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Effects of Visual Cues on Conditioned Salivation and Food Reinforcer Efficacy in Overweight/Obese and Healthy-Weight Women

by

Morgan Musquez

A thesis

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To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Morgan Musquez find it satisfactory and recommend that it be accepted.

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October 28, 2020

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MS 8112

RE: Study Number IRB-FY2021-40: Effects of Visual Cues on Conditioned Salvation and Food Reinforcer Efficacy in Obese and Healthy-weight Humans

Dear Ms. Musquez:
Thank you for your responses to a previous review of the study listed above. These responses are eligible for expedited review under OHRP (DHHS) and FDA guidelines. This is to confirm that I have approved your application.

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Sincerely,

Ralph Baergen, PhD, MPH, CIP Human Subjects Chair

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Thesis Abstract – Idaho State University (2022)

Food cues (FCs) serve as conditioned and discriminative stimuli for eating and likely play a role in obesity. This study aimed to condition and extinguish FCs in twenty-four healthy-weight and twenty-three overweight/obese women and determine the extent to which FCs induced changes in behavioral economic aspects of food reinforcer efficacy, namely values of demand (elasticity and intensity) and delay discounting (DD) for food. Participants underwent respondent conditioning with neutral visual cues paired with chocolate. Conditioned swallowing response (CR+), demand elasticity and intensity for food, and food DD were measured across three conditions: baseline, post-acquisition, and post-extinction. Results show FCs increased CR+ and demand intensity and decreased demand elasticity. Changes in CR+, elasticity, and intensity did not extinguish post-extinction. DD did not change across conditions. Finally, no group differences were observed across any of dependent variables. Conditioned FCs, then, not only increase conditioned salivation, but also alter demand for food.

Keywords: delay discounting, demand, food cue reactivity, food cues, obesity, respondent conditioning, visual stimuli

Effects of Visual Cues on Conditioned Salivation and Food Reinforcer Efficacy in Overweight/Obese and Healthy-Weight Women

Chapter I: Full Literature Review

Obesity

Obesity is a condition characterized by having a weight that is higher than the healthy weight range for a specific height (Centers for Disease Control and Prevention [CDC], 2020). Body Max Index (BMI) (as well as body fat percentage) is used as a measure to screen the health of an individual (CDC, 2020). To calculate BMI, an individual's weight (kg) is divided by height (m^2). In adults, a healthy-weight BMI ranges from 18.5 to 24.9. Individuals with BMIs greater than 24.9 are considered overweight or obese. An individual with a BMI between 25 and 29.9 is classified as overweight, where a BMI equal to or greater than 30 is considered obese, with obesity being further subdivided into classes. Class I consists of a BMI that ranges from 30 to 34.9, Class II consists of a BMI that ranges from 35 to 39.9, and Class III, categorized as extreme or severe obesity, consists of a BMI that is equal to or greater than 40.

Following the surge in obesity rates over the past several decades, recent data now estimate that over 42% of the American adult population is obese (CDC, 2020). Obesity is a risk factor for numerous health problems, including coronary heart disease, some types of cancer, type-2 diabetes, and premature death (CDC, 2020). Obesity is also expensive. For instance, a recent study estimated obesity-related medical costs to be $342.2 billion for the United States in the 2013 year (Biener et al., 2017). Given the rates of obesity and their negative consequences, research investigating the specific conditions under which excessive food intake occurs is needed.

Obesogenic environments have been linked to societal changes that have influenced obesity prevalence. Factors such as the heightened production and availability of food, the prevalence of fast food, lower availability of healthy food options (Swinburn, 2009; Swinburn, 1999), and higher portion sizes (National Institutes of Health, 2013) are associated with obesity trends. For example, among 5,443 adults living in the U.K., the number of fast-food restaurants near participants' homes and work environments was associated with greater consumption of fast food as well as a higher BMI, increasing the odds of obesity (Burgoine et al., 2014).

Despite the abundance of readily available energy-dense foods, not everyone who is exposed to an obesogenic environment becomes overweight or obese. Research investigating individual differences between those who are overweight/obese and those who are not, may elucidate our understanding of food consumption and the environment in which it occurs.

Food Cue Reactivity

A contributing factor to the obesogenic environment is the ubiquity of *food cues*. Food cues are images of food, food-related odors, and food-related advertisements that are present in in the greater environment. Research, from both human and animal studies, indicates that the presence of food cues increases food consumption (Boggiano et al., 2009; Ferriday & Brunstrom, 2008; Harris et al., 2009; Jansen et al., 2003; Petrovich et al., 2007; Reppucci & Petrovich, 2012; Versace et al., 2019; Weingarten, 1983). For instance, Harris et al. (2009) investigated effects of exposure to food advertisements on food consumption among children. Children viewed a television program with food or non-food advertisements interspersed between program segments. All children were given a snack while watching television. The results showed that children who viewed the food advertisements consumed more food relative to those in the non-food condition.

Likewise, Jansen et al. (2003) investigated cue-influenced food intake during a bogus taste test among overweight and healthy-weight children. Here, the type of food cue was manipulated within participants: smelling the food, consuming a small amount of food, and playing for 10 min (no-cue control). In both food cue exposure conditions, children who were overweight consumed a greater amount of food and exhibited increased salivary flow relative to healthy-weight children. However, food intake in overweight children did not significantly differ from healthy-weight children in the control condition. These findings may suggest overweight children may be especially susceptible to food cues in the environment.

The observation that some individuals are more likely to eat food while in the presence of food cues suggests there are individual differences regarding sensitivity to food cues, a phenomenon called *food cue reactivity (FCR)*. FCR refers to the physiological (e.g., saliva production, increased insulin levels and gastric activity), behavioral (e.g., food seeking and eating), and subjective (e.g., cravings) responses of an individual to food-related stimuli in the environment (Jansen, 1998). High FCR has been shown to increase the probability of food consumption (Boswell & Kober, 2016; Jansen, 1998; Jansen et al., 2011).

The tendency of food cue exposure to increase food intake has been well established among humans (Ferriday & Brunstrom, 2008; Jansen & van den Hout, 1991; Larsen et al., 2012; Overduin & Jansen, 1997; Sinha et al., 2019; Tetley et al., 2009; Wonderlich et al., 2013). In one such study, Sinha et al. (2019) examined the effect of food-cue imagery (i.e., a food cue script) on food consumption in adults. The food cue script was developed by recording each participant identifying a recent situation in which they were exposed to a highly palatable (HP) food cue and subsequent intake of that food. Participants then listened to either their HP food cue imagery script, a stress imagery script, or a relaxation imagery script once a day, with each script being

randomized and counterbalanced across sessions. Immediately following the imagery exposure, participants were presented with four bowls of HP food (e.g., chocolate pudding, potato chips, popcorn and mini chocolate chip cookies) and two bowls of healthy food (e.g., baby carrots and grapes). The results showed that both HP food craving and HP food consumption significantly increased with the onset of food-cue imagery. Further, exposure to HP food cue imagery increased HP snack intake compared to healthy snack intake. Indeed, this general finding is supported by a recent meta-analysis (Boswell & Kober, 2016) and also links high FCR to weight gain. This review, which included 45 studies of a total of 3,292 participants, found that high FCR and self-reported cravings predicted subsequent food intake and weight gain.

Collectively, these studies suggest that heightened FCR may play a role in overeating and weight gain. In an additional study examining the influence of BMI and typical portion sizes (as measured by self-report), Tetley et al. (2009) exposed 120 women to the sight and smell of pizza for a three-minute interval. Facets of FCR (i.e., desire to eat, cravings, and desired portion sizes of pizza) were measured by self-report prior to and following cue exposure. Participants who were overweight as well as participants who reported consuming the largest typical portion sizes had significantly larger increases in desired portion of pizza following cue exposure than their lean counterparts, providing further support of the finding that FCR is associated with greater food intake and higher weight.

The tendency for food cues to increase food intake is also supported in animal research (Boggiano et al., 2009; Petrovich et al., 2007; Reppucci & Petrovich, 2012; Weingarten, 1983). Boggiano et al. (2009) conditioned rats by giving them access to Oreo Double Stuf cookies and standard chow in a distinct “cookie” cage (i.e., the walls of the cage were covered with black construction paper). These pairings between cage and cookies lasted for 24 hours each and

occurred seven times in 22 days. During the intervals between exposures, rats were returned to their home cage where they had access to only standard chow. After the exposures were complete, rats were given a test session to determine the effects of the conditioned food cue of the cookie cage on standard chow consumption. They were placed in the "cookie" cage with access to only standard chow. Here, standard chow consumption was compared to standard chow intake while in their home cage. Rats in the "cookie cage" consumed significantly more standard chow compared to the standard chow intake while in the home cage.

As a whole, these studies provide evidence that environmental food cues can lead to increased food intake. In addition, these studies also indicate that individual differences such as obesity status may influence susceptibility to food cues. Moreover, the animal research shows that FCR can be conditioned. In other words, the association between specific cues and/or contexts with food consumption is a form of classical conditioning; the cues and contexts that are associated with food consumption (after multiple pairings) will become conditioned stimuli for food consumption.

However, an important methodological observation about the research on FCR, especially in human studies, is that the potency of the food cue in the studies is often assumed (Fedoroff et al., 1997; Ferriday & Brunstrom, 2008; Tetley et al., 2009; van den Akker et al., 2013). In other words, when a food cue image is presented, it is assumed that all participants have had a similar history with the image and therefore each image has equal potential for eliciting responses. In reality, the variation of experience with food cue images varies drastically from person to person, so using the same food cue images introduces uncontrolled variation into the research. One procedural consideration might be to *create* conditioned food cues in the laboratory by conditioning neutral stimuli with food. Indeed, observing the acquisition and

extinction of conditioned food cues in the laboratory would heighten the validity of research on FCR. Indeed, some studies have done this (Meyer et al., 2015; van den Akker et al., 2013) and are discussed below.

Van den Akker, Jansen, Frentz, and Havermans (2013) used a virtual learning laboratory to determine whether humans would show an increase in food cravings and salivation (i.e., conditioned responses) after repeated pairings of a specific, neutral stimulus with food intake. During conditioning, participants were exposed to two non-food related virtual environments with one serving as the conditioned stimulus (stimulus predicts food; CS+) and the other as an inhibitory conditioned stimulus (one that does not predict food; CS-). Specifically, when the CS+ environment was presented, participants were asked to drink a milkshake, and when the CS- environment appeared, no milkshake delivery followed. After conditioning trials, participants exhibited an increase in salivation compared to baseline measurements and a greater desire for milkshakes after exposure to the contextual CS+. These results provide evidence that neutral contexts, after pairings with a CS+, can begin to elicit similar physiological reactions to the sight or smell of food.

Of the current studies illustrating acquisition of conditioning processes with food cues in humans (Meyer et al., 2015; Schyns et al., 2018; van den Akker et al., 2013), Meyer et al. (2015) is the only to investigate differences in conditioning, specifically, in overweight and non-overweight particiapnts. In this procedure, Meyer et al. (2015) exposed lean and obese participants to three neutral shapes. One shape was selected to be paired with the delivery of chocolate milk (CS+), while the other two shapes were paired with water (CS-) or no liquid delivery (CS-). Swallowing rate was used as an indirect measure of salivation and was measured at baseline, after the stimulus pairing (post-acquisition), and after an extinction (unreinforced

trials) procedure (post-extinction). During the extinction phase, participants were presented with the shapes and no delivery of water or chocolate milk. Early in extinction (to test for acquisition), lean participants exhibited no difference between conditioned swallowing responses to the CS+, CS- (no delivery), or the CS- (water). In the obese group, however, participants exhibited a greater conditioned swallowing response in the presence of the CS+ compared to the CS-. In addition, extinction to the CS+ was not observed with obese individuals. It is worth noting, however, that the sample size of this study was relatively small, in part due to technical difficulties with collecting data and it is not clear whether examining behavior across more extinction trials would have results in extinction for obese participants.

Given the limitations of the Meyer et al. (2015) study and the few experiments examining the nature of classically conditioned responses to food cues, future research should focus on replicating and clarifying acquisition and extinction responses to food cues that influence acquisition and extinction. Additionally, the implications of disruptions to extinction (and the increased risk of relapse as result of these disruptions) underscore the need to investigate the extinction process as it relates to FRC.

Furthermore, research involving classically conditioned FCR has not addressed the extent to which a conditioned response to a food cue will occasion a situation in which food becomes more highly reinforcing; indeed, only self-reported cravings and conditioned responses such as salivation have been examined. Given that high FCR appears to be associated with subsequent operant behaviors such as increased food intake and choices for more immediate outcomes (Appelhans et al., 2011; Fedoroff et al., 1997; Jansen et al., 2009; Tetley et al., 2010), there is reason to suspect that conditioned food cues may result in changes in the reinforcing value of food.

Behavioral Economics and Food Reinforcer Value

When considering obesity from an operant standpoint, food functions highly as a reinforcer (Epstein et al., 2010b). A reinforcer is a stimulus, such as food, that increases the probability of a specific behavior, such as food seeking (Bickel et al., 2000; Hursh & Silberberg, 2008; Richardson & Roberts, 1996). Reinforcer value can be explored using the behavioral economic concept of reinforcer pathology – an interaction between two processes: 1) a persistently high valuation of a preferred commodity despite high response cost and 2) a consistently high preference for immediate consumption over delayed consumption of the commodity (Bickel et al., 2014). The interaction between overvaluation of a commodity and the declined value of a delayed commodity has been well observed in individuals with substance abuse disorders (Bickel et al., 2011). For instance, cigarette smokers will continue to work, despite high response requirements, for puffs of cigarettes more than they will for monetary rewards (Johnson & Bickel, 2003; Shahan et al., 2001), and opioid dependent individuals are extremely sensitive to delayed rewards (Kirby et al., 1999; Madden et al., 1997). Additionally, reinforcer pathology has been applied to obesity, with obese subjects demonstrating less sensitivity to price increases (Saelens & Epstein, 1996; Temple et al., 2008) and preferences for more immediate rewards (Appelhans et al., 2011; Boomhower et al., 2013; Boomhower & Rasmussen, 2014; Hendrickson et al., 2015; Rasmussen et al., 2010a; Robertson et al., 2017; Rollins et al., 2010; Weller et al., 2008). Reinforcer pathology can be measured by economic demand and delay discounting, respectively, and are described below.

Demand

Using the reinforcer pathology model, high valuation of a preferred outcome can be measured by insensitivity of behavior to increases in response cost (typically money, work, or

time). Historically, to establish reinforcer value, a progressive ratio schedule of reinforcement has been implemented. This is reinforcement schedule where the response requirement (or price) within session progressively increases after the delivery of each reinforcer. In other words, during a session, a subject might earn a reinforcer after one response requirement, such as a single lever press. However, the response requirement for subsequent reinforcers may then be increased to 3 responses, then 5, and so on until the response ratio is too high to maintain responding and responding ceases. The ratio at which discontinuation of responding occurs is referred to as the breakpoint. The higher the breakpoint, the more value the reinforcer has (Killeen et al., 2009; Richardson & Roberts, 1996).

It is important to point out that reinforcer value is dynamic. For example, the value of a reinforcer may be contingent on the context in which it is measured. Killeen and Reily (2001) provided evidence that deprivation and satiation can influence how a reinforcer is valued; animals will exhibit higher breakpoints for food when deprived, but not when satiated. Furthermore, breakpoint can also be influenced by the availability of alternative reinforcers. That is, it is simply unrealistic to assume that people are only provided with one available option; people are generally presented with multiple choices (i.e., reinforcers) where they can allocate behavior. Thus, it is necessary to present multiple reinforcers, while also varying the responses required for obtaining each reinforcer to determine the actual value of a given reward (Lappalainen & Epstein, 1990; Vuchinich & Tucker, 1998).

Additionally, it has been demonstrated that the progression of the ratios (e.g., geometric vs. arithmetic) results in different breakpoint values for the same reinforcer (Killeen et al., 2009). If the goal is to accurately measure the absolute value of a reinforcer, this is a challenge for the progressive ratio schedule's sensitivity.

A more sophisticated way to measure reinforcer efficacy is through behavioral economics. Behavioral economics integrates the principles of economics with the methods and concepts of the experimental analysis of behavior to examine behavioral choices (Madden, 2000). The foundation of behavioral economics is the economic context in which behavior occurs. For instance, a common method for quantifying reinforcer efficacy within the field of behavioral economics is economic demand, where the consumption of a reinforcer is examined across a range of prices or response requirements.

Economic Demand. Economic demand, which describes the relation between consumption and price (Bickel et al., 2000; Hursh, 1980; Hursh, 1984; Hursh, 2000; Madden, 2000) is a framework that can be used to better estimate relative reinforcer value. Similar to progressive ratio schedules, relative reinforcer value is defined as the price or effort an organism is willing to "pay" to produce a reinforcer (e.g., food). In economic demand, however, there are multiple opportunities to consume at one price because price is manipulated between sessions, as opposed to within session (such as what is done with a PR schedule). As such, consumption of a reinforcer is described as a function of price, such that as price increases, consumption of a reinforcer generally tends to decrease (Bickel & Vuchinich, 2000). Reinforcer value is conceptualized by measuring the sensitivity of behavior to increases in response cost (typically money, work, or time). Generally, as price increases, the consumption of a reinforcer decreases (Epstein & Saelens, 2000).

The extent to which a reinforcer is sensitive to price increases is referred to as elasticity (illustrated in Figure 1). While a product has lower price values, demand is further characterized as inelastic, or insensitive to price increases. If the number of reinforcers consumed (or consumption) was to decrease sharply (e.g., price values increase sharply, or buying power

decreases sharply), demand would be characterized as elastic – sensitive to price change (Hursh, 2000). A steeper decline in reinforcers consumed would be represented by a steeper slope of the curve in Figure 1, and therefore, indicates more elastic demand.

The part of the demand curve in which consumption changes very little as price increases (typically, the part of the curve in which price is low) is referred to as inelastic. The part of the demand curve in which consumption is highly sensitive to price increases (generally, higher prices) is said to be elastic (Hursh, 1980). The point of unit elasticity is where the slope of the demand curve is equal to -1 (see Figure 1); here a 1% increase in price results in 1% decrease in consumption. All data points below unit elasticity are said to be inelastic; all points above it are referred to as elastic.

Elasticity was originally described and calculated mathematically by the following linear elasticity demand equation (Hursh, 1980; Hursh, 1984):

$$\ln(Q) = \ln(L) + b(\ln P) - a(P) \quad (1)$$

where P is the price and Q is the quantity of reinforcers earned (also called consumption). As P increases, Q decreases, and the free parameters, *a* and *b,* describe the steepness of the decline. *L* is the demand at the minimum price or y-intercept of the curve. The parameter *b* represents inelasticity in the curve (i.e., the slope of the curve at smaller prices) where consumption is not sensitive to price increases. The parameter *a* represents the elastic part of the curve (i.e., the slope of the curve at higher prices) where consumption decreases as price increases (Hursh, 2000).

The price at which unit elasticity is determined (i.e., where the curve transitions from inelastic to elastic) is P_{max} (Bickel, et al., 2000; Hursh, 1980; Hursh 1984; Hursh 2000) and can be expressed through the equation:

$$P_{max} = (b+1)/a \quad (2)$$

P_{max} can also be considered the price at which responding is highest after consumption becomes elastic (see dashed line Figure 1). Thus, it can be used as an overall measurement of demand as a low P_{max} value indicates a highly elastic, less valuable reinforcer (i.e., consumers are not willing to pay as much for, or respond as frequently to, higher priced goods). Conversely, a high P_{max} value indicates a highly inelastic, more valuable reinforcer.

Response, or response output, is related to consumption and is comparable to the number of dollars that are spent in consuming goods. In other words, higher priced reinforcers require and emit more responses until elasticity is reached. This can be observed in Figure 2 where responses increase at lower price values until the point of unit elasticity is reached; then responding begins to decrease. The equation that describes this relation is as follows:

$$\ln(O) = \ln(L) + (b\text{-}1)\,(\ln P)\text{-}aP \quad (3)$$

where O represents the responses at each price. The maximum number of responses that occur at P_{max} is characterized by O_{max} (i.e., O_{max} is the solution to the equation at P_{max}).

Exponential demand. The linear model of demand includes three free parameters to characterize demand: slope, intercept and acceleration of change (*L*, *b*, and *a,* respectively). A more parsimonious approach, the exponential model of demand (Hursh & Silberberg, 2008), uses a single parameter to describe the rate of change in elasticity. This single parameter characterizes the decay of consumption with price increases. In addition to simplifying the characterization of demand, it is conducive to comparing demand for different reinforcers by standardizing differences among goods or reinforcers using this rate of decay as the dependent variable of interest. The equation that defines exponential demand is as follows:

$$\log Q = \log Q_0 + k(e^{-\alpha Q_0 P}\text{-}1) \quad (4)$$

where Q_0 is consumption at the lowest price or y-intercept, P is the unit price of the reinforcer, k is a constant representing the range of the dependent variable in logarithmic units, and α is the parameter that describes the slope of exponential decline in demand or elasticity. Additionally, α, the essential value parameter, is used to compare the value across different reinforcers. Reinforcers that have relatively high α values have higher elasticity (i.e., sensitivity to price increases), while reinforcers with relatively low α values are considered to be inelastic (i.e., insensitive to price increases).

Research has applied the concept of economic demand to obesity in both non-human and human models. For instance, Rasmussen et. al (2010b) compared food consumption of obese and lean Zucker rats in a free-feeding condition as well as under different response requirements, (i.e., fixed ratio schedules). Under both free-feeding conditions and low response requirements (fixed ratio schedules of 1-50), obese Zucker rats consumed more food than the lean rats. At higher response requirements (90-300), there were no significant differences in food consumption. This suggests that both groups were similarly sensitive to price increases at higher response requirements, thus also that genes influence obesity and food consumption at lower prices only. Food accessibility is indeed an important factor. At free-feeding or lower response requirement conditions, the strongest influences of genes were found; increasing the price or effort for food reduces genetic influence, again underscoring the importance of food availability in determining demand, especially at increasing prices.

Similar research using demand-like methods has also been conducted with humans in an applied setting. For instance, one study (Temple et al., 2008) compared the relative reinforcing value of food among healthy-weight and overweight children. In one experiment, children completed a computerized task that assessed the relative reinforcing value of pizza and non-food

alternatives (e.g., reading magazines, playing video games, or drawing and coloring). For every five points earned on a computer program, a portion of pizza or five minutes engaging in the non-food alternative activity could be exchanged. In addition, for every five points earned, the ratio value for earning pizza doubled while the ratio scheduled for the non-food alternative remained the same. While both groups responded similarly to food at lower response requirements, children who were overweight allocated more points towards food than their healthy-weight counterparts at increasing prices, suggesting that food had a higher reinforcer value among overweight children. These findings could implicate a higher reinforcing value of food as a factor related to obesity.

Delay to receipt of a commodity such as food is often subsumed in effort. For example, in working under ratio schedules, it is important that the time is takes an organism to produce a set number of responses to obtain a reinforcer is considered. Therefore, it is essential to examine sensitivity to delay as an individual difference variable that may also be related to food consumption.

Delay Discounting

Delay discounting, the second component of the reinforcer pathology model, refers to a decrease in an organism's valuing of a reinforcer as delay to its receipt increases. Delay discounting is also conceptualized as a preference for more immediate outcomes over delayed outcomes. For instance, an immediately available $10 reward is usually preferred to a delayed $10 reward (i.e., "Would you rather have $10 now or $10 next week?). Discounting rates are established by presenting an individual with choices between smaller, immediate rewards vs. larger, delayed rewards and systematically reducing the value of the smaller, immediate reward with each question. For example, "would you prefer $9 now or $10 in a day?" would likely yield

a choice for $9 now. On subsequent choices, the immediate amount might be reduced: “would you prefer $7 dollars now or $10 in a day?” While most individuals exhibit a preference for an immediate outcome relative to a delayed outcome (e.g., 10 dollars now is preferable to 10 dollars in 1 day), preference may reverse to the larger, delayed reward as the smaller, immediate reward decreases. This preference reversal is used to calculate the indifference point (i.e., the point at which the subjective value of the delayed reward is equal to the smaller, immediate reward). For instance, if an individual switches his/her preference from preferring the smaller, sooner reward ($7) to preferring $10 in 1 day, then the indifference point of 10 dollars in 1 day for that individual is said to be a value between 7 dollars and 8 dollars—the median $7.50 would be calculated as the indifference point. Indifference points for multiple delays are then plotted against delay on a figure (see Figure 3).

As the delay to receipt of a reward increases, the subjective value (i.e., the indifference point) of the reward decreases. This decrease can be described using Mazur’s (1987) hyperbolic equation:

$$V = A/(1+kD) \quad (5)$$

where V is the indifference point, A is the amount of the larger delayed outcome, D is the delay to the receipt of the larger reward, and k is a free parameter that quantifies the individual rate of discounting (Green et al., 1999; Kirby & Marakovic, 1996; Rachlin et al., 1991). Larger k values indicate a greater preference for smaller, sooner outcomes (i.e., more immediate choice patterns) while lower k values indicate a greater preference for larger, delayed outcomes.

Research indicates that there is a relation between obesity and preferences for immediate outcomes; both non-human animal and human studies show that preferences for smaller, sooner reinforcers (especially food) over larger, later reinforcers have been established as a significant

mechanism of obesity (DeHart et al., 2020; Amlung et al., 2016; Cummins & Macintyre, 2006; Nielsen et al., 2002).

With non-humans, food as a reinforcer has been studied using delay discounting paradigms (Boomhower et al., 2013; Boomhower & Rasmussen, 2014; Robertson et al., 2017). For instance, Boomhower et al. (2013) examined choice patterns among genetically lean and obese Zucker rats. Across most conditions, obese Zuckers discounted food more steeply than lean rats. In addition to implicating a pattern for immediate choice preferences in obesity among nonhuman animals, these findings suggest that some genetic factors may influence delay discounting associated with obesity.

Human research with hypothetical monetary outcomes and food-related outcomes has been examined with obese and healthy-weight individuals, with obese individuals exhibiting a pattern of preference for more immediate outcomes than healthy-weight individuals (Davis et al., 2010; Epstein et al., 2010b; Guerrieri et al., 2008; Hendrickson et al., 2015; Jarmolowicz et al., 2014; Nederkoorn et al., 2006; Rasmussen et al., 2010a; Weller et al., 2008). These choice patterns have also been investigated in the context of food reward sensitivity, an aspect of FCR. Appelhans et. al (2011) investigated food reward sensitivity (defined by the authors as the appetitive drive to consume palatable food, independent of physical hunger) and monetary choice patterns among 62 obese women. Results showed that higher food reward sensitivity was predictive of increased intake of palatable food among participants who had preferences for more immediate monetary outcomes.

The framework of behavioral economics, specifically reinforcer pathology, could aid in understanding choice patterns in eating behavior. Eating behavior represents a choice to consume food (including what, when, and how much to consume) among a variety of other alternatives

and available reinforcers. A large body of growing literature demonstrates that food consumption is heavily influenced by food availability in the environment. Manipulating aspects of food availability such as the effort or price to obtain food and the delay to its receipt influences food intake. While measures of food availability and food reinforcer efficacy, such as demand and delay discounting, assist in an understanding of food decision-making, the role of involuntary and conditioned physiological responses in the presence of food cues would provide a more complete illustration of eating behavior. In particular, a model that incorporates FCR would account for these processes.

Chapter II: Current Study

Introduction

Food cues are respondently-conditioned images of food, food-related odors, and food-related advertisements that are present in the environment. It has been well documented, from both human and non-human animal literature, that the presence of food cues increases food consumption (Boggiano et al, 2009; Ferriday & Brunstrom, 2008; Harris et al., 2009; Jansen et al., 2003; Jansen & van den Hout, 1991; Larsen et al., 2012; Overduin & Jansen, 1997; Petrovich et al., 2007; Reppucci & Petrovich, 2012; Sinha et al., 2019; Tetley et al., 2009; Weingarten, 1983; Wonderlich et al., 2013). However, there are individual differences regarding sensitivity to food cues, a phenomenon called *food cue reactivity (FCR)*. FCR refers to the physiological (e.g., saliva production, increased insulin levels and gastric activity), behavioral (e.g., food seeking and eating), and subjective (e.g., cravings) responses of an individual to food-related stimuli in the environment (Jansen, 1998). FCR is positively related to food consumption (Jansen, 1998; Jansen et al., 2011). Indeed, this general finding is summarized by a meta-analysis by Boswell & Kober (2016), which also links high FCR with obesity.

Some studies on FCR use food cues in a manner that assumes equal potency of the cues across all participants (e.g., Fedoroff et al., 1997; Ferriday & Brunstrom, 2008; Tetley et al., 2009). This procedural detail has limitations as the variation and history of experience with food cues (such as experience with food-related advertisements) is vastly different among individuals. To address this limitation, other studies have conditioned arbitrary cues (such as shapes or virtual environments) to food in the laboratory, which enhances validity of the research (e.g., Meyer et al., 2015 and van den Akker et al., 2013, respectively). One such study by Meyer et al. (2015) investigated differences in FCR in obese and lean participants. In this procedure, participants

were exposed to three neutral shapes. One shape was selected to be paired with the delivery of chocolate milk (stimulus predicts food; CS+) while the other two shapes were paired with water (stimulus does not predict food; CS-) or no liquid delivery (CS-). Swallowing rate was used as an indirect measure of salivation and was measured at baseline, after the stimulus pairing (post-acquisition), and after an extinction (unreinforced trials) procedure (post-extinction). Post-acquisition, lean participants did not develop a conditioned response. However, in the obese group, participants exhibited a greater conditioned swallowing response in the presence of the CS+ compared to baseline swallowing. Further, extinction to the CS+ was not observed with obese individuals; that is, they showed a resistance to extinction. It is worth noting, however, that the sample size of this study was relatively small (N = 33), and it is not clear whether examining behavior across more extinction trials would have resulted in extinction for obese participants.

Another limitation to FCR research is that while the role of respondent conditioning (i.e., conditioned physiological responses) has been examined in food cues, the extent to which a food cue will affect operant processes, specifically, the potentiation of reinforcement processes (i.e., choosing when and how much to eat), has not been explicated. However, there is literature indicating that obese individuals, compared to lean individuals, exhibit increased food-cue induced self-reported food cravings, desire to eat, and desired portion sizes (operant aspects of FCR) (Jansen et al., 2003; Sobik et al., 2005; Tetley et al., 2009). Additionally, choice patterns have been investigated in the context of food reward sensitivity, an aspect of FCR. For instance, Appelhans et. al (2011) investigated food reward sensitivity (defined as the consumption of palatable food, independent of physical hunger) among obese women. Higher food reward sensitivity was predictive of increased intake of palatable food among participants who exhibited choice patterns for more immediate rewards. Given that high FCR appears to be associated with

operant behaviors such as increased food intake and motivational consummatory responses, there is reason to suspect that conditioned food cues may result in changes to the reinforcing value of food as well.

The Reinforcer Pathology Model

The reinforcing value of a stimulus, especially one that has high value, can be characterized using the behavioral economic concept of reinforcer pathology – an interaction between two processes: 1) a persistently high valuation of a preferred commodity despite high response cost (i.e., demand) and 2) a consistently high preference for immediate consumption over delayed consumption of the commodity (i.e., delay discounting) (Bickel et al., 2014). The interaction between overvaluation of a commodity and the declined value of a delayed commodity has been observed in individuals with substance abuse disorders (e.g., Bickel et al., 2011) Johnson & Bickel, 2003; Kirby et al., 1999; Madden et al., 1997; Shahan et al., 2001). Moreover, the reinforcer pathology model has also been applied to obesity, with obese subjects demonstrating less sensitivity to price increases (Saelens & Epstein, 1996; Temple et al., 2008) and preferences for more immediate rewards (Appelhans et al., 2011; Boomhower et al., 2013; Boomhower & Rasmussen, 2014; Hendrickson et al., 2015; Rasmussen et al., 2010a; Robertson et al., 2017; Rollins et al., 2010; Weller et al., 2008). The two processes of reinforcer pathology – demand and delay discounting – and are described below.

Demand. When considering obesity from an operant standpoint, food functions highly as a reinforcer (Epstein et al., 2010b). Reinforcer value can be conceptualized by measuring the sensitivity of behavior to increases in response cost (typically money, work, or time). Generally, as price increases, the consumption of a reinforcer decreases. Economic demand, which describes the relation between consumption and price (Bickel et al., 2000; Hursh, 1980; Hursh,

1984; Hursh, 2000; Madden, 2000) can be used to estimate relative reinforcer value. The less sensitive behavior is to price increases (called inelasticity), the more value the reinforcer has.

Research with humans show that obese individuals show less sensitivity to effort, i.e., inelasticity, for food compared to lean controls (Epstein et al., 2007; Giesen et al., 2010; Jacobs & Wagner, 1984; Saelens & Epstein, 1996). For example, in an experiment by Temple et al. (2008), children completed a computerized task that assessed the relative reinforcing value of pizza and non-food alternatives (e.g., reading magazines, playing video games, or drawing and coloring). For every five points earned on a computer program, a portion of pizza or five minutes engaging in the non-food alternative activity could be earned. In addition, for every five points earned, the ratio value for earning pizza doubled while the ratio scheduled for the non-food alternative remained the same. While both groups responded similarly to food at lower response requirements, children who were overweight allocated more points towards food than their lean counterparts at increasing prices, suggesting lower elasticity.

Delay Discounting. The second behavioral process of the reinforcer pathology model is delay discounting (DD), which is a decrease in the value of a reinforcer as delay to its receipt increases. DD is determined by presenting an organism with choices between smaller, immediate rewards vs. larger, delayed rewards. For instance, an immediately available $10 reward is usually preferred to a delayed $10 reward (i.e., "Would you rather have $10 now or $10 next week?). A pattern of preference for smaller, more immediate outcomes compared to larger, delayed outcomes can be described as steep discounting, meaning behavior is more sensitive to delay. This sensitivity to delay is viewed as an individual difference variable (see Odum, 2011 and 2020), though experimental manipulations can change it as well (see Rung & Madden, 2018).

Research indicates that obesity predicts preferences for smaller, more immediate outcomes over larger, delayed outcomes (Amlung et al., 2016; Cummins & Macintyre, 2006; DeHart et al., 2020; Lawyer et al., 2015; Nielsen et al., 2002). With non-human animals, food as a reinforcer has been studied using DD paradigms (Boomhower et al., 2013; Boomhower & Rasmussen, 2014; Robertson et al., 2017). For instance, Boomhower et al. (2013) examined choice patterns among genetically lean and obese Zucker rats. Across most conditions, obese Zuckers discounted food more steeply (that is, preferred the smaller, immediate alternative) than lean rats.

Human delay discounting research with hypothetical monetary outcomes and food-related outcomes has been conducted with obese and lean individuals as well. Obese individuals tend to exhibit preferences for more immediate outcomes than healthy-weight individuals (Davis et al., 2010; Epstein et al., 2010b; Guerrieri, et al., 2006; Hendrickson et al., 2015; Jarmolowicz et al., 2014; Nederkoorn et al., 2006; Rasmussen, et al., 2010a; Schiff et al., 2016; Weller et al., 2008). For example, Lawyer et al. (2015) compared monetary discounting between obese and non-obese groups and found that those in the obese group discounting monetary rewards steeper than participants in the non-obese group. Further, Schiff et al. (2016) had obese and lean participants identify a preferred food item (i.e., chocolate bar, cookie, breadstick, or cracker) and then complete a DD task, in which participants choose between a small or large number of bites for the preferred food item after a short or long delay, respectively. Results show that obese participants are more prone to choose smaller, immediate food rewards over larger, delayed rewards relative to healthy-weight participants.

The framework of the reinforcer pathology model could aid in understanding choice patterns in FCR, especially with regard to obesity. Obesity status predicts higher FCR (Ferriday

& Brunstorm, 2008; Jansen et al., 2003; Meyer et al., 2015). Moreover, food consumption is choice behavior (including what, when, and how much to consume) among a variety of other alternatives and available behaviors. A body of literature demonstrates that food consumption is heavily influenced by food availability in the environment. For instance, manipulating aspects of food availability such as the effort or price to obtain food and the delay to its receipt influences food intake. However, little to any research on these aspects of food reinforcer value have been included in characterizing responses to food cues or FCR.

The Current Study

The purpose of the present study was to replicate and extend the acquisition and extinction of food cue conditioning on the conditioned swallowing response in humans using methods from the Meyer et al. (2015) study. We extended this study by incorporating measures of food reinforcer efficacy – that is, demand and delay discounting (DD) for food. We also examined the extent to which obesity status predicted classically conditioned salivation responses and food reinforcer efficacy by measuring three dependent variables: 1) conditioned swallowing response to food cues; 2) elasticity and intensity of demand for food; and 3) food DD. Independent variables for this study included time point (baseline, post-acquisition, and post-extinction; within-subjects) and obesity status (healthy-weight vs. overweight/obese; between subjects), therefore, this was a 2 x 3 mixed design.

Several hypotheses were proposed:

1) We expected to replicate the findings of the Meyer et al. (2015) study in that following an acquisition procedure, participants would exhibit increased conditioned swallowing responses (CRs+) compared to baseline CS presentations. Moreover, we hypothesized no

CRs+ would develop to cues paired with the absence of food (CS- trials) compared to baseline.

2) We also hypothesized that following acquisition of conditioned food cues, participants would demonstrate food-cue induced increases in values of demand (intensity, i.e., consumption at the lowest price, and inelasticity) for food as a reinforcer. We also hypothesized that participants would exhibit steeper rates of food DD following the acquisition procedure.

3) We hypothesized that overweight/obese individuals would demonstrate higher CRs+ to visual cues compared to healthy-weight particiapnts. Likewise, we predicted that across conditions, overweight/obese participants would exhibit higher CRs+, values of demand, and steeper DD compared to healthy-weight participants. *(*Note:* We also hypothesized that overweight/obese participants would condition more readily (fewer trials) to the CS+ than healthy-weight participants during conditioning. Unfortunately, we were unable to examine rate of acquisition due to the nature of acquisition paradigm.)

4) Finally, we predicted that, following acquisition, measures of CR+, demand elasticity and intensity, and DD would be significantly correlated with one another.

Method

Participants

Female (n =47) college students enrolled in lower division psychology courses were recruited from Idaho State University via SONA – an online subject pool. Female participates were used since they typically have little to no facial hair – an important characteristic for electrode placement (see method section). Sample size was determined by an *a priori* power analysis with an effect size = 0.25; a sample of 44 participants (22 healthy-weight 22

overweight/obese) resulted in $\alpha = 0.05$ and power = 0.8. A participant was eligible if she identified as a woman, was at least 18 years of age, and fluent in English. Exclusion criteria included a current or past diagnosis (within two years) of an eating disorder, current pregnancy, and/or a diagnosis of diabetes. The Institutional Review Board at Idaho State University approved all study procedures.

Measures and Materials

Subjective Hunger Questionnaire (SHQ; Appendix B). The SHQ is a three-item questionnaire that assesses self-reported hunger. The first two items query about when the participant last consumed a snack and meal (in hrs). The last item is a subjective hunger rating on a visual analog scale from 0 – 100 (Rasmussen et al., 2010a). Literature examining delay discounting (DD) for food shows a positive correlation between food DD and subjective hunger (Hendrickson & Rasmussen, 2017; Rodriguez et al., 2018).

Food Choice Questionnaire (FCQ; Appendix C). The FCQ ($\alpha = 0.85$; Hendrickson et al., 2015) is an adaptation of the Money Choice Questionnaire (Kirby & Marakovic, 1996) and a validated measure of DD for food. There are 27 hypothetical food choice questions that require participants to choose between smaller, immediate food outcomes (e.g., 3 bites now) versus larger, delayed food outcomes (e.g., 10 bites in 4 hours). To standardize bites, participants were given a ⅝ inch cube and asked to imagine the cube as one bite of their favorite food prior to administering the questionnaire. The FCQ assesses discounting (k) values for three food reward magnitudes (e.g., small = 8-13 bites, medium = 25-35 bites, large = 40-50 bites) across delays ranging from 0.5 to 24 hours. Participants that show preferences for smaller, immediate food outcomes over larger, delayed food outcomes demonstrate higher k values (i.e., more sensitivity to delay).

Food Purchasing Task (FPT; Appendix D). The FPT (α = 0.84; Epstein et al., 2010a) is a demand-based measure of food reinforcer efficacy. Participants are asked to indicate the number of portions they would be willing to purchase for a preferred food item at 18 different prices ranging from $0.00 to $1,120. The FPT was used to generate a food demand curve that describes the relation between demand at increasing prices, namely Q_0 values (demand intensity) and α values (slope of exponential decline in elasticity). To standardize portions, participants were given a ⅝ inch cube and asked to imagine it as one portion of their favorite food prior to administering the questionnaire.

Lifestyle and Demographics Questionnaire (Appendix E). Participants were asked basic demographic information including age, sex, ethnicity, income, and education level.

Biometric Measurements. Prior research has shown that swallowing and salivary response are highly correlated (Nederkoorn et al., 1999), therefore swallowing was used as a proxy for salivation. Swallowing was measured using an Electromyograph (EMG) and recorded at 250 Hz using a SR-Lab EMG amplifier (San Diego Instruments, Sand Diego, CA). A swallowing event was defined by the same criteria used by Meyer et al. (2015), which defined a swallow as an increase in electrical activity that surpassed a predefined threshold of activity. This electrical activity is measured in millivolts (mV); that is, EMG recordings are read as graphs which show electrical activity in muscles over time and indicate each time activity surpasses the threshold. The threshold was defined as 0.1 mV (baseline level electrical activity is approximately 0.0 mV).

Participants' height and waist circumference were measured and collected in centimeters (cm) using a standard measuring tape. Percent body fat (PBF) and weight data were collected

using a Tanita® 2204 Body Fat Scale. Participants' body mass index (BMI) was calculated by dividing a participant's body mass in kilograms by their height in meters squared (kg/m^2).

Procedure

Participants that met inclusion criteria were scheduled to participate in two 1-1.5-hour sessions (see Figure 4 for procedural flow chart). Session 2 could occur no earlier than one day and no later than seven days after Session 1. For both sessions, participants were asked to abstain from eating or drinking (including water) two hours prior to taking part in the study and were compensated with research credit.

Session 1

Participants arrived to the Health Decisions Laboratory at Idaho State University and were escorted to an office-sized room. After obtaining informed consent (Appendix A), researchers administered the Subjective Hunger Questionnaire (SHQ) to ensure that no self-reported food or drink was ingested two hours prior to the experimental session. Participants that reported eating or drinking in the last two hours were rescheduled or excused from the study. After completion of the SHQ, researchers attached three electrodes to the participant (two under the jaw about 1cm apart and one behind the left ear on the mastoid bone) (see Figure 5).

Participants were asked to sit in a stationary chair and watch a computer screen that displayed a neutral stimulus for 180 seconds (s) to establish a baseline level of swallowing in the presence of the assigned neutral cue. The researcher recorded the exact time of any activity that could disrupt accurate measurement of swallowing (e.g., coughing, sneezing, or verbalizations). Participants then completed the Food Choice Questionnaire (FCQ) and Food Purchasing Task (FPT) while the computer screen displayed the neutral stimulus to establish baseline reinforcer efficacy.

Next, participants completed the acquisition procedure in which they were presented with 20 conditioned stimulus trials (stimulus predicts food; CS+) for one visual stimulus (e.g., a blue triangle) and 20 inhibitory conditioned stimulus trials (one that does not predict food; CS-) for a second visual stimulus (e.g., a yellow circle) via computer screen. The assignment of stimuli to each participant was randomized from six colored shapes (e.g., blue triangle, red square, yellow circle, orange rectangle, green oval, and purple pentagon) (see Appendix H).

Figure 6 describes acquisition trials for CS+ and CS- stimuli. During CS+ trials, the computer screen displayed a shape (the same shape the participant received during baseline) for 7.5 s, which was followed by an unconditioned stimulus (US) delivery. For US delivery, the computer screen instructed the participants to eat one standardized bite of candy M&Ms® (i.e., one piece). Participants were given 10 s to consume the bite of food in which the computer screen displayed a 10 s countdown of the time remaining to consume the US. After 10 s elapsed, there was an 18.5 s intertrial interval (ITI) that followed in which the computer displayed a blank screen. Thus, the total time for a CS+ trial was 36 s. The CS- trials were the same, except following the presentation of a different shape (the CS-), no US was delivered. The CS- stimuli was presented for 7.5 s. To ensure consistency with CS+ trials, a 28.5 s ITI followed the CS- presentation, such that the total time for a CS- trial was 36 s. The presentation of CS+ and CS- trials was alternated throughout the procedure.

After completing the acquisition procedure, participants were given the Demographic and Lifestyle Questionnaire followed by the researcher collecting information about the participants' heights and weights. BMI was then calculated using the biometric measurements.

Session 2

Participants arrived at the same location as Session 1. Researchers administered the SHQ to ensure that no self-reported food or drink was ingested two hours prior to the experimental session. Participants that reported eating or drinking in the last two hours were excused from the study. After completion of the SHQ, participants completed the FCQ and FPT while in the presence of the CS+ to establish reinforcer efficacy post-acquisition. Following the operant tests of acquisition, electrodes were placed on the participant in the same manner as Session 1 and the extinction procedure began.

Testing for Acquisition and Extinction Procedure. To test for CS acquisition, the CS was presented after the CS-US pairings were complete, but without the M&Ms®. Therefore, swallowing rate was recorded during the first block (i.e., the first 10 trials) of the extinction procedure to test for acquisition, in which 5 CS+ and 5 CS- trials were presented (see Figure 7). The total number of swallows were counted for both CS+ and CS- in this first block.

Each extinction trial consisted of presenting a CS+ for 7.5 s with no food deliveries or instructions for eating. After the 7.5 s CS+ presentation, a 28.5 s ITI commenced, during which the computer displayed a blank screen. The same procedure was used for CS- trials, and forty (20 for CS+ and 20 for CS-) extinction trials took place. Consistent with Meyer et. al (2015), CS- stimuli were extinguished as well in order to maintain consistency with previous trials and ensure the participant remains naïve to the purpose of the experiment. Like the acquisition procedure, the presentation of CS+ and CS- trials were alternated throughout the procedure.

To test for extinction, swallowing was recorded during the final block (i.e., the last 10 trials) of the extinction procedure. Like the acquisition test, each participant received 5 CS+ and 5 CS- trials during the final block. The total number of swallows were counted for both CS+ and CS-. After completion of the extinction trials, the participants were instructed to complete the

FCQ and FPT as post-extinction measures of reinforcer efficacy, during which the computer screen displayed the CS+ image.

Analyses

Conditioned Swallowing Response

CS+ Conditioning. Prior to the analyses, all data were visually inspected for undetected responses. Consistent with Meyer et al. (2015), participants that had a recording of zero swallowing responses during baseline and the post-acquisition test (i.e., block 1) were not used in the analyses due to potential issues with electrode placement and/or electrode recording (see Meyer et al., 2015). This resulted in three participants being excluded. Therefore, the final data set for conditioned swallowing response (CR+) contained 44 participants (healthy-weight = 23, overweight/obese = 21). Due to the skewness of the distribution, CR+ data were $\log_{10}$ transformed – in the form of $\log_{10}(x + 2)$. This transformation only left one variable (baseline swallows for overweight/obese participants) non-normally distributed ($p = .02$), though this variable was less skewed than before the transformation.

CS- Conditioning. Because transforming the data did not lead to a normal distribution (data skewed heavily toward 0), a Friedman Test (the nonparametric alternative to the one-way analysis of variance [ANOVA] with repeated measures) was used to examine and compare conditioning of CR+ during CS- trials across all conditions (baseline, post-acquisition, and post-extinction) for healthy-weight and overweight/obese participants.

Stability. Although we were unable to examine rate of acquisition to the CS+ (i.e., how the strength of the CS+ changed across acquisition), stability during the extinction procedure was examined. For the extinction phase, for each participant, CR+ was plotted as a function of time and was individually examined throughout the extinction procedure. Stability was defined when

CRs+ were asymptotic for three consecutive trials – that is, the third data point in a trend had to fall between the range of the last two data points and the slope of the curve was close to zero.

Demand

To measure demand elasticity and intensity, the data from the Food Purchasing Task for each participant was fitted to the exponential model of demand (Hursh & Silberberg, 2008; Equation 1) using non-linear regression:

$$\log Q = \log Q_0 + k(e^{-\alpha Q_0 P} - 1) \quad (1)$$

Here, Q refers to the number of reinforcers bought at a given price, P. Q_0 is consumption at the lowest price (i.e., demand intensity), k is a constant representing the range of the dependent variables in logarithmic units, and α is the parameter that describes the slope of exponential decline in demand, i.e., elasticity or sensitivity to price. Reinforcers that have relatively high α values have higher elasticity (i.e., sensitive to price increases), while reinforcers with relatively low α values are considered to be inelastic (i.e., insensitive to price increases).

Free parameter values for Q_0 and α were determined for each participant. All demand data were inspected for relative fitness to the exponential model of demand equation, and if R^2 values for a participant were < 0.7, participants were removed from demand analyses – a common practice in demand literature (Hursh & Silberberg, 2008; Rasmussen et. al, 2010b). This resulted in two participants being excluded. Therefore, the final data set for demand contained 45 participants (healthy-weight = 23, overweight/obese = 22). Due to the skewness of the distribution, α and Q_0 values were $\log_{10}$ transformed.

Delay Discounting

Discounting (k) values were derived from participants' choice patterns across the 27 Food Choice Questionnaire (FCQ) outcomes. Each choice for the FCQ corresponds to a discrete

predetermined discounting value based on Mazur's hyperbolic discounting equation (see Hendrickson et al., 2015). For example, if a participant chooses 5 bites now (i.e., the smaller, sooner or SS) over 8 bites after 24 hours for one choice, their *k* value would be *greater* than the predetermined discounting value of 0.0252. If on another choice, the participant then chooses 10 bites after 17 hours over 4 bites now (i.e., the larger later or LL), their *k* value would be *less* than the predetermined value of 0.0855. This choice constitutes a preference reversal from SS to LL, which means an indifference point is somewhere between those two discounting values. The geometric mean is then taken between the two *k* values to avoid under-weighting the smaller of the two values. Therefore, the *k* value for this participant would be 0.0464. In this manner, each participant was assigned one *k* value for each magnitude based on her choices. Because small magnitude rewards are discounted more steeply (higher *k* values) than large magnitude rewards (Hendrickson et al., 2015; Lee & Rasmussen, 2021; Rodriguez et al., 2016), the omnibus (overall) *k* value was determined for each participant by calculating the geometric mean of the three magnitude (small, medium, large) *k* values (see Hendrickson et al., 2015 and Kirby & Marakovic, 1996 for scoring details).

When using the FCQ, it is expected that each participant will have one indifference point for each reward magnitude (one switch from LL rewards to SS rewards). However, multiple indifference points is categorized as inconsistent responding (multiple switches between larger, delayed rewards to smaller, more immediate rewards) (Kirby & Marakovic, 1996). Response consistency can be quantified as the proportion of responses consistent with the participants' determined indifference point. In the case of one preference reversal, this yields a consistency rate of 100%, meaning that the responses to the questions for a specified magnitude were perfectly aligned with the choice pattern that is described by the *k* value. If a participant had

more than one preference reversal, a *k* value yielding the highest consistency rate (i.e., highest proportion of correct responses) was assigned to them. If the highest consistency rate was represented by multiple *k* values, the geometric mean was then used to derive a single *k* value. Due to the skewness of the distribution, *k* values were transformed using square root transformations – a common practice in discounting research (Kirby et al., 1999; Hendrickson et al., 2015). Overall, the majority of the sample responded in a systematic pattern across all sessions. The consistency rates ranged from 92-93%, 94-97%, and 95-97% for baseline, post-acquisition, and post-extinction, respectively. All 47 participants were included in the analyses.

Relations of Dependent, Health, and Demographic Variables

Pearson *r* correlations were performed to determine the extent to which the dependent variables (CR+, Q_0 values, α values, and *k* values) correlated with one another under peak CS+ conditions (post-acquisition). Further, health and demographic variables that significantly correlated with dependent variables at baseline were included as possible covariates in main analyses.

Statistical Analyses

Data were analyzed using IBM® SPSS 28.0©. Main analyses consisted of 2 × 3 mixed ANOVAs (analysis of variance) or ANCOVAS (analysis of covariance), with obesity status (healthy-weight vs overweight/obese) as the between-subjects factor and condition (baseline, post-acquisition, post-extinction) as the within-subjects factor.

Results

Participant Characteristics

Of the total 47 women, 24 (51%) were classified as healthy-weight and 23 were classified as overweight/obese. Table 1 provides a summary of participants' characteristics for the current

study sample as a function of group membership. As expected, several health-related differences were found. Overweight/obese woman weighed more ($t(45) = 8.24$, $p < 0.001$, $d = 2.40$) and had higher BMIs ($t(45) = 8.04$, $p < 0.001$, $d = 2.35$), percent body fat ($t(45) = 10.34$, $p < 0.001$, $d = 3.02$), and waist circumferences ($t(45) = 8.11$, $p < 0.001$, $d = 2.37$) relative to healthy-weight woman. No other differences were observed.

Correlations of Variables

Table 2 shows Pearson's *r* correlations between health variables, demographic variables, and main dependent variables at Session 1 (baseline). Body mass index (BMI) was positively associated with percent body fat (PBF) ($p < 0.01$) and waist circumference ($p < 0.01$), and PBF was positively correlated with waist circumference ($p < 0.01$). Subjective hunger was negatively associated with BMI ($p < 0.01$), PBF ($p < 0.01$), and waist circumference ($p < 0.05$) but was not associated with any dependent variables. Age negatively correlated with food discounting (k) values ($p < 0.05$). (For Session 2, there were no significant associations between main dependent variables; Appendix I).

Conditioned Swallowing Response

CS+ Conditioning. Figure 8 shows mean conditioned swallowing responses (CRs+) as a function of condition (baseline, post-acquisition, and post-extinction) and obesity status (healthy-weight vs. overweight/obese). Because of skewness, data were log-transformed for analysis; Table 3 shows the transformed means. A 2 x 3 mixed ANOVA revealed a main effect of condition on CR+, $F(2, 84) = 5.58$, $p < 0.01$, $\eta^2 = 0.12$. There was no main effect of obesity status ($p = 0.45$) and no interaction ($p = 0.56$). Post-hoc contrasts revealed significant differences between baseline and post-acquisition conditions ($p < 0.01$) and baseline and post-extinction

conditions ($p < 0.05$), such that CRs+ were significantly higher in both post-acquisition and post-extinction conditions compared to baseline.

CS- Conditioning. Figure 9 shows mean CRs+ for CS- trials as function of condition. Because data were not normally distributed (despite transformations), a Friedman Test was used to compare CRs+ for CS- trials for both healthy-weight and overweight/obese participants. There were no effects of conditioning phase for either group (p's > 0.13). Table 4 shows transformed CRs+ for CS+ and CS- trials across all participants.

Stability

Acquisition Test. Despite significant differences between CS+ in baseline vs. post acquisition, only 11 of the 44 participants (healthy-weight = 7; overweight/obese = 4) showed stable CRs+ during the acquisition test (i.e., block 1; CR+ during the first 5 CS+ trials). A chi-square test of independence was performed to examine the relation between obesity status and stability during the acquisition test. The relation between these variables was not significant (p = 0.39), in that a similar number of healthy-weight and overweight/obese participants exhibited stable responding during the acquisition test.

Extinction Procedure. Of the 44 participants, 30 (healthy-weight = 16; overweight/obese = 14) displayed a stable swallowing response during the extinction procedure. Figure 10 shows the number of participants that exhibited stable CRs+ within 5-trial bins of the extinction procedure. The majority of healthy-weight participants showed stable CRs+ during the first 10 CS+ trials; the majority of those in the obese/overweight group showed CR+ stability during CS+ 11-20 trials. A chi-square test of independence was performed to examine the relation between obesity status and stability for the *entire* extinction procedure, and the relation was not significant (p = 0.84). More specifically, chi-square tests of independence showed no significant

differences between the relation of obesity status and stability in bin 1 ($p = 0.39$), bin 2 ($p = 0.05$), bin 3 ($p = 0.13$), or bin 4 ($p = 0.10$).

Demand

Demand Elasticity. Figure 11 shows mean demand elasticity (α values) as a function of obesity status and condition. Because of skewness, data were log-transformed for analysis; Table 4 shows the transformed means. A 2 x 3 mixed ANOVA revealed a main effect of condition ($F(2, 86) = 11.52$, $p < .001$, $\eta^2 = .21$) and a marginal main effect of obesity status on α values ($p = .08$) but no interaction ($p = .41$). All participants showed a decrease is elasticity across conditions, as post-hoc contrasts revealed that elasticity values at post-acquisition and post-extinction were significantly lower than baseline (p's < 0.01).

Demand Intensity. Figure 12 shows mean demand intensity (Q_0 values; $\log_{10}$-transformed) as a function of obesity status and condition. Because of skewness, data were log-transformed for analysis; Table 5 shows the transformed means. A 2 x 3 mixed ANOVA revealed a main effect of condition on Q_0 values, $F(2, 86) = 34.64$, $p < 0.001$, $\eta^2 = 0.45$. There was no main effect of obesity status ($p = 0.47$), and there was a marginal interaction between condition and obesity status on Q_0 values ($p = 0.08$). Post-hoc contrasts revealed that intensity values were significantly higher post-acquisition and during extinction compared to baseline (p's < 0.001).

Delay Discounting

Figure 13 shows mean food discounting (square root-transformed) as a function of obesity status and condition. Because of skewness, data were square root-transformed for analysis; Table 6 shows the transformed means. Since age was significantly correlated with baseline discounting values, a 2 x 3 mixed ANCOVA with age as a covariate was conducted to

examine main effects of conditioning and obesity status on discounting values. There were no main effects of condition ($p = 0.66$) or obesity status ($p = 0.29$) nor an interaction ($p = 0.44$).

Discussion

The purpose of the present study was to replicate and extend the Meyer et al. (2015) study by adding operant aspects of food reinforcer efficacy to more fully characterize food cue reactivity (FCR). Specifically, we determined the extent to which the acquisition and extinction of food cues affected conditioned salivation and behavioral economic aspects of food reinforcer efficacy – demand and delay discounting (DD). These variables were compared at baseline, post-acquisition, and post-extinction of a conditioned visual food cue. Moreover, we aimed to determine the extent to which obesity status played a role in these relations.

Conditioned salivation. Under baseline conditions, there were no differences in swallowing response between healthy-weight and overweight/obese participants. Following acquisition (post-acquisition), both groups exhibited a significantly higher conditioned swallowing response (CR+) in the presence of a conditioned food cue (CS+). Importantly, there were no changes in swallowing rate in inhibitory conditioned stimuli (CS-) trials across any of the three conditions (baseline, post-acquisition, post-extinction) for both healthy-weight and overweight/obese groups, indicating that the conditioning procedure was differentially effective at producing CRs+. These findings replicate the Meyer et al. (2015) results, who found that obese individuals developed a CR+ following food cue acquisition. Notably, we also found that those in the healthy-weight group exhibited CRs+ after the acquisition phase, which was inconsistent with Meyer et al. (2015), who only reported acquisition in the obese group.

One potential reason for this inconsistent finding in the healthy-weight individuals in our study vs. the Meyer et al (2015) study may be due to the extended nature of the acquisition

procedure in the current study. We extended this procedure from nine (in Meyer et al., 2015) to 20 CS+ trials. This may suggest that healthy-weight participants require more CS+ trials to develop acquisition to food cues relative to obese participants. In other words, obese individuals condition visual stimuli to food more readily than healthy-weight individuals. However, due to the nature of our acquisition paradigm, we could not examine rate of acquisition to food cues between healthy-weight and overweight/obese participants. To do so, we would have needed to provide several unreinforced CS+ trials to quantify the CR+ to the CS+ *during* the acquisition procedure. Hanley and Garland (2019) were able to do this with a respondently-conditioned tone and air puff with human subjects' conditioned eye blink response. To examine rate of acquisition, their acquisition paradigm consisted of 70% reinforced (with air puff) and 30% unreinforced (without air puff) CS+ trials, with assessment during the unreinforced trials. Future researchers may wish to incorporate a similar procedure with cue and food pairings, such that the strength of the CS+ could be examined during the process of acquisition.

While both healthy-weight and overweight/obese participants exhibited a CR+ following acquisition, no group differences in the strength of those CRs+ were observed. These findings do not replicate the Meyer et al. (2015) study, potentially for reasons already discussed above. Since lean participants in the Meyer et al. (2015) study did not acquire a CR+ to the CS+ and the obese participants did, one interpretation of their data was that obese participants demonstrate higher physiological reactivity (classical conditioning) to food cues. Indeed, there is literature indicating that obese individuals exhibit greater salivary flow (physiological reactivity) relative to healthy-weight controls upon food cue exposure (Ferriday & Brunstorm, 2008; Jansen et al., 2003). Therefore, our findings are inconsistent with previous research on salivary flow.

However, there are important methodological differences to consider when comparing

the current study with previous FCR literature. For instance, in most FCR research, a food cue is rarely conditioned; rather an assumed food cue (e.g., food-related advertisements) is used to elicit behavioral responses. Thus, one explanation for the current study's findings is that because both healthy-weight and overweight/obese participants experienced the same extended acquisition paradigm, the learning history associated with the food cue was the same for both groups, resulting in similar CRs+. An obese person, for example, may have greater experiences with an assumed food cue (such as an ad), which could confound the interpretations of a higher conditioned response.

Another potential explanation for our contrasting results could simply be due to the limited trials of the acquisition test itself. While we did observe differences between baseline and acquisition with both groups, only 11 of the 44 participants showed stable responding during the acquisition test. Therefore, it is unknown whether the strength of those conditioned responses had reached a peak level. Further, the majority of overweight/obese participants that acquired a stable, peak swallowing response did so in CS+ trials 11-20. In other words, most overweight/obese participants did not exhibit stable CRs+ during the first 5 CS+ trials that comprised the acquisition test. Therefore, the acquisition test phase was likely too short to see such differences between groups. Perhaps by extending the acquisition test from 5 to 10 or 15 CS+ trails, the difference in strength of CRs+ could have been observed between healthy-weight and overweight/obese participants. Thus, a longer acquisition test phase should be considered for future research.

Following the extinction procedure, both healthy-weight and overweight/obese participants did not exhibit a weakened CR+ in the number of trials that were programmed for the study. Similar to the acquisition procedure, we extended the extinction procedure from three

(in Meyer et al., 2015) to 10 trials. Ten extinction trials, however, were not enough to extinguish CRs+. Our results provide additional support for findings in which extinction paradigms such as this may not fully extinguish CR+ or subjective ratings of cue-induced cravings in the allotted number of trials in a study (Meyer et al., 2015 and Van Gucht et al., 2010, respectively). For instance, Van Gucht et al. (2010) found that implementing an extinction procedure of eight CS+ trials to a cue previously paired with chocolate did not result in lower chocolate cravings. However, using counterconditioning by pairing the CS+ with a highly disliked stimulus (for 8 CS+ trials) led to the cessation of chocolate cravings.

In the real world, extinction of food cue-related stimuli depends highly on the extent to which someone will turn down the food when the cue is presented, which may be unlikely for some. Even if rejection (i.e., not eating) of food occurs, it is clear many trials would still be needed to extinguish a food cue. The number of trials, however, is not well characterized. Because there were not enough extinction trials in the current study, researchers could design future studies that examine extinction of food cues to completion that would be individualized for each participant. Resistance to extinction of conditioned food cues may be an important aspect of obesity status as well.

Demand elasticity and intensity. Following acquisition, food cue exposure altered demand elasticity (sensitivity to effort) and intensity (consumption at the lowest price) for both healthy-weight and overweight/obese participants. Specifically, our results indicate that conditioned food cues decreased elasticity of demand – making food more inelastic to price. In other words, higher prices for food were tolerated when food cues were presented. In addition, conditioned food cues increased demand intensity, inducing more consumption of food at lower prices. These data suggest that the conditioned food cues potentiated the reinforcing properties of

food at both lower and higher prices. To our knowledge, this is the first report of food-cue induced changes in demand elasticity and intensity with food cues that are conditioned in a laboratory setting.

Similar to the CR+ data, the changes in demand elasticity and intensity were not reduced after the extinction paradigm, providing additional support for the use of an extended extinction procedure. Interestingly, following extinction, participants demonstrated even *less* sensitivity to price increases (i.e., greater inelasticity). This finding was unexpected and suggests that the extinction procedure – food cue exposure without M&M® reinforcement – further decreased elasticity (i.e., made sensitivity to price decrease). One important methodological factor may explain this finding – deprivation. The extinction procedure consisted of 40 CS trials in which participants experienced 20 CS+ (without reinforcement) and 20 CS- trials; this took 24 minutes to complete. One hypothesis is that deprivation of food across extinction played a role in decreasing elasticity. Indeed, other studies with deprivation and elasticity have shown that demand is more inelastic following periods of deprivation or withdrawal (Jensen M.B, et al., 2004 and Wade-Galuska, T., et al., 2011, respectively). One way to control for deprivation would be to test early in the experimental session after extinction has ensued. A simple way to do this might be to conduct the extinction trials in one session and then test the CS+ for extinction at the beginning of a new session the next day. This could reduce retention of participants, however.

Across conditions, no group differences were observed for food demand elasticity or intensity, meaning that upon food cue exposure, all participants were equally sensitive to price increases and were willing to purchase similar amounts of their favorite food at the lowest price. This finding is consistent with Rasmussen et al. (2010 and 2012) studies in which lean and obese

Zucker rats show similarity in elasticity. This finding is inconsistent, however, with previous food demand literature that compares reinforcer value between healthy-weight and obese participants, in which food has greater reinforcer value for obese individuals compared to healthy-weight individuals (Epstein et al., 2007; Giesen et al., 2010; Jacobs & Wagner, 1984; Saelens & Epstein, 1996; Temple et al., 2008).

Important methodological and analytic differences exist between the current study and other food demand studies, however. For instance, the current study used the Food Purchasing Task, which is a self-report measure that uses hypothetical food and monetary price for food as an independent variable. The applied studies referenced above used concurrent choice tasks in which participants responded for either real food options or sedentary activities (i.e., reading the news) via effort-based (fixed and progressive ratio) schedules (Epstein et al., 2007; Giessen et al., 2010; Saelens and Epstein, 1996). In these studies, reinforcer value is also relative because of the choice option.

While hypothetical and actual measures of demand are correlated (Amlung et al., 2012; Wilson et al., 2016, respectively), Epstein et al. (2018) found that real and hypothetical food demand measures could potentially be independent predictors of BMI. For instance, BMI was highly dependent on breakpoint (the ratio at which discontinuation of responding occurs during progressive ratio schedules; high break point = higher reinforcer valuation) for those with low demand intensity, such that those with low intensity scores only have high BMI if they have high breakpoints. By adding breakpoint to our methodology, we may have been able to control for this possible interaction to determine more distinct differences in reinforcer value between healthy-weight and overweight/obese participants.

Additionally, the current study also used the exponential demand equation to characterize data, which relies on logarithmically scaled differences in price and consumption, whereas the majority of applied studies use linearly scaled differences at lower ranges of price. Regardless of weight status, our results add to the body of literature on food-cue induced increases in FCR by incorporating a measure of reinforcer efficacy that is based on motivation in terms of sensitivity to increasing prices and consumption of food when it is highly available (i.e., lowest price).

Delay discounting. Food delay discounting (DD) did not change across any condition despite developing a CR+ in the presence of the CS+. This then may provide evidence that temporal choice patterns are less sensitive to exposure to conditioned food cues. To our knowledge, we are the first to report such findings. Further, there were no differences between healthy-weight and overweight/obese participants in DD for food. This finding does not replicate previous literature, which shows that obese participants discount food more steeply than lean participants (Rasmussen et al., 2010a; Hendrickson & Rasmussen, 2013; Hendrickson et al., 2015). An explanation for this unique finding, however, may be that grouping the overweight participants with the obese participants obscured discounting differences between the leanest and most obese participants. Indeed, Rasmussen et al. (2010a) examined food DD between the top (highest BMI) and bottom (lowest BMI) quartile and found differences in food discounting rates. However, it should be noted that the Rasmussen et al. (2010a) DD task was different than the current study DD task. Rasmussen et al. (2010a) used a titration discounting task, in which participants chose between small, standardized bites of food now vs 10 bites of food after five delays (1, 2, 5, 10, and 20 h). On subsequent questions, the smaller amount was titrated (increased or decreased) until an indifference point was found. Nonetheless, a study which

includes only obese participants as a comparison group would be needed to more conclusively state that there were not differences based on obesity status.

Relations of dependent variables. None of the main dependent variables were significantly associated with one another following acquisition, meaning that CRs+, demand elasticity and intensity values, and discounting values were not correlated after the acquisition procedure. For discounting values, this finding was expected due to discounting rates remaining unaffected when the conditioned food cue was present. It was unexpected, however, that CRs+ and demand values were not associated with one another, considering all variables were significantly altered following acquisition. Further, demand elasticity and intensity scores were not significantly associated.

Since we are the first (to our knowledge) to examine CRs+ and measures of reinforcer efficacy following conditioned food cue exposure, it is unknown whether these variables are related. More research is needed in this are to clarify such relation. Further, of the studies examining demand elasticity and intensity, associations between elasticity and intensity are often not reported. When this association is reported, it is not significant (e.g., Bruner &Johnson, 2014). These findings suggest that even though these aspects of FCR were affected by food cues, they are independent behaviors.

Limitations and conclusion. There were some limitations to this study. For instance, we only recruited female participants (due to electrode placement), and, therefore, could not compare possible gender differences. However, gender differences in FCR are not supported by a meta-analysis (Boswell & Kober, 2016), in which mixed-gender samples yield similar results as female-only samples. Nonetheless, future research should replicate and extend this study by incorporating a more diverse sample. Additionally, this study did not address how appetitive

M&M® candies were to the participants. By incorporating a hedonic food scale (e.g., 9-Point Hedonic Scale) as part of the eligibility criteria, this would ensure that all participants have the possibility to develop a CR+ during the acquisition paradigm and that food-related decisions (i.e., demand and DD for food) reflect food that is reinforcing. Another option is to allow participants to select their own preferred food from a range of others, though that may contribute variation in the intensity of the salivation response.

Further, because data were collected across all hours of the day (e.g., 8:00am – 8:00pm), chronotype – an individual attribute that reflects preference of timing for behaviors such as eating, physical activity, and sleeping (Beaulieu, et al., 2020) – and day timing (morning vs. evening) may be potential sources of variability. For instance, Beaulieu et al. (2020) found that overall appetite, regardless of chronotype, was lowest in the morning compared to evening and that a test meal was more filling in the morning compared to evening, with morning chronotypes feeling fuller than late chronotypes. Further, both food-liking and food-wanting scores were lowest in the morning and highest in the evening, with the highest values reported by late chronotypes. Indeed, peak food-liking and food-wanting is greatest from 5:00pm – 9:00pm (Byrne & Murray, 2017; Murray, et al., 2009). Late chronotype is also associated with an increased likelihood of developing obesity, less-healthy eating behaviors, and less-healthy lifestyles overall (Mota et al., 2016). Thus, it is unclear if time of day or chronotype may have obscured differences in CR+ acquisition or extinction, demand for food, and food discounting. Therefore, future research should examine time of day and chronotype as potential mechanisms for FCR to hedonic food cues.

As mentioned, our study was also limited in terms of allowing enough trials for extinction to occur. Though we extended the number of trials compared to the Meyer et al.

(2015) study, these trials were not sufficient to observe extinction. Future research should continue to present the CS+ without the US for each individual until extinction occurs in a stable manner.

In summary, our results suggest that conditioned food cues increase physiological responses measured by conditioned salivation and potentiate food reinforcer efficacy as measured by demand elasticity and intensity, but not DD for food. Therefore, food cues contribute somewhat to the reinforcer pathology model. There are several implications to our findings. For instance, conditioned food cues may not only momentarily alter the cephalic response to food (as measured by salivation) and reinforcer value (as measured by economic demand), but this effect may be persistent. Our results suggest that extinction of food cues and the potential effects on demand may take substantially longer than the acquisition of food cues. These findings replicate and extend by contributing to the food cue literature, such that food cues alter physiological processes such as salivation but also impact decision-making associated with food prices and availability. Finally, comparing the relations of conditioned salivation, demand, and DD for food in individuals who have FCR, such as those with binge eating disorder, may allow the cephalic and reinforcing properties of food to be better understood in these individuals.

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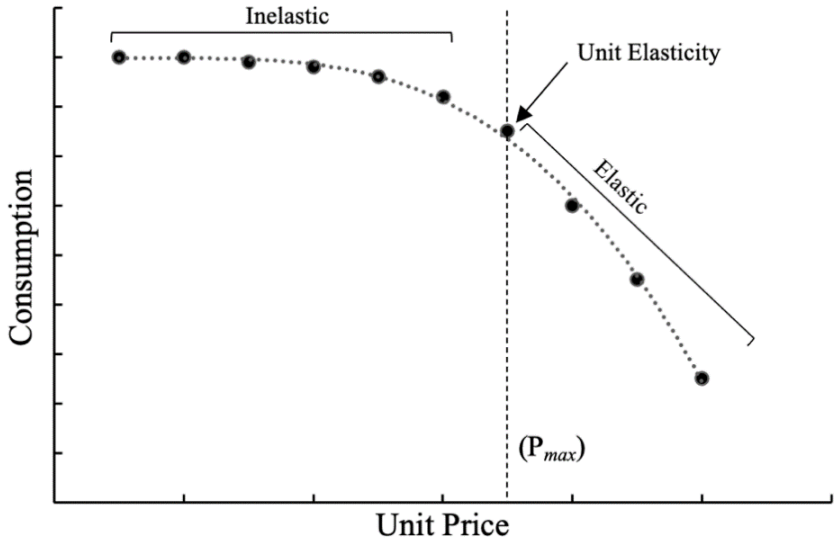


Figure 1. A hypothetical demand curve describing the relationship between consumption and increasing unit price. The point at which consumption becomes sensitive to increasing prices is referred to as unit elasticity.

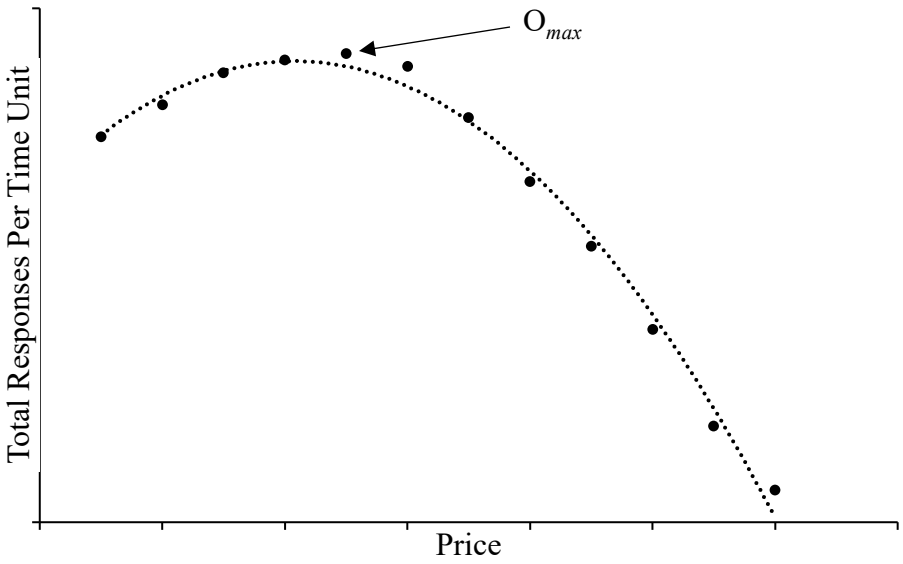


Figure 2. A hypothetical demand curve describing output as a function of increasing price. between consumption and increasing unit price. As price increases, responding increases initially as a result of higher response requirements (O_{max}) but eventually starts to decrease at higher prices.

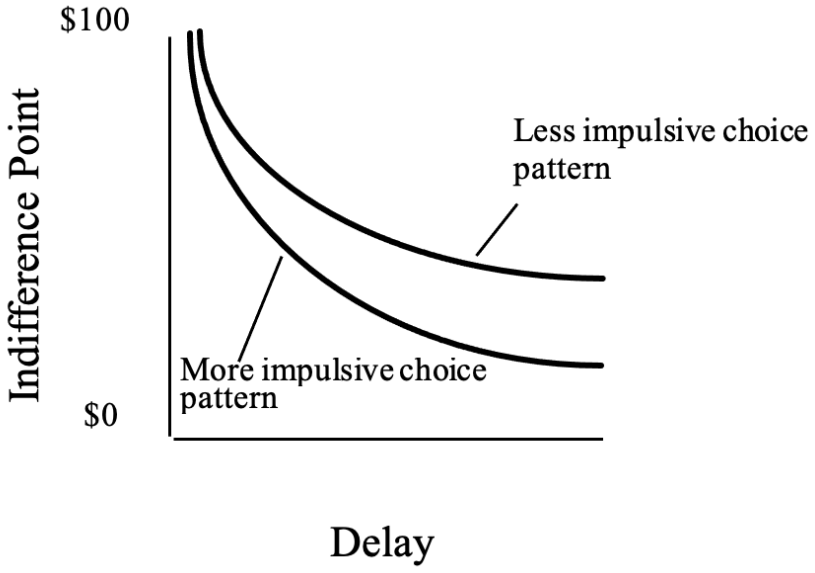


Figure 3. This graph demonstrates how indifference points decrease as the delay increases. That is, as delay for receiving a reward increases, the subjective values tend to diminish. In this graph, hypothetical data are shown for two individuals: one exhibiting a more impulsive choice pattern, and one demonstrating a less impulsive choice pattern.

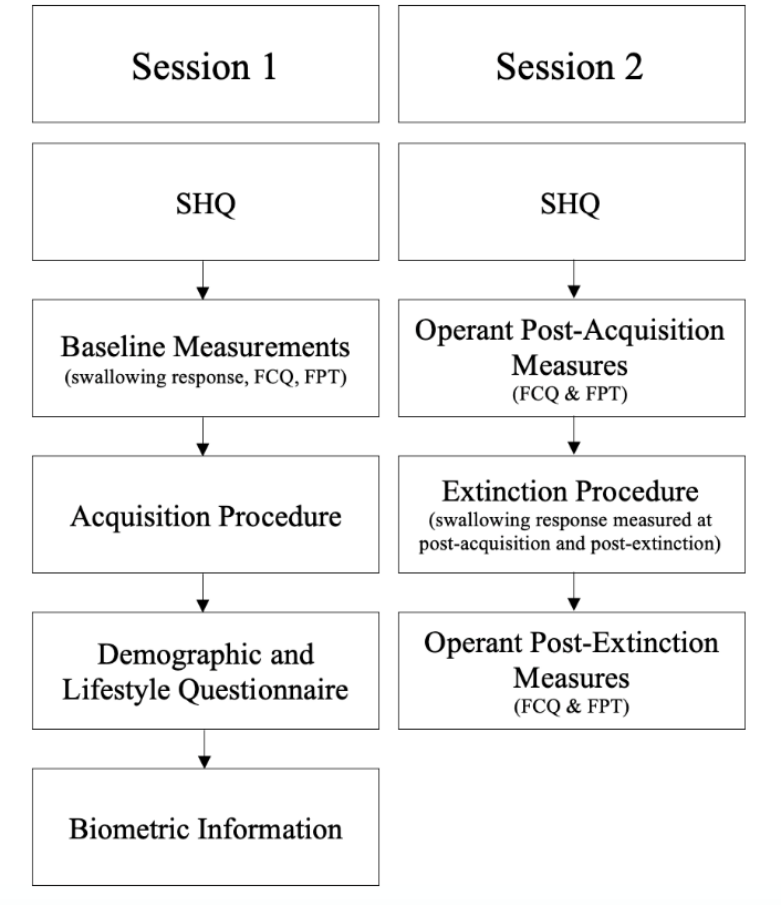


Figure 4. Procedural flow chart for Session 1and Session 2.

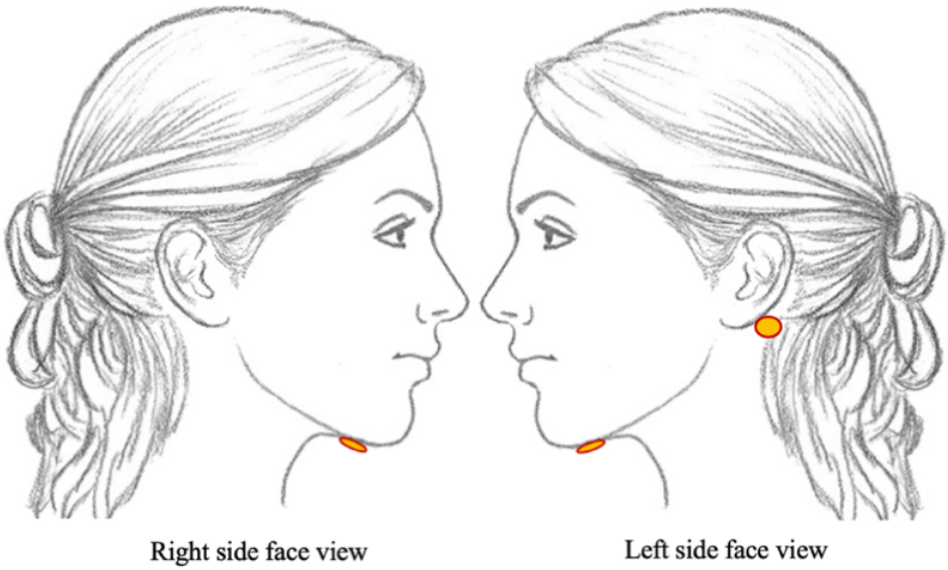


Figure 5. Placement of electrodes on particiapnts. Two electrodes were placed one cm apart under the participant's jaw and one electrode was placed behind the participant's left ear on the mastoid bone.

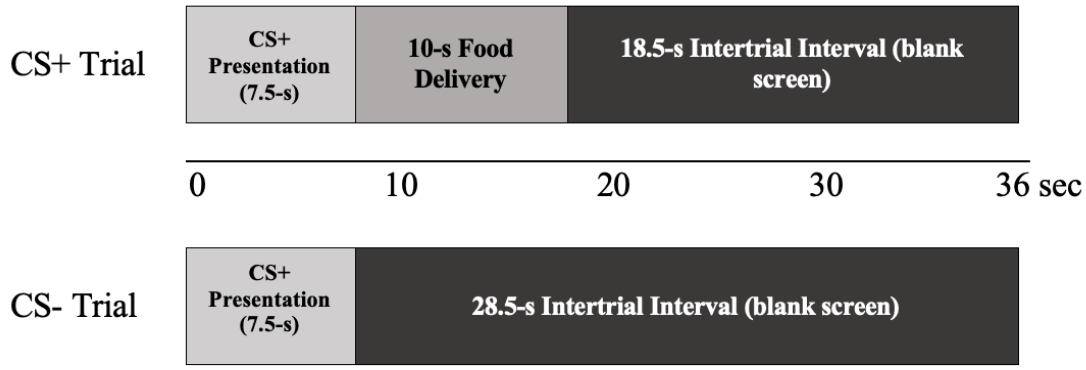


Figure 6. Procedures for CS+ presentation (top) and CS- (bottom) presentation. For CS+ presentations, the stimulus was presented for 7.5 s, then a piece of M&M® candy was delivered during the 10 s food delivery. An 18.5 s ITI followed (36 seconds total). For each CS- presentation, the CS- was presented for 7.5 s, but no food delivery followed. A 28.5 s ITI took place for each CS- presentation (36 seconds total).

Acquisition Procedure	20 CS+ and 20 CS- trials		
Extinction Procedure	**Acquisition Test** Block 1 (first block) 5 CS+ and 5 CS- trials	**Extinction** Block 2 10 CS+ and 10 CS- trials	**Post-Extinction Test** Block 3 (last block) 5 CS+ and 5 CS- trials

Figure 7. Visual representation of the acquisition and extinction paradigm. During the acquisition procedure, 20 CS+ and 20 CS- trials were administered. During the extinction procedure, the acquisition test consisted of the first 5 CS+ and 5 CS- trials (first block). This was followed by the extinction trials (10 CS+ and 10 CS- trials). The post-extinction test consisted of the last 5 CS+ and 5 CS- trials (last block).

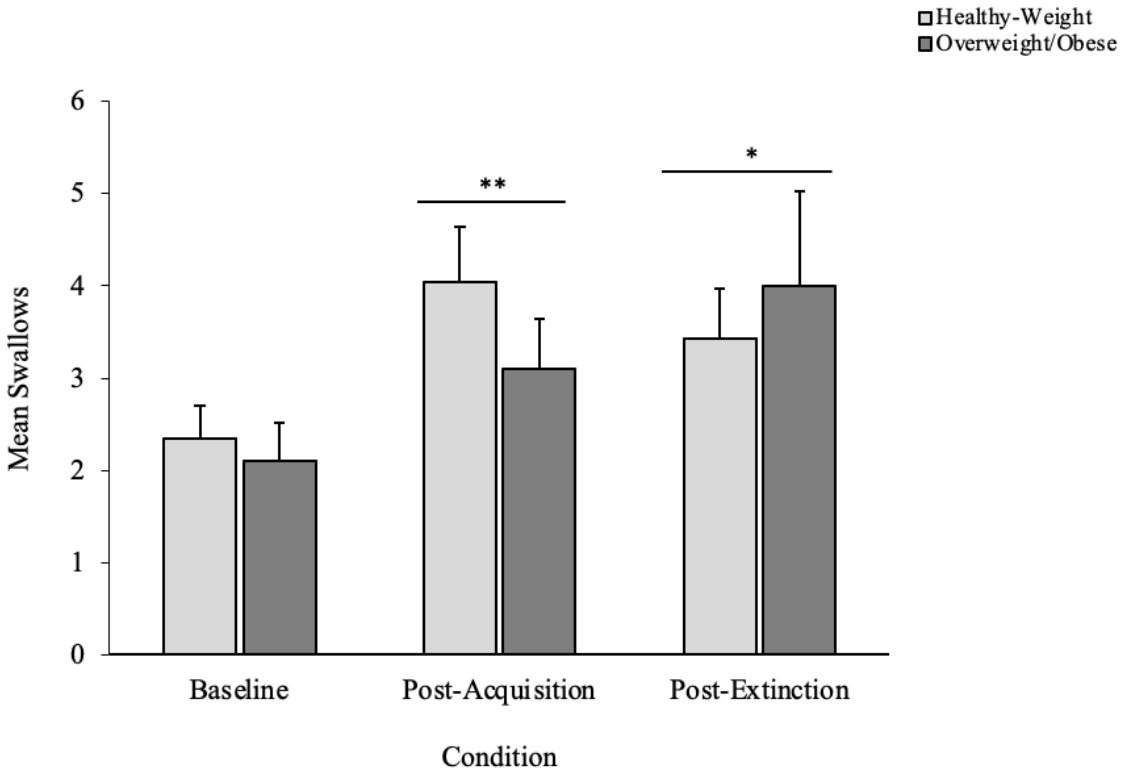


Figure 8. Mean swallowing (CR+) during CS+ trials as a function of conditioning phase and obesity status. Error bars represent 1 SEM.
* $p < 0.05$; ** $p < 0.01$.

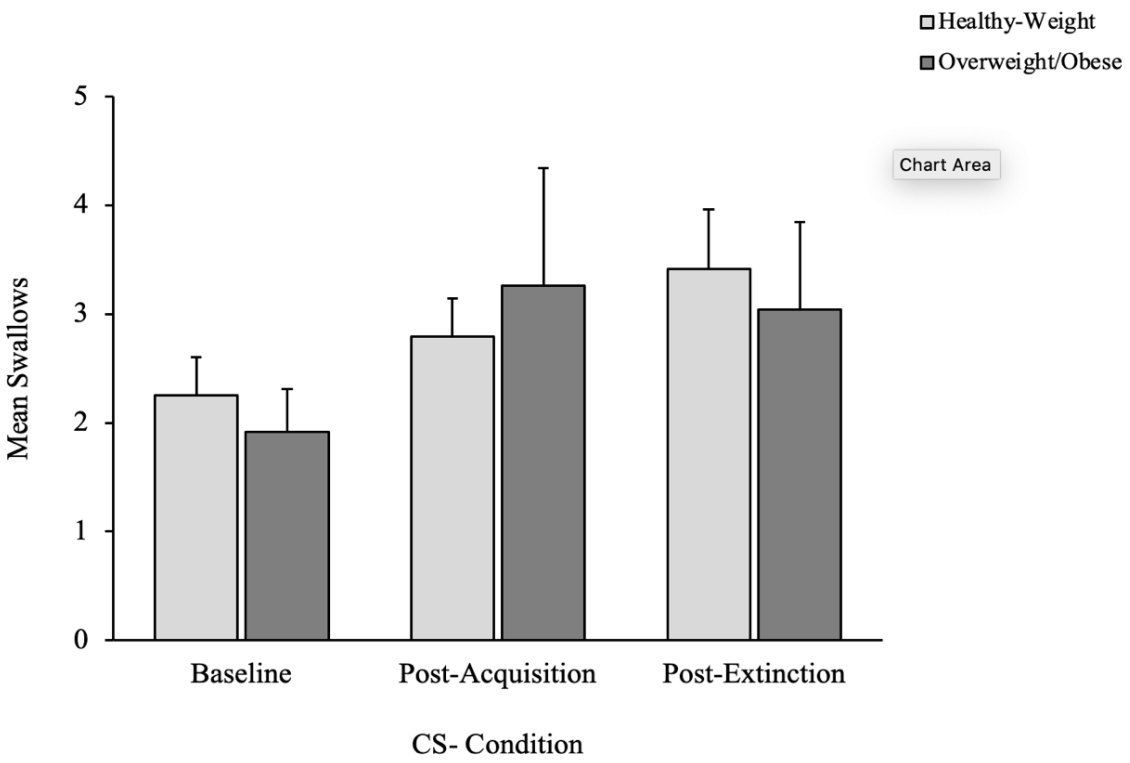


Figure 9. Mean swallows (CR+) during CS- trials as a function of conditioning phase and obesity status. Error bars represent 1 SEM.

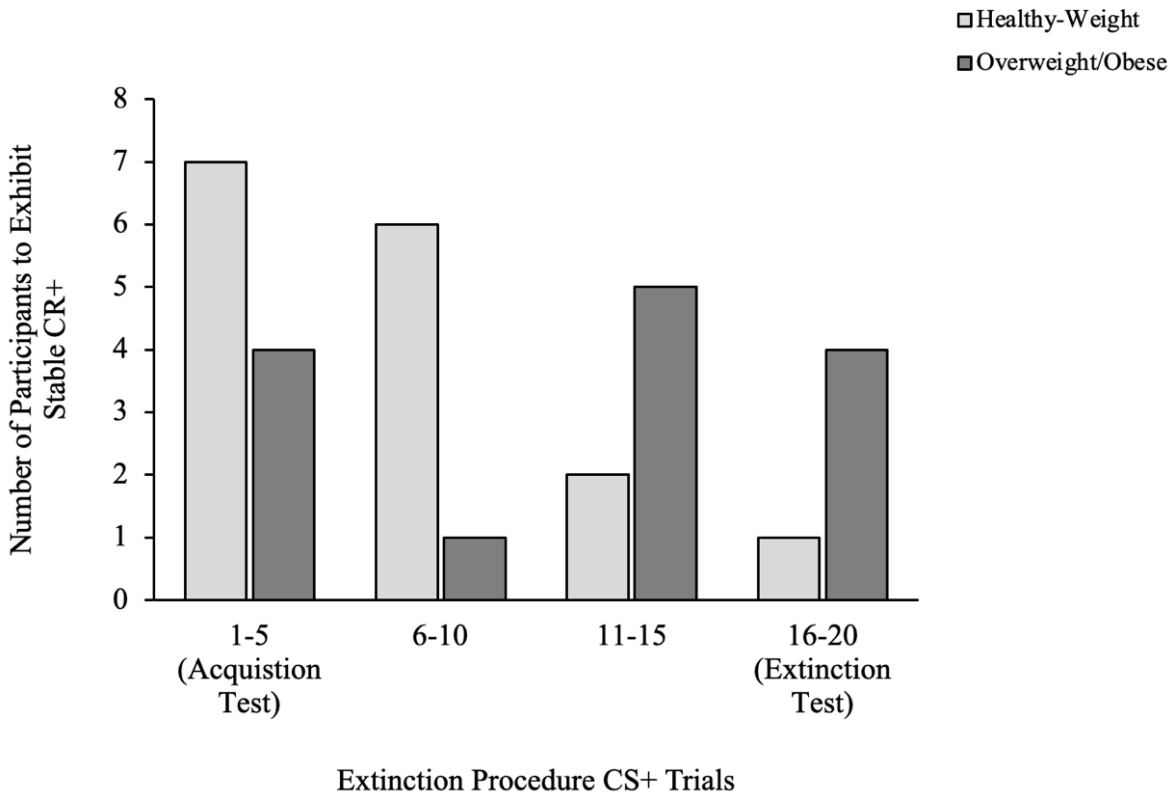


Figure 10. Number of healthy-weight and overweight/obese participants that exhibited a stable CR+ during the extinction procedure.

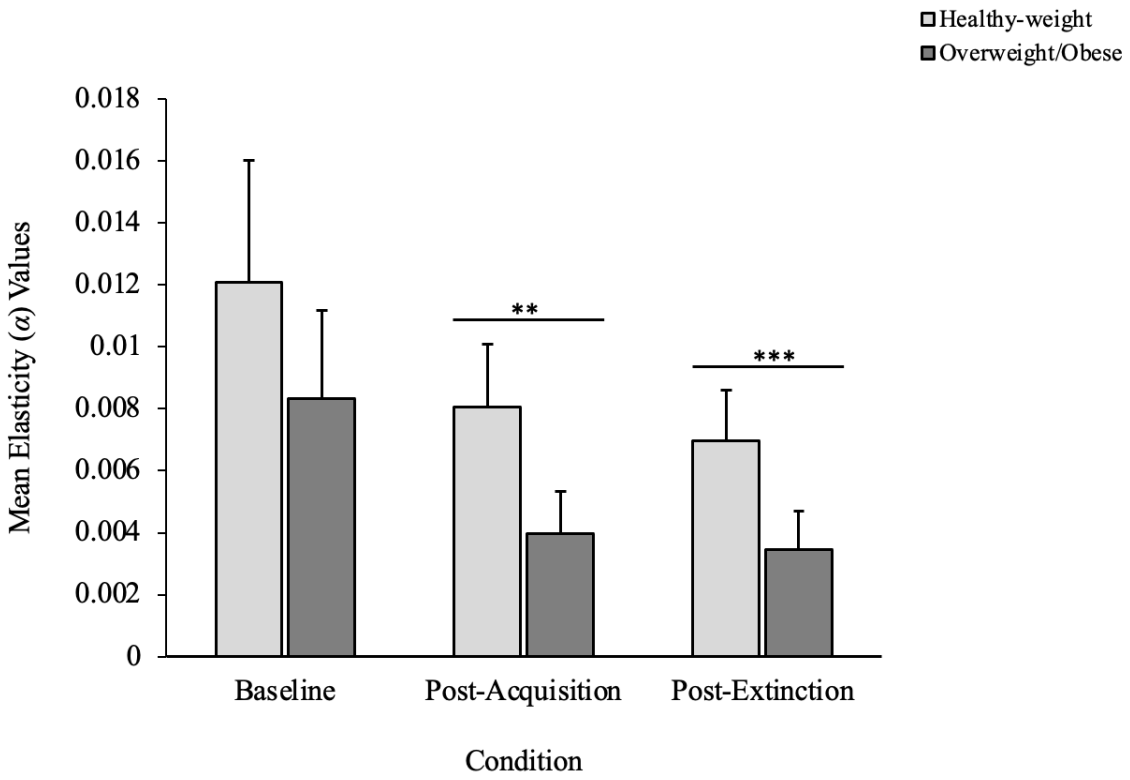


Figure 11. Mean demand elasticity (α values) as a function of condition and obesity status. Error bars represent 1 SEM.
** $p < 0.01$; *** $p < 0.001$.

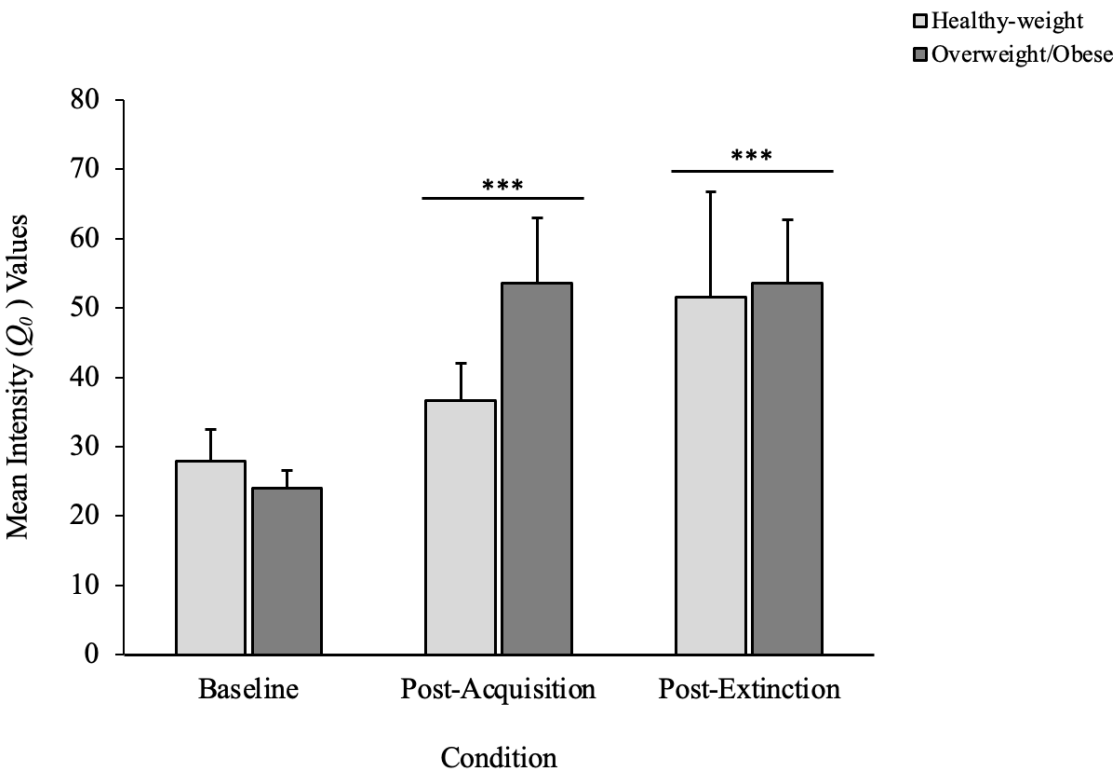


Figure 12. Mean demand intensity (Q_0 values) as a function of condition and obesity status. Error bars represent 1 SEM.
*** $p = < 0.001$.

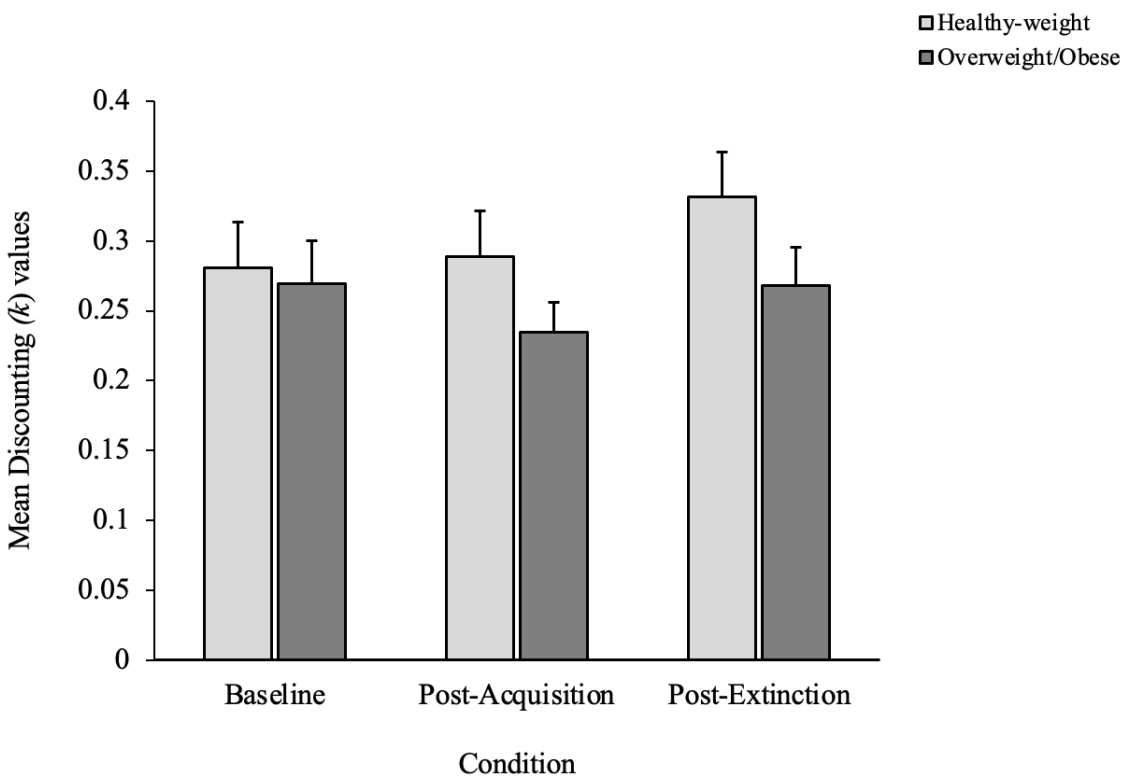


Figure 13. Mean food DD (*k* values) as a function of condition and obesity status. Error bars represent 1 SEM.

Table 1
Participant Characteristics

Characteristic	Total (n = 47) Mean (SE)	Healthy-weight (n = 24) Mean (SE)	Overweight/ Obese (n = 23) Mean (SE)	p
Age (years)	21.49 (.95)	20.92 (1.02)	22.09 (1.65)	0.55
% White[a]	77%	83%	70%	0.27
% Income > 70,000[a]	40%	46%	35%	0.44
Weight (kg)	71.92 (2.96)	56.69 (1.25)	87.81 (3.63)	< 0.001*
BMI (kg/m^2)	26.38 (1.06)	20.97 (0.38)	32.02 (1.35)	< 0.001*
% Body Fat	32.15 (1.44)	24.15 (1.02)	40.50 (1.21)	< 0.001*
Waist Circumference (cm)	81.30 (2.34)	69.33 (1.06)	93.78 (2.88)	< 0.001*
Subjective Hunger (0-100)				
Session 1	41.28 (4.15)	48.96 (5.93)	33.26 (5.45)	0.06
Session 2	44.89 (3.99)	51.67 (5.84)	37.83 (5.13)	0.08
Hours Since Last Meal				
Session 1	7.49 (0.77)	7.27 (1.00)	7.72 (1.21)	0.78
Session 2	7.59 (0.74)	8.18 (1.00)	6.98 (1.11)	0.42
Hours Since Last Snack				
Session 1	6.83 (0.72)	6.44 (0.92)	7.24 (1.13)	0.59
Session 2	6.41 (0.69)	6.33 (0.91)	6.50 (1.07)	0.91

[a]Largest group by percentage; *BMI*, Body Mass Index
* = $p < .001$

Table 2

Pearson's r correlations between dependent, health, and demographic variables across all participants at baseline

Variable	1.	2.	3.	4	5.	6.	7.	8.	9.
1. Age	-								
2. BMI (kg/m^2)	0.01	-							
3. % Body Fat	0.0	0.93**	-						
4. Waist Circumference (cm)	0.13	0.95**	0.93**	-					
5. CRs+ [log10 + 2 transformed]	-0.06	-0.09	-0.03	-0.06	-				
6. α Values [log10 transformed]	0.27	-0.05	-0.04	0.0	0.14	-			
7. Q_0 values [log10 transformed]	-0.09	-0.17	-0.13	-0.13	0.12	0.08	-		
8. k values [SQRT transformed]	-0.31*	-0.25	-0.04	-0.05	0.07	-0.14	-0.16	-	
9. Subjective Hunger	-0.16	-0.42**	-0.36*	-0.40*	-0.14	-0.07	0.05	0.23	-

*$p < 0.05$; **$p < 0.01$; *BMI,* Body Mass Index; *CRs+,* conditions swallowing responses; *α,* demand elasticity; Q_0, demand intensity; *k,* food discounting.

Table 3

Descriptive statistics for transformed CRs+ during CS+ and CS- trails between healthy-weight and overweight/obese participants

	Healthy-Weight (n = 23)					Overweight/Obese (n = 21)				
	Baseline CR+	CS+ Post-Acquisition CR+	CS- Post-Acquisition CR+	CS+ Post-Extinction CR+	CS- Post-Extinction CR+	Baseline CR+	CS+ Post-Acquisition CR+	CS- Post-Acquisition CR+	CS+ Post-Extinction CR+	CS- Post-Extinction CR+
Mean(*SE*)	0.60 (0.04)	0.74 (0.04)	0.66 (0.04)	0.70 (0.04)	0.70 (0.04)	0.57 (0.04)	0.66 (.05)	0.56 (0.05)	0.66 (0.05)	0.62 (0.05)
Range	0.30-0.90	0.30-1.11	0.30-0.85	0.30-1.11	0.48-1.15	0.30-0.90	0.30-1.00	0.30-0.95	0.30-0.95	0.30-0.95
Sum	13.88	16.91	15.15	15.88	16.08	11.92	13.80	10.58	13.17	12.35
Outliers[a]								1.28, 1.34	1.38	1.30

[a]Outliers = values > 3 standard deviations from mean were excluded in analysis; *CRs+*, conditioned swallowing response; *CS+*, stimulus that predicts food delivery; *CS-*, stimulus that does not predict food delivery

Table 4

Descriptive statistics for transformed α values across condition between healthy-weight and overweight/obese participants

	Healthy-Weight (n = 23)			Overweight/Obese (n = 22)		
	Baseline α values	Post-Acquisition α values	Post-Extinction α values	Baseline α values	Post-Acquisition α values	Post-Extinction α values
Mean (*SE*)	-2.24 (0.10)	-2.43 (0.14)	-2.46 (0.15)	-2.48 (0.62)	-2.72 (0.60)	-2.88 (0.70)
Range	-3.03--1.09	-4.58--1.49	-5.10--1.51	-3.03--1.09	-4.58--1.49	-5.10--1.51

α values, demand elasticity

Table 5

Descriptive statistics for transformed Q_0 values across condition between healthy-weight and overweight/obese participants

	Healthy-Weight (n = 23)			Overweight/Obese (n = 22)		
	Baseline Q_0 values	Post-Acquisition Q_0 values	Post-Extinction Q_0 values	Baseline Q_0 values	Post-Acquisition Q_0 values	Post-Extinction Q_0 values
Mean (*SE*)	1.34 (0.07)	1.48 (0.06)	1.55 (0.07)	1.32 (0.05)	1.61 (0.07)	1.59 (0.05)
Range	0.66-2.04	0.52-2.16	0.55-2.58	0.83-1.75	0.85-2.27	0.95-2.29

Q_0 values, demand intensity

Table 6

Descriptive statistics for transformed k values across condition between healthy-weight and overweight/obese participants

	Healthy-Weight (N)			Overweight/Obese (N)		
	Baseline *k* values	Post-Acquisition *k* values	Post-Extinction *k* values	Baseline *k* values	Post-Acquisition *k* values	Post-Extinction *k* values
Mean (*SE*)	0.51 (0.03)	0.52 (0.03)	0.56 (0.03)	0.50 (0.30)	0.47 (0.02)	0.50 (0.03)
Range	0.22-0.92	0.16-0.92	0.32-0.92	0.19-0.74	0.16-0.68	0.16-0.84

k values, food delay discounting

Appendix A: Informed Consent

Idaho State University
Human Subjects Committee
Informed Consent Form for Non-Medical Research

Cues and Decision Making

CONSENT TO PARTICIPATE IN RESEARCH
You are asked to participate in a research study conducted by Morgan Musquez and Erin B. Rasmussen, Ph.D. (208-282-5651), from the Department of Psychology at Idaho State University. You have been asked to participate in this research because you are 18 years or older and a student at Idaho State University and are fluent in English, do not have a current or past diagnosis of an eating disorder, current pregnancy, and/or a diagnosis of diabetes. Your participation in this research project is voluntary. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

1. **PURPOSE OF THE STUDY**
The purpose of this study is to examine responses to cue presentations. It also investigates patterns of food-related decision-making in adults.

2. **PROCEDURES**
If you volunteer to participate in this study, we would ask you to do the following: to not eat or drink anything two hours prior to beginning the study, to view visual images and complete several computerized questionnaires, including questions about your lifestyle, and to provide information on height, weight, and percent body fat. You will also be asked to eat some candy. All components of the study will be carried out in Garrison Hall room 504.

The first part of the study will present a series of pictures. You will be asked to eat small amounts of candy in some conditions. You will also be asked to complete a task on the computer regarding both hypothetical food and monetary rewards. Additionally, you will be asked to report information from several questionnaires on health/lifestyle habits. Finally, your height, weight, and body fat concentration will be measured. For accurate measurement, we will ask that you remove your shoes and socks momentarily while these data are collected. Body fat concentration will be assessed using a scale so no invasive procedures (like calipers) will be used. Full participation should take no longer than 60 minutes. You will receive 1 unit of credit for each ½ hour you participate.

3. **POTENTIAL RISKS AND DISCOMFORTS**
The only foreseeable risk is mild discomfort when answering questions regarding lifestyle related issues or mild discomfort associated with being weighed.

4. **ANTICIPATED BENEFITS TO SUBJECTS**
Participants will receive research credit upon completion of their participation in the study. Otherwise, there are no anticipated benefits.

5. **ANTICIPATED BENEFITS TO SOCIETY**
The results of the current study will help to increase our understanding of food related decision making.

6. **ALTERNATIVES TO PARTICIPATION**
Individuals are not obligated to participate in this research study.

7. **PAYMENT FOR PARTICIPATION**
You will receive 1 credit for every ½ hour of participation in this study. We expect most participants to earn about 1½ - 2 hours of credit.

8. **FINANCIAL OBLIGATIONS**
There are no financial obligations for participants.

9. **EMERGENCY CARE AND COMPENSATION FOR INJURY**
No element of this protocol places subjects in physical danger. If someone is injured during participation, standard emergency care (e.g., an ambulance) will be solicited. The subject will be solely responsible for costs of any medical care. No compensation is available for out-of-pocket expenses or lost wages if they suffer a research-related injury.

10. **PRIVACY AND CONFIDENTIALITY**
No personal identifiers will be associated with any of the data collected so your identity cannot be associated with your responses. The researchers will not disclose any of the information you provide with others without your written concent, unless required by law.

11. **PARTICIPATION AND WITHDRAWAL**
Your participation in this research is VOLUNTARY. If you choose not to participate, that will not affect your relationship with Idaho State University, or your right to receive services at Idaho State University to which you are otherwise entitled. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without prejudice to your future at Idaho State University.

12. **WITHDRAWAL OF PARTICIPATION BY THE INVESTIGATOR**
The investigators and/or the sponsor may stop your participation in this study at any time if circumstances arise which warrant doing so. The investigators will make the decision and let you know if it is not possible for you to continue. The decision may be made either to protect your health and welfare, or because it is part of the research plan. You may also be forced to withdraw if you do not follow the investigator's instructions.

13. **IDENTIFICATION OF INVESTIGATORS**
In the event of a research related injury or if you experience an adverse reaction, please immediately contact one of the investigators listed below. If you have any questions about the research, please feel free to contact Morgan Musquez or Erin B. Rasmussen, Ph.D., Garrison Hall, Campus Box 8112, Idaho State University, Pocatello, ID 83201-8112; (208) 282-5651.

14. **RIGHTS OF RESEARCH SUBJECTS**
You may withdraw your consent at any time and discontinue participation without penalty. If you have any questions regarding your rights as a research subject, you may contact the Human Subjects Committee office at 282-2179 or by writing to the Human Subjects Committee at Idaho State University, Mail Stop 8130, Pocatello, ID 83209.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE
I have read (or someone has read to me) the information provided above. I have been given an opportunity to ask questions, and all of my questions have been answered to my satisfaction. I have been given a copy of the informed consent form.

BY SIGNING THIS FORM, I WILLINGLY AGREE TO PARTICIPATE IN THE RESEARCH IT DESCRIBES.

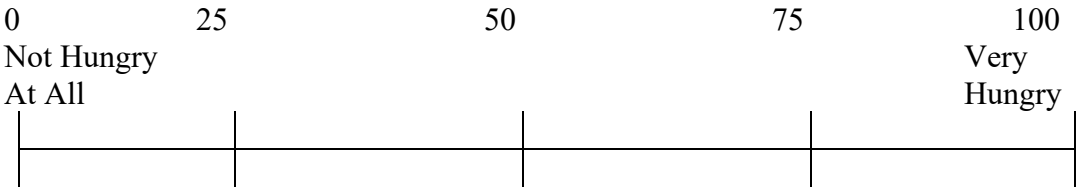
Participant's Signature: _____ Date: _____

Appendix B: Subjective Hunger Assessment

Subjective Hunger Questionnaire

1. How long ago was your last full meal? _____
2. How long has it been since you had anything at all to eat (e.g., a snack)? _____

Using the scale below, circle how hungry do you feel right now?



Appendix C: Food Choice Questionnaire

Kirby for Food

In the task that follows, you will have the opportunity to choose between food amounts after different delays. For this task, imagine the block in front of you as 1 standardized bite of your favorite food. Answer the questions as if what you would eat would be your favorite kind of food and as if the only options you would have to choose from would be those in the question. Please take the choices seriously. The reward choices are written on this form. Circle your reward choice for each question and answer every question as though you will actually receive that choice. The choices you make are up to you.

1.	Would you prefer	**19 bites now**	or	**30 bites in 23 hours?**
2.	Would you prefer	**20 bites now**	or	**40 bites in 5 hours?**
3.	Would you prefer	**4 bites now**	or	**8 bites in 5 hours?**
4.	Would you prefer	**35 bites now**	or	**50 bites in 30 minutes**
5.	Would you prefer	**5 bites now**	or	**8 bites in 1.5 hours?**
6.	Would you prefer	**11 bites now**	or	**25 bites in 15 hours?**
7.	Would you prefer	**9 bites now**	or	**13 bites in 1 hour?**
8.	Would you prefer	**24 bites now**	or	**35 bites in 1 hour?**
9.	Would you prefer	**28 bites now**	or	**45 bites in 24 hours?**
10.	Would you prefer	**15 bites now**	or	**30 bites in 5 hours?**
11.	Would you prefer	**7 bites now**	or	**10 bites in 30 minutes?**
12.	Would you prefer	**17 bites now**	or	**40 bites in 10 hours?**
13.	Would you prefer	**5 bites now**	or	**8 bites in 24 hours?**
14.	Would you prefer	**16 bites now**	or	**25 bites in 1.5 hours**
15.	Would you prefer	**23 bites now**	or	**50 bites in 7 hours?**
16.	Would you prefer	**15 bites now**	or	**35 bites in 8 hours?**
17.	Would you prefer	**22 bites now**	or	**50 bites in 15 hours?**
18.	Would you prefer	**8 bites now**	or	**13 bites in 2 hours?**
19.	Would you prefer	**31 bites now**	or	**45 bites in 1 hour?**
20.	Would you prefer	**4 bites now**	or	**10 bites in 17 hours?**
21.	Would you prefer	**14 bites now**	or	**25 bites in 2.5 hours?**
22.	Would you prefer	**5 bites now**	or	**10 bites in 6 hours?**
23.	Would you prefer	**25.5 bites now**	or	**40 bites in 1.5 hours?**

24. Would you prefer **15 bites now** or **35 bites in 10 hours?**
25. Would you prefer **25 bites now** or **45 bites in 2.5 hours?**
26. Would you prefer **5 bites now** or **13 bites in 12 hours?**
27. Would you prefer **21 bites now** or **30 bites in 0.5 hours?**

Appendix D

Food Purchasing Task

Imagine a TYPICAL DAY during which you eat snack foods. The following questions ask **how many servings of the snack food in front of you** would consume if they cost various amounts of money.

Assume a serving is equivalent to the amount in front of you.

The available snack food is _____ (preferred snack food).

Assume you have the same income/savings that you have now and NO ACCESS to any snack food other than the snack food offered at these prices. In addition, assume that you would consume the snack food that you request on that day; that is, you cannot save or stockpile snack food for a later date. Please respond to the questions honestly.

1. How servings of (preferred snack food) would you consume if they were **$0.01** each?
_____

2. How many servings of (preferred snack food) would you consume if they were **$0.05** each?
_____

3. How many servings of (preferred snack food) would you consume if they were **$0.13** each?
_____

4. How many servings of (preferred snack food) would you consume if they were **$0.25** each?
_____

5. How many servings of (preferred snack food) would you consume if they were **$0.50** each?
_____

6. How many servings of (preferred snack food) would you consume if they were **$1** each?
_____

7. How many servings of (preferred snack food) would you consume if they were **$2** each?
_____

8. How many servings of (preferred snack food) would you consume if they were **$3** each?
_____

9. How many servings of (preferred snack food) would you consume if they were **$4** each?
_____

10. How many servings of (preferred snack food) would you consume if they were **$5** each?
_____

11. How many servings of (preferred snack food) would you consume if they were **$6** each?
_____

12. How many servings of (preferred snack food) would you consume if they were **$11** each?
_____

13. How many servings of (preferred snack food) would you consume if they were **$35** each?
_____

14. How many servings of (preferred snack food) would you consume if they were **$70** each?
_____

15. How many servings of (preferred snack food) would you consume if they were **$140** each?
_____

16. How many servings of (preferred snack food) would you consume if they were **$280** each?
_____

17. How many servings of (preferred snack food) would you consume if they were **$560** each?
_____

18. How many servings of (preferred snack food) would you consume if they were **$1120** each?
_____

Appendix E: Demographics/Health questionnaire

PLEASE CIRCLE RESPONSE OR FILL IN THE BLANK WHERE INDICATED. Remember, your answers are anonymous and confidential.

1. What is your gender?
   a. Male
   b. Female

2. What is your age? ____

3. What is your ethnicity?
   a. Asian
   b. Black/ African American
   c. Hispanic/ Latino
   d. Native American
   e. White/ Caucasian
   f. Other

4. What is your religious affiliation? _____

5. Approximately what is your annual family income?
   a. Less than 10,000
   b. 10,000-20,000
   c. 20,000-30,000
   d. 30,000-40,000
   e. 40,000-50,000
   f. 50,000-60,000
   g. 60,000-70,000
   h. 70,000+

6. Do you smoke?
   a. Yes (continue to question 7)
   b. No (skip to question 14)

7. What tobacco product(s) do you typically use? _____

8. How many cigarettes do you smoke per day?
   a. 10 or less
   b. 11-20
   c. 21-30
   d. 31 or more

9. How soon after you wake up do you smoke your first cigarette?
   a. 0-5 minutes
   b. 30 minutes
   c. 31-60 minutes
   d. After 60 minutes

10. Do you find it difficult to refrain from smoking in places where smoking is not allowed (e.g., hospitals, government offices, cinemas, libraries, etc.?)
    a. Yes
    b. No

11. Do you smoke more during the first hours after waking up than during the rest of the day?
    a. Yes
    b. No

12. Which cigarette would you be the most willing to give up?
    a. First in the morning
    b. Any of the others

13. Do you smoke even when you are very ill?
    a. Yes
    b. No

14. How would you classify your exercise routine for a typical day?
    a. None
    b. Very light
    c. Light
    d. Moderate
    e. Vigorous

15. Which types of exercise do you typically engage in?

16. How long (in hours) do you engage in this/these exercise/s (per day)?

    _____

17. What is your best estimate for how many one-cup servings of grains (bread, cereal, pasta, rice, etc.) you eat per day?
    a. 1 or fewer
    b. 2-3
    c. 4-5
    d. 6 or more

18. What is your estimate for how many one-cup servings of fruits you eat per day (a piece of fruit is equal to a one-cup serving?)
    a. 1 or fewer
    b. 2-3
    c. 4-5
    d. 6 or more

19. What is your best estimate of how many one-cup servings of vegetables you eat per day?
    a. 1 or fewer
    b. 2-3
    c. 4-5
    d. 6 or more

20. What is your best estimate of how many one-cup servings of dairy products (milk, yogurt, cheese, etc.) you eat per day?
    a. 1 or fewer
    b. 2-3
    c. 4-5
    d. 6 or more

21. What is your best estimate of how many one-cup servings of protein (meat, fish, eggs, nuts, etc.) you eat per day?
    a. 1 or fewer
    b. 2-3
    c. 4-5
    d. 6 or more

22. What is your best estimate of how many servings of fats, oils, and sweets you eat per day?
    a. 1 or fewer
    b. 2-3
    c. 4-5
    d. 6 or more

23. Do you think you may have an eating disorder?
    a. Yes
    b. No

24. If you answered yes to questions 23, what eating disorder do you think you might have?
    ____ Anorexia Nervosa
    ____Bulimia Nervosa
    ____Binge Disorder
    ____Other (please specify): _____

25. Have you been diagnosed with an eating disorder within the past two years?
    a. Yes
    b. No

26. If you answered yes to question 25, please indicate which disorder you have been diagnosed:
    ____Anorexia Nervosa
    ____Bulimia Nervosa
    ____Binge Disorder
    ____Other (please specify): _____

27. How would you characterize the time it takes for you to complete a meal?
    a. 0-5 minutes
    b. 5-10 minutes
    c. 10-15 minutes
    d. 15-20 minutes
    e. 20-25 minutes
    f. 25-30 minutes
    g. 30-35 minutes
    h. Don’t know

Appendix F: Scripted Instructions read by Experimenter

Electromyograph Set Up Script

For the purposes of this study, I will place these two electrodes under your jaw and one electrode behind your left ear. The electrodes send small, painless electrical signals that you won't be able to feel. The electrodes will rest under your jaw and behind your ear for most of the procedure. You will be placed in a stationary chair and we ask that you try your best not to touch or move them at any point during the procedure.

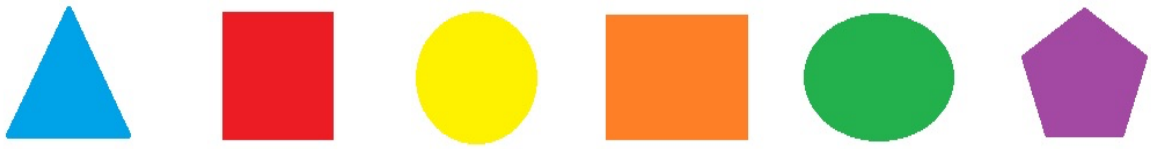
Conditioning Procedure Experimenter Script

In this procedure, you will be asked to view some images on this computer screen for certain periods of time. Occasionally, you will be instructed (on the computer screen) to eat a bite of chocolate. You will have 10 seconds, to eat the chocolate before moving on with the procedure. Pay close attention to the instructions on the computer. I will demonstrate a couple of example trials to show you how the procedure works. Do you have any questions?

Appendix G: **Body Measurement Instruction Sheet**

We will now be collecting information about your height, weight, body fat percentage, and waist circumference.This information will not be tied to you in anyway and will not be judged or scrutinized by the researcher. For this procedure you will need to take off your shoes and socks so that we are able to get an accurate height. Please also remove any extra clothing, like jackets, heavy sweaters, hats, etc. and remove any items in your pockets so that we are able to get an accurate measure of your weight and body fat percentage. For your waist circumference I will be using this measuring tape. We will have you face the wall away from the researcher and lift your shirt slightly so that we are able to get an accurate measure.

Appendix H: Visual Stimuli



Appendix I: Relations Between Main Dependent Variables

Pearson's r correlations between main dependent variables across all participants at post-acquisition

Variable	1.	2.	3.	4
1. CRs+ [log10 + 2 transformed]	-			
2. α Values [log10 transformed]	-0.19	-		
3. Q_0 values [log10 transformed]	-0.05	-0.15	-	
4. k values [SQRT transformed]	-0.08	0.05	0.15	-

CRs+, conditions swallowing responses; α, demand elasticity; Q_0, demand intensity; k, discounting.