audience (Oliver, Wardle, & Gibson, 2000). While distress was not related to total calories consumed, individuals in the stress condition reported higher preference for sweet high-fat foods compared to those in the non-stress condition (Oliver et al., 2000). Finally, an EMA study examined the influence of daily hassles on eating behavior (O'Connor, Jones, Conner, McMillan, & Ferguson, 2008). Hassles were defined as any events or situations that contribute to negative mood (e.g., annoyance, irritation, worry) and/or interfere with attainment of an established goal (Conner, Fitter, & Fletcher, 1999; O'Connor et al., 2008). Daily hassles were positively associated with food intake in a majority non-obese sample (13% of participants were obese). Specifically, interpersonal stressors (e.g., a fight with a partner), work-related stressors, and ego-threatening stressor (e.g., public

talk) were associated with increased intake in high fat, high sugar snacks, and fewer meals (O'Connor et al., 2008).

Studies in the addiction field have used the personalized guided imagery paradigm extensively and found significant associations between mood induction, emotional and physiological stress, and craving for a preferred substance. For example, guided imagery elicited subjective craving for cocaine (Sinha, Catapano, & O'Malley, 1999; Sinha, Fuse, Aubin, & O'Malley, 2000a), tobacco (Colamussi, Bovbjerg, & Erblich, 2007), and alcohol (Fox, Bergquist, Hong, & Sinha, 2007; Sinha et al., 2008) in substance dependent individuals. Additionally, guided imagery procedures have been shown to increase craving in non-dependent individuals (Chaplin, Hong, Bergquist, & Sinha, 2008; Rousseau, Irons, & Correia, 2011). To date, this paradigm has not been used to examine the association between stress response and drug consumption in a laboratory setting. Despite the association between heightened emotional states and increased food consumption, no studies have utilized the guided imagery technique in relation to food craving or consumption.

Overall, as indicated by the above studies, stress or negative emotions appear to be a factor in affecting motivation for and consumption of HFHS foods. Self-regulation strength may be depleted and decision making may switch to the "hot" system following stress which in turn is likely to potentiate the influence of environmental cues (Metcalf & Mischel, 1999; Muraven & Baumeister, 2000). Therefore, both personalized cues and personalized distress may be particularly relevant in craving and subsequent consumption. Although a number of studies link food overconsumption with distress, no study to date has used the personalized guided imagery procedure to examine this

relationship. Additionally, the studies to date have mostly focused on actual consumption of food and not subjective craving. Therefore, in this study, we will use the guided imagery paradigm to examine motivation for food measured via subjective craving and relative reinforcing value of food.

Using Behavioral Economics to Characterize Motivation for Food

Another approach that is widely used in addiction research and is relevant to dysregulated eating is behavioral economics (BE), a hybrid of microeconomics and behavior analysis, which examines daily consumption as a primary dependent measure of behavior (Hursh, 2000). In economic theory, it is assumed that individuals have limited budgets, thus they are forced to choose among the different alternatives, or “goods” (Chaloupka & Pacula, 2000). There are several indices in BE to describe the preference for one good over another, broadly defined as the relative reinforcing value of a commodity (RRV). Relative reinforcing value has been studied in addictions using laboratory paradigms and various self-report measures to elucidate the decision-making processes present in drug-seeking behavior. It is typically measured by pitting a fixed amount of a preferred substance (e.g., alcohol, cocaine, sedatives, caffeine, cigarettes, heroin) against escalating amounts of an alternative monetary award (Benson, Little, Henslee, & Correia, 2009; Correia & Little, 2006; Garrett & Griffiths, 1998; Griffiths, Rush, & Puhala, 1996; Griffiths, Troisi, Silverman, & Mumford, 1993; Jacobs & Bickel, 1999; Jones, Garrett, & Griffiths, 1999; Murphy & MacKillop, 2006). Participants tend to prefer the drug reward at lower monetary amounts and, as the monetary rewards escalate, they tend to switch their preference to money. Relative reinforcing value has been most

commonly represented via the crossover point, or the point at which an individual starts preferring the alternative reinforcer (i.e., money) over the preferred one (i.e., preferred drug) as the latter becomes gradually harder to obtain (Goldfield, Epstein, Davidson, & Saad, 2005). It may also be represented via demand indices which provide different dimensions of reinforcing value in addition to crossover point (Jacobs & Bickel, 1999; Murphy & MacKillop, 2006). Studies have found that RRV is sensitive to reinforcer magnitude (i.e., participants cross over to monetary rewards as the response cost increases), drug dependence (i.e., physical dependence increases RRV), and deprivation (i.e., deprivation increases RRV; Garrett & Griffiths, 1998; Griffiths et al., 1996; Jones et al., 1999). In addition, there is mounting evidence that RRV is an informative index predictive of substance use severity and treatment response. Higher RRV is associated with greater quantity and frequency of drinking, more negative consequences from alcohol, higher dependence, and poorer treatment response (Correia & Little, 2006; Gray & MacKillop, 2013; MacKillop & Murphy, 2007; MacKillop, Miranda, et al., 2010; Murphy & MacKillop, 2006; Murphy, MacKillop, Skidmore, & Pederson, 2009).

Importantly, measures of state RRV have been used to complement traditional measures of craving for substances in laboratory designs. Relative reinforcing value increases as a result of exposure to cues of preferred substance compared to an exposure to neutral cues, and it appears to provide incremental information above and beyond self-reported craving (Amlung, Acker, Stojek, Murphy, & MacKillop, 2011; MacKillop et al., 2008; MacKillop, O'Hagen, et al., 2010). Two studies also offer preliminary evidence for increases in RRV for alcohol following a negative mood induction (Amlung & MacKillop, in press; Rousseau, Irons, & Correia, 2011). Thus, measures of RRV can be

used in human laboratory studies to assess substance motivation that is correlated but not redundant with subjective craving.

The relative reinforcing value of food (RRV_{food}) originated in operant theory as food is a primary reinforcer and has been used as an operant for years (Skinner, 1938). Relative reinforcing value of food describes how much behavior a stimulus will support (Bickel, Marsch, & Carroll, 2000; Griffiths, Brady, & Bradford, 1979), for example, how many responses an individual will make to obtain food (Epstein & Saelens, 2000) or how much money a person is willing to allocate to food (Epstein, Dearing, & Roba, 2010). Thus, RRV_{food} characterizes motivation for food under conditions of response cost, yielding the value of food to the individual.

In the field of eating behavior and dysregulation, RRV_{food} has mainly been studied using laboratory paradigms where participants are placed on a concurrent reinforcement schedule and work for access to food vs. a non-food related activity. These studies have consistently found that higher RRV_{food} is associated with higher BMI and obesity in adults and children (Epstein et al., 2007; Saelens & Epstein, 1996; Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008) and that, compared to individuals with low RRV_{food} , those with high RRV_{food} consume more in ad libitum tasks (Epstein, Lin, Carr, & Fletcher, 2011; Epstein et al., 2004; Epstein, Dearing, Temple, & Cavanaugh, 2008; Rollins, Dearing, & Epstein, 2010; Saelens & Epstein, 1996; Temple et al., 2008). Similarly to RRV for drugs, RRV_{food} is sensitive to reinforcer magnitude (i.e., participants switched to less desirable alternative when the price of food increased) and food deprivation (i.e., participants valued food more when food deprived; Lappalainen & Epstein, 1990; Raynor & Epstein, 2003). The Multiple Choice Procedure (MCP), which

yields the crossover point via a questionnaire administration, has not been used with food items to date. However, since the laboratory findings in the study of food consumption are similar to those found for addictive substances using the MCP for drugs, the MCP for food items is likely a reliable analog to the procedures used in the laboratory and it can be used to study RRV_{food} more efficiently compared to laboratory paradigms.

Dysregulation of the processes by which individuals decide to consume certain foods relative to alternatives may be studied using BE paradigms. RRV appears to represent another dimension of motivation for food that is informative above and beyond craving. Considering that RRV is sensitive to cue reactivity and mood inductions in addiction research, RRV_{food} may also be sensitive to stress and food cues. Therefore, examining RRV_{food} under stressful conditions and in the presence of cues may elucidate the motivational pathways leading to overconsumption of HFHS foods and add to our understanding of motivation for food.

Current Study

Taken together, given the promise of applying addiction research paradigms to the study of motivation for HFHS food consumption, the goal of this study was to use a stress induction, a cue reactivity paradigm, and a behavioral economic index of RRV_{food} to understand motivation for HFHS foods. To date, the separate influences of stress and environmental cues on consumption of HFHS food have each been examined. However, no studies have investigated the interaction of stress with the presence of cues, and no studies have leveraged behavioral economic measures in this domain. Also, while in the addiction literature there is a clear link between negative affective states and craving for a

preferred substance, this relationship is less clear when food is concerned. The specific goal of the study was to examine craving and RRV_{food} for HFHS food following a stress induction, and subsequent exposure to a variety of food cues. The study used a mixed factorial 2 (Mood: Neutral/Stress) $\times 2$ (Cue: Neutral/Food) $\times 3$ (Time: Baseline/Post-Mood/Post-Cues) design with repeated measures on Time. This design allowed for examination of the main effects of stress and cues on craving and RRV_{food} , and also the interaction of stress with environmental cues on craving and RRV_{food} , further informing the field regarding basic processes by which stress and cues affect motivation for HFHS foods. The primary dependent variables were subjective craving and RRV_{food} . Self-reported negative and positive affect as well as physiological measures of stress (i.e. heart rate and blood pressure) were collected. In addition to the primary manipulations, the protocol permitted some participants to consume food ad libitum and their food consumption in calories and latency to first bite were measured, and subsequently examined for exploratory purposes.

The following hypotheses were posited: (1) Participants in the Stress Induction condition will report significantly higher negative affect (NA) and lower positive affect (PA) following the stress induction compared to participants in the Neutral Mood condition; (2) Participants in the Stress Induction condition will report significantly higher craving and RRV_{food} compared to participants in the Neutral Mood condition; (3) Participants in the Food Cues condition will report significantly higher craving and RRV_{food} following the cue exposure compared to participants in the Neutral Cues condition; (4) Participants in the Stress Induction + Food Cues condition will report the highest craving and RRV_{food} following the final (i.e., cue) exposure compared to

participants in the other three combinations of conditions. As secondary aims, psychophysiological and behavioral indices of stress and motivation for food were examined. Specifically, the heart rate (HR) and mean arterial pressure (MAP) were examined following each experimental manipulation in order to determine whether any effects of mood or cues are present. The main effects of environmental cues on the consumption of food measured in calories and the latency to the first bite of food were also examine.

CHAPTER 2

METHOD

Study Design

The study is a $2 \times 2 \times 3$ mixed factorial design of the effects of mood (Neutral Mood Induction, Stress Induction) and environmental cues (Neutral Cues, Food Cues) on motivation for food with repeated measures on time (Baseline, Post Mood Induction, Post Cue Exposure). Negative and positive affect were examined as dependent variables as a manipulation check for the effectiveness of the stress induction. The primary dependent variables were subjective craving and RRV_{food} . The secondary dependent variables included physiological arousal, actual food consumption, and latency to first bite of food. Participants were randomly assigned to one of four conditions (i.e., [1] Neutral Mood + Neutral Cues; [2] Neutral Mood + Food Cues; [3] Stress + Neutral Cues; [4] Stress + Food Cues) using block randomization by sex to ensure equivalence of groups. The order of exposures was not counterbalanced; participants always underwent the mood induction first and the cue exposure second. This was for two reasons. First, from an ecological validity standpoint, the study sought to examine the interaction of stress and environmental cues in which an individual first experiences a negative event and then is confronted with environmental food stimuli, the order of greatest relevance to naturalistic environments. Second, carryover effects are well-documented in the addiction literature on cue reactivity (Monti et al., 1987) making it plausible that order effects might be present. This, in turn, would substantially undermine statistical power as the effects

would have to be examined separately by order. Given that no previous studies have used these paradigms in this context, the study sought to maximize power.

Participants

Participants ($N = 133$, see Power Analysis below) were recruited from the Athens-Clarke County and the surrounding northeast Georgia region through advertising in local newspapers, on city and campus buses, and via flyers on bulletin boards. We assessed inclusionary and exclusionary criteria via a brief telephone screen. Inclusionary criteria included: 1) *Age 18-45*: To decrease variability, participants were no older than 45 years old; 2) *Absence of an eating disorder*: we screened out participants who reported disordered eating symptoms (i.e., loss of control over eating at least four times in the past month, purging, or BMI below 18). Based on previous studies presence of an eating disorder may influence the relative reinforcing value of food (Epstein et al., 2010; Epstein, Leddy, Temple, & Faith, 2007; Willner et al., 1998); 3) *Liking of study snack foods*: Participants had to endorse at least moderate liking (at least 4 on a 7-point Likert scale) for high-calorie snack foods (Epstein et al., 2010) in order to qualify for the study.

Exclusionary criteria included: 1) *Food allergies*: participants were excluded if they reported presence of any food allergies as they had to consume a preload bar as part of the study and there was a potential for them to consume other snack foods during the consumption period; 2) *Medication*: participants were excluded if they regularly took medication associated with weight loss or loss of appetite.

The sample size was determined using a power analysis via G*Power 3 software (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007).

Specifically, an *a priori* power analysis for the least powerful hypothesis (i.e., Hypothesis [4] – the interaction) in a factorial ANOVA was conducted. Based on previous studies on substance and food cues, medium effect sizes were predicted (f) of $\sim .30$ (Carter & Tiffany, 1999; MacKillop, O'Hagen, et al., 2010; Sobik et al., 2005). The power analysis indicated a minimum sample size of $n = 23$ participants per cell was required ($\alpha = .05$, $\beta = .86$). Based on this, a target total sample size of 100 participants was identified (i.e., 25 participants per cell), which increased β to 0.90. The study overenrolled participants and the final sample size was 133, increasing β to 0.99.

Assessment

Eligibility Telephone Screening. Participants were screened over the telephone for their age, the presence of an eating disorder, self-reported food allergies, and medication use (see Inclusionary and Exclusionary Criteria in the *Participants* section). They were also asked to identify their preferred HFHS snack food and to rate their liking for that snack food on a 7-point scale where 1 indicated no liking for the snack food and 7 extreme liking for the snack food. The participants only qualified if they rated the snack food at least 4 on this scale. Finally, participants verbally reported their height and weight in order for the experimenter to assess their BMI and ensure that it was not below 18.

Measures of Dependent Variables

Visual Analog Scales (VAS; Folstein & Luria, 1973). VAS was used to assess participants' craving for snack foods and their subjective affect following each experimental manipulation. To assess cravings participants were asked to rate the

following four statements on an 11-point scale where 0 indicated “*Not at all*” and 10 indicated “*Extremely*”: (1) “*How much do you crave a snack right now?*” (2) “*How much do you want a snack right now?*” (3) “*How much do you desire a snack right now?*” (4) “*How high is your urge for a snack right now?*” These items were combined into one composite “Craving” score (the Cronbach’s α s ranged from 0.96 to 0.98).

To assess subjective affect, the same 11-point scale was used to rate six mood states: calm, happy, relaxed, nervous, stressed, and sad. These items were combined into two composite scores: Negative Affect (nervous, stressed, sad; Cronbach’s α s ranged from 0.74 to 0.84) and Positive Affect (calm, happy, relaxed; Cronbach’s α s ranged from 0.60 to 0.87). A similar measurement method was used by the author of the guided imagery procedure (Sinha et al., 2008).

Multiple Choice Procedure (MCP; Griffiths et al., 1996, 1993). RRV_{food} was measured using the MCP adapted for food available in the study (see *Appendix A*). The participants made 26 choices between a fixed opportunity to receive unlimited access to the snack foods buffet for 30 minutes and escalating monetary amounts (from \$0 to \$15). Participants were informed that they were making choices for actual food and money as one of their choices would be selected at random and consequated. The index of RRV_{food} derived from the MCP was the crossover point, the point at which participants’ preferences switched from food to monetary reward. The crossover point was calculated as the mean of two prices: the last price at which the participant selected food and the first price at which the participant selected money.

Following procedures outlined by Griffiths and colleagues (1996, 1993) , the participants were trained in the instructions for MCP to ensure accurate responding. The experimenter explained the MCP instructions verbally. Subsequently, the experimenter presented the participant with two pens and asked the participant whether they would rather have a certain amount of money or the pens. The amounts of money progressively increased from \$0 to \$15, modeling the MCP for food. This was to ensure that the participant understood the premise of the MCP when they were presented with it in the experimental context and asked to make decision about access to food. Participants were then presented with a list of snack foods that would be available for consumption period (see *Appendix B*) to ensure that they were familiar with the commodity for which they were making choices. They were informed that later in the session, they would be making choices between access to these snack foods for 30 minutes and money, which would result in an actual reward. They were told that the choice would be selected randomly using a poker chip and they would receive the reward associated with that choice (either food or money). This selection procedure was demonstrated to the participants at the end of the MCP training.

Heart rate and mean arterial pressure (MAP). Participants' psychophysiological arousal was assessed via heart rate and blood pressure (systolic and diastolic) using a blood pressure cuff (Welch Allyn, Inc.; Skaneateles Falls, NY) following each manipulation. Mean arterial pressure was calculated using the mean of the systolic and diastolic blood pressure values.

Food consumption. Depending on their responses on the MCP, some participants had an opportunity to have unlimited access to a buffet of over 50 various snack foods for 30 minutes during the consumption period. Following the consumption period, the wrappers were catalogued and the leftover food was weighed in order to calculate the total amount of food consumed. Additionally, an experimenter observed the participants via a one-way mirror during their consumption period in order to measure the latency to the first bite in seconds using a stopwatch.

Measures of Descriptive Variables

Participants answered questions on a computerized questionnaire regarding their ethnicity, occupation, income, education level and other demographic variables. To assess subjective hunger, participants answered a single question (i.e., “*How hungry do you feel right now?*”) on an 11-point Visual Analog Scale where 0 indicated “*Not at all*” and 10 indicated “*Extremely*” (Folstein & Luria, 1973). Participants’ weight and body composition (i.e., % body fat and water content) were collected using a digital body composition scale (Tanita BF-680W; Tanita Corporation of America, Arlington Heights, IL). Their height and waist circumference were measured using a tape measure.

Procedure

The study comprised a telephone screen (see *Assessment*) and a single experimental session lasting 4.5 hours. The detailed chronology of the session is depicted in *Figure 1*. Participants received \$45 in compensation for their time (\$10/hour).

Additionally, they had an opportunity to receive up to additional \$15 based on their responses on the MCP.

Participants were scheduled for the experimental session between 1PM and 3PM. They were instructed to not eat two hours prior to their sessions and their food consumption was verified via a food recall interview. To minimize the effects of acute hunger on food reinforcement (Epstein et al., 2010; Reiss & Haverkamp, 1996), participants received a preload of a cereal bar (Strawberry Yogurt Nature Valley Chewy Granola Bar or Kashi TLC Honey Almond Chewy Granola Bar), each providing 140 calories of energy. They were also trained on completing the MCP (see *Assessment*).

Experimental manipulations consisted of a personalized mood induction (see the *Development and Implementation of Mood Induction* section below) and an *in vivo* cue exposure (see the *Cue Exposure* section below), in that order. Prior to and immediately following each experimental manipulation participants were assessed on the dependent variables using a brief (approximately 3 minutes) battery of questionnaires and the blood pressure cuff (MCP, craving and affect using VAS, and HR/BP; see *Figure 1*).

Following the post cue exposure assessment, participants randomly selected one poker chip with a number on it. The number on each poker chip corresponded to one item on one of three MCP assessments that the participants completed previously (i.e., Baseline, Post-Mood Induction, Post-Cue Exposure assessment). Based on the choice, participant received either access to the buffet of snack foods for 30 minutes or money (i.e., up to \$15). If the participants received money, they were nonetheless required to remain in the lab for 30 minutes without access to snack foods.

At the conclusion, participants were debriefed on the purpose of the study and compensated. All procedures were approved by the University of Georgia Institutional Review Board.

Development and Implementation of Mood Induction. We followed a manualized protocol for guided imagery developed by Sinha (Sinha, 2001b, 2010). Participants in the Stress Induction condition were asked to identify a recent (within the last year) stressful experience and rate their distress on a 10-point Likert scale (1-not at all stressful; 10-most stressful). Participants in the neutral condition identified a recent neutral or relaxing experience and rated their relaxation. Only situations not explicitly related to food or money were used, so as not to confound the stress induction with the outcome measures (i.e., MCP). Only situations rated at eight or above were used in the experimental session.

Participants were asked to describe the event in detail to the experimenter. They were informed that they would listen to an audio recording of their experience later in the session and assured of confidentiality. In order to develop the most compelling script, the experimenter adhered to the instructions provided by Sinha (Sinha, 2001b, 2010). For example, the experimenter used participant's own phrasing and alternated between sentences describing the situation and the physical sensations. An example of one script from each condition is provided in *Appendix C*. Once the script was written by the experimenter, a research assistant who had not interacted with the participant audio recorded the script. The audio recordings of the scripts were approximately five minutes in length.

Before the experimental manipulations, participants underwent an imagery training in order to ensure that they imagine the scene described to them vividly (Sinha, 2001b, 2010). This training reduces variability in baseline imagery across participants (Miller et al., 1987). Participants were guided into a relaxed state and subsequently guided to vividly imagine neutral scenes (e.g., reading a book) and physical sensations (e.g., tactile, olfactory). The experimenter then interviewed the participants about their ability to imagine the scenes.

During the mood induction, participants listened on the headphones to the audio-recorded script. In the neutral mood induction, participants listened to a standard, non-personalized script, designed to induce a neutral mood/relaxation (see *Appendix C1*). Participants in the stress induction condition listened to a personalized script of a stressful situation, which they described in the interview earlier in the session (see *Appendix C2* for an example).

Cue Exposure. Depending on random assignment, participants were presented with either an array of HFHS snack foods (e.g., chips, candy bars, string cheese; see *Appendix D1* for images) or an array of office supplies (i.e., notepads and pens; see *Appendix D2* for images) as a cue. This type of neutral cue is consistent with those used in other food cue-reactivity studies (Sobik et al., 2005). Participants listened on the headphones to an audio recording instructing them to select one object from the array and to interact with it. For instance, for the Food Cues condition, participants were asked to select one that appeals to them the most, pick it up, unwrap it, and smell it (see *Appendix E1* for a script). For neutral cues, participants were asked to select a notepad and a pen

that most appeal to them, and to write their names using the implement (see *Appendix E2* for a script). The procedure was approximately five minutes in length.

Data Analysis

Preliminary Analyses

Before testing the primary hypotheses, preliminary analyses were conducted to ensure data quality. To examine the distribution for normality, frequency histograms and expected normal probability plots for the variables of interest were generated (Tabachnick & Fidell, 2007). If the data were not distributed normally, they were logarithmically transformed, which was followed by another examination of normality post-transformation. To examine for outliers, the raw scores were transformed into z -scores and defined as an outlier if $z > 3.29$ (Tabachnick & Fidell, 2007). If outliers were identified, they were recoded as one unit above the highest non-outlying value (Tabachnick & Fidell, 2007). The baseline performance on scaled measures was examined for ceiling values that would preclude detection of changes (i.e., participants never crossed over to money or reported maximum craving).

Effects of Experimental Manipulations

The effects of stress and cues on mood, craving, and RRV_{food} were examined using a series of 2 (Stress Induction, Neutral Mood Induction) $\times$ 2 (Food Cues, Neutral Cues) $\times$ 3 (Baseline, Post Mood Induction, Post Cue Exposure) mixed ANOVAs. As a manipulation check, a statistically significant interaction of Time $\times$ Mood Induction was predicted such that participants in the Stress Induction condition would report the highest

negative affect (NA) and the lowest positive affect (PA) following the mood induction procedure. A significant Time $\times$ Mood interaction was predicted such that participants in the Stress Induction condition would report higher subjective craving and RRV_{food} following the mood induction procedure compared to participants in the Neutral Mood condition. A significant Time $\times$ Cues interaction was predicted such that participants in the Food Cues condition would report higher craving and RRV_{food} following the cue exposure manipulation compared to participants in the Neutral Cues condition. Finally, a significant Time $\times$ Mood Induction $\times$ Cues interaction was predicted such that participants in the Stress Induction combined with Food Cues condition would report the highest craving and RRV_{food} following the cue exposure. In order to probe the significant interactions, change scores were derived in NA, PA, craving and RRV_{food} across the assessment time points and the groups were compared on change scores using one-way ANOVAs. In order to examine psychophysiological indices of stress and craving, two $2 \times 2 \times 3$ ANOVAs were also conducted with HR and MAP as outcome variables. Again, the focus was on the two-way and three-way interaction terms.

Interrelationships among Motivational Variables

In order to explore the interrelationships among the motivational variables, Pearson's zero-order bivariate correlations were conducted. The correlations between NA, PA, craving, RRV_{food} , heart rate, and MAP were generated at baseline measurement for the entire sample, as well as separated by experimental groups based on significant effects of manipulations. For the separate between-group correlations, where notable

differences in magnitude were present, *r*-to-*z* transformations were applied to determine whether the coefficients were significantly different from one another.

Behavioral Outcomes

Among the participants who received access to snack foods, behavioral performance of latency to first bite (seconds) and total calories (kcal) consumed was examined. As the participants were not randomly assigned to the food vs. money group, the participants who received access to snack foods were compared to those who received money on demographic variables as well as motivational variables (i.e., craving, RRV_{food}) using one-way ANOVAs. Additionally, participants who received access to food were compared on demographic and motivational variables based on the experimental manipulations they underwent to ensure group equivalence. In order to examine the behavioral performance, two 2 (Stress Induction, Neutral Mood Induction) $\times$ 2 (Food Cues, Neutral Cues) ANOVAs were conducted in the sample of participants who received access to snack foods. The behavioral outcome variables were the latency to first bite in seconds and the total number of kcal consumed. In the ANOVA of total kcal consumed, sex and BMI were statistically controlled as men consume on average more calories per day than women and individuals with higher BMI may consume more calories than those with lower BMI.

To examine the interrelationships between motivational variables and behavioral performance, Pearson's zero-order bivariate correlations were conducted. The correlations between NA, PA, craving, RRV_{food} , heart rate, MAP, total number of kcal consumed, and latency to first bite were generated for the entire sample of participants

who received access to food, as well as separated by experimental groups based on significant effects of mood and cues. Again, for the separate between-group correlations, where notable differences in magnitude were present, *r*-to-*z* transformations were used to determine significant differences.

CHAPTER 3

RESULTS

Preliminary Analyses

For a complete description of participant demographic characteristics, see *Table 1*. Due to block randomization, the samples were nearly equivalent in sex distribution. There were no statistically significant differences between the samples on the demographic variables with the exception of Hispanic cultural background. Specifically, there were nine participants in the Neutral Mood + Food Cue condition who identified as Hispanic, significantly more than in the Neutral Mood + Neutral Cue condition. There were no significant differences between participants on their weight status or BMI. Over 60% of participants were in the normal weight range, 27% were overweight and 10% were obese. The mean hunger level in the sample was 4.90 ($SD=2.21$) and there were no statistically significant differences on baseline hunger between experimental groups ($F[3, 128]=1.31, ns$).

The total number of kcal consumed was logarithmically transformed. All other variables of interest were normally distributed thus transformations were not performed. There were no outliers in the dataset thus all values were included in the analyses and no values were recoded. Consistency of responding on the MCP was very high ($M = 0.99$; $SD = 0.01$), indicating that the participants fully understood the instructions for the MCP and did not switch back and forth between food and money. On the MCP, two participants' baseline responding was at the ceiling (i.e., selected all food options

regardless of cost). These two participants were removed from final analyses as their RRV_{food} was indeterminable. On the Craving assessment, one participant's baseline responding was at the ceiling (i.e., reported maximum craving of 10) and that participant was removed from the final analyses due to invariability in responding.

Effects of Experimental Manipulations

There were no baseline differences between the conditions on outcome variables. Omnibus tests were conducted using a 2 (Mood) $\times$ 2 (Cues) $\times$ 3 (Time) ANOVA with repeated measures on time. The key interaction effects are summarized in *Table 2* and the table with all ANOVA coefficients is included in *Appendix F*. With regard to the manipulation check, the predicted significant interactions were present between Time and Mood Induction condition (see *Table 2*). Participants in the Stress Induction condition increased in NA from baseline ($M = 1.38$, $SD = 1.25$) to post mood induction ($M = 3.81$, $SD = 2.14$) and decreased in PA from baseline ($M = 7.28$, $SD = 1.20$) to post mood induction ($M = 4.60$, $SD = 1.20$), while the participants in the Neutral Mood condition remained relatively stable on their NA (Baseline: $M = 1.68$, $SD = 1.55$; Post mood Induction: $M = 1.19$, $SD = 1.19$) and PA (Baseline: $M = 7.23$, $SD = 1.26$; Post mood Induction: $M = 7.57$, $SD = 1.41$) ratings between the two time points (see *Figure 2a* and *2b*). The Stress Induction group reported significantly higher increase in NA ($F[1, 131] = 110.20$, $p < 0.01$) and significantly higher decrease in PA ($F[1, 131] = 153.31$, $p < 0.01$) compared to the Neutral Mood group (see *Figures 2a* and *2b*). In contrast, no significant effects were observed for subjective craving, RRV_{food} , or indices of arousal (see *Table 2*).

The predicted Time $\times$ Cue interaction was present such that participants in the Food Cues condition reported the highest craving following the cue exposure (see *Table 2*). Participants in the Food Cues condition increased in craving from post mood induction ($M = 4.05$, $SD = 2.63$) to post-cue exposure ($M = 5.85$, $SD = 2.47$) while the participants in the Neutral Cues condition remained relatively stable from post mood induction ($M = 3.76$, $SD = 2.54$) to post-cue exposure ($M = 3.79$, $SD = 2.50$; see *Figure 3a*). Participants in the Food Cues condition had a significantly higher increase in craving compared to participants in the Neutral Cues condition ($F[1, 129] = 60.98$, $p < 0.01$; see *Figure 3a*). The predicted Time $\times$ Cue interaction was also found such that participants in the Food Cues condition reported the highest RRV_{food} following the cue exposure (see *Table 2*). Participants in the Food Cues condition increased in RRV_{food} from post mood induction ($M = 4.42$, $SD = 3.32$) to post-cue exposure ($M = 5.06$, $SD = 3.56$) while the participants in the Neutral Cues condition remained relatively stable from post mood induction ($M = 4.54$, $SD = 2.85$) to post cue exposure ($M = 4.67$, $SD = 3.20$; see *Figure 3b*). Participants in the Food Cues condition had a significantly larger increase in RRV_{food} compared to participants in the Neutral Cues condition ($F[1, 129] = 6.07$, $p < 0.05$; see *Figure 3b*).

The analyses also revealed findings that were unanticipated. Specifically, a significant Time $\times$ Cue interaction on PA was present such that participants in the Food Cues condition reported lower PA following the cue exposure ($M = 6.06$, $SD = 1.94$) compared to participants on the Neutral Cue condition ($M = 6.54$, $SD = 1.56$). The Neutral Cue group increased in PA from post mood induction to post cue exposure, while the Food Cues group decreased slightly ($F[1, 129] = 5.76$, $p < 0.05$; see *Figure 3c*).

The expected Time $\times$ Mood $\times$ Cue interaction on subjective craving or RRV_{food} was not present (see *Table 2*). There were no significant differences between the four combinations of conditions following the final experimental manipulation.

Interrelationships among Motivational Variables

The correlations are summarized in tables in *Appendix G*. At baseline, negative affect (NA) and positive affect (PA) were moderately negatively correlated ($r = -0.41, p < 0.01$). PA was positively correlated with heart rate (HR) at a statistical trend level ($r = -0.15, p < 0.10$). Craving was positively moderately correlated with RRV_{food} ($r = 0.42, p < 0.01$).

Following the mood induction manipulation, NA and PA were moderately negatively correlated in the Neutral Mood condition, ($r = -0.48, p < 0.01$) and in the Stress Induction condition ($r = -0.68, p < 0.01$). PA was also negatively correlated with HR in the Neutral Mood ($r = -0.24, p < 0.05$) and the Stress Induction condition ($r = -0.25, p < 0.05$). Craving and RRV_{food} were moderately correlated in both the Neutral Mood ($r = 0.48, p < 0.01$) and Stress Induction condition ($r = 0.53, p < 0.01$). The differences between the correlation coefficients in Stress Induction vs. Neutral Mood condition were not statistically significant.

Given that main effects of cue condition were present but mood by cue interactions were not present, the relationships between variables of interest using bivariate correlations were examined in the Neutral Cues condition and Food Cues condition following the cue exposure. Similarly to the baseline relationships and the post-mood induction relationships, NA and PA were moderately negatively associated in the

Neutral Cues condition ($r = -0.53, p < 0.01$) and the Food Cues condition ($r = -0.44, p < 0.01$). HR was not related to NA or PA in either condition. However, mean arterial pressure (MAP) was significantly positively correlated with NA ($r = 0.28, p < 0.05$) and negatively correlated with PA at a statistical trend level ($r = -0.20, p < 0.10$) in the Neutral Cues condition. As previously, subjective craving was moderately positively correlated with RRV_{food} in the Neutral Cues ($r = 0.51, p < 0.01$) and the Food Cues conditions ($r = 0.33, p < 0.01$). Subjective craving was also positively correlated with NA at a statistically significant level in the Neutral Cues condition ($r = 0.37, p < 0.01$) and the Food Cues condition ($r = 0.27, p < 0.05$). Subjective craving was significantly negatively correlated with PA in the Neutral Cues condition ($r = -0.32, p < 0.01$), but this relationship was not statistically significant in the Food Cues condition ($r = -0.20, ns$). The differences between the correlation coefficients in Neutral Cues vs. Food Cues condition were not statistically significant.

Behavioral Outcomes

Approximately half (51%) of the participants received money ($M_{\text{reward}} = \$8.77, SD = \4.31 ; Range: \$1.25 – \$15.00) as a result of the MCP task and 49% received food ($M_{\text{kcal consumed}} = 744.18, SD = 371.26$; Range: 133 – 1796 kcal). Among the participants who received access to food, the following are the sample sizes from each condition (1) Stress + Food = 18; (2) Stress + Neutral = 20; (3) Neutral + Food = 17; (4) Neutral + Neutral = 12. The sample sizes were statistically significantly different from each other ($\chi^2 = 201.00, p < 0.01$). Considering that there was a significant effect of the type of cues on RRV_{food} , the differences in sample sizes between those who received

access to food following the neutral cues exposure ($n = 32$) vs. following the food cues exposure ($n = 35$) were examined. The sample sizes were statistically significantly different ($\chi^2 = 67.00, p < 0.01$) with more participants from the Food Cues condition receiving access to food. This may be due to the fact that there was a significant effect of food cues exposure on RRV_{food} , thus participants in the Food Cues condition had more opportunity to receive food as their preferred outcome. There were no statistically significant differences on demographic variables between participants who received food and those who received money (p 's > 0.10). Demographic variables for the participants who received access to food are reported in *Table 3*. Participants who received access to food reported significantly higher crossover point (Food: $M = 6.38, SD = 3.56$; Money: $M = 3.27, SD = 2.28$; $F[1, 131] = 35.68, p < 0.01$) and craving (Food: $M = 5.54, SD = 2.54$; Money: $M = 3.98, SD = 2.62$; $F[1, 131] = 12.30, p < 0.01$) compared to those who received money. There were no statistically significant differences between the groups on HR and MAP. There were statistically significant differences on craving ($F = 3.97, p < 0.05$) and positive affect ($F = 4.54, p < 0.01$) between the four experimental groups, thus craving and positive affect were statistically controlled in the ANOVAs.

A trend-level effect of cues ($F[1, 61] = 3.41, p = 0.06$) was found for latency to first bite, such that participants in the Food Cues condition ($n = 35$) had a shorter latency to the first bite of food ($M = 26.33, SD = 28.28$) than participants in the Neutral Cues condition ($n = 32, M = 41.75, SD = 28.53$). There was also a trend-level main effect of craving ($F[1, 61] = 3.62, p = 0.07$), one of the covariates in the model. Given that a significant negative correlation between craving and latency to first bite was present (see

below), participants who reported higher craving also tended to wait less time before they started eating.

When total kcal consumed were examined, no significant effects of mood and cues, or an interaction of mood and cues was found. There was a significant main effect of sex ($F[1, 65] = 16.77, p < 0.01$). The main effect is attributable to the fact that male participants ($n = 35, M = 908.19, SD = 405.54$) consumed significantly more than female participants ($n = 32, M = 564.79, SD = 222.45$) as indicated by an independent samples t -test ($t = 7.78, p < 0.01$).

Bivariate correlations in the entire sample of participants who received access to food ($n = 67$) were examined. Subjective craving ($r = -0.28, p < 0.05$) was significantly correlated with latency to first bite such that the higher the craving the less time it took participants to begin eating. As trend-level main effects of cues on latency to first bite were found, bivariate correlations between the consumption and motivational variables following the cue exposure were examined separately by cue condition. In the Food Cues condition, subjective craving ($r = -0.43, p < 0.05$) was significantly correlated with latency to first bite such that the higher the craving, the less time it took participants to begin eating. This relationship was not present in the Neutral Cues condition ($r = 0.03, ns$). The difference between these correlation coefficients was statistically significant ($z = -1.91, p < 0.05$). In regards to kcal consumed, only MAP was moderately positively associated with the number of kcal consumed ($r = 0.40, p < 0.01$), with similar magnitude associations in the Neutral Cues ($r = 0.44, p < 0.01$) and Food Cues conditions ($r = 0.39, p < 0.05$). None of these correlation coefficients were significantly different from one another.

CHAPTER 4

DISCUSSION

Overview of Goals and Findings

The primary goal of this study was to examine the subjective craving for and relative reinforcing value (RRV_{food}) of high fat, high sugar (HFHS) foods under varying conditions of affect and in the presence of different environmental cues. As expected, exposure to a stressful personalized script significantly increased participants' negative affect and decreased their positive affect compared to participants who were exposed to a neutral, non-personalized script. However, exposure to a stressful mood induction did not influence craving or RRV_{food} . Consistent with the hypotheses, exposure to food cues significantly increased participants' subjective craving and RRV_{food} , compared to participants who were exposed to neutral cues. Analyses also revealed differences in positive affect following cue exposure such that participants exposed to neutral stimuli increased in positive affect while those exposed to food stimuli had a slight decrease. Contrary to the hypothesis, an interaction of stress and cues on subjective craving and RRV_{food} , was not present, meaning that participants did not systematically differ on how much they craved or valued HFHS foods depending on combined exposure to stress and food cues. Participants' heart rate and mean arterial pressure did not change significantly as a result of exposure to stress or food cues. Participants also did not differ on how many calories they consumed based on exposure to stress or food cues. However, participants who were exposed to food cues tended to start eating their food faster compared to

participants exposed to neutral cues. Thus, exposure to food cues had a significant effect on subjective craving, RRV_{food} , and positive affect, and a trend effect on the latency to first bite of food.

In correlational analyses of interrelationships among the motivational variables, negative and positive affect were significantly related to each other at baseline and following each experimental manipulation. Craving and RRV_{food} were consistently positively related to each other across the experimental manipulations. Importantly, the associations between these two motivational variables were of medium magnitude, indicating that while they are related to each other, they are not collinear with one another. Upon examining the behavioral outcomes, subjective craving was significantly related to latency to first bite in the Food Cues condition but not in the Neutral Cues condition, and the magnitude of relationship between craving and latency to first bite distinguished the two groups. Craving also had a trend-level main effect on latency to first bite. Thus, craving and exposure to food cues appear to be related to how quickly participants started eating the foods in the buffet.

Interpretation of Results

Effects of Mood Induction on Mood and Craving

The current study's findings that Sinha's guided imagery procedure increases negative affect are consistent with the studies in the addiction literature (Chaplin, Hong, Bergquist, & Sinha, 2008; Fox, Bergquist, Hong, & Sinha, 2007; Ray, 2011; Rousseau, Irons, & Correia, 2011; Sinha & O'Malley, 1999; Sinha et al., 2008; Sinha, Catapano, & O'Malley, 1999; Sinha, Fuse, Aubin, & O'Malley, 2000; Rajita Sinha et al., 2003). While

decreases in positive affect have not been found or examined in all studies (Ray, 2011; Rousseau et al., 2011; Sinha et al., 2003), most studies that examined positive affect changes following the stress induction found decreases following the guided imagery procedure.

The finding that the guided imagery procedure does not elicit craving for food is in contrast to the majority of studies using this paradigm in the addiction literature. When applied in samples of alcohol and cocaine-dependent individuals, the guided imagery procedure has consistently elicited subjective craving for preferred drugs (Chaplin et al., 2008; Fox et al., 2007; Ray, 2011; Sinha et al., 2000; Sinha & O'Malley, 1999; Sinha et al., 2003). However, there appears to be an important caveat to these findings. In a study that compared treatment-engaged AUD+ individuals and social drinkers, the personalized guided imagery procedure only elicited alcohol craving in AUD+ individuals but not in social drinkers (Sinha et al., 2008). The only study that used the guided imagery procedure to examine the RRV of alcohol in addition to subjective craving in a sample of social drinkers also did not find a main effect of stress on craving and RRV of alcohol (Rousseau et al., 2011). In that study, coping drinking motives moderated the relationship between exposure to stress and RRV of alcohol, but not subjective craving, such that only individuals with high drinking to cope motives increased in alcohol RRV following the stress induction (Rousseau et al., 2011). Therefore, it appears that in individuals who do not have a pathological relationship with alcohol, the relationship between stress and craving as well as RRV is more nuanced.

There is some support for our lack of findings of the effect of negative mood on urge to eat and eating in recent experimental studies. While one study that examined food

consumption following a mood induction in obese binge eating women found that those in the negative mood induction consumed significantly more than those in the neutral mood induction (Chua, Touyz, & Hill, 2004), most others failed to find this relationship (Dingemans, Martijn, van Furth, & Jansen, 2009; Loxton, Dawe, & Cahill, 2011; Munsch, Michael, Biedert, Meyer, & Margraf, 2008; Telch & Agras, 1996). Among these studies, those that measured the urge to eat or subjective hunger (as a proxy for urge to eat) found that stress either did not influence the rating of hunger (Chua et al., 2004) or decreased these ratings (Loxton et al., 2011). None of these studies measured RRV_{food} .

Thus, despite widely held beliefs that eating HFHS foods is a comforting activity, it appears that an acute negative mood induction does not generally produce increased urge to eat (Macht & Mueller, 2007; Tice, Bratslavsky, & Baumeister, 2001). It is also possible that if the sample consisted of individuals who had a problematic relationship with food, such as individuals with binge eating disorder, the guided imagery procedure would have been effective in eliciting food craving, similarly to studies with individuals with alcohol and cocaine dependence (Chaplin et al., 2008; Fox, Hong, Siedlarz, & Sinha, 2007; Ray, 2011; Sinha et al., 2000; Sinha & O'Malley, 1999; Sinha et al., 2003), but this is an empirical question. This is the first study that used the guided imagery paradigm to study the influence of mood on motivation for food and more studies in different samples would be helpful in clarifying whether a personalized stressor has the potential to elicit food craving.

Effects of Cue Exposure on Motivation for Food and Mood

The finding that cue exposure increases subjective craving for food is consistent with both the addiction (Carter & Tiffany, 1999) and eating (Jansen, 1998; Nederkoorn et al., 2000) bodies of literature. A meta-analysis of cue reactivity studies across different addictive substances found that cue exposure reliably elicited an urge to use the drug (Carter & Tiffany, 1999). Experimental studies that used some form of cue exposure have also found a relationship between cue exposure and increased urge to eat (Beaver et al., 2006; Fedoroff, Polivy, & Herman, 1997; Jansen, 1998; Nederkoorn et al., 2000; Sobik, Hutchison, & Craighead, 2005; Staiger, Dawe, & McCarthy, 2000). Additionally, studies that used a single-item measure of subjective hunger to measure motivation for food found that cue exposure was associated with an increase in subjective hunger in adults (Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009; Nederkoorn et al., 2000) and overweight children (Jansen et al., 2003). In the current study, exposure to cues also increased the crossover point on the MCP indicating that individuals increased in their RRV_{food} as a result of exposure to food cues. This was the first study to use the MCP adapted for food in an experimental design. Additionally, it appears to be one of the few studies that measured state RRV_{food} under varying experimental conditions to assess acute motivation for food. One experimental study that used a concurrent reinforcement schedule found that participants were willing to work harder for a piece of sandwich when they were presented with a visual cue of the sandwich (Johnson, 1974), which is consistent with our findings. In the addiction literature, RRV has been found to complement subjective craving measurement in assessing state motivation for substances under varying conditions of environmental cues and affective states (Amlung et al., 2011;

Amlung & MacKillop, in press; MacKillop et al., 2008; MacKillop, O'Hagen, et al., 2010; Rousseau et al., 2011). As such, this study is one of the first to assess state RRV_{food} in addition to craving, and it further underscores the incremental utility of RRV in measuring motivation for food above and beyond subjective craving.

Participants in the Food Cue condition reported lower PA compared to participants in the Neutral Cue condition following cue exposure. Previous studies that used the imaginal exposure to preferred substance cues and some studies that used the *in vivo* exposure have found positive associations between craving and NA and at times negative associations between craving and PA (Chaplin et al., 2008; Fox, Bergquist, et al., 2007; Ray, 2011; Sinha et al., 2008; Sinha et al., 2003). In the eating literature, the findings are mixed. One study did not find any effect of cue exposure on negative and positive affective states in women without any eating pathology (Nederkoorn et al., 2000). Cue exposure was associated with a decrease in positive affect in a college sample and a sample of individuals with binge eating symptomatology (Sobik et al., 2005). Cue exposure was associated with an increase in NA but had no effect on PA in a sample of bulimic women (Staiger et al., 2000). Another study that used a taste test in a sample of overweight and obese women with BED found decreases in NA following the taste test (Munsch et al., 2008). However, that study did not examine mood in response to cue exposure without the ability to taste the food. Importantly, the decrease in PA in the Food Cue exposure group was not significant, but the increase in PA in Neutral Cue group was. Therefore, while the groups differed in PA following the cue exposure, it is unclear what mechanisms were driving this difference.

Interaction of Mood and Cues on Motivation for Food

The predicted potentiation of motivation for food as a result of exposure to stress and food cues was not present. Based on previous findings in addictions research, it may be expected that stress and cues interact to produce the highest craving (Fox et al., 2007; Sinha et al., 2008, 2000; Sinha et al., 2003). However, one experimental study that specifically examined the multiplicative effects of stress induction and cue exposure found no such effect (Ray, 2011). In fact, it found attenuating effect of stress exposure as participants reported the highest craving following a neutral mood induction. One study in the eating literature that examined the influence of mood and cues on craving also did not find the interaction of stress and food cues (Loxton et al., 2011). Thus, current findings are in line with these two previous studies, one in the addiction field and one in the eating field, which failed to find multiplicative effects of stress and cues on craving. The findings of this study also suggest that a synergistic relationship between stress level and the presence of food cues is not present. Thus, the role of stress in acute motivation for food may be overemphasized and it might only be present for a certain subgroup of individuals, such as those with a pathological relationship to food or with specific negative reinforcement eating motives.

Physiological and Behavioral Indices of Mood and Food Motivation

In this study, the guided imagery procedure did not produce the expected physiological changes in heart rate and mean arterial pressure. The majority of previous studies that measured physiological indices of stress in the context of this paradigm in substance-dependent individuals found the expected increases in heart rate or blood

pressure or both over the course of the stress induction (Chaplin et al., 2008; Fox et al., 2007; Sinha et al., 1999, 2000; Sinha et al., 2003). However, the previously cited study which compared the social drinkers to AUD+ individuals found that only the AUD+ group exhibited physiological reaction to stress while the social drinkers' physiological response in the stress condition were not different from neutral mood (Sinha et al., 2008). It has been proposed that neuroadaptations related to chronic alcohol use and withdrawal produce a negative affective state which represents the shift from positive reinforcement motivation to drink to negative reinforcement motivation (Koob, 2003; Koob et al., 2004), therefore, AUD+ individuals have higher sensitivity to negative emotional states. Thus, in individuals without these neuroadaptations, the stress response may be less robust.

In addition, the guided imagery procedure consists of a personalized script of an event that made participants stressed or upset in the past year. Therefore, while it elicits negative affect, it may not produce the classic fight-or-flight response that would lead to increased heart rate and blood pressure. More studies in non-pathological samples are needed to determine whether the physiological response to the guided imagery procedure is typically present or whether it is specific to groups experiencing some level of clinical impairment. Additionally, all of the above-cited studies used the continuous measurement of heart rate and blood pressure, and multiple measurements were averaged to represent the response at each time point. In this study, HR and BP were measured following the conclusion of the guided imagery procedure using a blood pressure cuff. The study that compared social drinkers to AUD+ individuals found that any physiological response that the social drinkers had dissipated more quickly than that of AUD+ individuals (Sinha et

al., 2008). Therefore, it is possible that participants experienced an increase in HR and BP during the guided imagery procedure but it quickly dissipated following the exposure. Thus, in future studies using this paradigm, it may be important to measure the physiological responses to stress more finely to establish whether this paradigm elicits strong physiological responses in non-substance addicted individuals.

We also did not find an increase in HR and BP in response to exposure to food cues. In a meta-analysis of cue reactivity studies in addiction literature, the effect sizes for HR and other physiological indices were small but significant (Carter & Tiffany, 1999) indicating that individuals exposed to cues of a preferred substance exhibit an altered physiological state. One study which examined physiological reactions to food cues in normal weight individuals, found increased heart rate and blood pressure, among other indices, in response to exposure to palatable foods (Nederkoorn et al., 2000). They also found significant relationships between craving and BP following cue exposure. Similarly to the studies on stress, the physiological ratings in this study were taken continuously and averaged for each measurement time point. In our study, heart rate and BP were measured only once, following the cue exposure. Therefore, it is possible that more variability would be detected if the measurements were conducted continuously.

The anticipated effects of mood induction or cue exposure on actual food consumption in the laboratory were not present. Previous studies have generally found that the relationship between cue exposure and the amount of food consumed is often moderated by a third variable (Fedoroff et al., 1997; Jansen et al., 2003; Martin et al., 2008; Nederkoorn et al., 2000). Nederkoorn and colleagues found an interaction between impulsivity and hunger, such that impulsive participants consumed more food but only

when they reported feeling hungry (Nederkoorn et al., 2009). One study that compared restrained and unrestrained eaters on food consumption in response to olfactory and cognitive food cues found that participants only consumed more food following exposure to cues if they were restrained eaters (Fedoroff et al., 1997). Participants who did not restrict their calorie intake did not consume significantly more in the cue condition compared to neutral condition. A study that examined food reactivity in children found that food consumption was moderated by weight status with overweight children consuming more following a food cue exposure compared to normal weight children (Jansen et al., 2003). Therefore, the findings are mixed and it appears that while moderating variables are important, there has not been a study that established the main effects of cue exposure and subsequent consumption in a sample of majority normal-weight participants. The current findings suggest that stress and food cues do not unilaterally affect eating behavior.

Interestingly, cue exposure was associated with latency to the first bite of food at a trend level as was subjective craving. Participants who were asked to interact with the food item and think about the circumstances under which they would eat it or who reported higher subjective craving, started eating more rapidly than participants who were not exposed to food or whose craving was lower. While cue exposure might not influence the amount of food eaten, it appears to influence the sense of urgency upon initiation of consumption. In this study, participants had *ad libitum* access to snacks for 30 minutes while in some other studies measuring consumption, participants had access to food for 15-20 minutes (Chua et al., 2004; Martin et al., 2008). It is possible that over a longer period of time, participants would have consumed equivalent amounts of food in the

other studies as well, and that the other studies may be capturing the increased urgency to eat following the exposure to cues and experience of craving that this study captured via measurement of latency to first bite. Notably, food consumption and latency to first bite of food were secondary outcomes of interest, as the study was not designed to assess them as rigorously as the primary outcome variables (i.e., not all participants received access to food, participants were not randomly assigned based on experimental manipulation). Thus, replication of the behavioral outcomes findings is warranted.

Strengths and Limitations of the Current Study

These findings should be considered in the context of the study's strengths and limitations. In terms of strengths, the current study used an experimental design with well-validated addictions paradigms to study motivation for eating. At the same time, it used a brief behavioral measure of relative reinforcing value of food and the design allowed participants to actually receive one of the choices they made on the MCP, presumably adding salience to the task and increasing the ecological validity of this novel outcome measure. There are several novel findings that emerged. First, it adds to the literature suggesting that stress does not uniformly increase motivation for food or potentiate motivation when combined with environmental cues. Additionally, it is the first study to use a behavioral economic assessment to measure state levels of RRV_{food} and it indicates that an MCP can effectively be used for that purpose. Furthermore, these findings suggest that RRV_{food} represents another dimension of motivation for food, which is correlated with subjective craving but is not redundant with it. This study also suggests that while exposure to food cues does not influence the amount of food eaten, it may

affect how quickly individuals initiate food consumption. Therefore, exposure to environmental cues of HFHS foods may increase the readiness or urgency to consume the food.

Nonetheless, the findings of the current study should be viewed in the light of several limitations. As the main purpose of the current study was to examine the main effects and interactive effects of mood and environmental cues on motivation for food consumption, the moderators of these relationships were not examined. For example, studies have shown that stress may operate differently for different people. Only women with a high cortisol response reported higher cravings and consumption of HFHS foods in previous studies (Epel et al., 2001; Newman et al., 2007). Therefore, examining moderating effects of cortisol reactivity may shed more light on the relationship between stress and food motivation as well as consumption and not collecting cortisol was certainly a limitation of the current study. With regard to psychological moderators of the relationship between negative affect and motivation for food, examining motives for eating as well as eating styles as moderators may provide a more fine-grained analysis of this relationship. For example, a study that used the MCP to examine motivation for alcohol following stress induction and cue exposure found that drinking to cope moderated the relationship between stress induction and RRV of alcohol (Rousseau et al., 2011). Dietary restraint and disinhibition also appear to be potential moderators of the relationship between negative mood and motivation for food (Fedoroff et al., 1997; Loxton et al., 2011). A study using neuroimaging found that sensitivity to reward moderated brain activation in response to visual food cues (Beaver et al., 2006), thus it is another potential moderator for future studies of the interaction of stress and cue

exposure. Finally, potential diagnosis of an eating disorder such as Bulimia Nervosa or Binge Eating Disorder may be studied as a moderator of these relationships. For example, one study found that individuals with a diagnosis of an eating disorder have a stronger physiological reaction to food cues compared to non-pathological participants (Nederkoorn et al., 2000). Individuals with Binge Eating Disorder (BED) also consumed more compared to non-BED individuals in an *ad libitum* eating task, although there was no diagnosis by mood interaction (Telch & Agras, 1996). The study of these and other moderators is a priority for future studies.

The use of personalized mood induction, while innovative and widely used in addiction research, may also be considered a limitation. Since the mood induction was personalized, it was by definition not standardized, as the mood induction such as Trier Social Stress Task (Kirschbaum et al., 1993) would have been. This may have contributed to the lack of findings in the realm of physiological responses as the mood induction might not have produced a stress response in its traditional fight-or-flight sense. In fact, the guided imagery mood induction has not always produced a significant increase in cortisol levels suggesting that while participants increased in negative affect, they might not necessarily experience stress from an endocrine standpoint (Fox et al., 2007; Sinha et al., 2008). Relatedly, the physiological responses were not measured continuously and it is possible that doing so would have revealed physiological differences. Another limitation was that access to food was determined by participant choices and random selection, thus not all participants consumed food. As a result, there was no randomization for the participants who received access to food, and power to detect significant relationships was reduced. This was necessarily the case, however, as

food consumption was only considered as a secondary variable of interest. Finally, an important methodological consideration is that the study design did not counterbalance the order of manipulations, with the stress induction always preceding the cue exposure. As mentioned previously, this was an intentional design decision, as the interaction of stress and cues was the central question of the study and administering stress first followed by exposure to environmental stimuli was considered a more ecologically valid sequence. Thus, to optimally model a specific sequence of events and maximize power in doing so, the manipulations were not counterbalanced. However, as such, the reverse order of manipulations – effects of exposure to cues followed by stress – cannot be addressed. As intended, statistical power was maximized for the order for investigating the interactive effects of stress and cues on motivation for food in that order, but future studies will be needed to examine the separate and combined influences of cues on mood and motivation for food, and influences by order or manipulation.

Conclusions

Despite these limitations, the findings of this study offer new insights and support for future applications in the field of dysregulated eating. There is a common belief that food is comforting and that individuals eat in response to stress. The cognitive-behavioral model of binge eating also posits that individuals with eating disorders tend to binge eat in response to negative affect. Our study, alongside a few others, suggests that individuals do not generally experience craving or consume more as a result of a stressful stimulus, although it cannot speak to whether or not that is the case for individuals with disordered eating patterns. In contrast, these findings provide further evidence of the salience of

environmental cues and the importance of targeting environmental cues and the accessibility of food in order to manage cravings and the urgency to eat. It also provides more information to refine the role of negative affect in overconsumption – it is possible that its role is more insidious in that individuals tend to consume more with accumulated stress as opposed to in response to an acute stressor, or that negative affect is more likely to occur in response to an overconsumption episode, as opposed to prior to it. This study also underscores the value of using behavioral economic measures to assess the motivation for food (Epstein et al., 2011; Epstein et al., 2010; Rollins, Dearing, & Epstein, 2010), which can offer novel insights into motivation for food in addition to subjective craving. Indeed, behavioral economics may also be more broadly used to inform public policy on taxation of HFHS food items and subsidies for healthy food items, as has been applied to tobacco taxation (Chaloupka, Hu, Warner, Jacobs, & Yurekli, 2000; Chaloupka, Yurekli, & Fong, 2012; MacKillop et al., 2012).

In recent years, the research on potential addictive properties of HFHS foods has burgeoned (e.g., Brownell & Gold, 2012; Corsica, 2010; Davis et al., 2011). While the concept of “food addiction” is a controversial one, there is no doubt that the methods used in addiction research to study motivation for drugs of abuse are invaluable tools in studying dysregulated food consumption. As such, paradigms such as the ones used in this study, may help better understand the influence of different affective states and the presence of cues in the environment on the motivation to eat, informing the basic research on the mechanisms involved in dysregulated consumption. The end goal of enhancing the basic understanding of these processes is of course to more effectively treat conditions that stem from them: obesity, binge eating disorder, and perhaps food

addiction. As such, methods common in treating substance use disorders, such as pharmacotherapy, cue exposure and response prevention, or contingency management could be used to enhance treatment for eating dysregulation (Volpp et al., 2008). Given the increasing appreciation for a “toxic environment” which promotes overconsumption and obesity (Wadden, Brownell, & Foster, 2002), public policy prevention efforts are more important than ever. Adding behavioral economic methods to the investigation on dysregulated eating not only adds another dimension to the complex motivational pathways but also may allow for public policy recommendations when used at a large scale. In sum, methods imported from addiction have the potential to inform our understanding of dysregulated eating at multiple levels of analysis, from molecular and neurobiological underpinnings to large-scale public policy prevention programs, and the current study is one more step toward that end.

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TABLES

Table 1. Participant Characteristics.

Characteristic	Mean (SD)/%/Median (IQR)				
	Overall Sample <i>N</i> =133	Stress Induction + Food Cues <i>n</i> =32	Stress Induction + Neutral Cues <i>n</i> =34	Neutral Induction + Food Cues <i>n</i> =32	Neutral Induction + Neutral Cues <i>n</i> =35
Sex	50% Male; 50% Female	50% Male; 50% Female	50% Male; 50% Female	53% Male; 47% Female	49% Male; 51% Female
Age	21.4 (4.11)	20.16 (1.73)	21.00 (2.19)	22.50 (4.85)	21.94 (5.82)
Income	\$60,000-\$75,000 (\$15,000-\$30,000)- [\$105,000-\$120,000]	\$90,000-\$105,000 (\$45,000-\$60,000)- [\$105,000-\$120,000]	\$60,000-\$75,000 (\$15,000-\$30,000)- [\$105,000-\$120,000]	\$60,000-\$75,000 (\$15,000-\$30,000)- [\$90,000-\$105,000]	\$60,000-\$75,000 (\$30,000-\$45,000)- [\$90,000-\$105,000]
Years of Education	14.40 (2.28)	13.78 (1.50)	14.46 (1.75)	14.91 (2.48)	14.46 (3.00)
Race					
<i>White</i>	62%	47%	73%	69%	60%
<i>Black</i>	23%	34%	21%	13%	23%
<i>Asian</i>	9%	13%	6%	6%	11%
<i>Pacific Islander</i>	1%	0%	0%	3%	0%
<i>Biracial/Mixed</i>	5%	6%	0%	9%	6%
Hispanic Ethnicity	8%	9%	6%	19%	0%

BMI	24.36 (4.70)	24.27 (6.08)	24.12 (3.45)	24.41 (4.84)	24.63 (4.37)
Normal Weight	63%	72%	68%	56%	57%
Overweight	27%	22%	29%	31%	26%
Obese	10%	6%	3%	13%	17%
Waist Circumference					
All Sample	33.34 (5.10)	32.39 (5.18)	32.96 (3.49)	33.94 (4.24)	34.14 (6.91)
Males	34.62 (5.10)	33.14 (2.99)	34.35 (3.16)	33.50 (3.64)	37.61 (8.21)
Females	32.10 (4.82)	31.64 (6.74)	31.56 (3.32)	34.38 (4.86)	31.07 (3.48)
% Body Fat (N=131)					
All Sample	23.05 (9.46)	21.16 (8.67)	22.74 (8.69)	24.53 (11.21)	23.86 (9.10)
Males	17.16 (6.67)	15.66 (5.89)	16.42 (5.71)	16.81 (6.41)	19.64 (8.22)
Females	29.12 (7.97)	27.03 (7.23)	29.05 (6.19)	32.46 (9.86)	28.08 (8.08)

^a There was a significant difference between the office cue and snack food cue condition in the Hispanic identification with 9 participants in the food condition and 2 participants in the office condition identifying as Latino.

Table 2. *Mixed 2 (Induction: Neutral/Stress) × 2 (Cues: Neutral/Food) × 3 (Time: Baseline/Post-Mood Induction/ Post-Cue Exposure) ANOVAs on outcome variables of interest.*

Note: This table provides the statistics for the key interactions of the analyses of variances; a comprehensive table with all coefficients reported may be found in *Appendix E*.

DV	Time × Mood		Time × Cue		Time × Mood × Cue	
	F	η^2	F	η^2	F	η^2
Negative Affect	79.34**	0.381	1.29	0.010	1.43	0.011
Positive Affect	78.85**	0.379	4.60*	0.034	0.01	0.000
Craving	0.59	0.005	27.49**	0.176	1.32	0.010
RRV _{food}	0.64	0.005	3.06*	0.023	0.37	0.003
HR	0.27	0.002	0.78	0.006	2.28	0.017
MAP	0.61	0.005	2.20	0.017	1.55	0.012

Note: HR = Heart Rate; MAP = Mean Arterial Pressure; RRV_{food} = Relative Reinforcing Value of Food.

* $p < 0.05$

** $p < 0.01$

Table 3. *Characteristics of participants who received access to food.*

Characteristic	Mean (SD)/%/Median (IQR)
	N=67
Sex	52% Male; 48% Female
Age	21.63 (4.32)
Income	\$60,000-\$75,000 ([\$15,000-\$30,000]- [\$105,000-\$120,000])
Years of Education	14.57 (2.25)
Race	
<i>White</i>	63%
<i>Black</i>	24%
<i>Asian</i>	10%
<i>Pacific Islander</i>	1.5%
<i>Biracial/Mixed</i>	1.5%
Hispanic Ethnicity ^a	10%
Marital Status	
<i>Married</i>	7%
<i>Cohabiting</i>	3%
<i>Widowed</i>	0%
<i>Never Married</i>	90%
Current Student	
<i>Part Time</i>	9%
<i>Full Time</i>	84%
<i>Not a student</i>	8%
BMI	23.76 (3.62)
<i>Normal Weight</i>	67%
<i>Overweight</i>	27%
<i>Obese</i>	6%
Waist Circumference	
<i>All Sample</i>	32.76 (4.04)
<i>Males</i>	34.17 (3.70)
<i>Females</i>	31.22 (3.89)
% Body Fat (N=131)	
<i>All Sample</i>	22.40 (9.48)
<i>Males</i>	16.53 (6.49)
<i>Females</i>	28.81 (3.89)

FIGURES

Figure 1. *Timing Schematic of Experimental Procedures.*

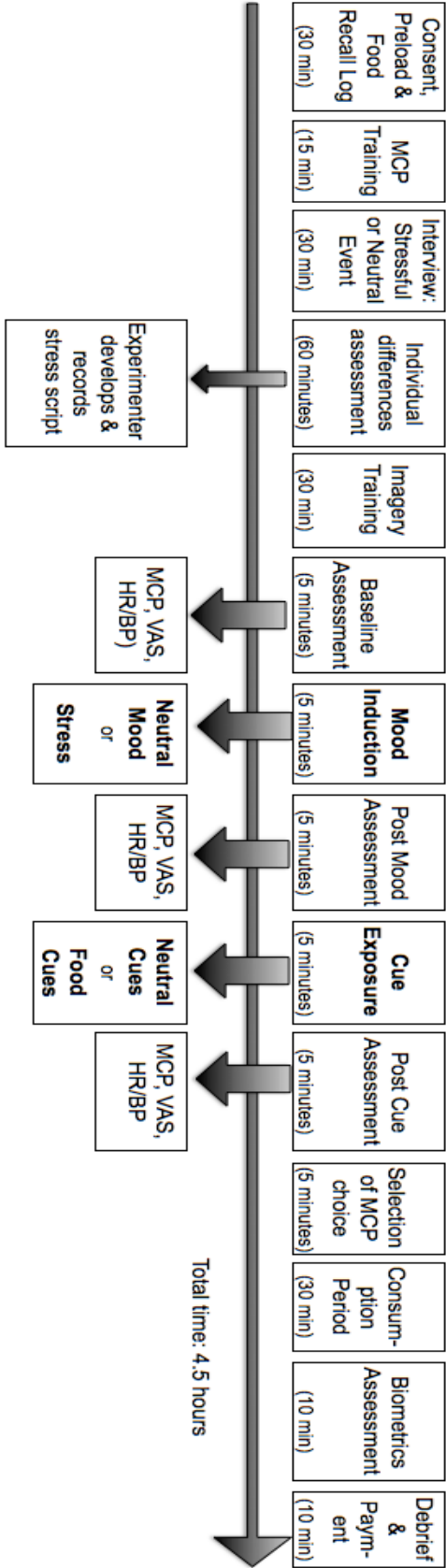
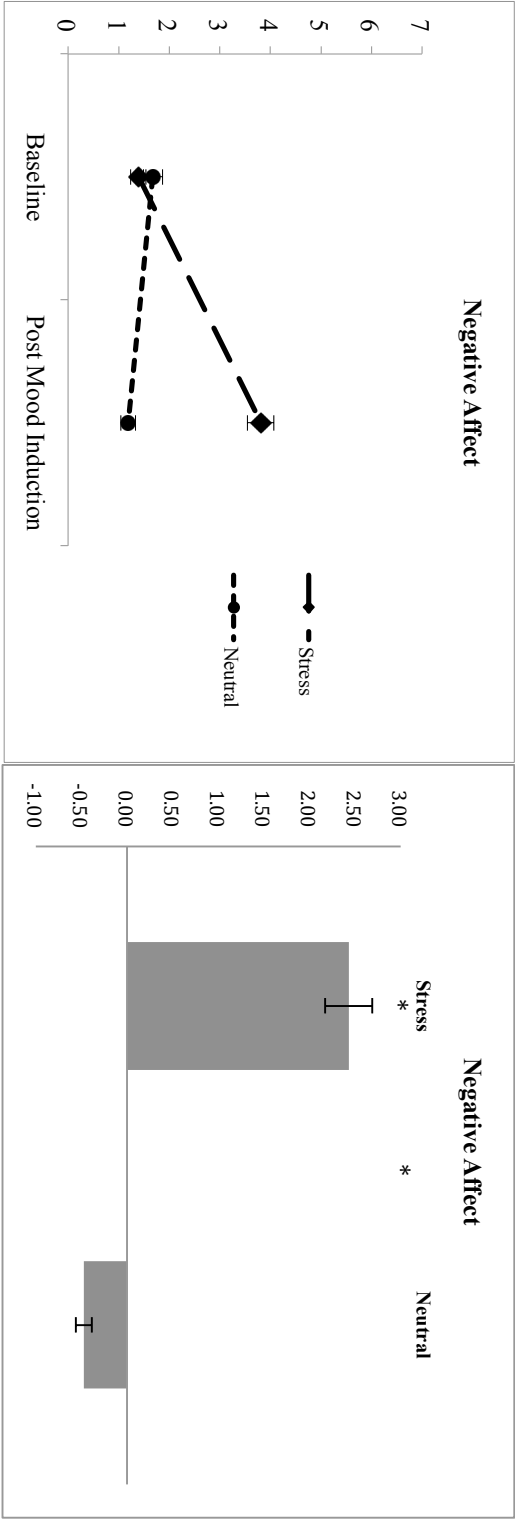


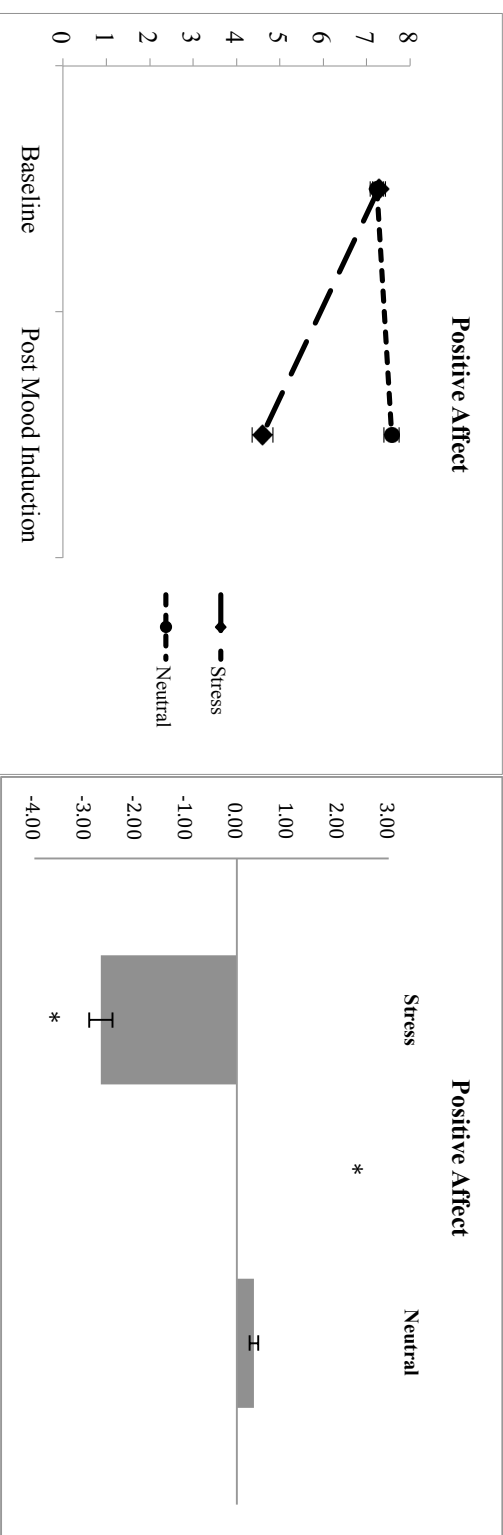
Figure 2. Change of Negative and Positive Affect between Baseline and Post-Mood Induction Assessment.

2a. Left Panel: Change in Negative Affect Over Time Between Subjects; **Right Panel:** Negative Affect Change Scores Between Subjects From Baseline to Post-Mood Induction.



Note: An asterisk above the error bars indicates statistically significant ($p < 0.05$) changes from Baseline to Post-Mood Induction assessment; an asterisk between the columns indicates statistically significant ($p < 0.05$) differences between participants in the Stress Induction condition and those in the Neutral Mood Induction condition.

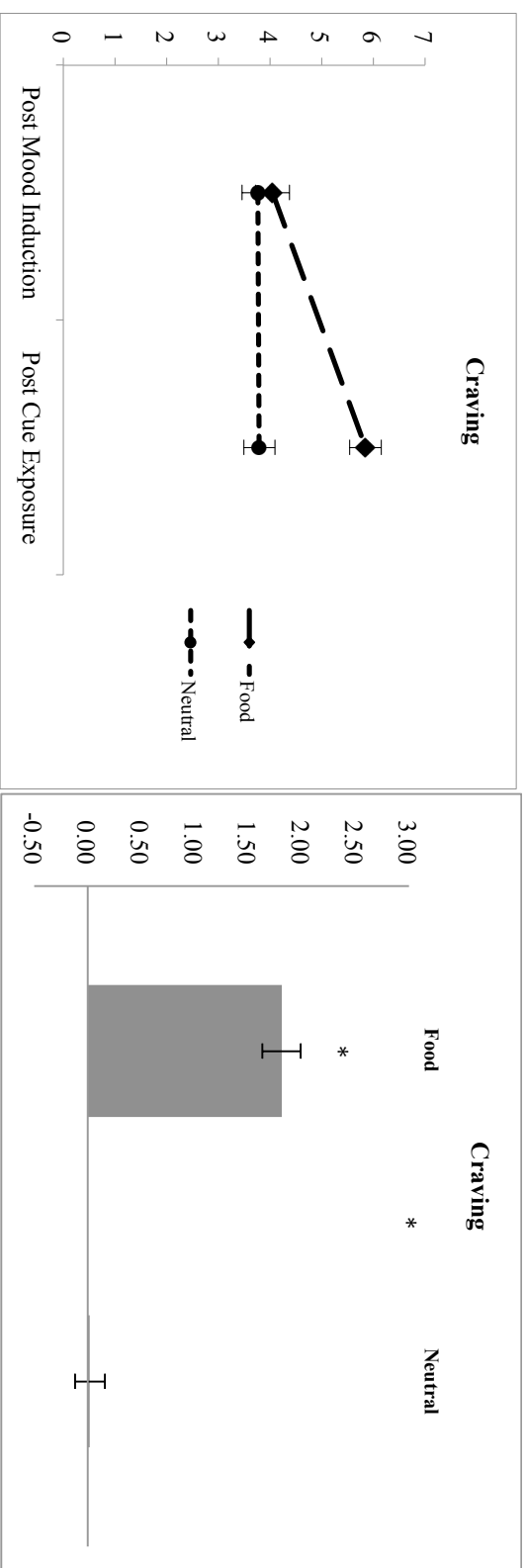
2b. Left Panel: Change in Positive Affect Over Time Between Subjects; Right Panel: Positive Affect Change Scores Between Subjects From Baseline to Post-Mood Induction.



Note: An asterisk above the error bars indicates statistically significant ($p < 0.05$) changes from Baseline to Post-Mood Induction assessment; an asterisk between the columns indicates statistically significant ($p < 0.05$) differences between participants in the Stress Induction condition and those in the Neutral Mood Induction condition.

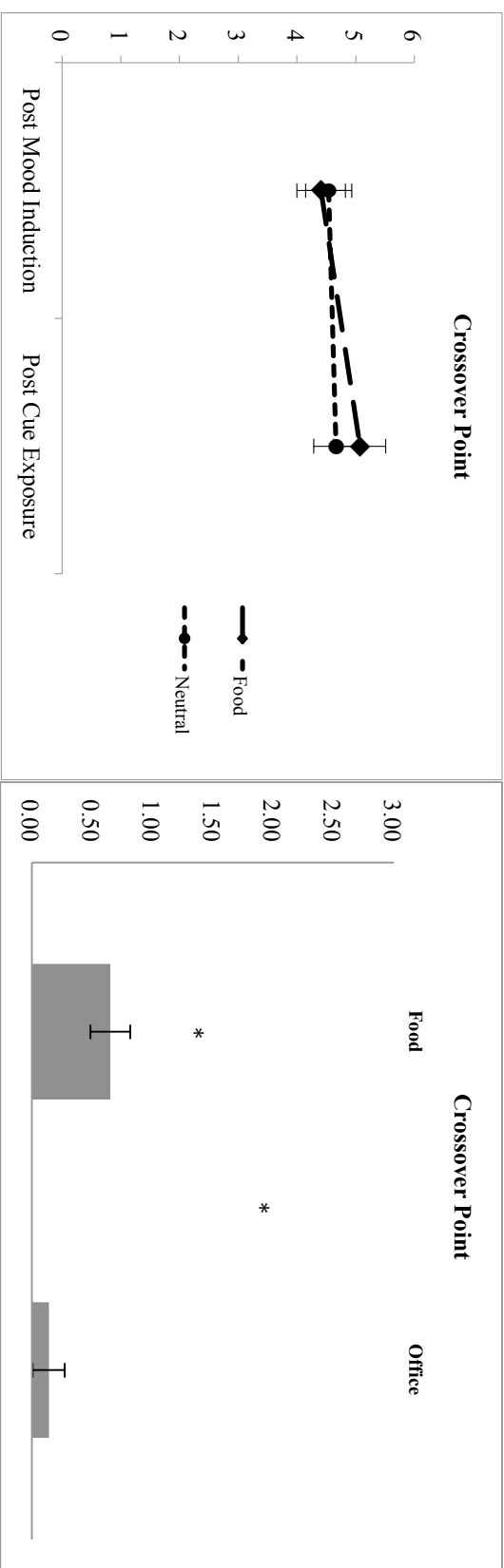
Figure 3. *Change of Craving, Crossover Point, and Positive Affect between Post-Mood Induction and Post-Cue Exposure Assessment.*

3a. Left Panel: *Change in Craving Over Time Between Subjects; Right Panel: Craving Change Scores Between Subjects From Post-Mood Induction to Post-Cue Exposure.*



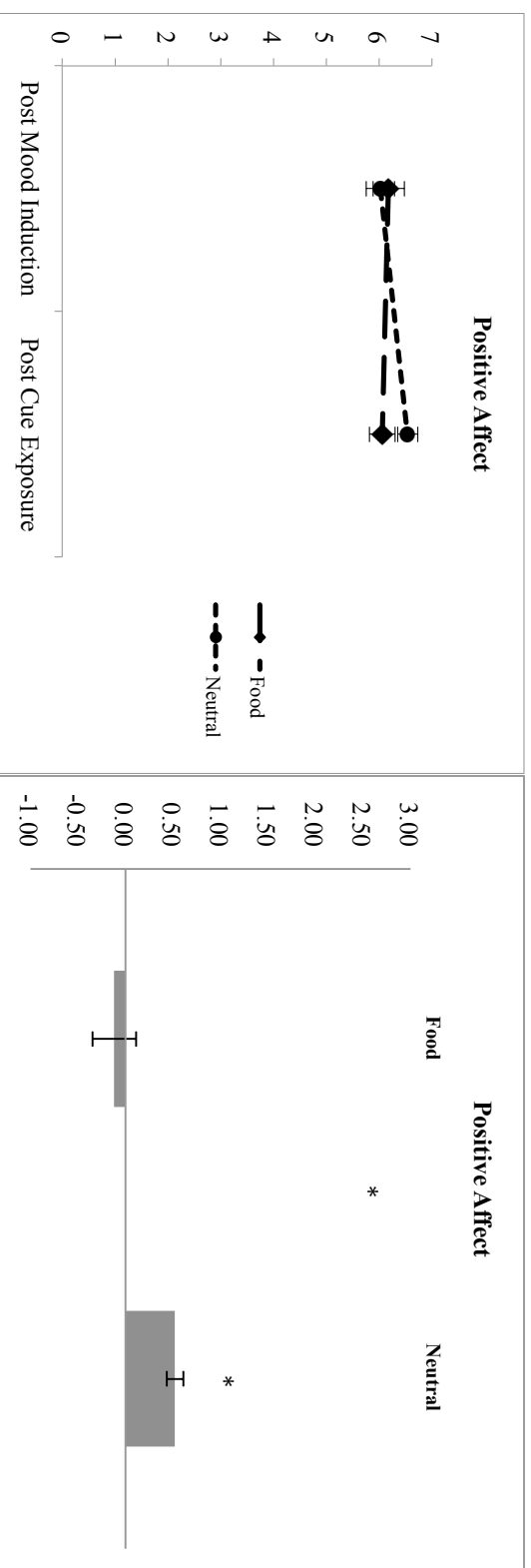
Note: An asterisk above the error bars indicates statistically significant ($p < 0.05$) changes from Post-Mood Induction to Post-Cue Exposure assessment; an asterisk between the columns indicates statistically significant ($p < 0.05$) differences between participants in the Food Cue and those in the Neutral Cue condition.

3b. Left Panel: Change in Crossover Point Over Time Between Subjects; Right Panel: Crossover Point Change Scores Between Subjects From Post-Mood Induction to Post-Cue Exposure.



Note: An asterisk above the error bars indicates statistically significant ($p < 0.05$) changes from Baseline to Post-Cue Exposure assessment; an asterisk between the columns indicates statistically significant ($p < 0.05$) differences between participants in the Food Cue and those in the Neutral Cue condition.

3c. Left Panel: Change in Positive Affect Over Time Between Subjects; Right Panel: Positive Affect Change Scores Between Subjects From Post-Mood Induction to Post-Cue Exposure.



APPENDICES

Appendix A. Multiple Choice Procedure.

Please answer the following questions based on how you are feeling right now. You will have an opportunity to receive one of your choices.

1. Would you rather have unlimited access to snack foods OR \$0?
2. Would you rather have unlimited access to snack foods OR \$0.01?
3. Would you rather have unlimited access to snack foods OR \$0.10?
4. Would you rather have unlimited access to snack foods OR \$0.50?
5. Would you rather have unlimited access to snack foods OR \$.75?
6. Would you rather have unlimited access to snack foods OR \$1?
7. Would you rather have unlimited access to snack foods OR \$1.25?
8. Would you rather have unlimited access to snack foods OR \$1.50?
9. Would you rather have unlimited access to snack foods OR \$1.75?
10. Would you rather have unlimited access to snack foods OR \$2?
11. Would you rather have unlimited access to snack foods OR \$2.50?
12. Would you rather have unlimited access to snack foods OR \$3?
13. Would you rather have unlimited access to snack foods OR \$3.50?
14. Would you rather have unlimited access to snack foods OR \$4?
15. Would you rather have unlimited access to snack foods OR \$4.50?
16. Would you rather have unlimited access to snack foods OR \$5?
17. Would you rather have unlimited access to snack foods OR \$6?
18. Would you rather have unlimited access to snack foods OR \$7?
19. Would you rather have unlimited access to snack foods OR \$8?
20. Would you rather have unlimited access to snack foods OR \$9?
21. Would you rather have unlimited access to snack foods OR \$10?
22. Would you rather have unlimited access to snack foods OR \$11?
23. Would you rather have unlimited access to snack foods OR \$12?
24. Would you rather have unlimited access to snack foods OR \$13?
25. Would you rather have unlimited access to snack foods OR \$14?
- 26.** Would you rather have unlimited access to snack foods OR \$15?

Appendix B. List of foods available in the snack food buffet.

1. Mini Chips Ahoy
2. Mini Oreo Bite Size
3. Nutter Butter Bites
4. Snyder's of Hanover Mini Pretzels 100 calorie pack
5. Fritos Original Corn Chips
6. Doritos Cool Ranch
7. Doritos Nacho Cheese
8. Cheez-It Extra Cheddar Snack Mix 100 Calorie Right Bites
9. Cheez-It Snack Mix 100 Calorie Right Bites (Cheez-its only)
10. Cheez-It Snack Mix 100 Calorie Right Bites (Variety Pack)
11. Fudge Shoppe Fudge Grahams 100 Calorie Right Bites
12. Snack Well's Fudge Pretzels 100 Calorie Pack
13. Market Pantry Sandwich Crackers (Peanut Butter on Toasted Crackers)
14. Goldfish Baked Snack Crackers
15. Reese's Peanut Butter Cups (Pack-a-Snack 8 individually wrapped cups)
16. Almond Joy (Individually wrapped)
17. Butter Fingers (Individually wrapped)
18. Snickers Fun Size
19. Keebler Club Crackers w/ Cheddar Cheese Sandwich Cracker
20. Keebler Cheese & Peanut Butter Sandwich Crackers
21. Keebler Toast & Peanut Butter Sandwich Crackers
22. CowPals Snack Cheese (Colby Jack)
23. Mini Babybel Original
24. Frigo Cheese Head String Cheese

25. Trader Joe's Dark Chocolate Bars
26. Trader Joe's Milk Chocolate Bars
27. Cheez-It Baked Snack Crackers
28. Lay's Classic Potato Chips
29. Cheetos Crunchy Cheese Flavored Snacks
30. Sunchips Original Multigrain
31. Quaker Chewy Chocolate Chip Granola Bar
32. Twizzlers Snack Size
33. Twix Fun Size
34. PayDay Snack Size
35. Starburst Fun Size
36. Nerds Fun Size
37. SweetTarts Fun Size
38. Sweetarts Pouches
39. Laffy Taffy Fun Size
40. 3 Musketeers Fun Size
41. Skittles Original Fun Size
42. Moon Pie Vanilla Minis
43. Moon Pie Chocolate Minis
44. Little Debbie Devil Cremes
45. M&M's Peanut
46. M&M's Milk Chocolate
47. M&M's Peanut Butter
48. Pringles Reduced Fat Original
49. Pringles Reduced Fat Sour Cream & Onion
50. Hostess Ho-Hos

- 51. Famous Amos Chocolate Chip Cookies
- 52. Little Debbie Mini Powdered Donuts
- 53. Take 5 Snack Size
- 54. M&M's Peanut Butter Fun Size
- 55. M&M's Peanut Milk Chocolate Fun Size
- 56. M&M's Peanut Fun Size

Appendix C. Samples of mood induction scripts.

C1. Neutral mood induction script.

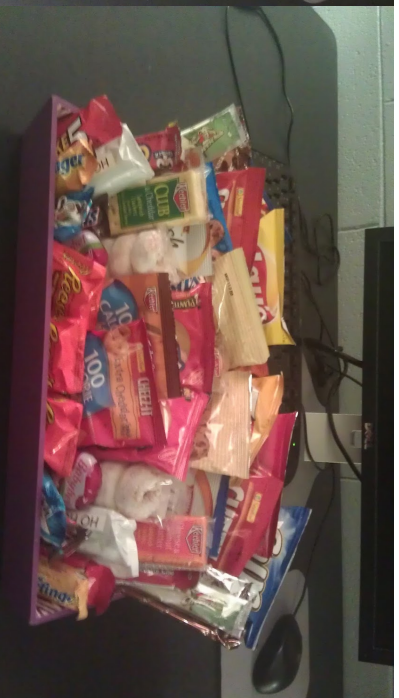
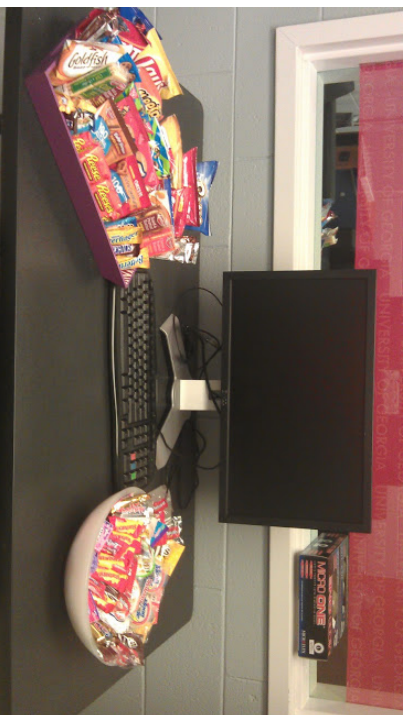
You are sitting on the beach on a bright summer day. You breathe in deeply as you notice a red kite against the cloudless blue sky. Your eyes trace the path of the kite as it whips up and down in spirals with the wind. The sun glares at you from behind the kite and makes the white sandy beach sparkle with reflection. You tense the muscles in your forehead and around your eyes, squinting to block out the bright sunlight. You follow with your eyes the long white tail, which dances from side to side beneath the soaring kite. You take in a few deep breaths of the fresh ocean air, noticing the smells of fish and the salt water. The warm sun beats down against your skin and a light gentle breeze blows over you. You listen to the soothing sound of the ocean waves, roaring and splashing as they come onto the sand, and quiet as the water goes back out to sea. You relax the muscles in your arms, back and legs as you lay back on the sand, feeling the soft fine granules of sand between your toes and fingers. The tension you're your body goes down and you feel comfortable and at ease. Your breathing slows down and the worry thoughts seem to fade away. There is a sense of lightness and you want to hold time and capture this moment. A feeling of peace overcomes you.

C2. Stress induction script.

It is a weekday evening around 9pm. You just left your daughter's house to go to church. You spent the day babysitting while your daughter was at work. You walk down the street to prayer. You just get to prayer and someone says that you have a phone call. Your heart beats faster. You walk over to the phone. You say hello. It's your daughter. You feel tension in your forehead. "Why do you take my money mom? Why do you steal my money?" She sounds angry. You are breathing faster. What is she talking about! "I have never seen your money. I didn't steal nothing," you tell her. You would never take your child's money. How could she accuse you? She knows better than that. The thoughts are racing through your head. She's yelling at you. "Why do you do that, why do you do that?" You feel tense all over. She says you have seen the money. Your head is pounding. "Do what? Tell me what I did because I didn't take your money." Your whole body is shaking. How can she say this to you, her mother. Your heart is racing. You have never taken anything from her. You are so mad you want to smash something. Her fiancé came home while you were babysitting. He went into their bedroom. Why doesn't she ask him? Your daughter was giving you a place to stay. You would never take something from her or your grandkids. You just bought groceries for everyone. There is heaviness in your chest. You feel betrayed and alone. She keeps raging at you. "Who else is going to take it mom?" You feel like crying. She doesn't believe you. Blood rushes to your head. You don't want to talk to her anymore. You hang up on her. You feel hurt and alone. Where are you going to live? Who are you going to stay with? You have never stolen from your kids. You wouldn't do that. How could your own daughter think that about you? There is a deep intense pain sensation inside you. You feel choked up. It hurts to be alive. Tears come to your eyes.

Appendix D. Pictures of cues used for exposure.

D1. Food cues.



D2. *Neutral cues.*



Appendix E. Cue exposure audio scripts.

E1. Food cues audio script.

- *“In a moment, I’m going to ask you to follow a number of instructions. Please follow each of these instructions. During this recording, please do not touch or handle anything in this room other than the things that I ask you to work with.”* [10 second pause]
- *“Please look at the tray with snack foods in front of you. Pick one snack food that you would like the most right now. Pick up that snack food from the tray. Hold the snack in a way that’s comfortable to you but do not open the packaging. Note the weight of the snack in your hand.”* [5 second pause]
- *“Look at the packaging of the snack food. Think of situations in your typical life when you most commonly get it. Perhaps it’s in the afternoon in between lunch and dinner. Perhaps it’s when you want reward yourself.”* [10 second pause]
- *“Open the packaging of the snack. Imagine typical places where you most commonly eat a snack food. Perhaps it is in your apartment on the couch. Perhaps it is in the office while you are having a break. Perhaps it is in class. Picture the place as clearly as you can.”* [15 second pause]
- *“Now, take a piece of the food out of the wrapper but do not eat it. Hold it in a way that is comfortable to you.”* [5 second break]
- *“Pick up the piece of food and put it half an inch away from your nose. Take five deep breaths inhaling the smell of the food. Try to fully smell, and almost taste, the food. Imagine what it would be like to eat it”* [15 second pause]
- *“Put the piece of food and the packaging on the plate on the table in front of you.”* [5 second pause]
- *“This is the end of this task. Please take off your headphones and wait for the experimenter.”* [3 second pause before end of recording]

E2. Neutral (office supplies) cues audio script.

- *“In a moment, I’m going to ask you to follow a number of instructions. Please follow each of these instructions. During this recording, please do not touch or handle anything in this room other than the things that I ask you to work with.”*

[10 second pause]

- *“Please look at the office supplies in front of you. Pick one pen and notepad that you like the most. Put the notepad in front of you on the table. Hold the pen in whichever hand is comfortable but do not write with it. Note the weight of the pen in your hand.”*

[5 second pause]

- *“Look at the notepad in front of you. Think of situations in your typical life when you most commonly use it. Perhaps it’s to write down information while you are on the phone with someone. Perhaps it’s in class when you take notes.”*

[10 second pause]

- *“Hold the pen in front of you and use it to write your name on the paper. Think about typical places where you most commonly use a pen. Perhaps it is at your desk while working. Perhaps it is in a store to sign a credit card receipt. Perhaps it is at your kitchen table while making a grocery list.”*

[15 second pause]

- *“Now put the pen on the table. Turn the page in the notepad. Pick up the pen and hold in a way that’s comfortable to you but do not write with it.”*

[5 second pause]

- *“Hold the pen in front of you and use it to write your name on the blank piece of paper four times.”*

[15 second pause]

- *“Put the pen on top of the notepad.”*

[5 second pause]

- *“This is the end of this task. Please take off your headphones and wait for the experimenter.”*

[3 second pause before end of recording]

Appendix G. Correlation matrices.

Note: ** $p < 0.01$; * $p < 0.05$; † $p < 0.10$.

G1. Correlations between the variables of interest at baseline.

	2	3	4	5	6	7
1 Baseline NA	-0.41**	0.14	<i>0.17†</i>	0.03	0.11	<i>0.16†</i>
2 Baseline PA	1.00	-0.02	0.05	<i>0.15†</i>	-0.06	-0.09
3 Baseline Craving		1.00	0.42**	-0.10	0.07	0.73**
4 Baseline RRV _{food}			1.00	<i>0.16†</i>	0.04	0.40**
5 Baseline HR				1.00	0.23**	-0.20*
6 Baseline MAP					1.00	0.19*
7 Baseline Hunger						1.00

G2. Correlations between the variables of interest at post-mood induction.

	1	2	3	4	5	6	7
1 Post-Mood NA	1.00	-0.48**	0.29*	0.16	0.02	0.16	0.35**
2 Post-Mood PA	-0.68**	1.00	-0.06	0.10	-0.24*	-0.07	-0.20†
3 Post-Mood Craving	0.12	-0.11	1.00	0.48**	-0.22†	0.18	0.64**
4 Post-Mood RRV _{food}	-0.09	0.16	0.53**	1.00	-0.23†	0.10	0.51**
5 Post-Mood HR	0.10	-0.25*	-0.15	-0.24†	1.00	0.12	-0.25**
6 Post-Mood MAP	0.06	-0.04	0.08	-0.08	0.16	1.00	0.25*
7 Post-Mood Hunger	-0.08	0.11	0.78**	0.35**	-0.19	0.20	1.00

*Note 2b: Neutral mood (n=67) reported above the diagonal, Stress (n=66) reported below the diagonal.

G3. *Correlations between the variables of interest at post-cue exposure.*

	1	2	3	4	5	6	7
1 Post-Cues NA	1.00	-0.53**	0.37**	0.12	-0.18	0.28*	0.19
2 Post-Cues PA	-0.44**	1.00	-0.32**	-0.01	-0.01	-0.20†	-0.25*
3 Post-Cues Craving	0.27*	-0.20	1.00	0.51**	-0.29*	0.21†	0.73**
4 Post-Cues RRV _{food}	-0.10	-0.01	0.33**	1.00	-0.43**	0.07	0.51**
5 Post-Cues HR	0.07	-0.16	-0.11	-0.13	1.00	0.11	-0.31**
6 Post-Cues MAP	-0.02	0.03	0.11	0.04	-0.06	1.00	0.20
7 Post-Cues Hunger	0.10	-0.12	0.84**	0.36**	-0.15	-0.20†	1.00

*Note 2c: Neutral cue (n=69) above the diagonal, Food cue (n=64) below the diagonal.