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Effects of long-term cycling between palatable cafeteria diet and regular chow on intake, eating patterns, and response to saccharin and sucrose

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HIGHLIGHTS

- Rats cycled between a cafeteria diet and chow develop binge-like eating behavior
- Cycled rats withdrawn from cafeteria diet ate less of a novel biscuit than chow rats.
- Cafeteria-fed and cycled rats 'wanted' saccharin less than chow-fed rats.
- Chow-fed rats and cycled rats 'liked' sucrose more than cafeteria-fed rats.
- These findings in rats may have important implications for yo-yo dieting in people.

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ABSTRACT

When exposed to a diet containing foods that are rich in fat and sugar, rats eat to excess and gain weight. We examined the effects of alternating this diet with laboratory chow on intake of each type of diet, the eating elicited by a palatable food (biscuits), and the drinking elicited by sweet solutions that did (sucrose) or did not (saccharin) contain calories. Each week for 13 weeks, cycled rats were provided with the cafeteria diet for three successive days/nights and the chow diet for the remaining four days/nights, whereas other rats received continuous access to either the cafeteria or the chow diets. On each of the 13 weeks, cycled rats ate more across the first 24 hour exposure to the cafeteria diet than rats continuously fed this diet. In contrast, cycled rats ate less across the first 24 hour exposure to the chow diet than rats continuously fed this diet and ate less when presented a novel palatable biscuit than chow-fed rats. The three groups exhibited similar licks per cluster to saccharin, but cafeteria-fed and cycled rats showed fewer clusters than chow-fed rats. In contrast, chow-fed rats and cycled rats exhibited more licks per cluster to sucrose than cafeteria-fed rats, but all three groups had a similar number of clusters. The results were discussed in relation to the effects of diet cycling on eating patterns, body weight, and 'wanting' and 'liking'. These findings with rats may have important implications for yo-yo dieting in people.

1. Introduction

The overconsumption of energy-rich foods is thought to play a major role in the current obesity epidemic [1,2]. One reason why energy-rich foods are eaten to excess is that they are hedonically pleasant [3]. The pleasure of eating such foods is also a reason why people find it difficult to refrain from eating them when trying to lose weight [4,5]. Moreover, refraining from eating such foods can elicit stress, and, in turn, eating energy-rich foods can alleviate stress [6–8]. These relations between overconsumption of hedonically attractive foods and weight gain, the stress produced by dieting, and the alleviation of this stress by consumption of such foods, characterize many people in western society. The long-term effects of this pattern of eating, so-called "yo-yo" dieting [9], are unclear. Some studies have reported that such diet cycling is associated with increased risk of binge-eating and psychopathology, as well as a slowed metabolic rate [10]. Others have failed to find a link between diet cycling and adverse health effects [11,12].

The long-term effects of diet cycling in rodents are also unclear. Again, some studies have found that cycling between low- and high-calorie diets results in binge-eating when the animals are shifted to the high calorie diet, as well as increased weight, fat intake, and ghrelin levels, relative to continuous access to a high-calorie diet [13–16]. Other studies have reported that a history of diet cycling and the accompanying changes in body weight do not lead to obesity, decreased lifespan, changes in metabolic rate, or chronically elevated blood pressure [14,17–20]. Although much is still uncertain regarding the long-term effects of "yo-yo" dieting, two consistent findings in rodent models are that withdrawal from a palatable energy-rich diet produces stress, and that a return to the energy-rich diet produces overconsumption or 'binging'

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[21,22]. However, little is known about the characteristics of eating across diet cycling.

The present study used rats to study the effects of cycling between a chow diet and a cafeteria diet containing many of the energy-rich foods eaten by people. There were three aims. The first was to examine whether cycling between the two diets altered intake of each: specifically, whether the cycled rats ate more when shifted to the cafeteria diet than rats continuously fed this diet but ate less when shifted to chow than those continuously fed this diet. The second aim was to determine whether the effect of shifting rats from the cafeteria diet to chow was specific to chow by comparing their intake of a novel palatable food (biscuits) with that of rats continuously fed chow. The final aim was to determine whether cycling rats between cafeteria and chow altered their ingestive responses to palatable sweet solutions that did (sucrose) or did not (saccharin) contain calories. Fig. 1 shows the experimental timeline.

2. Methods

2.1. Subjects

The subjects were 36 experimentally naïve male Sprague Dawley rats, obtained from a commercial supplier (Animal Resource Centre, Perth, Australia), aged 6–8 weeks and weighing 240–280 g upon arrival. They were housed in plastic boxes (22 cm height × 65 cm length × 40 cm width) with four rats per box, in a climate controlled room (22 °C) on a 12-hr reverse light/dark (lights off 9.00 am–lights on 9.00 pm) cycle. Rats were housed four per box due to ethical requirements to avoid any stress produced by housing rats individually. The protocols used were approved by the Animal Care and Ethics Committee of the University of New South Wales and were in accordance with the guidelines provided by the Australian National Health and Medical Research Council.

2.2. Diet

Rats were provided with chow and water and handled each day for one week. They were then randomly allocated to three groups ($n = 12$; groups did not differ in body weight): continuous access to standard lab chow (Group Chow) or to the cafeteria diet (Group Caf) or to cycling (Group Cyc) between chow (four days) and the cafeteria diet (three days). Standard chow provided 11 kJ per gram (kJ/g), 12% energy as fat, 20% protein and 65% carbohydrate (Gordon's Specialty Stockfeeds, NSW, Australia). The cafeteria diet consisted in standard chow, chow mixed with lard (pig fat) and condensed milk (©Homebrand), and a range of foods obtained from a local supermarket. These foods were high in protein and/or carbohydrates (meat pie, meat wrapped in rice paper, oats, and dog food roll) or high in fat and sugar (cake and biscuit; see Supplementary Table for details). Two foods high in protein/carbohydrates and two high in fat/sugar were always available and changed daily. The cafeteria diet provided an average of 15.3 kJ/g, 30% energy as fat, 12% protein and 58% carbohydrate. Food was placed inside the home cages, cafeteria diet being presented fresh daily, at 5 pm. Each week, energy intake was recorded after the first 24 h of each diet switch in the cycled group, and on the equivalent days for Groups Chow and Caf. Energy intake was calculated using the known energy content of each food (kJ/g).

2.3. Apparatus and data recording

Four chambers (20 cm height × 21 cm length × 23 cm width) were used to measure the intake of the biscuits and assess the pattern of drinking elicited by the sweet solutions, saccharin and sucrose. The side walls and lid were made of Perspex, the rear and front walls of aluminum, and the floor consisted of stainless steel rods (4 mm in diameter) spaced 1 cm apart. The front wall contained a circular hole through which rats could contact a drinking tube located outside the chamber. This ensured that only the rat's tongue made contact with the tube. Each contact with the tube completed a circuit recorded by a computer. The number of licks, clusters, and licks per cluster were collected using MATLAB (MathWorks Inc.).

2.4. Procedure

2.4.1. Training

The water bottles were removed from the home cages and 4 h later, the rats were placed in the chambers and allowed to drink water for 15 min on two successive days. This was done in order to familiarize rats with drinking in the chambers.

2.4.2. Test 1: Intake of biscuits

Intake of the biscuits was assessed once per week over the first six weeks of diet exposure. Rats in Groups Chow and Caf were exposed to biscuits while on their respective diets, while those in Group Cyc were exposed on their fourth day of the chow diet cycle. Each rat was placed in a chamber and provided with novel biscuits not previously included in the cafeteria diet (©Arnott's Shortbread Cream Biscuits; 369 kJ per biscuit: 0.9 g protein, 11 g carbohydrate, 4.5 g fat, 4.6 g sugar) and water for 30 min. Exposure to the biscuits occurred one hour into the dark phase in the absence of any food or fluid deprivation. The weight of the biscuit was recorded at the start and end of the session. Rats were returned to the home cage at the end of each session. On week six, rats were video recorded throughout the 30 minute test and recordings were later used to score feeding behavior. Week six was chosen for analysis because the amounts eaten in each of the groups were stable.

2.4.3. Test 2: Intake of saccharin

Following six weeks of feeding tests, the pattern of licking was examined in (the same) rats offered 0.2% (non-caloric) saccharin solution over four weeks. Each week, intake was assessed in Group Cyc 24 h after the switch to chow and 24 h after the switch to the cafeteria diet. Intake was assessed at the equivalent days in the chow and cafeteria groups.

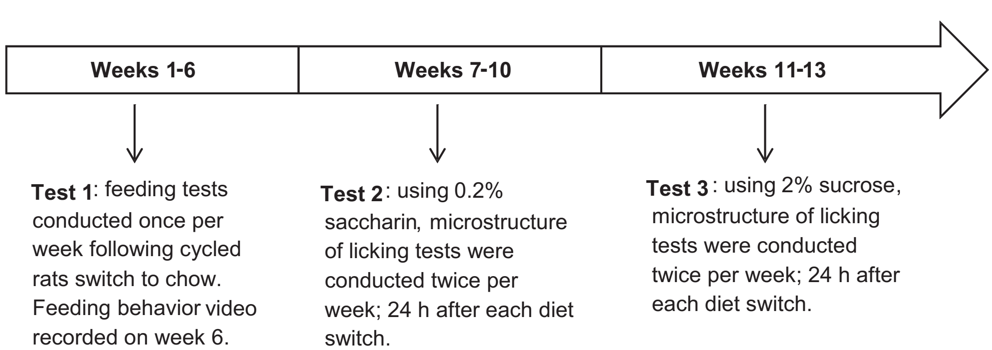

Fig. 1. A schematic illustrating the timeline for testing procedures across the experiment.