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INFLUENCE OF DIETARY VARIETY ON BINGING BEHAVIOR

JILL BONTRAGER
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Reviewed and approved* by the following:

Rebecca Corwin
Associate Professor of Nutritional Sciences
Thesis Supervisor

Jill Patterson
Assistant Professor of Nutritional Sciences
Honors Adviser

- Signatures are on file in the Schreyer Honors College.

ABSTRACT:

Binge eating has become a significant problem linked to many health conditions such as obesity, hypertension, and psychological disorders. Defined as the ingestion of large amounts of food during a short period of time, bingeing episodes are also marked with a sense of a lack of control. Bingeing is difficult to treat, but behavioral therapy has proven to be somewhat successful. Within this therapeutic approach, the introduction of binge foods back into the diet and increasing dietary variety are often used. However, research regarding which specific components of this approach are helpful is limited, due to ethical concerns regarding such research in human subjects. The present research made use of an animal model of binge eating, in order to determine the effects of a variety of optional fatty or sugary foods on binge consumption of those foods. In this model, binge-type eating is induced in non-food deprived rats through the provision of limited access to either a palatable fat (typically 100% vegetable shortening) or sugar (e.g. 10% sucrose). Past experiments have shown significant bingeing activity in the rats with intermittent (three times a week) access to palatable foods as compared to groups with daily access. Therefore, both intermittent (I) and daily (D) groups were included in the present study. In addition, in order to test the role that variety of palatable foods would have, a Variety group was provided fat and sugar on alternating days. In total, 5 groups were included: 1) Daily Sugar (DS): 1-hr access to a 10% sucrose solution every day; 2) Intermittent Sugar (IS): 1-hr access to a 10% sucrose solution on Tuesday, Thursday, and Saturday; 3) Daily Fat (DF): 1-hr access to 100% vegetable shortening every day; 4) Intermittent Fat (IF): 1-hr access to 100% vegetable shortening on Monday, Wednesday, and Friday; 5) Variety (V): 1-hr access to a 10% sucrose solution on Tuesday, Thursday, and Saturday, plus 1-hr access to 100% vegetable shortening on Monday, Wednesday, and Friday. Several new findings are reported. First, the shortening intake in the Variety (V) group did not differ significantly from either the intermittent

fat (IF) or the daily fat (DF) group. Even though the V group consumed slightly more than the DF group, it also consumed slightly less than the IF group. Thus, the V group did not meet our operational definition of bingeing, in which intakes need to significantly exceed that of the daily control group (in this case DF). Second, during week 4 of the study, and on the last day of the study, the V group consumed significantly less sucrose than the group that had sucrose daily (DS), and slightly less than the group that had intermittent access (IS). Taken together, these results suggest that daily consumption of a fatty or sugary "treat" protects against bingeing to some extent.

TABLE OF CONTENTS

LIST OF FIGURES:

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Chapter 1: INTRODUCTION

Food is seen as a commonplace necessity to some but as a means to destruction to others. While it is normal to occasionally overeat at a meal, there are millions of Americans who uncontrollably eat excessive amounts of food on a regular basis. Binge eating is linked to health problems such as obesity, as well as psychological disorders such as depression, substance abuse and anxiety [1-3]. While the term bingeing is used regularly to mean overeating, a clinically defined binge eater must meet characteristics having to do with the frequency, intensity and length of an episode. Therefore, the common use of the word "binge" to describe the consumption of too many sweets in a day does not meet the diagnostic criteria of a bingeing episode.

Binge eating is defined by both objective and subjective characteristics in the American Psychiatric Association's Diagnostic and Statistical Manual IV. Objectively, binge eating is a series of recurrent binge episodes in which each episode is defined as eating a larger amount of food than normal during a short period of time (usually within a 2-h period) than what would normally be consumed within that same time period [4]. According to a review of both diary and laboratory studies, the caloric intake during bingeing episodes is around 1,000 kcal on average, but ranged from 605.5 kcal to 4,394 kcal [5]. Foods consumed in a binge are typically high in fats, sugars or both [6]. Bingeing can also be defined by more subjective measures as a sense of losing control, either with the volume or type of food consumed. Although the cause of binge eating is unknown, a confluence of factors is thought to contribute. Bingeing can temporarily alleviate or numb negative feelings such as stress, anger, loneliness and boredom during an episode, but often leaves an individual with a sense of guilt and reproach afterwards [1].

Binge eating is a prevalent behavior in many Americans, and is a key defining characteristic of eating disorders such as Bulimia Nervosa (BN), Binge Eating Disorder (BED), and purge-type of Anorexia Nervosa (AN). However, many Americans engage in bingeing episodes without meeting the criteria of an eating disorder, which is diagnostically referred to as bingeing at sub-threshold levels. According to Hudson et al. in 2007, about 1 in 20 Americans engage in binge eating at some point during their life. The average onset for binge eating is between 12 and 13 years old, although individuals participate in bingeing behavior at all ages, with a lifetime prevalence of 4.0% of men and 4.9% of women [2].

In addition to posing a medical threat in terms of increasing the risk of obesity, hypertension and diabetes, binge eating is an expressive problem that indicates deeper psychological issues. A groundbreaking study conducted by Hudson et al. in 2007 examined such comorbidities by replicating the National Comorbidity survey in a face-to-face household survey conducted with 9,282 English-speaking adults 18 years of age and older. The survey asked questions about eating disorders and sub-threshold disorders in addition to questions about core disorders relating to anxiety, mood, substance abuse and impulse control. Of those who fit diagnostic requirements for binge eating, 76% fit criteria for at least 1 of the core DSM-IV disorders assessed, controlling for age, sex and race-ethnicity. In addition to considering those with disorders, a sub-threshold category of BN and BED was included as those who fit the sub-threshold category exhibited the same characteristics as those with a full disorder, but not to the same intensity [2].

A 2011 study by Swanson et al. looked specifically at adolescents, ages 13-18, gathering survey data from 10,213 participants regarding the prevalence and correlates of eating disorders in the United States. The findings echoed those of Hudson's study, showing that adolescents who binge reported their eating condition to cause some form of impairment in the last twelve months at the following rates for AN, BN, BED and sub-threshold BED: 97.1%, 78.0%, 62.6% and 34.6%. Suicide ideation was dangerously correlated in those with eating disorders, most significantly with those suffering from BN (53.0%) as compared to the healthy controls (11.2%) [3].

Regardless of the inevitable subjectivity that is present in retrospective survey methods, these surveys provide significant evidence of comorbidites associated with binge eating. Both Hudson and Swanson conclude that eating disorders, as well as sub-threshold conditions, present a public health concern due to their frequent association with other psychological disorders and role impairment. But even with the physical and psychological dangers associated with binge eating, the commonality of the disorder has masked its severity until quite recently. In the last decade, implications of the condition have sparked the interest of health professionals in both research and clinical settings to better understand the etiology.

At this point in time, the physiological and neurological components of binge eating are not yet understood, due in part to the complexity and challenges involved in researching this behavior. First, it is difficult to obtain enough willing participants with binge experience for experiments, especially after controlling for age, education, and other health conditions. Second, it is difficult to study the behavioral and neurological aspects of binge eating without perpetuating unhealthy eating habits of those with the disorder, or creating an environment where individuals could be susceptible to developing such habits. Third, it is unethical to manipulate or condone any type of this bingeing behavior through invasive research techniques in humans, no matter how vital the findings could be to advancing research. Fourth, it is difficult to examine all that encompasses bingeing in a research study in terms of subjective components such as emotions and stressors so closely linked to the behavior. Fifth, due to the complexities of humans, a cause and effect relationship cannot be effectively established due to an exceptional amount of variables. And sixth, it is against the law to determine any effective interventions for a treatment method without first demonstrating successful findings in an animal study. Due to these complications, studying the biological components of binge eating in humans is limited at this time, which has led scientists to depend on another form of research: animal models.

Overview of Animal Models in Binge Eating:

Animal models of bingeing provide a way to isolate the mechanisms behind bingeing using more invasive techniques and larger sample sizes. As discussed by Corwin and Buda-Levin in 2004, animal models are essential in progressing the understanding of the cause and effect of binge eating with the eventual goal of applying the findings to possible treatment methods. Several different binge behavior models exist in the literature to explore the behavior, using various techniques in terms of feeding patterns, inducement of stress and amount of access to food [7].

While models define bingeing operationally as repeated, intermittent overconsumption of food in a short amount of time in accordance with the DSM-IV, they possess various strengths and weaknesses in the ability to apply findings to the human condition of bingeing. It is worth mentioning that although these models provide a significant window into the behaviors of binge eating, the animals can only demonstrate the objective components of binge eating mentioned above, and cannot exhibit subjective findings, such as feeling guilty after a binge [4,6,8].

The models outlined below demonstrate binge eating as defined by an objective binge episode, while all animals maintain a normal weight. Thus, binge activity is successfully isolated from obesity, which has been shown in previous research to have a distinct difference in influence of reward in brain activity and behavior than with normal weight models [9]. Since around 70% of binge eaters maintain a BMI of <30, these studies consider the bingeing activity seen most prevalently in the American population [2]. The use of such models provides better mechanistic understanding behind the behavior, laying the foundation for future clinical strategies.

The Avena/Hoebel lab has spent the last decade developing the "Sugar Addiction Model," in which rodents are given repeated, intermittent access to sugar. After 12-h food deprivation, the experimental group is given 12-h access to sugar solution (25% glucose, or 10% sucrose) and chow, while the control group has 24-h access to both sugar and chow ad libitum. It is important to note that the experimental group is food deprived for 3-hours during the dark cycle before they are given access to sugar. Results show that within a few days, the experimental group starts bingeing in the first hour of access, and consumes larger sucrose amounts overall than the control group. Body weight and total daily energy do not differ between experimental and control groups, indicating that rodents eat less chow when sugar is available. The removal of sugar in the experimental group resulted in anxiety-like symptoms such as a decrease in body temperature and signs of increased aggressive behavior [9,10].

As the first animal model using a comprehensive set of criteria associated with bingeing and addiction, the Avena/Hoebel model is useful in paving the way for studying the behaviors associated with intermittent access to sugar. Understanding such behaviors could lead to better treatment strategies in suppressing bingeing behavior in clinical settings. In this model, bingeing behaviors are only evaluated after the rodents have been food deprived for a 12-h period, which provides a good comparison for the state of hunger experienced by a self-restricting binger. This data is not as useful, however, in modeling episodic bingeing that occurs as a reaction to emotional triggers or stress, independent of hunger. It is important to note that the Avena/Hoebel model does not fit DSM-IV criteria of a bingeing episode by providing 12-h access to palatable food rather than two hours. However, the fact that significant bingeing behavior occurred in the first hour of the access period is consistent with the other models overviewed.

Hagan et al. have developed two distinct animal models: one that simulates bingeing as a result of previous dieting history and stress and the other that examines subtypes of rodents within a single group. In the History of Dieting (HD) + Stress Model, the experimental group is exposed to a cycle of restriction of food and then re-feeding. This cycle consists of a 12-day cycle in which rodents are subjected to a few days of access to chow, followed by a 2-day access to a palatable food (oreo cookies) ad libitum. The stress component is modeled by 3 seconds of a 0.6mA foot shock just prior to the feeding test, with control rodents spending an equal amount of time in the shock chamber but with no shock administered. After 3 cycles, the HD + Stress group eats significantly more than the other 3 groups despite not being in a state of food deprivation (30-100% more kcals of Oreos than the other 3 groups), which is considered bingeing behavior [9,11,12]. This model can be effectively applied to the human bingeing population with a history of dieting, as well as those who binge in response to stress [4]. Such a response in humans was shown in a study done by Harrington et al.; a link between stress and trauma influencing binge eating was found across ethnicities [13].

In the second model developed by Hagan et al., rodents are initially sorted into groups based on intake of chow. Then, the consumption of a palatable food (M&M's®) is evaluated as the animals are exposed to stress in operant chambers. The rodents in the top tertile of palatable food intake were classified as binge-eating prone (BEP), and the lowest tertile was classified as binge-eating resistant (BER). After rodents were shocked, both the BEP and BER groups decreased intake, with a notable distinction--BEP decreased chow intake while BER decreased M&M's® intake. Under satiated conditions, the BEP will undergo higher levels of foot shock than BER to retrieve M&M's®[9,14]. While other models induce bingeing activity in rodents through variables such as irregular feeding and stress, the BEP-BER model considers a predisposition to bingeing through the HD protocol. By considering the difference in propensity to binge within a group, the BEP vs. BER Model can simulate aspects such as genetic predisposition.

Corwin et al. have developed the Limited Access Model, which simulates bingeing behaviors in rodents that have sporadic, time-limited access to a palatable food. It is important to note that animals in this model have no previous or current food deprivation, with continuous access to chow and water. Using at least two groups, the control group receives 1-2h access to a palatable food (usually pure vegetable shortening, such as Crisco®) while an experimental group receives 1-2h access to the Crisco® 3 times a week, on Monday, Wednesday and Friday. In this model, bingeing is operationally defined as when the intake of the palatable food within the 1-2h access period in the MWF group is more than the intake of the Daily group [9].

Results show that the Daily group consumes a consistent intake of Crisco® throughout the experiment at an average of ~2g(18 kcal) a day, while the MWF group consumes ~4-6g(36-54kcal) after a period of several weeks. Rodents in the Daily group, with limited-time access, serve as controls for palatability and thus establish a "normal" intake. Rodents in the MWF group consumed 51% of their daily energy intake during the 2h period of limited access, while the Daily group consumed only 32% during that same time period [15]. Therefore, the MWF group with sporadic, limited access showed bingeing as compared to the daily group. Similar findings have been reported using Crisco as the palatable food in different sexes, strain types, and age groups [16-18]. Even though significant bingeing occurs in the sporadic, limited-access group, weight gain is not significant as compared to the daily group. This is due to a "saw tooth" pattern of daily intake that emerges when rodents overeat on days when palatable food is available, and undereat when palatable food is not provided [16,17].

Corwin et al. have also applied the limited access model to rodent activity in operant chambers to assess how hard rodents are willing to work for access to a palatable food. Rats with sporadic access binged on Crisco® as compared to control rats, and also worked harder for the palatable food during operant sessions [19]. Bingeing behavior may be attributed to differing reward circuitry between the sporadic and daily rodents [9,20]. After demonstrating sporadic bingeing activity with shortening as the palatable food, the study was replicated using sucrose. Bingeing was obtained at 3.2% and 10% concentrations, but not at 32% [21].

The Limited-Access Model has clearly established bingeing behavior in the group with intermittent access to a palatable food as compared to a group with daily access to that same food. Such results have been shown using either a bowl of Crisco® vegetable shortening or a 60mL plastic syringe of sucrose concentrations (3.2%-10%) as the sole palatable food [15,21]. Bingeing behavior has not yet been evaluated when using several different palatable foods, such as both shortening and sucrose. By using several different "treats", the influence of variety on bingeing can be explored, not just the intermittency factor.

Food Variety and Bingeing Behavior:

This interest in considering the connection between food variety and bingeing behavior stems from research involving sensory specific satiety, in which variety within a meal stimulated a greater energy intake. Rolls et al. found that participants who ate a 4-course meal with varied components consumed 60% more calories than those who ate the same foods for each course, and also reported a greater feeling of pleasantness from their meal [22]. Meiselman et al. also found higher acceptance and intake of a varied midday meal as compared to a monotonous meal over a period of 5 days [23]. People generally binge on a variety of foods.

This link between variety and food intake has also been tested across days in an area of research known as diet monotony. Epstein et al. discusses the effects of habituation in food consumption when subjects receive the same foods over a period of time, effectively reducing both the intake and palatability of food [24]. Similar results were seen when Zimmerer et al. created a Monotony Index, finding that subjects with the most variety consumed the highest energy in calories and protein (33 kcal/kg/d and 1.35 g/kg/d) as compared to those who with the most monotonous diet (21 kcal/kg/d and 0.83 g/kg/d) [25]. Thus, a lack of variety in the diet shows a reduced intake in both a meal and across time in a diet. This same trend has also been shown in studies using the Limited Access Model within rodent groups that are presented with a monotonous diet. When the Daily group rodents are provided access to the same palatable food every day, intake decreases over a period of weeks [15-18, 24-25].

While variety has been shown to increase food intake in healthy human subjects, the influence of variety on bingeing has never been demonstrated. When considering the plethora of dietary options and accessibility to food in America, the fact that variety in diet promotes greater caloric intake may contribute in significant ways to bingeing behavior. Although the specific influence of variety on bingeing has never been studied in humans, the Limited Access Model is posing such questions in animals. If the presence of variety over time promotes bingeing behavior in rodents, it could serve as a catalyst to betting understanding the motivations behind human bingeing.

The objective of the present study is to examine the effect of variety on bingeing by providing animals shortening and sucrose access on alternate days. If daily access of the same food promotes monotony and therefore decreased intake, what would happen if a variety of foods were provided on that same daily access schedule? Would intake remain low because rodents were still provided something to eat every day, or would the variety of foods stimulate intake?

Two opposing hypotheses were considered. Hypothesis 1: intermittent access to a different palatable food on alternate days will result in *increased* binge size. This hypothesis is based on research regarding sensory specific satiety and food monotony as described above [22-25]. Hypothesis 2: intermittent access to a different palatable food on alternate days will result in *decreased* binge size. This hypothesis is based on data generated on the Daily group in the Limited Access Model (i.e. daily access to the palatable food results in decreased intake during the access period) [9, 15-19].

Chapter 2: METHODS

Eighty-seven male Sprague Dawley (Harlan, Indianapolis, IN) rats, 60 days of age and weighing 269-298g (+/- 0.82 g) at the start of the study, were individually housed in hanging stainless steel wire cages in a temperature- and humidity-controlled environment placed on a 12:12 light:dark cycle. All rats had continuous access to a nutritionally complete commercial laboratory rodent diet (Laboratory Rodent Diet 5001, PMI Feeds, Richmond IN; percent of calories as protein: 28.05%, fat: 12.14%, carbohydrate: 59.81%; 3.3 kcal/g) placed in hanging metal food hoppers at the front of the cage. Tap water also was freely available. All procedures were approved by the Pennsylvania State University Institutional Animal Care and Use Committee.

After seven days of adaptation to the vivarium, body weights were recorded and solid vegetable shortening (Crisco® All-Vegetable shortening, J.M Smucker Co., Orrville, OH) was provided during a single overnight period. Two groups of 12 rats each were then matched by body weight and the amount of shortening consumed [t-test; p NS for both measures] to form shortening-only groups (N=12).

The remaining 63 rats were then given 3-hour access to a 10% sucrose solution, and assigned to four groups that were matched for sucrose intake (F=1.31, p NS), as well as the previously measured overnight shortening intake (F=0.24, p NS). These four groups consisted of two sucrose-only groups (N=10 each), one "variety" group (N=10), and one chow-only group (N=9).

Bingeing Procedure:

For the next five weeks, chow and water were available ad libitum to all groups and the following feeding protocols were in effect:

Shortening access protocols

Shortening was provided for 1 hour in glass jars clipped to the front of the cage, starting 2.5 hours prior to the start of the dark cycle, to the groups that had access to shortening. One of these groups (N=12) had access to shortening for one hour on a daily (DF) basis, while another group (N=12) had access to shortening for one hour on an intermittent basis (IF), i.e. on Monday, Wednesday and Friday.

Sucrose access protocols

Sucrose was provided for 1 hour in plastic bottles in a 10% solution, starting 2.5 hours prior to the start of the dark cycle, to the groups that had access to sucrose. One of these groups (N=10) had access to sucrose for one hour on a daily (DS) basis, while another group (N=10) had access to sucrose for one hour on an intermittent basis (IS), i.e. on Tuesday, Thursday and Saturday.

Variety protocol

An additional group (N=10) was given access to shortening for one hour on an intermittent basis (Monday, Wednesday, Friday) and to sucrose for one hour on an intermittent basis (Tuesday, Thursday, Saturday). This group is designated as the Variety group (V).

Body weight controls (chow only protocol)

The final group (n=9) only had access to chow and water throughout the study. This group served as a body weight control.

Statistics:

The average 1-hr shortening intakes on Mondays, Wednesdays and Fridays and sucrose intakes on Tuesday, Thursdays, and Saturdays were analyzed. To assess changes in intake across the study, average weekly 1-h intakes were analyzed via 2-way analysis of variance (ANOVA) (Group X Week) with week as the repeated measure. For these analyses, data were expressed in two ways. First, grams of shortening or mL of sucrose were analyzed, in order to analyze the average quantity consumed. Second, energy intakes were normalized to body weight in order to determine if intakes increased independent of body weight gain [26]. This is because male rats continue to grow throughout life and increases in intake may have been due to the growth of the animal. In addition, each group's data were subjected to 1-way ANOVA to determine at what point escalations in intake occurred.

The average shortening intake and 1-hr energy intake (shortening or sucrose or chow), average daily energy intake and body weights were analyzed using 1-way ANOVA with [group] as the between subject measure. Daily energy intake during week five was analyzed using 2-way ANOVA with [group] as the between subject measure and [day] as the within subject (repeated) measure. Differences among groups were assessed using Tukey's Studentized Range (HSD) post-hoc test.

Chapter 3: RESULTS

Shortening:

Over the five-week period, the amount of shortening consumed by the IF and V groups increased, while shortening consumption remained relatively stable for the DF group. There was a main effect of group [$F(2,31) = 6.92$, p 0033)] due to the higher intake of the IF and V groups. There also was a main effect of time (week) [$F(4,124) = 28.62$, p 0.0001)] due to overall increased intake over the 5-week period. In addition, group and time interacted [$F(8,124) = 5.76$, p 0.0001)] due to different rates of increase in the groups (see Figure 1). Specifically, intake in the DF groups did not change significantly across the 5 weeks (ps ns), whereas by weeks 3 and 4, intake in the IF and V groups, respectively, became significantly greater than week 1, and remained greater than week 1 thereafter. Differences among the groups also emerged as the study progressed. Initially, intakes were not statistically different among the groups (week 1). However, by week 3, the IF rats were consuming more shortening than the DF rats, and continued to do so until the end of the study (ps > 0.05; Tukey's HSD). The V rats consumed significantly more shortening than the DF rats only during week 4 ($p < 0.05$; Tukey's HSD), and V intakes never were statistically different from IF.

When shortening intake was normalized to body weight, the same relationships held. That is, there were main effects of group [$F(2,31) = 7.05$, p 0.0033)] and time (week) [$F(4,124) = 19.05$, p 0.0001)], as well as a group by time interaction[$F(8,124) = 4.90$, p. 0.0001)] (Data not shown). Thus, the intake differences described above were not due to changes in body weight across the study.

Figure 1: Shortening average intake (g) during 1-hr access period each week

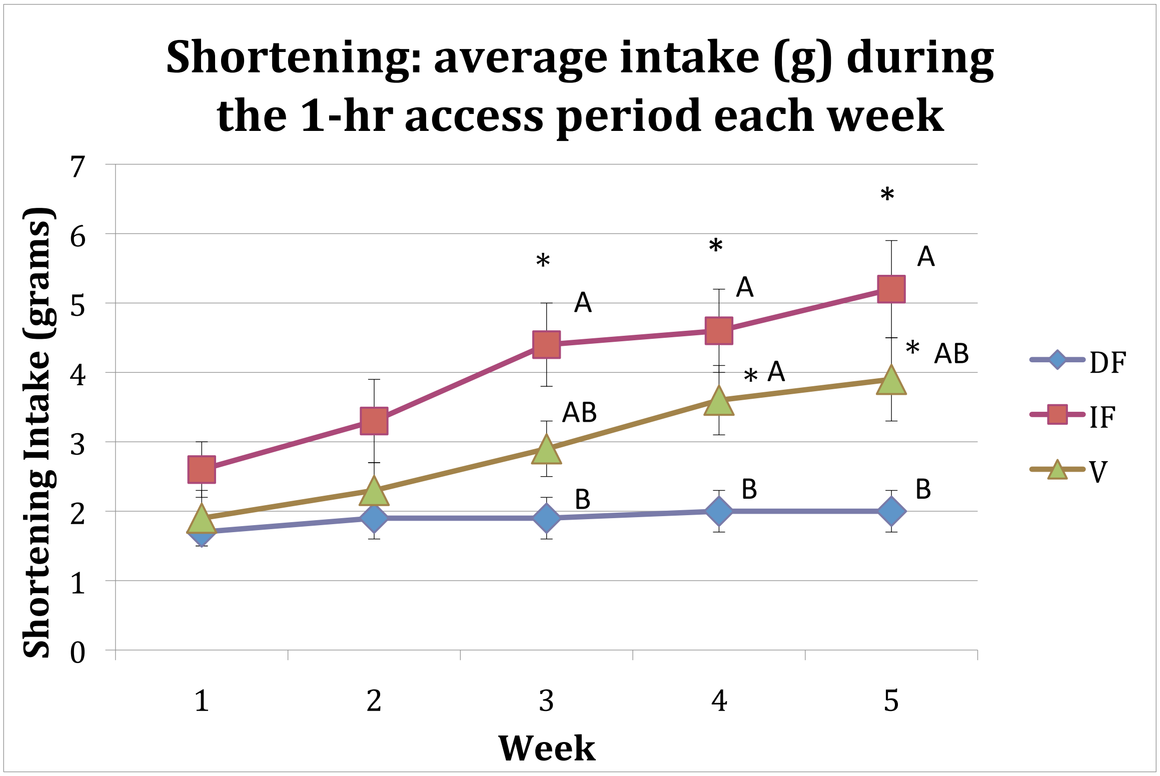

Fig 1. Average 1-hr shortening intake (g) each week. * indicates significantly different from week one within each group. Different letters indicate significant differences among groups within each week (groups that share the same letter are not statistically different).

Shortening intakes during each day of week 5 are presented in Figure 2; intakes on Monday, Wednesday, and Friday were subjected to statistical analysis, as these were the days that all three groups had access to shortening. On Monday, both the IF and V groups consumed significantly more shortening than the DF group consumed. However, on the remaining two days (Weds, Fri), only the IF group consumed significantly more than DF. That is, only the IF group met our operational definition of bingeing (intake greater than Daily) on those two days.

Figure 2: Shortening: consumption in week 5 (g)

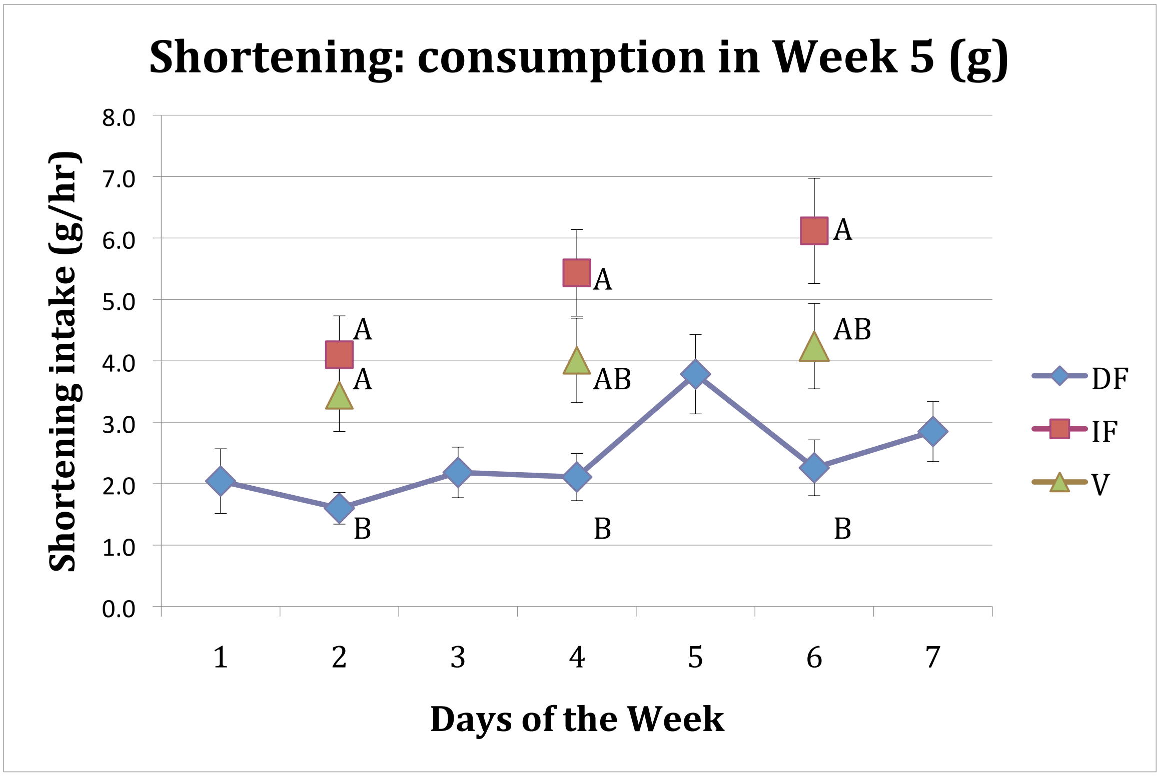

Fig 2. Shortening consumption in week 5. Different letters indicate significant differences among groups within each week (groups that share the same letter are not statistically different).

Sucrose:

There were no significant differences in sucrose intake among the DS, IS, and V groups when intakes were collapsed across the five weeks of the study (main effect of group [F(2,27) = 2.39, p. 0.1110]). However, there was an effect of week [F(4,108) = 22.89, p 0.0001)], due to increases in intake among the groups as the study progressed. There also was a group by week interaction [F(8,108) = 2.05, p 0.0477], due to differences in the rate at which intake escalated (Figure 3). Unlike the results with shortening described above, sucrose intake in the DS group gradually increased across the study, with intakes in weeks 4 and 5 being significantly greater than that of week 1 (ps < 0.05, Tukey's HSD). Similar results were obtained in the IS group (ps < 0.05 for weeks 4 and 5 relative to week 1, Tukey's HSD). In contrast, sucrose intake in the V group did not become significantly greater than week 1 until week 5 ($p < 0.05$, Tukey's HSD).

As a result, intakes among the groups only differed during week 4, with the V group consuming significantly less than the IS group ($p < 0.05$; Tukey's HSD). DS did not differ from the other two groups.

Figure 3: Sucrose: average intake (mL) during 1-hr access period each week

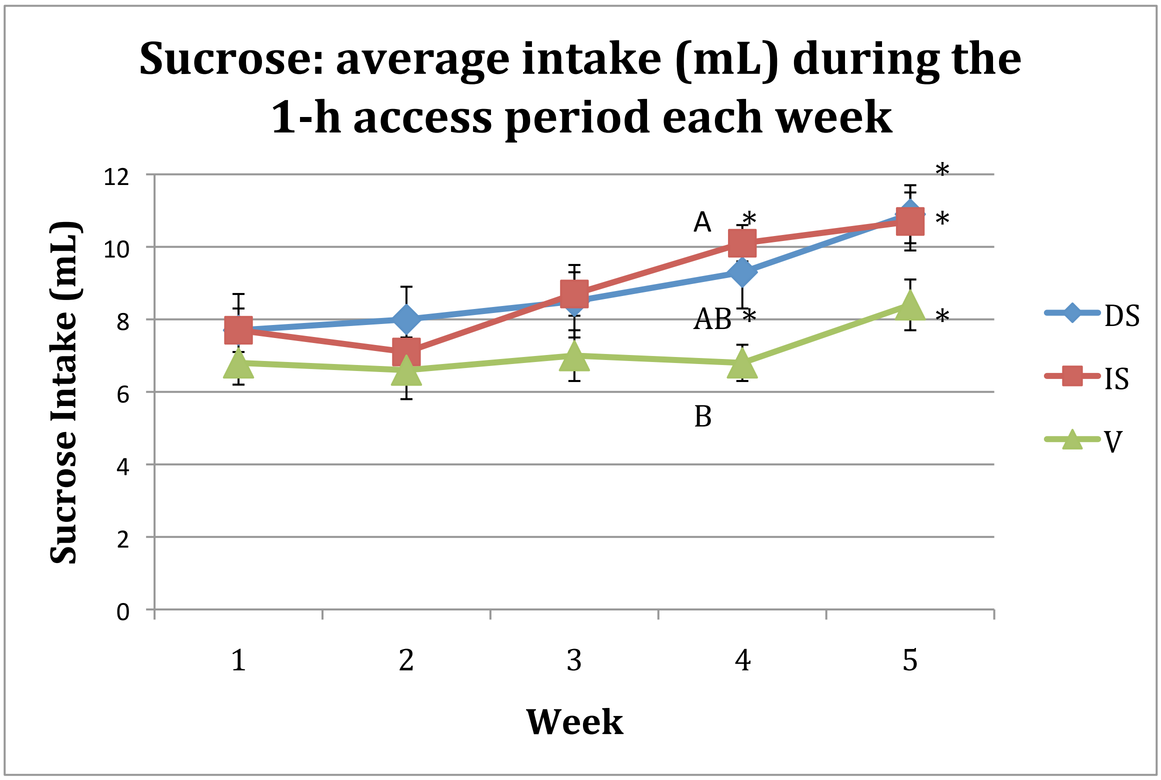

Fig 3. Average 1-hr sucrose intake (mL) each week. * indicates significantly different from week one within each group. Different letters indicate significant differences among groups within each week (groups that share the same letter are not statistically different).

Sucrose intake during each day of week 5 are presented in Figure 4; intakes on Tuesday, Thursday, and Saturday were subjected to statistical analysis, as these were the days that all three groups had access to sucrose. On Tuesday and Thursday, intakes among the groups did not differ. However, on Saturday the V group consumed significantly less sucrose than the DS group ($p < 0.05$; Tukey's HSD). Intake of sucrose in the IS group did not differ from either V or

DS.

Figure 4: Sucrose: consumption in week 5 (mL)

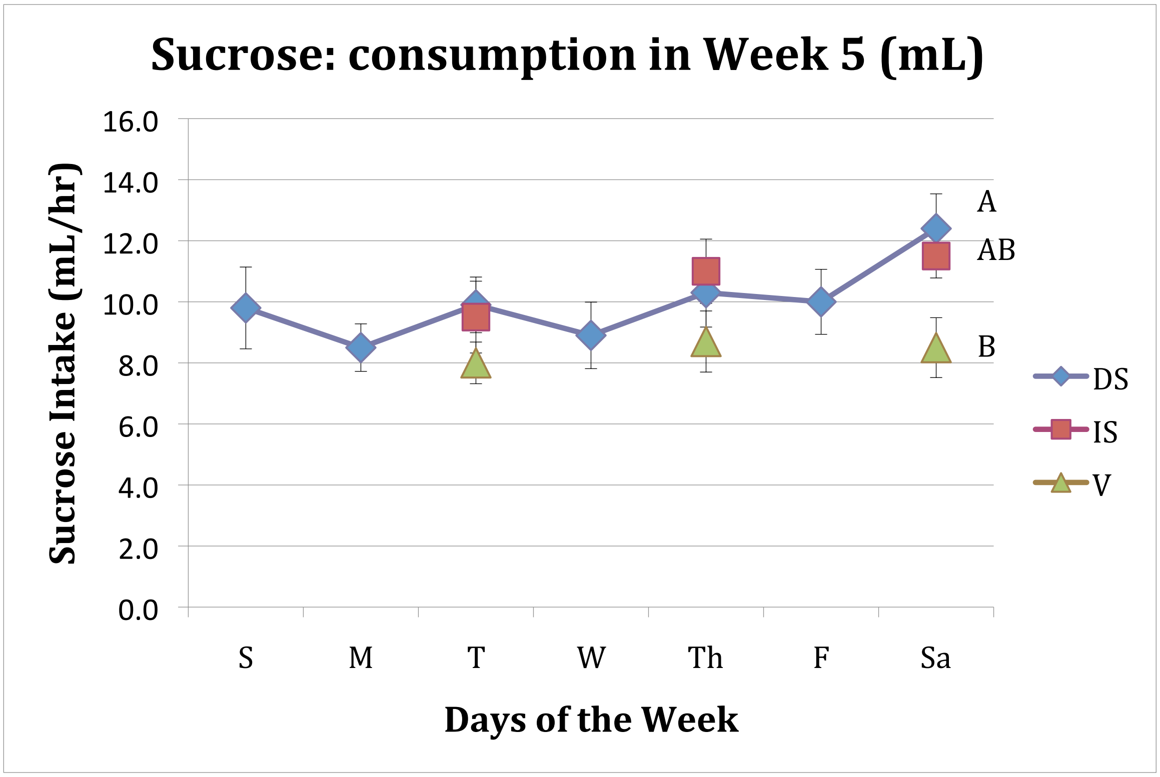

Fig 4. Sucrose consumption in week 5. Different letters indicate significant differences among groups within each week (groups that share the same letter are not statistically different).

Body weights:

Body weights increased across time (main effect of week [F(2,285) = 1558.85, p 0.0001]), but there was no effect of group nor was there a group by week interaction [F < 1.0, NS]. In addition, there were no differences among the groups for any week of the study (data not shown).

Chapter 4: DISCUSSION

Several new findings are reported. First, the shortening intake in the Variety (V) group did not differ significantly from either the intermittent fat (IF) or the daily fat (DF) group. Even though the V group consumed slightly more than the DF group, it also consumed slightly less than the IF group. Thus, the V group did not meet our operational definition of bingeing, in which intakes need to significantly exceed that of the daily control group (in this case DF). Second, during week 4 of the study, and on the last day of the study, the V group consumed significantly less sucrose than the group that had sucrose daily (DS), and slightly less than the group that had intermittent access (IS). Taken together, these results suggest that daily consumption of a fatty or sugary "treat" protects against bingeing to some extent.

Variety attenuates bingeing on shortening

In this study, the V group provided a way to test two different aspects of diet variation: daily access and variety. The results demonstrate that daily access to some kind of optional palatable food appears to reduce the amount consumed.

Previous work by Corwin et al. has established a relationship between binge behavior and intermittent access, suggesting that intermittent access (IF in this study) contributes to greater consumption of shortening as compared to daily access (DF in this study) [9,15-18].

Variety across days did attenuate bingeing on fat to some extent. As mentioned above, the V group did not binge as compared to the daily group on most weeks, but also consumed slightly less than the IF group. Although there was not a statistically significant difference in binge size between the IF and V groups, Figure 1 indicates that by week 5, the IF group consumed an average 5.2g of shortening (47.8 kcal) while the V group only consumed 3.9g (35.7 kcal). This finding is surprising, because past literature in dietary monotony shows significant increases in energy consumption when food is varied across time. Theoretically, the variety of shortening and sucrose presented to the V group should have stimulated greater intake than the IF group both in terms of daily intake and across time in the 5 week experiment [24,25]. The failure of the V group to consume more than the IF group was not due to ceiling effects on intake. Calculation of stomach capacity for rats of this size (280-390 g) indicates that intakes could have ranged from about 9 grams in week 1 to about 13 grams in week 5 [27].

The difference in V group intake as compared to IF intake could be due to a confluence of factors. While the IF group consumed shortening on an intermittent access schedule that has been shown to increase binge size in past studies, the V group received a palatable food six days a week, and were therefore similar to the daily group in that regard. It is possible that animals responded to the consistent provision of a treat by behaving just as the daily animals do—by decreasing intake.

Thus, the variation of palatable foods on alternate days attenuates the effect of intermittency on bingeing. This finding supports hypothesis 2, because access to different foods on alternate days in the V group led to a slightly *decreased* binge size as compared to IF.

Variety group consumes significantly less sucrose than other groups

The V group's intake of sucrose was significantly less than both the IS and DS groups in week 4 (Figure 3), and significantly less than DS on the last day of the study (Figure 4). These results are consistent with the shortening results: access to a palatable fatty or sugary treat every day attenuated sucrose bingeing to some extent.

In previous work done with the Limited Access Model, intermittent access to sucrose has led to significant bingeing behavior as compared to the daily group. In work done by Wojnicki et al., both 3.2% and 10% sucrose concentration showed bingeing in the intermittent group. There are a few possible reasons for inconsistency across studies using the Limited Access Model. First, the daily sucrose animals in the present study consumed an abnormally high amount of sucrose as compared to the daily sucrose animals from the previous study. Daily animals in the present study consumed 8-11mL by week 5, as compared to 6.2-8mL by week 5 in the Wojnicki's 2007 report [21].

There have been very few sucrose studies conducted using the Limited Access Model, therefore there are only a few studies against which the present results can be compared. Wojnicki et al.'s demonstration of bingeing in sucrose may be an aberrant finding, but that seems unlikely since the phenomenon has since been replicated in a follow-up study using the Limited Access Mode [28]. Avena et al. demonstrated similar bingeing with sugar in the Sugar Addiction Model in which the experimental group consumes significantly more sugar in the first hour after deprivation as compared to the control group [9,10]. Regardless of this inconsistency in daily group consumption, a key finding remains that the V group consumed less sucrose than either the IS or DS group on at least some days during the last two weeks of the study.

In addition to the effect of variety, we cannot rule out the influence of shortening on sucrose intake. It is possible that consuming relatively large amounts of shortening on some days could have reduced sucrose intake on alternate days. Such patterns of saw-tooth energy consumption have been seen in Avena, Hagan and Corwin's animal models, since rodents maintain normal body weight throughout the experiment despite bingeing behaviors [9]. If animals are compensating for the increased energy provided by the shortening by reducing sucrose intake, the present results may not be due to variety, but to the ability of rats to maintain energy homeostasis. Future studies will need to be done to address this possibility. Whether the results attained are explained through variety or energy density, one finding is evident: binge size is reduced when daily access to a palatable food is provided.

Future directions

Since the current study was the first to incorporate a Variety group into the Limited

Access Model, replication is necessary to test reliability of the findings as well as to provide information for future directions. In addition, it would be useful to assess the intake of a daily sucrose group in order to determine if the group in the present study consumed an abnormal amount of sucrose from the start as compared to other studies.

An interesting manipulation of the current model would be to add another variety group that received shortening two days in a row, followed by sucrose two days in a row, etc. By measuring this intake as compared to the original Variety group that received access to food on alternate days, it will be clearer to see the impact that energy density has rather than just palatability.

In addition, this study should be replicated using shortening and sucrose foods that are more similar in texture. By doing so, consumption of these palatable foods will be more uniformly distributed rather than eating shortening out of a bowl while licking sucrose out of a plastic syringe. Finally, as discussed above, it will be important to distinguish the influence of energy density from that of variety in future studies. This could be done by providing fatty and sugary foods that are isocaloric on alternate days.

Summary/conclusion

In summary, these findings demonstrate that variation of palatable foods across days does not lead to more significant bingeing behavior than intermittent access to one type of food. Thus, it seems that the frequency of opportunities to consume palatable foods, e.g. daily or intermittent, may be more critical in stimulating bingeing behavior than the variety of foods that are consumed. Indeed, a variety of alternating palatable foods actually attenuated bingeing on those foods.

This may have relevance to human research and clinical practice, since the results in this study suggest that providing access to a variety of "treats" seemed to show a protective effect against the bingeing seen in intermittent conditions. In an article by Murphy et al. on effective treatment for bingeing, cognitive behavioral therapy is presented as the most effective treatment method. As a part of this treatment method, the systematic re-incorporation of small amounts of "avoided" foods (typically those foods rich in fat and sugar) into the diet is recommended [29,30]. In addition, incorporation of variety in the diet has also been recommended [31].

Despite the consistent focus on incorporating small amounts of fatty or sugary treats as a protective effect against bingeing, there has not been much research conducted to find out if this method actually works. The results in the present study suggest that it might, but further research needs to be done in both rodents and humans to before definitive treatment recommendations can be made.

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Academic Vita
Jill Bontrager

Education:
Pennsylvania State University, University Park, PA 8/2008-5/2012
Major: Nutritional Sciences
Minor: Psychology
Honors: Nutritional Sciences

The Pantheon Institute Rome, Italy 5/2010-6/2010
Study abroad: International Nutrition

Work Experience:
Laboratory of Dr. Rebecca Corwin University Park, PA 7/2010-8/2011
Thesis student, Neurobiology
- Performed laboratory techniques and experiment preparation
- Closely interacted and collaborated with professors and doctoral students
- Wrote and researched for publishable results

Dining with Diabetes University Park, PA 8/2010-5/2011
Data Analyst for Penn State Cooperative Extension
- Member of community nutrition research group
- Entered, organized and analyzed statistical data
- Communicated and transferred data to Joslin Research Clinic

American Cancer Society Atlanta , GA 8/2011
Intern, National Home Office
- Worked in Cancer Control Sciences department with Colleen Doyle, director of nutrition and physical activity
- Researched international anti-obesity campaigns focusing on disease prevention

Campus Involvement:
Women's Leadership Initiative, class of 2010-2011. 8/2010 –5/2011
Selected member for leadership program in the College of Health and Human Development
- Attended bi-monthly meetings and sessions on leadership
- Developed skills in etiquette, interviewing, and leadership style
- Networked with professionals in health care field
- Designed and performed a service project

Penn State *LeaderShape Institute* 5/2011
Selected member for the 2011 class
- National 6-day intensive leadership program
- Participated in interactive activities, dialogues, team-building, and personal vision development

The Navigators 8/2008-5/2012
- Social Justice Committee member in The Navigators, 2009-present

- Spring break missions trips to New Orleans, 2009, and Atlanta, 2010
- Volunteer for Penn State's Dance Marathon, the largest student-run philanthropy in the world. Navs THON dancer in February, 2012.

Humanitarian Work 8/2008-present:

- Community development work in Vera Blanca, Costa Rica with *Association for Development through Education (ADE),* March 2011
- Volunteer at the Rose of Sharon Orphanage in San Juan de la Manguana, Dominican Republic, March 2012.
- Mentor for High School Ministry with Calvary Baptist Church, 2008-present

Awards/Honors:

2009-2012: Schreyer's Honors College Student
2008-2012: Dean's List
2010: Ambassador Travel Grant
2011-2012: Member of The Honors Society of Phi Kappa Phi

- Selected for the most competitive national society
- Invited members are in the top 7.5% of their class; multi-disciplinary