

Liquid sucrose bingeing in rats depends on the access schedule, concentration and delivery system

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Abstract

Previous studies have reported binge-type consumption of solid vegetable shortening in non-food deprived rats maintained on schedules of limited shortening access. The current study determined if limited access would promote binge-type consumption of sucrose solutions. Adult male rats (6 groups, $n = 10$ each) were provided with one of three different sucrose concentrations (3.2%, 10%, 32% w/v) for 2 h either everyday (Daily) or Monday, Wednesday, and Friday (Intermittent). A 'binge' during the 2-h access periods was operationally defined as Intermittent intakes significantly greater than Daily intakes. Sucrose initially was provided in a 100 ml glass tube equipped with a stainless-steel drinking spout. Under these conditions, there were no differences in sucrose intake between Daily and Intermittent groups at any of the concentrations. In contrast, when sucrose was provided in a modified 60 ml plastic syringe with the same drinking spout, intakes of the Intermittent groups consuming 3.2% and 10% sucrose were greater than those of the respective Daily groups, indicating that binge-type consumption of sucrose occurred. These results demonstrate that brief, intermittent access to low and moderate concentrations of sucrose can promote binge-type behavior, and the characteristics of the drinking apparatus can affect sucrose intake.

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1. Introduction

When various experimental protocols limit access to some environmental event (food, drug, running wheel) the behavior directed toward that event is usually greater in the groups given only limited access relative to groups that have more frequent access to the event. For example, non-food deprived rats given access to a running wheel every other day run significantly more during the first three hours of exposure than do rats given daily access to the running wheel [1,2]. Non-food deprived rats given access to either a 1.5% saccharin solution or 20% alcohol every other day consume significantly more of each liquid in a 24-h period than do rats given continuous access to either liquid [3,4]. When rats were given different numbers of 30-min access periods per day in an operant chamber, the frequency of dipper presentations and the duration of drinking bouts for 10% alcohol significantly increased with increased access restriction

[5]. Since other studies have reported similar results [6–9], the effects of limited access appear to be somewhat ubiquitous.

Research from our laboratory has shown that when solid vegetable shortening is made available for a 1- or 2-h period to non-food deprived rats placed under an intermittent (Mondays, Wednesdays, and Fridays) schedule of access, more shortening is consumed than when it is available under a daily schedule of access [10–15]. The use of intermittent limited access has been proposed as a behavioral model of binge-type eating with good construct validity [16].

Sucrose and glucose intake also appear to be sensitive to the schedule of access. When non-food-deprived rats have access to 32% sucrose for only 12 h each day, the intakes are greater than when rats have continuous access [17]. Rats given daily 12-h access to 25% aqueous glucose consume significantly more glucose by day 20 than do rats given continuous access [18]. Rats given daily 12-h access to a 10% sucrose solution consumed significantly more sucrose in the first hour on day 21 than they did on the first day of exposure. In contrast, there was no difference in the first hour intakes between day 1 and

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day 21 for rats given continuous access [19]. However, the effects of providing single sessions of brief access to different concentrations of sucrose on different days each week have not been reported. This would be of interest to the development of a behavioral model of binge-type eating, as humans suffering from bingeing-related eating disorders generally binge on restricted “forbidden” sweet and/or high-fat foods during brief periods of time at least twice a week [20]. Therefore, one of the goals of the present study was to determine if the conditions that promote bingeing on fat also promote bingeing on sucrose using the limited access behavioral model of binge-type eating.

2. Experiment 1: General methods

2.1. Animals

Sixty male Sprague Dawley rats (Harlan, Indianapolis, IN), 60 days of age and weighing 280–324 g (303 ± 1.05) at the start of the study, were individually housed in hanging stainless-steel wire cages in a temperature- and humidity-controlled environment with a 12:12 light:dark cycle. All rats were maintained on a nutritionally complete commercially available laboratory rodent chow (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). Chow and tap water were freely available throughout the entire study. All procedures were approved by the Pennsylvania State University Institutional Animal Care and Use Committee.

2.2. Statistics

Sucrose data ($\text{ml} \pm 0.5 \text{ ml}$) at each 30-min time point from each experiment were analyzed using 3-way repeated measures ANOVA [schedule of access (Daily, Intermittent) by sucrose concentration (Low, Medium, High) by time (30-min bins within a session)]. Total sucrose intake data were analyzed using 2-way ANOVA [schedule of access (Daily, Intermittent) by sucrose concentration (Low, Medium, High)]. Shortening intake ($\text{g} \pm 0.1$), total energy intake (sucrose plus chow or shortening plus chow) and body weight ($\text{g} \pm 1.0 \text{ g}$) data were analyzed using a 2-way ANOVA [schedule of access (Daily, Intermittent) by prior sucrose concentration exposure (Low, Medium, High)]. Significant effects were followed by comparisons using a least square differences table (LS Means table) with a Bonferroni correction applied; i.e., alpha was set at 0.0167 for the LS Means comparisons (0.05/3 comparisons per mean). For within-group repeated measures (time), data from each group were analyzed with one-way ANOVA, followed by Tukey’s HSD post-hoc test.

2.3. Experiment 1, Part 1: Sucrose only — different schedules of access; different concentrations

2.3.1. Methods

This part of the experiment was designed to determine if liquid sucrose solutions of different concentrations would promote binge-type consumption under conditions previously shown to promote binge-type eating of solid vegetable short-

ening [10–15]. Three different concentrations of sucrose (3.2%, 10% and 32% w/v or $\sim 0.1 \text{ M}$, $\sim 0.3 \text{ M}$ and $\sim 1 \text{ M}$, respectively) were provided for 2 h under two different schedules of access [Daily or Intermittent (Mondays, Wednesdays, Fridays)]. These concentrations were selected based upon previous reports that have shown that the amount of liquid sucrose consumed is a function of the sucrose concentration. Inverted “U”-shaped concentration-effect functions have been obtained under a variety of conditions including 24-h access [21], 30-min bottle tests, fixed ratio performance [22], and 15-min bottle tests [23]. The concentrations chosen for this study span the inverted “U”-shaped functions that have been reported. Based upon the established body of literature, it was inferred that binge-type consumption of liquid sucrose might depend upon both the schedule of access and the sucrose concentration.

During the first two weeks of adaptation to the vivarium, chow intake was measured on a daily basis and rats were weighed three times per week. All rats were then matched for chow intake and body weight, and divided into groups of 10 rats each. For one day only, each of the six groups was given a 4-h period of availability to their assigned sucrose solution (3.2%, 10%, 32% w/v) in order to acclimate the rats to the sucrose and to prevent neophobia in subsequent tests. The sucrose delivery system consisted of a 100 ml, graduated, glass cylinder fitted with a number-six silicon stopper that had a hole cored in the middle to accommodate a stainless-steel sipper spout (Girton Mfg. Co, Millville, PA, model #5.5F) commonly used on small rodent water bottles. Each 100 ml glass cylinder was filled with 30 ml of sucrose solution and hung on the outside of the cage adjacent to the water bottle.

Following this acclimation period the six groups were given a 2-h period of availability to their assigned sucrose solution starting 4 h prior to the start of the dark cycle. Three groups were placed under a daily schedule of access to a 2-h period of availability of sucrose while the other three groups were placed under an Intermittent (Mondays, Wednesdays, and Fridays) schedule of access. The group designations for the Daily groups were: Daily low (3.2%) concentration, DL, Daily medium (10%) concentration, DM, and Daily high (32%) concentration, DH. The group designations for the Intermittent groups were: Intermittent low concentration, IL, Intermittent medium concentration, IM, and Intermittent high concentration, IH. Bingeing was operationally defined as intakes of the Intermittent group being significantly greater than those of the Daily group during the 2-h period of availability. This is based upon the DSM-IV definition of a binge, i.e., eating in a discrete period of time (e.g. within any 2-h period) an amount of food that is definitely larger than would normally be consumed under similar circumstances [20].

It was initially determined that all rats would be given 6 weeks of exposure to each of their respective sucrose solutions with the aforementioned 100 ml graduated glass cylinders based upon previous reports that binge-type eating of solid vegetable shortening is typically well expressed within this time period [10–15]. However, due to breakage and difficulty in reading the liquid levels, the 100 ml graduated glass cylinders were replaced with modified 60 ml plastic syringes [BD301036, Becton

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