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Research report

Delay discounting moderates the effect of food reinforcement on energy intake among non-obese women☆

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ABSTRACT

Recent theoretical approaches to food intake hypothesize that eating represents a balance between reward-driven motivation to eat versus inhibitory executive function processes, however this hypothesis remains to be tested. The objective of the current study was to test the hypothesis that the motivation to eat, operationalized by the relative reinforcing value (RRV) of food, and inhibitory processes, assessed by delay discounting (DD), interact to influence energy intake in an ad libitum eating task. Female subjects ($n = 24$) completed a DD of money procedure, RRV task, and an ad libitum eating task in counterbalanced sessions. RRV of food predicted total energy intake, however the effect of the RRV of food on energy intake was moderated by DD. Women higher in DD and RRV of food consumed greater total energy, whereas women higher in RRV of food but lower in DD consumed less total energy. Our findings support the hypothesis that reinforcing value and executive function mediated processes interactively influence food consumption.

Introduction

Behavioral paradigms to study choice include concurrent choices in which the choice involves responding among alternate reinforcers, or choices that vary over time. These paradigms tap into different processes: measuring responding for current choices is a way to assess relative reinforcing value (RRV) of alternatives, whereas choice that varies over time is a way to assess delay discounting (DD), an important component of impulsivity and executive function. Theories of drug addiction posit that the balance between the motivation to consume drugs and self-regulation of discounting of future consequences (Bickel et al., 2007) or more general self-regulatory abilities (Wiers et al., 2007) is critical for drug use and abuse. The same logic has been applied to hedonic-motivated eating (i.e., eating for pleasure) or over-eating, with the hypothesis that eating involves a balance between the motivation to eat regulated by food reinforcement and the control of the impulse to eat (Appelhans, 2009; Epstein, Salvy, Carr, Dearing, & Bickel, 2010; van den Bos & de Ridder, 2006).

RRV refers to how hard someone will work to gain access to that reinforcer using progressive ratio schedules of reinforcement (Epstein, Leddy, Temple, & Faith, 2007). Having higher RRV of food is related to greater energy intake in an ad libitum eating task (Epstein et al., 2004a, 2004b; Epstein, Temple, et al., 2007), and obesity is associated with greater RRV for food (Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010; Saelens & Epstein, 1996; Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008). Further, greater RRV for a palatable food predicts future weight gain in children (Hill, Saxton, Webber, Blundell, & Wardle, 2009) and abdominal obesity in rats (la Fleur et al., 2007).

Delay discounting is a behavioral paradigm that assesses the choice between two rewards that vary in amount and availability, and discounting occurs when a small immediate reward is chosen over a larger delayed reward (Bickel, Madden, & Petry, 1998). A substantial body of research has demonstrated that drug dependent individuals (Bickel & Marsch, 2001; Bickel, Odum, & Madden, 1999; Kirby, Petry, & Bickel, 1999; Madden, Petry, Badger, & Bickel, 1997; Petry, 2001), gamblers (Dixon, Jacobs, & Sanders, 2006; Dixon, Marley, & Jacobs, 2003), and obese individuals (Weller, Cook, Avsar, & Cox, 2008) show enhanced discounting of future rewards. In terms of eating, this may mean that obese persons are

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likely to engage in impulsive behaviors such as overeating energy-dense foods while discounting future problems associated with obesity.

To date, there is limited research on the interactive effects of RRV for food and DD. Recent models have theorized that inhibitory processes such as DD and reward processes such as RRV of food interact to influence food and drug intake (Alonso-Alonso & Pascual-Leone, 2007; Appelhans, 2009; Bickel et al., 2007; van den Bos & de Ridder, 2006). For example, individuals who steeply discount delayed rewards may find it difficult to resist the immediate gratification of preferred palatable energy-dense foods, whereas those who discount delayed rewards less steeply are better able to resist palatable foods (Appelhans, 2009). The aim of the current study was to examine the independent and interactive effects of the RRV of food and DD on food intake.

Methods

Participants

Twenty-eight healthy, non-smoking non-obese women (body-mass-index [BMI] $< 30\ kg/m^2$) were recruited from flyers and through an existing database maintained in the laboratory. Interested participants were screened by phone to ensure that they met the inclusion criteria of being female, having no experience with the study methods, and moderate to high liking of the study foods ($\geq$4 on a 7-point Likert scale). Exclusionary criteria included taking medications that could influence taste, appetite, or olfactory sensory responsiveness, medical or psychological conditions that could impact eating or appetite, developmental or psychological disorders, food restrictions or allergies to the study foods, dieting, use of tobacco products, excessive alcohol drinking (>20 drinks per week), pregnancy, and prior participation in a laboratory study that used similar methods. This investigation was approved by the Social and Behavioral Sciences Institutional Review Board of the State University of New York at Buffalo, and the Pennsylvania State University Institutional Review Board.

Design and procedures

Eligible participants were scheduled for three 60–90 min weekday sessions between the hours of 11 am and 2 pm. Sessions were completed between 2 and 14 days apart, with all but two participants completing the sessions no longer than 7 days apart. Participants were instructed to refrain from eating and drinking anything except for water 3-h prior to each session, and were asked not to consume any of the food used in the RRV task 24 h prior to each session. Participants were asked to indicate their preferred food (macaroni and cheese or chicken nuggets) during the initial phone screen; this preferred food was used during the RRV task. Upon arrival to the first session, participants were taken to the experimental room where they read and signed consent forms. Same-day and 24-h food recalls were completed at each session to ensure compliance; one participant was rescheduled due to eating one of the study foods less than 24 h before the session. Participants completed one of three tasks per session: an ad libitum eating task, RRV task, and DD task in a counterbalanced order. Hunger and liking scales were administered immediately before and after each task. At the end of the first session, participants completed a demographic questionnaire. At the end of the final session, participants completed the Three-Factor Eating Inventory (Stunkard & Messick, 1985), Binge Eating Scale (Gormally, Black, Daston, & Rardin, 1982), and Questionnaire of Eating and Weight Patterns (Spitzer et al., 1992), and participants' heights and weights were measured. At study completion, each participant was debriefed and compensated with a $40 gift card.

Ad libitum eating task. Participants were provided with a tray containing large portions of lunch foods (Table 2) that were served in small individual bowls, cups, and plates. The lunch foods included both of the entrée foods that participants could choose for the RRV task, as well as salad ingredients and water ad libitum. Participants were instructed that they could eat as much of the presented foods as they liked and that additional portions of each item were available. The maximum amount of energy available if a person consumed both portions of all the lunch foods was 2411 kcal. No participant requested more than two portions of any item. Participants were instructed to remain in the experimental room for at least 20 min, after which they could stay for as long as they liked to complete their lunch. Three newspapers were available at a separate table in case the participant did not wish to consume any more food during the session. Foods were weighed before and after the session using an electronic scale (Denver Instrument XP-3000, Denver Instrument Company, Avada, Colorado) that was sensitive to 0.1 g; manufacturer's product information was used to compute the total energy intake of all lunch foods and energy intake of the preferred food. In the event that the participants mixed the individual foods, the foods were separated as much as possible before being individually weighed.

Relative reinforcing value (RRV) of food task. RRV of food was determined by measuring the number of responses on a progressive ratio schedule that participants made to gain access to their preferred food. This measure has been used to assess the RRV of food in previous studies (Epstein, Temple, et al., 2007; Temple et al., 2008). The experimental room included two identical computer stations; participants could freely work at either station. At one station the participant could earn access to their preferred palatable food and at the other station they could earn access to three local and national newspapers. The latter computer station was provided to prevent participants from working for access to their preferred food out of boredom, and also provided an assessment of the relative reinforcing value of food versus alternatives. In previous research we have shown that non-overweight youth find alternatives to food more reinforcing than food (Temple et al., 2008), and this study provided an opportunity to extend this finding to non-overweight adults. The computer screens at both stations displayed three boxes containing different shapes that rotated and changed color every time the mouse button was pressed. Similar to a slot machine, a point was earned when all of the shapes matched. For every 5 points earned, a 100 kcal portion of their preferred food or 2 min of reading was awarded, depending on the station. The schedule of reinforcement for food and reading began at a fixed ratio of 4 and then doubled (FR8, FR16, FR32, FR64, FR128, FR256, FR512, FR1024, and FR2048) each time 5 points were earned. For instance, the participant initially had to click the mouse four times to earn each point, but after the first portion was earned, the participant had to click 8 times for each point, and then double that amount after the second portion was earned. The computers recorded the number of responses. Participants were instructed to do one activity at a time (i.e., play the computer, eat or read) and that the session would end when they no longer wished to earn points for access to food or reading materials. Water was provided ad libitum.

Delay discounting (DD) task. The DD task was used to measure the degree to which women discounted a hypothetical reward of $10 with increasing time delay. The procedure was adapted from Odum, Baumann, and Rimington (2006), where the same monetary amount and delay times were used. Though the amount was hypothetical, it has been shown that hypothetical and real amounts of money are discounted similarly (Johnson & Bickel, 2002). In the discounting task, two stacks of index cards were placed on a table in front of the participant; the stack on the left showed an amount that was always available now (i.e., "Would