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The Role of Impulsivity in Dietary Restraint and Counter-Regulation

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ABSTRACT PAGE

Dietary restraint, or chronically controlling one's weight through diet, is a difficult pursuit. When faced with tempting foods, only a minority of restrained eaters manage to regulate their intake. Impulsivity, a multidimensional construct implicated in addictive behaviors, may be a factor that predicts regulation. The goals of the current study were twofold: firstly, we examined the effect of consuming a diet-violating preload on state impulsivity, and secondly, we examined how dietary restraint and changes in state impulsivity interact to influence subsequent overeating. In a laboratory study, female participants (n= 146) with differing levels of dietary restraint provided measures of their state impulsiveness before and after consuming a 16oz preload of either a milkshake (High Calorie group) or water (Control group). The two state impulsivity subtypes assessed were inhibitory control, measured using the Stop Signal Task (SST), and food-specific impulsive choice, measured using a modified Delay Discounting Task. Results showed that after consuming a preload, all participants showed decreases in food-specific impulsive choice but not in inhibitory control. For those in the milkshake condition who were high in dietary restraint, higher initial inhibitory control and larger decreases in food-specific impulsive choice predicted lower subsequent caloric intake. No effects of impulsivity on consumption were seen for participants in the Control condition. These results suggest that subtypes of state impulsivity play differential roles in the eating behaviors of restrained eaters, and highlight important predictors of counter-regulation. Understanding the causal pathway between restraint and counter-regulation informs future directions in creating healthy eating interventions.

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The Role of Impulsivity in Dietary Restraint and Counter-Regulation

Obesity and its related health risks are prevalent issues nationwide (Low, Chin, & Deurenberg-Yap, 2009). To address this growing problem, experts typically advise limiting caloric intake and leading an active lifestyle (Rolls, Drewnowski, & Ledikwe, 2005; Panel, N.O.E.I.E, 1998). However, although public health campaigns have touted such guidelines for years, little progress has been made: an estimated 33.0% of U.S. adults remain overweight or obese and prevalence trends continue to climb (Fryar, Carroll, & Ogden, 2012). Given these dismal statistics, more effective weight loss strategies alongside a clearer understanding of the causes of weight gain are clearly needed. To this end, researchers have focused on behavioral characteristics that predispose individuals to food-related problems and factors that thwart an individual's attempts to lose excess weight.

Because energy imbalance is fundamentally responsible for excess weight gain (Hill, 2006), almost all weight-loss interventions involve some form of caloric restriction (Tsai & Wadden, 2005). Those actively on a reduced-calorie regime, or a diet, must employ cognitive methods to control their eating, and this chronic exertion of cognitive measures to restrict food intake and regulate weight is known as dietary restraint (Bublitz, Peracchio, & Block, 2010; Johnson, Pratt, & Wardle, 2012). Logically, dietary restraint should promote weight-loss, but its effectiveness has long been a point of controversy. Correlational studies frequently show that restrained eaters have higher BMIs and experience more frequent weight cycling than their unrestrained peers (Anthes, 2014; Mann et al., 2007; Williamson et al., 1995). Indeed, a literature review conducted by Mann et al. (2007) found that almost two-thirds of weight-loss intervention participants regained weight within two years post-intervention. Such findings are alarming because weight-cycling not only impedes weight-loss but also leads to metabolic dysregulation (Montani, Schutz, & Dulloo, 2015) and poor psychological health

(Brownell & Rodin, 1994). These paradoxical outcomes bring into question the reliability of dietary restraint as a weight-management strategy.

To explain this paradoxical phenomenon, Herman and Polivy (1985) conducted a series of experimental studies that demonstrated counter-regulated eating in restrained eaters. Using the preload-counter-regulation paradigm, their group was the first to discover that after consumption of a diet-violating preload, such as a high caloric milkshake, restrained eaters ate more in a subsequent eating episode than did unrestrained eaters. Herman and Polivy explained these findings using their Boundary Model of Restrained Eating, which posits that restrained eaters have strict, cognitive dietary boundaries that dichotomize diet-congruent and incongruent foods. In situations where that boundary is crossed—such as after consuming a high caloric food—restrained eaters overeat, or counter-regulate. Over time, these recurrent episodes of overeating lead to weight gain and may account for the ineffectiveness of dietary restraint in weight-regulation.

In the decades since Herman and Polivy's original study, researchers have added to their findings. Not only do restrained eaters eat more after a preload, they also increase attentional allocation to palatable food cues (Fedoroff, Polivy, & Herman, 1997), change their consumption patterns based on external cues such as the perceived healthfulness of a brand (Cavanaugh & Forestell, 2013), and increase their consumption simply after smelling or seeing a palatable food (Fedoroff et al., 2003; Jansen & Van den Hout, 1991). In a study examining the effects of effortful inhibition on chocolate consumption, participants who were asked to suppress their thoughts of chocolate for one task later expended more effort working for chocolate in another task (Johnston, Bulik, & Anstiss, 1999). Findings like these seem to suggest that dietary restraint might ultimately backfire and result in overeating and weight gain.

But recent studies have identified caveats to this counter-regulatory pattern. Some restrained eaters, it appears, *do* successfully self-regulate without weight-cycling (Wing & Hill, 2001). For example, Westenhoefer, Broeckmann, Munch, & Pudel (1994) found that only restrained eaters with high disinhibition scores overate after a milkshake preload (for contrary results, see Van Strien, Cleven, & Schippers, 2000), and successful restrained eaters are characterized by higher cognitive flexibility and lower BMIs (Timko & Perone, 2004; Westenhoefer, Stunkard, & Pudel, 1998). Lowe and Timko (2004) argued that a restrained eater's diet status moderates the counter-regulation effect: Restrained eaters currently on a diet (restrained dieters) tend to uphold rigid diet boundaries that predispose them to counter-regulation if they overstep those boundaries, but restrained eaters not on a diet (restrained non-dieters) don't have such strict boundaries, and as a result are not as prone to counter-regulation. Lowe's group also found that restrained dieters exhibit more weight-cycling than restrained non-dieters, further suggesting that diet intentions play an important role. All in all, these mixed findings suggest that restrained eaters comprise a more heterogeneous group than previously thought.

Given that some people do succeed in dietary restraint, researchers have sought to identify the factors that facilitate a successful versus an unsuccessful trajectory. From a health psychology and behavioral economics framework, weight regulation can be seen as the product of many decisions accrued over time (Tucker, Simpson, & Khodneva, 2010). The delayed reward of weight regulation constantly competes with immediate temptations, such as indulging in a high caloric food or lounging on the couch instead of hitting the gym, and an individual must inhibit impulses and uphold the foresight to strive for that future goal. Because those who are high in impulsivity are known to experience difficulties resisting these immediate rewards (Whiteside & Lynam, 2001), it has been suggested that impulsivity may serve as one mechanism that accounts for counter-regulatory behaviors in restrained eaters.

Impulsivity, broadly defined, is the tendency to act rashly and without forethought. Although seemingly a singular construct, experts stress the importance of recognizing impulsivity's multi-dimensional nature. Impulsivity consists of trait and behavioral subdivisions, and both can be further subdivided into individual sub-constructs. Trait impulsivity maintains stability over time and is comprised of three major domains: emotion-based urgency (tendency to act rashly while experiencing strong emotions), deficits in conscientiousness (lack of premeditation and perseverance), and sensation seeking (tendency to seek novel and thrilling experiences). Behavioral or state impulsivity, on the other hand, is much more context-based and is directly measurable using behavioral tasks (Smith et al., 2007). Its three major subtypes are impulsive choice or decision making (inability to delay rewards), inhibitory control (failure to inhibit a prepotent response), and reflective impulsivity (failure to evaluate before acting). Although some research has shown overlap between different impulsivity sub-constructs (Cyders & Coskunpinar, 2011), most agree that these measures are largely unrelated (Reynolds, Ortengren, Richards, & de Wit, 2006; Sharma, Markon, & Clark, 2014; Smith & Guller, 2015). It is therefore advised that researchers avoid referring to "impulsivity" as a general construct and instead specify specific subtypes of interest (Smith et al. 2007), although to date many continue to neglect these distinctions.

Health psychology and addiction research have consistently identified impulsivity's importance in self-regulatory behaviors (de Witt, 2009). Those with higher levels of trait impulsivity tend to show higher rates of alcohol or drug abuse (Dick et al., 2010), pathological gambling (Dussault, Brendgen, Vitaro, Wanner, & Tremblay, 2011), and overeating (Fischer, Smith, & Cyders 2008). Momentary increases in state impulsivity can also lead to lapses among those trying to control their impulsive behaviors (de Wit, 2009). To address the mechanics of these relationships, theories of delay discounting suggest that increased levels of impulsivity may obscure the benefits of a delayed reward—in this case weight loss—and increase the value of an immediately rewarding but ultimately detrimental alternative (Epstein, Salvy, Carr, Dearing, & Bickel, 2010). For example, an unsuccessful dieter may succumb to the allure of a doughnut in lieu of the healthier apple and regress from her long-term weight loss goals. This tendency to discount delayed rewards is a hallmark of impulsive behavior which, accrued over time, can lead to goal-opposing outcomes.

Thus, similar to the addiction literature, impulsivity seems to play a role in the development of maladaptive eating and related health outcomes. Impulsive individuals have higher BMI (Jasinska et al., 2012), make more unhealthy food choices (Jasinska et al., 2012; Mullan et al. 2014), and have higher disinhibition (Emery, King, & Levine 2014; Leitch, Morgan, & Yeomans, 2013). Studies conducted in controlled settings have found similar results, with impulsive individuals showing greater food cue reactivity (Bongers et al., 2014; Tetley, Brunstrom, & Griffiths, 2009), greater attentional bias for food cues (Hou et al., 2011), and consuming more calories in taste tests (Guerrieri, Nederkoorn, & Jansen, 2007; for alternate findings see Greenwood, Broadbent, & Fuller-Tyszkiewicz, 2014). Some researchers have also attempted to induce state impulsivity using motor-based techniques, and although the reliability of their findings remains questionable, they nonetheless suggest that heightened levels of state impulsivity directly lead to increased caloric intake (Guerrieri et al., 2009; 2012; Houben & Jansen, 2011).

Given its associations with maladaptive eating, it seems probable that impulsivity may influence counter-regulation in restrained eaters. Existing findings suggest that among restrained eaters, those with high impulsivity had higher BMIs (Keller & Siegrist, 2014), lost less weight in treatment programs (Best et al., 2012; Van Koningsbruggen, Stroebe, & Aarts 2013), and showed stronger associations between restraint and disinhibition than their low impulsivity peers (Emery, King, Levine, 2014). In particular, an investigation by Jansen et al. (2009) using the preload-counter-regulation paradigm found that in the control and the food cue exposure conditions, restrained eaters high in impulsive action ate more than others, suggesting that dietary restraint may interact with impulsivity to determine diet success.

However, despite the advances in our understanding of impulsivity's role in eating behaviors, some important gaps still remain. Firstly, most studies have drawn conclusions solely based on a single measure of impulsivity that, as mentioned previously, neglects its multidimensionality. This practice is especially problematic when researchers draw trait-wide conclusions based on a state impulsivity measure, which can vary widely depending on situational factors such as hunger (Read & van Leeuwen, 1998) or food environment (DeVoe, House, & Zhong, 2013). Jansen's investigation of counter-regulation (2009), for example, employed the Stop Signal Task (SST), a measure of state impulsive action, under different preload conditions to assess impulsivity as a trait. Because their preload manipulation may have affected SST performance, this confound may have attributed to their failure to detect counter-regulation in the high caloric preload condition, a hallmark of Restraint Theory. Studies that assessed baseline inhibitory control found that those with low inhibitory control were more susceptible to an impulsivity manipulation and overeating (Houben & Jansen, 2011), thus highlighting the importance of baseline measures. As de Witt argued in her review (2009), engagement in an unintended, impulsive behavior can increase state impulsivity, which in turn perpetuates that behavior, but the situational variation in behavioral impulsivity and how it relates to restraint and consumption has not been examined.

The current study investigated whether state and trait impulsivity moderate the relationship between dietary restraint and counter-regulation. Using the classic preload-taste test paradigm and a mixed design, participants consumed either a milkshake (high calorie diet-violation) known to trigger counter-regulation (Herman & Mack, 1975) or water (control). Afterwards, they engaged in a bogus taste test involving snacks ranging in healthfulness and caloric content, and counter-regulated eating was determined by comparing the number of calories consumed in the bogus taste test between the two conditions. To assess the role of impulsivity, a comprehensive battery of trait and state impulsivity measures were administered before preload consumption. To investigate whether the preload shifted state impulsivity, two behavioral tasks—the delayed discounting task and the stop signal task—that have minimal practice-effects (Logan & Burkell, 1986; Reynolds, 2006) were administered both before and after the preload manipulation. Based on existing literature, we formulated two hypotheses: first, 1) the preload would increase state impulsivity in those high in dietary restraint, and secondly, 2) only individuals who are high in dietary restraint and also high in trait impulsivity or showed increased state impulsivity would counter-regulate after a diet-violating preload. Results from the current investigation will extend the literature by exploring multiple impulsivity constructs and their roles in counter-regulation.

Method

Participants

Participants were recruited at a medium-sized mid-Atlantic liberal arts university. A total of 146 females between the ages 18-35 years and without relevant food allergies or dietary restrictions were invited to participate. Because dieting behaviors can differ between genders and across ages (Davis, Shapiro, Elliott, & Dionne, 1993; Fredrickson et al., 1998), these gender and age restrictions served to reduce variability in our analyses. The composition of our sample was 52.4% White, 19.0% Asian, 12.2% Black, 6.8% mixed, 2.7% Hispanic/Latino, 2.0% other, and 4.8% unknown, and the mean age was 19.38 (±1.85) years.

Prior to participation, all participants were informed that the study involved consuming foods and completing a series of computer tasks. All procedures were approved by the Protection of Human Subjects Committee, and electronic and written informed consent were obtained from each participant at the beginning of the study. Participants received $10 compensation or partial course credit for their involvement in the study.

Materials

Stimuli

Preload. Participants were randomly assigned to either the High Calorie or Control conditions. In the High Calorie condition, the preload consisted of 500mL of strawberry milkshake, which consisted of 585.4 Calories, while in the Control condition, participants received 500mL of spring water. Beverages were served in a 16 oz. red solo cup with a straw for easier consumption.

Stop Signal Task images. Stimuli for the Stop Signal Task were comprised of images of 10 neutral household items, 10 high calorie foods, and 10 low calorie foods drawn from the food-pics database (Blechert, Meule, Busch, & Ohla, 2014). The images in this database have been rated on subjective properties such as valence, arousal, and complexity by a large sample of European and American adults. All images were resized to 420 X 315 pixels and depicted items presented on a white background. To prevent interference from low-level stimulus attributes, Analyses of Variance (ANOVAs) were performed to ensure that all image types were comparable in contrast, complexity, brightness, valence, familiarity, and arousal (all p's>.05). The high and low calorie food images differed only in perceived healthfulness and were comparable in all other aspects including palatability and cravings. The full selection of stimuli is shown in Appendix A.

Snack foods. The snack foods used in the ad libitum taste test consisted of two healthy options: 51.6 grams of almonds (6 calories/g) and 133.1 grams of grapes (0.65 calories/g), and two unhealthy options: 51.6 grams of chocolate chips (5 calories/g) and 49.1 grams of potato chips (6 calories/g). Each food was served in a separate bowl, and foods were arranged in a randomized order across participants. A total of 948.72 calories were available for consumption in the taste test.

Questionnaires.

Baseline measures. All participants answered demographic questions about their age, ethnicity, and racial background. Additionally, because physiological hunger and satiation influence food motivation (Martin et al., 2010), self-reported hunger state was measured using the physiological hunger subscale of the General Food Cravings Questionnaire-State (GFCQS; Nijs, Franken, & Muris, 2007; see Appendix A). This three-item measure required participants to respond to statements such as “I am hungry” and “I feel weak because of not eating” on a five-point Likert scale with the anchors 1 = “strongly disagree” and 5 = “strong agree”. In addition, participants completed the following validated questionnaires.

Trait Impulsivity. Trait impulsivity was assessed using the Barrett Impulsiveness Scale-15 (BIS-15; Spinella, 2007; see Appendix B). This self-report questionnaire is one of the most widely used psychometric measures of impulsivity and noted for its robust factor structure, high test-retest reliability, and internal consistency (Spinella, 2007). This modified 15-item version is a shortened form of the original (Patton et al., 1995) and was chosen because it maintains the original’s psychometric robustness while providing the added benefit of expedited data collection (Spinella, 2007).

The BIS-15 measures three facets of trait impulsivity: non-planning, motor, and attention impulsivity. Non-planning impulsivity refers to a person’s failure to plan for the future and is tapped by questions such as “I plan for job security” and “I plan for the future". Motor impulsivity refers to the tendency to act without thinking and its items include "I do things without thinking" and "I buy things on impulse". Lastly, attention impulsivity refers to an individual's difficulty in maintaining concentration and is assessed by questions such as "I am restless at lectures or talks" and "I'm easily bored solving thought problems." Participants rate each item on a 4-point Likert scale with the anchors 1 = rarely/never and 4 = almost always.

General eating behaviors.

Eating Inventory (EI; Stunkard & Messick, 1985; see Appendix C). This questionnaire, also known as the Three Factor Eating Questionnaire, is a 51-item self-report measure that evaluates dietary restraint, disinhibition, and perceived hunger. One of the most widely used questionnaires in the field, the EI is noted for its internal consistency, high test-retest reliability, and accurate reflection of eating behaviors (Stunkard & Messick, 1985; Williamson et al., 1995). The questionnaire consists of true-and-false or 4-point Likert scale items with diet-related questions such as "Dieting is so hard for me because I just get too hungry" and "Do your feelings of guilt about overeating help you to control your food intake?". The constructs measured by the EI are known to play important roles in disregulated eating (Johnson, Pratt, & Wardle, 2012) and were used in the current study to examine their interactions with impulsivity.

Perceived Self-Regulatory Success in Dieting Scale (PSRS; Fishbach, Friedman, & Kruglanski, 2003; see Appendix D) This questionnaire was used to assess dietary success. This 3-item measure's internal consistency ranges between α = .65-.72 (Fishbach et al., 2003; Meule, Papies, & Kubler, 2012). Using this measure, previous studies have found differences in food cue reactivity and eating behaviors as a function of dieting success (Papies, 2012). In the current study, this measure will permit us to examine the correlations between dieting success and impulsivity.

Behavioral measures.

Food Delayed Discounting Task. The Delayed Discounting Task (DDT; Richards, Zhang, Mitchell, & de Witt, 1999) is a widely used quantitative measure of impulsive decision making. It is based on the phenomenon of discounting, where future rewards of the same nominal amount are subjectively less in value than its immediate equivalent. To assess this discounting, the DDT requires participants to choose between an immediate, smaller reward and a larger, delayed reward at variable time points in the future. The indifference point, or the point at which individuals switch from choosing the immediate over the delayed reward, reflects an individual's subjective evaluation of a delayed reward in units of an immediate reward. By graphing an individual's indifference points at different delays, we can generate a delay discounting curve whose area under the curve (AUC) is inversely associated with their discounting or impulsive decision making (Myerson, Green, & Warusawitharana, 2001).

Traditionally, the DDT measures the discounting of monetary rewards, but many studies have examined other types of rewards such as addictive substances, health, and food. Such studies have found that non-monetary commodities can better reflect domain-specific discounting rates (Tucker, Simpson, & Khodneva, 2010). Because the current reward of interest is food, the present study employed a food-specific DDT modeled on the procedure used by Rasmussen and colleagues (2010).

In this computerized food DDT, participants were asked to choose between different bites of their favorite food at different intervals in time. The participant firstly indicated their favorite food to the experimenter and was shown a 1" cube to represent the size of a bite. The participant then began the food DDT, which was created using E-Prime software and displayed on a computer. Each trial presented a choice between a variable number of bites available immediately versus 10 bites available in 1h, 2h, 5h, 10h, or 20h, and the participant indicated their choice with a mouse click. All five delays were presented in randomized order, and the variable amounts for each delay were independently adjusted according to an adjustment procedure outlined in detail by Richards et al., 1999. Each delay was presented until its indifference point has been reached, and the task was completed when indifference points for all five delays have been determined. Each session of the food DDT lasted about 7 minutes, and participants completed the task at baseline and after preload consumption.

Stop Signal Task. The Stop Signal Task (SST; Logan, Schachar, & Tannock, 1997) is a measure of action impulsiveness and inhibition, hallmarks of executive control. This task requires participants to respond as fast as possible to a frequent “go” stimulus, but to inhibit their response when an infrequent “stop” signal occurs. The percentage of commission and omission errors reflects impulsiveness and response inhibition. In its standard form, the stimuli used in the SST are X or O letters, but modified versions with food images have been used to probe food-specific response inhibition (Meule, Lutz, Voegele, & Kubler, 2014; Svaldi, Naumann, Trentowska, & Schmitz, 2014).

A schematic of the food SST is shown in Figure 1. Each trial began with a jittered fixation (100-500ms) cross followed by the target image on the center of the screen. Participants were asked to indicate whether the image was a food or a non-food as fast and accurately as possible using the left and right hand response keys on a keyboard. The appropriate response keys were counterbalanced across participants. All images stayed on the screen for 1000ms and participants were required to respond while the image was on the screen. In 25% of trials, the stop signal, a bright blue frame, appeared around the image after a variable delay. The stop signal required participants to inhibit their go response and allow the trial to terminate without responding. The onset of the stop signal, or the stop signal delay (SSD), was adjusted across trials using the tracking procedure (Band, van der Molen, & Logan, 2003): if the participant successfully inhibited their response in a stop trial, then the SSD in the next stop trial was increased by 50ms (thus decreasing the probability of response inhibition). Conversely, if the participant failed to inhibit their response, then the SSD in the next stop trial was decreased by 50ms (thus increasing the probably of response inhibition). This tracking procedure was designed to produce a stop accuracy rate (StopACC) of about 50% at the end of the task.

Each participant first completed a practice session and then proceeded to three blocks of 64 trials each with short breaks in between. Each block consisted of 16 stop trials and 48 go trials presented in randomized order. For both stop and go trials, 50% displayed neutral images, 25% displayed high calorie images, and 25% displayed low calorie images. The SST lasted about 15 minutes and participants completed the task twice, at baseline and after preload consumption.

The main variable of interest from the SST was the stop signal reaction time (SSRT). This measure, defined as the length of the inhibitory response, is the global measure of impulsivity generated by the SST (Logan et al., 1997). The SSRT was calculated by subtracting the SSD from the mean go signal reaction time and higher values indicate better inhibitory control.

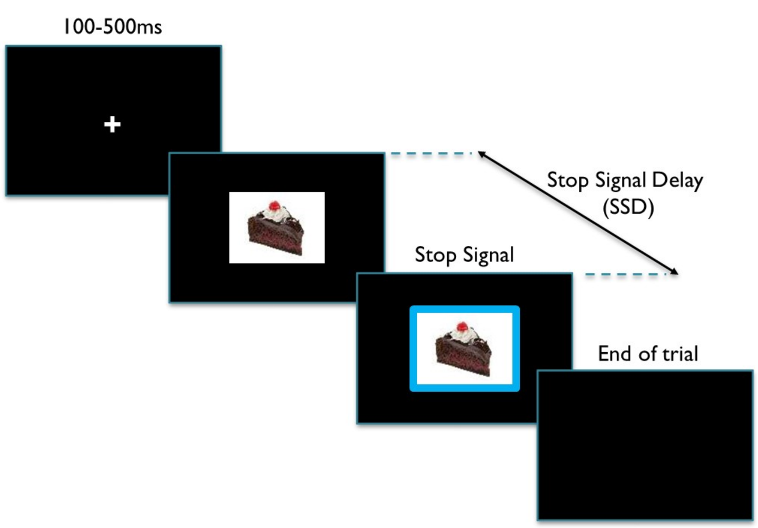


Figure 1. Schematic of the food stop signal task.

Matching Familiar Figures Task. The Matching Familiar Figures Task (MFFT; Cairns & Cammock, 1978) is a 20-trial task used to measure general reflective impulsivity. Our study used a computerized version of this task programmed with E-Prime Software. Participants were presented with a target image on a computer screen alongside six highly similar images. Only one of the six was the target's exact match, and participants were asked to use the mouse to identify this exact match. The task did not advance until the correct image had been identified. All participants completed two practice trials before proceeding to the 20 task trials. The length of the task ranged from 7 to 12 minutes and was only administered once, after preload consumption, due to practice effects on performance.

The MFFT generated one dependent variable, the MFFT iScore, which reflects errors relative to speed. The iScore was calculated by summing the time taken for first response (ms; Time) and number of errors until the correct response (Errors) across trials for each participant. These measures were then standardized and the iScore was calculated by subtracting zTime from zError. A higher iScore indicated lower state reflective impulsivity.

Procedure

This experiment consisted of two sessions, the first completed online at the participants' convenience, and the other completed within a week in the laboratory.

Online Session. The first session took place online at the participant's convenience. After online informed consent was obtained, participants proceeded to an online survey consisting of the trait impulsivity and eating behavior questionnaires (BIS, EI, and PSRS). Participants were requested to complete the entire survey in one sitting, which took about 30 minutes. Once the questionnaire was completed, an experimenter contacted each participant to schedule a laboratory session within one week. Participants were asked to refrain from eating 3 hours before the beginning of the laboratory session.

Laboratory Session. All laboratory procedures took place in a quiet room with the experimenter present. Participants were comfortably seated 60 cm from a computer screen for all tasks. After completing written consent, participants provided ratings of their present hunger levels and described when and what they last ate to further ensure compliance with pre-experimental instructions.

In the first part of the experimental session, participants provided baseline state impulsivity measures. These include the SST and the DDT, which were counterbalanced across participants. After completion of these baseline measures, intake of the preload took place. Under the guise of a taste test, participants were presented with a beverage in a 16oz. solo cup with a straw and a taste rating form (see Appendix F). Depending on their random group assignment, the beverage consisted of either 500mL of a milkshake (High Calorie group) or the same volume of water (Control group). In order to boost the milkshake's perceived caloric content, participants in the High Calorie group were also told the following: *"This high calorie milkshake consists of whole milk and full fat, premium ice cream. It is a rich and indulgent dessert".*

Participants in both conditions were asked to drink the beverage in its entirety and provide ratings on various taste and sensory attributes. The experimenter left the room for 7 minutes for participants to consume the preload. If a participant did not manage to finish the preload within that time frame, they were allotted 2 more minutes to do so. Only participants who managed to finish at least 50% of the preload were included in the analysis.

Once the preloads were consumed, the SST and the DDT were re-administered in the same order as baseline, followed by the MFFT and GFCQS hunger subscale. After completion of these computer tasks, the participants proceeded to the snack taste test. In this ad libitum taste test, a selection of four snack foods were provided for participants to taste and rate. Participants were asked to try at least a bite of everything but to consume as much or as little as they wanted in the given time. In order to maintain the supposed purpose of the experiment, a questionnaire with taste and preference ratings were provided with the snacks. The experimenter left the room for 15 minutes for the participant to complete this task.

At the end of 15 minutes, the experimenter re-entered the room and removed the snacks for weighing. Participants then provided height and weight measurements before being debriefed and thanked for their participation. The entirety of the study session lasted about 1.5 – 2.0 hours. See Figure 2 for a schematic of the laboratory session's progression.

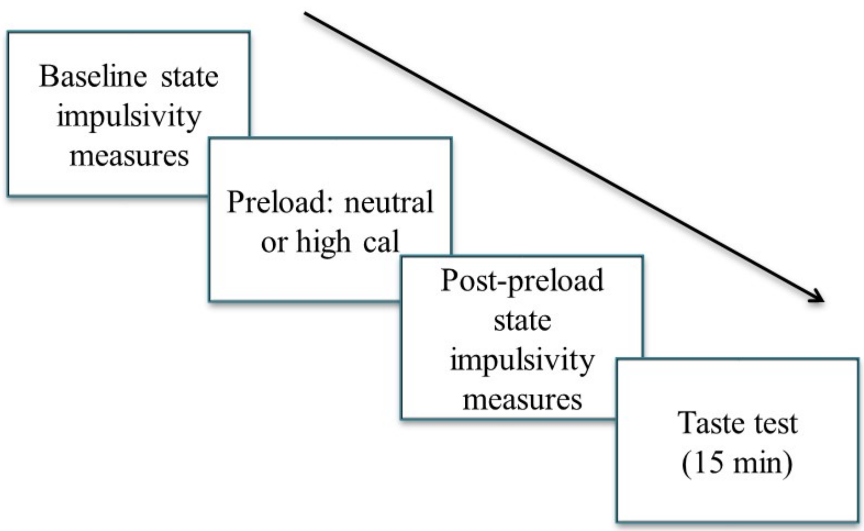


Figure 2. Schematic of the laboratory session procedure.

Data Analyses

Food Delay Discounting Task. Because delay-discounting tasks rely on self-report, precautions should be taken to identify and remove unreliable responders (Johnson & Bickel, 2008). Based on Johnson & Bickel's recommendations, participants whose discount rates increased over time were defined as unreliable responders and were removed from the analyses of the food DDT. After accounting for unreliable responders (*n* = 10), and technical errors during data collection (*n* = 2), 129 participants remained for the food DDT analysis (water *n* = 62, milkshake *n* = 67).

Data extraction methods for DDTs have been extensively outlined by previous authors (Rachlin et al. 1991; Richards et al. 1999). Two principal methods exist: 1) deducing a theoretically-based *k* constant that reflects the discount rate, or 2) calculating the area under the curve (AUC) as a measure of impulsive choice. For the present purposes, the AUC method was employed. Thus, based on the paradigm outlined by Myserson et al. (2001), our data extraction procedure was as follows:

1. All participants and their two food DDT sessions were analyzed separately.
2. Each participant provided an indifference point for each of the five delay intervals. The five delay intervals and all indifference points were normalized, and a delay interval by indifference point graph was generated from the normalized scores.
3. To calculate the AUC, a Riemann sums approximation was used. This technique divided the delay intervals into discrete portions, calculated the area of each portion using the formula (x2-x1)[(y1+y2)/2], and summed the areas to generate the overall function's area, or the AUC. Because the x and y values are both normalized, the area under the curve can vary between 0.0 (steepest possible discounting) and 1.0 (no discounting).

Calculations were performed for baseline (FoodDDT1) and post-preload (FoodDDT2) sessions, and larger AUCs reflect less food-specific impulsive choice. A difference score (FoodDDTΔ) was also calculated by subtracting the FoodDDT1 from its corresponding FoodDDT2 (FoodDDT2—FoodDDT1). This difference score reflected the change in impulsive choice after the preload, with positive scores indicating decreased impulsiveness.

Stop Signal Task. Examination of accuracy rates by block revealed that several participants ceased to engage in the go task after the second or third block, possibly due to a lack of motivation or fatigue. This resulted in unusually high stop signal accuracies (StopACC) and unusually low go signal accuracies (GoACC) in the raw data. This noncompliance issue was unexpected and required us to consider exclusion criterion prior to data analysis.

An examination of each participant's pattern of responses across the three blocks in each SST session revealed that noncompliant participants showed significant drops in GoACCs and significant increases in StopACCs in successive blocks. Based on these observations, we defined noncompliant participants as those whose GoACC rates dropped by over 30% between any two successive blocks in either SST session. We believe that this exclusion criterion provides a standardized method accounts for atypical within-subject variability that's indicative of nonsystematic responders. Furthermore, our criterion does not directly impose cut-offs on the SST's main impulsivity measures (the StopACC and GoRT), thus precluding any spurious findings due to data selectivity.

Applying this criterion to account for noncompliance (n = 49), along with SST technical issues (n = 2), a total of 88 participants remained for analysis of the SST. According to previous literature, the adjusting stop signal delay (SSD) procedure used in the current study should produce a StopACC of about 50% (Logan et al., 1997). The StopACCs of the current sample, was 54.6% for session one and 55.5% for session two, both falling close to the ideal 50%. Independent samples t-tests showed that the included and excluded participants did not differ on any trait variables except for the attentional subscale of the BIS (included=10.36, excluded= 9.41, $t(145)=-2.06$, $p=.042$).

With the filtered sample, we calculated the means for our variables of interest for each participant. These variables included reaction time (ms) in go trials (GoRT), StopACC or percentage of commission errors (i.e. rate of incorrect responses to stop trials), and the SSRT, the global measure of inhibitory functioning calculated using the integration method (see Band et al., 2003 for full details on calculation). In addition to overall performance, GoRT and StopACC measures were also calculated separately for neutral and food image trials.

Statistical Procedures. Statistical procedures were performed separately for each impulsivity measure. Firstly, correlations were conducted to examine relationships between the impulsivity subtype and general eating behaviors. Next, for the two state impulsivity variables, a repeated-measures ANOVA was performed to examine the effects of beverage condition and dietary restraint on changes in state impulsivity. For the trait impulsivity variables, hierarchical multiple regressions were performed to examine their interactions with dietary restraint and preload condition to predict snack caloric intake. Similarly for the state impulsivity measures, hierarchical multiple regressions were conducted to examine the effects of beverage condition, dietary restraint, and changes in state impulsivity on snack consumption. All models included all possible interaction terms, and significant interactions ($p < .05$) were followed up with conditional effects analyses. Because controlling for changes in state hunger did not significantly affect results, the statistical models presented here will not include hunger as a variable.

Results

Participant Characteristics

Of the 146 participants recruited for the study, 7 were excluded from all analyses due to failure to complete the experiment. This included participants who consumed less than 50% of the preload (n= 4) or were unable to complete the tasks (n= 3), thus providing 139 participants (High Calorie n = 72, Control n = 67) for analyses. Further task-specific exclusion criterion were used for state impulsivity analyses and are described above in the data analyses section.

To ensure that the two groups did not differ on any pre-existing variables, we conducted independent samples *t*-tests comparing participants in the High Calorie (*n* = 72) and Control (*n* = 67) groups on various trait measures. As shown in Table 1, participants did not differ in age, BMI, time since they last ate, or any of the baseline trait variables measured.

Table 1.

Descriptive statistics (Mean ± *SD*) and statistical results comparing baseline variables in the Control and High Calorie conditions.

	High Calorie (*n* = 72)	Control (*n* = 67)	*t*	*p*
Age (years)	19.5 ± 1.5	19.3 ± 2.2	-.440	.661
BMI (kg/m^2)	23.0 ± 3.8	22.9 ± 4.6	-.129	.898
Eating Inventory:				
Restraint (0 – 21)	8.06 ± 4.9	9.48 ± 5.0	1.688	.094
Disinhibition (0 – 18)	7.28 ± 3.1	6.94 ± 3.2	-.632	.529
Perceived Hunger (0 – 14)	6.43 ± 3.2	6.01 ± 3.0	-.799	.426
Barratt Impulsivity Scale:				
Attentional (5 – 20)	10.1 ± 2.9	9.94 ± 2.7	-.240	.811
Motor (5 – 20)	10.3 ± 1.7	10.1 ± 1.5	-.688	.492
Non-planning (5 – 20)	10.8 ± 3.2	10.4 ± 2.9	-.781	.436
PSRS (3 – 21)	3.93 ± 1.1	4.2 ± 1.1	1.66	.099
Baseline Hunger (1 – 5)	3.48 ± .66	3.34 ± .63	-1.30	.196
Time since last ate (h)	5.31 ± 3.7	5.00 ± 3.5	-.506	.614

Correlations between Trait and State Impulsivity

We conducted correlations to examine relationships between trait and state measures of impulsivity administered in the study. Only participants who passed all task-specific data filters as described above were included in this analysis (*n* = 83). As shown in Table 2, significant correlations were obtained between pre and post measures for the state impulsivity measures (i.e., FoodDDT and SST). Although several significant correlations emerged among the BIS trait impulsivity subscales, the state impulsivity measures (FoodDDT, SST, and MFFT) were not significantly correlated. Looking at associations between state and trait impulsivity measures, FoodDDT1 significantly correlated with BIS attentional, while the MFFT correlated with BIS attentional and BIS non-planning. Notably, the SSRT was unrelated to all of the trait impulsivity subscales.

Table 2.

Pearson correlations among trait and state impulsivity measures.

		1	2	3	4	5	6
1	FoodDDT1	1	.158	.077	-.066	.192	.244*
2	SSRT1		1	-.130	-.065	-.036	-.180
3	MFFT			1	.243*	.113	.323**
4	BISa				1	.354**	.238*
5	BISm					1	.287**
6	BISn						1

* = *p* < .05, ** = *p* < .01.

Trait Impulsivity

Does Trait Impulsivity correlate with General Eating Behaviors?

To determine whether trait impulsivity measures (BIS scores) were associated with participants' BMI and eating habits (i.e., restraint, disinhibition), correlation analyses were conducted. As shown in Table 3, those with higher scores on the BIS attentional and motor subscales were more disinhibited and experienced more perceived hunger (all p values < .05). Moreover, those who scored higher on the BIS motor subscale also had higher BMIs (p < .01).

Table 3.

Pearson correlations between trait impulsivity and general eating behaviors.

	Attentional	Motor	Non-planning
Restraint	0.065	-0.022	-0.149
Disinhibition	.175*	.264**	0.098
Perceived hunger	.189*	.209*	0.103
BMI	-0.075	.222**	0.125
PSRS	0.001	-0.098	-0.109

* = p < .05, ** = p < .01.

Does trait impulsivity interact with preload condition to predict snack consumption?

Means for snack consumption outcomes for the two groups are shown in Table 4. To determine whether trait impulsivity interacted with preload condition to predict snack consumption, we performed a series of multiple regression analyses in which preload condition and each BIS subscale served as predictors and total snack consumption served as the dependent variable. Each of these regression models were significant (all R^2's > 0.14, all p values < .001), and each showed a main effect of preload condition in which those in the High Calorie condition consumed fewer snack calories than those in the Control condition (all p values < .001). Moreover, as shown in Figure 3, the BIS attentional subscale interacted with preload condition to predict snack consumption (β= .695, t= 2.25, p=.026). Simple slopes analyses of this interaction showed that for those in the High Calorie condition, BIS attentional positively predicted snack consumption (p= .003), while no effects were seen in the Control condition (p > .05).

Table 4.

Snack consumption (Mean ± *SD*) in Control and Preload conditions.

	Control (*n* = 67)	High Calorie (*n* = 72)	# Available
Healthy	178.8 ± 97.93	122.6 ± 85.79	396.1
Grapes	64.2 ± 29.02	49.47 ± 30.58	86.52
Almonds	114.6 ± 84.99	73.08 ± 69.55	309.6
Unhealthy	198.1 ± 128.5	145.6 ± 112.3	552.6
Potato chips	122.3 ± 84.38	100.4 ± 85.08	294.6
Chocolate	75.8 ± 60.79	45.55 ± 49.73	258.0
Total	376.9 ± 169.5	268 ± 174.5	948.7

All values indicate number of Calories.

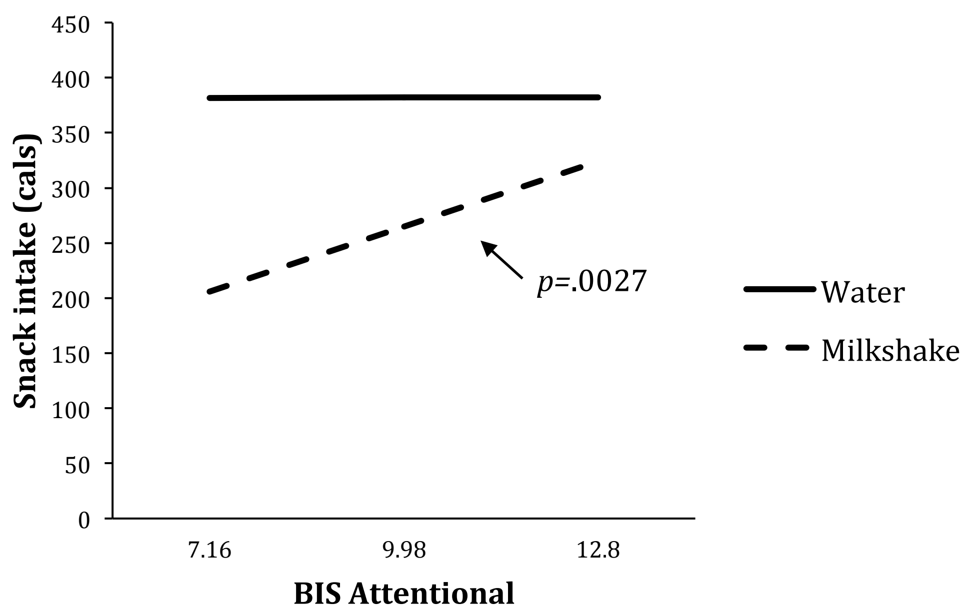


Figure 3. Snack consumption as a function of preload condition and BIS attentional impulsivity. For those in the High Calorie group, BIS attentional positively predicted snack caloric consumption.

To examine whether dietary restraint affected the relationships between trait impulsivity and snack consumption, dietary restraint was added as a moderator to each of the above analyses. None of the models from those analyses showed a significant three-way interaction (all *p*-values > .05), suggesting that dietary restraint and trait impulsivity do not interact to affect food intake.

State Impulsivity Measures

Does performance on the Food Delay Discounting Task correlate with General Eating Behaviors?

Correlations were performed between FoodDDT variables and general eating behaviors to examine their overall associations. Results, displayed in Table 5, showed no significant correlations between FoodDDT scores and any of the eating behaviors measured in the study.

Table 5.

Pearson correlations between FoodDDT variables and general eating behaviors.

	FoodDDT1	FoodDDT2	FoodDDTΔ
Restraint	.032	.014	-.014
Disinhibition	-.002	.001	.003
Perceived hunger	-.040	.057	.113
BMI	.125	.071	-.033
PSRS	-.115	-.151	-.079

Do Restraint and Preload Condition interact to predict change in the FoodDDT ?

To examine whether dietary restraint and preload condition interacted to predict changes in FoodDDT scores, a repeated-measures ANOVA with the variables session (before or after preload), preload condition (High Calorie or Control), and restraint entered as a continuous variable was performed. Results show a main effect of session, *F*(1,125)=8.626, *p*=.004, where FoodDDT scores after preload consumption (*M* = .482, *SD* = .284) were significantly higher than scores at baseline (*M* = .350, *SD* = .221), indicating an overall decrease in food-specific impulsive choice after preload consumption. No other significant variables nor interactions emerged. Thus, although all participants decreased in food-specific impulsive choice after a preload, the data provide no evidence that the preload condition or dietary restraint affected the magnitude of this change.

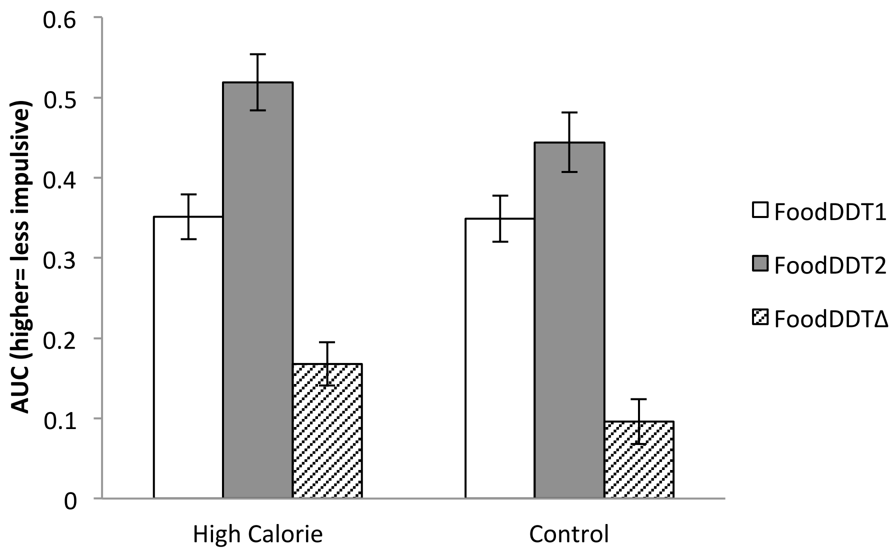


Figure 4. Graph of FoodDDT scores (AUC) by beverage group and session. Higher AUCs indicate less food-specific impulsive choice.

Do changes in the FoodDDT predict snack consumption?

We conducted a hierarchical linear regression predicting snack consumption from preload condition, dietary restraint, and FoodDDTΔ. Each variable was entered individually at Step 1, followed by all two-way interactions at Step 2, and finally the three-way interaction in Step 3. Results from this analysis are shown in Table 6. The first two models showed a main effect of preload condition (*β* = -.284, *t* = -3.33, *p* = .001), as reported above, and a preload*FoodDDTΔ interaction (*β* = -.348, *t* = -2.18, *p* = .030). Simple slopes analyses showed that FoodDDTΔ was more negatively related to snack consumption in the High Calorie condition than in the Control condition. However, the individual slopes of these relationships were not significant (both *p*-values > .15).

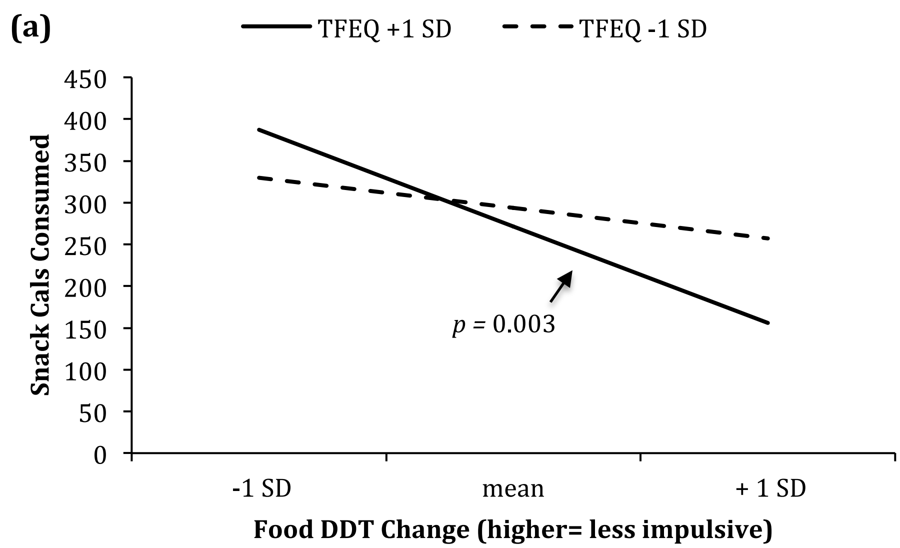
The final model in the hierarchical regression emerged as significant, $R^2 = 0.196$, $F(7,120) = 4.17$, $p<.001$, and revealed a significant FoodDDTΔ*Preload*Restraint interaction ($\beta = -.594$, $t = -2.02$, $p = .045$). As shown in Figure 5, conditional effects analyses revealed a marginally significant Restraint*FoodDDTΔ interaction in the High Calorie group ($p = .082$), and further examination in this group revealed that FoodDDTΔ negatively predicted snack consumption among those with average restraint ($p < .001$) and high restraint (TFEQ +1 SD; $p = .003$), but not for those with low restraint (TFEQ -1 SD; $p = .110$). This effect remained significant when controlling for BIS total, disinhibition, or changes in state hunger.

To further understand the three-way interaction, we inspected the corresponding means. This inspection revealed that the effect was driven by positive FoodDDTΔ scores (which reflect decreased impulsive choice) correlating with decreased snack consumption, rather than negative scores predicting increased consumption. In other words, for those with average or high dietary restraint who consumed a milkshake, decreased impulsive choice predicted decreased consumption while minimal changes predicted increased consumption and counter-regulatory eating.

Table 6.

Hierarchical linear regression model predicting snack consumption (calories) from beverage, dietary restraint, and FoodDDTΔ

Step	Predictors	Model Statistics			Predictor Statistics		
		R^2	F_{change}	df	β	t	p
1	Preload (Pre)	.135	6.47	3, 124	-.284	-3.33	.001
	Restraint (Res)				-.093	-1.10	.273
	FoodDDTΔ				-.189	-2.23	.027
2	Pre*Res	.168	1.59	3, 124	.043	.236	.813
	Pre*FoodDDTΔ				-.348	-2.18	.031
	Res*FoodDDTΔ				-.113	-.629	.530
3	FoodDDTΔ*Pre*Res	.196	4.09	1, 120	-.594	-2.02	.045



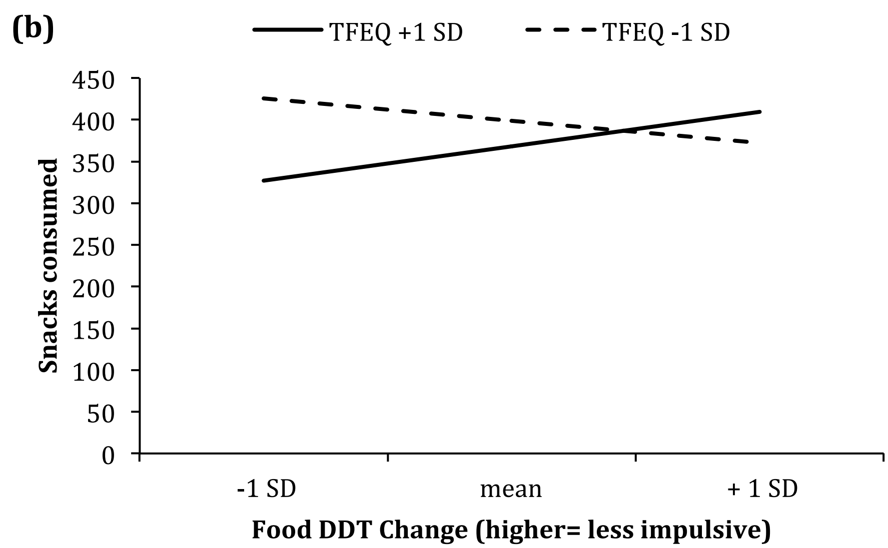


Figure 5. Snack calories consumed in (a) High Calorie and (b) Control conditions as a function of FoodDDT change scores and dietary restraint. For those high in dietary restraint who consumed a milkshake, FoodDDTΔ positively predicted snack consumption (*p* = .003).

Stop Signal Task

Does performance on the Stop Signal Task correlate with General Eating Behaviors?

Correlations were performed between SST variables and general eating behaviors to examine their overall associations. Results, displayed in Table 7, showed no significant correlations between SSRT scores and any of the eating behaviors measured in the study (all *p*-values > .05).

Table 7.

Pearson correlations between SST variables and general eating behaviors.

	SSRT1	SSRT2	SSRTΔ
Restraint	-.068	.006	.089
Disinhibition	.120	.036	-.106
Perceived hunger	.039	.085	.045
BMI	-.064	-.136	-.072
PSRS	-.129	-.088	.060

Do Restraint and Preload Condition interact to predict change in the SSRT?

Means for SSRT scores by session and group are shown in Table 8. To examine factors that predicted changes in SSRT scores, a repeated-measures ANOVA with the variables session (before or after preload), preload condition (Control or High Calorie), and dietary restraint entered as a continuous variable was performed. No significant variables or interactions emerged (all *p*-values > .05). Thus, the data provide no evidence that the preload condition or dietary restraint affected SSRT scores.

Table 8.

SSRT scores (Mean ± *SD*) by beverage group and session.

	High Calorie (*n*= 49)	Water (*n* = 40)
SSRT1 (ms)	174.3 ± 89.3	165.1 ± 95.8
SSRT2 (ms)	179.2 ± 66.3	166.8 ± 99.9
SSRTΔ (ms)	4.153 ± 74.4	1.720 ± 77.7

Do Changes in the SSRT Predict Snack Consumption?

We conducted a hierarchical linear regression to examine the effects of Preload condition, dietary restraint, and SSRTΔ on snack consumption. The same stepwise procedures used for the FoodDDTΔ were mirrored here. The final model was not significant, $R^2 = 0.126$, $F(7,80)=1.65$, $p = .13$, and therefore our data fails to support the hypothesis that changes in inhibitory control that resulted from preload consumption significantly predict snack consumption.

Does baseline performance on the Stop Signal Task predict snack consumption?

We conducted post-hoc analyses to examine whether SSRT at baseline (SSRT1) predicted snack consumption. A hierarchical linear regression, mirroring the same stepwise procedures above, was used to examine how dietary restraint, preload condition, and SSRT1 predicted snack consumption. Results from those analyses are shown in Table 9. The overall model was marginally significant, $R^2 = 0.1656$, $F(8, 79) = 1.96$, $p = 0.06$. Significance tests of the predictors showed a marginally significant main effect of preload ($\beta = -.185$, $t = -1.71$, $p = .091$), as seen previously, a marginally significant main effect of SSRT1 ($\beta = .203$, $t = 1.92$, $p = .058$), where SSRT1 scores positively predicted caloric consumption, and a significant SSRT1*Preload*Restraint interaction ($\beta = .876$, $t = 1.95$, $p = .055$). Separate within-group analyses showed that this interaction was driven by a Restraint*SSRT1 interaction in the High Calorie group ($p = 0.025$) but not in the Control group ($p > .05$). Simple slopes comparisons in the High Calorie group showed that for those with high restraint scores (+1 *SD*), SSRT1 positively predicted consumption ($p = .018$). In other words, those with high restraint seemed to counter-regulate only if their action impulsivity was also high. No such effects were seen for those with low restraint (see Figure 6).

Table 9.

Hierarchical linear regression model predicting snack consumption (calories) from beverage, dietary restraint, and SSRT1

Step	Predictors	Model Statistics			Predictor Statistics		
		R^2	F_{change}	df	β	*t*	*p*
1	Preload (Pre)	.072	2.17	3,84	-.185	-1.71	.091
	Restraint (Res)				.006	.054	.957
	SSRT1				.203	1.92	.058
2	Pre*Res	.108	1.08	3,81	-.246	-1.07	.286
	Pre*SSRT1				-.147	-.577	.566
	Res* SSRT1				.340	1.32	.190
3	SSRT1*Pre*Res	.148	3.79	1,80	.876	1.95	.055

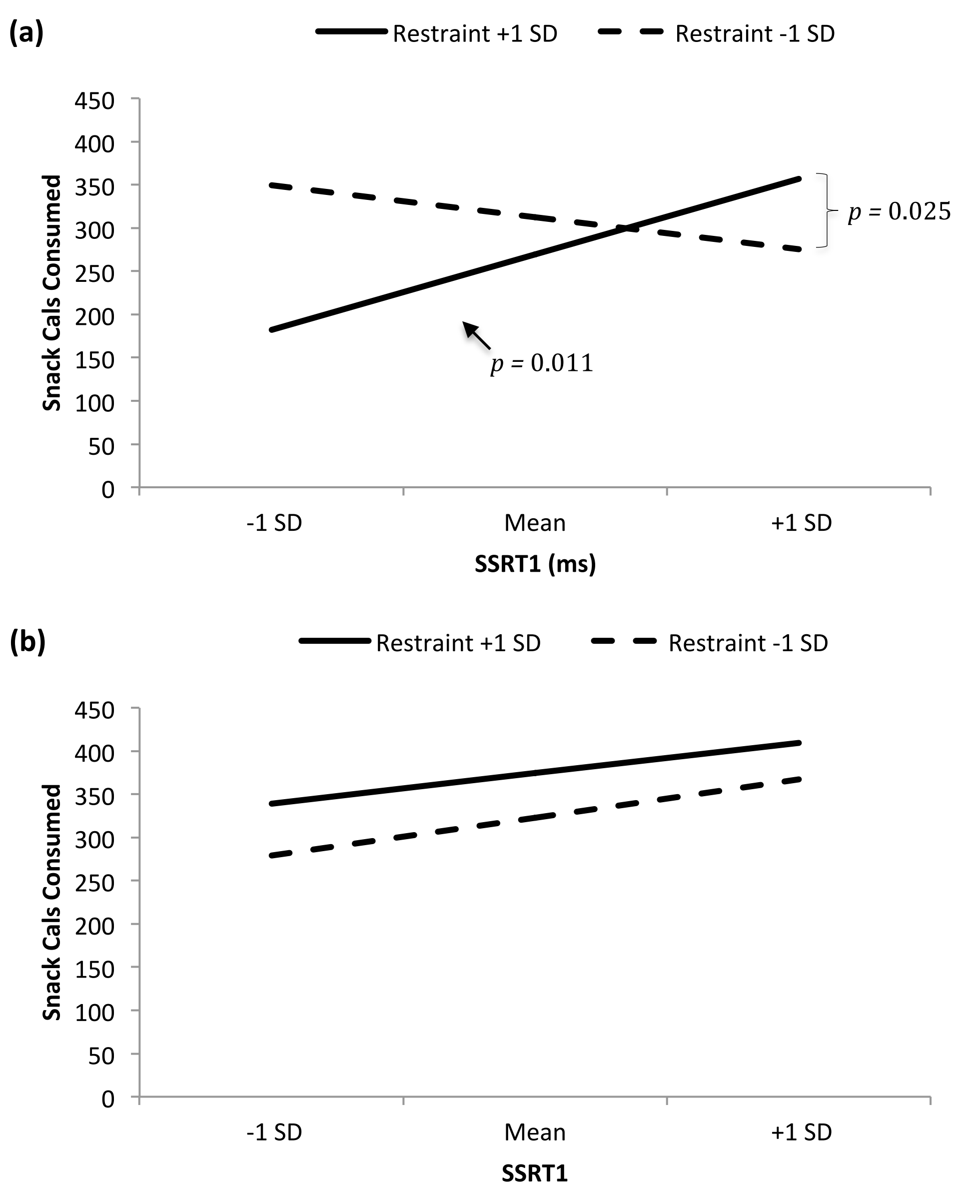


Figure 6. Snack consumption (calories) in the (a) High Calorie and (b) Control conditions as a function of SSRT1 and dietary restraint. Slopes differed significantly in the High Calorie condition (p = 0.025), where those with high restraint scores showed a positive association between SSRT1 and caloric consumption (p = 0.011).

To summarize, the current results indicate that overall, those in the High Calorie group consumed fewer snack calories than those in the Control group. However, variations in consumption were seen as a function of dietary restraint and impulsivity in the High Calorie group. Among the trait impulsivity measures, lower attentional impulsivity predicted less consumption. Among the state impulsivity measures, those high in dietary restraint who had a greater decrease in food-specific impulsive choice or higher baseline inhibitory control showed better self-regulation in food consumption.

Discussion

Current findings provide several important insights into the role of impulsivity in overeating in restrained and unrestrained eaters. Results showed that subtypes of state impulsivity play differential roles in the eating behaviors of restrained eaters, and highlight important predictors of counter-regulation. As one of very few studies to assess impulsivity's trait and state sub-constructs, the current investigation provides an important contribution to the literature.

In line with previous literature, our data showed a notable absence of correlations between trait and state impulsivity measures. Food-specific impulsive choice, a state measure, correlated only with non-planning impulsivity, while inhibitory control did not correlate with any trait impulsivity measures. Previous authors have stressed the importance of differentiating among impulsivity's subtypes (Allom, Panetta, Mullan, & Hagger, 2015; Reynolds et al., 2005; Smith & Guller, 2015; Havik et al., 2012), and we provide further support for the independence of these constructs.

Our data underscore the importance of focusing on the sub-constructs of impulsivity by demonstrating their differential associations with general eating behaviors. With respect to trait impulsivity, we found that those with higher attentional or motor impulsivity tended to have higher disinhibition and more perceived hunger, while motor impulsivity correlated positively with BMI. Along with previous findings (Lyke & Spinella, 2003; Leitch, Morgan, & Yeomans, 2013) our results support the link between trait impulsivity and maladaptive eating behaviors. Different aspects of trait impulsivity are predictive of different food-related behavioral outcomes.

In contrast, state impulsivity measures did not correlate with general eating behaviors. Neither food-specific impulsive choice, as assessed by the food DDT, nor behavioral inhibitory control, as assessed by the SST, showed significant correlations with dietary restraint, disinhibition, perceived hunger, or BMI. These results concur with some existing findings (Leitch, Morgan, & Yeomans, 2013; Rasmussen et al., 2010) but differ from others who reported positive associations between state impulsivity and BMI and binge eating symptomology (Nederkoorn, et al., 2006; Svaldi et al., 2014; Schiff et al., 2015). These inconsistencies suggest that state impulsivity may not reliably reflect trait-level variables such as dietary restraint, perhaps due to its contextual variability. For example, previous investigators have found that delay discounting increases when under heightened cognitive load (Hinson, Jameson, & Whitney, 2003) or when exposed to aversive stimuli (Flora, Wilkerson, & Flora, 2003), and inhibitory control can shift after priming with loss of control concepts (Rotenberg et al., 2004; Guerrieri et al., 2009), thus showing that behavioral measures are prone to environmental influences. Our results add to the importance of accrediting impulsivity's multidimensionality in any investigation of eating behaviors.

In terms of predicting overeating by manipulating exposure to a preload in a laboratory setting, trait and state impulsivity again exhibited different patterns of results. Among the trait impulsivity subscales, low attentional impulsivity predicted increased caloric consumption in the milkshake condition, suggesting a counter-regulatory effect. This finding corroborates with previous studies showing that trait impulsivity predicts increased caloric intake under certain conditions such as negative mood (Emery, King, & Levine, 2014), an unrestricted eating environment (Leitch, Morgan, & Yeomans, 2013), or after food context conditioning (Van den Akker, Jansen, Frentz, & Havermans, 2013), and highlights attentional impulsivity's strong association with overeating (Meule, 2013). However, our data did not show any interactions between trait impulsivity and restraint to predict caloric intake. In light of ambiguous precedents—previous studies have both found (Van Koningsbruggen, Strobe, & Aarts 2013; Emery, King, Fischer, & Davis, 2013) and failed to find (Greenwood, Broadbent, & Fuller-Tyszkiewicz, 2014; Larsen, Hermans, & Engels, 2012) such interactions—this was neither expected nor surprising. If anything, the absence of such an interaction in our data adds to the likelihood that trait impulsivity may not play a firm role in episodic counter-regulation in restrained eaters.

The present investigation was the first to examine changes in state impulsivity caused by preload consumption. Of the two repeated-measures state impulsivity assessments used in our study, only food-specific impulsive choice decreased significantly after milkshake and water consumption. Impulsive choice reflects an individual's ability to postpone immediate gratification—in this case for bites of a favorite food—and persist in goal-directed behavior to achieve desired outcomes (Epstein, Salvy, Carr, Dearing, & Bickel, 2010). Previous studies have found that future food or drug rewards are discounted more steeply after deprivation than after satiation (Giordano et al., 2002; Field, Santarcangelo, Sumnall, Goudie, & Cole 2006). However, the absence of a difference between conditions in our investigation suggests that both milkshake and water enacted a similar suppression effect on food-specific impulsive choice. In other words, changes in impulsive choice may be one mechanism by which appetite suppression occurs after beverage consumption.

More interestingly, our results showed that changes in food-specific impulsive choice predicted counter-regulation in high restraint eaters. Among those with high restraint in the milkshake condition, only those whose food-specific impulsive choice decreased consumed fewer snack calories. These findings suggest that decreases in delay discounting may be a mechanism that facilitates food-related self-regulation. Previous studies have found that decreases in impulsive choice predict and precede drug abstinence (Bickel et al., 1999), suggesting that it may be a prerequisite to successful self-regulation. Experimental studies have shown that mindfulness training or episodic future thinking can temporarily decrease futuristic discounting (Hendrickson & Rasmussen, 2013; Morrison, Madden, Odum, Friedel, & Twohig, 2014), and both techniques have been found to independently decrease food consumption (Dassen, Jansen, Nederkoorn, & Houben, 2015; Hendrickson & Rasmussen, 2013). Given its probable role in self-regulatory processes, future studies should further investigate the possibility of targeting food-specific impulsive choice to influence food intake.

While our food challenge caused shifts in food-specific impulsive choice, no such changes were detected for inhibitory control, and any changes that did occur did not predict snack food consumption. These results run counter to our expectations, but we offer the following interpretations, which are not mutually exclusive. Firstly, it is possible that a preload manipulation simply did not affect inhibitory control. This explanation concurs with the argument that inhibitory control is a more stable, trait-like impulsivity subtype (Avila & Parcet, 2000), or at least more resistant to change. In previous studies that have induced shifts in inhibitory performance, investigators employed more potent stressors such as sleep deprivation or mild electric shocks (de Witt, 2008; Boehler et al., 2009). The current investigation employed a comparatively benign manipulation, beverage consumption, which may not have been potent enough to affect inhibitory control in restrained or unrestrained eaters.

The lack of significant inhibitory change might also shed light on the construct of inhibitory control measured by the stop signal task. While the food delay-discounting task captured food-specific impulsive choice—and therefore shifted accordingly after beverage consumption—the stop signal task is known to provide a more general measure of inhibitory control (Logan, 1994), which may not have been sensitive enough to capture shifts in food-specific inhibitory control after preload consumption. Some authors have also suggested that inhibitory performance might be stimulus-dependent.

For example, Pessoa, Padmala, Kenzer, & Bauer (2011) found that happy and fearful faces used as stop signals improved response inhibition while high-threat stimuli impaired performance, suggesting that stimuli can affect performance. Enhanced processing of go stimulus promotes go responses (Boehler et al., 2009). Although the Stop Signal Task used in the current study included neutral and food stimuli, the paradigm used did not permit us to determine different indices of inhibitory control for each of those stimuli (Svaldi et al., 2012). Future investigations should consider paradigms with separate adjustment procedures for each stimulus type, thus enabling separate stop signal reaction times to be calculated for both neutral and food stimuli.

Alternatively, it is also possible that inhibitory control was depleted after a longer time lapse than that used in our study. Our results showed that better initial response inhibition predicted reduced snack intake after consuming a milkshake, suggesting that the magnitude of inhibitory control played a role in counter-regulation. This is in line with previous correlational studies that found inverse relationships between inhibitory control and health outcomes (Batterink, Yokum, & Stice, 2010), and may be explained by the Ego-Strength Model of Self-Regulation (Baumeister et al., 1998; Muraven & Baumeister, 2000). According to this model, self-control is a limited resource that degrades over time and after cognitive challenges. In the current investigation, our participants' inhibitory resources may have been depleted over the course of the multiple-task experiment, and the second stop signal task may not have reflected that decrease because it was administered about 20 minutes before the snack taste test. In the time between the second stop signal task and the taste test, participants progressed through tasks and questionnaires that likely further depleted their inhibitory resources. Once participants arrived at the last stage of the experiment, only those with high initial inhibitory control may still have had resources left over to regulate eating. Those with a smaller store of inhibitory control may have expended all their resources and therefore counter-regulated. Future studies should examine this possible mechanism.

It is worth comparing the current SST findings to those of Jansen et al. (2009), whose paradigm matched ours closely. In their investigation, Jansen found that high restraint high impulsive individuals ate more than others in a no preload control condition, but self-regulated after consuming a high caloric preload. In our investigation, however, differences between participants were observed in the high caloric preload condition, where those with high restraint and low impulsiveness self-regulated. Several possibilities may explain these differences. Firstly, Jansen's methodology split participants based on dietary restraint and inhibitory control, both continuous variables, and therefore reduced the power of their statistical tests (Irwin & McClelland, 2003). In our analysis we employed regressions and kept both dietary restraint and inhibitory control as continuous variables, thus increasing analytical power to detect effects. Secondly, the differences in our ranges of inhibitory control scores are also telling. In Jansen's high restraint low impulsivity group, the average stop signal reaction time (SSRT) was 151ms, whereas in our investigation a low SSRT was 85ms and considerably lower than Jansen's. This could have explained their inability to find evidence of self-regulation in the high restraint low impulsivity group, as their sample's impulsivity scores may not have been low enough. Finally, depletion of limited self-regulatory resources may also explain their findings. While the current investigation measured baseline inhibitory control, Jansen's group assessed inhibitory control at the end of the experiment, after the ad-lib taste test. As posited, if inhibitory control were a limited resource that depletes over time, much would have been expended during the experimental tasks and taste test. In particular, restrained eaters who successfully regulated their intake may have done so by expending inhibitory resources during the taste test, and therefore would have presented higher impulsiveness scores on the stop signal task. This methodological confound may have obviated their ability to detect an association between low impulsivity and self-regulation that was identified in the present investigation.

An unexpected finding in the present investigation was that those with low restraint and high inhibitory control ate comparable amounts in both conditions. This finding, which contradicts Restraint Theory, is actually not unusual. Many studies that employed the preload paradigm have also found that unrestrained eaters did not self-regulate by reducing their intake after a high caloric preload (Lawrence et al., 2015; Jansen et al., 2009). One explanation for these results is that all individuals are naturally inclined to gravitate toward high calorie palatable foods, regardless of levels of dietary restraint (Birch, 1992). The difference in unrestrained individuals, however, is that because they are unconcerned about caloric intake, they do not experience the guilt and cognitive distress that plague restrained eaters after an indulgence (Herman & Polivy, 1975). But as current results show, this doesn't necessarily mean that unrestrained eaters self-regulate. Unrestrained eaters show wide variations in dietary habits (Boon, Stroebe, Schut, & Igntema, 2002; Canetti, Bachar, & Berry, 2002; O'Connell, Larkin, Mizes, & Fremouw, 2005; Polivy, 1976), and current evidence suggests that perhaps they are not always models of self-regulation and healthy eating.

A few limitations in the current investigation must be addressed. Firstly, the generalizability of our conclusions is limited due to the homogeneous make-up of our sample, which comprised of mostly Caucasian females. Although this adds to the vast existing literature on this population, very little is known about the eating behaviors of males. Future studies should aim to explore the effects of dietary restraint and impulsivity in other populations.

Secondly, the comprehensiveness of our impulsivity measures required us to compromise on experimental brevity. The entire experimental session comprised of several cognitively engaging tasks that lasted over an hour, and this caused participant fatigue and disengagement in some tasks. We have accounted for this by excluding those who demonstrated noncompliance from the analyses, but this unfortunately substantially decreased our sample size, particularly for the stop signal task analyses. Future investigations on behavioral impulsivity should limit the time spent in lab.

Overall, the current findings point to individuals with high restraint and low or decreased impulsivity as those who self-regulate successfully. Our identification of these underlying mechanisms of counter-regulation provides a better understanding of successful healthy eating that hopefully will inform future strategies for effective weight loss and maintenance. Future strategic agendas should seek to boost baseline inhibitory control levels or enhance decreased food-specific impulsive choice to promote self-regulated eating and combat obesity.

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Appendix A

Stop Signal Task Stimuli

Figure A1. Neutral stimuli.

Figure A2. Healthy food stimuli.

Figure A3. Unhealthy food stimuli.

Appendix B

General Food Cravings Questionnaire- State
Physiological Hunger Subscale

The General Food Cravings Questionnaire-State employs a 5-point Likert scale (1 = strongly disagree, 5 =strongly agree).

1. If I ate right now, my stomach wouldn’t feel as empty.

2. I am hungry.

3. I feel weak because of not eating.

Appendix C

Barratt Impulsive Scale- 15

4-point Likert-type scale (1 = rarely/never, 2= sometimes, 3=often, 4 = almost always)

1. I act on impulse.
2. I act on the spur of the moment.
3. I do things without thinking.
4. I say things without thinking.
5. I buy things on impulse.
6. I plan for job security.
7. I plan for the future.
8. I save regularly.
9. I plan tasks carefully.
10. I am a careful thinker.
11. I am restless at lectures or talks.
12. I squirm at plays or lectures.
13. I concentrate easily.
14. I don't pay attention.
15. Easily bored solving thought problems.

Appendix D

Eating Inventory

Please answer true or false to indicate if the following statements relate to you:

1. When I smell a sizzling steak or see a juicy piece of meat, I find it very difficult to keep from eating, even if I have just finished a meal.	T	F
2. I usually eat too much at social occasions, like parties and picnics.	T	F
3. I am usually so hungry that I eat more than three times a day.	T	F
4. When I have eaten my quota of calories, I am usually good at not eating any more.	T	F
5. Dieting is so hard for me because I just get so hungry.	T	F
6. I deliberately take small helpings as a means of controlling my weight.	T	F
7. Sometimes things just taste so good that I keep on eating even when I am no longer hungry.	T	F
8. Since I am often hungry, I sometimes wish that while I am eating, an expert would tell me that I have had enough or that I can have something more to eat.	T	F
9. When I feel anxious, I find myself eating.	T	F
10. Life is too short to worry about dieting.	T	F
11. Since my weight goes up and down, I have done on reducing diets more than once.	T	F
12. I often feel so hungry that I just have to eat something.	T	F
13. When I am with someone who is overeating, I usually overeat too.	T	F
14. I have a pretty good idea of the number of calories in common food.	T	F
15. Sometimes when I start eating, I just can’t seem to stop.	T	F

16. It is not difficult for me to leave something on my plate.	T	F
17. At certain times of the day, I get hungry because I have gotten used to eating then.	T	F
18. While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it.	T	F
19. Being with someone who is eating often makes me hungry enough to eat also.	T	F
20. When I feel blue, I often overeat.	T	F
21. I enjoy eating too much to spoil it by counting calories or watching my weight.	T	F
22. When I see a real delicacy, I often get so hungry that I have to eat right away.	T	F
23. I often stop eating when I am not really full as a conscious means of limiting the amount that I eat.	T	F
24. I get so hungry that my stomach often seems like a bottomless pit.	T	F
25. My weight has hardly changed at all in the last ten years.	T	F
26. I am always so hungry it is hard for me to stop eating before I finish the food on my plate.	T	F
27. When I feel lonely, I console myself by eating.	T	F
28. I consciously hold back at meals in order not to gain weight.	T	F
29. I sometimes get very hungry late in the evening or at night.	T	F
30. I eat anything I want, any time I want.	T	F
31. Without even thinking about it, I take a long time to eat.	T	F
32. I count calories as a conscious means of controlling my weight.	T	F

33. I do not eat some food because they make me fat.	T	F
34. I am always hungry enough to eat at any time.	T	F
35. I pay a great deal of attention to changes in my figure.	T	F
36. While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calorie goods.	T	F

Please answer the following questions by circling the number above the response that is appropriate to you.

37. How often are you dieting in a conscious effort to control your weight?

1	2	3	4
rarely	sometimes	usually	always

38. Would a weight fluctuation of 5 lbs. affect the way you live your life?

1	2	3	4
not at all	slightly	moderately	very much

39. How often do you feel hungry?

1	2	3	4
only at mealtimes	sometimes between meals	often between meals	almost always

40. Do your feelings of guilt about overeating help you control your food intake?

1	2	3	4
never	rarely	often	always

41. How difficult would it be for you stop eating halfway through dinner and not eat for the next four hours?

1	2	3	4
easy	slightly difficult	moderately difficult	very difficult

42. How conscious are you of what you're eating?

1	2	3	4
not at all	slightly	moderately	extremely

43. How frequently do you avoid 'stocking up' on tempting foods?

1	2	3	4
almost never	seldom	usually	almost always

44. How likely are you to shop for low calorie foods?

1	2	3	4
unlikely	slightly unlikely	moderately likely	very likely

45. Do you eat sensibly in front of others and splurge alone?

1	2	3	4
never	rarely	often	always

46. How likely are you to consciously eat slowly in order to cut down on how much you eat?

1	2	3	4
unlikely	slightly unlikely	moderately likely	very likely

47. How frequently do you skip dessert because you are no longer hungry?

1	2	3	4
almost never	seldom	at least once a week	almost every day

48. How likely are you to consciously eat less than you want?

1	2	3	4
unlikely	slightly likely	moderately likely	very likely

49. Do you go on eating binges though you are not hungry?

1	2	3	4
never	rarely	sometimes	at least once a week

50. On a scale of 0 to 5, what number would you give yourself.?

0 – eat whatever you want, whenever you want
1 – usually eat whatever you want, whenever you want it
2 – often eat whatever you want, whenever you want it
3 – often limit food intake, but often 'give in'
4 – usually limit food intake, rarely 'give in'
5 – constantly limiting food intake, never 'giving in'

51. To what extent does this statement describe your eating behavior? 'I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow'.

1	2	3	4
not like me	little like me	pretty good description of me	describes me perfectly

Appendix E

Perceived Self-Regulatory Success in Dieting Scale

1. How successful are you in watching your weight?

1 2 3 4 5 6 7

Not
Very
Successful
Successful

2. How successful are you in losing extra weight?

1 2 3 4 5 6 7

Not
Very
Successful
Successful

3. How difficult do you find it to stay in shape?

1 2 3 4 5 6 7

Not
Very
Difficult
Difficult

Appendix F

Taste Rating Form

How **sweet** was this food?

1	2	3	4	5	6	7
Not at all sweet						Very sweet

How **salty** was this food?

1	2	3	4	5	6	7
Not at all salty						Very salty

How **sour** was this food?

1	2	3	4	5	6	7
Not at all sour						Very sour

How **bitter** was this food?

1	2	3	4	5	6	7
Not at all bitter						Very bitter

How would you rate this food's **healthfulness**?

1	2	3	4	5	6	7
Very unhealthy						Very healthy

How much do you like this food overall?

1	2	3	4	5	6	7
Strongly dislike						Strongly like