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Wanting and liking: Separable components in problematic eating behavior?

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ABSTRACT

Some individuals may have an addictive-like response to certain foods, possibly contributing to problematic eating. Highly processed foods, with added fats and/or refined carbohydrates, are suggested to be most associated with addictive-like eating. The incentive sensitization theory suggests that wanting (e.g. craving) may drive compulsive drug use rather than liking (e.g. enjoyment), but it is unknown whether highly processed foods elicit similar wanting and liking patterns as drugs of abuse, or whether individual differences exist. The current study examines the association of highly processed foods with craving and liking, and whether these relationships differ by food addiction symptomology, cognitive restraint, or body mass index (BMI). Participants ($n = 216$) reported craving and liking for 35 foods and completed the *Yale Food Addiction Scale* (*YFAS*) and *Three Factor Eating Questionnaire* (*TFEQ*). Highly processed foods were craved more overall. Craving of highly processed foods was predicted negatively by restraint and positively by *YFAS* score. Liking of highly processed foods was predicted negatively by restraint and positively by BMI. In conclusion, craving and liking appear distinct with respect to highly processed foods, and may be influenced by addictive-like eating, cognitive restraint, and BMI. This suggests that the incentive sensitization framework may also be relevant for problematic food consumption, especially for individuals reporting food addiction symptoms.

1. Introduction

The prevalence of obesity and eating-related problems worldwide is a matter of scientific and public interest. In the past 30 years, global overweight and obesity rates have risen by 27.5% for adults and 47.1% for children, and the number of overweight and obese individuals is now over 2 billion (The GBD 2013 Obesity Collaboration, 2014). Overweight and obesity are estimated to be a greater health burden than smoking and problem drinking (Jia & Lubetkin, 2010; Sturm, 2002), and are associated with many preventable chronic diseases, such as cardiovascular disease, high blood pressure, type-2 diabetes, and some cancers. In addition to the current threat, the rates of overweight and obesity are rising; in the past 40 years, the increase in mean BMI has accelerated, and global prevalence is now twice as high as in 1980 (Malik, Willett, & Hu, 2013; Stevens et al., 2012). In the United States, the country with the highest rates of overweight and obesity, it is estimated that by 2030, 65 million more adults will become obese (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011). These trends have facilitated the need for more in-depth research on obesity, particularly on potential mechanisms of overeating.

1.1. Evidence for "food addiction"

There is growing evidence that certain foods, particularly highly processed foods (i.e. foods high in added refined carbohydrates and/or fat), may trigger biological and behavioral mechanisms in a manner akin to drugs of abuse. In animal studies, it has been shown that rats undergo neurobiological changes in the reward system, such as the down-regulation of dopamine receptors, in response to intermittent sugar binges or heightened consumption of high-sugar, high-fat foods (Avena, Bocarsly, Rada, Kim, & Hoebel, 2008; Avena, Rada, & Hoebel, 2009; Johnson & Kenny, 2010). Further, rats demonstrate elevated motivation to seek out these high-fat, high-sugar foods and experience symptoms of withdrawal (e.g. teeth chattering) when sugar is removed from the diet (Avena, Long, & Hoebel, 2005; Colantuoni et al., 2002, 2001; Lenoir, Serre, Cantin, & Ahmed, 2007).

In humans, the *Yale Food Addiction Scale* (*YFAS*; Gearhardt,

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Corbin, & Brownell, 2009; Gearhardt, Corbin, & Brownell, 2016) is currently the only validated tool to operationalize behavioral indicators of addictive-like eating. The measure applies the diagnostic criteria for substance-related and addictive disorders (American Psychiatric Association, 2000; American Psychiatric Association, 2013) to the consumption of highly palatable foods, such as losing control over consumption, or continued use despite negative consequences. Individuals who endorse many behavioral indicators of addictive-like eating on the *YFAS* show similar biological (Davis et al., 2013; Gearhardt et al., 2011) and behavioral characteristics (Gearhardt, White, Masheb, & Grilo, 2013; Gearhardt et al., 2012, 2011; Meule, Lutz, Vogele, & Kübler, 2012; Murphy, Stojcek, & MacKillop, 2014; Pivarunas & Conner, 2015) as individuals with substance-use disorders, for example elevated impulsivity, reward dysfunction, and emotion dysregulation. Individuals with high *YFAS* scores are more likely to have increased body mass index (BMI), more frequent food binges, and stronger cravings for certain foods (Pursey, Stanwell, Gearhardt, Collins, & Burrows, 2014).

In particular, highly processed foods with added fat and refined carbohydrates, such as pizza, chocolate, cake, and cookies, have been shown to be more associated with problematic, addictive-like eating than foods in their natural form, such as nuts, fruit, and vegetables (Curtis & Davis, 2014; Schulte, Avena, & Gearhardt, 2015). Highly processed foods are also more frequently consumed among individuals reporting *YFAS* indicators of food addiction (Pursey, Collins, Stanwell, & Burrows, 2015). Additionally, strong cravings (Gilhooly et al., 2007; Ifland et al., 2009; Weingarten & Elston, 1991; White & Grilo, 2005), stress-triggered consumption (Epel, Lapidus, McEwen, & Brownell, 2001; Oliver & Wardle, 1999; Oliver, Wardle, & Gibson, 2000; Zellner et al., 2006), loss of control (Arnow, Kenardy, & Agras, 1992; Vanderlinden, Dalle Grave, Vandereycken, & Noorduin, 2001; Waters, Hill, & Waller, 1999), and binge eating (Rosen, Leitenberg, Fisher, & Khazam, 1986; Vanderlinden et al., 2001; Yanovski et al., 1992) are all more strongly associated with highly processed foods than less processed foods. Finally, neuroimaging studies suggest that cues for highly processed foods activate the reward-related systems in humans in a similar manner as cues for drugs of abuse (Tang, Fellows, Small, & Dagher, 2012; Volkow, Wang, Fowler, Tomasi, & Baler, 2011).

1.2. Craving and liking

Given that an addictive-like process may underlie problematic eating behavior for some individuals, mechanisms relevant to addictive disorders may also contribute to "food addiction." The incentive sensitization theory (Robinson & Berridge, 1993, 2000) is a preeminent framework in the field of addiction research, which posits that "wanting" (e.g. craving, desire, motivation) of the substance, more than "liking" (e.g. enjoyment, pleasure) the effects of the substance, indicator of compulsive and problematic substance use. In other words, in the context of addiction, liking may stay relatively stable, or even decrease, as wanting increases. Thus, it may be especially important to target the biological, behavioral, and psychological underpinnings of wanting, rather than liking, in addiction-focused prevention and intervention efforts. This framework is also applicable to food reward (Berridge, 1996, 2009), and indeed wanting and liking of sucrose have been separated in animal models using pharmaceutical manipulations and hyperdopaminergic knockout mice, resulting in increased wanting but stable or decreased liking (Berridge & Valenstein, 1991; Peciña, Cagniard, Berridge, Aldridge, & Zhuang, 2003; Smith & Berridge, 2005; Wyvell & Berridge, 2000). Wanting also appears to increase with prolonged sucrose consumption (Avena et al., 2005). While the role of incentive sensitization in humans is less clear, there is research supporting this framework for drug consumption (see review by Leyton, 2007), and the separation of wanting and liking in humans in response to food cues and consumption can be shown both in behavioral studies (Finlayson, King, & Blundell, 2007; Finlayson, King, & Blundell, 2008) and neuroimaging studies (Born et al., 2011; Jiang, Soussignan, Schall, & Royet, 2015).

In the context of food addiction, however, the partitioning of wanting and liking in humans has not been extensively investigated. There is evidence that food addiction is associated with elevated craving for food, which corresponds closely to wanting (Robinson & Berridge, 1993). For example, Meule and Kübler (2012) showed that higher scores on the *YFAS* do predict greater food cravings, but the authors did not distinguish between food types (i.e. high-sugar, high-fat). Similarly, Davis, Levitan, Kaplan, Kennedy, and Carter (2014) showed that a food addiction diagnosis by the *YFAS* predicted greater snack food craving, but this study used a limited range of foods (i.e. candy bars, cookies, potato chips). There is limited research on the association between both craving and liking of highly processed foods and the *YFAS*. Gearhardt, Rizk, and Treat (2014) examined how symptoms of addictive-like eating, as measured by the *YFAS*, may be associated with craving and liking of various foods. While this study was unable to decouple craving and liking, it did show that both were increased for highly processed foods, those which have been most implicated in addictive-like responses (Schulte et al., 2015). However, there were also some limitations to this research, such as the inclusion of only overweight/obese females, which may have constrained the ranges of craving and liking, as well as the range of *YFAS* scores (Gearhardt, Boswell, & White, 2014).

1.3. Cognitive restraint

Restraint may also be associated with differences in craving and liking for food. Although restraint is a key construct in the field of eating (Heatherton, Polivy, & Herman, 1990; Herman & Mack, 1975; Ruderman, 1986), it is still unclear exactly what measures of restraint are assessing. Restraint was originally conceptualized as a biological construct with restrained individuals simply eating less than an individual pre-determined set point (Nisbett, 1972), but measures of restraint have not been consistently associated with either BMI or overall caloric intake (Herman & Mack, 1975; Snoek, van Strien, Janssens, & Egnels, 2008; Stice, Fisher, & Lowe, 2004). More recently, restraint has been proposed to be a cognitive process that reflects a conscious desire to restrict actual food intake (Laessle, Tuschl, Kotthaus, & Prike, 1989). Despite this desire to limit consumption, restrained eaters are more prone to overeat following a stressor or a caloric pre-load, suggesting that cognitive restraint is associated with disinhibited eating (Fedoroff, Polivy, & Herman, 1997; Mills & Palandra, 2008; Ruderman, 1985; Wardle, Steptoe, Oliver, & Lipsey, 2000). However, it's unclear whether cognitive restraint precedes disinhibited eating (Herman & Polivy, 1990; Howard & Porzelius, 1999; Polivy & Herman, 1985), or if cognitive restraint develops as a compensatory mechanism following episodes of disinhibited eating (Grilo & Masheb, 2000; Hilbert et al., 2014; Reas & Grilo, 2007; Spurrell, Wilfley, Tanofsky, & Brownell, 1997). Although understanding the casual role of cognitive restraint in eating problems calls for more longitudinal research, another approach to investigating cognitive restraint is to evaluate whether it shows similar or distinct associations with craving and liking for foods, relative to other eating-related constructs (e.g. food addiction, BMI). To date, there is mixed evidence regarding associations between craving and liking and cognitive restraint. Some studies have found positive associations between craving and cognitive restraint (Fedoroff, Polivy, & Herman, 2003; Hill, Weaver, & Blundell, 1991; Massey & Hill,

2012; Polivy, Coleman, & Herman, 2005), while others have found no associations (Gearhardt, Rizk et al., 2014; Hill et al., 1991; Jáuregui-Lobera, Bolaños-Ríos, Valero, & Ruiz Prieto, 2012; Rodin, Mancuso, Granger, & Nelbach, 1991; Weingarten & Elston, 1991). Regarding liking, positive associations (Fedoroff et al., 1997), negative associations (Keskitalo et al., 2008), and no associations with cognitive restraint (Lemmens et al., 2010; Lähteenmäki & Tuorila, 1995) have been found. Thus, the association of cognitive restraint with craving and liking is not fully understood.

1.4. Body Mass Index

Elevated BMI may also be associated with differences in craving and liking. Some studies have found that higher BMI is positively associated craving, particular for high-fat foods (Franken & Muris, 2005; Rissanen et al., 2002; Rodin et al., 1991; White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002). However, Gearhardt, Rizk et al. (2014) found that in a sample of all overweight/obese individuals, higher BMI was associated with lower craving for fatty foods. The association of BMI with food liking has also not always been consistent; a number of studies have found positive associations between BMI and liking of salty, sweet, and high-fat foods (Cox, Hendrie, & Carty, 2016; Deglaire et al., 2015; Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992; Laurent-Jaccard, De Matteis, Hofstetter, & Schutz, 1994; Mela & Sacchetti, 1991). However, other studies suggest that higher BMI is associated with less liking of certain food types, such as sweet, fatty and salty food (Cox et al., 1998; Gearhardt, Rizk et al., 2014), and yet another study showed no differences in liking between lean and obese participants (Cox, Perry, Moore, Vallis, & Mela, 1999). Thus, more exploration is needed to understand the association between BMI and craving of liking.

1.5. The current study

In the current study, we aim to further investigate the incentive sensitization model by examining the associations of food craving and liking with food addiction, cognitive restraint, and BMI in a community sample of men and women that range from underweight to obese. Utilizing hierarchical linear modeling, we will examine 1) the association between craving and liking for highly processed versus minimally processed foods at level one, and 2) whether individual characteristics (food addiction symptoms, cognitive restraint, BMI) alter these associations at level two. As highly processed foods (e.g. ice cream, pizza, French fries) relative to minimally processed foods (e.g. nuts, fruits, vegetables) are more strongly implicated in addictive-like eating (Schulte et al., 2015), we predict that craving, more so than liking, will overall be higher for highly processed foods. Further, as the dissociation of wanting and liking is thought be a feature of addictive processes, we predict that food addiction symptoms will be more strongly associated with food craving than food liking. Finally, we hypothesize that BMI and cognitive restraint will not show this pattern, as they are not measures of addiction.

2. Method and materials

2.1. Participants

Participants ($n = 216$) from the United States were recruited through Amazon Mechanical Turk (MTurk) and completed all measures remotely via online questionnaires. While samples from MTurk are not nationally representative, the participant pool is large and demographically diverse, comparable to traditional convenience samples (Paolacci & Chandler, 2014). Participants were offered $0.75 for the completion of 20-min task, approximately $2.25 per hour, higher than the median hourly rate of $1.38 for MTurk studies (Horton & Chilton, 2010). Participants were excluded from analyses if they provided incorrect answers to catch questions ("Who was the first president of the United States?," "Have you ever had a fatal heart attack while watching TV?," "What is 2 + 2?; " $n = 6$), provided impossible data (e.g. height 6′1″, weight 21 lbs.; $n = 3$), or identified with a gender other than male or female or did not provide this information ($n = 4$). The University of Michigan Health and Behavioral Sciences Institutional Review Board approved the current study and written informed consent was obtained from all participants.

Participants were asked to self-report demographic information. Participants' age ranged from 19 to 75 years old ($M = 38.15$, $SD = 14.02$), 61.6% were female ($n = 133$), and reported ethnicity varied (80.1% Caucasian/White, 3.2% Asian/Pacific Islander, 5.1% Hispanic, 4.6% African-American, 0.5% Arab, 1.4% reported Other, and 5.1% Biracial/Multiracial). BMI was determined by self-reported height and weight. Height and weight may be under-reported and thus bias BMI (Connor Gorber, Tremblay, Moher, & Gorber, 2007; Taylor et al., 2006), an adjustment algorithm was developed by Connor Gorber, Shields, Tremblay, and McDowell (2008) based on a nationally representative Canadian sample. Analyses of the current study were conducted with both unadjusted and adjusted BMI, and no differences were seen. The adjusted BMI variable is used in the current study. Participants fell into all weight categories ($M = 27.98$, $SD = 6.28$): 2.8% underweight (min = 16.64; $n = 6$), 43.1% normal weight ($n = 93$), 28.7% overweight ($n = 62$), and 25.4% obese (max = 51.95; $n = 55$). The distribution of BMI in this sample was positively skewed (1.07, $SE = 0.17$), thus analyses were performed with the log-transformed BMI data (skewness = 0.47, $SE = 0.17$). No differences were seen, thus for clarity of interpretation, the reported results reflect the non-transformed BMI variable.

2.2. Procedures and assessment measures

2.2.1. Three-Factor Eating Questionnaire

Cognitive restraint was measured using the cognitive restraint of eating subscale of the *Three-Factor Eating Questionnaire* (*TFEQ*), which has excellent internal consistency and test-retest validity (Stunkard & Messick, 1985). Though there are multiple measures of cognitive restraint, we chose to use the *TFEQ,* as it has been suggested as the best measure of cognitive restraint and an appropriate measure of actual restriction of food intake (French, Jeffery, & Wing, 1994; Laessle et al., 1989). The *TFEQ* cognitive restraint scale is comprised of 21 items: 12 true/false statements, eight 4-point scales (i.e. "Never" to "Always", "Not at all" to "Very much"), and one 6-point scale (0–5). In the current study, scores on the *TFEQ* cognitive restraint scale ranged from 10 to 18 ($M = 13.26$, $SD = 2.10$). Scores were normally distributed.

2.2.2. Yale Food Addiction Scale

The *Yale Food Addiction Scale* (*YFAS*) examines addictive-like eating behavior using the DSM-IV-TR diagnostic criteria for substance dependence. It has been shown to have adequate reliability (Gearhardt et al., 2009) and adequate internal consistency in a diverse sample (Gearhardt, Boswell et al., 2014). The *YFAS* contains 25 items to assess behavioral indicators of addictive-like eating and clinical impairment/distress. The measure can be scored to produce a symptom count, ranging from 0 to 7, or a dichotomous diagnosis indicating whether the individual meets criteria for a diagnosis of food addiction (three or more symptoms and clinical impairment/distress). The current study utilized the symptom count method of scoring the *YFAS*, and participants' symptoms ranged from 0 to 7 ($M = 1.93$, $SD = 1.56$). In this sample, the *YFAS* symptom count

distribution was positively skewed (1.11, $SE = 0.17$), thus *YFAS* symptom count data were log-transformed after adding 1, as symptom count could be 0, and analyses were run with the log-transformed data (skewness = 0.07, $SE = 0.166$). No differences were seen, thus the reported results reflect the non-transformed *YFAS* symptom count variable.

2.2.3. Craving and liking

Craving and liking were assessed for 35 nutritionally diverse foods, systematically selected based on processing, fat, sodium, sugar, carbohydrate, protein, and fiber content. Foods were categorized as processed if they contained added fat and/or refined carbohydrates (e.g. sugar, flour). Eighteen of the selected foods were highly processed, (e.g. chocolate, cake, chips, cheeseburger, pizza, French fries, cookies), and seventeen were minimally processed (e.g. nuts, chicken breast, apple, egg, broccoli).

General Labeled Magnitude Scales (*gLMS*) were developed to assess craving and liking, based on practices by Bartoshuk et al. (2004) and Kalva, Sims, Puentes, Snyder, and Bartoshuk (2014).

Labeled scales (e.g., Visual Analog Scales) are susceptible to inconsistencies due to differences in experience of participants, for example, someone who has experienced child labor may say that is the most intense pain they had ever endured, while a child might say a skinned knee is the highest pain ever experienced. The *gLMS* aims to "stretch" the labeled scale, such that all ratings are made with the participant's minimum and maximum experience intensity in mind, which allows for ratings that are not confounded by individual differences to be compared across participants (Bartoshuk et al., 2004).

Craving was defined for the subject as an intense desire or want for something. For *gLMS* training, the participant was asked to think of the strongest craving they had ever experienced of any kind as an anchor for the top of the scale. Then, subjects rated their craving for each of the 35 foods on a scale from 0 ("No craving at all") to 100 ("Strongest craving you've ever experienced of any kind").

Liking was measured in a similar manner. For *gLMS* training on the hedonic scale, participants were first asked to thing of the thing in the world they dislike the most to anchor the bottom of the scale and the thing in the world they like the most to anchor the top. Participants then rated their liking for each of the 35 foods on a scale from −100 ("Greatest dislike") to 100 ("Greatest like").

The order in which the craving and liking questions were presented to participants was evenly counterbalanced, such that some participants rated craving first and others reported liking first.

3. Results

3.1. Craving

Hierarchical linear modeling (Raudenbush & Bryk, 2002) with robust standard errors was used to examine associations between processing (dichotomous, such that unprocessed foods were coded as 0, and processed foods were coded as 1) and individual differences (food addiction symptoms, cognitive restraint, BMI) with craving reports for each food. Data were analyzed using HLM7 (Raudenbush, Bryk, & Congdon, 2011) with two-level regression analyses, with participants' reports of how much they craved the 35 foods set as the outcome, and nutritional components of individual foods at level one, nested within the 216 participants' characteristics at level two. By using this multi-level analysis, we were able to investigate both the association of food attributes with reported craving, and the influence of individual characteristics on the association of food attributes and craving. That is, we aimed to understand if and how individual characteristics (*YFAS* symptom count, cognitive restraint, BMI) changed the association between processed (versus unprocessed) foods and craving. A significance level of $p < 0.05$ was used in this study. There were no missing cases.

Processing had main effects on the reported craving of a food, as seen in the level-one equation. The intercept for the level-one equation (β_0) represents the model-predicted participant-reported craving for an unprocessed food. The partial slope can be interpreted as the influence of processing (β_1) on reported craving (Table 1).

Level-One Equation for Processing as a Predictor of a Reported Craving of a Food:

$$Craving_{ij} = \beta_{0j} + \beta_{1j}*\left(Processing_{ij}\right) + r_{ij}$$

Chi-square tests revealed significant variation across participants reported craving focusing on processing, $\chi^2(212) = 246.83$, $p = 0.050$. Thus, food-specific predictors of the intercept and processing were examined and both treated as random effects. Within level-one regression analyses, processing was seen as a large, positive predictor for craving in the average individual ($d = 0.711$). That is, processed foods on average were given higher craving ratings ($M = 39.04$) than unprocessed foods ($M = 35.58$).

YFAS symptom count (centered), cognitive restraint (centered), and adjusted BMI (centered) were then entered into this model as level-two predictors to examine whether individual characteristics alter the association between processing and craving ratings. Though there were significant correlations between *YFAS* symptom count and BMI ($r = 0.233$), and *YFAS* symptom count and cognitive restraint ($r = 0.148$), these correlations were not strong enough to warrant multicollinearity concerns. For level-two equations, the intercept indicates the average value of the relevant level-one variable, assuming mean values for all level-two parameters. For example, γ_{10} indicates the average impact of an unprocessed food on craving ratings for a participant with average scores on *YFAS* symptom count, cognitive restraint, and BMI. The partial slopes within the level-two equations represent the association between a one-unit increase in a level-two predictor and the effect of the level-one predictor on craving. For example, the regression coefficient for the effect of *YFAS* symptom count (γ_{11}) represents the model-predicted impact of a one-unit increase in *YFAS* symptom count on the association between processing and craving.

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

$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(YFAS\ Symptom\ Count_j) + \gamma_{02}*(Cognitive\ Restraint_j) + \gamma_{03}*(BMI_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}*(YFAS\ Symptom\ Count_j) + \gamma_{12}*(Cognitive\ Restraint_j) + \gamma_{13}*(BMI_j) + u_{1j}$$

An average participant, defined as a participant with mean values on all level-two parameters, reported an average craving of 37.33, on a scale from 0 ("No craving at all") to 100 ("Strongest craving every experienced of any kind"), for an unprocessed food item (γ_{00}).

With respect to individual characteristics, two patterns emerged. *YFAS* symptom count was a small, positive predictor of the association between reported craving and processing ($d = 0.297$); as *YFAS* symptom count increased, craving for processed foods increased compared to craving for unprocessed foods. Cognitive restraint was a moderate, negative predictor of the association between reported craving and processing ($d = -0.323$), meaning that as cognitive restraint increased, craving for processed foods decreased moderately compared to craving for unprocessed

Table 1
Hierarchical lineal model with craving as outcome variable.

Parameter	Estimate	Std Error	*t*-Value	*d.f.*	*p*-Value	*d*-Value
For Intercept, β_0						
Intercept, γ_{00}	37.335	1.036	36.038	212	<0.001	4.950
YFAS symptom count, γ_{01}	1.278	0.772	1.656	212	0.099	0.227
Cognitive restraint, γ_{02}	0.209	0.535	0.391	212	0.696	0.054
BMI, γ_{03}	0.233	0.161	1.452	212	0.148	0.199
For Processing slope, β_1						
Intercept, γ_{10}	3.501	0.677	5.174	212	<0.001	0.711
YFAS symptom count, γ_{11}	0.899	0.416	2.164	212	0.032	0.297
Cognitive restraint, γ_{12}	−0.748	0.317	−2.355	212	0.019	−0.323
BMI, γ_{13}	0.026	0.097	0.267	212	0.789	0.037

Note. BMI = Body Mass Index; *YFAS* = *Yale Food Addiction Scale*.

foods. BMI did not significantly alter the association between craving and processing.

3.2. Liking

Hierarchical linear modeling with robust standard errors was also used to examine associations between processing and individual differences with liking reports for each food.

The intercept for the level-one equation (β_0) represents the model-predicted participant-reported liking for an unprocessed food. The partial slope can be interpreted as the influence of processing (β_1) on reported liking (Table 2).

Level-One Equation for Processing as a Predictor of a Reported Craving of a Food:

$$Liking_{ij} = \beta_{0j} + \beta_{1j}*\left(Processing_{ij}\right) + r_{ij}$$

Chi-square tests revealed significant variation across participants' reported liking based on level of processing, $\chi^2(212) = 252.56$, $p = 0.029$. Therefore, food-specific predictors of the intercept and processing were examined and both treated as random effects. On average, processing was not significantly associated with liking ratings ($p = 0.091$).

YFAS symptom count, cognitive restraint, and BMI were entered into the model as level-two predictors to examine changes in the association between processing and liking ratings based on participant-specific characteristics.

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

$$\beta_{0j} = \gamma_{00} + \gamma_{01}*(YFAS\ Symptom\ Count_j) + \gamma_{02}*(Cognitive\ Restraint_j) + \gamma_{03}*(BMI_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}*(YFAS\ Symptom\ Count_j) + \gamma_{12}*(Cognitive\ Restraint_j) + \gamma_{13}*(BMI_j) + u_{1j}$$

An average participant reported a mean liking of 32.25, on a scale from −100 ("Greatest dislike") to 100 ("Greatest like"), for an unprocessed food item (γ_{00}). For unprocessed foods, *YFAS* symptom count, cognitive restraint, and BMI did not alter the association between processing and liking.

Two patterns emerged during this analysis. Cognitive restraint was a moderate, negative predictor of the association between reported liking and processing ($d = -0.330$); as cognitive restraint increased, liking for processed foods decreased moderately compared to liking for unprocessed foods. BMI was a small, positive predictor of the association between reported liking and processing ($d = 0.282$); as BMI increased, liking for processed foods increased slightly compared to liking for unprocessed foods. *YFAS* symptom count did not significantly impact liking ratings for processed foods.

4. Discussion

This study examined the effects of individual differences (food addiction symptomology, cognitive restraint, and BMI) on craving and liking of highly processed versus minimally processed foods. In the current sample, craving was elevated for highly processed foods on average, and this association increased with *YFAS* symptom count. The association between liking and processing was weaker, however, only trending toward significance ($p = 0.091$). Individuals with higher cognitive restraint indicated lower craving and liking for highly processed foods. Finally, for individuals with elevated BMI, craving of highly processed foods remained stable and liking increased.

Table 2
Hierarchical lineal model with liking as outcome variable.

Parameter	Estimate	Std Error	*t*-Value	*d.f.*	*p*-Value	*d*-Value
For Intercept, β_0						
Intercept, γ_{00}	32.251	1.285	25.088	212	<0.001	3.446
YFAS symptom count, γ_{01}	0.657	0.880	0.747	212	0.456	0.103
Cognitive restraint, γ_{02}	0.506	0.644	0.786	212	0.433	0.108
BMI, γ_{03}	0.299	0.171	1.749	212	0.082	0.240
For Processing slope, β_1						
Intercept, γ_{10}	1.883	1.108	1.699	212	0.091	0.233
YFAS symptom count, γ_{11}	0.436	0.648	0.673	212	0.502	0.092
Cognitive restraint, γ_{12}	−1.246	0.518	−2.404	212	0.017	−0.330
BMI, γ_{13}	0.332	0.162	2.051	212	0.041	0.282

Note. BMI = Body Mass Index; *YFAS* = Yale Food Addiction Scale.

4.1. Food processing

In the present study, highly processed foods were generally related to elevated craving, but not significantly associated with elevated liking. Studies have consistently found associations between craving and food processing (Gilhooly et al., 2007; Ifland et al., 2009; Weingarten & Elston, 1991; White & Grilo, 2005; White et al., 2002); the positive association between craving and processing in this study corroborates these previous findings. However, the finding that elevated liking was not significantly associated with processing was surprising, given that it is generally assumed that processed foods are liked more than non-processed foods. Viewing highly processed foods seems to elicit reward responses (Simmons, Martin, & Barsalou, 2005), and foods high in sugar and fat have been associated with higher self-reported liking in some studies (Cox et al., 2016; Finlayson et al. , 2007; Warwick & Schiffman, 1990). However, there is also prior research that is consistent with the current findings; one study found no difference in liking of processed versus non-processed foods (Cox et al., 1999), and another found a negative association (Cox et al., 1998). Further research should continue investigating the contribution of food processing to altered craving and liking of certain foods in the general population.

4.2. Addictive-like eating

The association between highly processed foods and increased craving was significantly stronger for individuals who exhibited indicators of food addiction measured by the *YFAS*, relative to individuals without food addiction symptomology. Additionally, endorsement of addictive-like eating indicators on the *YFAS* was not related to liking of highly processed foods. This pattern of elevated craving, but not liking, suggests that the incentive sensitization framework of addictive disorders (Robinson & Berridge, 1993, 2000) may be relevant for problematic consumption of highly processed foods, particularly for individuals endorsing *YFAS* indicators of addictive-like eating. Further, *YFAS* food addiction indicators were not related to craving or liking for minimally processed foods. In substance-use disorders, there is an interaction between the addictive substance and an individual's propensity to develop an addictive-like response (Everitt & Robbins, 2005; Koob & Le Moal, 2005; Volkow & Morales, 2015). Similarly, the present results support a substance-based, food addiction framework, where highly processed foods appear to interact with individual characteristics (e.g. addictive-like eating) to differentially activate addictive mechanisms (e.g. craving). As such, it may be that highly processed foods have a central role in activating an addictive-like process and contributing to problematic eating behavior in certain individuals, though future research is needed.

The present findings are inconsistent with the only previous study examining food craving and liking and their associations with *YFAS* symptoms of food addiction. Using a similar paradigm as the one in the current study, Gearhardt, Rizk et al. (2014) were not able to separate craving and liking in the overall sample or among individuals with elevated reports of *YFAS* food addiction symptomology. However, their sample may have had limited generalizability, given the exclusion of men and healthy weight individuals, and the limited range of reported food addiction symptoms. Thus, the present sample may have been more sufficiently powered to detect the observed patterns of craving and liking, as well as individual differences. Another advantage to the current study was the use of the *gLMS* (Bartoshuk et al., 2004; Kalva et al., 2014), which may be more suitable than a 7-point Likert scale for differentiating individuals' food experiences, especially across groups.

In light of the current findings, it is important to note that food liking is dynamic, changing over time, and may decrease as individuals eat more rewarding foods (Burger & Stice, 2012). The incentive sensitization framework clarifies that rewarding substances (i.e. drugs) are often initially consumed for the pleasurable effects, but during a transition to addiction, these pleasurable effects are diminished, and the substances are reportedly liked less (Robinson & Berridge, 2008). Some evidence has also been presented supporting a similar pattern of change in food liking; Burger and Stice (2012) found that individuals who more frequently consumed ice cream exhibited reduced reward-region (e.g. striatum) responsivity, while reported craving of ice cream increased. Thus the frequency of consumption of certain foods may influence the relationship between craving and liking over time.

4.3. Cognitive restraint

Individuals reporting elevated cognitive restraint exhibited a different pattern of craving and liking than persons with greater reported indicators of addictive-like eating. In the current sample, increased cognitive restraint, as measured by the *TFEQ* (e.g. successful limitation of food consumption; Stunkard & Messick, 1985), was associated with lower levels of craving and liking for processed foods. However, this contrasts with previous research in healthy participants, which found positive associations between craving/liking and cognitive restraint (Komatsu & Aoyama, 2014; Polivy et al., 2005). One possibility for these discrepant findings is that the association between cognitive restraint and craving/liking may differ based on exposure to other factors. For example, pre-meal/post-meal consumption, high stress, and exposure to food cues or caloric preloading are all known to affect restrained eaters differently than unrestrained eaters (Born et al., 2011; Fedoroff et al., 1997; Rotenberg & Flood, 2000; Wardle et al., 2000). Thus, it is possible that different associations between cognitive restraint and food craving/liking would emerge in response to exposure to other conditions. Future studies are needed to examine the effects of certain states on craving and liking in individuals exhibiting higher levels of cognitive restraint.

4.4. Body Mass Index

For highly processed foods, the associations of craving and liking with BMI were different than their associations with *YFAS* symptom count or cognitive restraint. For individuals with higher BMIs, craving ratings did not differ, but liking ratings were more positive. Thus, the current study suggests that liking may be more strongly associated with BMI than craving for highly processed foods. The present finding that BMI was not related to craving of highly processed foods was unexpected, given evidence in prior work for increased craving associated with higher BMI (Franken & Muris, 2005; Rodin et al., 1991; White et al., 2002). However, as *YFAS* symptom count was included in the model with BMI in the current study, it is possible that an addictive-like eating phenotype is more strongly associated with elevated craving than BMI. However, higher BMI appears to be more closely related to liking than food addiction symptoms. Thus, individuals with elevated BMI who do not endorse food addiction symptoms may benefit more from interventions that target food liking, rather than craving.

4.5. Limitations

The current study used a cross-sectional design, thus only correlational relationships between the variables may be inferred. Future research is needed to explore how these relationships may develop, and how well these patterns can predict eating behavior.

The current participants were recruited from MTurk, samples from which can be used in the place of traditional convenience samples (Paolacci & Chandler, 2014), however it is not nationally representative, thus generalizations should be made cautiously. Within the current sample, Hispanic and African-American populations were underrepresented, and Caucasian/White and multi-/biracial populations and females were overrepresented (United States QuickFacts, 2015). All measures were collected through self-report, thus it will be important to examine the behavioral and biological correlates of craving and liking and individual differences. Finally, participants were not asked to weigh themselves before self-reporting on their weight, which may have led to inaccurate reports. Future research would benefit from the direct measurement of height and weight.

5. Conclusion

Craving and liking of certain foods and food types, especially highly processed foods, may contribute to problematic eating behaviors. This study investigated changes in craving and liking associated with food addiction, cognitive restraint, and BMI as individual factors, and how these associations may change for highly processed foods versus minimally processed foods. Different patterns emerged for all three individual factors, adding to the evidence suggesting that they are separate mechanisms, each of which affect eating behaviors differently. This study was also able to disentangle craving and liking of food within a wide range of participants. Most notably, increased reports of *YFAS* indicators of food addiction were positively associated with craving, but not liking, for highly processed foods. This provides evidence that the incentive sensitization model may be relevant for "food addiction" and elevated craving for highly processed foods may contribute to compulsive consumption in a similar manner as in compulsive drug use. Further, the current findings support previous research that suggests highly processed foods may be most implicated in addictive-like eating behavior (Schulte et al., 2015), which may warrant the term "food addiction" to be refined to "highly processed food addiction."

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