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Sucrose and fat content significantly affects palatable food consumption in adolescent male and female rats

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ABSTRACT

Hyperpalatable foods are highly pleasurable and possess a heightened capacity to stimulate eating. Adolescents appear especially vulnerable to hyperpalatable foods. These foods are typically high in sugar, fat, or both, but the specific elements that underlie their increased consumption are still not clearly understood. Combinations of high fat and high sugar may particularly intensify overeating. Animal models allow investigation of the consumption of these foods separately from many of the environmental and psychological influences that impact eating in humans. The current study compared intakes of sucrose, fat, and a sucrose-fat combination when offered to male and female rats intermittently (2 h, three times per week for five weeks) during the vulnerable period of adolescence. Consumption of these foods, and of freely available normally nutritive lab chow was measured. Animals given the sucrose-fat food consumed significantly more than all other groups and were the only group to show significant increases in consumption during the first week. Moreover, the sucrose-fat group consumed significantly less chow than any other group. In comparison with previous reports in adult rats, adolescent rats appeared to heighten consumption of the sucrose-fat food more markedly and to show less pronounced sex differences. These data highlight the unique vulnerability and increased biological susceptibility of adolescent rats to sweet-fat food rewards and demonstrate the need to similarly investigate the preference for and the consumption of different hyperpalatable foods in human adolescents.

1. Introduction

Hyperpalatable foods are increasingly available in today's eating environment. Hyperpalatable foods are those that seem to produce enhanced pleasure when consumed resulting in an enhanced capacity to stimulate eating (Gearhardt, Grilo, DiLeone, Brownell, & Potenza, 2011b). These foods are typically high in sugar, fat, or the combination (Drewnowski, 1995; Gearhardt et al., 2011b) but it is still poorly understood what specific elements of these foods underlie their heightened consumption.

Foods high in sugar or fat are heavily preferred due, at least in part, to evolutionary drives to consume more energy-dense foods (Gerber, Williams, & Gray, 1999). Today's hyperpalatable foods with artificially elevated levels of sugar and/or fat (Schulte, Avena, & Gearhardt, 2015) are significantly more rewarding than less processed foods (Gearhardt, Davis, Kuschner, & Brownell, 2011a). Combinations of high fat and high sugar may specifically intensify overeating. For example, people most prefer sweetened-high fat solutions to high-fat only or sweet-only solutions (Drewnowski & Greenwood, 1983). In addition, people prone to binge eating typically report the greatest craving for (Blundell et al., 2010) and binging on (Bartholome, Raymond, Lee, Peterson, & Warren, 2006) sweet-high fat foods. Given the link between hyperpalatable foods and overeating (Erlanson-Albertsson, 2005), understanding the preference for and the consumption of different hyperpalatable foods has implications not only for binge eating disorders but also for the obesity epidemic.

Similar to humans, rats show increased intake of processed foods high in fat and/or sugar such as cookies and candy bars (Rolls, Rowe, & Turner, 1980; Sampey et al., 2011). Moreover, binge-like eating of high fat (e.g. Corwin et al., 1998; Dimitriou, Rice, & Corwin, 2000), high sugar (e.g. Wojnicki, Stine, & Corwin, 2007)

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and sweet-high fat foods (e.g. Kinzig, Hargrave, & Honors, 2008) readily develops in rats. Typically, binge-like eating in rats is induced using restricted food access which significantly escalates intake over time; a pattern not observed with daily availability (see Corwin, Avena, & Boggiano, 2011 for review). Importantly, this limited availability aligns animal models with observations that humans also binge on those "forbidden" foods which they usually deny themselves (e.g. Kales, 1990; Theim et al., 2007). Current research on binge-like eating in rats has little comparison of consumption patterns among different types of preferred foods (i.e. high fat, high sugar and sweet-high fat foods) though the limited existing data suggest a similar preference in rats for sweet-high fat food. For example, adult male rats consume more sweet-fat chow compared to pure vegetable shortening or 10% sucrose solution (Berner, Bocarsly, Hoebel, & Avena, 2009) and show the greatest intake of a sucrose-fat food relative to fat only or sucrose only foods (Wojnicki, Charny, & Corwin, 2013).

Adolescents appear especially susceptible to the influence of hyperpalatable foods. Adolescence begins with physical changes that precede puberty (Spear, 2000) and includes extensive brain growth and development (Johnson, Blum, & Giedd, 2009). In humans, adolescence is typically viewed as lasting from 10 to 19 years old (WHO, 2017). Teenagers consume more added sweeteners (Guthrie & Morton, 2000) and fast food (Powell, Nguyen, & Han, 2012) than any other age group with forty-one percent of adolescents reporting eating fast food within the last 24 h (Powell et al., 2012). This increased consumption of hyperpalatable food by adolescents likely represents a combination of environmental and biological factors. For example, much of the sale and marketing of hyperpalatable foods is targeted to children and adolescents (Powell, Szczypka, Chaloupka, & Braunschweig, 2007). However, significant development of dopaminergic brain systems during the adolescent period also produces enhanced biological responses to rewarding stimuli such as hyperpalatable foods (Davey, Yücel, & Allen, 2008).

Given the vulnerabilities of adolescents, it is important to examine the consumption of hyperpalatable foods during this developmental period. Since rats show the same preferences as humans for high sugar (Hajnal, Smith, & Norgren, 2004) and high fat foods (Wojnicki, Charny, & Corwin, 2008), they provide an excellent research model to investigate intake separately from the complex environmental and psychological contributors to human eating (Lardeux, Kim, & Nicola, 2013).

In rats, adolescence spans similar milestones as humans from the beginning of sexual maturation to the transition to adulthood, extending from approximately postnatal day 21–63 (Sengupta, 2013; Spear, 2000). Research to date has shown binge-like eating of high sucrose food in male adolescent rats (Cottone et al., 2009) and of sweet-fat foods in female adolescent rats (Bekker, Barnea, Brauner,& Weller, 2014; Klump, Suisman, Culbert, Kashy, & Sisk, 2011). In line with human data, adolescent female rats consume more sweet-fat food than adult females (Bekker, Barnea, Brauner, & Weller, 2014). However, a systematic examination of how fat and sugar content impacts food consumption during the adolescent period remains lacking. This vital evaluation can serve as a first step to understanding how hyperpalatable foods may heighten consumption.

Another identified influence on human adolescent behaviour is sex. For example, adolescent boys consume more added sweeteners in their diet than girls (Guthrie & Morton, 2000). Few studies have examined sex differences in rats and most use adult, not adolescent, rats. The limited data have shown increased binge eating of fat (Babbs, Wojnicki, & Corwin, 2011) and sweet-fat (Klump, Racine, Hildebrandt, & Sisk, 2013) foods in adult females compared to males. Mechanisms underlying these sex differences are unclear but it is possible that they are driven by gonadal hormones. Briefly, testosterone increases food intake, estradiol inhibits intake and progesterone has no effect except in pharmacological doses in rats (see Asarian & Geary, 2013 for review). Preliminary data collected in adolescent rats suggest sex differences may be less pronounced than in adults, as adolescent females consume more sugar but equal amounts of sugar-fat relative to males (Tenk, Bell, & Ossenkopp, 2011). Given the current gaps in research, we aimed to map any existing sex differences in an adolescent rat model.

The current study provides a novel evaluation of how food composition may drive increased consumption during adolescence. We examined the consumption of different foods (100% sucrose, 100% vegetable shortening, 9% sucrose-91% vegetable shortening mixture) following repeated, time-limited presentations in adolescent female and male rats. The subsequent consumption of a nutritive rodent chow after food access was also investigated. Our aim was to evaluate the influence of sucrose and fat content on intake and the resulting impact on nutritive chow consumption, during the vulnerable period of adolescence while probing for existing sex differences.

2. Methods

2.1. Subjects

Long Evans rats (32 female and 30 male) were obtained from Charles River Laboratories, Canada. Rats were approximately 35 days old (±2 days) and weighed on average 125 g (females) and 150 g (males) at the start of the experiment. This timing ensured that puberty, used to denote a decisive beginning to adolescence (Sengupta, 2013), had begun in both females and males before food exposure. The onset of puberty, defined by vaginal opening (females) or balanopreputial separation (males), occurs in females at approximately 32–34 days old but not in males until about 45–48 days old (Sengupta, 2013). Following one week acclimatization, rats were housed individually in standard polypropylene cages (45 × 22 × 20 cm) with metal-grid floor inserts in a temperature-controlled colony room (21 ± 1 °C) maintained on a 12:12h light-dark cycle (0700 lights on). Animals received 2 days of socialization and handling before the experiment. Animals were randomly assigned to each of the four food conditions: sucrose, fat, sucrose-fat, or lab chow control. Except when rats were presented with these foods as described below, they were allowed *ad libitum* access to powdered lab chow (ProLab, RMH 3000, 59% carbohydrate, 15% fat, 26% protein, 4.2 kcal/g). This access to the standard diet mirrors that used by Berner, Avena, and Hoebel (2008). Tap water was always freely available. All groups were $n = 8$ except for the Male-Sucrose and Male-Sucrose-Fat groups (n's $= 7$). Procedures were approved by the Western University Animal Care Committee and were in accordance with the Canadian Council of Animal Care (CCAC) guidelines.

2.2. Apparatus

Grid floor inserts (45 × 22 cm) were used to anchor black PVC plastic tubing (6 cm high, 7.5 cm diameter). All feeding dishes were placed in this tube to prevent tipping. Glass containers (6 cm high, 7.1 cm diameter) with a metal lid containing a 3.2 cm diameter access hole were filled with powdered lab chow and placed in this tube. This food dish prevented chow powder spillage. Intermittently available foods were presented in glass containers (5.3 cm high, 5.7 cm diameter), replacing the powdered chow containers during periods of access.