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Access conditions affect binge-type shortening consumption in rats

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ABSTRACT

When non-food-deprived rats are given intermittent access to certain substances, consumption of those substances is greater than when more frequent access is provided. The present study examined the effects of three different shortening access conditions on subsequent shortening intake in rats. Each of the three different shortening conditions lasted five weeks and was followed by a five-week period in which shortening access was limited by time (1 h of availability) on either an Intermittent (Monday, Wednesday, Friday) or Daily schedule of access. In Part 1, limiting the quantity of shortening provided during the 1-h period of availability attenuated subsequent 1-h shortening intake in the Intermittent access group, but had no statistically significant effect in the Daily access group. In Part 2, unrestricted availability of shortening (24 h/day–7 days/week) attenuated subsequent 1-h shortening intake in all groups. In Part 3, shortening non-availability for five weeks enhanced subsequent 1-h shortening intake in all groups. It was also shown that rats under an Intermittent, but not a Daily, schedule of access consumed as much shortening during a 1-h period of availability, as was consumed in 24 h when shortening availability was unrestricted. These results demonstrate that while intermittent access is necessary and sufficient to stimulate binge-type eating in rats, the behavioral history can modulate binge size.

1. Introduction

A considerable body of research has shown that behavior directed toward consuming various foods is increased when the time during which those foods are available is decreased. For example, non-food-deprived rats drink more of a 1.5% w/v saccharin solution or 20% w/v alcohol during a 24-h period when provided every other day than when provided on a continuous basis [1,2]. The frequency of dipper presentations and the duration of drinking bouts for 10% alcohol increase when the number of access periods each day is reduced [3]. Other research has also shown that non-food-deprived rats consume more of an optional fat (binge) during a 1–2-h period of access when it is provided intermittently on Mondays Wednesdays and Fridays (MWF) [4–8] or every third day [9] than when it is provided daily for 1–2 h. "Bingeing" is operationally defined as Intermittent 1-h shortening intakes>Daily 1-h shortening intakes in these studies, based upon the DSM-IV criterion of consuming more in a brief period of time than is normally consumed during a similar period of time and under similar circumstances [10]. Only access to the fat is limited; chow and water are always freely available, i.e. the rats are never food-deprived [4–8]. Furthermore, body weight and body fat do not differ between binge rats and chow-fed controls [4]. Similar results have also been obtained for various concentrations of liquid sucrose [11]. The use of intermittent limited access has been proposed as a behavioral model of binge-type eating with good construct and face validity [12]. Recent research suggests the predictive validity of this approach, as well [13].

All of the above studies increase consumption by restricting the time during which the ingestant is available. Time-limited procedures do not promote cumulative overconsumption; rather, they promote brief bouts of excessive intake, i.e. bingeing. This is different from protocols in which extended access (long session duration) promotes cumulative overconsumption, such as that reported for certain drugs of abuse [14], or for fat, in which extended access induces hyperphagia and obesity [15]. Extended access (12 h vs. 30 min) also has been reported to increase operant responding for sugar [16]. In short, consumption of a variety of items can be modulated by maintaining a constant session duration while altering session frequency (3 times a day, daily, every other day, etc.), or by altering session duration and keeping session frequency constant. Both of these approaches involve alterations in the time during which some commodity is provided. While time-related access has been extensively studied, the effect of limiting the amount provided has not.

Limitation of the quantity available has relevance to the incorporation of "forbidden foods" into the diet [17]. "Forbidden foods" are typically high in fat and those who are trying to lose weight often restrict access to these foods. However, these foods are consumed in large quantities during a binge. The forbidden foods hypothesis of human bingeing suggests that these two conditions are related, i.e. the foods upon which people binge are those to which they have limited their own access [17]. Websites available to the public suggest that

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incorporation of forbidden foods into the diet will produce "normal" eating patterns, but such ideas have not been subjected to controlled experiments to our knowledge. Would occasional consumption of small quantities of forbidden foods protect against the subsequent development of binge eating? Conversely, would "nibbling" on forbidden foods throughout the day protect against subsequent bingeing? The present study addressed these questions using an established rat model of binge-type eating. The effects of both time-limited and quantity-limited access to fat on subsequent binge-type consumption of fat are reported.

2. General methods

2.1. Overall design

There were three 10-week parts each consisting of two 5-week sub-parts (Table 1). In the "A" sub-parts, access to shortening was manipulated in different ways; in the "B" sub-parts, our standard limited access protocols (Intermittent or Daily 1-h access to shortening) were in place. The goal was to determine the effects of the various access manipulations (Parts 1A, 2A, and 3A) on subsequent binge-type intake (Parts 1B, 2B, and 3B).

2.2. Animals

Fifty male Sprague Dawley rats (Harlan, Indianapolis, IN), 60 days of age and weighing 268–307 g (280.7±5.6) 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. All rats were maintained on a nutritionally complete commercial laboratory rodent chow (Laboratory Rodent Diet 5001, PMI Feeds, Richmond IN; percent of energy as protein: 28.05%, fat: 12.14%, carbohydrate: 59.81%; 3.3 kcal/g). Chow and tap water were available ad libitum throughout all parts of the study. The Pennsylvania State University Institutional Animal Care and Use Committee approved all procedures.

During the first two weeks of adaptation to the vivarium, chow intake was measured on a daily basis, body weights were determined three times per week, and unrestricted access to solid vegetable shortening (Crisco® All-Vegetable Shortening, J.M Smucker Co., Orrville, OH) was provided during a single overnight period. Prior to the start of the experiment, five groups of 10 rats each were matched by body weight, average amount of chow consumed during three consecutive 24-h periods, and the amount of shortening consumed during the overnight access period [$F(4,45)<1$, NS for all]. The experimental manipulations for each group are described in detail for each study, below.

2.3. Statistics

Body mass-adjusted shortening intake (kcal/body mass$^{0.67}$; [18]) was used throughout. For Parts 1A, 1B, and 2A shortening intake was analyzed using 3-way repeated measures ANOVA: [access schedule (Daily, Intermittent)×amount of shortening available (full bowl, 2 g)×time (week)]. Differences among groups for each week were assessed using pre-planned LS means comparisons, with a Bonferroni correction applied ($p=0.05/3$ comparisons per group=0.0167). For analyses of shortening intake involving the NS group (Parts 2B, 3A, and 3B), as well as all analyses of total energy intake (shortening plus chow) and body weight, 2-way ANOVA was used [group×time (week)] followed by Tukey's HSD post-hoc test. Differences among groups in absolute body weights at the end of week 5 of each sub-part, body weight change during each sub-part, total cumulative energy intake, shortening intake for week 5 of each sub-part, percent protein by weight, percent carbohydrate by weight, and percent fat (chow fat and shortening) of each sub-part were determined using 1-way ANOVA followed by Tukey's HSD.

Table 1
Shortening availability in each part

	Part					
	1A	1B	2A	2B	3A	3B
Intermittent (I)	TL[a]	TL	Continuous	TL	None	TL
Intermittent (I-QL)	QL[b]	TL	Continuous	TL	None	TL
Daily (D)	TL	TL	Continuous	TL	None	TL
Daily (D-QL)	QL	TL	Continuous	TL	None	TL
No shortening (NS)	None	None	None	TL Intermittent	None	TL Intermittent

[a] Time-limited (1-h access to full bowl).
[b] Quantity-limited (1-h access to 2 g).

3. Part 1

The goal of Part 1 was to determine the effects of quantity-limited shortening consumption on subsequent quantity-unlimited shortening consumption, i.e. on binge-type consumption of shortening. The quantity-limitation provided a way to limit access in the Intermittent group to an even greater extent than the time-limited procedure affords. In addition, it provided a way to control for amount consumed during the access period independent of the schedule of availability, since the amount provided was that which Daily rats normally consume. Chow and water were available ad libitum throughout the study, i.e., the rats were never food-deprived. Only access to the shortening was manipulated.

3.1. Methods — Part 1

3.1.1. Part 1A: quantity-limited access to shortening for some groups, time-limited for all

For the first five weeks, two groups of rats (I, I-QL) were placed on an intermittent schedule of access (Mondays, Wednesdays, and Fridays) to shortening while two other groups were placed on a daily schedule of access (D, D-QL). For all four groups, shortening availability was time-limited to 1 h. For one of the Intermittent groups (I) and one of the Daily groups (D), the quantity of shortening provided during the 1-h period of availability was unlimited. That is, the I and D groups received a full bowl during the 1-h period. For the other Intermittent and Daily groups (I-QL and D-QL, respectively) the quantity of shortening provided during the 1-h period was limited to ~2 g (2.0–2.2 g) in that previous work indicated that this was the average amount typically consumed by groups with 1–2 h of Daily time-limited access to a full bowl of shortening [4–8]. The goal was to "clamp" intake to that normally consumed by Daily rats. In this way, rats in the I-QL, D-QL, and D groups would consume the same amount of shortening within the 1-h period, regardless of the schedule of availability. This would allow for any effects of the Intermittent or Daily schedules to be determined independent of the amount consumed.

A fifth group of rats (NS) had no shortening access.

3.1.2. Part 1B: quantity-unlimited and time-limited shortening access

During the next five-week period, access to shortening was limited by time (1 h), but not by amount. That is, all four groups (I, I-QL, D, D-QL) were given a full bowl of shortening (quantity-unlimited) during the 1-h period of shortening availability under their respective schedules of access. The NS group again had no access to shortening.

3.2. Results — Part 1

3.2.1. Part 1A

3.2.1.1. Shortening. During each week of the initial 5 weeks, the I group consumed significantly more shortening (LS Means, p 0.0167) during the