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Development of bingeing in rats altered by a small operant requirement

F.H.E. Wojnicki [a], D.S. Johnson [b], G. Charny [c], R.L.W. Corwin [a,*]

[a] Pennsylvania State University, Nutritional Sciences, 110 Chandlee Laboratory, University Park, PA 16802, United States
[b] University of Pennsylvania, School of Medicine, Department of Pathology and Laboratory Medicine, Virology, Philadelphia, PA 19104, United States
[c] Womack Army Medical Center, Department of Emergency Medicine, 2817 Reilly Street, Fort Bragg, NC 28310, United States

HIGHLIGHTS

- Response cost attenuates binge-type eating.
- Binge size is context and response-cost dependent.
- Extended shortening abstinence does not increase binge size.
- 24-h food-deprivation increases binge size.
- A history of home cage access alters subsequent operant performance.

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ABSTRACT

Previous studies have shown that providing an optional food for a brief period of time to non-food deprived rats on an intermittent basis in the home cage engenders significantly more intake (binge-type behavior) than when the optional food is provided for a brief period on a daily basis. Experiment 1 examined the effects of placing a small operant response requirement on access to an optional food (vegetable shortening) on the establishment of binge-type behavior. Experiment 2 examined the effects of different schedules of reinforcement, a period of abstinence from shortening, and 24 h of food deprivation on established binge-type behavior. In Experiment 1 the group of rats with 30-min access to shortening on an intermittent basis in their home cages (IC) consumed significantly more shortening than the group with 30-min daily access in the home cage (DC). The group with 30-min intermittent access in an operant chamber (IO group) earned significantly more reinforcers than the group with 30-min daily access in an operant chamber (DO). In Experiment 2, the IO group earned significantly more reinforcers than the DO group regardless of the response cost, the period of shortening abstinence, and overnight food deprivation. These results demonstrate that while intermittent access generates binge-type eating, the size of the binge (intake) can be altered by different contingency arrangements.

1. Introduction

Binge eating in humans is defined as consuming more food in a discrete period of time than would normally be consumed during the same period of time under similar circumstances accompanied by a sense of loss of control during the binge episode [1]. A behavioral model of binge-type eating in non-food deprived rats has been developed in which intermittent (Monday, Wednesday, Friday) access to an optional food provided in the home cage for a brief period of time from 20 min [2] to 2 h [3] promotes significantly greater (excessive) intake relative to daily access for the same brief period. These optional foods have included vegetable shortening containing trans fat [4], vegetable shortening devoid of trans fat [5], lard [6], liquid sucrose [7], different concentrations of semi-solid fat emulsions [8], different concentrations of fat/sucrose dispersions [9], and different fat concentrations in emulsions made with different biopolymers [10].

While this animal model has examined bingeing primarily in the home cage context, several studies have also examined operant performance after the establishment of bingeing in the home cage where either shortening [11–13], or cocaine after a history of shortening intake, [14] served as the reinforcer. Common to all of these studies is the finding that the intermittent groups earned significantly more reinforcers (either shortening or cocaine) than the daily groups under a variety of different schedules of reinforcement. Additionally, the number of shortening reinforcers earned during a session (i.e., amount of shortening consumed) is less than the amount of shortening that is normally consumed in the home cage. Furthermore, both the intermittent and daily groups consume additional shortening in the home cage 30–40 min after an operant session. This finding indicates that the rats are

* Corresponding author at: The Pennsylvania State University, College of Health and Human Development, Nutritional Sciences Department, 110 Chandlee Laboratory, University Park, PA 16801, United States.
E-mail address: rxc13@psu.edu (R.L.W. Corwin).

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not sated during the operant sessions and the requirement of an operant contingency reduces shortening intake relative to home cage access.

The present study addressed two questions. The first was whether bingeing on shortening will develop or be altered when rats without a history of intermittent access to shortening in the home cage are required to lever press for a specified amount of shortening per delivery from the start of the study. Stated otherwise, would adding a small response requirement (Fixed Ratio 1) prevent the development of bingeing in the intermittent operant group relative to the daily operant group, and would intake in the operant chamber equal intake in the home cage? The second question was whether altering environmental contingencies (schedules of reinforcement, abstinence from shortening and 24-hr food deprivation) would alter binge-type behavior.

2. Material and methods

2.1. Animals

Forty eight male Sprague Dawley (Harlan, Indianapolis, IN) rats, 60 days of age and weighing 277–310 g (295.8 ± 0.97 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 in the same animal colony room. All rats had continuous access to tap water and to a nutritionally complete commercial 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) placed in hanging metal food hoppers at the front of the cage throughout the study, except for 2–3 sessions when two groups were trained to lever press in an operant chamber. All rats were allowed to adapt to the vivarium and light cycle for 7 days prior to the start of the study. All procedures were approved by the Pennsylvania State University Institutional Animal Care and Use Committee.

2.2. Operant chambers

Rats were tested in twelve identical operant chambers (Model H10-11R-TC; Coulbourn Instruments, Allentown, PA) located in a room adjacent to the vivarium. The back wall of each chamber contained a house light (Model H11-01R) located at the top of the middle panel of the chamber. The front wall of each chamber contained a response lever (Model H21-03R) located in the middle panel and a triple cue lamp (H11-02R) located above it. Located in the right panel was a lip to collect shortening delivery and a triple cue light above the tray to indicate shortening delivery. Whipped vegetable shortening was used as the reinforcer for lever pressing. Whipped shortening was delivered in 0.1 g units from a 20 ml glass syringe (Popper & Sons, New Hyde Park, NY) driven by an infusion pump (Model E73-01-3.3 rpm) into a receptacle located below the triple cue lamp adjacent to the response lever. Care was taken to minimize any air pockets in the 20 ml syringe that would affect the amount delivered. This was accomplished by placing whipped shortening into a self-lock plastic bag and then squeezing the shortening into a 60 ml syringe. 20 ml of shortening from the 60 ml syringe was then squeezed into a 20 ml syringe. The plunger of the 20 ml syringe was then used to compact the shortening up to the 20 ml marker thereby removing air pockets. The presence of air pockets in the 20 ml syringe affects the amount of shortening delivered. Without the removal of air pockets reinforcer magnitude would randomly change throughout the session. When a reinforcer was scheduled to be delivered all three cue lamps flashed for 2 s prior to the start of the reinforcer delivery, during the 2 s while the whipped shortening was being delivered, and for 1 s after the delivery. All experimental contingencies were programmed with Graphic State 2™ state notation (Coulbourn Instruments, Allentown, PA).

2.3. Establishment of shortening as a reinforcer

In order to establish shortening as a reinforcer [15–16] all rats were provided with solid vegetable shortening (Crisco® All-Vegetable shortening, J.M. Smucker Co., Orrville, OH) in glass jars clipped to the front of the cage for three overnight periods. Each period was separated by 24 h without shortening available. Following the three overnight access periods, all rats were then provided with daily 1-hr access to shortening in their home cages for seven consecutive days. Body weights were recorded on the eighth day. Four groups (N = 12 each) were then matched by body weight (group ranges 323.8 g ± 3.1 to 325.6 g, ±2.9) [($F(3,47) = 0.10$, $p = 0.9570$] and perfectly matched on the average amount of shortening consumed (group ranges 2.2 g ± 0.4 to 2.2 g ± 0.3) for the last three days [($F(3,47) = 0.0$, $p = 1.000$].

2.4. Operant training procedure

After grouping the rats, one group was allowed to adapt to the operant chamber for one, 1-h session and then overnight food-deprived. They were then trained to consume 0.1 g of shortening delivered from a syringe every 40 s for 30 min and were provided 5–7 g of chow after the session. During the next one to two sessions all rats were trained to lever press with 0.1 g of shortening serving as the reinforcer. After lever pressing was established, all rats were returned to ad libitum chow for 3 days. On the fourth day, they were overnight food deprived again and placed on a Fixed Ratio 1 (FR1) schedule of reinforcement. Following this session they were then returned to ad libitum chow for the remainder of the study. This procedure was then repeated for a second group of rats. After all lever press training was completed, these two groups of rats had at least 7 days of ad libitum chow with no shortening available before the start of the experimental procedures. The other two groups of rats were not given shortening during the lever press training of the first two groups of rats and were also food deprived (15 g chow) for two successive days in tandem with each of the operant groups. The 15 g of chow had the approximate caloric value of 3 g of shortening plus 7 g of chow received by the operant groups during training. In summary, food deprivation was imposed during the lever training sessions and all rats had ad libitum access to chow for the remainder of the study with the exception of the last condition of the study.

For the entire study, either chow was singularly available or shortening was singularly available, but not both at once. Stated otherwise, chow hoppers were removed for all groups during home cage shortening access, and chow/food pellets were not available during operant sessions.

2.5. Experiment 1

2.5.1. Home cage access vs. operant access

Seven days following lever press training one of the two non-lever trained groups was provided 30-min of shortening access in their home cages on an intermittent basis (Mondays, Wednesdays, and Fridays [MWF]) for the remainder of the experiment and was designated "IC". The second non-lever trained group was provided 30-min of shortening access in their home cages on a daily basis (7 days/week) for the remainder of the experiment and was designated "DC". These two groups were considered control groups for any effects of time across the 8 weeks of the study, and to be sure that this batch of rats responded as has been reported previously to the limited access protocol.

One of the groups trained to lever press was exposed to 30-min operant sessions on an intermittent basis (MWF) for four weeks under a FR1 schedule of reinforcement, and was designated as "IO". The other group trained to lever press was exposed to 30-min operant sessions on a daily basis (7 days/week) under a FR1 schedule of reinforcement and was designated as "DO". During these 4 weeks the only shortening the two operant groups consumed was that which they earned in the operant chambers, i.e., no additional shortening was provided in the