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Can the reinforcing value of food be measured in bulimia nervosa?

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Abstract

Binge eating is a core clinical feature of bulimia nervosa (BN). Enhanced reinforcing value of food may play a role in this behavioral disturbance, but a systematic behavioral assessment of objective measures of the rewarding value of binge eating is lacking. The purpose of this study was to quantify the reinforcing value of food in BN patients as compared with normal controls. A progressive ratio (PR) computerized work task was completed under binge and non-binge instruction. The task consisted of 12 trials. The first trial required 50 keyboard taps to earn one portion of yogurt shake, and subsequent trials required progressive work increments of 200 taps for each additional portion. Completion of all 12 trials required 13,800 taps to earn 2,100 ml of shake. The breakpoint, defined as the largest ratio completed before a participant stopped working, was the measure of reinforcing efficacy. Ten patients and 10 controls completed the experiment. Under binge instruction, patients completed more trials and taps, and had a higher breakpoint than controls. The non-binge instruction yielded opposite findings; compared to controls, patients completed fewer trials and taps, and had a lower breakpoint. These results support the feasibility and potential utility of a PR task to quantify the reinforcing value of food in patients with BN.

Keywords

Bulimia nervosa; progressive ratio task; reinforcing value of food

INTRODUCTION

Binge eating, accompanied by inappropriate compensatory behavior to avoid weight gain, is a core clinical feature of Bulimia Nervosa (BN). Enhanced reinforcing value of food may play a role in this behavioral disturbance (Bohon & Stice, 2011), but an objective behavioral assessment of measures of reward is lacking in this patient population.

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The field of behavioral economics provides methods by which to measure the reinforcing efficacy of motivated behaviors, like smoking (Bulik & Brinded, 1994; Epstein, Bulik, Perkins, Caggiula, & Rodefer, 1991), drug use (Comer et al., 1998; Stafford, LeSage, & Glowa, 1998), physical activity (Saelens & Epstein, 1999), and eating (Epstein & Leddy, 2006; Epstein, Leddy, Temple, & Faith, 2007; Lappalainen & Epstein, 1990; Raynor & Epstein, 2003; Saelens & Epstein, 1996) in a laboratory setting. In general, these laboratory paradigms quantify the reinforcing efficacy of a target behavior in terms of the amount of "work" an individual is willing to expend to access it (Hodos, 1961). Specifically, the progressive ratio (PR) task measures the reinforcing value of a motivated behavior by requiring the participant to expend progressively increasing amounts of work to gain access to it (Roane, 2008). In humans, effort or "work" is often based on the number of taps on a computer keyboard. The PR breakpoint is defined as the number of responses completed for a reinforcer before the participant stops working for it; the more reinforcing a stimulus is, the higher the breakpoint (Hodos, 1961).

Human eating behavior can be measured during laboratory test meals and is related to two food attributes, hedonics and liking (Mitchell, Crow, Peterson, Wonderlich, & Crosby, 1998; Walsh & Boudreau, 2003). It has, however, been suggested that the reinforcing value of food may be a more powerful determinant of food intake than either food hedonics or liking (Epstein & Leddy, 2006). Laboratory studies demonstrate that when asked to binge eat, patients with BN consume binge quantities of food at single-item and multi-item meals (Kaye et al., 1992; Kissileff, Walsh, Kral, & Cassidy, 1986; LaChaussee, Kissileff, Walsh, & Hadigan, 1992; Walsh, Kissileff, Cassidy, & Dantzic, 1989; Walsh, Kissileff, & Hadigan, 1989). The purpose of the current study was to determine if patients with BN were willing to work at a PR task in order to obtain a binge quantity of food during a single-item laboratory test meal. We hypothesized that: 1) Both BN and NC subjects would perform more total work and achieve a higher breakpoint under binge vs. non-binge instruction; and 2) Under binge instruction, BN subjects would work harder (more total work and a higher breakpoint) than NC subjects to obtain a larger quantity of food.

METHODS

Participants

Patients meeting the *Diagnostic and Statistical Manual of Mental Disorders, 4th edition* (Association, 1994) criteria for BN, and healthy normal controls, were recruited to participate in a laboratory study conducted by the Eating Disorders Research Unit at the NYSPI, Columbia University Medical Center from Oct 2005 to March 2008. All BN participants were female outpatients between the ages of 18 and 45 years. Exclusion criteria included co-morbid substance abuse or a DSM-IV Axis I psychiatric diagnosis other than depression. Controls were matched on age, gender, and BMI. The New York State Psychiatric Institute (NYSPI) /Columbia University Department of Psychiatry Institutional Review Board approved this study. Written informed consent was obtained from participants prior to study.

Progressive Ratio (PR) Computer Task

The PR computer task consisted of 12 trials, and work consisted of finger presses on a computer keyboard. The work required in the first trial was 50 keyboard presses to earn a 175 ml portion of a strawberry yogurt shake; an additional 200 keyboard presses were required to complete each subsequent trial and earn an additional 175 ml aliquot of shake. Thus, the first completed trial required 50 keyboard presses and the remaining trials required 250 presses, then 450, 650, 850, 1050, 1250, 1450, 1650, 1850, 2050, and 2250 responses. To earn the maximum amount of shake (2100 ml), the participant had to complete 12 trials

and perform 13,800 keyboard presses within a 60-min period. The breakpoint, defined as the largest ratio completed before a participant stopped working, was the primary measure of reinforcing efficacy.

Study Sessions

All studies were conducted in the Biological Studies Unit (BSU) at the NYSPI. Studies were scheduled over a four-day period within one week as follows: acclimation day (Tuesday), day off (Wednesday), study day 1 (Thursday), and study day 2 (Friday).

Acclimation Day—Acclimation day had several purposes: to train subjects on the PR computer task; to familiarize subjects with the BSU setting and with the instruction to binge (BN) or overeat (NC); and to determine if a BN subject was able to binge and purge in the laboratory setting. BN subjects who could successfully binge and purge in the laboratory proceeded to the experimental study days 1 and 2. Those who could not were not studied further.

Subjects arrived at 10:00 a.m., and, after an overnight fast, a standardized research breakfast (≈300 kcal/1256 KJ) was provided. Immediately after breakfast, participants practiced the identical PR task used on the experimental study days. Before starting the PR task, participants were given a 2 fl. oz. serving of yogurt shake to taste. A clear plastic glass that contained a 175 ml visual reference portion was also provided and the subject was instructed to “Imagine that you are working for the number of yogurt shake portions you would like drink this afternoon.” During the PR task, a computer screen image of a pitcher, initially empty, increased in its content of shake with each completed PR trial. In addition, a 175 ml aliquot of shake was also pumped into an actual pitcher, placed to the left of the computer screen, after the completion of each PR trial. After completion of the PR computer task, the pitcher of shake was removed. Participants then remained in a private room in the BSU until 3 pm. During the interim, they could read, write, or sleep, but were asked not to eat or drink anything except water; compliance was monitored via closed circuit TV. At 3 pm, participants were seated at a table and provided with an empty glass and a full pitcher of yogurt shake. Although subjects may have worked for less than a full pitcher of shake during the actual PR task, on acclimation day (only) they were provided with the maximum amount they could possibly earn (2100 ml for 12 completed PR trials) and were instructed as follows: “Today we want you to let yourself go and drink as much as you can. In other words, binge. If you are someone who does not binge, we want you to let yourself go and drink as much as you can. In other words, overeat. “The pitcher was removed at 3:30 pm, but subjects remained in the BSU for additional 30-minutes before discharge (4 pm). Access to a private bathroom was permitted throughout the afternoon session.

Study Days 1 and 2—Subjects arrived at 10:00 a.m., after an overnight fast, and a standardized research breakfast (≈300 kcal/1256 KJ) was provided. After breakfast, subjects remained in a private room in the BSU until they performed the PR computer task later that afternoon. During the interim, they could read, write, or sleep, but were asked not to eat or drink anything except water; compliance was monitored via closed circuit TV.

Subjects began the PR task at 2 pm. Before starting, they were given a 2 fl. oz. portion of the yogurt shake to taste. A 175 ml visual reference portion was provided, and the participant was then given either a binge instruction (“Today we want you to work for the number of yogurt shake portions that you can binge on. If you are someone who does not binge, we want you to work for the number of yogurt shake portions that you can overeat on.”) or a non-binge instruction (“Today we want you to work for the number of yogurt shake portions that you can drink comfortably, without restricting or bingeing.”). The order of the binge

and non-binge days was counter balanced across subjects. The PR computer task was identical to that used on acclimation day. During the task, a pitcher image on the computer screen allowed subjects to visualize the amount of shake earned during the session, and the actual pitcher, initially empty, filled with a 175 ml aliquot shake upon completion of each PR trial.

After completion of the PR task, participants remained in a private room in the BSU. At 3 pm, participants were provided with yogurt shake. As distinct from acclimation day, only the amount of shake that was actually earned (i.e., 175 ml per completed trial) was provided. Prior to drinking the shake, participants were provided with the appropriate binge instruction ("Today we want you to let yourself go and drink as much as you can. In other words, binge. If you are someone who does not binge, we want you to let yourself go and drink as much as you can. In other words, overeat. ") or non-binge instruction ("Today we want you to drink comfortably, without restricting or bingeing."). The pitcher was removed at 3:30 pm, but subjects remained in the BSU for additional 30 minutes before discharge. Access to a private bathroom was permitted throughout the afternoon session.

Instruments

Eating Disorder Examination (Fairburn & Cooper, 1993)—The Eating Disorders Examination, administered by a trained research assistant, was used to determine the energy content of a typical binge, as well as the frequency of binge and purge episodes.

Visual Analogue Scales—Immediately before starting the PR computer task on binge instruction day, participants completed visual analogue scale (VAS) ratings in response to the following questions: "How tense or anxious do you feel right now?"; "How hungry are you right now?"; "How full are you right now?"; "How much do you want to eat right now?"; "How much do you want to binge right now?" Responses were indicated on a 100 ml scale that was anchored by "not at all" on one end and "extremely" on the other.

Profile of Mood States (McNair, Lorr, & Dropplemen, 1971)—Immediately before starting the PR computer task on binge instruction day, participants completed the 65-item standard version of the Profile of Mood States (POMS). Six subscale scores (tension, depression, anger, vigor, fatigue, confusion) and a total mood disturbance score (TMD) score ranging in value from - 24 to 177; lower scores indicating more stable mood profiles and higher scores indicating less stable mood profiles were determined.

Outcome Measures

Results of the PR task were the primary outcome measures. These included the PR breakpoint (measure of reinforcing efficacy), total work (i.e., the total number of key board presses), the number of number of completed trials, the amounts of shake earned (g) and consumed (g), and percent of earned shake that was consumed. Secondary outcome measures included POMS scores and VAS ratings in both participant groups, and EDE measures in the BN patients.

Statistical Analyses

The mean and standard deviation (SD) for clinical characteristics, POMS scores, VAS ratings, PR task performance, and ingestive behavior were determined for BN and NC participants. The independent samples (Student's) *t*-test was used to compare differences in clinical characteristics, POMS scores, VAS ratings, PR task performance, and ingestive behavior between the BN and NC groups. The paired sample *t*-test was used to compare PR task performance and ingestive behavior under non-binge and binge instruction within the BN and NC groups.

A mixed model analysis of variance (ANOVA) with one within-subjects factor (instruction) and one between-subjects factor (diagnosis) was conducted to compare the PR breakpoint and total work. Four post-hoc comparisons were conducted: BN vs. NC subjects under non-binge instruction; BN vs. NC subjects under binge instruction; BN subjects under non-binge vs. binge instruction; NC subjects under non-binge vs. binge instruction. The p values from the t- tests for these comparisons were multiplied by 4 in accord with the Bonferroni correction for multiple comparisons.

Pearson correlation coefficients were calculated to determine the relationship between the PR breakpoint and shake consumption in BN and NC participants under binge and non-binge condition. In BN participants, Pearson correlation coefficients were also calculated to determine the relationship between the PR breakpoint and EDE measures, POMS scores, and VAS ratings at the binge meal.

Means +/− SD are reported; t-tests were two-tailed. Statistical significance was set at the p 0.05 level. Statistical analyses were performed by using SPSS for WINDOWS software (version 17.0, 2008; SPSS Inc., Chicago, IL). Effect sizes (Cohens *d*) were calculated as the mean difference between the two groups being compared for a given variable divided by the mean SD of the two groups on that variable.

RESULTS

Participant Characteristics

Ten NC and 10 BN patients completed the three-day study. Nine additional BN participants who were recruited and consented did not complete the study. Of these, one withdrew consent after acclimation day, four were unable to binge on acclimation day, and four failed to comply with either the binge or non-binge instruction on the experimental study days. The BN group was comprised of one Asian American and nine Caucasian participants. The NC group was comprised of one African American, one Asian American, two Hispanic, and six Caucasian participants. No significant between-group differences in age, height, weight, or BMI were observed (Table 1).

Progressive Ratio Task Performance

PR task performance on the non-binge study day was compared to performance on the binge study day within each participant group (Table 2). Compared with the non-binge instruction, patients with BN completed significantly more trials, performed significantly more total work, and achieved a significantly higher breakpoint on the binge instruction day. They also earned and consumed significantly more shake under binge instruction; however, no difference in the percent of shake consumed was observed. The PR breakpoint and shake consumption were significantly and positively correlated under binge (r=0.975, p<0.001) and non-binge (r=0.728, p<0.05) instructions.

In a similar manner, NC participants also completed significantly more trials, performed significantly more total work, and achieved a significantly higher breakpoint on the binge instruction day. The controls also earned and consumed significantly more shake under binge instruction, but there was no significant difference in the percent of shake consumed. The PR breakpoint and shake consumption were significantly and positively correlated under non-binge instruction (r=0.898, p<0.001) but failed to correlate under binge instruction(r= −0.047, p=0.898).

Results of the mixed model ANOVA showed a significant instruction by diagnosis interaction for the PR breakpoint (F(1,18)=16.2, p<0.01). The nature of this interaction was examined using post-hoc t-tests corrected with the Bonferroni adjustment for multiple

comparisons (Table 2). These revealed that patients and controls had similar breakpoints under non-binge instruction; however, under binge instruction the breakpoint was significantly higher in BN vs. NC participants. Similarly, ANOVA results for total work showed a significant instruction by diagnosis interaction ($F(1,18)=18.929$, $p<0.001$): under non-binge instruction, the BN and NC groups performed similar amounts of work, but under binge instruction the BN group performed significantly more work than did the NC group. Effect sizes were consistently large under binge instruction, and small to medium under non-binge instruction.

The purpose of acclimation day was largely instructional; participants practiced the PR computer task, and regardless of outcome, were provided with a full pitcher of shake. It is noteworthy that the amount of shake consumed on acclimation day was similar to the amount consumed on binge instruction day in both the BN (1197.8 g vs. 1279.3 g, p=0.71) and NC (615.3 g vs. 610.6 g, p=0.929) groups.

Relationship between EDE measures and the PR Breakpoint

Results of the EDE indicated that, one month prior to study, BN participants reported 48.6 (+/− 38) binges, 69.2 (+/− 57.6) purges, and a typical binge intake of 3248 (+/− 2864)) kcal. Although the BN group demonstrated a significantly higher breakpoint under binge instruction, the breakpoint did not correlate significantly with patients' history of binge eating episodes (r= −0.025, p=0.945), purging episodes (r= −0.293, p=0.41), or kcal content of binge episodes (r= 0.176, p=0.626). Similarly, total work performed also failed to correlate with the number of binges (r= −0. 008, p=0.982), number of purges (r= −0.307, p=0.389), and kcal content of a typical binge (r= 0.138, p=0.705) reported on the EDE.

POMS Scores and VAS Ratings on Binge Instruction Day

On binge instruction day, immediately before starting the PR computer task, the BN and NC participants differed significantly on some POMS scores and VAS ratings (Table 1). Patients with BN scored significantly higher than controls on the POMS depression, fatigue, and confusion subscale scores, as well as the total POMS score; however, only the anger and the depression subscale scores correlated with the breakpoint in BN patients (r= 0.655, p<0.05, and r= 0.774, p<0.01, respectively). The between group difference in response to the VAS rating of "How tense or anxious do you feel right now?" approached statistical significance, and the VAS rating of "How much do you want to binge right now?" was significantly higher in BN patients than in controls. Nevertheless, within the BN group, no significant correlations were found between the PR breakpoint and VAS ratings of tension (r= -0.195, p=0.589), hunger (r=0.278, p=0.437), fullness (r= −0.21, p=0.56), want to eat (r=0.222, p=0.538), and want to binge(r=0.124, p=0.732).

DISCUSSION

This study demonstrates that patients with BN and healthy controls will work at a PR computer task to earn and consume food in a laboratory setting. As expected, both groups performed more work and achieved a higher breakpoint at the binge vs. non-binge meal. However, on the binge instruction day, the BN group achieved a significantly higher breakpoint, performed significantly more total work, and consumed a significantly larger amount of shake compared to the NC group. These significant between-group differences were not observed on the non-binge day.

Eating behavior in bulimia nervosa

Previous studies of BN using laboratory meal studies have documented that during both single- and multi-item meals BN participants consumed more than controls when asked to

binge (Kissileff et al., 1986; Walsh et al., 1989a; Walsh et al., 1992; LaChaussee et al., 1992). In contrast, in meals when individuals with BN are asked to eat normally, they generally consumed less than controls during both multi-item and single-item non-binge meals (Kissileff et al., 1986; Walsh, Kissileff & Hadigan, 1989b; Walsh et al., 1992; LaChaussee et al., 1992). The results of the current study follow a similar pattern, but, in addition, document that BN participants worked harder than controls to obtain the food that they subsequently binged on.

Studies of reinforcing efficacy of food

The amount of work an individual will perform to obtain a food item is a measure of its reinforcing value (Epstein & Leddy, 2006). To date, only three studies have measured the reinforcing value of food in individuals with eating disorders. Of these, only one was specific to BN. Goldfield et al. (Goldfield, Adamo, Rutherford, & Legg, 2008) used a stress induction procedure and found that increased stress raised the amount of work for food by binge eaters.Nasser et al. (2008) and Bulik and Brinded (1994) manipulated hunger and found that the reinforcing value of food was not altered by food deprivation in participants with binge eating disorder or BN. Although we did not directly manipulate stress or hunger, measures obtained (i.e., POMS tension score, VAS tension/anxiety rating, VAS hunger rating) failed to correlate with the PR breakpoint under binge instruction.

Research suggests that the increased reinforcing efficacy of a food results in increased food intake (Goldfield et al., 2008). In the current study, the PR breakpoint, our primary measure of reinforcing efficacy, was significantly and positively correlated with shake consumption in BN patients at both the binge and non-binge meals. In controls, the PR breakpoint and shake consumption were correlated in the non-binge condition, but failed to correlate at the binge meal. Although the reason for this is unclear, we speculate that while controls were willing to work for more shake under the binge instruction, they simply could not consume all of their earnings. It is also noteworthy that while binge meal shake consumption and the PR breakpoint were significantly correlated in our BN patients, their history of binge frequency and kcal intake during a typical binge, as reported on the EDE, failed to correlate with the breakpoint measure. This may suggest that an objective laboratory measure of food intake may better capture the reinforcing value of food in BN patients compared to subjective self-report measures.

Mood and bulimic behaviors

Retrospective reports suggest that individuals with BN have more negative mood, both in general and prior to a bulimic episode, than do normal controls (Smyth et al., 2007). The relation of mood to bulimic behaviors has also been examined in real-time using ecological momentary assessment (EMA) measurements of BN patients in their natural environment. Using EMA, Smyth et al. (Smyth et al., 2007) used the Negative Affect (NA) scale from the Positive and Negative Affect Scale (PANAS) (Watson, Clark, & Tellegen, 1988) to examine the relation of negative mood to bulimic behaviors over a two-week period. Results indicated that BN participants reported more negative affect on days when at least one binge eating or vomiting event occurred; furthermore, negative affect severity ratings increased up to the point of the bulimic event and decreased thereafter. Similarly,Crosby et al. (2009) used the NA scale of the PANAS to evaluate the relation of mood to bulimic behaviors over a two-week period. Results indicated that the highest rates of bingeing and purging episodes occurred on days characterized by stable high negative affect or increasing negative affect over the course of a day. In the current study, negative affect (measured by the POMS depression subscale score) was significantly and positively correlated with willingness to work (measured by the PR breakpoint) for the opportunity to engage in bulimic behaviors.

While not a naturalistic study, the PR task did provide a real-time measure of the relation of mood and bulimic behavior in a laboratory setting.

Study limitations

Several limitations of our study warrant comment. First, our sample size was small; nonetheless, statistically significant between-group differences were observed. Second, while it is possible that the eating behavior of BN patients who are willing to binge and purge in a laboratory setting may differ from other individuals with this disorder, our BN participants ate in a manner similar to that reported in the literature. Third, methodological differences in the design of operant tasks make it difficult to compare findings across studies. Our study used a PR ratio schedule of 200 keyboard taps. Although this PR schedule is identical to that which was used to measure the reinforcing efficacy of exercise in patients with AN (Klein et al., 2010; Schebendach, Klein, Foltin, Devlin, & Walsh, 2007), it is possible that the use of a different PR schedule, or use of a variable ratio schedule, may have yielded different findings. Fourth, in the current study, yogurt shake was the exclusive reinforcer and alternate choices, like cigarettes or money, were not made available. Fifth, it has been suggested that food may be more reinforcing for individuals who are cigarette smokers (Bulik & Brinded, 1994; Epstein et al., 1991). Unfortunately, smoking status was not controlled for in our study. Sixth, reinforcing efficacy of food may be influenced by food deprivation (Epstein, 2003; Raynor & Epstein, 2003). Although our participants were instructed to remain without food or beverage (water excepted) for ≈ 10-hr. immediately prior to their morning arrival, abstinence could not be ensured. Upon arrival, participants were provided with a 300 kcal standardized breakfast which was immediately followed by a 4-hr period of monitored abstinence from food and beverage (water excepted). Seventh, yogurt shake may not have been a familiar nor typical binge food for our BN participants; however, the same shake formulation has been used in prior studies of eating behavior in BN.

Future directions

The "Work to Binge" paradigm developed here may be used provocatively in conjunction with biological measures that may be relevant to BN. Such experimental design may assist with determining the relevance of a model for BN, in which the binge eating may be viewed as a "motivated" behavior with several relevant components (e.g. including desire/motivation for reward, decision-making around the reward, consumption of the reward, and subsequent subjective response) (Berridge & Robinson, 2003; Sharp, Monterosso, & Montague, 2012), with each component likely to be mediated in part by overlapping but distinct brain reward circuitry and mechanisms. This approach has been used with success in the clinical substance use disorder literature. For example, Martinez et al. (Martinez et al., 2004) utilized a laboratory "work" paradigm, in which patients with a history of cocaine abuse were offered a choice between drug of choice (cocaine) and an alternative reinforcer (equivalent monetary reward), and subsequently "worked" (through an operant task) to obtain the reinforcer. Subjects also underwent neuroimaging studies (in this case, PET neurochemical neuroimaging studies). Results supported that the choice for drug over an alternate reinforcer was inversely associated with magnitude of ventral striatal DA response in the neuroimaging studies, specifically implicating the role of striatal DA in mediating flexible choosing between alternative rewards. Thus, the combination of behavioral paradigms which parse reward into its component processes, in conjunction with biological studies, may allow for associations between specific components of reward processes and neurobiological measures to be obtained. In this way, such studies could provide a vehicle for translation from preclinical studies which simultaneously examine neurobiology in conjunction with operant responding behaviors.

Conclusion

This study supports the feasibility and potential utility of the novel application of a PR ratio operant task to quantify the reinforcing value of food in patients with BN. Future studies that elucidate factors that modulate the reinforcing value of food may be helpful in the development of behavioral alternatives and improved treatment options for these individuals. This study also provides further evidence of an association between affective state and motivation to engage in binge eating and purging behaviors, and suggests that the PR task may prove to be an additional method of exploring this relationship in patients with BN.

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REFERENCES

American Psychiatric Association A.P.. Diagnostic and statistical manual of mental disorders, 4th edition. Washington D.C.: APA Press; 1994.

Berridge KC, Robinson TE. Parsing reward. Trends in Neurosciences. 2003; 26(9):507–513. [PubMed: 12948663]

Bohon C, Stice E. Reward abnormalities among women with full and subthreshold bulimia nervosa: A functional magnetic resonance imaging study. International Journal of Eating Disorders. 2011; 44(7):585–595. [PubMed: 21997421]

Bulik CM, Brinded EC. The effect of food deprivation on the reinforcing value of food and smoking in bulimic and control women. Physiology & Behavior. 1994; 55(4):665–672. [PubMed: 8190792]

Comer SD, Collins ED, Wilson ST, Donovan MR, Foltin RW, Fischman MW. Effects of an alternative reinforcer on intravenous heroin self-administration by humans. European Journal of Pharmacology. 1998; 345(1):13–26. [PubMed: 9593589]

Crosby RD, Wonderlich SA, Engel SG, Simonich H, Smyth J, Mitchell JE. Daily mood patterns and bulimic behaviors in the natural environment. Behaviour Research and Therapy. 2009; 47(3):181–188. [PubMed: 19152874]

Epstein LH. Effects of deprivation on hedonics and reinforcing value of food. Physiology & Behavior. 2003; 78(2):221–227. [PubMed: 12576119]

Epstein LH, Bulik CM, Perkins KA, Caggiula AR, Rodefer J. Behavioral economic analysis of smoking: Money and food as alternatives. Pharmacology Biochemistry and Behavior. 1991; 38(4): 715–721.

Epstein LH, Leddy JJ. Food reinforcement. Appetite. 2006; 46(1):22–25. [PubMed: 16257474]

Epstein LH, Leddy JJ, Temple JL, Faith MS. Food reinforcement and eating: A multilevel analysis. Psychological Bulletin. 2007; 133(5):884–906. [PubMed: 17723034]

Fairburn, CG.; Cooper, Z. The eating disorder examination, 12th edition. In: Fairburn, CGW.; T, G., editors. Binge eating: Nature, assessment, and treatment. New York: Guilford Press; 1993. p. 317-360.

Goldfield GS, Adamo KB, Rutherford J, Legg C. Stress and the relative reinforcing value of food in female binge eaters. Physiology & Behavior. 2008; 93(3):579–587. [PubMed: 18158166]

Hodos W. Progressive Ratio as a Measure of Reward Strength. Science. 1961; 134(3483):943–944. [PubMed: 13714876]

Kaye WH, Weltzin TE, McKee M, McConaha C, Hansen D, Hsu LK. Laboratory assessment of feeding behavior in bulimia nervosa and healthy women: methods for developing a human-feeding laboratory. The American Journal of Clinical Nutrition. 1992; 55(2):372–380. [PubMed: 1734674]

Kissileff HR, Walsh BT, Kral JG, Cassidy SM. Laboratory studies of eating behavior in women with bulimia. Physiology & Behavior. 1986; 38(4):563–570. [PubMed: 3823170]

Klein DA, Schebendach JE, Gershkovich M, Bodell LP, Foltin RW, Walsh BT. Behavioral assessment of the reinforcing effect of exercise in women with anorexia nervosa: further paradigm development and data. International Journal of Eating Disorders. 2010; 43(7):611–618. [PubMed: 19806608]

LaChaussee JL, Kissileff HR, Walsh BT, Hadigan CM. The single-item meal as a measure of binge-eating behavior in patients with bulimia nervosa. Physiology & Behavior. 1992; 51(3):593–600. [PubMed: 1523236]

Lappalainen R, Epstein LH. A behavioral economics analysis of food choice in humans. Appetite. 1990; 14(2):81–93. [PubMed: 2337342]

Martinez D, Broft A, Foltin RW, Slifstein M, Hwang D-R, Huang Y, et al. Cocaine Dependence and D2 Receptor Availability in the Functional Subdivisions of the Striatum: Relationship with Cocaine-Seeking Behavior. Neuropsychopharmacology. 2004; 29(6):1190–1202. [PubMed: 15010698]

McNair, D.; Lorr, M.; Droppleman, L. Profile of Mood States. San Diego: Educational and Industrial testing Services; 1971.

Mitchell JE, Crow S, Peterson CB, Wonderlich S, Crosby RD. Feeding laboratory studies in patients with eating disorders: A review. International Journal of Eating Disorders. 1998; 24(2):115–124. [PubMed: 9697010]

Nasser JA, Evans SM, Geliebter A, Pi-Sunyer FX, Foltin RW. Use of an operant task to estimate food reinforcement in adult humans with and without BED. Obesity. 2008; 16(8):1816–1820. [PubMed: 18535551]

Raynor HA, Epstein LH. The relative-reinforcing value of food under differing levels of food deprivation and restriction. Appetite. 2003; 40(1):15–24. [PubMed: 12631501]

Roane HS. On the applied use of progressive-ratio schedules of reinforcement. Journal of applied behavior analysis. 2008; 41(2):155–161. [PubMed: 18595280]

Saelens BE, Epstein LH. Reinforcing Value of Food in Obese and Non-obese Women. Appetite. 1996; 27(1):41–50. [PubMed: 8879418]

Saelens BE, Epstein LH. The rate of sedentary activities determines the reinforcing value of physical activity. Health Psychology;Health Psychology. 1999; 18(6):655–659.

Schebendach JE, Klein DA, Foltin RW, Devlin MJ, Walsh BT. Relative reinforcing value of exercise in inpatients with anorexia nervosa: Model development and pilot data. International Journal of Eating Disorders. 2007; 40(5):446–453. [PubMed: 17497709]

Sharp C, Monterosso J, Montague PR. Neuroeconomics: A Bridge for Translational Research. Biological Psychiatry. 2012; 72(2):87–92. [PubMed: 22727459]

Smyth JM, Wonderlich SA, Heron KE, Sliwinski MJ, Crosby RD, Mitchell JE, et al. Daily and momentary mood and stress are associated with binge eating and vomiting in bulimia nervosa patients in the natural environment. Journal of Consulting and Clinical Psychology. 2007; 75(4): 629–638. [PubMed: 17663616]

Stafford D, LeSage MG, Glowa JR. Progressive-ratio schedules of drug delivery in the analysis of drug self-administration: a review. Psychopharmacology. 1998; 139(3):169–184. [PubMed: 9784071]

Walsh BT, Boudreau G. Laboratory studies of binge eating disorder. International Journal of Eating Disorders. 2003; 34(S1):S30–S38. [PubMed: 12900984]

Walsh, BT.; Hadigan, CM.; Kissileff, H.; LaChaussee, JL. Bulimia nervosa: a syndrome of feast and famine. In: Anderson, GH.; kennedy, SH., editors. The Biology of Feast and Famine: Relevance to Eating Disorders. San Diego, CA: Academic Press, Inc; 1992. p. 3-20.

Walsh BT, Kissileff HR, Cassidy SM, Dantzic S. Eating Behavior of Women With Bulimia. Arch Gen Psychiatry. 1989a; 46(1):54–58. [PubMed: 2910221]

Walsh BT, Kissileff HR, Hadigan CM. Eating Behavior in Bulimia. Annals of the New York Academy of Sciences. 1989b; 575(1):446–455. [PubMed: 2633674]

Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: The PANAS scales. Journal of Personality and Social Psychology. 1988; 54(6): 1063–1070. [PubMed: 3397865]

- A PR computerized work task was completed by BN and NC participants.
- BN patients performed more work and had a higher breakpoint under binge instruction.
- Under non-binge instruction, patients performed less work and had a lower breakpoint.
- Negative affect was significantly correlated with the breakpoint in BN.

Table 1

Comparison of Clinical Characteristics, Profile of Mood States Scores, and Visual Analogue Scale Ratings in Bulimia Nervosa (BN) and Normal Control (NC) Participants

	BN (n = 10)		NC (n = 10)		
Clinical Characteristics	**Mean +/−**	**SD**	**Mean +/−**	**SD**	***P*** *
Age (yr)	23.9	4.3	24.8	4.2	0.63
Height (inch)	65.1	2.6	65.5	2.2	0.75
Weight (lbs)	135.2	16.9	133.0	12.5	0.74
BMI (kg/m^2)	22.4	2.1	21.9	1.2	0.56
Profile of Mood States [a]					
Tension	7.7	7.1	3.4	2.1	0.10
Depression	11.0	13.7	0.3	0.7	< 0.05
Anger	2.8	4.3	0.6	1.3	0.15
Vigor	6.9	5.6	13.9	9.9	0.07
Fatigue	5.2	5.2	1.0	1.7	< 0.05
Confusion	6.1	3.9	1.8	1.6	< 0.01
Total Mood Disturbance Score	25.9	25.3	− 6.8	14.2	< 0.01
Visual Analogue Scale Ratings [b]					
Tense/Anxious	27.7	34.5	3.8	5.3	0.06
Hungry	77.7	45.5	101.0	31.7	0.20
Full	33.1	40.2	8.8	18.3	0.10
Want to Eat	93.7	38.0	102.2	29.1	0.58
Want to Binge	89.1	48.7	3.0	6.4	< 0.001

*Student's t test

[a, b]Between-group comparisons immediately prior to the PR task on binge instruction day.

Table 2

Progressive ratio task performance and ingestive behavior in bulimia nervosa (BN) and normal control (NC) participants under non-binge and binge instruction. [a]

	Non-Binge Meal				Binge Meal				Non-Binge vs. Binge Meal	
	BN (n=10)	NC (n=10)	Student's t test p [b]	Cohen's d [c]	BN (n=10)	NC (n=10)	Student's t test p [b]	Cohen's d [c]	BN Paired t test p [b]	NC Paired t test p [b]
Trials Completed	2.6 ± 1.2	3.3 ± 1.3	> 0.8	− 0.559	7.8 ± 2.7	4.9 ± 2	0.05	1.221	< 0.01	0.02
Total Work (presses) [d, e]	670 ± 676	1065 ± 788	0.7	− 0.538	6330 ± 4182	2505 ± 2558	0.03	1.103	< 0.01	< 0.01
Breakpoint [f]	370 ± 235	510 ± 250	> 0.8	− 0.577	1410 ± 532	830 ± 394	0.05	1.239	< 0.01	0.02
Shake Earned (g)	470 ± 204	580 ± 214	> 0.8	− 0.526	1385 ± 513	813 ± 270	0.03	1.395	< 0.01	0.02
Shake Consumed (g)	379 ± 158	446 ± 111	> 0.8	− 0.491	1279 ± 537	611 ± 125	0.01	1.713	< 0.01	< 0.01
Shake Consumed (kcal)	325 ± 135	382 ± 95	> 0.8	− 0.488	1096 ± 460	523 ± 107	0.01	1.713	< 0.01	< 0.01
(KJ)	1361 ± 565	1599 ± 398			4589 ± 1926	2190 ± 448				
% Shake Consumed	82.7 ± 14.4	80.0 ± 18.9	> 0.8	− 0.179	91.2 ± 9.1	80.3 ± 12.4	0.4	0.755	0.2	> 0.8

[a] All values are means ± SD

[b] Bonferroni corrected

[c] Cohen's d is a measure of effect size

[d] Log transformation

[e] ANOVA for total work: significant diagnosis by instruction interaction, $p < 0.001$

[f] ANOVA for breakpoint: significant diagnosis by instruction interaction, $p < 0.01$