Research report

The association of food characteristics and individual differences with ratings of craving and liking

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ARTICLE INFO

ABSTRACT

Craving and liking are related to eating-related problems, but less is known about the association of specific food characteristics (e.g., sugar, fat) with craving/liking. The relation of individual differences in eating behavior with these craving and liking patterns is also relatively unknown. We examine the nomothetic impact of sugar, fat and processing on food craving and liking and the moderation of these effects by idiographic factors (e.g., Body Mass Index [BMI], hunger). One hundred and five overweight and obese women completed craving and liking ratings on 180 foods that differed in levels of sugar, fat and processing. Food craving was linked positively to fat content, but negatively to sugar. Food liking was associated negatively with sugar content and processing level. Addictive-like eating predicted elevated overall food craving and liking, and increased craving and liking for processed foods. Attempted restriction efforts were unrelated to craving and liking. BMI was associated with less craving for fattier foods and lower liking for the average food. Hunger was associated with increased craving for the average food. These findings highlight the role of fat in cravings and differences in craving and liking based on BMI, loss of control over eating, and hunger. These findings are relevant to theories of problematic eating and the development of eating-related interventions.

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Introduction

Craving and liking for foods are thought to influence patterns of food consumption, overeating, obesity, and binge eating (Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992; Finlayson, King, & Blundell, 2007; Hill, 2007). Despite the proposed importance of these constructs, limitations exist in the understanding of the nomothetic (normative) associations between food attributes (e.g., sugar, fat) and food craving and liking. There is also limited knowledge regarding how idiographic (individual-level) factors (e.g., disinhibited eating, obesity) are related to craving and liking. A greater understanding of food craving and liking may highlight mechanisms associated with problematic eating that could be targeted for intervention.

Food craving

Craving has been proposed as an important construct in motivating eating, overeating, and binge eating (White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002). The best way to define craving has been a matter of debate, but generally food craving is

defined as an urge, want or desire for a particular food (Berridge, Ho, Richard, & DiFeliceantonio, 2010; Hill, 2007; Pelchat, 2002). Although there are behavioral measures proposed to measure craving (Finlayson & Dalton, 2012), the most common approach to measuring this construct is for participants to self-report their craving for a predetermined list of food (Rodin, Mancuso, Granger, & Nelbach, 1991; Weingarten & Elston, 1991; Zellner, Garriga-Trillo, Rohm, Centeno, & Parker, 1999). Chocolate has been identified at or near the top of many craving lists (Massey & Hill, 2012; Rodin et al., 1991; Weingarten & Elston, 1991; Zellner et al., 1999) and other sweets (e.g., cookies, cakes, pastries, ice cream) are also identified as frequently craved foods (Christensen & Pettijohn, 2001; Massey & Hill, 2012; Pelchat, 1997; Rodin et al., 1991; Weingarten & Elston, 1991; Zellner et al., 1999). White et al. (2002) identified four categories of frequently craved foods: high-fat foods (e.g., fried chicken, sausage, fried fish, hot dogs), sweets (e.g., brownies, cookies, candy, chocolate), starchy carbohydrates (e.g., rolls, waffles, biscuits, bread), and high-fat foods served at fast-food restaurants (e.g., hamburger, French fries, chips, pizza). Elevated levels of craving for sweets and other high carbohydrate foods[1] (especially during times of neg-

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[1] Although sugar is a type of carbohydrate, prior research has often distinguished between craving for sweets (e.g., cake, chocolate) and craving for more general carbohydrates that include foods high in sugar and/or other carbohydrates, like flour (e.g., doughnuts, pasta, crackers).

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ative affect) led to the proposal that craving for carbohydrates was driven by the potentially mood altering effects of increased serotonin resulting from carbohydrate consumption (Wurtman & Wurtman, 1995). Alternatively, many of the frequently craved high-carbohydrate foods were also high in fat (Drewnowski et al., 1992) and craving for low-fat foods is relatively rare (Pelchat, 1997). Thus, it is unclear whether fat or carbohydrates (such as sugar) may be more closely linked with craving. Of note, the majority of craved foods (e.g., chocolate, French fries) are also foods that have been processed to increase palatability by the addition of sugar, fat and/ or salt, which may impact craving levels (Rodin et al., 1991; White et al., 2002).

Individual differences have also been associated with food craving. Attempts to restrain eating have been proposed as a trigger for increased food craving (Hill, 2007; Polivy, Coleman, & Herman, 2005), although this literature is somewhat mixed. Restrained eating has not been associated with craving in some studies (Hill, Weaver, & Blundell, 1991; Jáuregui-Lobera, Bolaños-Ríos, Valero, & Prieto, 2012; Rodin et al., 1991; Weingarten & Elston, 1991), whereas others have found that restrained eaters report a stronger desire to eat chocolate, higher general levels of craving, a greater likelihood of consuming craved foods, and increased craving in response to food cues (Fedoroff, Polivy, & Herman, 2003; Massey & Hill, 2012; Polivy et al., 2005).

Disinhibited eating may also be linked with food cravings (Greeno, Wing, & Shiffman, 2000; Mitchell, Hatsukami, Eckert, & Pyle, 1985). A relatively new and controversial theory suggests that some forms of disinhibited eating could be caused by an addictive response to highly processed foods (Avena, Rada, & Hoebel, 2008; Gold, Frost-Pineda, & Jacobs, 2003; Johnson & Kenny, 2010). A central component of addiction is a loss of control over consumption (American Psychiatric Association, 2000). Addictive-like eating as measured by the Yale Food Addiction Scale (YFAS) is strongly related to binge eating tendencies (Gearhardt, Corbin, & Brownell, 2009) and is related to increased frequency of binge eating episodes in clinical populations (Gearhardt, White, Masheb, & Grilo, 2013; Gearhardt, White, Masheb, Morgan, Crosby, & Grilo, 2012). Yet, it is currently unclear whether the YFAS assesses an addictive response to certain foods or solely disinhibited eating caused by other mechanisms. Elevated craving is also a core feature of addiction (Sayette, Martin, Wertz, Shiffman, & Perrott, 2001); thus, "food addiction" would theoretically be related to greater food cravings. The literature on this topic is limited, but self-identified chocolate "addicts" have been found to report higher overall levels of chocolate craving (Macdiarmid & Hetherington, 1995) and greater cravings in response to external chocolate cues relative to participants who did not report feeling addicted to chocolate (Tuomisto, Hetherington, Morris, Tuomisto, Turjanmaa, & Lappalainen, 1999). Similarly, participants with higher scores on the YFAS (Gearhardt et al., 2009) indicated higher levels of trait food craving (Meule & Kübler, 2012).

General tendencies to experience food cravings have been associated with higher body mass index (BMI) (Franken & Muris, 2005), and more frequent craving for processed high-fat foods is associated with obesity (White et al., 2002). Higher BMI has also been related to more consistent (but not more frequent) craving for certain high-fat food types (e.g., chips, seafood, pork/ham/ bacon and Mexican food) (Rodin et al., 1991). Moreover, carbohydrate and sweets cravings are frequently reported triggers for eating in overweight relative to lean women (Björvell, Roennberg, & Roessner, 1985) and binges for obese women (Greeno et al., 2000).

An area of limited research is the role of state hunger on food cravings. Prior research has found that elevated craving is related to higher scores on trait-based susceptibility to hunger (Hill et al., 1991), but little research has explored how fluctuations in state-based hunger levels are related to craving response.

Food liking

Food liking has been defined as the "qualitative, affective (hedonic) evaluation of food; the degree of experience of pleasure or displeasure" (Mela, 2001), and increased food liking correlates with increased consumption (Drewnowski & Hann, 1999). Sugar and fat have been identified as important contributors to food palatability (Cordain et al., 2005), and participants generally report more liking of high-fat sweet and savory items relative to low-fat versions (Finlayson et al., 2007). The role of processing in food liking has received little systematic attention, although highly liked foods are often processed (e.g., chocolate, fries) (Finlayson et al., 2007).

Restrained eating may also be related to food liking. Fedoroff, Polivy, and Herman (1997) found that liking ratings for a number of palatable foods did not differ between restrained and unrestrained eaters at baseline, but exposure to food cues resulted in elevated liking ratings for restrained eaters. In contrast, restrained eaters did not exhibit stronger liking for high-fat foods than unrestrained eaters on tasks that indirectly measured food liking (Roefs, Herman, MacLeod, Smulders, & Jansen, 2005). Greater disinhibited eating in dieters is associated with higher liking ratings for sweets, pastries served with coffee, fruit-based sweet foods, butter and margarine (Lähteenmäki & Tuorila, 1995). The association of disinhibited eating related to addictive-like eating behavior and food liking has not been previously examined.

The association of food liking and elevated BMI is currently a topic of debate. Some studies have found that obese compared with lean participants indicate greater preferences for high-fat versus low-fat foods (Laurent-Jaccard, De Matteis, Hofstetter, & Schutz, 1994). Higher body fat in lean subjects was also related to increased preferences for fat (Mela & Sacchetti, 1991). Furthermore, obese individuals with a history of weight cycling relative to weight-stable obese participants reported higher preferences for dairy solutions with higher fat/sugar content (Drewnowski & Holden-Wiltse, 1992), and obese participants frequently identified high carbohydrate/ fat, high-fat sweets, and meats as their favorite foods (Drewnowski et al., 1992). Other research has found that obese compared with lean participants indicate lower food liking for salty and sweet foods (the role of fat was not examined) (Cox, Galen, Hedderley, Perry, Moore, & Mela, 1998). Thus, the current literature on food liking and body weight is not entirely consistent.

A limited number of studies have examined the separate contribution of fat and sugar to food liking in overweight/obese participants. Drewnowski, Brunzell, Sande, Iverius, and Greenwood (1985) found that obese relative to normal-weight individuals preferred the taste of sugar/fat mixtures that were relatively low in sugar, but high in fat. In contrast, other research suggests that young overweight participants' liking rates were only associated with increased sugar content (but not fat levels) (Warwick & Schiffman, 1990). Overall, it appears that fat and sugar are related to food liking in obesity, but the direction of the relationship is unclear and the association of food processing with liking in obesity has received little attention.

Elevated state-based hunger has been associated with increased pleasantness ratings of food pictures (Stoeckel, Cox, Cook III, & Weller, 2007). Further, increased hunger is associated with preferences for foods with higher fat content (Finlayson et al., 2007) and higher pleasantness ratings for sweet beverages (Laeng, Berridge, & Butter, 1993).

In sum, food craving and liking are potentially important factors in eating behavior. The relevant nutritional attributes of commonly craved foods are not entirely clear, but sugar and fat have been identified as important components. Food liking also appears related to sugar and fat levels. The relationship between restrained eating and craving and liking is relatively mixed, but disinhibited-type eating appears to be more consistently associated with increased

craving and liking for food. Little research exists on the association of addictive-like eating with liking and craving, although it may be associated with increased craving. Elevated food cravings have been linked to higher BMI, but the association between body weight and food liking is less clear. Finally, hunger may increase food craving and liking.

Some of the inconsistencies in the craving and liking literature may be due to methodological considerations. Previous studies on craving and liking have often focused on a limited number of food products, relied on participants' recall or used food stimuli that do not vary along multiple dimensions theoretically linked to overconsumption (e.g., sugar, fat) (Christensen & Pettijohn, 2001; Rodin et al., 1991; Weingarten & Elston, 1991; Zellner et al., 1999). Processed foods often contain higher levels of fat/sugar and less protein and fiber than naturally occurring foods, which may increase the hedonic impact of processed foods (Gearhardt, Davis, Kuschner, & Brownell, 2011; Monteiro, Levy, Claro, de Castro, & Cannon, 2011). No prior studies have examined how craving and liking ratings may differ based on whether sugar and fat were naturally occurring (e.g. sugar in a banana, fat in nuts) relative to added during processing (e.g. sugar in candy, fat in pizza). Individual differences in eating behavior are often associated with a number of potentially co-occurring factors (e.g., obesity, hunger), but prior studies have typically examined only one predictor at a time. Little research has examined how individual differences may impact the relationship between food characteristics and craving and liking. For example, it is possible that high-sugar content may typically be associated with food liking, but may be less related to liking for individuals who are trying to avoid high-calorie foods.

The current study was designed to address some of the existing limitations in the food craving and liking literature. Food craving and liking ratings were gathered for 180 food pictures that differed in levels of sugar, fat and processing. This approach allows for the examination of the nomothetic impact of these food characteristics on ratings of craving and liking. For example, one can measure the degree to which variations in fat, sugar, or processing are related to craving. Additionally, the association of idiographic factors (i.e., attempted dietary restraint, addictive-like eating, BMI, hunger) with patterns of sugar-, fat-, and processing-based craving and liking will be examined.

Materials and methods

Participants

One hundred and five overweight and obese women between the ages of 18 and 50 years were recruited from the community. The mean age of participants was 31.27 (SD = 9.70) and 42.0% of participants identified themselves as Caucasian, 33.0% as African-American, and 13.0% as multiracial. The mean BMI of participants was 35.07 (SD = 8.05, range 25.37–72.62), which resulted in 28.0% of participants falling in the overweight category (BMI between 25.0 and 29.9), 48.0% in the obese category (BMI between 30 and 34.9), and 24% in the severely obese category (BMI $\geq$ 35). Sixteen participants had incomplete data on study measures, which resulted in a final sample size of 89 participants. Participants with missing data did not differ from participants with complete data in age, race/ethnicity, educational status or BMI ($p > .20$).

Procedures

Participants were instructed to eat as they normally do prior to coming to the study. The study was conducted between 9 am and 6 pm. During the course of the 2-hour study, the participants completed tasks in the following order: a self-report measure of current hunger; a food-related visual-search task[2]; craving and liking ratings for all foods; self-report measures associated with eating pathology and behaviors; and assessments of height and weight.

Stimulus set

Food stimulus set

The 180 food photos used in the current study varied along three dimensions of interest: fat (M = 12.39 g, SD = 16.03, range 0–54), sugar (M = 17.16 g, SD = 23.46, range 0–120) and processing (half of the foods were processed). Sample foods included ice cream (high in fat, sugar, and processing), a hamburger (high in fat and processing, lower in sugar), a banana (higher in sugar, low in fat and processing), and steamed vegetables (low in fat, sugar, and processing). Inter-dimensional associations were minimized during stimulus selection, and the association between fat/sugar content and processing ranged from –.111 (fat and sugar) to .336 (sugar and processing). All food pictures were gathered from stock picture websites, digitally available sources of food pictures or were photographed by the researchers for this study. All pictures were presented using E-Prime 2.0 software (Psychology Software Tools, 2002) in color and were edited to remove any nonfood objects. The food pictures were centered in a white background and then resized to a 5.5 × 5.5 cm^2. Nutrition information was gathered from either 1) www.nutritiondata.com, 2) food packaging or food company websites or 3) the website for a food company that manufactures a similar food product. Two of the 180 foods were removed from analyses due to outlying nutritional characteristics.

Craving and liking rating task

Participants were asked to rate their level of craving and liking for each of 180 foods. Regarding craving, each participant was provided the following instruction for each food, "Now you will be rating how much you crave each of the specific foods right now, on the scale below. Craving refers to how intensely you desire or want the pictured food. How strongly do you crave (desire or want) the pictured food right now?" Participants' current craving for the food was assessed on a seven-point Likert scale that ranged from "not at all" to "extremely." Regarding liking, each participant was provided the following instruction for each food, "Now you will be rating how much you like or enjoy eating each of the specific foods. How much do you like or enjoy eating the pictured food?" Liking was measured on a seven-point Likert scale that ranged from "strongly dislike" to "strongly like." The order of craving and liking ratings and the order of the foods presented were randomized across participants.

Measures

Eating Disorders Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994)

The EDE-Q is a well-established measure of eating disorder psychopathology that provides four subscales (Restraint, Eating Concern, Weight Concern, Shape Concern) (Fairburn & Beglin, 1994; Luce & Crowther, 1999). The restraint subscale was used in the subsequent analyses and it reflects attempts to restrict eating behavior and food consumption, but does not specify whether the attempts were successful or unsuccessful. The average attempted restraint rating was 3.12 on a 6-point scale (SD = 1.67).

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[2] Results of the visual-search task are published elsewhere – see Gearhardt, Treat, Hollingworth, and Corbin, 2012.

Yale Food Addiction Scale (YFAS) (Gearhardt et al., 2009)

The YFAS is a 25-item measure of addictive eating behavior based on the DSM-IV-TR criteria for substance dependence. The YFAS symptom count score indicates the number of eating-related addiction symptoms experienced during the past 12 months. The YFAS appears to have adequate internal reliability, convergent validity and incremental validity (Gearhardt et al., 2009, 2012). The mean number of symptoms endorsed was 3.06 (SD = 2.13).

Body Mass Index (BMI)

After removal of shoes and coats, height and weight were measured to the nearest millimeter and .1 kg, respectively, and BMI was calculated.

Hunger rating

Participants rated their present level of hunger on a 100-mm visual analog scale that ranged from "not at all hungry" to "extremely hungry." The average hunger rating was 33.02 (SD = 25.90).

Personal information questionnaire

This self-report measure assesses demographic data including age, education, and race/ethnicity.

Results

Food craving

Hierarchical linear modeling (Raudenbush & Bryk, 2002) with robust standard errors was used to analyze women's craving of foods. A two-level regression analysis was conducted, consisting of participants' craving ratings of 180 foods at level one, which were nested within 89 participants at level two. This analytic approach allowed us to evaluate separately but simultaneously (a) the normative or nomothetic influences of food-specific characteristics on participants' ratings of food craving (at level one); and (b) the idiographic influences of participant-specific characteristics on participants' utilization of the food-specific characteristics when judging craving (at level two).

The level-one equation below specified three main effects on each participant's food craving ratings: level of processing (dummy-coded), fat (centered), and sugar (centered). Therefore, the intercept for the level-one equation (β_0) reflects the model-predicted craving rating for a food with low processing and average fat and sugar content. The three partial slopes in the level-one equation (β_1, β_2, and β_3) indexed the impact of the three food characteristics when rating craving. For example, a value of .12 for β_1 would indicate that craving increases .12 points for processed, relative to unprocessed foods with average fat and sugar content.

Level-One Equation for Food-Specific Predictors of Perceived Food Craving:

$$\text{Craving Rating} = \beta_0 + \beta_1(\text{Processing}) + \beta_2(\text{Fat}) + \beta_3(\text{Sugar}) + r$$

Chi-square tests revealed significant variation across participants in the intercept and the three utilization parameters at level one, $\chi^2(84) = 3731.49, 1401.59, 471.01,$ and 492.64, respectively, all ps < .001. In other words, significant individual differences emerged for craving of the average low-processed food, as well as for processing-, fat-, and sugar-linked cravings. Therefore, all four parameters were treated as random in the level-two equations below.

The level-two equations examined the participant-specific predictors of variability in the four random level-one parameters. Four participant-specific predictors were evaluated: EDE-Q Restraint (centered), YFAS (centered), BMI (centered), and Hunger (centered). The associations between the participant-specific predictors ranged from .045 (Hunger and BMI) to .183 (Symptom Count and BMI), indicat-

ing that multicollinearity was not of concern. The intercept in each level-two equation indicated the average value of the relevant level-one parameter, assuming mean values for all level-two predictors. For example, γ_{20} indexed the average impact of fat content on craving ratings for a participant with average EDE-Q Restraint, BMI, YFAS, and Hunger scores. The partial slopes in the level-two equations for the utilization parameters indicated the change in the effect of processing, fat, or sugar on craving associated with a one-unit increase in the relevant level-two predictor. The regression coefficient for the BMI effect on the association of fat content with craving (γ_{22}), for example, indicated the model-predicted change in the impact of fat associated with a one-unit increase in BMI, controlling for other participant characteristics.

Level-Two Equations for Participant-Specific Predictors of Level-One Parameters

$$\beta_0 = \gamma_{00} + \gamma_{01}(\text{EDE-Q Restraint}) + \gamma_{02}(\text{BMI}) + \gamma_{03}(\text{YFAS}) + \gamma_{04}(\text{Hunger}) + u_0$$

$$\beta_1 = \gamma_{10} + \gamma_{11}(\text{EDE-Q Restraint}) + \gamma_{12}(\text{BMI}) + \gamma_{13}(\text{YFAS}) + \gamma_{14}(\text{Hunger}) + u_1$$

$$\beta_2 = \gamma_{20} + \gamma_{21}(\text{EDE-Q Restraint}) + \gamma_{22}(\text{BMI}) + \gamma_{23}(\text{YFAS}) + \gamma_{24}(\text{Hunger}) + u_2$$

$$\beta_3 = \gamma_{30} + \gamma_{31}(\text{EDE-Q Restraint}) + \gamma_{32}(\text{BMI}) + \gamma_{33}(\text{YFAS}) + \gamma_{34}(\text{Hunger}) + u_3$$

Table 1 presents the results of the modeling, organized by the four level-one parameters (i.e., the intercept and the three main-effect utilization coefficients; β_0 through β_3). Effect sizes were computed using recommended procedures (Oishi, Ishii, & Lun, 2009). The average craving rating, γ_{00}, was 2.97; the average participant reported craving the average, low-processed food near the middle of the seven-point Likert rating scale.

Examination of the intercepts for the three utilization parameters suggested significant normative effects of some food-specific characteristics (i.e., fat and sugar content) on the average participant's food cravings. The average utilization of fat, γ_{20}, was .006 (d = .582), indicating that participants' craving increased by .006 with every one-gram increase in fat. The magnitude of this effect indicated that participants showed a moderate degree of fat-based cravings, such that higher-fat foods were craved moderately more than lower-fat foods. Participants relied to a similar, but negative, degree on sugar when rating food cravings ($\gamma_{30} = -.005$, d = -.652), making moderately stronger craving ratings for lower-sugar foods, relative to higher-sugar foods. On average, participants did not display processing-linked cravings (d = -.128).

Several significant participant-specific predictors of variability in the four level-one parameters emerged. YFAS symptomatology was a moderate-to-large positive predictor of cravings for the average low-processed food ($\gamma_{03} = .130$, d = .623); those who reported more YFAS symptoms craved foods more than their peers. Hunger emerged as a large, positive predictor of average food cravings ($\gamma_{04} = .006$ d = .582), indicating that food cravings increased as hunger increased.

YFAS symptomatology emerged as a moderate-to-large positive predictor of reliance on food processing when judging craving (d = .537), revealing that those with greater YFAS symptoms showed stronger processing-linked cravings than their less symptomatic peers. Similarly, YFAS symptomatology was a positive, moderate-magnitude, trend-level predictor of fat-based cravings (d = .415), whereby those who endorsed greater YFAS symptoms craved higher-fat foods more than lower-fat foods, in comparison with those who endorsed fewer YFAS symptoms. Finally, BMI emerged as a negative, moderate-magnitude predictor of craving for higher-fat versus

Table 1
Multilevel modeling results for craving rating task.

Parameter	Estimate	Standard error	t value	df	p value	d value
For intercept, β_0						
Intercept, γ_{00}	2.974	.097	30.713	84	<.001	6.702
EDE-Q Res, γ_{01}	−.069	.071	−.974	84	.333	−.213
BMI, γ_{02}	−.631	.488	−1.294	84	.199	−.282
YFAS, γ_{03}	.130	.046	2.856	84	.005	.623
Hunger, γ_{04}	.018	.004	4.295	84	<.001	.937
For processing slope, β_1						
Intercept, γ_{10}	−.034	.059	−.588	84	.558	−.128
EDE-Q Res, γ_{11}	−.029	.041	−.721	84	.473	−.157
BMI, γ_{12}	.030	.292	.104	84	.918	.023
YFAS, γ_{13}	.087	.033	2.628	84	.010	.573
Hunger, γ_{14}	.000	.002	.053	84	.958	.012
For fat slope, β_2						
Intercept, γ_{20}	.006	.002	2.665	84	.009	.582
EDE-Q Res, γ_{21}	−.001	.001	−1.141	84	.257	−.249
BMI, γ_{22}	−.018	.008	−2.316	84	.023	−.505
YFAS, γ_{23}	.002	.001	1.903	84	.060	.415
Hunger, γ_{24}	.000	.000	.808	84	.421	.176
For sugar slope, β_3						
Intercept, γ_{30}	−.005	.002	−2.990	84	.004	−.652
EDE-Q Res, γ_{31}	.001	.001	1.419	84	.160	.310
BMI, γ_{32}	−.000	.007	−.013	84	.989	−.003
YFAS, γ_{33}	−.000	.001	−.574	84	.567	−.125
Hunger, γ_{34}	−.000	.000	−1.616	84	.110	−.353

EDE-Q Res, Eating Disorders Examination-Questionnaire Restraint Subscale; BMI, Body Mass Index; YFAS, Yale Food Addiction Scale.

lower-fat foods (d = −.505). Thus, as BMI increased, the level of fat-based cravings decreased.

Food liking

Hierarchical linear modeling (Raudenbush & Bryk, 2002) with robust standard errors was also used to analyze participants' liking ratings of foods. Equations at levels one and two were analogous to those for the craving data, with the exception of the change in the criterion variable at level one. Chi-square tests revealed significant variation across participants in the intercept and the three utilization parameters at level one, $\chi^2(84) = 2041.01$, 1118.50, 413.64,

and 361.19, respectively, all $ps < .001$. Therefore, participant-specific predictors of these four random effects were examined.

Table 2 presents the results of the modeling. The average low-processed food received an average liking rating of 4.659 (γ_{00}). Examination of the intercepts for the utilization parameters suggested significant nomothetic effects of food-specific characteristics (i.e., processing and sugar content) on the average participant's liking ratings. The average impact of processing, γ_{10}, was −.167 (d = −.713), indicating that participants' liking ratings declined to a moderate-to-large degree for processed foods, relative to nonprocessed foods. Sugar content was also related to participants' reported food liking (d = −1.193), showing markedly stronger liking ratings for low-

Table 2
Multilevel modeling results for liking rating task.

Parameter	Estimate	Standard error	t value	df	p value	d value
For intercept, β_0						
Intercept, γ_{00}	4.659	.084	55.273	84	<.001	12.062
EDE-Q Res, γ_{01}	.024	.060	.407	84	.685	.089
BMI, γ_{02}	−.805	.387	−2.080	84	.041	−.454
YFAS, γ_{03}	.095	.040	2.340	84	.022	.510
Hunger, γ_{04}	.003	.003	.742	84	.460	.162
For processing slope, β_1						
Intercept, γ_{10}	−.167	.051	−3.268	84	.002	−.713
EDE-Q Res, γ_{11}	−.039	.037	−1.047	84	.298	−.228
BMI, γ_{12}	−.028	.281	−.099	84	.921	−.022
YFAS, γ_{13}	.071	.027	2.642	84	.010	.577
Hunger, γ_{14}	.002	.002	1.176	84	.243	.257
For fat slope, β_2						
Intercept, γ_{20}	.001	.002	.399	84	.691	.087
EDE-Q Res, γ_{21}	−.001	.001	−1.035	84	.304	−.226
BMI, γ_{22}	−.013	.008	−1.693	84	.094	−.369
YFAS, γ_{23}	.002	.001	2.095	84	.039	.457
Hunger, γ_{24}	−.000	.000	−.224	84	.823	−.049
For sugar slope, β_3						
Intercept, γ_{30}	−.008	.001	−5.467	84	<.001	−1.193
EDE-Q Res, γ_{31}	.001	.001	.708	84	.481	.154
BMI, γ_{32}	.003	.006	.605	84	.547	.132
YFAS, γ_{33}	−.000	.000	−.138	84	.891	−.030
Hunger, γ_{34}	−.000	.000	−1.125	84	.264	−.246

EDE-Q Res, Eating Disorders Examination-Questionnaire Restraint Subscale; BMI, Body Mass Index; YFAS, Yale Food Addiction Scale.

sugar foods, relative to high-sugar foods. On average, participants did not significantly differ in their liking of higher-fat versus lower-fat foods (d = .087).

Several significant participant-specific predictors of variability in the level-one random parameters emerged. YFAS symptomatology was a moderate positive predictor of liking for the average low-processed food (γ_{03} = .095, d = .510); those who reported more YFAS symptoms liked foods more than their peers. BMI emerged as a moderate, negative predictor of average food liking (γ_{02} = −.805, d = −.454), indicating that food liking decreased as BMI increased.

On average, YFAS symptomatology emerged as a moderate, positive predictor of liking for processed, relative to nonprocessed, foods (d = .577). Moreover, YFAS symptomatology emerged as a moderate-magnitude, positive predictor of liking for foods with higher, rather than lower, fat content (d = .457). In contrast, BMI was a trend-level negative predictor for fat-based liking at a moderate level (d = −.369). This suggests that participants with higher BMIs may like higher-fat foods less than lower-fat foods.

Discussion

In a sample of overweight/obese women, we examined the nomothetic impact of certain characteristics of a large food set of 180 foods (i.e., sugar, fat, processing) on craving and liking, as well as idiographic predictors (i.e., attempted dietary restraint, addictive-like eating, BMI, hunger) of the association of these food characteristics with food craving and liking.

Nomothetic associations between food characteristics and craving and liking

Regarding food-specific attributes, higher levels of fat were moderately related to greater craving. These findings are consistent with prior research that identified high-fat foods as frequently craved (Drewnowski et al., 1992; Pelchat, 1997). In contrast, as sugar levels increased, participants reported moderately decreased craving, and the degree of food processing was not significantly related to food craving[3]. These results appear inconsistent with previous research that identified carbohydrates (such as sugar) as the major contributor to food craving (Wurtman & Wurtman, 1995). Yet, Drewnowski et al. (1992) identified that foods linked with "carb craving" were frequently high in fat (as well as carbohydrates). Thus, the current findings appear to support Drewnowski's (1992) proposal that the fat level may have a stronger association with food craving than certain types of carbohydrates (i.e., sugar) or processing. These findings also highlight the importance of relying on large sets of food that vary reasonably independently on relevant dimensions (i.e., sugar, fat, processing) when evaluating how separate food characteristics are related to food craving and liking.

In contrast to craving, fat levels on average were not related to food liking. Lower liking ratings were associated with greater food processing and higher sugar levels. Given that elevated sugar and fat levels are commonly implicated in greater palatability (Cordain et al., 2005) and food processing is often employed to increase the hedonic response, this pattern of results is surprising. The negative associations of liking with sugar/processing and lack of relationship with fat could potentially be related to all of the participants being overweight/obese females. This population may have conflicting goals regarding processed foods that are high in sugar (e.g., candy, sugar-sweetened cereals), as these foods may be palatable, but may also be linked with weight gain. Thus, sugary/processed

foods may be rated as less liked, whereas less processed, lower sugar foods with variable levels of naturally occurring fat (e.g., nuts, meats, fruits) may be seen as contributing less to weight gain (and be rated more positively). Future research on the association between perceived healthiness and food liking, as well as comparisons between lean and obese samples, will be important in understanding how liking varies as a function of nutritional characteristics.

Idiographic predictors of associations between food characteristics and craving and liking

Restrained and addictive-like eating

Attempted dietary restraint was not associated with food craving or liking. This may reflect differences in successful versus unsuccessful restraint, as the EDE-Q restraint subscale assesses attempts at restricting food intake regardless of whether the attempts were successful or unsuccessful. Although previous research has suggested that successful restriction (associated with disorders like AN) is related to reduced food craving and liking (Drewnowski, Halmi, Pierce, Gibbs, & Smith, 1987; Gendall, Sullivan, Joyce, & Bulik, 1997; Sunday & Halmi, 1990), the participants in the current study were all overweight/obese. Thus, it may be more likely that they were unsuccessfully restricting their food intake, which might be less related to differences in craving and liking. It will be important for future research to examine the impact of success on the association of restraint with food craving and liking.

In contrast, disinhibited eating (as measured by the YFAS) was associated with increased craving and liking for the average food and more processed foods, as well as elevated liking and trend-level craving for high-fat food. Thus, in a sample of overweight/obese women, addictive-like eating appears to be a robust predictor of food craving and liking, whereas attempts to restrict eating appear to be unrelated. The ability to detect differential associations of restrained and disinhibited eating indicated by the YFAS with food craving and liking highlights the importance of examining multiple idiographic predictors in the same model of eating behaviors. However, it is important to note that it is still unclear whether the YFAS truly captures an addictive-like response to food or is solely capturing disinhibited eating resulting from a different mechanism. The YFAS is strongly associated with general measures of disinhibition (Gearhardt et al., 2009) and in the current study was highly correlated with the Binge Eating Scale (Gormally, Black, Daston, & Rardin, 1982) (r = .751), which is a general measure of binge eating. Yet, many of the constructs tested here are relevant to the hypothesis that addictive-like processes may be contributing to some types of disinhibited eating. For example, the high-fat processed foods that were more craved/liked by participants endorsing more addictive-like eating (e.g., pizza, French fries) are commonly consumed foods in binge eating episodes (Yanovski et al., 1992), and consumption of these food types are associated with addiction-like neurobiological changes in some animal models (Johnson & Kenny, 2010; Tellez et al., 2013). Given the proposed importance of craving in addictive behaviors, the association between addictive-like eating and elevated craving is consistent with theories of "food addiction."

Other aspects of an addiction model were not supported. Sugar has been strongly implicated in theories of "food addiction" (Avena et al., 2008), but addictive-like eating in the current study was not associated with sugar-linked craving and liking. Additionally, the incentive sensitization model of addiction suggests that wanting (e.g., cravings) and liking become uncoupled as compulsive consumption develops, with wanting (but not liking) becoming a strong predictor of problematic intake (Robinson & Berridge, 2001). In the current study, participants reporting more addictive-like eating exhibited similar-magnitude increases in average, fat-based, and processing-based craving and liking. Thus, they did not exhibit the predicted pattern of disassociation between wanting and liking.

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[3] To ensure that associations between food characteristics were not accounting for these results, the analyses were also run with each food characteristic separately (e.g., sugar only). The pattern of results remained the same.

Further research is needed to evaluate whether mechanisms implicated in addiction contribute to food craving and liking. Regardless, the current study clearly demonstrates that individuals who report struggling with a loss of control over their eating show elevated craving and liking for foods in general, as well as for high-fat and processed foods.

BMI

Prior research has inconsistently linked obesity with more frequent craving for high-fat foods (Rodin et al., 1991; White et al., 2002), but the current study suggests that the magnitude of craving for fattier foods is lower for overweight/obese women with the highest BMIs. Higher BMI was also associated with reduced liking for the average food and trend-level lower liking ratings for fattier foods. The current study includes only overweight/obese women, thus the variability in BMI is restricted relative to prior work. Future studies comparing the level of fat craving and food liking for lean relative to overweight/obese women will be important to understand this effect across a range of weight classes.

Hunger

Increased state hunger was associated with increased craving for the average food, but was not associated with elevated craving for any specific food type or food liking. This global finding is consistent with the proposal that hunger increases motivation to seek out food (Berridge et al., 2010), but may not alter evaluations of palatability or increase desire for certain food characteristics.

Implications

The current study has implications for interventions directed at improving health. On average, craving for high-fat foods is elevated in a sample of overweight/obese women. Thus, interventions designed to help individuals adhere to healthier dietary choices may benefit from increased focus on dealing with craving for high-fat foods.

In overweight/obese women, disinhibited (rather than restrained) eating associated with the YFAS appears to be far more related to increased craving and liking. Thus, addressing food craving and liking may be important in interventions designed to reduce loss of control over eating. For example, cognitive-behavioral techniques that focus on the long-term rewards for adhering to healthier choices (e.g., greater longevity) versus the short-term reward of consuming the food (e.g., pleasant taste) have been linked to increased activation of brain regions associated with self-control and decreased activation of regions associated with craving (Kober, Kross, Mischel, Hart, & Ochsner, 2010). Additionally, the treatment of disinhibited eating may reduce food craving and liking, which may increase success in attempts to eat healthier foods. Elevated hunger also is associated with elevated food cravings. Strategies to lose weight that result in increased hunger (such as fasting and extreme calorie restriction) may fail due to increased cravings. Thus, attempts to improve dietary intake that focus on more consistent patterns of eating throughout the day may be more successful.

There are also limitations to consider when interpreting the current pattern of results. First, the current study examined the association between fat/sugar/processing with craving and liking in a large and diverse set of food. There are a number of additional food characteristics that are important for future studies to explore, such as sodium, other types of carbohydrates, and fiber. Second, the inclusion of only overweight/obese women provided an opportunity to examine craving and liking in a sample at risk for eating-related problems, but did not provide the opportunity to examine these constructs in men or lean participants. The inclusion of participants with these characteristics will be important in future studies. Third, there are a number of ways to operationalize food craving and liking (as well as wanting), including behavioral performance (e.g., relative reinforcement value paradigms), taste tests, and neural response. The inclusion of multi-method approaches in future research designed to examine these constructs will be important. Fourth, successful relative to unsuccessful restraint was not assessed in the current study. Future studies will benefit from examining how different types of dietary restraint may be differentially related to food craving and liking.

Conclusions

Despite these limitations, the current study significantly extends the previous craving and liking literature. The inclusion of foods that vary along multiple theoretically meaningful dimensions (i.e., fat, sugar, processing) and eating-related idiographic characteristics that often co-occur (e.g., obesity, disordered eating) provides an opportunity to examine how each of these characteristics is related to craving and liking in the context of other relevant predictors. The current study particularly highlights the role of fat in food cravings, as well as differences in craving and liking based on BMI, addictive-like eating, and hunger. These findings may inform the development of interventions designed to improve diet quality and aid in weight loss.

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