

# Women who are motivated to eat and discount the future are more obese

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# Women Who Are Motivated to Eat and Discount the Future Are More Obese

Leonard H. Epstein<sup>1</sup>, Noelle Jankowiak<sup>1</sup>, Kelly D. Fletcher<sup>1</sup>, Katelyn A. Carr<sup>1</sup>, Chantal Nederkoorn<sup>2</sup>, Hollie A. Raynor<sup>3</sup> and Eric Finkelstein<sup>4</sup>

**Objective:** Food reinforcement and delay discounting (DD) independently predict body mass index (BMI), but there is no research studying whether these variables interact to improve prediction of BMI.

**Methods:** BMI, the relative reinforcing value of high (P<sub>MAX\_HED</sub>) and low (P<sub>MAX\_LED</sub>) energy dense food, and DD for \$10 and \$100 future rewards (DD<sub>10</sub>, DD<sub>100</sub>) were measured in 199 adult females.

**Results:** P<sub>MAX\_HED</sub> ( $P = 0.017$ ), DD<sub>10</sub> ( $P = 0.003$ ), and DD<sub>100</sub> ( $P = 0.003$ ) were independent predictors of BMI. The interaction of P<sub>MAX\_LED</sub>  $\times$  DD<sub>10</sub> ( $P = 0.033$ ) and DD<sub>100</sub> ( $P = 0.039$ ), and P<sub>MAX\_HED</sub>  $\times$  DD<sub>10</sub> ( $P = 0.038$ ) and DD<sub>100</sub> ( $P = 0.045$ ) increased the variance accounted for predicting BMI beyond the base model controlling for age, education, minority status, disinhibition, and dietary restraint. Based on the regression model, BMI differed by about 2 BMI units for low versus high food reinforcement, by about 3 BMI units for low versus high DD, and by about 4 BMI units for those high in P<sub>MAX\_HED</sub>, but low in DD versus high in P<sub>MAX\_HED</sub> and high in DD.

**Conclusion:** Reducing DD may help prevent obesity and improve treatment of obesity in those who are high in food reinforcement.

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## Introduction

Positive energy balance from overeating is one cause for obesity. A factor that influences the motivation to eat is food reinforcement, assessed by how hard someone will work for food when different types of food or food versus another commodity are concurrently available (1). Food reinforcement is cross-sectionally related to obesity (2–4) and prospectively related to weight gain (5, 6). Energy intake mediates the relationship between food reinforcement and body mass index (BMI) (7). High food reinforcement in the absence of strong alternative reinforcers predicts poor weight loss in children participating in behavioral treatment (8).

Decision making involves not only concurrent choices assessed in food reinforcement, but also intertemporal choices, such as the choice about whether to choose a small immediate reward or a larger, delayed reward. This type of choice is thought of as delay of gratification or delay discounting (DD), which has also been cross-

sectionally related to obesity (9–11) and prospectively related to weight gain (12, 13). The ability to delay gratification is also a predictor of child weight loss in structured treatment programs (8).

High food reinforcement and the inability to delay gratification interact to influence eating (14) as well as weight loss (8), such that those who are high in food reinforcement and cannot delay gratification consume more calories and lose less weight than those who are high in food reinforcement but can delay gratification. The balance between the motivation to consume food and the inability to delay gratification is called reinforcement pathology (15, 16). One useful analogy to put this balance into perspective of everyday behaviors is to relate reinforcement pathology to driving a car, with the motivation to eat represented by the accelerator, and self-control represented by the brake. People with reinforcement pathology have too much gas to stimulate eating, and inadequate brakes when they try to stop or prevent eating. These two factors represent different

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**Author contributions:** LHE conceived of the study, LHE, NJ and KDF conceived the study methods, NJ and KDF supervised the implementation of the experiments, LHE and KDF performed data analysis, LHE generated tables and figures and initial draft of the manuscript and all authors contributed to revisions and had final approval of the submitted and published versions. Appreciation is granted to Lauren Nitecki, Georgiana Pascanu, Kirstie Clune, Andrew Pittner, Patrick Vanini, Erin Brewer-Spritzer and Tinuke Oluyomi Daniel for data collection, data entry and protocol implementation

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aspects of brain activation, with reinforcement processes related to mesolimbic and mesocortical activation, while delay of gratification is related to frontal activation, and is considered to be part of executive function (17, 18). One important hypothesis that has not yet been tested is the relationship between reinforcement pathology and BMI. Based on the existing research, it is expected that food reinforcement and DD would be related to BMI, with highest BMI for those with reinforcement pathology, who are high in food reinforcement and unable to delay gratification.

## Methods

### Participants

Participants were 199 females in an experimental online grocery shopping study recruited from an existing family database, flyers posted around the University at Buffalo campuses and in the community, web-based recruitment (e.g., ads on Craig's list and on the department's website) and targeted direct mailings. Inclusion criteria included: 19 years of age or older and the primary grocery shopper for a household containing at least one child between the ages of 2 and 18; could purchase the majority of their groceries once a week; no dietary restrictions that could interfere with the study, including food allergies or religious or ethnic practices that limit food choice; medical conditions that could alter nutritional status or intestinal absorption (e.g., inflammatory bowel disease); not currently pregnant; at least a moderate liking ( $\geq 3$  on a 5-point Likert-type scale) of the food used in the study and willingness to consume the food; and no psychopathology or developmental disabilities (e.g., attention deficit hyperactivity disorder) that would limit participation. Participants were compensated \$290, minus the cost of a week's worth of groceries they selected in the online grocery store, which they received at study completion. The study was approved by the University at Buffalo Social and Behavioral Sciences Institutional Review Board. Participant characteristics are shown in Table 1.

### Procedures

Participants were studied across six weekly sessions. Before the first session, participants completed a basic demographics form and Three Factor Eating Questionnaire (TFEQ) (19, 20). Participants were asked to refrain from eating or drinking, other than water, for 2 h before each appointment. Upon arrival to the laboratory, participants read and signed consent forms and a study agreement. Next, they completed a same-day food recall and hunger scale, and were then given a preload of a Nature Valley Oats 'n Honey or Nature Valley Oats 'n Dark Chocolate granola bar (General Mills; Minneapolis, MN, 42 g, 190 kcal, 7 g fat, 29 g carbohydrates, 4 g protein). The amount given was based on their self-reported body weight during screening and was equivalent to approximately 2 kcal for every kilogram of body weight. The inclusion of a preload is designed to assess hedonic rather than homeostatic hunger. During the rest of session one, participants completed response inhibition (data not reported), food reinforcement, and DD tasks. Over the next five sessions, subjects selected their weekly household groceries in the online supermarket that included nearly 6,000 food items under varying price conditions to determine the influence of subsidizing healthy foods or taxing less healthy foods. The economic analyses from the shopping sessions will be reported elsewhere. After the completion of the purchasing sessions, participant's height, and weight were taken and they were debriefed and compensated.

**TABLE 1** Participant characteristics (mean  $\pm$  SD)

<i>N</i>	199
Age	42.7 $\pm$ 7.3
Body mass index (kg/m <sup>2</sup> )	27.6 $\pm$ 7.3
Years of education	16.0 $\pm$ 3.0
Minority (non-Caucasian) (n)	46
Caucasian (n)	153
RRV <sub>HED</sub>	0.37 $\pm$ 0.20
PMA <sub>LED</sub>	24.2 $\pm$ 32.4
PMA <sub>HED</sub>	12.1 $\pm$ 17.8
DD <sub>10</sub>	0.61 $\pm$ 0.28
DD <sub>100</sub>	0.70 $\pm$ 0.25
Hunger (after preload)	35.4 $\pm$ 25.5
Liking LED foods	4.5 $\pm$ 0.7
Liking HED foods	4.6 $\pm$ 0.7

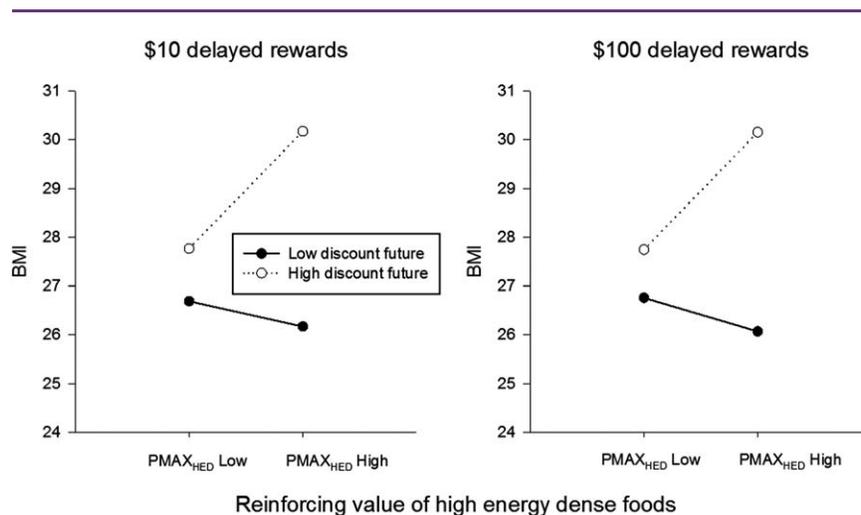
RRV<sub>HED</sub> = PMA<sub>HED</sub>/(PMA<sub>HED</sub> + PMA<sub>LED</sub>). *N* for RRV<sub>HED</sub> = 197, as two people did not respond for either PMA<sub>LED</sub> or PMA<sub>HED</sub>.

### Measures

**Food reinforcement.** The relative reinforcing value of low energy dense (PMA<sub>LED</sub>) and high energy dense (PMA<sub>HED</sub>) foods were assessed using a computer program, where subjects responded by pressing a mouse button (3, 21). Participants earned a point by meeting schedule requirements. The programmed reinforcement schedules for both types of food were progressive fixed ratio schedules with response requirements of 4, 8, 16, 32, 64, 128, ..., 2,048 and so forth for each point. For every five points earned, they received a 30 g portion of their preferred low (LED: ED  $\leq$  2.0) or high (HED: ED  $>$  2.0) energy dense snack food (LED foods, ED: carrots and dip, 0.76; celery and dip, 0.60; apple slices, 0.57; bananas, 0.86; applesauce, 0.41; low fat strawberry yogurt, 1.00; mandarin oranges, 0.37; pineapple chunks; 0.60; HED foods, ED: Chips Ahoy!<sup>®</sup> Cookies, 4.85; Little Debbie<sup>®</sup> Zebra Cakes, 4.34; Reese's Peanut Butter Cups<sup>®</sup>, 5.00; M&M's<sup>®</sup>, 5.00; Hershey's<sup>®</sup> milk chocolate, 4.88; Mini Oreos<sup>®</sup>, 4.48; Doritos<sup>®</sup> Nacho Cheese, 5.00; and Pringles<sup>®</sup> Original, 5.36). The task was setup on two computer stations: one for LED and one for HED, so that participants could freely move between stations to earn as many portions as they wanted. Participants were instructed to perform one activity at a time (i.e., play the computer game or eat), and the session would end when they no longer wished to earn points toward portions of either type of food. Food portions were brought to the participant after they were earned and could be eaten right away or later during the task; however, the food could not be eaten once the task ended. Water was provided *ad libitum*.

The primary dependent measure was the relative reinforcing value for LED (PMA<sub>LED</sub>) or HED (PMA<sub>HED</sub>) foods operationalized as  $P_{max}$ , or the maximal reinforcement schedule that the participant completed for LED and HED foods. The relative reinforcing value of HED versus LED food (RRV<sub>HED</sub>) was established by the formula: PMA<sub>HED</sub>/(PMA<sub>HED</sub> + PMA<sub>LED</sub>).

**DD task.** DD task measures the degree to which people discount a hypothetical reward of \$10 (DD<sub>10</sub>) and \$100 (DD<sub>100</sub>) with an increasing time delay (22). In the discounting task, two sets of cards



**Figure 1** Interaction of food reinforcement for high energy dense foods (PMAx<sub>HED</sub>) and delay discounting for \$10 (DD<sub>10</sub>, left graph) and \$100 (DD<sub>100</sub>, right graph) delayed rewards on BMI. Hierarchical regression analyses revealed that the interaction of PMAx<sub>HED</sub> × DD<sub>10</sub> ( $F_{inc}[1,190] = 4.35, P = 0.038$ ) and PMAx<sub>HED</sub> × DD<sub>100</sub> ( $F_{inc}[1,190] = 4.07, P = 0.045$ ) increased variance accounted for beyond the base model that included DD<sub>10</sub> or DD<sub>100</sub>, age, education, minority status, dietary disinhibition, and dietary restraint. BMI values were calculated from the regression models based on using  $\pm 1$  standard deviation values for PMAx and DD values.

were placed on the table in front of the participant; one stack showed a dollar amount available now, and the other stack showed a dollar amount available after a time delay. For each trial, the participant was asked to choose between the two monetary amounts, and the “available now” cards were shifted so that the value of the immediate outcome changed after each trial. Participants experienced the task using both \$100 and \$10 as the hypothetical reward with the presentation of the hypothetical rewards counterbalanced. Values for the monetary reward consisted of 26 values ranging from 0.1 to 100% of the delayed reward to which they were compared. For each time delay (1, 2 days, 1, 2 weeks, 1, 6 months, and 2 years), the immediate reward cards were titrated down then up for half of the subjects, and up then down for the other half of the subjects, the order of which was counterbalanced. Indifference points for each of the values of the delayed reward at each of the time delays were computed. Indifference points were determined for each time delay as the average of two determinations: the last immediate reward chosen when the participant switched preference from the immediate to the delayed reward when the immediate rewards were presented in descending order, and the first immediate reward value chosen when the participant switched preference from the delayed reward to the immediate reward when the immediate reward values were presented in ascending order. Area under the curve values for \$10 rewards (AUC<sub>10</sub>) and AUC for \$100 rewards (AUC<sub>100</sub>) were calculated from the indifference points for each delay (23). AUC values range from 0 (highest possible discounting) to 1 (no discounting).

**Hunger and food liking.** Subjective ratings of hunger were collected before consumption of the preload and before and after the RRV task using a 100 mm visual analogue scale anchored by not hungry (0) to extremely hungry (100). Food hedonics were measured

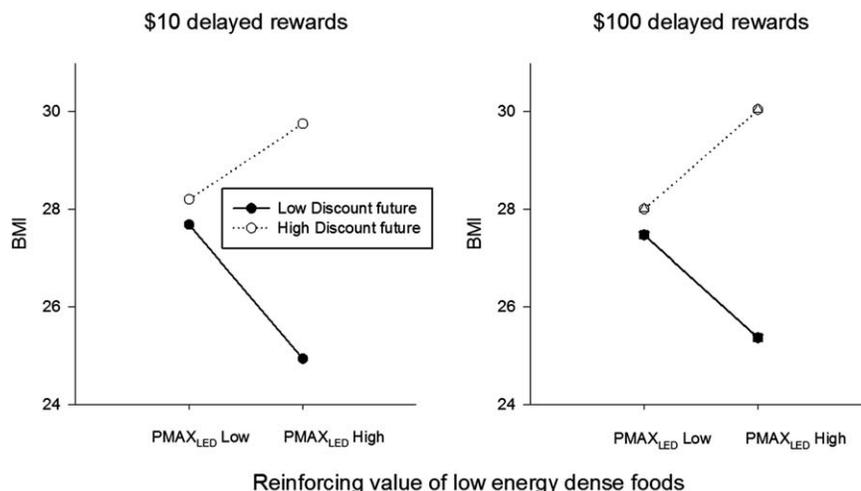
before and after the RRV task using a 5-point Likert-type scale ranging from do not like at all (1) to like very much (5). Hunger refers to the hunger scores following consumption of the preload during session one.

**Three Factor Eating Questionnaire.** The TFEQ is a validated instrument with subscales that assess dietary restraint, hunger, and disinhibition (19, 20).

**Anthropomorphic measurements.** Height was measured with a digital stadiometer (Measurement Concepts and Quick Medical, North Bend, WA) and weight was assessed using a Tanita digital scale (Arlington Heights, IL). BMI was calculated using the formula  $BMI = kg/m^2$ .

**Years of education.** Years of highest parental education was used as an indicator of socioeconomic status because it may shape occupational status and income (24), and is more stable than occupational status or income beyond early adulthood (25).

**Analytic plan.** The analytic plan was designed to assess the interactive effects of LED and HED food reinforcement and DD of small and moderate rewards on BMI. First, zero-order correlations were used to establish the relationships among the variables. Next, hierarchical linear regression was used, with the first step, including different measures of food reinforcement and DD as predictors of BMI, and the next step adding the interaction of food reinforcement and DD on BMI. These models were run controlling for age, education, minority status and dietary disinhibition, and dietary restraint. These variables were controlled since age (26) and education (27) can moderate the influence of DD, and education (4), and dietary disinhibition and dietary restraint (28) can moderate the effect of



**Figure 2** Interaction of food reinforcement for low energy dense foods ( $PMAx_{LED}$ ) and delay discounting for \$10 ( $DD_{10}$ , left graph) and \$100 ( $DD_{100}$ , right graph) delayed rewards on BMI. Hierarchical regression analyses revealed that the interaction of  $PMAx_{LED} \times DD_{10}$  ( $F_{inc}[1,190] = 4.63, P = 0.033$ ) and  $PMAx_{LED} \times DD_{100}$  ( $F_{inc}[1,190] = 4.34, P = 0.039$ ) increased variance accounted for beyond the base model that included  $DD_{10}$  or  $DD_{100}$ , age, education, minority status, dietary disinhibition, and dietary restraint. BMI values were calculated from the regression models based on using  $\pm 1$  standard deviation values for PMAx and DD values.

food reinforcement on BMI. Minority status was included as a control variable since it was an independent predictor of BMI in this sample. Dietary hunger was also an independent predictor of BMI, but it was strongly related to dietary disinhibition ( $r = 0.61, P < 0.001$ ), and both variables were not included in the model to reduce colinearity. The final set of models were to assess whether age, education, minority status, dietary disinhibition, or restraint moderated the effects of reinforcement pathology on BMI. The effect of adding each additional variable was evaluated by determining whether it significantly increased variance accounted for using a  $F_{inc}$  test. The data were entered and analyzed using SYSTAT 11 (29).

## Results

The zero-order correlations showed that the  $RRV_{HED}$  ( $r = 0.197, P = 0.005$ ),  $PMAx_{HED}$  ( $r = 0.168, P = 0.017$ ),  $DD_{10}$  ( $r = -0.206, P = 0.003$ ),  $DD_{100}$  ( $r = -0.208, P = 0.003$ ), years of education ( $r = -0.256, P < 0.001$ ), minority status ( $r = 0.182, P = 0.01$ ) and the TFEQ disinhibition ( $r = 0.366, P < 0.001$ ) and hunger scores ( $r = 0.140, P = 0.049$ ) were correlated with BMI.  $PMAx_{LED}$  was not independently related to BMI ( $r = -0.042, P = 0.55$ ). Years of education were related to  $RRV_{HED}$  ( $r = -0.164, P = 0.021$ ) and  $DD_{10}$  ( $r = 0.184, P = 0.009$ ).

Hierarchical regression models showed that adding the interaction of  $PMAx_{HED} \times DD_{10}$  ( $P = 0.034$ ) increased variance accounted for predicting BMI from  $r^2 = 0.285$  to  $r^2 = 0.301$  ( $F_{inc}[1,190] = 4.35, P = 0.038$ ). Similarly, the interaction of  $PMAx_{HED} \times DD_{100}$  ( $P = 0.05$ ) increased  $r^2$  accounted for from  $r^2 = 0.284$  to  $r^2 = 0.299$  ( $F_{inc}[1,190] = 4.07, P = 0.045$ ) (Figure 1). A similar pattern was observed for LED foods, as the interaction of  $PMAx_{LED} \times DD_{10}$  ( $P = 0.03$ ) increased variance accounted for from  $r^2 = 0.285$  to

$r^2 = 0.302$  ( $F_{inc}[1,190] = 4.63, P = 0.033$ ). Finally, adding the interaction of  $PMAx_{LED} \times DD_{100}$  ( $P = 0.04$ ) increased variance accounted for from  $r^2 = 0.283$  to  $r^2 = 0.299$  ( $F_{inc}[1,190] = 4.34, P = 0.039$ ) (Figure 2).

No significant improvement in variance accounted for was observed for the interaction of  $RRV_{HED} \times DD_{10}$  or  $RRV_{HED} \times DD_{100}$ . Moderator analyses did not show that age, education, minority status, TFEQ disinhibition, or restraint moderated the interaction of  $PMAx_{LED}$ ,  $PMAx_{HED}$  or  $RRV_{HED}$  by  $DD_{10}$ , or  $DD_{100}$  to predict BMI.

## Discussion

We have shown for the first time that the balance between the motivation to eat and ability to delay gratification for both LED and HED foods predicts BMI. The pattern of the interaction between the reinforcing value of HED foods and DD is as predicted, with minimal effects of DD when food reinforcement is low, but marked increases in BMI when food reinforcement is high. The lowest BMI is for women who find LED foods reinforcing and who are able to delay gratification. Thus, those who find LED foods reinforcing also benefit from the ability to delay gratification in regards to a lower BMI. The reinforcing value of LED foods is rarely considered as a factor influencing weight, but it makes sense that being motivated to eat these foods may be a positive factor that influences lower weight. In the present study, eating LED foods may substitute for eating HED foods.

The reinforcing value paradigm compared responding for concurrently available LED and HED foods, as opposed to HED foods versus alternatives to food which is an alternative approach to studying food reinforcement (1). While comparing two types of food may not

provide as large a contrast between reinforcers as food versus non-food alternatives, both the proportion of responding for HED versus LED foods and responding for HED foods predicted BMI, and responding for LED and HED foods interacted with DD to predict BMI. Since the reinforcing value of any commodity depends on the alternatives available (1), differences between the characteristics of a food versus an alternative to eating are likely to be more dissimilar than if two foods are compared. Obese children find food more reinforcing than lean children, who find some alternatives to food more reinforcing than food (30), leading to the hypothesis that some obese people may find food more reinforcing than other activities due to the lack of access to more reinforcing alternatives. This is consistent with the observation that obese children lose less weight if they find food highly reinforcing and have decreased access to alternative reinforcers (8).

Reinforcement pathology explains from 1.5% to 1.7% of the additional variance in BMI relative to base models, which is modest, but may be important due to the multiple factors that influence obesity. The results suggest BMI is 2 units higher if participants were high in food reinforcement than if they were low in food reinforcement (28.80 vs. 26.80,  $\pm 1$  SD based on the regression model). The effect of discounting the future is greater, as those high versus low in discounting the future have a difference of 3.01 BMI units (29.14 vs. 26.13) for discounting \$10 and 3.03 BMI units (29.15 vs. 26.12) for discounting \$100, suggesting that reducing future discounting would have a bigger impact on BMI than modifying food reinforcement. The biggest effects on BMI may come from modifying DD in those who are high in food reinforcement. Previous research on reinforcement pathology and obesity has shown that if food reinforcement is high, then effects on eating (14) or weight loss (8) can be muted by the ability to delay gratification. The results of this study are consistent with these studies, as BMI was not elevated if food reinforcement was low, or if reinforcement for HED foods was elevated, but the person did not discount the future. If people were high in food reinforcement and high versus low in discounting the future, they had a difference of 4.00 BMI units (30.17 vs. 26.17 for discounting \$10) or 4.08 (30.15 vs. 26.07 for discounting \$100) BMI units. The reduction in BMI when DD is considered independently or interacting with food reinforcement suggests that modifying DD represents a target for weight control.

One approach to reducing DD is to improve working memory. Working memory is related to discounting the future (31), and the better the working memory bandwidth the greater the opportunity for the person to hold information about current options and future opportunities (32). Reduced working memory capacity may relegate the person to focusing only on the current alternative, discounting the future (32). To support this hypothesis, research has shown that working memory training reduces DD in stimulant addicts (31) and alcohol consumption in social drinkers (33). Working memory training has been used to complement obesity treatment to enhance short-term treatment effects (34).

An alternative approach to reduce discounting of the future is to take advantage of prospection, or the ability to pre-experience the future (35). Since DD is characterized by a preference for smaller immediate reward over larger delayed rewards, than the ability to consider the future may influence how individuals make these choices. Prospection allows the person to put themselves in the future (episodic future thinking) as they are considering whether to

choose a small but very palatable immediate reward or a larger delayed reward. Episodic future thinking can reduce DD in lean and overweight/obese women (36) and energy intake in overweight/obese women (37). Research is needed that incorporates episodic future thinking into obesity treatment programs to assess effects of episodic future thinking on DD and weight control.

Food reinforcement pathology is not moderated by age, education, minority status, dietary disinhibition, or dietary restraint. The absence of moderators suggests that the effect of reinforcement pathology on BMI is evident across all types of women. This is particularly relevant since education, dietary disinhibition, and dietary restraint have been shown to moderate the effects of either food reinforcement or DD on BMI. It is important to determine if these results can be extended from cross-sectional relationships to prospective relationships, such that women high in food reinforcement and low in the ability to delay gratification may be at risk for weight gain and obesity independent of their age, educational levels, minority status, or their degree of dietary disinhibition or dietary restraint.

These results add to the research on the importance of reinforcement pathology for eating, obesity and weight loss. Research has shown the inability to delay gratification is associated with obesity in males and females (11), but other studies suggest this relationship is greater in females than males (10). On the other hand, men may be more susceptible to the effects of food reinforcement on eating (38). Research is needed including both sexes to determine whether reinforcement pathology predicts BMI in both men and women.

This research needs to be extended to children. Research has shown that food reinforcement (6) and the inability to delay gratification (12, 13) are independent predictors of weight gain in children. No research has assessed whether reinforcement pathology in young children is a better predictor of weight gain than either of these risk factors separately. This warrants special consideration since children may be at greater risk for reinforcement pathology since their prefrontal cortex is not fully developed so they may not have the ability to delay gratification associated with strong food reinforcement (39, 40). Based on these developmental differences, it may be important to provide developmentally appropriate self-control strategies/training as children's self-control and prefrontal cortex matures.

Reinforcement pathology represents the balance between motivation to eat and the ability to delay gratification of food. Using the analogy of driving a car, people with reinforcement pathology have a lead foot on the gas pedal to eating, and inadequate brakes when they try to stop. Research to improve this balance is needed to prevent obesity among those at risk, as well as facilitate weight loss among those whose reinforcement pathology has led to obesity. **O**

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