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Environments predicting intermittent shortening access reduce operant performance but not home cage binge size in rats

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HIGHLIGHTS

- Rats had intermittent or daily access to optional fat.
- Cues associated with fat access were predictable or unpredictable.
- Intermittent access to fat induced bingeing regardless of cue predictability.
- Predictable cues reduced operant responding regardless of fat access.

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ABSTRACT

When non-food-deprived rats are given brief access to vegetable shortening (a semi-solid fat used in baked products) on an intermittent basis (Monday, Wednesday, Friday), they consume significantly more and emit more operant responses for shortening than a separate group of rats given brief access to shortening every day. Since both groups are traditionally housed in the same room, it is possible that the environmental cues associated with placing shortening in the cages (e.g., investigator in room, cages opening and closing, etc.) provide predictable cues to the daily group, but unpredictable cues to the intermittent group. The present study examined the effects of providing predictable environmental cues to an isolated intermittent group in order to examine the independent contributions of intermittency and predictability on intake and operant performance. Two groups of rats were housed in the same room, with one group provided 30-min intermittent (INT) access and the second group provided 30-min daily access (D) to shortening. A third group (ISO) of rats was housed in a room by themselves in which all environmental cues associated with intermittent shortening availability were highly predictable. After five weeks of home cage shortening access, all rats were then exposed to several different operant schedules of reinforcement. The INT and ISO groups consumed significantly more shortening in the home cage than the D group. In contrast, the INT group earned significantly more reinforcers than both the ISO and D groups under all but one of the reinforcement schedules, while ISO and D did not differ. These data indicate that intermittent access will generate binge-type eating in the home cage independent of cue predictability. However, predictable cues in the home cage reduce operant responding independent of intermittent access.

1. Introduction

Intermittent access to a variety of substances promotes robust intake of those substances during the period that they are available. This phenomenon has been described in rodents for alcohol [1–6], nicotine [7], fatty or sugary foods [8,9], and in children for snack items [10]. Research from this laboratory and others using a limited access binge eating model has shown that brief periods of intermittent access to 100% vegetable shortening result in binge-type behavior in non-food deprived rats [11–21]. In this model, non-food deprived rats given brief access (20 min to 2-h) to vegetable shortening on Mondays, Wednesdays, and Fridays consume significantly more shortening during the access period than do rats given daily access for the same amount of time. While the above studies have elucidated various factors that contribute to bingeing, it remains unanswered as to what it is about intermittency per se that promotes bouts of excessive intake.

One possible explanation for why intermittency promotes binge-type behavior may relate to the uncertainty associated with eating opportunities, even if food is readily available [22]. For instance, adolescents who routinely eat dinner with the family have a lower risk of binge eating than adolescents who rarely eat dinner with the

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family [23,24]. Binge episodes often are not planned [25] and daily energy intake can vary widely even within individuals [26]. Furthermore, intolerance for uncertainty has been reported in subjects with bulimia nervosa [27], and chaotic/uncertain eating behavior has been reported among those with binge eating disorder [28]. In short, those who binge have a relatively low tolerance for uncertainty but often engage in uncertain/chaotic eating patterns within environments of food abundance. Interventions for the treatment of binge eating attempt to reduce uncertainty associated with eating and palatable food consumption by establishing regular eating patterns and incorporating "forbidden" foods back into the diet [29]. It is possible that uncertainty surrounding opportunities to consume palatable foods within environments of food abundance contributes to eating pathology.

In the limited access rat bingeing protocol, the intermittent groups are housed in the same colony room as the daily groups. As such, the intermittent groups are exposed to cues every day that are associated with shortening presentation (the presence of the experimenter entering and leaving the room, opening and closing of cages, placement and removal of jars from the jar clips, etc.), but shortening is only provided on 3 days each week. Stated otherwise, the cues associated with shortening availability do not reliably predict consummatory opportunities for the intermittent group, because shortening is not always provided. As a result, the food–cue associations become ambiguous/uncertain. This may be analogous to environments of food abundance in which a plethora of cues is associated with palatable food availability (e.g. sight and smell of baked goods), but may not predict an opportunity to actually consume those foods (e.g. money may be limited). While uncertainty appears to be associated with binge-type consumption of palatable foods, its causal relationship to bingeing has not been determined. Since the factors/variables constituting uncertainty are numerous and ill-defined, the present study reduced uncertainty by making intermittent presentation of vegetable shortening certain and predictable in one group of rats. Home cage intake and operant performance using several different schedules of reinforcement in this group were then compared to that of rats housed under our standard conditions described above.

2. Materials and methods

2.1. Animals

Thirty-six male Sprague Dawley rats (Harlan, Indianapolis, IN), 60 days of age and weighing 251–285 g (268.4 ± 1.2 g) at the start of the study, were individually housed in hanging stainless steel wire cages in a temperature- and humidity-controlled environment on a 12:12 light:dark cycle. All rats had continuous access to tap water and to a nutritionally complete commercially available pelleted rodent diet (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.

After five days of adaptation to the vivarium, daily chow intake was recorded for 3 consecutive days (days 6 through 8), body weights were recorded (day 8) and vegetable shortening (Crisco® All-Vegetable shortening, J.M. Smucker Co., Orrville, OH) was provided during a single overnight period (days 8 to 9). Three groups of 12 rats each were then matched by the 3-day average chow intake, body weight and the amount of overnight shortening consumed [ps NS, $F < 1.0$ for all three measures]. All procedures were approved by The Pennsylvania State University Institutional Animal Care and Use Committee.

2.2. Bingeing procedure (home cage protocol)

For the next five weeks, chow and water were available ad libitum to all groups. In addition, shortening was provided in glass jars clipped to the front of the home cage starting 2 h prior to the start of the dark cycle. A fading procedure to establish shortening consumption during a 30-min period of time was used over the first three of these five weeks in order to equalize length of home cage shortening access to operant session length. During the fading procedure, the shortening was provided for 1 h during the first week, for 45 min during the second week, and for 30 min for the duration of the study. A recent study has shown that this fading procedure will establish bingeing when the final access period is only 20 min [11]. For one group of rats shortening was provided on an intermittent (INT) basis (Mondays, Wednesdays, and Fridays), and for another group shortening was provided on a daily (D) basis. These two groups were housed in the same colony room where other studies were also being conducted. Each group was housed in the top twelve cages of a 15-cage rack. The racks were arranged such that the INT and D groups for each study faced one another, i.e., the INT group could see the D group. Furthermore, the back of the D group rack for one study abutted the back side of a rack of cages for another study, i.e., the INT and D groups in the second study could not see the rats in the first study. In this way, the colony was able to accommodate 3 concurrent studies in which the INT and D groups faced one another and were visually isolated from the groups of other studies by creating 3 "rows" of studies. The colony was also arranged such that the testing for each group was staggered, e.g., the study at the front of the room was conducted first while the studies at the back of the room were conducted last. Once rats acclimated to the colony, they continued to sleep while other studies were conducted until the cages in their particular row began to be opened and closed.

The third group of rats (ISO) was provided shortening on the same days and at the same time relative to lights out as the first intermittent group. However, the presentation of shortening was made predictable by housing these animals in a separate isolated colony room with no other animals present. This colony room was located in a side hallway away from the "normal traffic" of the vivarium, and the room was entered only on days in which shortening was provided. A glass window in the door to the room provided visual inspection of the animals without entering. All animal care functions, i.e., weighing rats, filling food hoppers, changing water bottles and changing dropping pads, were performed on the three days that shortening was provided.

2.3. Apparatus

Twelve identical operant chambers (Model H10-11R-TC; Coulbourn Instruments, Allentown, PA) located in a room adjacent to the animal rooms were used for the operant testing. Experimental contingencies were programmed with Graphic State 2™ state notation. The back wall of each chamber contained a house light (Model H11-01R) located in the middle panel at the top of the chamber. The front wall of each chamber contained a retractable response lever (Model H23-17R) located in the middle panel and a triple cue lamp (H11-02R) located above the response lever. Whipped vegetable shortening was used as the reinforcer for lever pressing. It 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 on the right panel adjacent and parallel to the response lever. A triple cue lamp located directly above the shortening receptacle was used to signal shortening delivery. Care was taken when packing the shortening into the 20 mL syringe to minimize any air pockets that would affect the amount delivered during each reinforcer delivery.

2.4. Operant procedures

2.4.1. General procedures

Previous studies have assessed operant performance in intermittent and daily groups after lever pressing had been established using the method of hand shaping by successive approximations [18,21]. The current study used an autoshaping procedure instead of hand