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FOOD CRAVINGS

Topic Editors

Adrian Meule and Boris C. Rodríguez-Martín

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FOOD CRAVINGS

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Pictures of foods and beverages with varying degrees in color components, object size, brightness, contrast, and visual complexity (figure from Blechert et al., 2014)

Food craving refers to an intense desire or urge to consume a specific food. In Western or Westernized societies, these craved foods usually have high palatability and are energy dense, that is, they have high sugar and/or fat content. Accordingly, the most often craved food is chocolate. Food craving is a multidimensional experience as it includes cognitive (e.g. thinking about food), emotional (e.g. desire to eat or changes in mood), behavioral (e.g. seeking and consuming food), and physiological (e.g. salivation) aspects. Experiences of food craving are common, that is, they do not reflect abnormal eating behavior per se. However, very intense and frequent food craving experiences are associated with obesity and eating disorders such as bulimia nervosa and binge eating disorder. The aim of this research topic was to gather new contributions to a variety of aspects of food craving, which include its assessment, cognitive and emotional triggers, moderators, and correlates of food craving, and the relevance of food cravings in clinical issues, among others.

Table of Contents

04 ***Food Craving: New Contributions on Its Assessment, Moderators, and Consequences***
Boris C. Rodríguez-Martín and Adrian Meule

07 ***A Short Version of the Food Cravings Questionnaire—Trait: The FCQ-T-reduced***
Adrian Meule, Tina Hermann and Andrea Kübler

17 ***Exploring the Factor Structure of the Food Cravings Questionnaire-Trait in Cuban Adults***
Boris C. Rodríguez-Martín and Osana Molerio-Pérez

29 ***Cafeteria Diet Impairs Expression of Sensory-Specific Satiety and Stimulus-Outcome Learning***
Amy C. Reichelt, Margaret J. Morris and R. F. Westbrook

40 ***Food-Pics: An Image Database for Experimental Research on Eating and Appetite***
Jens Blechert, Adrian Meule, Niko A. Busch and Kathrin Ohla

50 ***Temptation in the Background: Non-Consummatory Exposure to Food Temptation Enhances Self-Regulation in Boys but not in Girls***
Aiste Grubliauskiene and Siegfried Dewitte

55 ***Mental Imagery Interventions Reduce Subsequent Food Intake Only When Self-Regulatory Resources are Available***
Benjamin Missbach, Arnd Florack, Lukas Weissmann and Jürgen König

66 ***Pickles and Ice Cream! Food Cravings in Pregnancy: Hypotheses, Preliminary Evidence, and Directions Forfuture Research***
Natalia C. Orloff and Julia M. Hormes

81 ***A Regulatory Focus Perspective on Eating Behavior: How Prevention and Promotion Focus Relates to Emotional, External, and Restrained Eating***
Stefan Pfattheicher and Claudia Sassenrath

89 ***How Relevant is Food Craving to Obesity and Its Treatment?***
Marc N. Potenza and Carlos M. Grilo

94 ***Food Cravings, Appetite, and Snack-Food Consumption in Response to a Psychomotor Stimulant Drug: The Moderating Effect of "Food-Addiction"***
Caroline Davis, Robert D. Levitan , Allan S. Kaplan, James L. Kennedy and Jacqueline C. Carter

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Food craving: new contributions on its assessment, moderators, and consequences

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Keywords: food, cravings, emotional eating, obesity, pregnancy, binge eating, food addiction

Food craving refers to an intense desire to consume a specific food. In Western societies, these foods usually have high palatability and are energy dense, that is, they have high sugar and/or fat content. Food craving is a multidimensional experience as it includes cognitive (e.g., thinking about food), emotional (e.g., desire to eat or changes in mood), behavioral (e.g., seeking and consuming food), and physiological (e.g., salivation) aspects (Nederkoorn et al., 2000; Cepeda-Benito et al., 2000a).

Subjective self-report appears to be the most viable method for the assessment of craving as other measurement modalities (e.g., peripheral autonomic responses) typically suffer from a lack of specificity (Shiffman, 2000). The most often used instruments are the *Food Cravings Questionnaires* (FCQs; Cepeda-Benito et al., 2000a,b). Momentary food craving can be measured with a 15-item state version (FCQ-S) while the frequency of food craving experiences can be measured with a 39-item trait version (FCQ-T), which contains nine subscales. However, factor structure could not be replicated in some studies and as the FCQ-T usually has very high internal consistency, researchers often report its total score only. Consequently, such a long measure may not be necessary in order to assess a general index of trait food craving. In the current research topic, Meule et al. (2014) present a reduced version of the German FCQ-T (FCQ-T-r), which consists of 15 items only. Results showed that correlates of this short version were similar to those that have been found for the long version, for example, that FCQ-T scores are able to predict food-cue induced craving (Meule et al., 2012a,b). Following up on this, Rodríguez-Martín and Molerio-Pérez (2014) also could not replicate the nine-factorial structure of the Spanish FCQ-T (Cepeda-Benito et al., 2000b). They could demonstrate, however, that scores of the Spanish FCQ-T-r were highly correlated with scores of the long version as well as with the 24 excluded items. Moreover, it was shown that validity indices were similar for both versions, providing further support that the FCQ-T-r represents an adequate alternative for the assessment of trait food craving as measured by the FCQ-T.

Animal models are an important part of research on eating behavior. While people can be asked if they experience a desire to eat a food, measuring food craving in animals is not straightforward. Following abstinence from sugar, rats will exhibit a larger binge than ever before, which may be interpreted as an experience of craving (Avena et al., 2005). A rather indirect measure of food craving may be sensory-specific satiety (SST; specifically, the lack thereof). It refers to a temporary decline in food liking and food wanting derived from consuming a certain food in comparison to other unconsumed foods (Havermans et al., 2009). Reichelt et al. (2014) present a study in which rats consumed a so-called cafeteria diet of palatable, high-calorie foods for 2 weeks. They found that these rats showed impaired SST following consumption of a high-calorie solution, which may suggest that exposure to obesogenic diets impacts upon neurocircuitry involved in motivated control of eating behavior.

The ingestion of food is associated with a rewarding consequence and, thus, the incentive value of that particular food increases and its sensory attributes become signals for satisfaction (Havermans, 2013). Therefore, through Pavlovian conditioning, exposure to food-cues can likely trigger food craving. In experimental research, this can easily be examined by presenting pictorial food stimuli on a computer screen while psychophysiological data or subjective ratings are recorded. However, food image sets vary considerably across laboratories and image characteristics and food composition are often unspecified. Moreover, study results may be adversely affected by confounding variables such as perceptual characteristics of the stimuli. To remedy this, Blechert et al. (2014) developed a comprehensive database of food and non-food images along with detailed meta-data. This database will facilitate standardization and comparability across studies and will advance experimental research on food craving and eating behavior as it enables to match and control stimulus sets on a range of important variables.

Exposure to tempting food-cues, however, does not trigger food craving or lead to food consumption in each and every situation. Grubliauskiene and Dewitte (2014), for example, show that boys actually ate fewer candies following an unobtrusive pre-exposure to candies as compared to when there was no pre-exposure. Unexpectedly, however, this effect could not be shown for girls. Moreover, as was firstly demonstrated by Morewedge et al. (2010), instead of inducing food craving (i.e., having a sensitizing effect), repeatedly imagining the consumption of a food leads people to habituate to it and consequently reduces consumption of that food. Missbach et al. (2014) were able to replicate this finding with different food items than were used in the original studies. Importantly, they found that this habituation effect was neutralized by self-regulatory depletion. That is, repeated imagination of food consumption only reduces subsequent food intake when self-regulatory resources are available.

Research consistently demonstrates gender differences in food craving: women are more likely to experience food cravings than men (Weingarten and Elston, 1991). It is tempting to assume that these differences are related to hormonal differences between women and men, particularly as many women experience increases in food cravings perimenstrually and prenatally (Hormes, 2014). However, research on these experiences is scarce. Orloff and Hormes (2014) review the available literature on food cravings during pregnancy. They challenge the notion that perimenstrual or prenatal food craving is associated with hormonal changes, but suggest that cultural and psychosocial factors are more important determinants of food craving experiences during pregnancy and of excess gestational weight gain.

Food craving can occur as a result of specific mood states (often negative mood) and is marked by anticipation of mood enhancing effects of food intake (Cepeda-Benito et al., 2000a). Food craving is also associated with external eating, that is, it is often triggered by cues in the environment. Pfattheicher and Sassenrath (2014) report that emotional eating is positively related to individual differences in prevention focus while external eating is positively related to individual differences in promotion focus. Hence, this study showed that trait-like self-regulatory orientations are differentially related to specific eating styles, which may inspire intervention approaches for the reduction of food craving.

Potenza and Grilo (2014) briefly summarize contemporary research on food craving such as its neuronal underpinnings. They also highlight its relevance in obesity and binge eating disorder and suggest that research on and therapy of these disorders may benefit from providing an addiction framework. For instance, some approaches that effectively target drug cravings have also been shown to reduce food cravings. In a similar vein, Davis et al. (2014) investigated the effects of a methylphenidate challenge in individuals exhibiting addiction-like eating behavior. Individuals with "food addiction" reported more intense food craving than controls and were resistant to the food intake suppression that is typically induced by dopamine agonists. This supports that compulsive overeating is related to increased food craving and dopamine signaling-strength differences.

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A short version of the *Food Cravings Questionnaire—Trait*: the FCQ-T-reduced

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One of the most often used instruments for the assessment of food cravings is the *Food Cravings Questionnaire* (FCQ), which consists of a trait (FCQ-T; 39 items) and state (FCQ-S; 15 items) version. Scores on the FCQ-T have been found to be positively associated with eating pathology, body mass index (BMI), low dieting success and increases in state food craving during cognitive tasks involving appealing food stimuli. The current studies evaluated reliability and validity of a reduced version of the FCQ-T consisting of 15 items only (FCQ-T-r). Study 1 was a questionnaire study conducted online among students ($N = 323$). In study 2, female students ($N = 70$) performed a working memory task involving food and neutral pictures. Study 1 indicated a one-factorial structure and high internal consistency ($\alpha = 0.94$) of the FCQ-T-r. Scores of the FCQ-T-r were positively correlated with BMI and negatively correlated with dieting success. In study 2, participants reported higher state food craving after the task compared to before. This increase was positively correlated with the FCQ-T-r. Hours since the last meal positively predicted food craving *before* the task when controlling for FCQ-T-r scores and the interaction of both variables. Contrarily, FCQ-T-r scores positively predicted food craving *after* the task when controlling for food deprivation and the interaction term. Thus, trait food craving was specifically associated with state food craving triggered by palatable food-cues, but not with state food craving related to plain hunger. Results indicate high reliability of the FCQ-T-r. Replicating studies that used the long version, small-to-medium correlations with BMI and dieting success could be found. Finally, scores on the FCQ-T-r predicted cue-elicited food craving, providing further support of its validity. The FCQ-T-r constitutes a succinct, valid and reliable self-report measure to efficiently assess experiences of food craving as a trait.

Keywords: food craving, Food Cravings Questionnaire, psychometric properties, validity, reliability, body mass index, dieting success, food-cues

INTRODUCTION

Craving refers to an intense desire or urge to use a substance and frequent experiences of craving are a core feature of substance use disorders (Tiffany and Wray, 2012). However, the term craving does not only refer to drug-related, but also to other substances like food or non-alcoholic beverages (Hormes and Rozin, 2010). Accordingly, food craving refers to an intense desire or urge to eat specific foods of which chocolate is the most often craved one among other highly palatable foods (Weingarten and Elston, 1990, 1991). Cultural differences have also been noted: for example, a preference for savory over sweet foods in Arabian countries or the presence of rice cravings in Asian countries (Hill, 2007; Komatsu, 2008). It is the intensity and specificity that differentiates food craving from feelings of plain hunger (Hill, 2007). Although food craving and hunger often co-occur, an energy deficit is not a prerequisite for experiencing food craving, that is, it can also occur without being hungry (Pelchat and Schaefer, 2000). Food craving experiences are common and reported by the majority of adults. That is, although more intense and more frequent experiences of food craving are associated with overeating, they do not necessarily reflect abnormal eating behavior and are not synonymous with increased food intake (Hill, 2007).

The sight, smell, or taste of food and food-cues elicit so-called cephalic phase responses, which prepare the organism for food ingestion and are associated with increases in craving for those foods (Nederkoorn et al., 2000). Physiologically, those responses involve increases in salivary secretion, cardiovascular activity (e.g., heart rate and blood pressure), body temperature, electrodermal activity, and respiration (Vögele and Florin, 1997; Nederkoorn et al., 2000; Legenbauer et al., 2004). Yet, attempts to measure craving objectively, for example based on physiological data, have been criticized for being unspecific and subjective self-report seems the only viable assessment modality (Shiffman, 2000). The term craving is somewhat vague and often subjects are asked to indicate on a one-item rating scale how strong they crave or desire a specific object. Therefore, there is a need to assess craving as a multidimensional construct with standardized questionnaires instead of single questions. This is particularly important in non-English speaking countries because there is no simple equivalent expression for craving (Hormes and Rozin, 2010).

Several self-report measures for the assessment of food craving have been developed such as the *Food Cravings Questionnaires* (FCQs; Cepeda-Benito et al., 2000a,b), the *Attitudes to Chocolate Questionnaire* (ACQ; Benton et al., 1998; Müller et al., 2008), the *Orientation toward Chocolate Questionnaire* (OCQ; Cartwright and Stritzke, 2008; Rodgers et al., 2011), the *Food Craving Inventory* (FCI; White et al., 2002; Komatsu, 2008; Jáuregui Lobera et al., 2010; Nicholls and Hulbert-Williams, 2013), and the *Questionnaire on Craving for Sweet or Rich Foods* (QCSRF; Toll et al., 2008). Each of these measures represents a different approach to the craving construct. Both the ACQ and OCQ are designed to measure cravings specifically related to chocolate and emphasize the relationship between craving and feelings of guilt (Benton et al., 1998) or the conflict between approach and avoidance inclinations during the experience of craving (ambivalence model; Cartwright and Stritzke, 2008). The FCI measures cravings related to different classes of food (high fats, sweets, carbohydrate/starches, fast-food fats; White et al., 2002). The QCSRF measures the intensity of craving for sweet or rich foods with a mixture of questions referring to momentary craving, but mainly to craving during the past week (Toll et al., 2008). Therefore, all of these instruments assess habitual cravings related to specific kinds of food and are restricted to certain dimensions of food cravings.

As opposed to these questionnaires, the FCQs were constructed to assess craving for a variety of foods, without confining them to certain categories or specific foods, as for example chocolate. Furthermore, the FCQs cover behavioral, cognitive and physiological aspects of food cravings. Finally, the FCQs combine two versions that measure current and habitual food cravings. Therefore, the FCQs are the only currently available food craving questionnaires that (1) do not refer specifically to chocolate or similar, (2) assess food cravings on a multidimensional level, and (3) measure food cravings as trait and state. Moreover, there is evidence that the FCQs can be used easily as a measure for specific cravings, for example by replacing references to food with references to chocolate (Rodriguez et al., 2007).

The FCQs are arguably the most extensively validated food craving measures and are available in English (Cepeda-Benito et al., 2000b), Spanish (Cepeda-Benito et al., 2000a), Dutch (Franken and Muris, 2005; modified version from Nijs et al., 2007), Korean (modified version from Noh et al., 2008), and German (Meule et al., 2012a). The trait version of the FCQs (FCQ-T) consists of 39 items and items are scored on a 6-point scale ranging from *never* to *always*. Its original form comprises nine subscales measuring food cravings as (1) intentions to consume food, (2) anticipation of positive reinforcement, (3) relief from negative states, (4) lack of control over eating, (5) preoccupation with food, (6) hunger, (7) emotions, (8) cues that trigger cravings, and (9) guilt (Cepeda-Benito et al., 2000a,b). However, the factorial structure could only partially be replicated in subsequent studies in obese individuals, in a study using the chocolate-adapted version, and in a study using the German version (Rodriguez et al., 2007; Vander Wal et al., 2007; Meule et al., 2012a; Crowley et al., in press). Specifically, results yielded fewer factors in those studies, that is, eight, seven, or six subscales (Rodriguez et al., 2007; Vander Wal et al., 2007; Meule et al., 2012a; Crowley et al., in press). Internal consistency of the total scale is very high ($\alpha > 0.90$) across different versions and samples (Cepeda-Benito et al., 2000a,b, 2003; Nijs et al., 2007; Rodriguez et al., 2007; Vander Wal et al., 2007; Moreno et al., 2008; Meule et al., 2012a).

The state version of the FCQs (FCQ-S) consists of 15 items to be scored on a 5-point scale ranging from *strongly disagree* to *strongly agree*. Its original form comprises five subscales measuring current food craving in relation to (1) an intense desire to eat, (2) anticipation of positive reinforcement, (3) relief from negative states, (4) lack of control over eating, and (5) hunger (Cepeda-Benito et al., 2000a,b). Like for the trait version, subscales could only be partially replicated in a sample of obese individuals and using the German version (Vander Wal et al., 2007; Meule et al., 2012a). Again, internal consistency for the total scale is usually high ($\alpha > 0.90$) (Cepeda-Benito et al., 2000a,b; Nijs et al., 2007; Vander Wal et al., 2007; Moreno et al., 2008; Meule et al., 2012a).

Scores on the FCQ-T are positively correlated with BMI, scores on the disinhibition subscale of the *Eating Inventory*, eating disorder psychopathology, food addiction symptoms, and low dieting success (Cepeda-Benito et al., 2000a,b, 2003; Franken and Muris, 2005; Meule et al., 2011b, 2012c; Meule and Kübler, 2012). Accordingly, FCQ-T scores are elevated in patients with bulimia nervosa, binge eating disorder, and obesity (Abilés et al., 2010; Van den Eynde et al., 2012). Thus, higher scores on the FCQ-T are associated with higher scores on various self-report measures related to overeating and with higher body mass in both non-clinical and clinical samples.

Scores on the FCQ-S are positively correlated with length of food deprivation, current negative affect, and are sensitive to food intake and food-cue exposure (Cepeda-Benito et al., 2000b, 2003; Vander Wal et al., 2005, 2007; Meule et al., 2012a,d, in revision; Meule and Kübler, in revision). Thus, unlike scores on the FCQ-T, scores on the FCQ-S are indeed affected by momentary physiological and psychological states and environmental circumstances. Further support for a valid differentiation between state and trait food cravings is provided by the FCQs' retest-reliabilities: 3-week retest-reliability for the FCQ-T is high [$r_{(tt)} > 0.80$] while it is, expectedly, substantially lower for the FCQ-S [$r_{(tt)} < 0.60$] (Cepeda-Benito et al., 2000b; Vander Wal et al., 2007; Meule et al., 2012a). Yet, the FCQ-T is also sensitive to changes in eating behavior: decreased scores on the FCQ-T can be observed after bariatric surgery and behavioral weight-loss treatment in obese individuals (Batra et al., 2013; Rieber et al., 2013; Giel et al., in press).

The FCQ-T and FCQ-S are not independent from one another. For example, scores on the FCQ-T and FCQ-S are weakly positively correlated and, accordingly, scores on FCQ-S are also associated with measures of overeating, but not as consistent as scores on the FCQ-T (Cepeda-Benito et al., 2000b, 2003; Moreno et al., 2008; Meule et al., 2012a; Van den Eynde et al., 2012). One explanation for this could simply be that individuals with more frequent food craving experiences (i.e., "high trait cravers") have a higher probability to experience craving in general and, thus, it is more likely that they coincidentally experience craving during data collection. Another possibility could be that completing eating-related questionnaires facilitates current food craving, particularly in high trait cravers. Beyond the fact that sometimes correlations between absolute FCQ-T and FCQ-S scores can be observed, it has been found recently that *increases* in FCQ-S scores during cognitive tasks involving pictures of palatable foods are positively correlated with FCQ-T scores (Meule et al., 2012d; Meule and Kübler, in revision). That is, it appears that the FCQ-T represents a valid measure for the assessment of susceptibility for food-cue elicited craving, which, in turn, can be assessed with the FCQ-S. This is further supported by a study by Tiggemann and Kemps (2005) who found that scores on the FCQ-T predicted craving intensity when participants were instructed to imagine their favorite food.

Although in some studies subscales of the FCQ-T have been found to be differentially related to other aspects of eating behavior (Moreno et al., 2008, 2009; Meule and Kübler, 2012; Meule et al., 2012a), it appears that many researchers only use its total score, which is reasonable in light of its instable factor structure and very high internal consistency. Thus, and because the FCQ-T represents rather a long self-report measure, the aim of the present study was to develop and validate a short form of the FCQ-T. For this purpose, we chose 15 items of the FCQ-T with the highest item-total-correlations from the German validation study (Meule et al., 2012a).

Two studies were conducted to examine reliability and validity of this reduced form of the FCQ-T (FCQ-T-r). Factor structure was tested in study 1 which was an online questionnaire-based study. As only items with high item-total-correlations were selected, we expected a one-factorial structure with high internal consistency. A positive correlation was expected with BMI and a negative correlation with self-perceived dieting success as a preliminary indication for validity. In study 2, female participants performed a working memory task involving highly palatable food-cues. As scores on the FCQ-T have been found to be positively correlated with current food-cue elicited craving, we expected that scores on the FCQ-T-r would be positively correlated with increases in state food craving during the task and that scores would predict particularly state food craving after, but not before the task. Again, a positive correlation was expected between FCQ-T-r scores and BMI and a negative correlation between FCQ-T-r scores and self-perceived dieting success. Additionally, small-to-large positive correlations were expected between FCQ-T-r scores with self-reported impulsivity, restrained eating, and eating disorder psychopathology, similar to those found in the German validation study of the long version of the FCQ-T (Meule et al., 2012a).

STUDY 1

METHODS

Food Cravings Questionnaire—Trait—Reduced (FCQ-T-r)

As noted above, 15 items with the highest item-total-correlations were selected from the German FCQ-T (Meule et al., 2012a). Items and their corresponding original item numbers (cf. Cepeda-Benito et al., 2000a,b) are displayed in **Table 1**. Items included in the FCQ-T-r belonged to the original version's subscales *lack of control over eating* (5 items), *thoughts or preoccupation with food* (5 items), *intentions and plans to consume food* (2 items), *emotions before or during food craving* (2 items), and *cues that may trigger food craving* (1 item). That is, the FCQ-T-r does not include items of the original version's subscales *anticipation of positive reinforcement*, *anticipation of relief*, *hunger*, and *guilt*.

Dieting questions and sociodemographic and anthropometric information

Participants were asked to report their age (years), sex (male/female), height (meters), weight (kg), occupation (student/other), and citizenship (German/other)[1]. Dieting status (yes/no) was assessed with a single question ("Are you currently restricting your food intake to control your weight (e.g., by eating less or avoiding certain foods)?"; cf. Meule et al., 2012b). Self-reported dieting success was measured with the *Perceived Self-Regulatory Success in Dieting Scale* (PSRS) which contains three items that are scored on 7-point scales (Meule et al., 2012c). Internal consistency was acceptable (Cronbach's $\alpha = 0.64$) in the current study.

Procedure and participants

Student councils of several German universities were contacted by e-mail and asked to distribute the study's website URL using their mailing lists. Questionnaire completion took approximately 5–10 min. Every question required a response in order to continue. Study period lasted 2 weeks. The website was visited 403 times and 353 individuals started the study. A total of 324 complete datasets were recorded. Data were filtered with the homepage's (www.soscisurvey.de) data quality check method which is based on the time participants spend completing each page. As a result, data of one participant were excluded and, thus, the final sample size was 323. Most participants were women ($n = 271$, 83.9%), students ($n = 285$, 88.2%), and had German citizenship ($n = 308$, 95.4%). One-hundred and thirty-six participants (42.1%) reported to be current dieters.

Data analysis

Firstly, it was tested if data met requirements for exploratory factor analysis using the *Kaiser-Meyer-Olkin Measure of Sampling Adequacy* and *Bartlett's Test of Sphericity*. Although a one-factorial structure was expected, we chose to use exploratory factor analysis to reveal if there was an influence of the items' original subscale. Thus, exploratory factor analysis with principal component analysis was calculated and the number of factors was determined with parallel analysis. Items means, standard deviations, and item-total-correlations were calculated for item analysis. Cronbach's α was calculated to evaluate internal consistency. Relationships between FCQ-T-r scores and sample characteristics and dieting success, respectively, were tested with independent t-tests (sex, dieting status) and Pearson correlation coefficients (age, BMI, PSRS). All statistical tests are reported two-tailed. Exact p-values are reported in case of significant ($p < 0.05$) and

[1]Note that self-reports of some of these variables are potentially biased. For example, height often is overestimated and weight is underestimated (Gorber et al., 2007). However, it has also been found that although such discrepancies exist, reports are usually sufficiently accurate (Bowman and Delucia, 1992). Moreover, anonymous, web-based studies have been found to be advantageous for the assessment of sensitive questions such as body weight (Kroh, 2005; Kays et al., 2012). Thus, we argue that self-reported height and weight probably did not—or only minimally—adversely affect results.

Table 1 | Factor loadings and item statistics of the *Food Cravings Questionnaire—Trait—reduced* in study 1.

Item	Original item no.[a]	Factor loading	*M* (*SD*)	r_{itc}
1. When I crave something, I know I won't be able to stop eating once I start. [Wenn ich ein starkes Verlangen nach etwas verspüre, weißich, dass ich nicht mehr aufhören kann zu essen, wenn ich erst mal angefangen habe.]	2.	0.76	2.81 (1.19)	0.72
2. If I eat what I am craving, I often lose control and eat too much. [Wenn ich das esse, wonach ich ein starkes Verlangen verspüre, verliere ich oft die Kontrolle und esse zu viel.]	3.	0.77	2.86 (1.20)	0.73
3. Food cravings invariably make me think of ways to get what I want to eat. [Wenn ich ein starkes Verlangen nach bestimmten Nahrungsmitteln verspüre, denke ich ausnahmslos darüber nach, wie ich das bekomme, was ich essen will.]	5.	0.73	2.52 (1.19)	0.68
4. I feel like I have food on my mind all the time. [Ich habe das Gefühl, dass ich die ganze Zeit nur Essen im Kopf habe.]	6.	0.74	2.28 (1.15)	0.69
5. I find myself preoccupied with food. [Ich ertappe mich dabei, wie ich mich gedanklich ständig mit Essen beschäftige.]	8.	0.75	2.30 (1.19)	0.70
6. Whenever I have cravings, I find myself making plans to eat. [Immer wenn ich ein starkes Verlangen nach bestimmten Nahrungsmitteln verspüre, merke ich, dass ich gleich plane etwas zu essen.]	18.	0.70	3.08 (1.14)	0.66
7. I crave foods when I feel bored, angry, or sad. [Ich verspüre ein starkes Verlangen nach bestimmten Nahrungsmitteln, wenn ich mich gelangweilt, wütend oder traurig fühle.]	20.	0.68	3.15 (1.34)	0.64
8. I have no will power to resist my food crave. [Ich habe nicht die Willensstärke, um meinen Essensgelüsten widerstehen zu können.]	25.	0.68	2.87 (1.21)	0.63
9. Once I start eating, I have trouble stopping. [Wenn ich einmal anfange zu essen, fällt es mir schwer wieder aufzuhören.]	26.	0.81	2.54 (1.19)	0.77
10. I can't stop thinking about eating no matter how hard I try. [Ich kann nicht aufhören übers Essen nachzudenken, wie sehr ich mich auch bemühe.]	27.	0.81	1.82 (1.04)	0.76
11. If I give in to a food craving, all control is lost. [Wenn ich dem starken Verlangen nach bestimmten Nahrungsmitteln nachgebe, verliere ich jegliche Kontrolle.]	29.	0.84	1.87 (1.12)	0.80
12. Whenever I have a food craving, I keep on thinking about eating until I actually eat the food. [Immer wenn ich ein starkes Verlangen nach bestimmten Nahrungsmitteln verspüre, denke ich so lange weiter ans Essen bis ich diese tatsächlich esse.]	32.	0.79	2.35 (1.17)	0.75
13. If I am craving something, thoughts of eating it consume me. [Wenn ich ein starkes Verlangen nach bestimmten Nahrungsmitteln verspüre, verzehren mich die Gedanken daran diese zu essen geradezu.]	33.	0.76	1.90 (1.09)	0.71
14. My emotions often make me want to eat. [Meine Emotionen bringen mich oft dazu etwas essen zu wollen.]	34.	0.73	2.61 (1.23)	0.70
15. It is hard for me to resist the temptation to eat appetizing foods that are in my reach. [Wenn sich appetitliche Nahrungsmittel in meiner Reichweite befinden, fällt es mir schwer der Versuchung zu widerstehen sie zu essen.]	36.	0.63	3.50 (1.17)	0.58

[a] *Original item numbers refer to the 39-item version as displayed in Cepeda-Benito et al. (2000a,b), Meule et al. (2012a). Note that the German items were used in the current studies.*

marginally significant ($p < 0.10$) tests, except for $p < 0.001$ or $p \geq 0.10$ (*ns*).

RESULTS

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO = 0.93) and Bartlett's Test of Sphericity [$\chi^2_{(105)} = 3540.35$, $p < 0.001$] indicated that the data were adequate for conducting an exploratory factor analysis. Scree plot and parallel analysis clearly indicated a one-factorial structure (**Figure 1**) which explained 55.85% of variance. Factor loadings and item statistics are presented in **Table 1**. Internal consistency was high (Cronbach's $\alpha = 0.94$).

Women had higher FCQ-T-r scores ($M = 39.48$, $SD = 13.21$) than men [$M = 33.19$, $SD = 11.28$, $t_{(321)} = 3.22$, $p < 0.001$] and dieters ($M = 43.49$, $SD = 13.42$) had higher scores than non-dieters [$M = 34.82$, $SD = 11.62$, $t_{(321)} = 6.21$, $p < 0.001$]. Scores on the FCQ-T-r were weakly positively correlated with BMI and moderately negatively with dieting success (**Table 2**). The correlation between FCQ-T-r scores and BMI was slightly increased when controlling for sex ($r = 0.18$, $p < 0.001$) and was not significant when controlling for dieting status ($r = 0.08$, *ns*). The correlation between FCQ-T-r scores and dieting success was slightly reduced when controlling for sex ($r = -0.40$, $p < 0.001$) or dieting status ($r = -0.40$, $p < 0.001$)[2].

CONCLUSION STUDY 1

The FCQ-T-r had a one-factorial structure and high internal consistency. Women and current dieters had higher FCQ-T-r scores, replicating findings from studies using the long version (e.g., Cepeda-Benito et al., 2003; Meule et al., 2012a). Scores were weakly positively correlated with BMI which corresponds to correlations between $r = 0.10$–0.30 in studies with the long version (e.g., Franken and Muris, 2005; Meule et al., 2012a). Moreover, scores were moderately negatively correlated with self-perceived dieting success, which exactly matches the correlation of $r = -0.42$ found in the German validation study of the full version (Meule et al., 2012a).

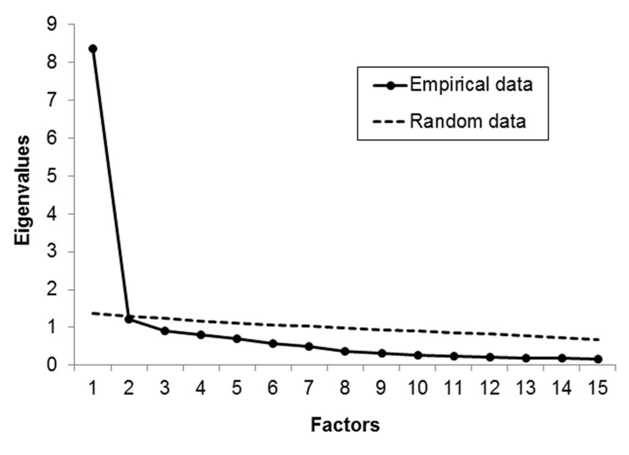

FIGURE 1 | Scree plot and parallel analysis of eigenvalues in study 1.

STUDY 2

METHODS

Questionnaires

Similar to study 1, participants completed the FCQ-T-r ($\alpha = 0.93$) and the PSRS ($\alpha = 0.63$). They also completed the FCQ-S before ($\alpha = 0.87$) and after the working memory task ($\alpha = 0.92$). Furthermore, restrained eating was measured with the *Restraint Scale* (RS; $\alpha = 0.77$) (Herman and Polivy, 1980; Dinkel et al., 2005). Impulsivity was measured with the short form of the *Barratt Impulsiveness Scale* (BIS-15; Spinella, 2007; Meule et al., 2011a) using its total score ($\alpha = 0.73$) and its subscales representing *non-planning* ($\alpha = 0.63$), *motor* ($\alpha = 0.69$), and *attentional impulsivity* ($\alpha = 0.64$). Eating disorder psychopathology was assessed with the *Eating Disorder Examination—Questionnaire* (EDE-Q; $\alpha = 0.95$) (Fairburn and Beglin, 1994; Hilbert and Tuschen-Caffier, 2006). Participants also reported the time since their last meal (hours), their age (years), and height and weight were measured for calculation of BMI (kg/m^2).

Stimuli

Thirty pictures of high-calorie foods and 30 pictures of neutral objects were selected from the *food.pics* database (cf. www.food-pics.sbg.ac.at; Meule and Blechert, 2012)[3]. Food pictures did not contain meat or fish because vegetarians were not excluded from the study. Exemplary food and neutral pictures are displayed in **Figure 2**. Picture categories did not differ in visual complexity as based on jpg file size, edge detection, and subjective ratings [all $ts_{(58)} < 1.48$, *ns*]. Food pictures represented

Table 2 | Descriptive statistics of and correlations between variables of study 1.

N = 323	*M* (*SD*)	1.	2.	3.	4.
1. FCQ-T-r	38.47 (13.11)	–	−0.07	0.15**	−0.42***
2. Age (years)	24.43 (5.64)		–	0.16**	−0.11*
3. Body-mass-index (kg/m^2)	22.00 (3.36)			–	−0.32***
4. Perceived Self-Regulatory Success in Dieting	12.14 (3.26)				–

FCQ-T-r, Food Cravings Questionnaire—Trait—reduced.
$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

[2]We also performed analyses separately for men and women. Results were similar with regard to factor structure (men: first two empirical eigenvalues 6.90 and 1.58, first two simulated eigenvalues 2.05 and 1.78; women: 8.56 and 1.18, 1.42, and 1.33), explained variance (men: 46.01%, women: 57.07%), internal consistency (men: $\alpha = 0.91$, women: $\alpha = 0.95$), and correlations with dieting success (men: $r = -0.34$, $p = 0.01$; women: $r = -0.41$, $p < 0.001$). However, FCQ-T-r scores were unrelated to BMI in men ($r = -0.00$, *ns*), but correlated with BMI in women ($r = 0.21$, $p = 0.001$).

[3]Picture numbers in the food.pics database: 6, 9, 10, 22, 27, 38, 41, 42, 56, 71, 82, 83, 89, 106, 111, 113, 115, 116, 120, 133, 137, 142, 143, 145, 159, 165, 166, 167, 172, 173, 1000, 1001, 1002, 1003, 1004, 1005, 1007, 1009, 1011, 1012, 1013, 1014, 1015, 1016, 1019, 1020, 1021, 1023, 1024, 1025, 1026, 1028, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036.

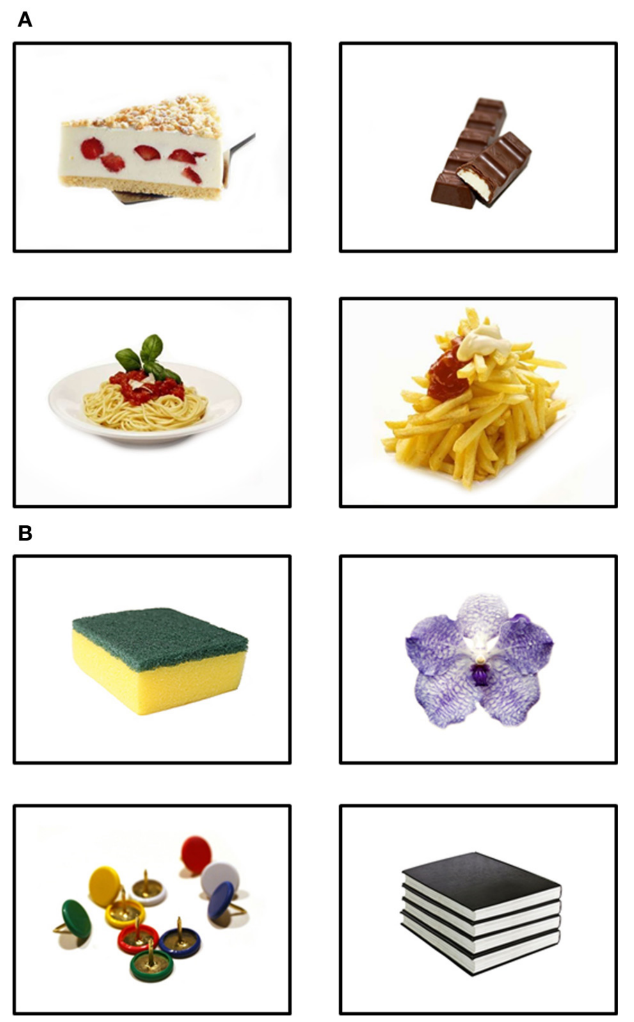

FIGURE 2 | Exemplary pictures of (A) food and (B) neutral items used in study 2.

food items with a mean calorie content of $M = 354.77$ kcal/100 g ($SD = 148.01$) and mean calories displayed on each image were $M = 736.95$ kcal/image ($SD = 832.70$).

n-back task

A working memory task, a version of the *n*-back paradigm, was used in the current study. In this task, stimuli are presented one-by-one and subjects are instructed to press a button whenever a stimulus is presented that is the same as the one presented *n* trials previously (so-called *targets*; in this case, it was a 2-back task). Participants first performed a practice block (14 trials) with numbers and received feedback in case of a false response. The main task consisted of a block with food pictures and a block with neutral pictures (order of blocks was counterbalanced across subjects). Each block contained 120 trials including 30 targets. Each picture was presented four times, but only once as target. Order of trials was pseudo-randomized such that order of target trials was equal in both blocks. Presentation time was 1500 ms or until a response was made. Inter-trial interval (blank screen) was 1000 ms.

Procedure and participants

Female psychology students ($N = 70$) were recruited in exchange for course credits. As men less frequently experience food cravings (Cepeda-Benito et al., 2003), they were excluded from the current study to avoid a confounding effect of gender and to ensure comparability to prior studies (cf. Meule and Kübler, in revision). Descriptive statistics of participant characteristics are depicted in **Table 3**. After signing informed consent, participants completed the FCQ-S and then performed the *n*-back task. After the task, they completed the FCQ-S again, followed by completion of the other questionnaires. Finally, weight and height was measured.

Data analysis

As the aim of the present study was to examine the relationships between the FCQ-T-r and state food craving, task performance in the *n*-back task will be reported elsewhere. Relationships between the FCQ-T-r and trait-related variables (age, BMI, PSRS, RS, BIS-15, EDE-Q) were evaluated with Pearson correlation coefficients. Scores on the FCQ-S after the task were compared to scores before the task with a paired-samples *t*-test. Furthermore, a difference score (FCQ-S after the task minus before the task) was calculated for correlational analyses with positive values indicating increases in state food craving during the task. Relationships between the FCQ-T-r and state-dependent variables (hours since the last meal, FCQ-S before the task, FCQ-S after the task, FCQ-S difference score) were evaluated with Pearson correlation coefficients. Finally, linear regression analyses were performed with current food deprivation (i.e., hours since the last meal) and FCQ-T-r scores as predictor variables and FCQ-S scores before the task, after the task, and the difference score as dependent variables. The interaction term of food deprivation × FCQ-T-r scores also was included in all models as relationships between FCQ-T-r scores and state food craving may be moderated by current food deprivation (e.g., maybe higher associations can be found in relatively sated vs. hungry individuals). All statistical tests are reported two-tailed. Exact *p*-values are reported in case of significant ($p < 0.05$) and marginally significant ($p < 0.10$) tests, except when $p < 0.001$ or $p \geq 0.10$ (*ns*).

RESULTS

Trait variables

Scores on the FCQ-T-r were moderately negatively correlated with self-perceived dieting success. Small-to-large positive correlations were found with BMI, attentional impulsivity, restrained eating, and eating disorder psychopathology. Scores on the FCQ-T-r were not correlated with age, non-planning impulsivity, motor impulsivity, or the BIS-15—total score (**Table 3**).

State variables

State food craving was increased after the task ($M = 37.69$, $SD = 11.21$) as compared to before [$M = 34.94$, $SD = 9.35$, $t_{(69)} = 3.21$, $p = 0.002$]. Scores on the FCQ-T-r were not correlated with current food deprivation, but were marginally significantly, positively correlated with state food craving before the task and the FCQ-S difference score and significantly correlated with state food craving after the task (**Table 4**; **Figure 3**).

Table 3 | Descriptive statistics of trait variables in study 2 and correlations with the *Food Cravings Questionnaire—Trait—reduced* (FCQ-T-r).

***N* = 70**	***M* (*SD*)**	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
1. FCQ-T-r	36. 99 (12.42)	–	−0.16	0.26*	−0.35**	0.64***	−0.12	0.01	0.40**	0.15	0.66***
2. Age (years)	22.00 (3.28)		–	0.07	0.04	−0.07	0.04	−0.04	0.07	0.03	−0.08
3. Body mass index (kg/m^2)	21.47 (2.82)			–	−0.43***	0.47***	0.06	0.05	0.11	0.11	0.36**
4. Perceived Self-Regulatory Success in Dieting	12.36 (3.20)				–	−0.42***	0.03	−0.01	−0.13	−0.06	−0.44***
5. Restraint Scale	12.10 (4.92)					–	−0.14	0.04	0.32**	0.11	0.78***
6. BIS-15—non-planning	11.01 (2.29)						–	0.58***	0.05	0.75***	−0.21#
7. BIS-15—motor	11.33 (2.39)							–	0.11		
8. BIS-15—attentional	10.41 (2.52)								–	0.57***	0.29*
9. BIS-15—total	32.76 (5.06)									–	0.05
10. EDE-Q—total	1.23 (1.02)										–

BIS-15, short form of the Barratt Impulsiveness Scale; EDE-Q, Eating Disorder Examination—Questionnaire.
*#p < 0.10, *p < 0.05, **p < 0.01, p < 0.001.*

Table 4 | Descriptive statistics of state variables in study 2 and correlations with the *Food Cravings Questionnaire—Trait—reduced* (FCQ-T-r).

***N* = 70**	***M* (*SD*)**	**1.**	**2.**	**3.**	**4.**	**5.**
1. FCQ-T-r	36. 99 (12.42)	–	−0.02	0.20#	0.31**	0.22#
2. Food deprivation (hours)	4.57 (5.11)		–	0.27*	0.21#	−0.03
3. FCQ-S—before task	34.94 (9.35)			–	0.77***	−0.10
4. FCQ-S—after task	37.69 (11.21)				–	0.56***
5. FCQ-S—difference score	2.74 (7.14)					–

FCQ-S, Food Cravings Questionnaire—State.
*#p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001.*

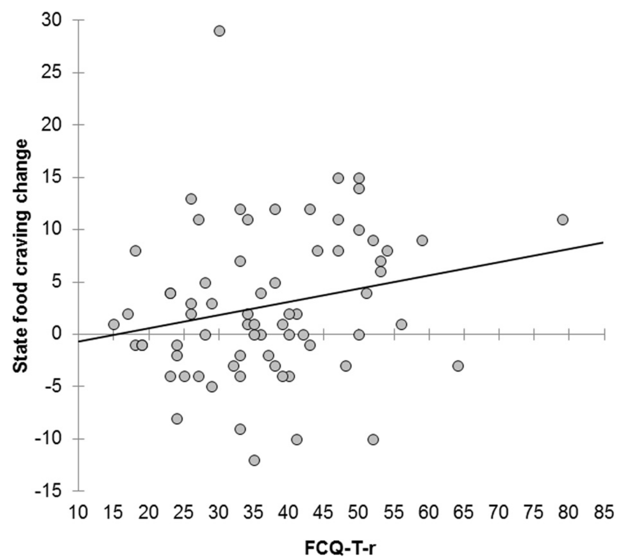

FIGURE 3 | Scatterplot showing the correlation between scores on the Food Cravings Questionnaire—Trait—reduced (FCQ-T-r) and increases in state food craving in study 2 ($r = 0.22$, $p = 0.07$). Exclusion of the two outliers on the top and the right-hand corner did not essentially alter this correlation ($r = 0.24$, $p = 0.05$).

Regression analyses

Food deprivation, but not FCQ-T-r scores, positively predicted state food craving before the task. Contrarily, FCQ-T-r scores positively predicted state food craving after the task while the influence of food deprivation was only marginally significant. Finally, FCQ-T-r scores, but not food deprivation, marginally significantly, positively predicted increases in state food craving during the task (**Table 5**).

Conclusion study 2

Again, the FCQ-T-r had high internal consistency and scores were weakly positively correlated with BMI and moderately negatively correlated with self-perceived dieting success. Furthermore, positive correlations were found with attentional impulsivity, restrained eating, and eating disorder psychopathology, which is in line with results of validation studies using the long version (Cepeda-Benito et al., 2000b, 2003; Moreno et al., 2008; Meule et al., 2012a). Overall, state food craving increased during performing the food-related working memory task. Importantly, FCQ-T-r scores specifically were related to increases in state food craving during the task and to increased state food craving after, but not before the task, independent of current food deprivation. Hence, the FCQ-T-r successfully proved to be a measure of the susceptibility to experience food-cue elicited craving, similar to findings of studies employing the long version (Tiggemann and Kemps, 2005; Meule et al., 2012d). It should be noted, however, that the association between FCQ-T-r scores and increases in state food craving is low, which is in line with correlations between $r = 0.20$–0.30 found in prior studies using the full version (Tiggemann and Kemps, 2005; Meule and Kübler, in revision).

Table 5 | Regression analyses for predicting state food craving by food deprivation and scores on the *Food Cravings Questionnaire—Trait—reduced* (FCQ-T-r).

	FCQ-S before			FCQ-S after			FCQ-S difference		
	β	*t*	*p*	β	*t*	*p*	β	*t*	*p*
Food deprivation (hours)	0.25	2.14	0.04	0.20	1.71	0.09	−0.01	−0.12	*ns*
FCQ-T-r	0.18	1.59	*ns*	0.30	2.59	0.01	0.23	1.87	0.07
Food deprivation × FCQ-T-r	−0.20	−1.68	*ns*	−0.13	−1.11	*ns*	0.05	0.43	*ns*

FCQ-S, Food Cravings Questionnaire—State.

DISCUSSION

The aim of the current study was to develop and validate a short form of the FCQ-T. For this purpose, 15 items with the highest item-total-correlations were selected from the original 39-item version (Cepeda-Benito et al., 2000a,b; Meule et al., 2012a). Expectedly, the FCQ-T-r clearly demonstrated a one-factorial structure in study 1 and had high internal consistency in both studies. The conceptual framework by Cepeda-Benito and colleagues (Cepeda-Benito et al., 2000a,b) acknowledges that food craving represents a multi-faceted construct and, thus, should be measured as such. Specifically, it was identified by the authors that food cravings embrace cognitive, physiological, and behavioral aspects such as (1) concrete intentions and plans to consume food, (2) anticipation of an increase in positive mood or (3) relief from negative states after eating, (4) a loss of control over eating, (5) thoughts or preoccupation with food, (6) hunger, (7) cues that may trigger food cravings, (8) emotions experienced before or during craving, and (9) guilt as a result of (giving into) craving (Cepeda-Benito et al., 2000a,b). Thus, our reduced version of the FCQ-T with only one factor somewhat deviates from the theoretical basis of the original version. It appears that the FCQ-T-r includes essential cognitive and behavioral aspects of food craving experiences such as thinking about food, intending to eat food and losing control over food intake. As a result of their low item-total-correlations, the FCQ-T-r does not include items related to the expected effects of eating such as anticipation of mood enhancing effects after eating and feelings of guilt after giving into cravings. Some researchers have included feelings and cognitions after eating (such as guilt) as an integral component of food craving (Benton et al., 1998; Cartwright and Stritzke, 2008). However, in line with other researchers (May et al., 2012), we would argue that the core components of food craving are its emotional and environmental triggers, mental imagery and cognitive elaboration, and behavioral consequences, that is, searching for and consuming food, which are aspects that are covered by the FCQ-T-r. Furthermore, the FCQ-T-r does not include items for the assessment of habitual hunger. In the FCQ-T, the hunger subscale had the lowest internal consistency (Meule et al., 2012a) and this is also the case in related measures of eating behavior (e.g., Renner et al., 2012). Thus, it may be that it is difficult for individuals to report about their habitual feelings of hunger, which leads to low reliability of such questions. To summarize, although the FCQ-T-r may have the limitation that only a subset of facets associated with food craving is covered, it may at the same time have the advantage that (1) aspects which are difficult to report such as habitual experiences of hunger or (2) aspects that may only be epiphenomenal such as expectations about thoughts and feelings after eating are excluded.

Moreover, although the FCQ-T-r covers fewer facets of food craving, relationships with validity indices were similar to studies that used the full version. That is, FCQ-T-r scores were elevated among women and current dieters, and a small positive relationship was found with BMI and a moderate negative relationship with self-perceived dieting success, replicating prior studies (e.g., Cepeda-Benito et al., 2003; Franken and Muris, 2005; Meule et al., 2012a). In addition, large positive correlations were observed with restrained eating and eating disorder psychopathology which, again, replicates previous studies using the full version (e.g., Cepeda-Benito et al., 2003; Moreno et al., 2008; Meule et al., 2012a; Van den Eynde et al., 2012). With regard to trait impulsivity, correlations were found with the attentional impulsivity subscale only, which is in line with recent findings showing that measures associated with overeating (e.g., the FCQ-T) are particularly related to attentional impulsivity, but only weakly and inconsistently with non-planning or motor impulsivity (Meule, 2013).

Validity was further supported by associations between the FCQ-T-r and self-reported current food craving before and after a food-related working memory task. It has been shown recently that participants reported elevated scores on the FCQ-S after they had performed food-related tasks assessing executive functions such as working memory (Meule et al., 2012d; Meule and Kübler, in revision). In those studies, scores on the FCQ-T were positively correlated with increases of FCQ-S scores during the task. Likewise, in the current study, FCQ-T-r scores were weakly positively correlated with increases in state food craving during a working memory task involving palatable food-cues. We could further demonstrate that FCQ-T-r scores were specifically related to food-cue elicited craving, but not to baseline craving levels. That is, state food craving before the task was predicted by current food deprivation, but not by trait food craving. Contrarily, trait food craving, but not food deprivation, predicted increases in state food craving as well as state food craving after the task.

Shortcomings of the current studies were, firstly, that the majority of participants in study 1, and all participants in study 2, were female students and most of them had normal weight. Thus, interpretation of the current results is limited to this population and results need to be replicated in other samples, particularly men and individuals with obesity or eating disorders. Secondly, as the FCQ-T-r only captures a subset of aspects related to food craving that are included in the full version, additional studies are necessary which directly compare the FCQ-T-r with the FCQ-T to evaluate if the reduced version can be used as a par for par substitute of the full version or if its use leads to different results. However, we would argue that associations with validity measures highly correspond to those found in validation studies of the original version, which does support its use as an alternative measure of trait food craving. This is also supported by a recent study using the Spanish FCQ-T, in which the FCQ-T-r was highly correlated with the full version and the remaining 24 items. Furthermore, correlations with validity measures were similar for the FCQ-T and FCQ-T-r (Rodríguez-Martín and Molerio-Pérez, in revision; see this Research Topic). Thirdly, future studies in which other methods for the assessment of state food craving are used would be valuable in further validating the FCQ-T-r. For example, such studies could include physiological recordings, such as heart rate, during food-cue exposure or ecological momentary assessment. Based on the current findings, scores on the FCQ-T-r should also predict heightened physiological reactivity in response to food-cues or more frequent food craving experiences in daily life, particularly in tempting situations.

To conclude, the current studies showed that the FCQ-T-r has high internal consistency. Relationships with validity measures were comparable to those in studies using the original version. Scores on the FCQ-T-r specifically predicted cue-elicited food craving, providing further support of its validity. Thus, the FCQ-T-r constitutes a succinct, valid and reliable self-report measure to efficiently assess experiences of food craving as a trait.

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Exploring the factor structure of the Food Cravings Questionnaire-Trait in Cuban adults

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Food cravings refer to an intense desire to eat specific foods. The Food Cravings Questionnaire-Trait (FCQ-T) is the most commonly used instrument to assess food cravings as a multidimensional construct. Its 39 items have an underlying nine-factor structure for both the original English and Spanish version; but subsequent studies yielded fewer factors. As a result, a 15-item version of the FCQ-T with one-factor structure has been proposed (FCQ-T-reduced; see this Research Topic). The current study aimed to explore the factor structure of the Spanish version for both the FCQ-T and FCQ-T-reduced in a sample of 1241 Cuban adults. Results showed a four-factor structure for the FCQ-T, which explained 55% of the variance. Factors were highly correlated. Using the items of the FCQ-T-reduced only showed a one-factor structure, which explained 52% of the variance. Both versions of the FCQ-T were positively correlated with body mass index (BMI), scores on the Food Thoughts Suppression Inventory and weight cycling. In addition, women had higher scores than men and restrained eaters had higher scores than unrestrained eaters. To summarize, results showed that (1) the FCQ-T factor structure was significantly reduced in Cuban adults and (2) the FCQ-T-reduced may represent a good alternative to efficiently assess food craving on a trait level.

Keywords: assessment, food cravings, factor analysis, reliability, food cravings questionnaire-trait, elaborated intrusion theory of desire

INTRODUCTION

Food craving is a motivational state, defined as an intense desire to eat specific foods (Tiggemann and Kemps, 2005). It is a common experience in everyday life for the majority of individuals. However, frequent experiences of food craving are associated with over- or binge eating (Kemps and Tiggemann, 2010; Havermans, 2013). Additionally, experiencing food cravings habitually could be a psychological factor that contributes to diet failure (Meule et al., 2012).

Cross-cultural studies have shown differences in the type of food cravings (Hormes and Rozin, 2010). Because of this, those instruments which assess general responses to food cues could be more useful than those which target specific foods. In order to assess habitual food cravings, the Food Cravings Questionnaire-Trait (FCQ-T) was designed (Cepeda-Benito et al., 2000b). This is the most extensively validated and adapted food craving measure, currently available in English, Spanish, Dutch, Korean and German (Cepeda-Benito et al., 2000a,b, 2003; Nijs et al., 2007; Rodríguez et al., 2007b; Noh et al., 2008; Meule et al., 2012).

The FCQ-T also measures craving for specific foods, but those are not explicitly pre-defined as in other questionnaires such as the Food Craving Inventory (White et al., 2002). The FCQ-T assesses food cravings as a multidimensional construct, divided in nine subscales (Cepeda-Benito et al., 2000a): intentions and plans to consume food; anticipation of positive reinforcement that may result from eating; anticipation of relief from negative states and feelings as a result of eating; possible lack of control over eating if food is eaten; thoughts or preoccupation with food; craving as a physiological state; emotions that may be experienced before or during food cravings or eating; environmental cues that may trigger food cravings; and guilt that may be experienced as a result of cravings and/or giving into them.

Scores on the FCQ-T have been positively related to body mass index (BMI) (Meule et al., 2012), sensitivity to reward (Franken and Murris, 2005), rigid dietary control strategies (Meule et al., 2011), obesity (Vander-Wal et al., 2007), eating disorder symptoms (Cepeda-Benito et al., 2003; Moreno et al., 2008) and food addiction symptoms (Meule and Kübler, 2012).

Another important variable that has not been investigated with the FCQ-T yet is food thoughts suppression (Barnes and Tantleff-Dunn, 2010). According to the Elaborated Intrusion Theory of Desire (EI-Theory), elaboration of unwanted intrusive thoughts about a desired target is a gateway which leads to cravings (Kavanagh et al., 2005). An intrusive thought could emerge from an associative process linked with: physiological deficit, negative affect, external cues, other cognitive activity and anticipatory responses to the target; but their progressive elaboration is the key process for the cravings' maintenance.

Food-related thoughts may play an important role in the maintenance of unhealthy eating behaviors and the suppression of these thoughts could provoke increased consumption of the desired food (May et al., 2012). Furthermore, there is evidence that supports the futility of the intention to suppress food-related thoughts to control food cravings in real life settings (Rodríguez-Martín et al., 2013). However, it is important to highlight that some individuals are more vulnerable to both intrusive thoughts about food and food cravings, even if they are not attempting to suppress them (May et al., 2012).

Although both the English and Spanish version of the FCQ-T yielded nine dimensions of food cravings, analyses of the factor structure of the FCQ-T showed fewer factors for the German and Dutch version (Nijs et al., 2007; Meule et al., 2012), as well as in overweight and obese individuals (Vander-Wal et al., 2007), including bariatric surgery candidates (Crowley et al., 2014). As a result, two reduced versions have been proposed: a 21-item version for assessing general food craving on a trait level (Nijs et al., 2007) and a 15-item version of the FCQ-T (FCQ-T-reduced) with a one-factor structure (Meule et al., 2014).

One possible explanation for these variations could be the difficulties encountered when translating the term craving into other languages. The majority of native speakers of 20 languages generally agreed that whatever translation they provided, was not completely adequate for capturing the meaning of the word *craving* (Hormes and Rozin, 2010). In fact, meanings could change among native speakers from the same language in different countries. For example craving could be translated in Spanish as *ansia* (Rodríguez et al., 2007a) or *antojo* (Cepeda-Benito et al., 2000a), but in Cuba many individuals mainly use some expressions such as "anxiety to eat" [ansiedad de comer], to refer to a strong desire to eat. In this context, *anxiety* does not refer to an emotion that leads to eating (Macht, 2008)[1], instead it means craving[2]. Some researchers are currently using the term *craving* in Spanish without translation (González and Donaire, 2012; Jáuregui-Lobera et al., 2012a,b).

Another explanation could be the context itself. Cubans prefer sweet and fatty foods over fruits and vegetables (Porrata-Maury, 2009), which is consistent with the food preferences generally associated with Western culture (Cepeda-Benito et al., 2000a); but our food environment could be quite different to the Spanish. Extreme difficulties experienced in Cuba between 1990 and 1995, known as the *special period*, conditioned a decrease of food availability for the majority of the population. For example, Cubans consumed approximately 1863 kcal of food per day during 1993 (Jiménez-Acosta et al., 1998), which is a very low amount of energy intake taking into account that participants of the well-known Minnesota Starvation Experiment consumed 1800 kcal of food per day during 6 months in 1945 (Kalm and Semba, 2005). After the *special period*, data from a national survey conducted during 2001 showed that overweight and obesity rates increased rapidly (Jiménez-Acosta et al., 2012). As it has been suggested the perception of harshness could promote overeating (Laran and Salerno, 2013) and individuals would be less motivated to exert their self-control (Hoffman and Kotabe, 2012).

Language and environment could influence the way food craving is experienced in everyday life. However, it is important to highlight that the nine-factor structure was obtained by confirmatory factor analysis (CFA) (Cepeda-Benito et al., 2000a,b; Moreno et al., 2008) while divergent factor structures were obtained by exploratory factor analysis (Nijs et al., 2007; Vander-Wal et al., 2007; Meule et al., 2012; Crowley et al., 2014; Meule et al., 2014). Exploratory factor analysis (EFA) is technically different from CFA: the first is used for theory-building, whereas the second is used primarily for theory-testing (Matsunaga, 2010). Because of this, it is necessary to explore the factor structure, validity and reliability of the Spanish version of FCQ-T and FCQ-T-reduced among Cuban adults.

As a first step a CFA was performed to test whether the data fit into the nine subscales of the Spanish FCQ-T as found by Cepeda-Benito et al. (2000a). A second step was to perform principal component analyses (PCA) on both the FCQ-T and FCQ-T-reduced, to analyze the resulting components, taking into account the particularities of the Cuban context previously described. PCA is considered as an effective tool to reduce a pool of items into a smaller number of components with loss of as little information as possible, (Matsunaga, 2010), whereas the number of factors was determined with parallel analysis (Hayton et al., 2004).

According to previous results, it was expected that PCA show a number of factors less than nine for the FCQ-T. With regard to reliability and validity indices, we expected for both versions high internal consistency, positive correlations with BMI, weight cycling and higher scores in restrained eaters and women as compared to unrestrained eaters and men. Finally, according to the EI-theory's prediction, a strong correlation between food cravings and food thoughts suppression was also expected.

MATERIALS AND METHODS

PARTICIPANTS

Sample characteristics are displayed in **Table 1**. Participants were 1241 individuals from the general population, who were between 18 and 64 years old ($M = 32.57$, $SD = 12.88$), with 68.7% being females. Regarding marital status, most of the participants 53.1% were single while 41.6% were married. In addition, 63.4% had obtained secondary education. The majority of participants were classified as *healthy* by the Cuban National Health Care System[3] (see Procedures section). Finally, BMI ranged between 18.52 and 39.47 kg/m^2 ($M = 26.06$, $SD = 4.14$). BMI was additionally classified according to standard guidelines (WHO, 2011) as normal weight (BMI = 18.50–24.99 kg/m^2), overweight (BMI = 25.00–29.99 kg/m^2) and obese (BMI > 30.00 kg/m^2).

Exclusion criteria included pregnancy, lactation, active eating disorders (Vander-Wal et al., 2007) or any diagnosed psychopathological disorder. Older adults (≥65 years) were also excluded, as it has been observed that there are changes at this stage not only in the amount or type of food and nutrients they consume, but in the way they think about food (Elsner, 2003).

MEASURES

Socio-demographic/anthropometric and clinical data

Participants were asked to provide age; gender; height; education level; marital status and current weight. Finally, clinical

[1]Some expressions like "My anxiety makes me eat" (Mi ansiedad me hace comer) could be more accurate to describe *emotional eating*. Other expressions like "I eat because of my anxiety" (Como por ansiedad) are more ambiguous and the researchers usually need to ask for its meaning.

[2]"Anxiety" could additionally mean *yearning* [see "Anxiety" (Ansiedad), a very popular song written by the Venezuelan composer José Enrique Sarabria in 1958].

[3]In Cuba each individual is regularly seen by the family physician who classifies his or her illness status.

Table 1 | Socio-demographic and clinical data of the sample.

Variable	Class	Freq.	%
Gender	Female	852	68.7
	Male	389	31.3
BMI	Normal weight	520	41.9
	Overweight	520	41.9
	Obese	201	16.2
Education	Primary	74	6.0
	Secondary	785	63.4
	Higher	380	30.7
Marital Status	Single	659	53.1
	Married	516	41.6
	Divorced	58	4.7
	Widow	8	0.6
Health condition	Healthy	958	77.2
	Asthma	77	6.2
	High blood pressure	80	6.4
	Diabetes	12	1.0
	Others	114	9.2

and psychopathological diagnoses were retrieved from medical records.

Restrained eating was assessed using a single item

Do you often restrain your food intake to reduce or maintain your weight? (Yes/No)

Weight cycling was assessed using 3 items from the Weight cycling questionnaire, with a Cronbach's $\alpha = 0.76$ (Rodríguez-Martín et al., 2012b)

(1) "How often are you a yo-yo dieter?"; (2) "How often do you start a diet and quit?" and (3) "How often do you regain more weight than you lost on a diet?" The Weight Cycling Questionnaire is a brief assessment of individuals' tendency to experience weight fluctuations (Peterson, 2008). Individuals respond to questions on a 5-point Likert scale ranging from 1 (never) to 5 (always). Higher scores represent a history of more diet failures.

Food cravings questionnaire-trait

The Spanish version of the questionnaire (Cepeda-Benito et al., 2000a) measures the intensity of nine trait dimensions of food cravings (see Introduction section). Instructions asked participants how frequently each statement "would be true for you in general" using a 6-point scale that ranged from 1 (*never* or *not applicable*) to 6 (*always*).

Food cravings questionnaire-trait-reduced

This is a 15-item version of the FCQ-T (Meule et al., 2014). Selected items were those with the highest item-total-correlations in the German FCQ-T validation study (Meule et al., 2012) and belonged to subscales from the Spanish version (Cepeda-Benito et al., 2000a; Moreno et al., 2008) *lack of control over eating* (items 2,3,25,26,29), *thoughts or preoccupation with food* (items 6,8,27, 31, 32), *intentions and plans to consume food* (items 5,18), *emotions before or during food craving* (items 20,33), and *cues that may trigger food craving* (item 35).

Food thought suppression inventory

This 15-item inventory was created based on the White Bear Suppression Inventory (Wegner and Zanakos, 1994), as a measure of food thought suppression (Barnes et al., 2009; Barnes and White, 2010). It was validated for a Cuban sample with a Cronbach's $\alpha = 0.95$ (Rodríguez-Martín et al., 2012a). Participants respond to questions such as, "There are foods that I try not to think about" on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

PROCEDURES

The study was approved by the Scientific Council at the authors' institution. Forty Psychology students called *surveyors* were trained for the sample selection and assessment (16 h at the authors' institution). Training included lectures about overweight and obesity, eating behavior and food cravings, as well as practical sessions on data collection. All the characteristics of the study were explained to them and they were also instructed to contact the main researcher in case of further doubts. After that, each surveyor was assigned to a supervisor from a health care institution from their municipality.

The sample selection was carried out in each surveyor's *health area* by inviting members of the corresponding community to participate through verbal announcements. All participants were visited in-person, informed about the study procedures by a surveyor, and signed an informed consent prior to assessment. Surveyors were asked to assess individuals who agreed to previously complete the corresponding measurements of weight and height at their physician's office and fulfilled the inclusion criteria after the revision of their medical records. The time required to complete the questionnaires never exceeded 45 min. All the participants voluntarily accepted to participate in the study and no compensation was offered to them.

STATISTICAL ANALYSES

CFA was performed with AMOS version 18 using the maximum-likelihood estimation method. The model fit was evaluated with the same fit indices reported by Cepeda-Benito et al. (2000b), which were: the χ^2 statistic; the Goodness-of-Fit Index (GFI); the Normed-Fit Index (NFI); the Tucker-Lewis Index (TLI); the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA). For the GFI, NFI, TLI, and CFI, values of approximately 0.90 or greater reflect an adequate fit (Byrne, 1989; Mulaik et al., 1989). Finally, values of the RMSEA of 0.05 or less indicate a close fit, values between 0.05 and 0.08 indicate adequate fit, and values greater than 0.10 indicate need for improvement in the model (Browne and Cudeck, 1993). All other analyses were performed with SPSS version 20. PCA was performed on both the FCQ-T and the FCQ-T-reduced, using an oblique rotation (Promax, $\kappa = 4$) because correlations between factors were expected. The number of factors was determined with parallel analysis (Hayton et al., 2004), which is considered one of the most accurate factor retention methods (Matsunaga, 2010). The *Kaiser-Meyer-Olkin Measure of Sampling Adequacy* and *Bartlett's Test of Sphericity* were used in order to test if data met requirements for exploratory factor analysis.

As a measure for internal consistency, Cronbach's α was determined for the full version of each questionnaire, as well as for the factors of the FCQ-T. Additionally, to examine the construct validity of each version, Pearson correlations were calculated between FCQ-T and FCQ-T-reduced scores and age, BMI, and scores on the Weight Cycling Questionnaire and Food Thought Suppression Inventory. Values of r above 0.1,0.3, and 0.5 were interpreted as small, medium and large effect sizes, respectively (Sink and Mvududu, 2010). Finally, differences in scores of both the FCQ-T and FCQ-T-reduced between men and women and between restrained and unrestrained eaters were tested with t-tests. Effect sizes were calculated with Cohen's d from t-test values using ViSta 7, where values of 0.2,0.5, and 0.8 were defined as small, medium and large effects, respectively (Ledesma et al., 2009). All statistical tests are reported two-tailed and p-values marked as *ns* refer to $p = 0.05$.

RESULTS

FCQ-T

The CFA fit indices of the FCQ-T were as follows: $\chi^2_{(90)} = 1159.729$, $p < 0.001$; GFI = 0.79; NFI = 0.84; TLI = 0.84; CFI = 0.86; and RMSEA = 0.07. Except for the RMSEA, all indices did not suggest a good fit for the nine-factor structure of the FCQ-T.

The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO = 0.97) and Bartlett's Test of Sphericity [$\chi^2_{(741)} = 27727.31$, $p < 0.001$] indicated that the data were adequate for conducting a PCA. Scree plot and parallel analysis indicated a four-factor structure (**Figure 1**), which explained 55.30% of variance. Eigenvalues before rotation were 16.2, 2.5, 1.6, and 1.2 and after rotation were 13.33, 10.91, 9.89, and 10.39.

A visual inspection of **Table 2** shows that our four-factor solution was not merely a combination of the nine original subscales. Factor 1 grouped items of *thoughts about food*, *intentions to consume food*, *guilt from cravings*, *lack of control* and *positive reinforcement*. Factor 2 included items of *lack of control over eating*, *cues that trigger food cravings* and one item of *guilt from cravings*. Factor 3 included items of *craving as hunger*, *anticipation of positive reinforcement from eating* and one item of *intentions to consume food.* Factor 4 included items of *emotions experienced during food cravings* and *anticipation of relief from negative states and feelings as a result of eating*.

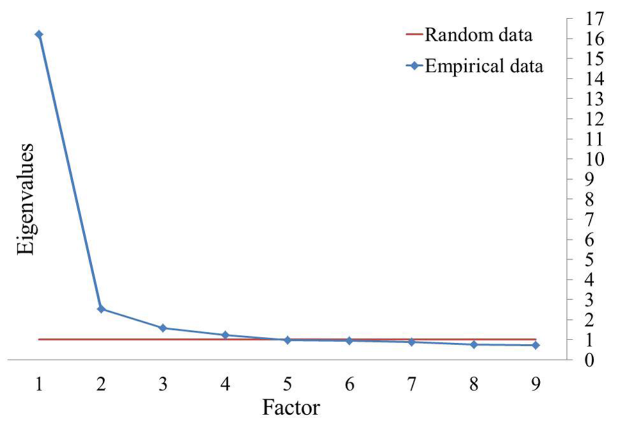

FIGURE 1 | Scree plot and parallel analysis of eigenvalues in FCQ-T.

Item difficulties ranged between 2.16 and 4.87, with highest mean scores grouped within Factor 3 (from 3.06 to 4.87, see **Table 2**). Range of item-total-correlations was $r = 0.451–0.755$ (**Table 2**) and factors were highly correlated with each other as with the FCQ-T total score (**Table 3**). Internal consistency was Cronbach's $\alpha = 0.92$ for the FCQ-T total score and for the subscales were as follow: $\alpha_{F1} = 0.93$, $\alpha_{F2} = 0.91$, $\alpha_{F3} = 0.85$, and $\alpha_{F4} = 0.84$.

Regarding construct validity of the FCQ-T, results are displayed in **Table 2.** FCQ-T total scores showed positive correlations with age (small effect size), weight cycling (from small to medium effect size), BMI (medium effect size) and food thoughts suppression (large effect size). Scores of Factor 1 and Factor 2 showed the same pattern as FCQ-T total scores, but in Factor 3 and Factor 4 the effect sizes tended to decrease and were considered as small for weight cycling and from small to medium for BMI. The effect size of food thoughts suppression was large either for the FCQ-T total score or for each subscale.

Restrained eaters had higher scores on food craving and all its dimensions than unrestrained eaters (**Table 4**). Women had significantly higher scores than men, except scores on Factor 3 (**Table 4**). Effect sizes could be generally considered small for gender and from small to medium for restrained eating.

FCQ-T-REDUCED

Just like the FCQ-T, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO = 0.95) and Bartlett's Test of Sphericity [$\chi^2_{(105)} = 10356.65$, $p < 0.001$] indicated that the FCQ-T-reduced data were also adequate for conducting a PCA. Scree plot and parallel analysis clearly indicated a one-factor structure (**Figure 2**), which explained 51.93% of variance. Factor loadings and item statistics are presented in **Table 5**. Internal consistency was Cronbach's $\alpha = 0.93$.

As can be seen in **Table 3**, the FCQ-T-reduced was highly correlated with the FCQ-T total score and all its dimensions. In addition, the FCQ-T-reduced showed positive correlations with age (small effect size), weight cycling (from small to medium effect size), BMI (medium effect size) and food thoughts suppression (large effect size). **Table 5** shows that women had higher FCQ-T-reduced scores than men and restrained eaters had higher scores than unrestrained eaters. Effect size could be considered small for gender and from small to medium for restrained eating. Finally, the FCQ-T-reduced showed a high correlation with the 24 excluded items ($r = 0.905$; $p < 0.001$).

DISCUSSION

The aim of the current study was to explore the factor structure, validity and reliability of the Spanish version of the FCQ-T and FCQ-T-reduced among Cuban adults. We included individuals

Table 2 | Factor loadings and item statistics of the food craving questionnaire trait.

Item	Factor				Description	Initial factor	Mean (*SD*)	$r_{\text{item-total correlation}}$
	1	2	3	4				
5	**0.528**	0.238	0.140	−0.067	Sin duda alguna, las ganas de comer me hacen pensar cómo voy a conseguirlo. [Food cravings invariably make me think of ways to get what I want to eat.]	Intentions to eat	2.98 (1.87)	0.708**
6	**0.778**	0.140	−0.143	0.000	No hago más que pensar en la comida. [I feel like I have food on my mind all the time]	Food-related thoughts	2.29 (1.56)	0.689**
7	**0.618**	0.246	−0.104	0.002	A menudo me siento culpable cuando deseo ciertas comidas. [I often feel guilty for craving certain foods]	Guilty feelings	2.61 (1.82)	0.666**
8	**0.778**	−0.151	0.089	0.008	A veces me encuentro pensativo preocupado con comida. [I find myself preoccupied with food]	Food-related thoughts	2.58 (1.73)	0.638**
9	**0.530**	−0.264	0.300	0.167	Como para sentirme mejor. [I eat to feel better]	Positive reinforcement	2.96 (1.81)	0.612**
10	**0.502**	−0.234	0.479	−0.018	Algunas veces, mi vida parece perfecta cuando como lo que me apetece. [Sometimes, eating makes things seem just perfect]	Positive reinforcement	3.41 (1.91)	0.605**
17	**0.499**	0.312	−0.159	0.042	Cuando como algo que deseo con intensidad me siento culpable. [When I eat what I am craving I feel guilty about myself]	Guilty feelings	2.61 (1.89)	0.606**
18	**0.415**	0.081	0.314	0.013	Cada vez que deseo comer algo en particular me pongo a hacer planes para comer. [Whenever I have cravings, I find myself making plans to eat]	Intentions to eat	3.22 (1.89)	0.676**
27	**0.805**	0.232	−0.148	−0.060	Por mucho que lo intento, no puedo parar de pensar en comer. [I can't stop thinking about eating no matter how hard I try]	Food-related thoughts	2.30 (1.66)	0.732**
28	**0.818**	0.102	−0.151	−0.024	Gasto demasiado tiempo pensando en lo próximo que voy a comer. [I spend a lot of time thinking about whatever it is I will eat next]	Food-related thoughts	2.16 (1.60)	0.667**
29	**0.582**	0.377	−0.079	−0.012	Si me dejo llevar por la tentación de comer pierdo todo mi control. [If I give in to a food craving, all control is lost]	Lack of control	2.53 (1.85)	0.743**
30	**0.901**	−0.024	−0.099	−0.110	A veces me doy cuenta de que estoy soñando despierto y estoy soñando en comer. [I daydream about food]	Food-related thoughts	2.16 (1.60)	0.612**
31	**0.528**	0.322	0.185	−0.133	Cada vez que se me antoja una comida sigo pensando en ella hasta que me la como. [Whenever I have a food craving, I keep on thinking about eating until I actually eat the food]	Food-related thoughts	3.08 (1.88)	0.755**
32	**0.485**	0.288	0.174	−0.044	Cuando tengo muchas ganas de comer algo estoy obsesionado con comerlo. [If I am craving something, thoughts of eating it consume me]	Food-related thoughts	3.02 (1.86)	0.752**
1	0.189	**0.356**	0.152	0.071	Cuando estoy con alguien que esta comiendo me entra hambre. [Being with someone who is eating often makes me hungry]	Cue-depending Eating	3.47 (1.80)	0.619**

(Continued)

Table 2 | Continued

Item	Factor				Description	Initial factor	Mean (*SD*)	$r_{\text{item-total correlation}}$
	1	2	3	4				
2	0.259	**0.523**	−0.024	0.077	Cuando tengo deseos intensos de comer, una vez que empiezo no puedo parar. [When I crave something, I know I won't be able to stop eating once I start]	Lack of control	3.01 (1.84)	0.687**
3	0.056	**0.551**	0.203	0.048	A veces, cuando como lo que se me antoja, pierdo control y como demasiado. [If I eat what I am craving, I often lose control and eat too much]	Lack of control	3.86 (1.85)	0.680**
4	0.054	**0.669**	−0.014	0.124	Detesto no poder resistir la tentación de comer. [I hate it when I give into cravings]	Guilty feelings	3.36 (1.99)	0.671**
22	−0.218	**0.558**	0.491	0.020	Si tengo la comida que deseo, no puedo resistir la tentación de comerla. [If I get what I am craving I cannot stop myself from eating it]	Lack of control	4.37 (1.74)	0.639**
25	0.120	**0.591**	0.153	0.015	No tengo la fuerza de voluntad de resistir mis deseos de comer lo que se me antoja. [I have no will power to resist my food crave]	Lack of control	3.54 (1.99)	0.704**
26	0.462	**0.485**	−0.102	0.028	Una vez que me pongo a comer tengo problemas en dejar de comer. [Once I start eating, I have trouble stopping]	Lack of control	2.79 (1.87)	0.737**
34	−0.069	**0.602**	0.206	0.048	Cada vez que voy a un banquete termino comiendo más de lo que necesito. [Whenever I go to a buffet I end up eating more than what I needed]	Cue-depending Eating	3.93 (1.94)	0.527**
35	−0.044	**0.665**	0.238	0.013	Es difícil resistir la tentación de tomar comidas apetecibles que están a mi alcance. [It is hard for me to resist the temptation to eat appetizing foods that are within reach]	Cue-depending eating	3.91 (1.94)	0.680**
36	0.230	**0.456**	−0.017	0.211	Cuando estoy con alguien que se pasa comiendo, yo también me paso. [When I am with someone who is overeating, I usually overeat too]	Cue-depending eating	3.10 (1.93)	0.717**
11	−0.209	0.186	**0.706**	−0.036	Se me hace la boca agua cuando pienso en mis comidas favoritas. [Thinking about my favorite foods makes my mouth water]	Feelings of hunger	4.69 (1.69)	0.474**
12	−0.202	0.220	**0.709**	−0.114	Siento deseos intensos de comer cuando mi estómago está vacío. [I crave foods when my stomach is empty]	Feelings of hunger	4.87 (1.57)	0.446**
13	0.164	0.102	**0.592**	−0.086	Siento como que mi cuerpo me pidiera ciertas comidas. [I feel as if my body asks me for certain food]	Feelings of hunger	4.00 (1.73)	0.607**
14	0.262	0.048	**0.404**	0.005	Me entra tanta hambre que mi estómago se siente como un pozo sin fondo. [I get so hungry that my stomach seems like a bottomless pit]	Feelings of hunger	3.49 (1.79)	0.580**
15	−0.019	−0.013	**0.783**	−0.013	Cuando como lo que deseo me siento mejor. [Eating what I crave makes me feel better]	Positive reinforcement	4.35 (1.71)	0.451**
16	0.321	−0.228	**0.359**	0.314	Cuando como lo que deseo me siento menos deprimido. [When I satisfy a craving I feel less depressed]	Feelings of relief	3.06 (1.85)	0.615**
23	−0.058	0.317	**0.616**	−0.047	Cuando se me antoja una comida, intento comerla tan pronto como pueda. [When I crave certain foods, I usually try to eat them as soon as I can]	Intentions to eat	4.10 (1.75)	0.628**

(Continued)

Table 2 | Continued

Item	Factor				Description	Initial factor	Mean (*SD*)	$r_{\text{item-total correlation}}$
	1	2	3	4				
24	0.008	0.092	**0.708**	−0.025	Comer lo que me apetece mucho me sienta estupendamente. [When I eat what I crave I feel great]	Positive reinforcement	4.14 (1.76)	0.593**
19	0.321	−0.124	0.237	**0.401**	El comer me tranquiliza. [Eating calms me down]	Feelings of relief	3.09 (1.78)	0.675**
20	−0.093	0.238	−0.007	**0.662**	Siento deseos de comer cuando estoy aburrida, enfadada, o triste. [I crave foods when I feel bored, angry, or sad]	Negative affect	3.19 (1.85)	0.622**
21	−0.250	0.146	0.122	**0.680**	Después de comer no tengo tanta ansiedad. [I feel less anxious after I eat]	Feelings of relief	3.40 (1.83)	0.522**
33	0.182	0.132	−0.129	**0.585**	A menudo deseo comer cuando siento emociones fuertes. [My emotions often make me want to eat]	Negative affect	2.72 (1.79)	0.613**
37	0.297	−0.080	0.214	**0.442**	Comer me alivia. [When I eat food, I feel comforted]	Positive reinforcement	3.10 (1.81)	0.699**
38	−0.095	0.210	−0.128	**0.798**	Cuando estoy muy estresada me entran deseos fuertes de comer. [When I'm stressed out, I crave food]	Negative affect	3.07 (1.85)	0.610**
39	0.089	−0.013	−0.221	**0.743**	Me entran deseos fuertes de comer cuando estoy disgustado. [I crave foods when I'm upset]	Negative affect	2.24 (1.61)	0.484**

$^{**}p < 0.001$.

Table 3 | Correlations between study variables.

	Mean (*SD*)	FCQ-T-r	FCQ-T	$F1_{FCQ-T}$	$F2_{FCQ-T}$	$F3_{FCQ-T}$	$F4_{FCQ-T}$	Age	BMI	WCQ
FCQ-T-r	45.02 (19.74)									
FCQ-T	120.81 (44.70)	973**								
$F1_{FCQ-T}$	37.92 (18.12)	0.942**	0.937**							
$F2_{FCQ-T}$	35.34 (14.01)	0.907**	0.917**	0.782**						
$F3_{FCQ-T}$	32.70 (9.74)	0.696**	0.789**	0.651**	0.702**					
$F4_{FCQ-T}$	20.79 (8.96)	0.807**	0.854**	0.756**	0.707**	0.605**				
Age	32.57 (12.88)	0.191**	0.182**	0.186**	0.177**	0.145**	0.117**			
BMI	26.06 (4.14)	0.346**	0.324**	0.292**	0.361**	0.196**	0.252**	0.521**		
WCQ	4.98 (2.87)	0.232**	0.219**	0.190**	0.251**	0.079**	0.210**	0.040 ns	0.276**	
FTSI	39.68 (17.82)	0.733**	0.720**	0.736**	0.660**	0.499**	0.555**	0.197**	0.330**	0.240**

FCQ-T, Food Craving Questionnaire-Trait; FCQ-T-r, Food Craving Questionnaire-Trait-reduced; $F1_{FCQ-T}$, Factor 1 of the Food Craving Questionnaire-Trait [Σ items 5–10, item 17, item 18, item 27–32]; $F2_{FCQ-T}$, Factor 2 of the Food Craving Questionnaire-Trait [Σ item 1–4, item 22, item 25, item 26, item 34-36]; $F3_{FCQ-T}$, Factor 3 of the Food Craving Questionnaire-Trait [Σ items 11–16, item 23, item 24]; $F4_{FCQ-T}$, Factor 4 of the Food Craving Questionnaire-Trait [Σ items 19-21, item 33, item 37–39]; BMI, Body Mass Index; WCQ, Weight Cycling Questionnaire; FTSI, Food Thoughts Suppression Inventory; $^{**}p < 0.001$.

from the general population; the majority of them were overweight and obese.

The factor structure of the Spanish version of the FCQ-T was considerably reduced in this study, which is consistent with previous results obtained with the German and Dutch versions (Nijs et al., 2007; Meule et al., 2012). However, our four-factor structure is not merely a combination of the nine original subscales.

Factor 1 included items related to the *conscious elaboration of food cravings*, which included food-related thoughts (e.g., "I spend a lot of time thinking about whatever it is I will eat next"), some guilty feelings (e.g., "I often feel guilty for craving certain foods"), intentions to eat (e.g., "Whenever I have cravings, I find myself making plans to eat"), a sense of lack of control (e.g., "If I give in to a food craving, all control is lost"), and positive reinforcement (e.g., "Sometimes, eating makes things seem just perfect"). It is important to highlight that this factor could be enough to assess food cravings, because of its large eigenvalue.

Table 4 | Food cravings comparisons according to gender and restrained eating.

	Gender Mean (*SD*)					Restrained Eating Mean (*SD*)				
	$F_{(n=852)}$	$M_{(n=389)}$	$t_{(1239)}$	Sig.	*d*	No ($n = 737$)	Yes ($n = 504$)	$t_{(1239)}$	Sig.	*d*
FCQ-T	124.48 (46.43)	112.78 (39.57)	4.306	<0.001	0.26	113.56 (43.77)	131.42 (43.97)	7.048	<0.001	0.41
F1	39.37(18.77)	34.75 (16.20)	4.198	<0.001	0.26	35.25 (17.62)	41.83 (18.16)	6.381	<0.001	0.37
F2	36.62 (14.20)	32.53 (13.18)	4.814	<0.001	0.29	32.81 (13.88)	39.03 (13.38)	7.869	<0.001	0.45
F3	33.05 (9.94)	31.94 (8.91)	1.891	0.059	0.11	31.94 (9.69)	33.81 (9.48)	3.362	0.001	0.19
F4	21.40 (9.29)	19.45 (8.02)	3.575	<0.001	0.22	19.57 (8.93)	22.58 (8.70)	5.888	<0.001	0.34
FCQ-T-r	47.01 (20.35)	40.65 (17.57)	5.326	<0.001	0.32	41.72 (19.27)	49.83 (19.44)	7.256	<0.001	0.42

FCQ-T, Food Craving Questionnaire-Trait; FCQ-T-r, Food Craving Questionnaire-Trait-reduced; F1 $_{FCQ-T}$, Factor 1 of the Food Craving Questionnaire-Trait; F2 $_{FCQ-T}$, Factor 2 of the Food Craving Questionnaire-Trait; F3 $_{FCQ-T}$, Factor 3 of the Food Craving Questionnaire-Trait; F4 $_{FCQ-T}$, Factor 4 of the Food Craving Questionnaire-Trait.

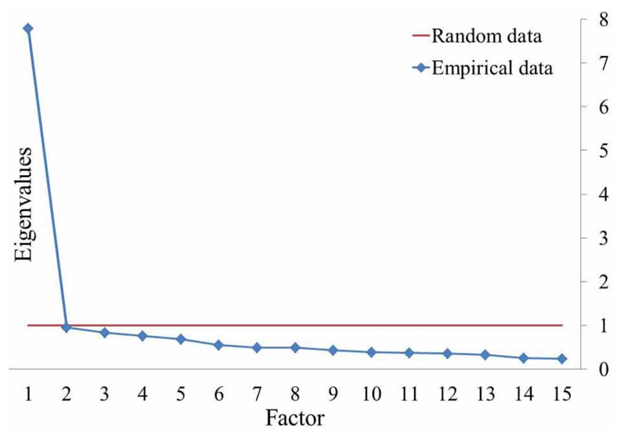

FIGURE 2 | Scree plot and parallel analysis of eigenvalues in FCQ-T-reduced.

Accordingly, Factor 1 is consistent with the EI-theory, which describes the conscious experience of craving as a cycle of mental elaboration of an initial intrusive thought (May et al., 2012). This food-related thought is initially pleasurable, based on previous experiences of *positive reinforcement*, motivating the individual to elaborate it by retrieving cognitive associations and creating mental imagery of the target, which included some consummatory fantasies. Then, this "exquisite torture" (Kavanagh et al., 2005) tends to increase the intentions to obtain the desired target. Finally, guilty feelings might accompany this process. It is necessary to point out that that items of guilty feelings and food-related thoughts were also grouped together under one subscale in the German FCQ-T (Meule et al., 2012).

Factor 2 could be named as *lack of control under environmental cues*. The Spanish translation of item 4 (**Table 2**) could be additionally interpreted as a feeling caused by lack of control ("Detesto no poder resistir la tentación de comer"/"I hate it when I give into cravings"). Participants tended to understand this sentence as "I hate when I cannot resist the temptation of eating" and they usually focused on the following idea: "I cannot resist the temptation of eating." Many participants emphasized this idea to surveyors while they completed the FCQ-T by saying: "Yes, I cannot resist the temptation of eating!"

Other items of this factor refer to cue-elicited eating. It has been observed that reward-related cues can instigate voluntary action to obtain such reward, through their impact on motivation and behavioral intention (Lovibond and Colagiuri, 2013). Paradoxically, it has been observed that weak temptations have a higher inhibiting effect on self-regulation processes than strong temptations (Kroese et al., 2010). Following the EI-theory, encounters with external cues, can trigger intrusive images or thoughts, starting an elaborative cycle sustained on individual motivation oriented toward the target. (May et al., 2012).

Factor 3 is linked with hedonic hunger rather than physiological hunger. Hedonic hunger substantially contributes to overeating in everyday life. As it has been suggested, delicious foods activate the neurochemical signals more potently than less tasty substances (Davis, 2013). In addition, it has been observed that food words activate eating simulations, particularly when these words refer to tempting food objects (Papies, 2013). In line with the EI-theory, the majority of items of this factor could be referred to the cognitive or physiological cues that trigger intrusive thoughts about food (May et al., 2012).

Finally, Factor 4 could be named as *eating to regulate emotions* or emotional eating, which is consistent with the five way model proposed by Macht (2008). Regarding item 37 (**Table 2**), although it belongs to the *positive reinforcement* subscale, its translation could also be interpreted as a feeling of relief. Additionally, emotional associations to food are the last topic that triggers food-related thoughts proposed by the EI-theory (May et al., 2012). Items from the original sub-scale of negative affect (Cepeda-Benito et al., 2000a) denote this type of triggers.

In line with other findings (Nijs et al., 2007; Vander-Wal et al., 2007; Meule et al., 2012; Crowley et al., 2014) the current results show that fewer factors than the original nine subscales of the FCQ-T can be found using PCA. It should be noted, however, that these reduced factor structures differed between studies and were different compared to the factor structure found in the current study. The four-factor structure obtained in the current study may represent how food cravings are commonly experienced in the majority of Cuban adults. In line with the EI-theory this factor structure could be divided into two broad dimensions. The first

Table 5 | Factor loadings and item statistics of the food craving questionnaire trait-reduced.

Item	Factor loading	Description	Original item no.	Initial factor	Mean (*SD*)	$r_{\text{item-total correlation}}$
1	0.722	Cuando tengo deseos intensos de comer, una vez que empiezo no puedo parar. [When I crave something, I know I won't be able to stop eating once I start]	2	Lack of control	3.01 (1.84)	0.722**
2	0.679	A veces, cuando como lo que se me antoja, pierdo control y como demasiado. [If I eat what I am craving, I often lose control and eat too much]	3	Lack of control	3.86 (1.85)	0.687**
3	0.734	Sin duda alguna, las ganas de comer me hacen pensar cómo voy a conseguirlo [Food cravings invariably make me think of ways to get what I want to eat.]	5	Intentions to eat	2.98 (1.87)	0.735**
4	0.734	No hago más que pensar en la comida. [I feel like I have food on my mind all the time]	6	Food-related thoughts	2.29 (1.56)	0.722**
5	0.650	A veces me encuentro pensativo preocupado con comida. [I find myself preoccupied with food]	8	Food-related thoughts	2.58 (1.73)	0.648**
6	0.679	Cada vez que deseo comer algo en particular me pongo a hacer planes para comer. [Whenever I have cravings, I find myself making plans to eat]	18	Intentions to eat	3.22 (1.89)	0.685**
7	0.623	Siento deseos de comer cuando estoy aburrida, enfadada, o triste. [I crave foods when I feel bored, angry, or sad]	20	Negative affect	3.19 (1.85)	0.634**
8	0.719	No tengo la fuerza de voluntad de resistir mis deseos de comer lo que se me antoja. [I have no will power to resist my food crave]	25	Lack of control	3.54 (1.99)	0.724**
9	0.795	Una vez que me pongo a comer tengo problemas en dejar de comer. [Once I start eating, I have trouble stopping]	26	Lack of control	2.79 (1.87)	0.788**
10	0.783	Por mucho que lo intento, no puedo parar de pensar en comer. [I can't stop thinking about eating no matter how hard I try]	27	Food-related thoughts	2.30 (1.66)	0.771**
11	0.791	Si me dejo llevar por la tentación de comer pierdo todo mi control. [If I give in to a food craving, all control is lost]	29	Lack of control	2.53 (1.85)	0.784**
12	0.784	Cada vez que se me antoja una comida sigo pensando en ella hasta que me la como. [Whenever I have a food craving, I keep on thinking about eating until I actually eat the food]	31	Food-related thoughts	3.08 (1.88)	0.782**
13	0.779	Cuando tengo muchas ganas de comer algo estoy obsesionado con comerlo. [If I am craving something, thoughts of eating it consume me]	32	Food-related thoughts	3.02 (1.86)	0.777**
14	0.633	A menudo deseo comer cuando siento emociones fuertes. [My emotions often make me want to eat]	33	Negative affect	2.72 (1.79)	0.638**
15	0.673	Es difícil resistir la tentación de tomar comidas apetecibles que están a mi alcance. [It is hard for me to resist the temptation to eat appetizing foods that are within reach]	35	Cue-depending eating	3.91 (1.94)	0.683**

$^{**}p < 0.001$.

dimension is linked to the conscious elaboration of food cravings (Factor 1) and the second to *triggers* of intrusive thoughts about food (Factors 2–4).

Our results tend to confirm that the factor structure of the FCQ-T seems to be rather unstable across different versions and samples using PCA, which is supported by lower fit indices obtained from CFA in the current sample. The FCQ-T-reduced, however, showed a clear one-factor structure and high internal consistency, replicating the results obtained in the original German sample (Meule et al., 2014). Furthermore, the FCQ-T-reduced was highly correlated with the FCQ-T total score and its subscales, as well as with the excluded items. Finally, it is important to note that PCA explained a relatively small amount of variance for both the FCQ-T and the FCQ-T-reduced which suggests that the number of retained factors could be scarce.

Both the FCQ-T and FCQ-T-reduced showed very similar validity indices, as found in previous studies. That is, total scores were positively correlated with weight cycling and BMI. Although small or moderate relationships with BMI have also been found in other studies (Meule et al., 2012, 2014), BMI is not only influenced by eating behavior or food cravings, but many other factors such as genetics and environment.

With respect to weight cycling, dieters tend to experience stronger cravings that are more difficult to resist, and for the foods they are not allowing themselves to eat (Massey and Hill, 2012). For example, overweight and obese individuals with a lifetime number of weight-loss treatments more than five showed higher scores on FCQ-T than those with fewer weight-loss treatments (Fabbricatore et al., 2012).

Women and restrained eaters obtained higher scores than men and unrestrained eaters. It has been observed that women report higher levels of craving than men (Cepeda-Benito et al., 2003). In addition, obese and overweight female patients attending a low calorie diet therapy experienced more cravings for food than their male pairs (Imperatori et al., 2013). Finally, food cravings fully mediated the inverse relationship between rigid control strategies and dieting success (Meule et al., 2011) and it has been observed that chronic food restriction can trigger the desire to eat, even in the absence of hunger (Pelchat and Schaefer, 2000).

The fact that the highest correlation was found between food cravings and food-thoughts suppression brings an additional support to the EI-theory (May et al., 2012). This may be the most used strategy to control unwanted thoughts about food, but it is counterproductive (Erskine, 2008; Erskine and Georgiou, 2010). Thus, it should be assessed in future studies as an important predictor of food cravings (Barnes and Tantleff-Dunn, 2010).

The positive correlation between age and food cravings was an unexpected result. The relationship of food cravings with age might not even be strictly linear, but more complex and many factors such as gender or the effort required to achieve thought suppression could be involved. Regarding *gender,* a previous study has found that concerns about eating in men were most pronounced in the age range of 55–64 years while in women highest scores were found in those younger than 24 years (Hilbert et al., 2012). With respect to the effort required to achieve thought suppression, a recent experiment found that *suppression effort* increased linearly according to the participants' age, but *perceived difficulty* did not (Magee et al., 2014).

Another explanation for this result can be found in the extreme difficulties experienced in Cuba during the *special period* (Jiménez-Acosta et al., 2012). Taking into account the requirement of daily energy intake during 1993, the indices consumed according to age ranges were: 100% from 0 to 6 years; 90% from 7 to 13 years; 70% from 14 to 65 years and 90% in older adults (Jiménez-Acosta et al., 1998). Furthermore, the amount of energy intake exceeded the requirements for children and older adults during 1997 but barely reached 80% for youngsters and middle-aged adults (Jiménez-Acosta et al., 1998). Regarding eating, maybe the *special period* was longer and harder for youngsters and middle-aged adults. This harsh environment could condition strong food cravings in a complete generation of Cuban adults (currently older than 30 years old). It is thought that cravings for sugar and fat evolved to enhance human energy intake in unpredictable nutritional environments (Davis, 2013).

Nevertheless, the above explanation regarding the effect of the *special period* which might have conditioned an increase in food cravings in adults older than 30 years old is rather speculative and future studies should address this issue. It would be interesting to compare a Cuban cohort affected by the *special period* with the same cohort in other countries that did not experience the same difficulties regarding variables such as BMI, eating behavior and food cravings.

To summarize, both the FCQ-T and FCQ-T-reduced showed good validity indices and high internal consistency. However, the FCQ-T factor structure was significantly reduced in Cuban adults and contextual differences might have contributed to obtain this four-factor structure. Finally, the FCQ-T-reduced may represent a good alternative to efficiently assess food craving on a trait level because it showed high correlations with the FCQ-T total score as well as the rest of the items, and because its validity indices are similar to the full version.

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Cafeteria diet impairs expression of sensory-specific satiety and stimulus-outcome learning

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A range of animal and human data demonstrates that excessive consumption of palatable food leads to neuroadaptive responses in brain circuits underlying reward. Unrestrained consumption of palatable food has been shown to increase the reinforcing value of food and weaken inhibitory control; however, whether it impacts upon the sensory representations of palatable solutions has not been formally tested. These experiments sought to determine whether exposure to a cafeteria diet consisting of palatable high fat foods impacts upon the ability of rats to learn about food-associated cues and the sensory properties of ingested foods. We found that rats fed a cafeteria diet for 2 weeks were impaired in the control of Pavlovian responding in accordance to the incentive value of palatable outcomes associated with auditory cues following devaluation by sensory-specific satiety. Sensory-specific satiety is one mechanism by which a diet containing different foods increases ingestion relative to one lacking variety. Hence, choosing to consume greater quantities of a range of foods may contribute to the current prevalence of obesity. We observed that rats fed a cafeteria diet for 2 weeks showed impaired sensory-specific satiety following consumption of a high calorie solution. The deficit in expression of sensory-specific satiety was also present 1 week following the withdrawal of cafeteria foods. Thus, exposure to obesogenic diets may impact upon neurocircuitry involved in motivated control of behavior.

Keywords: obesity, sensory-specific satiety, devaluation, incentive value, Pavlovian conditioning

INTRODUCTION

Access to highly palatable and calorically rich foods is a major contributing factor to the increasing rates of obesity worldwide (Caballero, 2007). Eating is essential for survival and is underpinned by the fundamental physiological need to consume energy. However, our basic requirements for nutrients and energy to maintain physiological homeostasis are often exceeded by an abundant source of readily available and convenient sources of foods and drinks. Consumption beyond basic homeostatic needs, purely based on the rewarding properties of palatable foods, is proposed to be a central contributor to the current worldwide obesity epidemic (Berthoud, 2004).

A range of animal and human data demonstrates that excessive consumption of palatable food leads to changes in the sensitivity of brain reward circuitries. These reward pathways are highly conserved across species and have been associated with altered responsiveness to reward (e.g., food) in obesity. Studies have demonstrated diminished responsiveness to perform food motivated behaviors and rewarding intracranial self-stimulation in obese rats (Volkow and Wise, 2005; la Fleur et al., 2007; Pickering et al., 2009; Johnson and Kenny, 2010) and reduced sensitivity to reward (measured by ratings of motivation and pleasure derived from engaging in rewarding behaviors) in obese humans (Davis et al., 2004).

Reward-based feeding, or eating for pleasure, can be prompted by learning that certain highly palatable foods are associated with discrete cues. Studies using functional brain imaging in obese subjects show that palatable foods and food-associated cues increase activity in cortical regions associated with motivational control and reward-based feeding including the orbitofrontal cortex (OFC), insula, amygdala, hypothalamus, striatum, and midbrain regions including the ventral tegmental area (VTA; Wang et al., 2001; Stice et al., 2008; Martin et al., 2010).

It has been proposed that sensitivity to cues predictive of food reward is increased in obesity (Stice et al., 2008), and may modulate the associative properties of food-related cues, evoking cravings for particular foods, triggering over-consumption (Meule et al., 2012; Jastreboff et al., 2013; Meule et al., 2014). Reducing the incentive value of a particular food associated with an operant response or a conditioned stimulus (CS) by lithium-induced devaluation, or pre-feeding to satiety decreases performance of particular responses (Dickinson et al., 1996; Balleine and Dickinson, 1998; Reichelt et al., 2011, 2013). Recently, rats ingesting a sucrose solution or a high fat/high sugar solution were shown to demonstrate impairments in outcome devaluation in an operant setting (Kendig et al., 2013; Furlong et al., 2014), indicating that consumption of high-energy foods can induce differences in reward-oriented instrumental behavior. This value driven control of responding has also been observed in a Pavlovian setting, whereby rats will reduce food seeking (goal-tracking or magazine-approach) behaviors associated with presentation of a CS whose associated unconditioned stimulus (US) has been separately devalued (Pickens et al., 2003, 2005; Ostlund and Balleine, 2007; Johnson et al., 2009; Lelos et al., 2011). These results suggest that the motivational value of a palatable outcome can control the performance of food seeking behaviors and if these associations are maladaptive, cues may promote responding regardless of whether the food is valued, so evoking over-eating. Another notion is that obesity may enhance resistance to satiation (Morgan, 1974; Capaldi et al., 1981), whereby a sated animal will continue to perform an instrumental response to gain food reward even when the incentive value of food is low. This concept bears many similarities to habitual responding, whereby a well-practiced behavior can be evoked through the presence of a stimulus alone (Dickinson et al., 1995; Killcross and Coutureau, 2003).

In addition to food-associated cues promoting consumption, the variety of foods in diets have also been shown to influence consumption. Animal and human studies show that food consumption increases when there is more variety in a meal or diet and that greater dietary variety is associated with increased body weight and adiposity. The presentation of a wide range of foods evokes over-eating, known as the "buffet effect" (Rolls et al., 1981; Rolls, 1984). This overeating plays an important role in food choice and meal termination, and may constitute one of the mechanisms that contributes to obesity. This enhancement of food consumption when presented with a variety of available foods may have an evolutionary advantage, potentially to prevent nutritional deficiencies (Rolls, 1981). The converse of the variety effect is the depressed consumption when the diet is unchanged. This depression is likely due to sensory-specific satiety, which has been defined as the decrease in the hedonic pleasantness of a food after it is eaten (Snoek et al., 2004). This decrease in the palatability of a consumed food shifts preference toward other foods, resulting in their consumption (Rolls, 1981). Following satiation on one food mice, rats, and primates also choose to eat an alternative food (Rolls et al., 1989; Dickinson et al., 1996; Balleine and Dickinson, 1998; Ahn and Phillips, 1999; Reichelt et al., 2011, 2013; Ahn and Phillips, 2012).

Animals rapidly gain weight when provided with a variety of foods (cafeteria diet) compared to a diet of just one food (Rolls et al., 1981) suggesting that food variety may not only impact upon body mass as a factor of increased consumption but may also impact upon sensory-specific satiety. Thus, a diet high in variety may influence the devaluation of a particular food associated with a CS, and also constrain behavioral control based on incentive value.

Effects of food variety on sensory specific satiety have been little explored, particularly in animal models. In this study we sought to establish the impact of a rodent model of diet-induced obesity that utilizes a diet reflective of a modern obesogenic diet (Hansen et al., 2004; Martire et al., 2013) upon CS-outcome associations and the expression of specific satiety.

MATERIALS AND METHODS

EXPERIMENT 1A – IMPACT OF OUTCOME-DEVALUATION ON PAVLOVIAN CONDITIONED APPROACH

Subjects

Subjects were 32 experimentally naïve male Sprague–Dawley rats obtained from Animal Resources Center (Perth, WA, Australia). Rats were 6 weeks old at arrival and weighed 230–270 g. They were housed in groups of four in plastic cages (36 cm wide × 26 cm high × 62 cm deep) located in a temperature and humidity controlled room (Mean temperature 20 ± 2°C, humidity 50 ± 5%) on a 12 h light: 12 h dark cycle (lights on at 07:00). Testing was carried out during the light phase of the cycle, between 08:00 and 13:00. During testing, rats were water restricted (2 h access per day between 13:00 and 15:00). Food was available ad lib throughout testing; in the control diet condition this was standard laboratory chow and in the cafeteria diet condition this was laboratory chow supplemented with a range of foods eaten by people (see below). During behavioral training water access was restricted within the home cages to 3 h per day following training sessions. All experimental procedures were approved by the Animal Care and Ethics Committee at the University of New South Wales and were in accordance with the National Institutes of Health Guidelines for the Care and Use of Laboratory Animals (revised 1996).

Diet

Rats were handled daily and allowed to acclimatize to housing for one week. Standard lab chow and water was available ad lib. Following this acclimatization, rats were randomly allocated to either standard lab chow (Group Chow) or a high fat cafeteria diet (Group Cafeteria) condition ($N = 16$ per group). Standard chow provided 11 kJ/g, 12% energy as fat, 23% protein, and 65% as carbohydrate (Gordon's Specialty Stockfeeds, NSW, Australia). The cafeteria diet consisted of lab chow supplemented with four commercially available foods. Rats were given a standardized selection of foods each day which previous studies from our laboratory show are equally well preferred; each day foods consisted of two savory items (e.g., pies, dim sims) and two sweet items (e.g., cookies, cakes, biscuits). This diet provided an average of 13.8 kJ/g, 33% energy as fat, 11% protein, and 56% as carbohydrate, in addition to that provided by the standard laboratory chow. Rats consuming this cafeteria diet obtain approximately four times the energy and have a fat mass 2.5times greater than control rats fed standard laboratory chow (Martire et al., 2013). The cafeteria diet was presented inside the home cages daily, at 13:00 h; the cafeteria foods were available *ad libitum* and changed daily to allow measurements of energy intake and prevent spoilage. Water was available *ad libitum*. Energy intake and body weight were measured once per week. On the intake measurement days foods were consistent across weeks, rats received beef pie (8.55 kJ/g, Coles, Australia), Dim Sims (7.9 kJ/g, Coles, Australia), jam roll (14.9 kJ/g, Coles, Australia), lamington cakes (13.8 kJ/g, Coles, Australia) in addition to standard lab chow (11 kJ/g).The amount consumed was the difference between the weight of the food allocated to a cage and that remaining 24 h later. Energy intake for each cage was calculated using the known energy content (kJ/g) and macronutrient content (% protein, carbohydrate, and fat) of each food. This was divided between the numbers of rats in the cage ($N = 4$) to obtain mean energy consumption per rat. Rats were exposed to the cafeteria diet for 2 weeks prior to Pavlovian conditioned approach training.

Apparatus

Rats received Pavlovian training in four chambers (30 cm wide, 21 cm high, and 24 cm deep) located in sound-attenuating boxes (Med Associates, St Albans, VT, arranged in a two-by-two array in a room which remained dark throughout the experiment. Each chamber consisted of three walls and a ceiling, with the door serving as the fourth wall. The ceiling, door and back wall were made from clear Perspex and the left and right walls were made from stainless steel. The floor of each chamber consisted in stainless steel rods (4.8 mm in diameter, spaced 16 mm apart). Each chamber was illuminated by a 3W house light located at the top center of one wall and a speaker was fitted into this wall. The opposite walls of the chambers were fitted with a recessed magazine with two metal spouts to allow separate delivery of solutions via pumps. The solutions used were 10% (w/v) sucrose flavored with 0.05% (w/v) cherry Kool Aid, and 10% (w/v) maltodextrin flavored with 0.05% (w/v) grape Kool Aid.

An infra-red camera located in the sound attenuating box allowed behavior to be recorded to DVD for subsequent scoring of magazine entry behavior. A computer equipped with MED-PC software (version IV; Med Associates Inc.) controlled the stimulus and outcome presentations. The stimuli consisted of a 2 kHz 78 dB pure tone and a 75 dB white noise measured by a sound level meter (Dick Smith Electronics, Australia).

Procedure

Pavlovian conditioning. Rats were trained to consume the solutions from the magazine during a 30 min session, repeated over 2 days. Pavlovian training was carried out over 12 days (one session per day) during which two discriminable auditory stimuli (CS): white noise or tone – presented 10 times each in a randomized order each session for 15 s. Each CS (noise or tone; counterbalanced across rats) was consistently followed by presentation of one of the solutions, e.g., tone followed by 0.1 ml of cherry flavored sucrose [outcome 1 (O1)] and noise followed by 0.1 ml of grape flavored maltodextrin[outcome 2 (O2)] as shown in **Figure 1A**. Each stimulus presentation was separated by a variable inter-trial interval (ITI; mean 90 s) and a PreCS (15 s).

Outcome devaluation. Devaluation consisted in allowing the rats to drink to satiety one of the solutions (O1 or O2). Rats were placed in individual plastic cages (30 cm wide, 25 cm high, 45 cm deep) with a wire mesh ceiling and a sawdust covered floor. Rats were presented with either 50 ml of grape maltodextrin or cherry sucrose solution in a measuring tube bottle with a ball bearing drinking spout. One half of the rats were devalued with outcome O1, the other half with O2. Therefore, each rat was devalued with an outcome associated and not associated with each auditory cue. Rats were returned to their home cages for 2 h and were then tested.

Test. Magazine activity was measured by head entry into the recessed magazine during non-reinforced auditory CS presentations. There were three randomized presentations of the white noise and of the tone, each presentation being 15 s in duration and each presentation separated by a variable stimulus free period ITI (mean = 90 s) and 15 s PreCS. Two observers, "blind" with respect to the assignment of groups, scored the amount of time each rat spent entering the magazine during each CS presentation. The correlation between their scores was high, $r = 0.82$.

EXPERIMENT 1B – SENSORY-SPECIFICSATIETY IN CAFETERIA DIET EXPOSED RATS

Subjects and apparatus

Rats from Experiment 1A were tested for consumption in individual plastic cages (30 cm wide, 25 cm high, 45 cm deep) with a wire mesh ceiling and a sawdust covered floor 1 week after finishing Experiment 1A. Two palatable solutions were used as described in Experiment 1A; 10% (w/v) sucrose flavored with 0.05% (w/v) cherry Kool Aid and 10% (w/v) maltodextrin flavoured with 0.05% (w/v) grape Kool Aid dissolved in tap water. These solutions were matched for energy content (1680 kJ per 100 ml)and previously demonstrated to be equally preferred and discriminable (Reichelt

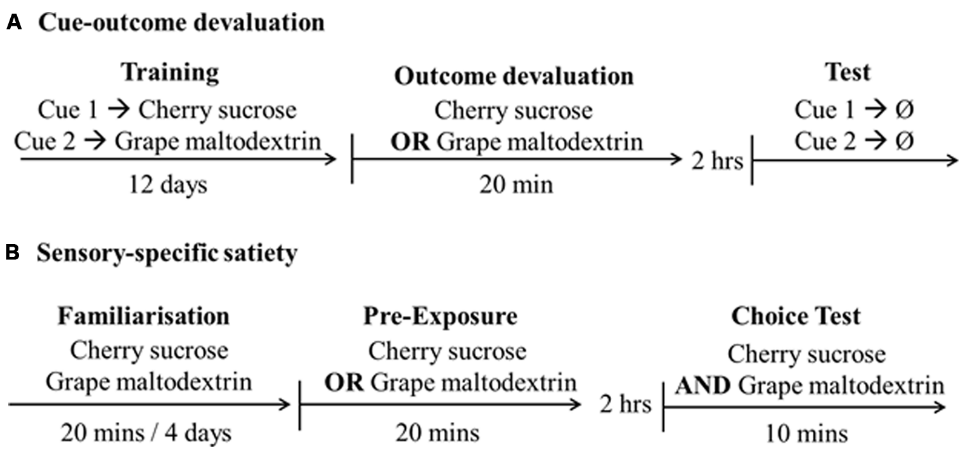

FIGURE 1 | Design and timeline of the studies. (A) Cue-outcome devaluation and **(B)** Sensory-specific satiety, indicating outcomes [cherry sucrose, grape maltodextrin, or no reward (Ø)].

et al., 2013). Rats were presented with 50 ml of the solutions in a plastic measuring tube bottle with a ball bearing drinking spout.

Procedure

As shown in **Figure 1B** rats were familiarized with the solutions in the individual testing chambers over a 2 day period. Rats received a ball spouted bottle containing 50 ml of each solution separately in a 20 min session across the 2 days. Rats received two tests on consecutive days. Rats were placed in the testing chambers and allowed to freely consume one solution for 20 min. This solution was the cherry flavored sucrose for half of the rats and grape flavored maltodextrin for the remainder. They were then returned to their home cage for 2 h. The rats were then returned to the individual testing chambers for 10 min and presented with two bottles; one containing the solution which the rats had drank 2 h previously and the second bottle containing the other solution. Volumes consumed were recorded as ml. On Day 1 rats were exposed to a solution (e.g., cherry sucrose) and then tested with both solutions presented simultaneously (cherry sucrose and grape maltodextrin). On Day 2, rats were exposed to the alternative solution (grape maltodextrin) and then tested with both solutions simultaneously. Thus, a within-subject comparison could be made in a fully counterbalanced manner.

EXPERIMENT 2 – EXPRESSION OF SENSORY-SPECIFIC SATIETY FOLLOWING LIMITED PRE-EXPOSURE VOLUME

Subjects

Subjects were 24 naïve adult male Sprague-Dawley rats obtained from Animal Resources Centre (Perth, Western Australia). They weighed between 435–510 *g* and were housed in the manner described previously with *ad libitum* access to water and standard chow.

Apparatus

Individual consumption cages were identical to that described in Experiment 1.The two solutions used in this experiment were 10% (w/v) sucrose and 14% (w/v) vanilla Sustagen (Nestle) dissolved in tap water. These solutions were used in Experiments 2 and 3 to assess the reliability of effects observed with cherry flavored sucrose and grape flavored maltodextrin solution. Solutions were matched for energy content of 1680 kJ per 100 ml; pilot studies indicated the solutions were equally preferred and discriminable.

Procedure

The rats were familiarized with these solutions in a 2 day pilot study, where the rats were exposed to one solution (e.g., sucrose) on day one, and the other solution (e.g., vanilla Sustagen) on day two. One week later they received one test of sensory-specific satiety. The rats were allowed to consume a limited volume of an outcome during pre-exposure in order to assess whether the smaller volume consumed by cafeteria diet fed rats was capable of inducing sensory-specific satiety. The rats were presented with 10 ml of either solution during pre-exposure for 20 min. Rats were returned to their home cages for 120 min. At test, rats were presented with a two bottle choice test as described previously.

EXPERIMENT 3 – SENSORY-SPECIFIC SATIETY IN CAFETERIA DIET WITHDRAWN RATS

Subjects and diet

Adult male Sprague–Dawley rats ($N = 24$), obtained from Animal Resources Center (Perth, Western Australia), were used as subjects and housed as described above. Half of the rats ($N = 12$) were maintained on the cafeteria diet described previously for 10 weeks, and the remainder were fed standard chow. After 10 weeks the cafeteria diet was withdrawn from the rats and replaced with standard chow for 1 week prior to testing.

Apparatus

The two solutions used in this experiment were 10% (w/v) sucrose and 14% (w/v) vanilla Sustagen (Nestle) dissolved in tap water (as Experiment 2). Rats were presented with 50 ml of the solutions in a plastic measuring tube bottle with a ball bearing drinking spout. Rats were tested for consumption in the individual plastic and wire cages described previously.

Procedure

The rats were already familiar with these solutions from a pilot study that tested whether consumption of the two solutions was comparable across diet groups across a 2 day period where the rats were exposed to one solution (e.g., sucrose) on day one, and the other solution (e.g., vanilla Sustagen) on day two, so both groups were matched in their history of consuming each of the test solutions. Rats were tested a week later for specific satiety over a 2 day period as described in Experiment 1B.

Statistical analysis

Results are expressed as mean ± SEM. Data were analyzed using IBM SPSS Statistics 22 and GraphPad Prism 6. Data were analyzed using repeated measures analysis of variance (ANOVA), analysis of covariance (ANCOVA), or independent t-test where appropriate. *Post hoc* tests were performed where significant interactions were observed, and controlled by Bonferroni correction. The critical F was chosen to maintain the type 1 error rate at less than 0.05.

RESULTS

EXPERIMENT 1A – IMPACT OF OUTCOME-DEVALUATION ON THE CONTROL OF PAVLOVIAN RESPONDING

Body weight

Rats exposed to the cafeteria diet for 14 days had significantly greater body weights than chow fed animals (**Figure 2A**). This was confirmed by repeated measures ANOVA with between subject factors of diet (cafeteria, chow) and within subject factor of diet exposure (days). This revealed a significant main effect of diet exposure, $F(4,120) = 1003.9$, $p < 0.001$, no main effect of diet, $F(1,30) = 2.0$, $p = 0.165$, and a significant interaction between diet exposure × diet, $F(4,120) = 21.9$, $p < 0.001$. Inspection of the simple main effects indicated that all rats increased in weight across exposure to cafeteria and chow diets, (F's > 141.1, $p < 0.001$). However, cafeteria diet fed rats were significantly greater in body mass after 14 days exposure, $F(1,30) = 13.2$, $p = 0.001$.

Energy consumption

Rats fed the cafeteria diet consumed, on average, 2.5 times more energy (as kJ) than the chow fed rats, as shown in

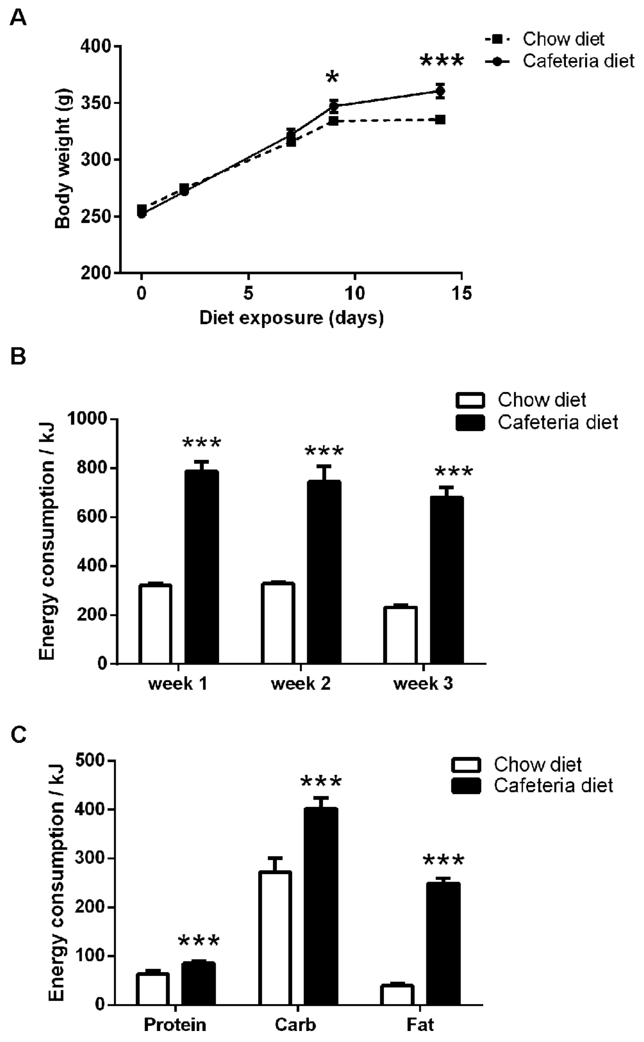

FIGURE 2 | (A) Body weight of cafeteria ($N = 16$) and chow ($N = 16$) diet rats. **(B)** Total energy intake over 24 h (kJ/rat). **(C)** Macronutrient intake over 24 h (protein, carbohydrate, and fat) as energy (kJ/rat). Data presented as mean (±SEM). $^*p < 0.05$, $^{***}p \leq 0.001$ compared to chow, Bonferroni corrected.

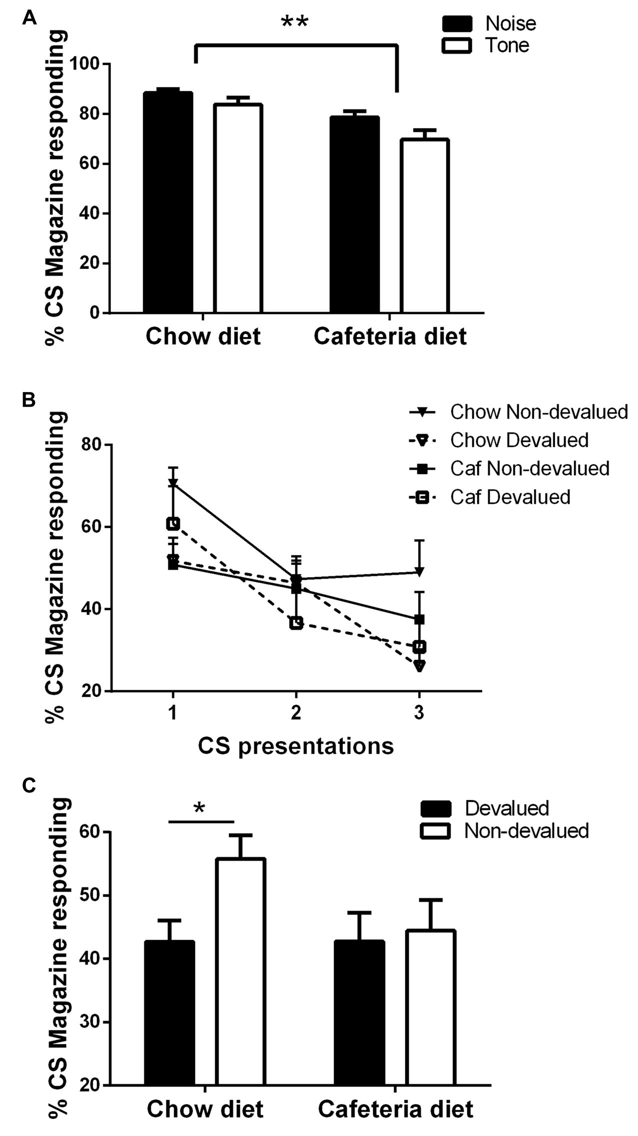

FIGURE 3 | (A) Magazine responding in the final training session; **(B)** Magazine responding (Mean CS1-3) at test and **(C)** Mean magazine responding at test across all CSfor chow diet rats ($N = 14$) and cafeteria diet rats ($N = 15$). Data presented as mean (±SEM). $^*p < 0.05$, $^{**}p < 0.01$ Bonferroni corrected.

Figure 2B. Repeated measures ANOVA between subject factors of diet (cafeteria, chow) and within subject factor of diet exposure (week) revealed a significant main effect of diet, $F(1,3) = 433.4$, $p < 0.001$, no significant main effect of diet exposure, $F(2,6) = 3.5$, $p = 0.097$, and no significant diet x exposure interaction, $F < 1$. As shown in **Figure 2C**, rats fed the cafeteria diet consumed significantly more energy (kJ) as protein, ($t = 8.4$, $df = 6$, $p < 0.001$), carbohydrate, ($t = 8.0$, $df = 6$, $p < 0.001$), and fat, ($t = 21.7$, $df = 6$, $p < 0.001$), than chow fed rats.

Training

As illustrated in **Figure 3A**, both cafeteria diet and chow fed rats learned about the CS–US relations, as shown by % time spent making magazine responses during the 15 s CS presentations on the last day of training relative to the PreCS. This was confirmed by ANOVA with within-subject factors of CS (noise, tone), and between-subject factors of diet (cafeteria, chow), which revealed a significant main effect of CS [$F(1,27) = 8.5$, $p < 0.01$] and diet [$F(1,27) = 13.4$, $p < 0.01$], indicating that the chow rats spent a greater % of time in the magazine during the CS presentations, and that these rats responded more to the noise than tone. There were no statistically significant two-way interactions between CS × diet ($F < 1$). Chow and cafeteria fed rats responded equally during the PreCS periods (Mean % PreCS magazine responses: chow = 8.1 (±2.2), cafeteria = 10 (±3.6), independent samples t-test $t < 1$. Furthermore, there was no difference between responding to the CS based on its associated outcome pairing, confirmed by ANOVA demonstrating no significant main effect of counterbalancing

[$F(1,25) = 1.8$, $p = 0.197$]. No interactions were significant (F's < 4.03).

Outcome devaluation

Three rats were excluded from the statistical analysis (two from the chow and one from the cafeteria diet condition) due to not consuming the solution during the outcome devaluation or failing to make magazine responses during the extinction test. Chow fed rats consumed a significantly greater volume of the devalued outcome during pre-exposure [Mean (±SEM): Cafeteria = 8.93 ml (0.79 ml), Chow = 14.1 ml (0.85 ml); independent samples t-test $t = 4.44$, $df = 27$, $p < 0.001$].

Test

The test session was divided into three time points, each consisting of a presentation of the CS associated with the devalued outcome and the CS associated with the non-devalued outcome. As shown in **Figure 3B**, chow fed rats generally responded more to the CS associated with the non-devalued outcome, whereas cafeteria fed rats responded more to the CS associated with the devalued outcome during the first 2 CS presentations (time point 1which includes CS associated with devalued and non-devalued outcome). Analysis of % magazine responding across the three time points (CS associated with devalued and non-devalued outcome) by repeated measures ANCOVA with within subjects factors of devaluation (devalued, non-devalued) and time point (1–3), between subject factor of diet (cafeteria diet, chow), and covariate of volume consumed during outcome devaluation (consumption) revealed significant main effect of time point [$F(2,44) = 4.287$, $p < 0.001$] and devaluation [$F(1,22) = 6.3$, $p < 0.05$], but no significant main effect of diet [$F(1,22) = 2.73$, $p = 0.113$] or consumption [$F(1,22) = 1.16$, $p = 0.29$]. Significant interactions were observed between devaluation × diet [$F(1,22) = 8.66$, $p < 0.01$], time × devaluation [$F(1,22) = 3.97$, $p < 0.05$], time × devaluation × consumption [$F(2,44) = 3.86$, $p < 0.05$] and time × devaluation × diet [$F(2,44) = 3.29$, $p < 0.05$], no other interactions were significant ($Max\ F = 3.37$). Simple main effects were used to break down the devaluation × diet interaction. As shown in **Figure 3C**, no significant effect of devaluation was observed in cafeteria diet fed rats ($F < 1$), however, a significant effect of devaluation was observed in chow diet fed rats [$F(1,26) = 8.662$, $p < 0.01$].

EXPERIMENT 1B – SENSORY-SPECIFIC SATIETY IN CAFETERIA DIET EXPOSED RATS

Body weight

Rats assigned to the cafeteria and chow diets continued to be exposed to the allocated diet throughout training and testing. At test, rats in the cafeteria diet group were significantly heavier than chow fed rats [Mean (±SEM): Cafeteria = 530 g (13.5 g), chow = 457.9 g (7.8 g), $t = 4.6$, $df = 30$, $p < 0.001$].

SENSORY-SPECIFIC SATIETY TEST

Familiarization

As shown in **Figure 4A**, chow fed rats consumed a greater volume than cafeteria diet fed rats, but both groups drank similar amounts of both solutions. These observations were confirmed by a repeated measures ANOVA with within subject factors of solution (cherry sucrose, grape maltodextrin) and between subject factor of diet (cafeteria, chow), which revealed a significant main effect of diet [$F(1,30) = 13.6$, $p < 0.001$, but no significant main effect of solution ($F < 1$) or solution × diet interaction ($F < 1$).

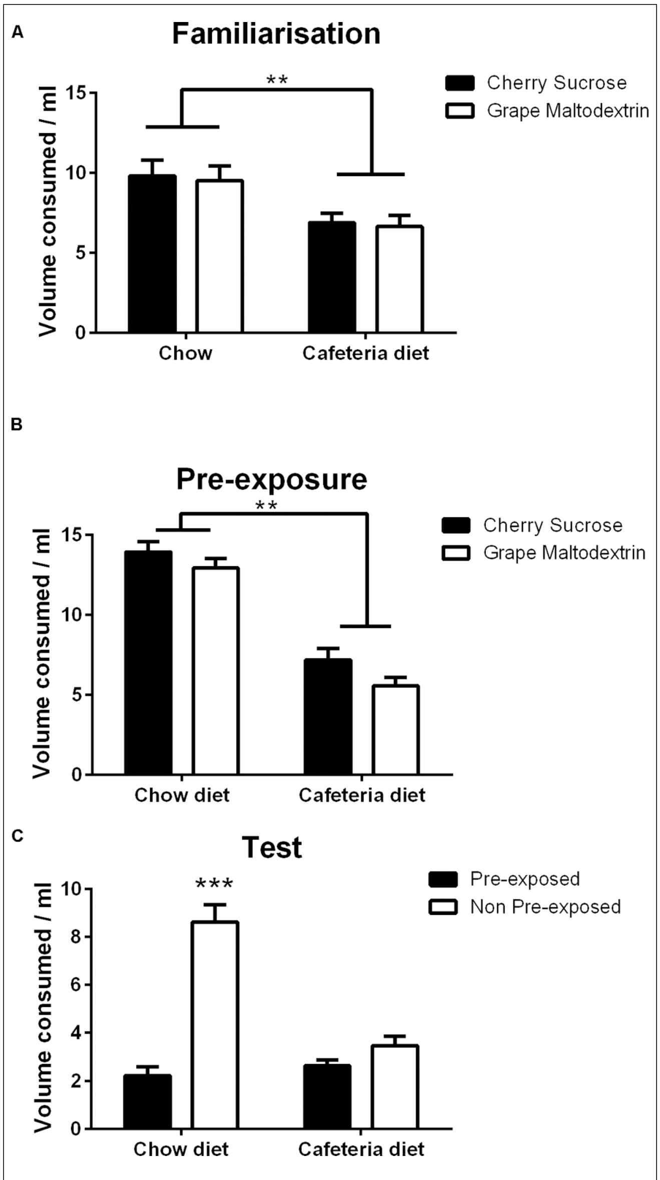

FIGURE 4 | Consumption of sample solutions during (A) Familiarization to the two solutions, (B) Pre-exposure to the solutions prior to test, (C) Sensory-specific satiety test indicating the mean volume consumed of the pre-exposed and non-pre-exposed solutions during two bottle choice testing by chow (*N* = 16) and cafeteria (*N* = 16) diet fed rats. Data presented as mean (±SEM). $^{**}p < 0.01$, $^{***}p < 0.001$. Bonferroni corrected.

Pre-exposure

Rats consumed similar volumes of each solution, and chow fed rats consumed a greater volume than cafeteria fed rats as shown in **Figure 4B**. This observation was confirmed by ANOVA with within subject factors of solution (cherry sucrose, grape maltodextrin) and between subject factor of diet (cafeteria, chow), which revealed a significant main effect of solution [$F(1,30) = 6.2$, $p < 0.05$], which was due to greater intake of the cherry sucrose than the grape maltodextrin, a significant main effect of diet [$F(1,30) = 102.6$, $p < 0.001$], and no significant solution diet × interaction ($F < 1$).

Two bottle choice test

Chow fed rats consumed a greater volume of the non-pre-exposed solution, indicating sensory-specific satiety, whereas cafeteria diet rats consumed similar volumes of both the pre-exposed and non-pre-exposed solution, indicating the absence of sensory-specific satiety, as shown in **Figure 4C**. This observation was confirmed by a repeated measures ANCOVA with within subject factors of exposure (pre-exposed, non-pre-exposed), between subject factor of diet (cafeteria, chow) and covariate of volume consumed during pre-exposure, which revealed a significant main effect of exposure [$F(1,29) = 4.598$, $p < 0.05$], no significant main effect of diet [$F(1,29) = 3.233$, $p = 0.083$], no significant effect of pre-exposure volume [$F(1,29) = 1.468$, $p = 0.235$]. A significant exposure × diet interaction was observed [$F(1,29) = 11.777$, $p < 0.01$], but no significant interaction between exposure and volume consumed during pre-exposure ($F < 1$). Simple main effects analysis of the solution exposure × diet interaction indicated that there was no effect of exposure in the cafeteria diet fed rats ($F < 1$), but a significant effect of exposure in chow fed rats [$F(1,29) = 40.107$, $p < 0.001$]. Thus, cafeteria diet fed rats treated the pre-exposed and non-pre-exposed solutions as equivalent, indicative of impaired sensory-specific satiety.

Preference between the two solutions consumed at test was equivalent, indicated by similar volumes consumed [Chow diet – Means (±SEM): cherry sucrose = 11.4 ml (0.78 ml), grape maltodextrin = 10.3 ml (0.89 ml). Cafeteria diet – Means (±SEM): cherry sucrose = 6.6 ml (0.97 ml), grape maltodextrin = 5.6 ml (0.58 ml)]. This observation was confirmed by repeated measures ANOVA with within subject factor of solution (cherry sucrose, grape maltodextrin) and between subject factor of diet (cafeteria, chow), with no significant main effect of solution [$F(1,30) = 1.569$, $p = 0.22$], a significant main effect of diet [$F(1,30) = 31.2$, $p < 0.001$], and no significant solution × diet interaction ($F < 1$).

EXPERIMENT 2 – EXPRESSION OF SENSORY-SPECIFIC SATIETY FOLLOWING LIMITED PRE-EXPOSURE VOLUME

Pre-exposure

Rats consumed equal volumes of each solution [Mean (±SEM) = sucrose 9.41 ml (0.36 ml), vanilla 9.16 ml (0.37 ml), independent samples *t*-test: $t < 1$].

Two bottle choice test

Chow fed rats consumed a greater volume of the non-pre-exposed solution, indicative of intact sensory-specific satiety [Means (±SEM): pre-exposed solution = 3.87 ml (0.69 ml), non-pre-exposed solution = 10ml (0.78 ml), paired samples *t*-test: $t = 4.95$, $df = 23$, $p < 0.001$]. Thus, rats pre-exposed to a limited volume of up to 10 ml demonstrated intact sensory-specific satiety. It can therefore be suggested that a smaller volume of solution during pre-exposure was sufficient to produce sensory-specific satiety at test in chow fed rats.

EXPERIMENT 3 – SENSORY-SPECIFIC SATIETY IN CAFETERIA DIET WITHDRAWN RATS

Body weight

At test, rats withdrawn from the cafeteria diet were still significantly heavier than rats only fed chow [Mean (±SEM): Ex-Cafeteria = 696.7 g (11 g), chow = 582.3 g (10.9 g), $t = 7.419$, $df = 22$, $p < 0.001$].

Pre-exposure

Rats consumed similar volumes of each solution, and chow fed rats consumed a greater volume than rats previously cafeteria diet fed (Mean (±SEM) Ex-Cafeteria = sucrose 16 ml (0.83 ml), vanilla 16.08 ml (1.4 ml), Chow = sucrose 21.08 ml (1.05 ml), vanilla 18.42 ml (1.07 ml). This observation was confirmed by ANOVA with within subjects factors of solution (sucrose, vanilla) and between subjects factor of diet (ex-cafeteria, chow), which revealed no significant main effect of solution [$F(1,22) = 1.4$, $p = 0.257$], a significant main effect of diet [$F(1,22) = 11.1$, $p < 0.01$], and no significant solution × diet interaction [$F(1, 22) = 1.0$, $p = 0.497$].

Two bottle choice test

Rats only ever fed chow consumed a greater volume of the non-pre-exposed solution, indicating sensory specific satiety, whereas rats withdrawn from the cafeteria diet and fed chow consumed similar volumes of both the pre-exposed and non-pre-exposed solutions, indicating the absence of sensory specific satiety, as shown in **Figure 5**. This observation was confirmed by ANCOVA with within subject factors of exposure (pre-exposed, non-pre-exposed), between subject factor of diet (ex-cafeteria, chow) and a covariate of pre-exposure volume consumed (pre-exposure) which revealed no significant main effect of exposure ($F < 1$), a significant main effect of diet [$F(1,21) = 3.56$, $p < 0.05$], and a significant exposure × diet interaction [$F(1,21) = 13.97$,

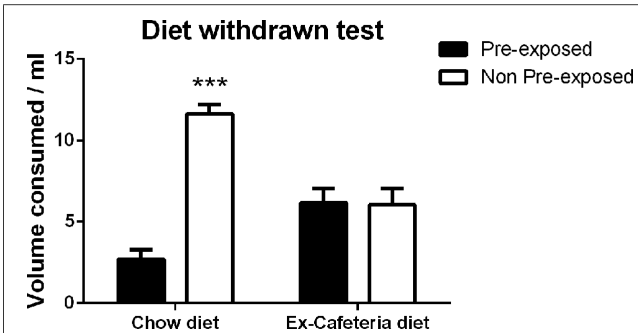

FIGURE 5 | Two bottle choice test of sensory-specific satiety following pre-exposure to palatable solutions in rats 1 week after withdrawal of the cafeteria diet (*N* = 12) and chow fed control rats (*N* = 12). Data presented as mean (±SEM). ***$p < 0.001$.Bonferroni corrected.

$p = 0.001$]. There was no main effect of pre-exposure volume as a covariate [F(1,21) = 3.56, $p = 0.073$], or exposure x pre-exposure interaction ($F < 1$). The simple main effects analysis indicated that there was no effect of exposure in the cafeteria diet fed rats ($F < 1$), however, there was a significant effect of exposure in chow fed rats [$F(1,21) = 32.564$, $p < 0.001$]. Thus, rats previously consuming a cafeteria diet still demonstrated impaired sensory-specific satiety 1 week following withdrawal of the cafeteria diet, indicative of a prolonged effect of the cafeteria diet.

In addition, there was no preference between the two different solutions consumed at test. ANOVA, with within subject factors of solution (sucrose, vanilla) and between subject factor of diet (ex-cafeteria, chow), confirmed that there was no significant main effect of solution [$F(1,22) = 1.6$, $p = 0.22$], diet [$F(1,22) = 3.6$, $p = 0.072$], and no significant solution × diet interaction ($F < 1$).

DISCUSSION

The results of the present experiments show that rats fed a cafeteria diet, containing foods eaten by people, were impaired in both the value-driven guidance of food seeking responses by cues associated with palatable solutions and in the expression of sensory-specific satiety. Moreover, this impairment in the expression of sensory specific satiety among rats fed the cafeteria diet was also present when this diet was removed and replaced with standard chow for 1 week. Finally, this impairment did not appear to be due to differences between the amounts consumed of the pre-exposed solution as chow fed rats exhibited sensory specific satiety independently of the amounts consumed of the pre-exposed solution, as shown by our analysis of covariance.

Neuroimaging studies in humans and non-human primates link the OFC to hedonic processing and the alignment of eating with the value of a food (Kringelbach et al., 2003; Kringelbach, 2005). Furthermore, primate studies indicated that consuming a food to satiety decreased neural responsiveness in the OFC, and this responsiveness is recovered upon the presentation of a new food (Rolls et al., 1990). Thus, the OFC has been implicated as a key neural region in the evaluation of the pleasurable aspects of palatable foods and in encoding the sensory attributes of these values. In light of the observation that sensory-specific satiety is impaired in rats fed a cafeteria diet, and evidence that the OFC is a critical region involved in integrating an updating value-based information about reward-predictive cues (Delamater, 2007; Ostlund and Balleine, 2007; Clark et al., 2012), we suggest that that the outcome-value encoding systems are disrupted following exposure to palatable foods in cafeteria diets. An implication of this suggestion is that presentation of a novel food to cafeteria-fed rats would fail to recover neural responses in the OFC and that this may disrupt the selection of a different food in the case of sensory specific-satiety and the updating of the incentive value of a food outcome to direct conditioned responding.

Rats fed a cafeteria diet responded to two cues predictive of separate palatable reward during training. However, following devaluation of one of these outcomes by specific satiety, cafeteria fed rats did not modulate magazine responding in accordance with the incentive value of the outcome. Our results indicate that chow rats were sensitive to devaluation, but cafeteria diet rats were not when analysis was carried out across all trials. However, it is worth noting that the magnitude of the devaluation effect changed across trials. This indicates that consumption of an obesogenic cafeteria diet may impact upon brain regions involved in the formation of stimulus-outcome associations and incentive value, such as the basolateral amygdala (BLA), striatum and OFC, as described previously. Johnson et al. (2009) reported that the BLA plays a critical role in devaluation performance after multiple-reinforcer Pavlovian conditioning. However, Johnson et al. (2009) utilized taste aversion as opposed to specific satiety to modulate the value of the appetitive outcomes, and also demonstrated that post-training BLA lesions disrupted the expression of incentive value-controlled behaviors. Similarly, Balleine et al. (2011) and Ostlund and Balleine (2007) found that OFC lesions disrupted the influences of Pavlovian stimuli during outcome-specific Pavlovian-instrumental transfer. The influence of outcome-related stimuli on choice involves a larger circuit including the OFC, the striatum, and the amygdala. In particular, the central nucleus of the amygdala has been shown to be necessary for conditioned approach to cues measured by sign-tracking behaviors (Gallagher et al., 1990; Parkinson et al., 2000); in addition, sensory-specific satiety is disrupted by transient inactivation of the central nucleus of the amygdala (Ahn and Phillips, 2002). Therefore, our observation of impaired sensory-specific satiety and cue-outcome associations may indicate that the cafeteria diet also affected central amygdala function.

The failure to detect an effect of the devalued outcome on the magazine approach responses elicited by its CS associate is consistent with human neuroimaging studies demonstrating differential activation of reward neurocircuitry (particularly the mesocorticolimbic dopamine system) by food-associated cues in obese subjects (Stoeckel et al., 2008, 2009; Jastreboff et al., 2013). Previous devaluation studies in rats have demonstrated that the BLA has a fundamental role in the maintenance of detailed sensory-specific outcome representations, allowing the integration of new information about outcome value into existing associative structures (Ostlund and Balleine, 2007). Furthermore, regions of the striatum, in particular the ventrolateral (Lelos et al., 2011), dorsomedial, and dorsolateral striatum (Corbit and Janak, 2010), have been implicated in Pavlovian outcome devaluation, as has the NAc core and shell (Corbit et al., 2001). However, OFC and BLA lesions have no detectable effects on the formation or flexible use of sensory-specific flavor-nutrient associations in a devaluation task (Scarlet et al., 2012), or consumption tests following devaluation (Corbit et al., 2001; Corbit and Janak, 2010; Lelos et al., 2011). Similarly, the NAc core and shell has been shown to be necessary for the control of Pavlovian conditioned responding following devaluation by LiCl induced nausea (Singh et al., 2010). These data suggest that NA core and shell are part of a circuit necessary for the use of cue-evoked information about expected outcomes to guide behavior, particularly involving regions such as the OFC and BLA that project to the NAc.

This is the first study to demonstrate impairment in the expression of sensory-specific satiety in rats fed a cafeteria diet, which may underpin maladaptive eating behaviors in obesity. Studies investigating whether obesity affects sensory-specific satiety in people have reported mixed results. Tey et al. (2012) found that people with a greater body mass index and fat mass showed decreased sensory-specific satiety at baseline. This study also showed that people who regularly consumed the same three energy dense snack foods showed a reduction in sensory-specific satiety over time, so eating of these snack foods became less influenced by the previously consumed foods. In contrast, limiting the variety of snack foods available resulted in decreased hedonic ratings of snack foods and reduced intake in both normal weight and overweight adult participants, indicative of long term sensory-specific satiety (Raynor et al., 2006). In contrast, a previous study with obese and normal weight participants showed no differences in sensitivity to sensory-specific satiety (Snoek et al., 2004).

In this study, we observed that cafeteria diet rats consumed equal volumes of the pre-exposed and non-pre-exposed solutions. This is an intriguing observation, as the failure of cafeteria diet fed rats to consume more of the novel solution may be construed as being protective against overeating and thus long term weight gain. Consumption of a varied diet of palatable foods that appears to disrupt the expression of sensory specific satiety may therefore result in a reduced susceptibility to the variety effect. This indicates that cafeteria diet fed rats may fail to “disinhibit” consummatory responses when given access to an assortment of novel, palatable foods. This is in contrast to literature describing the “buffet effect” whereby dietary variety promotes over consumption by switching to ingestion of novel foods (Rolls, 1981). Our data suggests that diets high in variety may override sensory specific satiety and promote consumption in general.

In the present experiments, rats fed the cafeteria diet consumed less of the palatable solutions than the chow fed rats. The reduced intake of palatable solutions is perhaps due to greater amounts of moisture in the cafeteria diet, thus the physiological impact of water restriction may be lessened, or to a lower hedonic value accruing to the solutions after constant exposure to a highly palatable diet in comparison to laboratory chow diet. Another alternative is that the decreased consumption in cafeteria diet fed rats was due to metabolic satiety, and that the decreased volumes consumed at test reflect this as opposed to impaired specific satiety. However, our analysis accounted for volume consumed during pre-exposure as a covariate factor, indicating that the expression of specific satiety was not influenced by the volume consumed. Furthermore, although we demonstrated that a limited pre-exposure volume of 10 ml was sufficient to evoke sensory specific satiety in chow fed rats, we did not test smaller volumes, as cafeteria diet rats consumed between 5–7 ml during pre-exposure. Additionally, following diet withdrawal ex-cafeteria diet fed rats consumed equal volumes overall of the solutions at test, yet exhibited a pronounced impairment in sensory-specific satiety, suggestive that this observation was not due to metabolic satiety.

These data suggest that cafeteria diet fed rats may fail to retain short-term information regarding recently consumed palatable foods (Henderson et al., 2013), and hence fail to exhibit sensory-specific satiety. Memory deficits and hippocampal dysfunction have been associated with diet-induced obesity (Greenwood and Winocur, 1990; Baybutt et al., 2002; Davidson et al., 2005; Granholm et al., 2008; Kanoski and Davidson, 2010, 2011; Darling et al., 2013), and these may contribute to overconsumption. In this model, a vicious cycle of obesity and deficits in hippocampal-dependent higher-order processes occur – including episodic memory (i.e., remembering what we have eaten) and our sensitivity to internal hunger and satiety cues (Davidson et al., 2007; Francis and Stevenson, 2011). This leads to impairments in inhibiting retrieval of the memory of the appetitive post-ingestive consequences of energy intake by environmental food-related cues, increasing the likelihood that those cues would evoke additional appetitive behavior (Davidson et al., 2005). However, it has been demonstrated hippocampal lesions do not influence sensory-specific satiety, or incentive value controlled instrumental responding in rats (Reichelt et al., 2011).

Habituation theory describe show sensory stimuli influence factors related to ingestive behavior, whereby responsiveness changes to foods and food-associated stimuli that are repeatedly experienced during a meal (Epstein et al., 1992, 2009; Raynor and Epstein, 2001). When people eat the same food during a meal they become habituated to the motivating properties of the food and decrease their consumption. Thus, when presented with a range of foods during meals the amount consumed increases, most likely because habituation is stimulus specific and because variety may introduce dishabituation effects (Raynor and Epstein, 2001). Exposure to the cafeteria diet which contains a variety of foods that are changed daily may have altered habituation to these foods and thus underpin the observed deficit in the expression of sensory-specific satiety.

Dopamine is proposed to play a role in motivated behaviors, and findings by Ahn and Phillips (1999) indicated that that NAc and PFC dopamine efflux may form an important signal encoding the relative incentive salience of foods and thus act as a determinant of the pattern of behaviors observed in sensory-specific satiety. Thus, our observation of impaired sensory-specific satiety in a rat model of dietary obesity may be a behavioral manifestation of mesocorticolimbic dopamine system dysfunction. The impact of diet-induced obesity may have effects on multiple brain regions, possibly impacting on levels of opioids (Woolley et al., 2007a,b) and/or dopaminergic transmission (Ahn and Phillips, 1999, 2002; Johnson and Kenny, 2010; Kenny et al., 2013).

CONCLUSION

Our current findings demonstrate that exposure to obesogenic “cafeteria” diets disrupt both the expression of sensory-specific satiety and stimulus-outcome associations. These observations are of importance in the understanding of how obesity may impact upon the processing of appetitive outcomes and associated stimuli, and also to how maladaptive associations may control food seeking behavior in the absence of physiological and homeostatic requirements. Future studies should extend our current observations, further reducing the pre-exposure volume and interrogating the enduring nature of the sensory specific satiety deficit we observed following 1 week diet withdrawal, and also whether the cue-devaluation effect persists following diet withdrawal.

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Food-pics: an image database for experimental research on eating and appetite

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Our current environment is characterized by the omnipresence of food cues. The sight and smell of real foods, but also graphically depictions of appetizing foods, can guide our eating behavior, for example, by eliciting food craving and influencing food choice. The relevance of visual food cues on human information processing has been demonstrated by a growing body of studies employing food images across the disciplines of psychology, medicine, and neuroscience. However, currently used food image sets vary considerably across laboratories and image characteristics (contrast, brightness, etc.) and food composition (calories, macronutrients, etc.) are often unspecified. These factors might have contributed to some of the inconsistencies of this research. To remedy this, we developed *food-pics*, a picture database comprising 568 food images and 315 non-food images along with detailed meta-data. A total of $N = 1988$ individuals with large variance in age and weight from German speaking countries and North America provided normative ratings of valence, arousal, palatability, desire to eat, recognizability and visual complexity. Furthermore, data on macronutrients (g), energy density (kcal), and physical image characteristics (color composition, contrast, brightness, size, complexity) are provided. The *food-pics* image database is freely available under the creative commons license with the hope that the set will facilitate standardization and comparability across studies and advance experimental research on the determinants of eating behavior.

Keywords: standardized food images, food pictures, food-cues, image properties, ERP, fMRI, eating behavior, obesity

INTRODUCTION

Our current environment is characterized by frequent cues for highly palatable foods. Many researchers partially attribute rising obesity rates and problems in eating-related self-regulation to this factor (Meule and Vögele, 2013). To examine the factors underlying appetitive responses to foods, research is increasingly using food images (Van Der Laan et al., 2011). Visual food cues constitute, like odors, a primary sensory input that allows predictions about the edibility and palatability of a food object. Thus, visual food cues can be regarded conditioned stimuli that are associated with the hedonic and homeostatic effects of ingestion and are therefore themselves rewarding (Dagher, 2012). Also, overt eating behaviors are under strong conscious control and therefore do not always reveal underlying response tendencies. Using food images, neurocognitive and indirect measures have been particularly successful in the study of subtle appetitive and regulatory determinants of overt eating behavior.

The "picture viewing approach" is validated by several lines of evidence. *First*, food deprivation/hunger affects the response to food images on several levels. Short term food deprivation affects responses to food pictures as demonstrated for implicit food evaluation (e.g., Seibt et al., 2007; Hoefling and Strack, 2008), salivation (e.g., Wooley and Wooley, 1981), autonomic responding (e.g., Rodriguez et al., 2005), visual attentional processing (e.g., Stockburger et al., 2009b) and neural reward system activity (e.g., Labar et al., 2001; Uher et al., 2006; Castellanos et al., 2009; Goldstone et al., 2009). *Second*, food image responses reliably differentiate individuals with abnormal eating behavior from healthy controls: altered food cue processing has been reported in individuals with restrained (Blechert et al., 2010; Burger and Stice, 2011), external (Nijs et al., 2009) or emotional eating (Bohon et al., 2009), as well as in patients with eating disorders (Blechert et al., 2011; Nikendei et al., 2012) or obesity (Nijs and Franken, 2012; Martens et al., 2013). *Third*, food picture viewing tasks have been adapted to train eating control, for example, through food-specific inhibition tasks (e.g., stop-signal task; Van Koningsbruggen et al., 2013) or attentional retraining (Werthmann et al., 2013; Kakoschke et al., 2014; Kemps et al., 2014) with measurable effects on actual food intake, supporting the notion that responding to food images is causally involved in eating behavior. In sum, there is good evidence that the food picture viewing approach is a useful tool for the study of eating behavior and appetitive/motivational brain systems. However, a number of factors need to be taken into account during selection of images to be able to draw firm conclusions. These factors broadly fall into the categories (1) *food types*, (2) *individual differences,* and (3) *image characteristics*.

Regarding *food types*, cultures around the world have brought about a vast variety of foods that researchers need to consider when designing experiments. What might be the dimensions that need to be considered during image selection? First, foods differ in *caloric content,* which has been shown to affect early electrocortical responses (Toepel et al., 2009; Meule et al., 2013). However, caloric density often goes along with the degree of *food processing*: processed foods are often more energy-dense than natural, unprocessed foods. Processed foods furthermore differ in their *colors* from whole foods like fruits and vegetables, which utilize the entire color spectrum. Thus, image selection according to caloric density should simultaneously consider level of processing and colors. Besides caloric density, *macronutrients,* that are proteins, fats, and carbohydrates, should be taken into account, if craving for certain types of food is a construct of interest (e.g., craving for carbohydrates, Corsica and Spring, 2008). Furthermore, there are distinguishable food *classes* such as vegetables, meat-containing dishes, fruits, and snacks which each differ in their (seasonal) availability, readiness to eat, flavor, nutritional composition, healthiness, color, and familiarity. Obviously, the categorization of foods into some classes is dependent not only on individual experiences and availability of certain foods but also on the research questions asked. It is for that reason, that *food-pics* provides a variety of food images that cover many food classes and that, most importantly, can be classified as needed by the user.

Not only is there a wide variety of food types to choose from but researchers need to consider the targeted population and therefore *individual differences* for image selection. For example, if vegetarians or vegans are part of the sample, meat containing images should probably be avoided as these trigger altered neural and behavioral responses in vegetarians compared to omnivores (Stockburger et al., 2009a). Similar considerations apply to food preferences based on cultural, religious or health grounds (Hoffman et al., 2013). Individual preferences affect brain responses, which is why some studies individualize stimuli to match each participant's preferences (e.g., Hollmann et al., 2012; Giuliani et al., 2013). Further individual differences in age and gender, educational status, and body mass index (BMI) should be considered for images selection (Caine-Bish and Scheule, 2009; Raffensperger et al., 2010; Berthoud and Zheng, 2012).

A third class of factors are *image characteristics*. Unfortunately, dimensions such as brightness, contrast, or spatial frequencies have not received much attention in studies using food-related images. However, effects of such image features on visual perception and stimulus-evoked neuronal responses are well known. Consequently, it is recommended to carefully control the physical properties of visual stimulus material (Knebel et al., 2008; Willenbockel et al., 2010; Kovalenko et al., 2012; Ball et al., 2013). For example, the role of image complexity and spatial frequencies for neural responses are heavily debated in the field of face processing (Vuilleumier et al., 2003; Thierry et al., 2007; Rossion and Jacques, 2008) and are increasingly considered during affective picture viewing (Bradley et al., 2007; Delplanque et al., 2007; Wiens et al., 2011). Thus, similar standards must apply to studies using food pictures rendering standardized stimulus sets and associated meta-data essential. To this end, Foroni et al. (2013) recently presented an image database featuring food (natural, transformed), rotten food, non-food objects (natural, artificial), animals, and scenes along with normative ratings by 73 healthy participants and physical image properties (size, brightness and spatial frequency). They focused on the natural (food, non-food) and artificial distinction in their data analyses. While their database (Foodcast Research Image Database, FRIDa) represents an important step forward in the field of food picture research and their variety of images is broad, the number of edible food items is relatively restricted and, in part, specific to the Mediterranean cuisine. Moreover, their normative data stem from a small sample with little demographic diversity, resulting in a relatively low number of ratings per image.

In the present study, we present *food-pics*, a stimulus set of 568 food and 315 non-food images. In our study design (normative ratings, image characteristics), we aimed to be complementary to FRIDa and at the same time address some of its limitations. *Food-pics* was aggregated to represent a wider range of foods to allow applicability in western countries. Our normative participant samples ($N = 1988$) were selected to represent typical university student samples but, in total, span a comparatively wide range of age (11–77 years), BMI (12–67 kg/m^2), and cultural background (German-speaking countries and the USA), to provide robust and generalizable normative data on commonly used perceptual and psychological parameters like palatability, desire to eat, recognizability, familiarity, valence and arousal. Physical image characteristics, that is, color, size, contrast, brightness, and complexity, were computed to complement the dataset and allow the selection of physically matching groups of images. Our analyses explore several example dimensions relevant to study design: (1) *image type* (e.g., food vs. non-food images) and *food type* (e.g., vegetables vs. meat vs. fruits, high- vs. low-calorie dense food, sweet vs. savory food, whole vs. processed food), (2) *individual differences* (e.g., demographics such as age, gender, and BMI, but also cultural background and vegetarianism) and (3) *state variables* (e.g., hunger and current weight reduction diet) on image ratings. We also explored the relationship of (4) *image characteristics* (e.g., contrast, brightness, complexity) with subjective ratings and nutritional content.

METHODS

STIMULI

The database comprises 568 food images including sweet (e.g., ice cream, chocolate), savory (e.g., pistachios, sandwiches), processed (e.g., hamburger, French fries, potato chips, chocolate bars) and whole foods (e.g., vegetables and fruits) and beverages (e.g., coffee, orange juice). Images of single items (e.g., one apple), several items (e.g., three apples) as well as full meals (e.g., roast beef with vegetables), were included. The food images are complemented by 315 non-food images comprising animals ($n = 37$, e.g., butterflies, dogs), flowers and leaves ($n = 42$), common household objects ($n = 89$, e.g., bucket, flat iron), office supply ($n = 20$, e.g., paper clip, ball pen), kitchen accessories ($n = 46$, e.g., toaster, pan), as well as tools ($n = 23$, e.g., pliers, screws), food packaging ($n = 33$, e.g., pizza box; no food visible on packaging), and other objects ($n = 25$). Images were selected from a commercially available database (Hemera Photo Objects, Vols. I-III), collected from non-copyrighted sources on the internet, or taken in our lab using an Olympus SZ-31MR digital camera (OlympusCorp., Tokyo, Japan). All images are color photographs with a resolution of 600×450 pixels (96 dpi, sRGB color format). Images were standardized on background color (white) and selected/edited to be relatively homogeneous with regard to, viewing distance (≈80 cm), angle and simple figure-ground composition. The background was adapted to meet eating conditions: some foods can be presented without dishware (e.g., fruits or hamburger), while others naturally require a plate or bowl (e.g., soup or fruit salad).

IMAGE CHARACTERISTICS

For each image, we computed relevant image properties that characterize the images' physical appearance using customized scripts written in Matlab R2011b (The Mathworks, Inc. Natick, USA). Scripts can be downloaded from the *food-pics* website (www.food-pics.sbg.ac.at). With the exception of the RGB channel contribution, all properties were computed after converting the colored image to gray values by forming a weighted sum of the red, green, and blue color channels: $0.2989 \times \text{red} + 0.5870 \times \text{green} + 0.1140 \times \text{blue}$. This procedure converts RGB images to gray-scale by eliminating the hue and saturation information while retaining image luminance (Poynton, 2012). The following image properties were analyzed:

Color, quantified as the proportional contribution of the red, green, and blue channel, averaged across all non-white pixels. For example, a tomato is characterized by a strong contribution of the red channel (see **Figure 1**).

Size, quantified as the proportion of non-white pixels relative to total number of pixels (identical as in Foroni et al., 2013).

Brightness, quantified as the difference between the mean luminance of all non-white pixels of the gray scale image and the white background (Foroni et al., 2013). Thus, the most salient objects (i.e., very dark objects on white background) yielded the highest brightness values.

FIGURE 1 | Example pictures illustrating image characteristics from low (left) to high parameter value (right).

Within-object contrast, quantified as the standard deviation of luminance across all non-white pixels of the gray scaled image. For example, an image of a black chocolate bar on a white plate contains pixels with luminance values ranging from very dark to white. Thus, this image is characterized by a high standard deviation of luminance values. By contrast, an image of whipped cream on a white plate comprises very few dark pixels, and so is characterized by a small standard deviation.

Spatial frequencies

Median power of each object was analyzed by computing a two-dimensional fast Fourier transform on the gray-scale images. One-dimensional power spectra were obtained by computing a radial average of the two-dimensional power spectra. This procedure yields a measure of the image's spatial frequencies, reflecting variations in pixel luminance, independent of their location in the image. To represent spectral power in a single value for each image, we computed the median power across all spatial frequencies.

Complexity

While some images display a single homogenous object (e.g., a slice of cheese), other images display multiple objects (e.g., an assortment of different fruits) or objects consisting of multiple components (e.g., a pizza). Images that are complex in this sense are characterized by multiple object outlines. Thus, we analyzed the images for outlines using a Canny edge detection algorithm (Canny, 1986) and quantified image complexity by computing the proportion of outline-related pixels within the image. However, the number of outline-pixels is also determined by the object's size—a magnified version of the identical object would have larger outlines and would yield a higher complexity value. Therefore, we also computed a *normalized complexity* measure that is independent of object size, by additionally dividing the proportion of outline-related pixels by the total number of non-white pixels in the image. Size and brightness were computed in the same way as reported by Foroni et al. (2013).

MACRONUTRIENTS

Number of kcal and macronutrient composition (proteins, carbohydrates, fat) of a depicted food were estimated for each food image by a trained research assistant (psychology master level student) using food databases on the internet and food packaging information. Kcal and macronutrients are provided as kcal/100g and grams/100g as well as total kcal and grams, respectively, for the depicted portion. Whenever multiple food items were displayed (e.g., grapes) counts were provided to facilitate analyses of experimental test meals. To cross-validate the accuracy of these data, a second research assistant (also a psychology master level student) estimated these data a second time for a randomly selected subsample of 38 food items[1]. Agreement between the two coders was excellent; Pearson correlations ranged from $r = 0.84$ to $r = 0.99$ with a mean of $r = 0.95$.

[1]Image numbers were 4, 9, 10, 15, 26, 41, 46, 64, 85, 95, 101, 110, 116, 134, 148, 152, 153, 159, 185, 189, 192, 193, 194, 198, 199, 205, 206, 211, 244, 248, 249, 262, 264, 265, 282, 298, 308, 309.

PARTICIPANTS

Four samples completed an anonymous online survey (see **Table 1** for sample descriptions) to provide normative data for *food-pics*. Only participants who completed all ratings for at least 3 food images were included (see "Online Survey" below). The first sample ("*UniHagen sample*," $n = 638$) comprised undergraduates of the University of Hagen, a German distance teaching university, who completed the survey in exchange for course credit and the option of participating in a raffle for 3 × 50 Euro upon completion. The second sample was recruited through mailing lists of several universities in Germany, Switzerland and Austria ("*German-speaking sample*," $n = 831$). The third sample addressed US-participants ("*US sample*," $n = 496$), recruited though the online work marketplace "Mechanical Turk" at Amazon, where registered users work on online tasks

Table 1 | Demographic characteristics by sample.

	German-speaking sample	US-American Sample	UniHagen	Austrian children and youth
AGE				
Mean (*SD*)	24.7 (5.46)	35.9 (13.41)	32.8 (10.07)	13.9 (1.56)
Median (Min, Max)	23 (18–65)	32 (18–77)	30 (17–73)	14 (11–18)
GENDER				
Male (%)	16.7	36.3	17.2	60.9
NATIONALITY (%)				
Germany	93.0	0	93.1	4.35
Austria	3.01	0	2.35	91.3
Switzerland	0.12	0	1.1	0
Other European country	2.17	0	2.19	4.35
Non-European country	1.68	0	1.25	0
USA	0	98.7	0	0
Canadian	0	0.4	0	0
Other	0	0.80	0	0
BODY MASS INDEX (kg/m^2)				
Mean(*SD*)	22.5 (3.70)	27.3 (7.29)	23.4 (4.68)	18.7 (2.77)
Median (Min, Max)	21.7 (14.2–45.3)	25.7 (15.5–67.4)	22.4 (12.1–60.5)	18.6 (14.6–24.34)
EATING STYLE (%)				
Omnivore	75.9	92.3	77.7	95.7
Vegetarian	20.2	5.4	19.6	4.3
Vegan	3.9	2.2	2.7	0.0
CURRENTLY DIETING				
(%)	10.3	23.8	9.9	4.3
EMPLOYMENT (%)				
High school	1.2	10.7	0.0	100
College/University	86.8	11.3	100	0.0
Apprenticeship	5.1	0.6	0.0	0.0
Self-employed	1.1	21.6	0.0	0.0
Unemployed	1.2	17.1	0.0	0.0
Other	4.6	38.7	0.0	0.0
PROGRESS IN SURVEY				
% Completed	77.6	69.6	89.8	78.3
% Partial completion	22.4	30.4	10.2	21.7

in exchange for payment. The fourth sample addressed children and youth at an Austrian high school ("*Children/youth sample*," $n = 23$) to extend the age range. The German-speaking and the Children/youth samples were also offered participation in a raffle for 3×50 Euros. All surveys were completed between May and August 2013. The ethics board of the University of Salzburg had approved the study.

ONLINE SURVEY

As participants could not be expected to reliably rate all 882 images, each participant rated a random subset of images, separately drawn from non-food and food images. Due to different modes of compensation (course credit, payment, raffle) the samples differed in the number of images rated by each participant: UniHagen sample 40 non-foods/80 foods, German-speaking sample 25/40, US sample 17/35, and Children/Youth sample 5/35. On average, each image was rated by 48.8 ($SD = 22.9$) participants.

The survey commenced with an assessment of demographics (age, gender, height, occupation, nationality) and eating habits (weight, diet: omnivore/vegetarian/vegan, weight-loss dieting) before displaying a detailed explanation as well as an example rating for all scales. During the survey, one image was displayed at a time and ratings were required for the dichotomous item *familiarity* (yes or no) and *recognizability* (easy or difficult). Visual analog scales (VAS, approximately 8 cm long) were displayed to rate *complexity* (only the extremes were labeled, scale ranged from "very little" to "very high"), *valence* (from "very negative" to "very positive"), and *arousal* (from "not at all" to "extremely"). Food items were additionally rated on *palatability* (from "not at all" to "extremely") and *desire to eat* (from "not at all" to "extremely"). General instructions read "how palatable is this food for you in general?" and "how much would you like to eat this food right now if it was in front of you." Anchors on each visual analog scale for each image read "Palatability" (in German "Schmackhaftigkeit"): "not at all" to "extremely"; and "Desire to eat" (German "Verlangen"): "not at all" to "extremely." Complexity (German "Komplexität"): "very low" to "very high"; was explained as being characterized by "many components, details and subobjects" as well as by "many edges and borders." The VAS was displayed as a solid bar along which a cursor was to be moved; the rating was logged upon mouse click. The scale represented, invisible to the participants, 100 points (from 1 to 100).

DATA ANALYSES

To describe and explore the *food-pics* normative database and to highlight some variables that might guide users during image selection and study design we performed the following analyses:

(1) *Image type*: Descriptive data are given on stimulus valence and arousal across different stimulus classes (including non-food images) in the database. For foods (and most remaining analyses), palatability and desire to eat ratings are of prime importance and are reported as a function of *caloric content* (high- vs. low-calorie foods), *sweetness* (sweet vs. savory foods) and *degree of processing* (whole vs. processed foods).

(2) *Individual differences* and *demographics:* Effects of gender, age, and BMI, as well as diet (omnivore vs. vegetarian), and culture (German speaking vs. North American) were explored with regard to palatability and desire to eat ratings.

(3) *State variables:* Hunger ratings were correlated with palatability and desire to eat ratings. Likewise, dieters ("current weight reduction diet") were compared with non-dieters on palatability and desire to eat ratings.

(4) *Image characteristics, ratings, and macronutrients*: Correlational analyses explored relationships between subjective ratings, image characteristics, and nutrients.

Generally, due to the high statistical power in the present sample, we only report effects with at least medium ($\eta^2 > 0.06$, Cohen's $d > 0.3$) effect sizes unless otherwise noted. Within each subgroup of comparisons we used paired sample Student t-test to compare subgroups of images or display 95% confidence intervals.

RESULTS

IMAGE TYPE

To provide an example characterization food and non-food objects were classified into several specific categories. Food objects were categorized, based on the dominant food in the image, into fruits (13.3% of all food images), vegetables (20.7%), chocolates (11.4%), meat (11.1%), fish (2.28%), nuts (1.76%), beverages (1.58%) and 38% other foods without clear dominance of one food type. Non-food images were categorized into flowers & leaves (13.4%), animals (10.1%), tools (7.32%), household items (non-kitchen, 28.3%), kitchen utensils (14.6%), office supply (6.37%), food packaging (10.5%) and other items (1%). **Figure 2** displays valence, arousal, palatability, and desire to eat ratings for these categories along with 95% confidence intervals. Objects, flowers & leaves and animals were rated more positively on valence compared to tools, household and kitchen utensils as revealed by non-overlapping confidence intervals. Flowers & leaves and animals were also rated more positive on valence than most of the foods, except for fruit. Within foods, fruits were most popular, both in terms of valence and palatability and in terms of desire to eat. Interestingly, meat was rated lowest on palatability and desire to eat (closely followed by nuts for desire to eat).

In addition, as previous research has contrasted foods according to *caloric density, degree of processing, and gustatory qualities*, we classified our food pictures into high vs. low caloric density (median split regarding caloric density = kcal/100 g) as well as into processed (32.0% of all foods) vs. whole (66.7% of all foods, 1.3% not classifiable) and sweet (42.8%) vs. savory foods (38.8%, 18.4% not classifiable; see **Table 2** for means and standard deviations of all ratings of the different food types) and determined palatability and desire to eat ratings for each category. *High vs. low calorie-dense* foods received lower ratings in terms of palatability, $t_{(1942)} = 13.0$, $p < 0.001$, $d = 0.46$, and desire to eat, $t_{(1942)} = 9.3$, $p < 0.001$, $d = 0.42$. *Sweet* vs. *savory* foods received higher ratings in terms of palatability, $t_{(1960)} = 20.3$, $p < 0.001$, $d = 0.46$, and desire to eat, $t_{(1960)} = 18.8$, $p < 0.001$, $d = 0.42$. *Whole* vs. *processed* foods received higher ratings in terms of

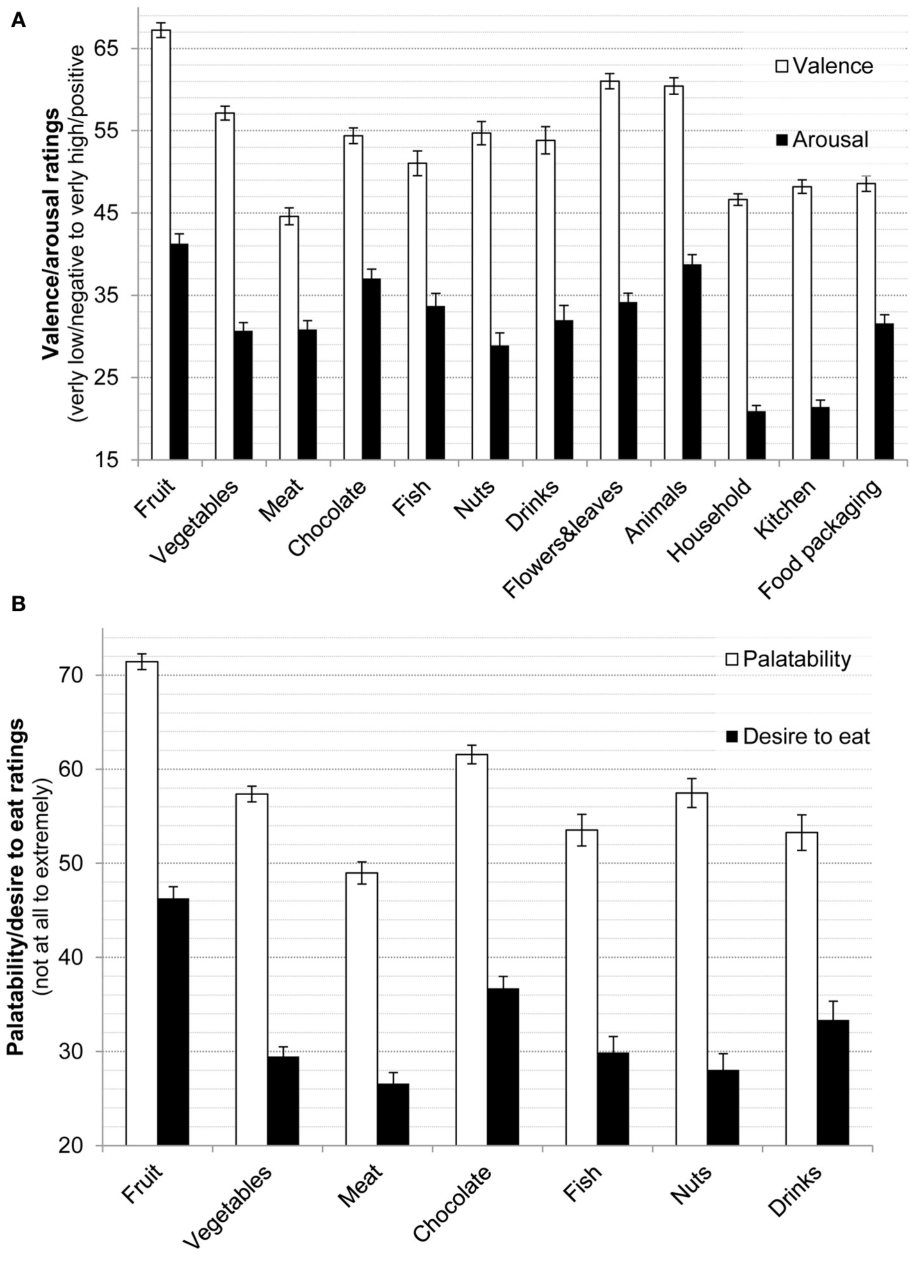

FIGURE 2 | (A) Means and 95% confidence intervals for valence ("very negative" to "very positive") and arousal ("very little" to "very high") across all image categories. **(B)** Means and 95% confidence intervals for palatability and desire to eat (both "not at all" to "extremely") across food types.

palatability, [$t_{(1858)} = 15.1$, $p < 0.001$, $d = 0.35$] and desire to eat, [$t_{(1858)} = 9.86$, $p < 0.001$, $d = 0.23$]. In brief, valence and arousal ratings largely mirrored these differences and familiarity and recognizability was consistently high (>93.2% of all foods were rated as recognizable and 94.6% of all foods were rated as familiar).

INFLUENCE OF DEMOGRAPHICS AND INDIVIDUAL DIFFERENCE VARIABLES: CULTURE, GENDER AND VEGETARIANISM, BMI AND AGE

In brief, effects of culture (North America vs. German speaking) on all food ratings (all foods, high calorie vs. low calorie/processed vs. non-processed foods, meat vs. non-meat) were significant but of small effect size ($\eta_p^2 < 0.06$) when considering age and gender differences between the samples as covariates.

Women gave lower desire to eat ratings for all foods compared to men [$M = 32.2$, $SD = 19.6$ vs. $M = 40.5$, $SD = 20.5$, $t_{(1963)} = 7.70$, $p < 0.001$, $d = 0.42$] whereas no gender differences were found for palatability [$M = 58.8$, $SD = 14.5$ vs. $M = 59.1$, $SD = 15.6$, $t_{(1963)} < 1.00$].

V*egetarians* rated meat containing images lower than omnivores on palatability [$M = 19.6$, $SD = 21.2$, vs. $M = 56.1$, $SD =$

Table 2 | Subjective ratings as a function if different food types (mean, standard deviations).

	High calorie	Low calorie	Processed	Whole	Sweet	Savory
Palatability	56.8 (16.8)	60.9 (15.4)	57 (16.1)	62.8 (17)	62.2 (16.6)	55.5 (16.4)
Desire to eat	32 (21.5)	35.1 (20.7)	32.4 (21)	36.1 (21.7)	37.5 (22.5)	30.4 (21)
Valence	52 (16.7)	58.1 (16.2)	52.3 (16.1)	61.2 (18.3)	56.9 (16.8)	52.2 (15.7)
Arousal	33.4 (20.9)	34.7 (21.4)	33.9 (20.6)	34.6 (22.6)	37 (22.3)	32.2 (20.4)
Recognizability (%)	94.6 (8.72)	96.1 (9.30)	93.2 (9.25)	96.4 (7.3)	94.4 (9.27)	93.4 (10.4)
Familiarity (%)	94.6 (8.73)	96.2 (9.35)	95.1 (8.42)	97.6 (6.9)	95.2 (9.58)	96.1 (8.66)

Recognizability and Familiarity were dichotomous yes/no decisions.

21.2, $t_{(1879)} = 29.6$, $p < 0.001$, $d = 1.72$] and desire to eat [$M = 7.46$, $SD = 13.2$, vs. $M = 31.3$, $SD = 26.3$, $t_{(1879)} = 16.8$, $p < 0.001$, $d = 1.21$].

BMI was not associated with palatability [$r_{(1916)} = 0.029$, *n.s.*] and positively but weakly correlated with desire to eat [$r_{(1961)} = 0.117$, $p < 0.001$, for high-calorie foods, $r_{(1961)} = 0.146$, $p < 0.001$, for low calorie foods $r_{(1961)} = 0.059$, $p < 0.001$]. Correlations of *age* with palatability and desire to eat were very weak ($rs < 0.1$).

INFLUENCE OF STATE VARIABLES: HUNGER AND CURRENT DIETING

Interestingly, being currently on a weight reduction diet (13.6% answered this question with yes) did influence ratings only to a minor degree. Dieters did not differ from non-dieters on palatability ratings [$M = 59.0$, $SD = 14.9$, vs. $M = 58.8$, $SD = 14.8$, $t_{(1963)} < 1.00$] and gave slightly elevated desire to eat ratings [$M = 37.1$, $SD = 19.9$, vs. $M = 33.5$, $SD = 20.1$, $t_{(1963)} = 2.71$, $p = 0.007$, $d = 0.21$]. Hunger (averaged across pre- and post-questionnaire ratings) was weakly positively correlated with palatability, $r_{(1965)} = 0.120$, $p < 0.001$ ($r = 0.04$ and $r = 0.141$ for low- and high-calorie food images, respectively), but showed a medium sized positive correlation with desire to eat, $r_{(1965)} = 0.528$, $p < 0.001$ ($r = 0.473$ and $r = 0.524$ for low- and high-calorie food images, respectively).

IMAGE CHARACTERISTICS, RATINGS AND MACRONUTRIENTS

The main purpose of including image characteristics was to allow for matching of different stimulus sets in studies using neurocognitive measures (e.g., set of high and low calories, i.e., Toepel et al., 2009). Since we had no neurocognitive measures in this database, we explored how image characteristics were related to (a) the subjective ratings and (b) macronutrients of the displayed foods. Such data could serve to raise awareness of the importance to control for such characteristics by an appropriate selection of images in future research. To do so, we computed Pearson correlations (images on rows) between picture characteristics and subjective ratings (averaged across all participants) as well as with macronutrients.

The only correlation of close to medium size indicated that image with stronger contribution of the red color channel were rated as more arousing, $r_{(883)} = 0.279$, $p < 0.001$. In addition, image complexity (edge detection), as well as normalized image complexity (complexity relative to image size) correlated with subjectively rated complexity [$r_{(883)} = 0.349$, $p < 0.001$ and $r_{(883)} = 0.248$, $p < 0.001$]. A higher contribution of the green color channel went along with lower concentrations of protein, fat and carbohydrates as well as with lower number of calories ($r = -0.251$, $r = -0.209$, $r = -0.257$, and $r = -0.313$, respectively)

DISCUSSION

The present study presents *food-pics*, a database of images of foods for experimental research on food perception and eating behavior. Previous studies are limited considerably in stimulus selection and/or characterization of stimulus material and food contents hampering the comparability of findings across laboratories. *Food-pics* comprises a large variety of foods and non-foods along with detailed data on image characteristics, food contents, and normative ratings. We presented example analyses of food types, individual differences, state effects, and image characteristics to explore key variables relevant for experimental design of food viewing studies.

Regarding *food types,* our results confirm that calorie content is a relevant determinant of subjective responses, in line with a several studies showing distinct neural responses for high- vs. low-calorie images (e.g., Killgore et al., 2003; Cornier et al., 2007; Toepel et al., 2009; Frank et al., 2010). Interestingly, our normative data suggest slightly lower palatability and desire to eat ratings for high-calorie images (small to medium effect size), possibly reflecting the rising awareness of the unhealthy nature of these foods in the populations studied here or self-presentation biases. Other self-report studies show the opposite (Richter et al., under review), as do implicit measures (Houben et al., 2012). It is possible that food restrictions prior testing played a role here because food deprivation renders particularly high-calorie foods more attractive (Goldstone et al., 2009). Our data indicate that participants were not very hungry [$M = 28.5$, $SD = 25.4$, on a 1 (not hungry) to 100 (very hungry) scale] but hunger correlated slightly stronger with palatability/desire to eat ratings of high- compared to low-calorie images. Sweet compared to savory foods were rated more palatable and with stronger desire to eat, as were whole vs. processed foods. One has to keep in mind that we used all images of the respective type of the database so it might well be that certain subcategories with a high number of images contributed more than others (e.g., 76 images displayed fruit in the whole and sweet categories). Together these results suggest that image selection will substantially influence (rating) results, depending on the proportion of high-calorie, sweet and whole foods in a specific category. Processed foods are often higher in caloric density, however, researchers could still match the total amount of calories displayed in the images between whole and processed foods by selecting pictures with larger amounts of whole foods (e.g., wild berry mix, 53,75 kcal, image #214) and pictures with smaller amounts of processed foods (e.g., 4 pretzels, 44 kcal, #494). Although recognizability and familiarity of the objects were relatively high, it should be noted that participants performed a yes/no task and did not name the objects.

Individual differences such as restraint, external or emotional eating, eating disorders, or obesity are central independent variables in the study of eating behaviors. However, sampling error can induce group differences on other individual difference variables unless carefully stratified. Age and BMI differences are tolerable to some degree because they showed only minor influence on ratings in our analyses (rs < 0.117). Gender and vegetarianism are more relevant for sampling/matching because lower ratings for palatability and desire to eat were found for women in general and for vegetarians specifically for meat-containing foods. These results reflect in part also inconsistencies in the literature with regard to gender: women are sometimes reported to experience cravings more frequently (Cepeda-Benito et al., 2003) but also restrain and worry about their eating more than men (Dinkel et al., 2005). The present data suggest that in a large unselected sample and across a wide range of foods, women give lower palatability/desire to eat ratings. Thus, normative ratings provided along with the images are reported separately for vegetarians and omnivores and for males and females to facilitate selection of suitable images.

State variables like hunger are obviously important in the food context. Hunger influenced desire to eat to a higher degree than palatability, which is in line with findings that specific state cravings correlate with food deprivation (Cepeda-Benito et al., 2003; Meule et al., 2012) and interesting in the context of the discussion whether "wanting" (∼desire to eat) and "liking" (∼palatability) are dissociable in humans (Finlayson et al., 2007; Havermans et al., 2009; Finlayson and Dalton, 2011; Havermans, 2011). Hunger might further interact with caloric density as discussed above. Interestingly, current dieting did not influence results much: only a small increase in desire to eat was found for dieters as compared to non-dieters. The literature on dieting effects is mixed: some studies have found dieting to decrease food cravings (reviewed in Martin et al., 2011) other studies found the opposite (Massey and Hill, 2012). On the other hand, weight reduction has been reported to lead to long term weight gain (so called "yoyo effects") although the mechanisms are not clear (Ochner et al., 2013). These findings underscore the necessity to assess the short and long-term dieting status, the diet success (i.e., weight reductions) as well as the current hunger levels of the participants.

Just as the appearance of foods influences their acceptability for consumption (Wadhera and Capaldi-Phillips, 2014), *image characteristics* have been shown to affect neurocognitive measures (Vuilleumier et al., 2003; Bradley et al., 2007; Delplanque et al., 2007; Thierry et al., 2007; Rossion and Jacques, 2008) which is why we calculated the key measures that have been established in the field of visual perception (Knebel et al., 2008; Willenbockel et al., 2010; Wiens et al., 2011; Kovalenko et al., 2012; Foroni et al., 2013). Lacking neurocognitive measures in the present study, we explored their relationship with normative ratings and macronutrients. Red color went along with higher arousal ratings whereas green color was indicative of lower calories and lower concentrations of protein, fat, and carbohydrates. Colors should therefore be considered in the study design. Expectedly, our objective index of complexity (reflecting the number of object-components displayed in the image) correlated positively with rated complexity. However, the low to medium sized correlation indicates that subjective and objective measures of complexity are partially independent constructs and studies need to make their pick of which index to use depending on study aims. Future studies might further measure image aesthetics which was not measured here but might be related to expected palatability. Further research should also employ neurocognitive measures to determine which objective and subjective image characteristics influence neural responses. In the lack of such evidence, researchers could use *food-pics* metadata to match image sets on factors unrelated to their independent variable, particularly when comparing different food types against each other. For example, if the influence of caloric density is to be examined, high- and low-caloric density image sets could be matched for total amount of calories in the image, sweet/savory and processed/whole food proportion, and green color contribution to increase the specificity of the comparisons. If matching is not possible or not desired, researchers should still describe their images in more detail using the metadata provided with *food-pics* or list the image numbers in a footnote or supplementary material.

In conclusion, we hope that *food-pics* will facilitate experimental research on food perception, eating behavior and appetitive responses. Databases such as *food-pics* will increase the comparability of study results and therefore facilitate research communication as it is the case in object recognition, face processing or emotional picture viewing. *Food-pics* as well as normative rating data can be downloaded free of charge from the first author's website at www.food-pics.sbg.ac.at upon completion of appropriate license agreements.

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Temptation in the background: non-consummatory exposure to food temptation enhances self-regulation in boys but not in girls

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The abundance of calorie-dense low-nutrient food in everyday life raises the question as to how children deal with such opportunities. We investigate whether pre-exposure to the object of temptation in a situation that discourages consumption boosts children's ability to resist similar temptation subsequently. We show that 7–12-year-old boys, but not girls, demonstrate increased resistance to a temptation after pre-exposure to a similar temptation. Future research might explore the role of exposure to temptation in girls.

Keywords: self-regulation, children, food, exposure to temptation

INTRODUCTION

Are sweets consumed in larger quantities if available at home? The intuitive answer is yes, and several studies confirm this intuition (Chandon and Wansink, 2002; Painter et al., 2002; Gorin et al., 2013). Contradicting this intuition, other research has shown that pre-exposure to food temptation can reduce subsequent consumption of a similar temptation, at least in adults, reflecting a mechanism of efficient self-regulation (Fishbach et al., 2003) that is based on change in preference (Geyskens et al., 2008). For children, one may argue that food availability may be more likely to induce subsequent consumption as they may lack efficient self-regulation strategies (Mischel and Underwood, 1974). Policy makers accordingly seem to assume that restricting access to unhealthy food is the best way to curb children's overconsumption tendencies (Wardle, 1990).

However, prior findings suggest that the change in preference that is supposed to underlie the boosted subsequent resistance to temptation (Geyskens et al., 2008), one instantiation of self-regulation, may be more basic. Egan et al. (2007) demonstrated that children, similarly as adults, demonstrate cognitive dissonance by reducing the attractiveness of a previously rejected option (stickers). This suggests that children's cognitive development may be advanced enough to also display the resistance to temptation after the pre-exposure to a similar temptation. We argue that exposure to temptation might boost rather than hurt subsequent resistance to temptation when the context of exposure discourages consumption. We consider a context of exposure to discourage consumption when a child autonomously assumes that consuming the tempting item is not desirable in that specific situation.

This paper addresses the question if exposing children to temptation in a context that discourages consumption enhances their subsequent resistance to a similar temptation, which has been documented in adults (Geyskens et al., 2008).

EXPOSURE TO TEMPTATION AND RESISTANCE IN CHILDREN

A number of studies have demonstrated that food availability influences consumption (Hill and Peters, 1998). In the lab, food availability (Mischel and Ebbesen, 1970) reduced children's willingness to wait for a larger food reward and promoted the choice of immediate smaller rewards. Field studies with 10–14-year-old children show that the availability of palatable foods at home is negatively associated with fruit and vegetable intake and positively associated with the consumption of soft drinks, sweets, and crisps (Vereecken et al., 2010).

Prior research on food exposure has conceptualized exposure to temptation without taking into account important boundary conditions. During pre-exposure to temptation in a situation in which free consumption is not appropriate (e.g., while waiting for other members of a party during a restaurant dinner) people seem to activate regulatory strategies to deal with the challenge. These strategies linger and when another similar tempting opportunity is subsequently presented, the successful strategies are more easily re-activated. This is theoretically consistent with prior research showing that exposure to food temptation without consuming it reduces adults' desire and consumption in a subsequent tempting situation (Geyskens et al., 2008; Dewitte et al., 2009).

We argue that exposing children to temptation may boost rather than hurt subsequent resistance to temptation when the temptation is presented within a task context that discourages consumption (e.g., a word formation task with candy letters). In the face of temptation, this task goal corresponding to the word formation task would induce a goal conflict between the desire to consume the food and the situational inappropriateness of its consumption (e.g., a task cannot be accomplished if the candy is consumed). To solve this conflict, self-regulation – or conflict resolution – mechanisms will be activated. We argue that the activation of these conflict resolution mechanisms will facilitate subsequent resistance to temptation. We predict that children who are exposed to a temptation in a situation discouraging consumption will show increased resistance to a subsequent similar temptation, compared to children who are not pre-exposed to a temptation. At this point it is useful to note that, although superficially similar, our empirical focus differs from the delay-of-gratification paradigm in that these researchers were interested in resistance during the very exposure to temptation, whereas our interest is in measuring *subsequent* resistance to temptation after pre-exposure to temptation.

It is not clear whether primary school children would be able to solve a goal conflict between consumption and restriction in the face of a food temptation in a similar way as adults do. Some of the essential abilities for temptation control develop rather late. For instance, aiming to resist a temptation 7–11-year-old children have been shown to employ physical distraction strategies, such as covering their eyes, but they still do not spontaneously use cognitive distractions, such as changing the meaning of a temptation in their mind (Demetriou, 2000). Inhibition ability is still maturing at the age of 9 or even 12 (Williams et al., 1999; Leon-Carrion et al., 2004; Best et al., 2009; Best and Miller, 2010). Seven to eight-year-olds demonstrated a larger interference effect during a Stroop task than did adults, presumably because of their underdeveloped ability to actively inhibit distractors (Tipper et al., 1989). Interference suppression strategies in children might therefore not always be adequate. For example, they adopted a verbal strategy for a task (activate brain regions responsible for verbal processing) that was not inherently verbal (Bunge et al., 2002). The lack of self-regulation abilities in children might lead to succumbing to a temptation already during the first pre-exposure to temptation, in which resistance to temptation during the exposure is the essential feature.

In spite of these age-related procedural deficits in sophisticated self-regulation skills, we argue that pre-exposure to temptation in an involving context that effectively discourages consumption may help even children's successful resistance to subsequent temptation. Recent research has shown that pairing positive pictures or palatable food with a no-go task lowered their evaluations (Veling et al., 2008, 2011a,b; Houben and Jansen, 2011). After making a choice, even 4-year-olds reliably decreased preferences for the rejected option (Egan et al., 2007), suggesting that the change in preference is less dependent on higher-level capacities, such as language, teaching, and socialization, than previously thought. In all these cases, learning that a stimulus was associated with inaction appeared to be easy, and it lingered to influence subsequent behavior. By associating tempting food (candy) with not responding (not eating, Van Osselaer, 2008) children might exercise momentary conflict resolution mechanisms which then linger and lead to resisting temptation in case another opportunity of consuming palatable food occurs. Thus a child is likely to benefit from pre-exposure to temptation if the situational cues induce a task goal that opposes the goal to consume the tempting item (e.g., completing a competitive task by using candies as objects). The focus of this research is to examine experimentally whether pre-exposure to food temptation is likely to enhance subsequent resistance to a similar temptation in children, based on our assumption that the conflict resolution mechanisms used during pre-exposure are still easily accessible.

MATERIALS AND METHODS

DESIGN AND PARTICIPANTS

This study utilized a unifactorial (pre-exposure to temptation: yes versus no) between-subjects design to test the effect of pre-exposure to temptation on children's consumption behaviors.

Children aged between 7 and 12 years ($n = 183$), drawn from ten classes in two primary schools, were invited to participate in the study. Age was not significantly different between conditions. There were slightly more boys in the pre-exposure condition (54%) as compared to a control condition (49.2%). Participation was also contingent on children meeting the criteria of no history of behavioral or eating disorders. Informed consent from parents was acquired for 155 children (84%); as six children were absent at the time of the research, the final sample comprised 149 children. Two female experiment leaders conducted the experiment. Both experimenters collected data from both conditions.

PROCEDURE

The study was completed individually and consisted of two phases: an exposure to temptation manipulation phase and a bogus taste test of a similar temptation.

Upon entering the school cafeteria children were greeted and asked for their name and age. Then, just before the exposure to temptation phase, their hunger state was measured on a visual three-point scale. This was achieved by presenting them with three cartoon drawings of children with their stomach showing different levels of hunger (Rolls et al., 2000). Then, the availability of the temptation was manipulated in the context of a 2-min word formation task. Each child was asked to use as many of 25 given letters as possible to form one or multiple words. During this task the experimenter was present at a distance in the same room. To induce a goal conflict, half of the children had to construct words from letter-shaped candy (pre-exposure condition). Children were not instructed not to eat candy. The experimenter observed unobtrusively whether the candies were eaten. None of children consumed the candy during this task. Another half of the children constructed words from cardboard letters without any candy present (no pre-exposure condition).

The second task involved a taste test, which was the same for all participants. Each participant was presented with two bowls, one with 100 g of regular *M&Ms®* and another with 100 g of *Smarties®*. Each child received a questionnaire about the candies, which included questions about several features of the candies (e.g., which is more delicious, *M&Ms* or *Smarties*?). Also included were questions about how much they liked *M&Ms* and *Smarties* on a three-point scale with three drawings of faces (frowning, neutral, and smiling). All children were allowed to taste as many of the *M&Ms* and *Smarties* as they desired. An experiment leader inconspicuously weighted the amount of candy left by each child.

Following standard practice, we considered the amount of candy consumed during the taste test as an indication of (a lack of) resistance to temptation. We expected that resistance to temptation in the pre-exposure to temptation condition would be better than resistance to temptation in a no pre-exposure to temptation condition. Additionally, we asked the teachers to provide the "good behavior" ratings, with higher numbers representing better behavior.

RESULTS

Prior to analyses, 18 children were excluded. Four (5.9%) were lactose-intolerant, nine (13.4%) did not like the candies involved, and five (7.5%) did not properly perform the taste test as they ate none of the candy. The remaining sample consisted of 131 children (49% female). The consumption was log-transformed because its distribution was skewed. The effect of age was not significant, and is not discussed further. Since gender played a role, it was included in all analyses. The conditions differed neither in gender [$X^2(1) = 0.36$, $p = 0.55$], nor in age [$F(1,126) = 0.12$, $p = 0.73$], nor in hunger level distribution [$F(1,126) = 0.55$, $p = 0.46$]. The "good behavior" ratings were higher in girls than in boys [$F(1,126) = 10.73$, $p = 0.001$], but these ratings neither influenced consumption ($r = 0.02$, $p = 0.85$), nor were they related to the consumption in each condition (pre-exposure condition: $r = 0.14$, $p = 0.28$; no pre-exposure condition: $r = 0.18$, $p = 0.14$).

To investigate resistance to temptation in children, a between-subject ANCOVA was used, with quantity of candy (*Smarties* and *M&Ms* combined, in grams) consumed during the taste test as the dependent variable, pre-exposure to temptation and gender as the independent variables, and hunger level as a covariate. Neither the main effect of gender [$F(1,126) = 2.6$, $p = 0.11$, $\eta_p^2 = 0.02$], nor that of pre-exposure on consumption [$F(1,126) = 2.59$, $p = 0.11$, $\eta_p^2 = 0.02$] was significant. There was a positive effect of hunger on consumption [$F(1,126) = 6.38$, $p = 0.01$, $\eta_p^2 = 0.05$]. The analysis revealed an interaction of pre-exposure to temptation and gender [$F(1,126) = 7.02$, $p = 0.01$, $\eta_p^2 = 0.05$; **Figure 1**][1]. Simple effect analyses showed the expected effects of pre-exposure to temptation on consumption only for boys. For boys, the consumption after pre-exposure to temptation was lower than that in the no pre-exposure condition [$M = 10.45$ vs. 26.34; SD = 11.98 vs. 32.18; $F(1,126) = 9.4$, $p < 0.003$, $d = -0.65$]. For girls, the consumption after pre-exposure to temptation was not different from consumption in the no pre-exposure condition ($M = 11.98$ vs. 12.23; SD = 13.38 vs. 13.20; $F = 0.52$, $p = 0.47$, $d = -0.02$), being relatively low in both conditions. In pre-exposure condition, the consumption in boys was not different from the consumption in girls ($M = 10.45$ vs. $M = 11.98$, SD = 11.98 vs. 13.38, $F = 0.55$, $p = 0.46$, $d = -0.12$). In no pre-exposure condition, the consumption was higher for boys than for girls ($M = 26.34$ vs. 12.23, SD = 32.18 vs. 13.20, $F = 8.77$, $p = 0.004$, $d = 0.57$).

[1]The results with the calories as dependent variable are similar, there is an interaction of pre-exposure to temptation and gender [$F(1,126) = 7.38$, $p = 0.08$, $\eta_p^2 = 0.06$].

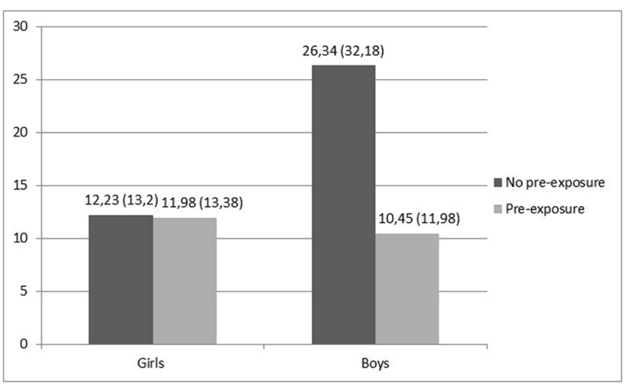

FIGURE 1 | The interaction of pre-exposure to temptation and gender on consumption (grams consumed).

DISCUSSION

The results offer experimental support for the hypothesis that exposure to calorie-dense, low-nutrient foods may facilitate resistance to temptation and hence ultimately have a beneficial effect on weight regulation in boys. The findings provide evidence that boys' resistance to temptation increases after pre-exposure to temptation in situations where consumption is discouraged, thereby replicating findings in adults and suggesting that this type of self-regulation emerges early in life. The findings also question food policy assumptions (Wardle, 1990) that any exposure to tempting food cues always leads to overconsumption. Educators and parents could more effectively protect children against unhealthy food overconsumption by creating an environment that promotes the resistance to food by the children. For instance, boys might be offered to play a game where they can decide to save candy (which is present) in exchange for larger rewards later on (De Boer et al., 2014). However, the outcome should be interpreted cautiously because after exposure to temptation the resistance to temptation increased in boys, but not in girls.

Although the findings in boys are similar to the findings in adults in other studies, the conflict resolution mechanisms, leading to increased resistance, used by children might be different from the ones used by adults. For adults, a temptation often leads to the automatic activation of higher-priority goals, probably because of overlearning this association over the course of life (Fishbach et al., 2003, 2010; Papies et al., 2008). Children might not yet possess enough experience to have established a solid temptation – higher-priority goal association. Therefore for children solving a conflict might be more situational, present at the very concrete situation rather than relating to higher-priority goal. Future research could address the question on the nature of the conflict resolution mechanisms in children.

In this study, pre-exposure to temptation surprisingly did not influence resistance to temptation in girls. It is in contrast with other research which finds that girls typically react better to certain strategies by altering their eating-related behavior (Clark et al., 2007) as they are more than boys concerned about their weight status (Rolls et al., 1991). There are two possibilities why girls did not react to the pre-exposure manipulation. First, the interaction may reflect a real difference between genders because self-regulation strategies might have matured better in girls. This is consistent with the finding that girls' self-regulation level without or with pre-exposure was similar to the boys' self-regulation level after pre-exposure. In this sample, girls might already mastered their intake of tempting and unhealthy food without any external help and thus pre-exposure was not able to reduce their consumption which was low to begin with. However, it is not likely that girls of this age have already mastered food intake regulation to such an extent in the light of the finding that young adult females are still struggling with a response conflict regarding food and do react to pre-exposure to temptation (Geyskens et al., 2008).

Another possibility why girls did not alter their consumption may reside in the fact that the specific task distracted girls more than boys to such an extent that the goal conflict was reduced. During the task of pre-exposure to temptation, children were asked to form words from candy in the shape of letters, which requires attention and verbal skills. Being more skillful at focusing their attention to a specific target, more successfully ignoring tangential information (Pascualvaca et al., 1997), and being better in verbal tasks (Weiss et al., 2003), girls might have been more interested in the task and they might have completed that task more fluently than boys. Being more interested in the task, they might have not paid enough attention to the presented temptation (the candy letters) for the desire to consume them to occur. This could have prevented the conflict from appearing in the first place. Another possible explanation of difference in gender might be the level of compliance. As shown by a "good behavior" rating, girls generally tend to comply with the rules more than boys. Although these ratings did not influence the consumption during the taste test, this taste test could have been interpreted differently by girls and boys. However, the influence of the compliance is not straightforward. If girls had complied more during the taste test, they might have focused on the rule not to consume much (both in pre-exposure and no pre-exposure conditions), whereas boys, not caring much about the rules, might have consumed as much candy as they wanted, which was influenced by prior exposure to temptation. On the other hand, boys, not caring about the instructions, might have gorged with the candy in both conditions.

The study has a number of limitations. First, this is only one study demonstrating a better resistance to temptation after pre-exposure to a similar temptation in boys, but not in girls. Further studies with the same procedure and including gender as an independent variable should clarify whether the difference in gender that we find in this study is task specific, context specific (the experimenter leaders were both female), or more general. Further studies should look into whether studies with less gender-specific tasks and/or male experiment leaders result in the same outcome.

An interesting questions for future studies is which self-regulatory strategies are more active during pre-exposure – inhibiting the eating goal or activating the restriction goal. To solve a conflict during pre-exposure to temptation children might either concentrate more on completing the task or inhibit the urge to eat the presented candy. The answer to this question could provide valuable insights about children's self-regulatory strategies in the presence of a temptation.

The interpretation of the findings that the self-regulatory strategies used during pre-exposure to temptation are still accessible during the second conflict with a similar temptation raises other questions for future research. One of them is whether these self-regulatory strategies would function in the same way if children were directly told not to consume the candy during the pre-exposure. If so, how strict should restrictions be? It could be that the direct request not to consume the candy will eliminate the need for self-regulatory strategies.

Another limitation of the present findings is that cognitive dissonance may be an alternative explanation of the effect. Per this account, less consumption by boys after not consuming the candy in the pre-exposure phase might be explained by their reduction of the preference of the candy upon their non-consumption. Not compatible with a cognitive dissonance explanation is the presence of a slightly different temptation in two tasks. Exactly the same items are usually used in a cognitive dissonance paradigm. However, we agree that we did not entirely rule out the cognitive dissonance account and it could be an interesting area of research for future studies. Based on the fact that self-regulation mechanisms are applied only when needed, the pre-exposure to temptation would reduce the preference for a temptation when there is an opportunity to consume in the second phase, but not – when there is no such opportunity. Based on cognitive dissonance account, the preference for a temptation should be reduced both when there is and there is no opportunity to consume that temptation in the second phase.

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Mental imagery interventions reduce subsequent food intake only when self-regulatory resources are available

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Research has shown that imagining food consumption leads to food-specific habituation effects. In the present research, we replicated these effects and further examined whether the depletion of self-regulatory resources would reduce the habituation effects of imagined food consumption. Since self-regulatory resources have been shown to reduce habituation effects during the perception of emotional stimuli, we expected a reduction in habituation effects from imagined food consumption when self-regulatory resources were depleted. In Study 1, we replicated habituation effects as a response to imagining gummy bear consumption with a high (36) and medium number (18) of repetitions in a camouflaged taste test. Participants imagining gummy bear intake showed decreased food intake compared with participants who imagined putting a coin into a laundry machine. The number of repetitions did not significantly moderate the observed habituation effect. In Study 2, we investigated whether self-regulatory depletion would impede habituation effects evoked by the imagination of walnut consumption. Participants in a depleted state did not show a reduction in food intake after imagining walnut intake compared with participants in a non-depleted state. We discuss directions for future research and processes that might underlie the observed moderating effect of self-regulatory resources.

Keywords: mental imagery, self-regulation, satiation, habituation, depletion, regulation of food intake

INTRODUCTION

Food intake is important for survival but also has negative consequences such as overweight and obesity, which are accompanied by massive societal and financial burdens (Reilly and Kelly, 2011). Thus, understanding the fundamental underlying mechanisms of food intake is pivotal. A fact challenging individuals' self-regulation is the presence of food cues in their environments (Swinburn et al., 1999). Indeed, a common view is that cues leading individuals to imagine the consumption of food (e.g., cues from sensory marketing) powerfully increase appetite and the likelihood of food consumption through perceptual modulation (Barsalou, 2008; Elder and Krishna, 2010). However, although this might be true in many cases, researchers have shown that mechanisms of habituation can help individuals cope with these challenges (Papies et al., 2012). Research on sensory-specific satiety, for instance, has shown that individuals habituate to specific foods while consuming such foods (Rolls et al., 1981; Hetherington, 1996) in a modality-specific way (Havermans and Mallach, 2014). Even more interesting, recent research has also found that individuals habituate while imagining the consumption of specific food (Morewedge et al., 2010). Since research on the habituation effects of imagined food consumption is rare, the objective of the present research was to examine whether these kinds of habituation effects could be replicated across different kinds of food items, different amounts of repetitions and most importantly whether similar limiting circumstances would hold for imagined food consumption as they do for other kinds of habituation. In particular, we studied whether habituation effects would decrease when self-regulatory resources were depleted compared with when they were not depleted. This latter point is of major relevance because the depletion of self-regulatory resources usually increases impulsive behavior such as the consumption of palatable food (Vohs and Heatherton, 2000; Hagger et al., 2010; Heatherton and Wagner, 2011), and it would be of interest to determine whether reduced habituation effects contribute to such phenomena.

Repeatedly imagining oneself eating a certain food was shown to decrease subsequent consumption of the same food (Morewedge et al., 2010). To further contribute to the understanding of such habituation effects, we investigated whether the effects would increase with the number of repetitions, whether they would occur for different food items, and whether they would be reduced when self-regulatory resources were depleted.

THEORETICAL BACKGROUND

Perception and food cognitions involve perceptual simulations and mental images (Bensafi et al., 2007; Barsalou, 2008). Thinking about a desired food increases a person's motivation to consume that food (elaboration intrusion theory of desire) and is defined as an interplay between associative and elaborative cognitive processes (Kavanagh et al., 2005). External food cues trigger the activation of anticipatory signaling of the autonomous nervous system in preprandial phases. For example, external food cues increase the production of gastric juices and saliva and activate hormonal release to prepare the body for impending food intake (Rodin, 1985). At the same time, the desire to eat increases (Dadds et al., 1997). Spontaneous mental images can lead to similar responses (May et al., 2012). Such images are involved in the development of cravings for alcohol (Statham et al., 2011) and food (Tiggemann et al., 2010; Kemps et al., 2012; Meule et al., 2012; Bullins et al., 2013; Rodriguez-Martin et al., 2013).

Whereas it is evident that thoughts about food can enhance appetite, recent research also suggests that repeatedly imagining food consumption upon being instructed to do so by an experimenter may lead to different effects than thoughts about food without multiple repetitions. In a landmark study Morewedge et al. (2010) showed that 30 repetitions of imagining the consumption of a specific food (e.g., M&M's; cheese cubes) resulted in decreased consumption of the food afterward compared with three repetitions. Hence, imagining food intake does not always lead to increases in food intake. Morewedge et al. (2010) speculated that habituation processes are involved in these effects. Indeed, habituation effects for food consumption have been found for the actual consumption of food before (Epstein et al., 2009a,b; Carr and Epstein, 2011).

According to the memory-based associative conditioning theory, habituation occurs when the presentation of new stimuli is no longer surprising. The presentation of stimuli that already represent information that is stored in short-term memory leads to a reduction in stimulus response (Wagner et al., 1981; Epstein et al., 2009b). A core principle of the standard operating procedure (SOP) model is that when a stimulus is presented, the stimulus is represented in the form of a memory node, which is then activated to a high state of activity (maximally active; the A1 state). Over time, the activity decays, leading to a lower level of activation (processing is more peripheral; the A2 state), and after further decay, such activity becomes inactive (the I state). Information flow is unidirectional from the A1 to A2 to I states; thus, processing in the other direction (from A2 to A1) cannot occur. During food intake, a switch between a state of maximum activity (A1) to a less active and more peripheral processing state (A2) occurs. Sensory-specific satiety, a decrease in the ability to derive pleasure from a certain food after repeatedly being exposed to it, is therefore defined as a habituation process (Rolls et al., 1981; Swithers and Hall, 1994). Repeatedly thinking about consuming a certain food can be seen as a simulation of real food intake without being physically exposed to the food. The experience is similar to an exposure to internally stored memories about the sensory, contextual, and emotional characteristics of an experience (Pylyshyn, 2002; Kosslyn, 2003). When objects are visualized, neural regions are activated in a way that is similar to the actual process of seeing the objects (Ganis et al., 2004), although qualitative differences in the neural dynamics can be observed (Lee et al., 2012; Johnson and Johnson, 2014). Hence, simulating food intake appears to evoke regulating mechanisms that are similar to those evoked from actual food intake.

Interestingly, the SOP model implies (Wagner et al., 1981), that memory processes are the basis for habituation processes and that habituation should be reduced when these memory processes are blocked. In line with this assumption, research has found that distraction is able to reduce habituation effects. For example, individuals were less likely to habituate to the consumption of popcorn when being distracted by actively watching a movie (Epstein et al., 2009b; Harris et al., 2009). Also, results of a recent meta-analysis supported the assumption that distraction leads to an increase in the amount of food consumed (Robinson et al., 2013). A different line of research has shown that the depletion of self-regulatory resources blocks inhibition in eating behavior (Vohs and Heatherton, 2000; Kahan et al., 2003). This research did not study habituation effects directly, but it showed that individuals with reduced self-regulatory resources were less likely to limit their food intake. Self-regulation and executive functioning are proposed to share the same resources. Depleting these resources was associated with reduced inhibitory effects (Kaplan and Berman, 2010). Direct evidence for habituation-reducing effects of the depletion of self-regulatory resources comes from research on the perception of emotional stimuli. Wagner and Heatherton (2013) asked participants in one condition to complete a task that demanded self-regulatory control. In this task, participants had to watch a 7-min nature documentary and inhibit their reading of words presented at the bottom of the screen. They found that this task resulted in a reduction in habituation as a response to emotional pictures observed in the amygdala compared with a control task (Wagner and Heatherton, 2013). Since habituation needs cognitive resources to occur, and since self-regulatory depletion already impedes habituation on the level of very basic brain processes, we posit that habituation while imagining food intake should decrease when individuals' self-regulatory resources are depleted.

THE PRESENT STUDY

The main objectives of the present study were first to replicate the habituation effects after the repeated imagination of food consumption with different food items and different numbers of repetitions and second to test whether the effects would be moderated by self-regulatory depletion. To replicate (Morewedge et al., 2010) findings, we used gummy bears in Study 1 and walnuts in Study 2. To examine the moderating effect of self-regulatory depletion, we varied whether participants had to complete a depleting task in advance in Study 2.

According to the SOP model, increasing the number of repetitions should result in an even more pronounced effect on behavior – thus leading to a larger reduction in food intake. Therefore, we hypothesized that in conditions with a larger number of repetitions, the reduction in food intake due to habituation would be higher than in conditions with a smaller number of repetitions. Therefore, we varied the number of repetitions in Study 1 and tested for habituation in the different conditions.

We furthermore posit that the effects of repeatedly imagining food consumption are based on very general mechanisms and are not linked to a specific kind of food. Therefore, we introduce two new foods into the experimental paradigm to broaden the food spectrum. Morewedge et al. (2010) used foods containing large amounts of fat (cheese cubes: ∼20–30% fat content) and sugar (M&M's: ∼66% sugar) with specific sensory and health characteristics. In the present research, we examined whether habituation would occur after participants imagined themselves consuming gummy bears (Study 1) and walnuts (Study 2). We used gummy bears to study whether the effect could be replicated with a food that is relatively easy to imagine (mignon design in the form of bears). We expected to observe habituation effects after participants repeatedly imagined the consumption of gummy bears. In Study 2, we used walnuts because they are only marginally processed foods and do not include added micro or macronutrients. Although walnuts contain a high amount of fat (~63%), generally walnuts are regarded as healthy and natural foods. In contrast, M&M's, cheese, and gummy bears are highly processed foods. Again, we argue that habituation is defined as a very general mechanism that occurs independently from the imagined food. We expected to observe habituation effects after participants imagined walnut consumption.

Finally, we argue that habituation to the target food should occur only when cognitive resources are available. If cognitive resources are intact, it should be possible to induce the habituation effect. That is, the switch from the A1 to the A2 state will occur, and food intake should be reduced. On the other hand, if cognitive resources are depleted, no habituation effect should occur, and food intake should not be reduced. Therefore, we hypothesized that when a person is in a state of self-regulatory depletion, cognitive resources are not available for habituation to occur. Thus, performing mental imagery with foods in this condition does not lead to habituation and no decrease in food intake in a subsequent taste test was expected (Study 2).

STUDY 1

The main objectives of Study 1 were to replicate the habituation effect after participants imagined food consumption and to test this effect with a large and medium number of repetitions. To examine these objectives, we applied a 2 (*number of repetitions*: 18 vs. 36) × 2 (*imagery item*: gummy bears vs. coins) between-subjects design. Participants were asked to imagine consuming gummy bears or inserting a coin into a laundry machine. We expected a habituation effect after the imagined consumption of the gummy bears and that the habituation effect would be stronger for 36 compared with 18 repetitions.

MATERIAL AND METHODS

Participants

A sample of 101 undergraduate students from the University of Vienna participated in the study on a voluntary basis. Participants were recruited via Internet forums, social media, and flyer postings on the campus of the University. They were asked to refrain from eating 3 h before the experiment and were blinded to the true intentions of the study. They believed they were taking part in a taste and rating test of gummy bears. All ranges of BMI and age were included in the sample. Six participants were excluded from the statistical analyses because they indicated that they did not imagine food consumption as they were asked to. This resulted in a total sample of 95 participants (77 female and 18 male) with a mean age of 24.01 years ($SD = 5.1$) and a mean BMI of 22.02 kg/m^2 ($SD = 2.7$) across both sexes. Ten participants (four male, six female) were classified as overweight ($BMI \geq 25$ kg/m^2) and one male participant as obese ($BMI \geq 30$ kg/m^2), whereas all other participants displayed a BMI between 18.5 and 24.99 kg/m^2 and were therefore considered to have a normal weight.

Study design

The study was designed as a camouflaged taste test of gummy bears presented immediately after a repetitive mental imagery paradigm. This intervention involved repeatedly imagining the consumption of gummy bears or, as a control, visualizing oneself putting coins into a laundry machine with a given number of repetitions of either 18 or 36. Participants were randomly assigned to the 2 (*number of repetitions*: 18 vs. 36) × 2 (*imagery item*: gummy bears vs. coins) between-subjects design using urn randomization (Wei and Lachin, 1988). Unbeknownst to the participants, the qualitative results of the subsequent taste test were not analyzed further, whereas in fact, the amount of gummy bears consumed was the main variable of interest in this study.

Procedure

After arriving at the laboratory, all participants stated their age, sex, body weight, and height and completed questionnaires on current hunger, fullness, overall liking of gummy bears, and restrained eating. Subsequently, participants were asked to perform the mental imagery paradigm, which was explained as a "test of mental visualization skills."

Participants in the gummy bear condition received detailed instructions on how to imagine the consumption of gummy bears either 18 or 36 times. Participants in the control condition were told to imagine putting a 50¢ coin into a laundry machine (motor control task) with an equivalent number of repetitions. The control task was designed to involve imagined motor behaviors that were similar to those from the imagined consumption task. The numbers of 18 and 36 repetitions were chosen to balance between applied practicability and to avoid demanding too much or too little from the participants. A standard package of gummy bears available in an Austrian supermarket contains 72 gummy bears. Thus, 36 repetitions represents half of a standard package available at Austrian supermarkets. Followed by a short introduction from the experimenter, participants were seated in one of the eight separated booths of our sensory lab. They were given detailed written instructions on the mental imagery task procedure (see Table S1). In the description of the task, we stressed a precise wording and asked the participants in the consumption imagery group to focus on sensory and textural characteristics of the imagined food item and on the eating experience of the imagined food itself. In the control group, participants were asked to focus on the sensory and textural characteristics of the imagined coin item and on the action (motoric) experience of throwing the coin in the laundry machine. To keep track of each repetition, we asked the participants to count each repetition on a checklist using pen and paper. We verified the checklists at the end of the experiment. Additionally, we encouraged the participants to spend at least 15 s for every repetition, but did not measure the cumulative time spent for the complete mental imagery task.

After the imagination task, participants were asked to engage in a taste test of different colored gummy bears. Each bowl contained 83 g of gummy bears. Participants were told to eat *ad libitum* from the bowl. The bowls were weighed before and after the taste test to assess the amount of gummy bears eaten. Also, participants rated their hunger, fullness, and liking of the gummy bears once more, completed questionnaires to assess the vividness of their mental imagery, and answered the manipulation check question about whether or not they performed this task. Finally, participants were informed that the experiment was over, were debriefed, thanked for their cooperation, and dismissed.

MEASURES

Manipulation check

To examine whether participants really performed the required mental imagery task, they were asked to indicate whether they had conducted the task or not ("Did you really perform the task we asked you to?").

Hunger status and liking of the product

Visual analog scales (VASs) were used to measure appetite sensations (Stubbs et al., 2000). We used a 120 mm horizontal line with the extremes of the sensations *hunger* and *fullness* at the ends of the line. Participants had to quantify their subjective feeling by placing a mark across the line. We asked participants "how hungry do you feel?" and "how full do you feel?" with the anchor points "0 = not hungry" and "120 = very hungry" and "0 = not full" and "120 = very full," respectively. To measure how much they liked the product, we used a VAS with three anchor points ("not at all," "neither. . .nor," "very much").

Visual imagery

To assess visual imagery, participants were asked to visualize visual images and rated four different scenes on the vividness of four different aspects of these scenes on a 5-point Likert scale (1 = *no picture at all; you merely know that you are thinking about the object*; 5 = *perfectly clear; as vivid as normal vision*) using the Vividness of Visual Imagery Questionnaire (Marks, 1973). An everyday preference for using visual mental images was assessed via the Individual Difference Questionnaire consisting of 13 statements. Participants rated their agreement with each statement on the 5-point Likert scale (1 = *complete agreement*; 5 = *complete disagreement*). Adapted German versions of both questionnaires were used (Hirschfeld et al., 2012) with an internal consistency in the current study of α (Vividness of Visual Imagery Questionnaire) = 0.93 and α (Individual Difference Questionnaire) = 0.72.

Restrained eating

An adapted German version of the 10-item Restraint Scale (Dinkel et al., 2005) was used to assess concern for dieting and weight fluctuation among participants. Concern for dieting was assessed with questions about dieting frequency (0 = *never;* 4 = *always*), weight fluctuation affecting the participants' lives (0 = *not at all*; 3 = *very much*), sensible eating in front of others (0 = *never*; 3 = *always*), thinking about food all the time (0 = *never;* 3 = *always*), feeling guilty after overeating (0 = *never*; 3 = *always*), and mindfulness of one's own eating behavior (0 = *not at all*; 3 = *extremely*). Dieting frequency was assessed with questions regarding their maximum amount of weight gain in kilograms within 1 month (0 = *0–2.5 kg*; 1 = *2.5–5 kg*; 2 = *5–7.5 kg*; 3 = *7.5–10 kg*; 4 = > 10 kg), their maximum amount of weight gain in kilograms within 1 week (0 = *0–0.5 kg*; 1 = *0.5–1 kg*; 2 = *1–1.5 kg*; 3 = *1.5–2.5 kg*; 4 = > 2.5 kg), their typical weight fluctuation within 1 week (0 = *0–2.5 kg*; 1 = *2.5–5 kg*; 2 = *5–7.5 kg*; 3 = *7.5–10 kg*; 4 = > 10 kg), and their maximum weight in kilograms above their desired weight in kilograms (0 = *0–0.5 kg*; 1 = *0.5–3 kg*; 2 = *3–5 kg*; 3 = *5–10 kg*; 4 = > 10 kg). The scale values were averaged across the items. High values indicated restrained eating. Internal consistency in the current study was α (Restraint Scale) = 0.67.

Eating behavior

The amount of gummy bears consumed served as the primary dependent variable. We weighed the bowl of gummy bears before and after the experiment with a standard scale to three decimals places. At the end of the experiment, we assessed participants' reasoning about the possible effect of imagining food intake on their hunger status.

Ethics statement

The experimental procedure was reviewed and approved by the University of Vienna Ethics Committee (*reference number*: 00065), and written informed consent was obtained from all participants before data collection. Participants were informed that they could withdraw their participation at any time during the experiment.

Statistical analysis

Results were considered significant at an α level of $p \leq 0.05$. Results marked *ns* refer to *p*-values > 0.05 (for a summary of the data, see Table S2).

RESULTS AND DISCUSSION

Eating behavior

We hypothesized that participants would eat a smaller amount of gummy bears when they repeatedly imagined eating gummy bears compared with putting coins into a laundry machine. Furthermore, we expected this effect to be more pronounced for 36 compared with 18 repetitions. To test the hypotheses, a 2 (*repetition number*: 18 vs. 36) × 2 (*imagery item*: gummy bears vs. coins) between-subjects ANOVA with gummy bear intake as the dependent variable was computed. As expected, participants consumed a smaller amount of gummy bears when they repeatedly imagined eating gummy bears ($M = 24.63$ g, SD = 11.02 g) compared with when they repeatedly imagined putting coins into a laundry machine ($M = 32.94$ g, SD = 16.94 g) [$F_{(3,95)} = 8.61$, $p = 0.004$, $\eta^2_p = 0.09$] (see **Figure 1**). In contrast to our hypothesis, the interaction between repetition number and imagery item was not significant [$F_{(1,95)} = 0.51$, $p = 0.47$].

As expected, liking gummy bears had a pronounced effect on gummy bear consumption [$F_{(1,95)} = 13.8$, $p = 0.04$, $\eta^2_p = 0.13$]. Liking gummy bears did not change significantly from before ($M = 80.17$, SD = 23.58) to after the experiment was conducted ($M = 77.55$, SD = 26.99) [$F_{(1,95)} = 0.12$, $p = 0.29$]. None of the following parameters had effects on the amount of gummy bears consumed: (i) hunger assessed before the experiment [$F_{(1,95)} = 0.36$, $p = 0.55$]; (ii) fullness before the experiment [$F_{(1,95)} = 0.11$, $p = 0.78$]; (iii) time of last meal intake [$F_{(1,95)} = 0.14$, $p = 0.71$]; (iv) restrained eating scores [$F_{(1,95)} = 1.26$, $p = 0.27$]; (v) BMI scores, [$F_{(1,95)} = 0.39$, $p = 0.53$]; (vi) gender [$F_{(1,95)} = 2.80$, $p = 0.09$]; (vii) Vividness of Visual Imagery Questionnaire scores

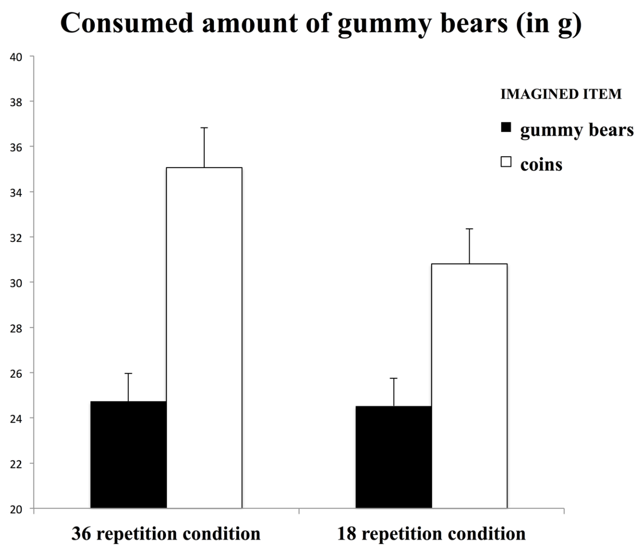

FIGURE 1 | Consumed amount of gummy bears (in g) as a function of imagined item (gummy bears vs. coins) and amount of repetitions (18 repetitions vs. 36 repetitions). Error bars indicate standard errors of the means (Study 1).

[$F_{(1,95)} = 0.08$, $p = 0.78$]; or Individual Difference Questionnaire scores [$F_{(1,95)} = 0.29$, $p = 0.59$]. In an analysis of covariance, the inclusion of the above variables did not affect the reported habituation effect [$F_{(1,95)} = 4.32$, $p = 0.04$, $\eta_p^2 = 0.05$].

No changes in fullness from before ($M = 49.32$, SD = 26.91) to after the mental imagery task ($M = 58.26$, SD = 25.89), [$F_{(1,94)} = 1.27$, $p = 0.29$] or in hunger from before ($M = 33.26$, SD = 24.41) to after the mental imagery task ($M = 28.99$, SD = 23.69), [$F_{(1,94)} = 0.81$, $p = 0.48$], were observed.

Participants' expectations

To examine whether the reported habituation effect could be evoked by participants' expectations, we also analyzed these expectations. Importantly, most participants did not expect a habituation effect. 90% of the participants inferred that imagining gummy bear intake might stimulate their appetite, 8% reasoned that thinking about food intake might decrease their appetite, and 2% assumed that it might have no effect on their appetite. When we excluded participants who expected a decrease in their appetite (eight participants), a between-subjects ANOVA still showed a significant main effect of the imagery task [$F_{(3,87)} = 7.51$, $p = 0.007$, $\eta_p^2 = 0.08$], indicating a lower consumption of gummy bears among participants who repeatedly imagined eating gummy bears ($M = 25.00$ g, SD = 11.27 g) compared with those who repeatedly imagined putting coins into a laundry machine ($M = 33.31$ g, SD = 16.13 g).

To sum up, in Study 1, we replicated the habituation effect after imagining food consumption. Importantly, the participants' expectations could not account for this effect.

Morewedge et al. (2010) found no habituation effect for three compared with 30 repetitions. Hence, at least more than three repetitions are necessary to produce the effect. In Study 1, the number of repetitions (18 vs. 36) did not significantly moderate the effect. We expected that a larger number of repetitions would be necessary for the habituation effect to occur. The present data did not confirm this hypothesis but reflected the strength of the habituation effect. In Study 2, we examined whether self-regulatory depletion would impede habituation effects while participants imagined food consumption.

STUDY 2

The main objective of Study 2 was to test the hypothesis that a depletion of self-regulatory resources would decrease the habituation of imagined food consumption. We formulated this hypothesis because self-regulatory depletion has been shown to reduce habituation in other contexts (Wagner and Heatherton, 2013). We applied a 2 (depletion vs. non-depletion of self-regulatory resources) × 2 (*imagery item*: walnuts vs. coins) between-subjects design. We varied whether participants completed a task that depleted or did not deplete their self-regulatory resources. Furthermore, we asked participants to imagine either consuming food or putting a coin into a laundry machine. As the target food, we used walnuts in Study 2.

MATERIAL AND METHODS

Participants

For Study 2, we recruited exclusively female participants via online forums, social networks, and message boards at the University of Vienna. We decided to include only women in the present study because the probability of observing an effect with a small sample size would be higher in a homogenous sample. In Study 1, men tended to eat more than women. Therefore, in Study 2, 90 females participated in the experiment. Four participants had to be excluded from the study because they failed the manipulation check. Four participants were excluded from the statistical analyses to preserve data homogeneity (cut-off > 2.5 SD of mean walnut consumption). Hence, data from 82 female participants were included in the statistical analyses. These participants had a mean age of 24.52 years (SD = 3.19) and a mean BMI of 21.38 kg/m^2 (SD = 2.70). 11 were classified as overweight (BMI ≥ 25 kg/m^2), one as obese (BMI ≥ 30 kg/m^2), whereas all other participants displayed a normal BMI between 18.5 and 24.99 kg/m^2. Most of the participants were undergraduate students in the nutritional sciences who volunteered to take part in the experiment.

Similar to Study 1, participants were deprived of food for 3 h and blind to the true purposes of the study, believing that they were participating in a taste test of different brands of walnuts. As compensation, every participant received a lottery ticket. As in Study 1, all ranges of BMI and age were included in the sample.

Study design

Study 2 was designed as a camouflaged taste test of walnuts, but in contrast to Study 1, the taste test was preceded by two interventions. First, a counting task with two different variations of difficulty was applied in order to induce a state of high and low self-regulatory depletion (Webb and Sheeran, 2003; Hagger and Chatzisarantis, 2013). Subsequently, the mental imagery paradigm was performed as the second task in the dual-task procedure either by asking participants to imagine that they were eating walnuts or, as a control, to imagine putting a 50¢ coin into a laundry machine with a given number of 18 repetitions. Participants were randomly assigned to a 2 (depletion vs. non-depletion of self-regulatory resources) × 2 (*imagery item*: walnuts vs. coins) between-subjects design using an online randomizer tool (Urbaniak and Plous, 2008). The amount of walnuts consumed was the main dependent variable in this experiment, and the questionnaire results of the taste tests were not analyzed further.

Procedure

Participants completed questionnaires with regard to their current hunger and overall liking of walnuts and stated their age, height, and body weight. Next a "test of mathematical abilities" was introduced, but it was in fact a counting task that was based on a test for assessing automatization difficulties in patients with dyslexia (Fawcett et al., 1996; Webb and Sheeran, 2003). The test was used to manipulate self-regulatory depletion in the present study. Participants in the high self-regulatory depletion condition were told to count backward from one thousand in multiples of seven while standing on only one leg. This procedure has been shown to evoke self-regulatory depletion in the past because participants need to resist the desire to quit this exercise due to their struggle to try not to lose their balance while engaging in a complicated counting task (Hagger and Chatzisarantis, 2013). Participants in the low self-regulatory depletion condition were instructed to count backward from 500 in multiples of five while standing on both legs, a task that was expected to require no self-control. After that, participants completed three manipulation check items to assess effort, difficulty, and fatigue (Webb and Sheeran, 2003) and rated their current mood by completing the short German version of the profile of mood states (Dalbert, 1992). Afterward, participants were seated in one of the classrooms of our facilities. We ensured that participants were not distracted in any way and seated them in an empty classroom. They were given detailed written instructions on the mental imagery task procedure (see Table S1). As in Study 1, we asked the participants to focus on sensory and textural characteristics of the imagined food item and on the eating experience. Participants in the control group were asked to focus on the sensory and textural characteristics of the imagined coin item and on the action (motoric) experience of throwing the coin in the laundry machine. To keep track of each repetition, we asked the participants to count each repetition on a checklist using pen and paper. We verified the checklists at the end of the experiment. Additionally, we encouraged the participants to spend at least 15 s for every repetition, but did not measure the cumulative time spent for the complete mental imagery task and therefore could not assess how much time each individual spent for the task.

Subsequently, participants engaged *ad libitum* in a taste test of different brands of walnuts, which were weighed before and after the experiment unbeknownst to the participants. Each participant was presented a total of 120 g of walnuts equally distributed in four identical bowls. Then participants completed the mental imagery manipulation check and the sub-scale for restrained eating from the Dutch Eating Behavior Questionnaire and the short version of the Barratt Impulsiveness Scale. Finally, participants were debriefed, thanked, and dismissed after receiving a lottery ticket as compensation.

MEASURES

Manipulation check

To examine whether participants really performed the required mental imagery task, they were asked to indicate whether they conducted the task in the instructed way or not ("Did you really perform the task we asked you to?").

Mood

Positive and negative mood states were examined. The short German version of the profile of mood states was used (Dalbert, 1992). After an initial question "How do you feel right at this moment?" participants rated 19 different items including grief ($n = 3$), desperation ($n = 3$), rage ($n = 3$), fatigue ($n = 4$), and positive mood ($n = 6$) on seven-point Likert scales ranging from 1 (*not at all*) to 7 (*very much*). Internal consistencies were α (*grief*) = 0.86, α (*rage*) = 0.77, α (*desperation*) = 0.81, α (*fatigue*) = 0.91, and α (*positive mood*) = 0.89.

Hunger status

To measure hunger before and after the experiment, a VAS with a length of 100 mm was used with four anchor points consisting of "not hungry at all," "hungry," "very hungry," and "extremely hungry" (Stubbs et al., 2000). Liking of walnuts was assessed using the same VAS with three anchor points used in Study 1 for the gummy bears.

Task perceptions

We also measured whether self-regulatory depletion was successfully induced by the manipulation. Participants were instructed to rate the counting task on seven-point Likert scales ranging from 1 (*not at all*) to 7 (*very much*) according to whether the task was fatiguing, difficult, and required effort. The internal consistency in the current study was α (difficult, fatiguing, effortful) = 0.87 (Webb and Sheeran, 2003). High values indicate a strong self-regulatory depletion.

Trait impulsiveness

The short German version of the Barratt Impulsiveness Scale-15 was used to assess trait impulsiveness (Meule et al., 2011). This measure is commonly used to measure impulsive behavior as a trait. The Barratt Impulsiveness Scale-15 consists of three factors, which are non-planning, motor, and attentional impulsivity. Each factor consists of five items, which were rated on a 4-point scale ranging from 1 (*never*) to 4 (*always*). Statements for non-planning include "I plan tasks carefully"; for attention impulsivity, "I am restless during lectures or talks"; and for motor impulsivity, "I say things without thinking" (Spinella, 2007). The items were averaged into an overall impulsivity measure. High values indicate high trait impulsivity. Internal consistency in the present study was α (Barratt Impulsiveness Scale-15) = 0.78.

Restrained eating

The German translation of the sub-scale for restrained eating of the Dutch Eating Behavior Questionnaire was used (Van Strien et al., 1986). This scale consists of 10 items that target restrained eating with questions such as "When you have put on weight, do you eat less than you usually do?" or "Do you deliberately eat less in order to avoid becoming heavier?" These questions were answered on a 5-point Likert scale ranging from 1 (*never*) to 5 (*very often*). Internal consistency in the present study was α (*Dutch Eating Behavior Questionnaire*) = 0.91. High values indicate restrained eating.

Eating behavior

The amount of walnuts consumed as assessed by weighing the walnuts before and after the experiment with a standard scale to three decimals places served as the primary dependent variable.

Ethics statement

The experimental procedure was reviewed and approved by the University of Vienna Ethics Committee (*reference number*: 00065), and written informed consent was obtained from all participants before data collection. Participants were informed that they could withdraw their participation at any time during the experiment.

Statistical analysis

Results were considered significant at an α level of $p \leq 0.05$ (results marked *ns* refer to *p*-values > 0.05).

RESULTS AND DISCUSSION

Self-regulatory depletion induction

Independent *t*-tests revealed significant differences in perceived difficulty, effort, and fatigue between the two ego-depletion conditions. In the depleted self-regulatory condition, participants rated the counting task as significantly more difficult, $t(80) = 11.65$, $p < 0.001$; effortful, $t(80) = 7.87$, $p < 0.001$; and fatiguing, $t(80) = 12.50$, $p < 0.001$, than participants in the non-depleted self-regulatory condition (**Figure 2**). This indicates a successful induction of self-regulatory depletion (Hagger and Chatzisarantis, 2013; Hagger et al., 2013). The self-regulatory depletion manipulation did not affect positive mood [$F_{(1,80)} = -1.41$, *ns*], grief [$F_{(1,80)} = 0.85$, *ns*], desperation [$F_{(1,80)} = 0.24$, *ns*], rage [$F_{(1,80)} = 0.71$, *ns*], or overall fatigue [$F_{(1,80)} = 1.19$, *ns*].

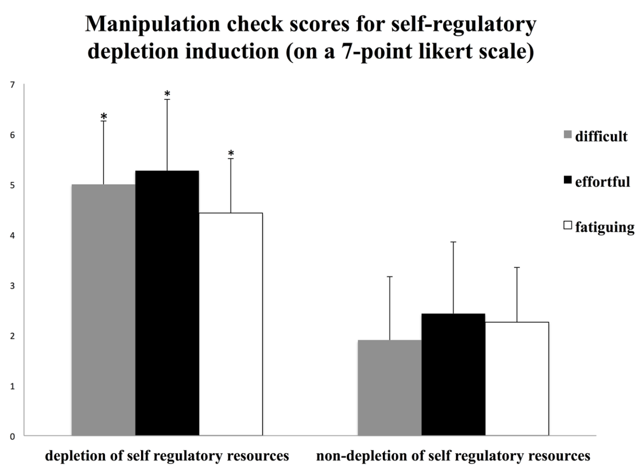

FIGURE 2 | Manipulation check scores for self-regulatory depletion induction (on 7-point Likert scale) displaying difficulty, effort and fatiguing as a function of resource depletion (depletion vs. non-depletion of self-regulatory resources). Asterisk indicates $p < 0.05$.

Eating behavior

We hypothesized that participants would eat a smaller amount of walnuts when they repeatedly imagined eating walnuts compared with imagining putting coins into a laundry machine. Furthermore, we expected this effect to be less prevalent in a state with depleted self-regulatory resources compared with a state with non-depleted resources. To test the hypotheses, we computed a 2 (depletion vs. non-depletion of self-regulatory resources) by 2 (imagery item: walnuts vs. coins) between-subjects ANOVA with walnut consumption as the dependent variable.

The results are depicted in **Figure 3**. In line with our hypothesis, participants in the non-depletion condition ate a smaller amount of walnuts when they imagined eating walnuts ($M = 29.62$ g, SD = 7.53 g) compared with when they imagined putting coins into a laundry machine ($M = 35.49$ g, SD = 7.53 g) [$F_{(1,39)} = 6.26$, $p = 0.02$, $\eta_p^2 = 0.14$]. By contrast, participants in the depletion condition did not differ in their intake of walnuts when they imagined eating walnuts ($M = 36.29$ g, SD = 9.77 g) compared with when they imagined putting coins into a laundry machine ($M = 35.63$ g, SD = 8.14 g), [$F_{(1,39)} = 0.06$, $p = 0.82$]. The interaction between self-regulatory depletion and the imaginary item was only marginally significant but had a medium effect size [$F_{(3,80)} = 3.18$, $p = 0.08$, $\eta_p^2 = 0.04$; see **Figure 3**]. The main effect of repeatedly imagining eating walnuts ($M = 32.95$ g, SD = 8.91 g) compared with repeatedly imagining putting coins into a laundry machine ($M = 35.27$ g, SD = 7.74 g) on the amount of walnuts consumed was not significant [$F_{(3,80)} = 2.03$, $p = 0.16$, $\eta_p^2 = 0.03$]. The main effect of the self-regulatory depletion manipulation on the amount of walnuts consumed was marginally significant. Participants ate more walnuts when self-regulatory resources were depleted ($M = 37.89$ g, SD = 11.26 g) compared with when

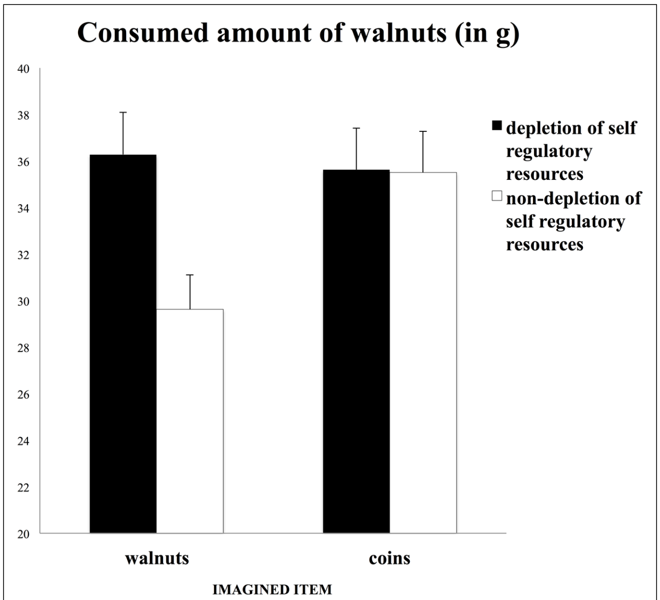

FIGURE 3 | Consumed amount of walnuts (in g) as a function of imagined item (walnuts vs. coins) and state of self-regulatory resources (depletion vs. non-depletion of self-regulatory resources). Error bars indicate standard errors of the means (Study 2).

they were not depleted ($M = 33.26$, SD $= 9.36$), [$F_{(3,80)} = 3.43$, $p = 0.07$, $\eta_p^2 = 0.04$].

A one-way analysis of covariance revealed that none of the following parameters showed effects on the amount of walnuts consumed: (i) BMI scores [$F_{(1,80)} = 0.01$, $p = 0.93$]; (ii) hunger prior to the experiment [$F_{(1,80)} = 0.10$, $p = 0.92$]; (iii) impulsivity scores [$F_{(1,80)} = 0.03$, $p = 0.86$]; (iv) restrained eating scores [$F_{(1,80)} = 0.16$, $p = 0.69$]; and (v) liking walnuts [$F_{(1,80)} = 0.24$, $p = 0.63$]. Liking walnuts did not change significantly from before ($M = 82.61$, SD $= 24.65$) to after the experiment was conducted ($M = 84.38$, SD $= 23.70$) [$F_{(1,80)} = 1.91$, $p = 0.17$]. There were no changes in hunger from before ($M = 41.13$, SD $= 20.92$) to after the mental imagery task ($M = 27.03$, SD $= 20.51$) across intervention groups [$F_{(1,82)} = 0.15$, $p = 0.93$].

To sum up, in Study 2, we found initial evidence that self-regulatory depletion can reduce habituation effects on the intake of food after imagining the consumption of the food.

GENERAL DISCUSSION

Recent research has provided initial evidence that imagining the consumption of food leads to habituation effects that are similar to those that occur with the actual consumption of food (Morewedge et al., 2010). The objective of the present research was to replicate this effect with different kinds of foods and to test the hypothesis that self-regulatory depletion reduces habituation effects from the imagined consumption of food. The main reasoning for the latter was that habituation effects are basically memory effects that require cognitive resources. Therefore, the depletion of cognitive resources should reduce habituation effects that occur from imagining the consumption of food. The results of two studies showed that the habituation effect from food consumption is a stable phenomenon that occurs for different kinds of foods. Study 1 provided a replication of the initial habituation effects induced by mental imagery by Morewedge et al. (2010) and generalized these over another kind of food (gummy bears) as well as over different (smaller and larger) amount of imagery repetitions. In addition, the results of Study 2 provided initial evidence that the depletion of self-regulatory resources impedes habituation effects from imagining the consumption of food.

We replicated the findings of previous experiments using mental imagery (Morewedge et al., 2010) with two different food items (gummy bears and walnuts) with different optical and perceived health characteristics. The finding that habituation occurred with both types of food is in line with the assumption that habituation effects are independent of food characteristics (Epstein et al., 2009b). Furthermore, 18 and 36 repetitions showed similar effects on food intake (Study 1), indicating that 18 repetitions of mental imagery are enough to induce the habituation effect. Study 1 provided a replication of the initial habituation effects induced by mental imagery by Morewedge et al. (2010) and generalized these over another kind of food (gummy bears) as well as over different (smaller and larger) amount of imagery repetitions. We know from previous studies that three repetitions are not sufficient (Morewedge et al., 2010). Hence, the habituation-inducing threshold lies between 3 and 18 repetitions. This finding has implications for future research, because high numbers of repetitions can have side effects such as depletion or even impatience of participants and can lead to infeasibility of the mental imagery task. The finding that habituation effects occur on lower levels shows that it is possible to study the phenomenon with a decreased amount of repetitions. This implies that the phenomenon of habituation is limited in the extent, and that more repetitions do not necessarily lead to stronger habituation effects. Conducting 18 repetitions can be a time consuming task, thus future research should try to narrow down the threshold in which habituation to imagined foods occurs, using lower amounts of repetitions. A lower number of repetitions might lead to a more practicable approach using mental imagery and consequent habituation to reduce food intake.

At this point, we can only speculate why the different amount of imagery repetitions yielded a habituation effect of the same strength. Assumingly, the central process of imagery and habituation in the working memory might offer the answer. The working memory is a system with limited cognitive capacity (Cowan, 2004), and it is therefore possible that performing a vivid mental imagery task more than 18 times (36) might be overly taxing for the working memory (image vividness is related to capacity of cognitive resources (Bywaters et al., 2004)) in that the retrieval, maintenance, and refreshment of a repeated vivid mental imagery might have used all the available (working memory) resources (Kosslyn, 1996; Gunter and Bodner, 2008). As habituation also needs memory capacity to take place, we could assume that when the memory resources reached a capacity limit after a certain number of repetitions of the vivid mental imagery (we encouraged the participants to vividly imagine the food consumption), there were no more resources which could be used to strengthen the habituation effects even more over the next couple of repetitions.

To date, habituation effects of imagined food consumption have been found with M&M's, cheese cubes (Morewedge et al., 2010), gummy bears (Study 1), and walnuts (Study 2). Similar to the studies by Morewedge et al. (2010), the results of the present studies showed that imagining the consumption of food does not reduce hunger or lead to a feeling of fullness.

Habituation effects after imagining food consumption do not represent demand effects because they deviate from the common expectation that thinking about food consumption increases appetite and hunger. In Study 1, we asked participants about their expectations and found that most of them expected an increase in consumption after imagining food consumption.

An interesting question is whether habituation effects from imagining food consumption follow the same rules as other habituation effects. Previous research has shown that habituation effects for example, those related to the perception of pictures or the consumption of food are reduced when individuals are distracted (Epstein et al., 2009b; Harris et al., 2009) or when their self-regulatory resources are depleted (Wagner and Heatherton, 2013). The finding from Study 2 that habituation was reduced when individuals' self-regulatory resources were depleted implies that the habituation effects from visualization are based on processes that are similar to those involved in other forms of habituation.

It is difficult to explain the observed finding that the depletion of self-regulatory resources reduces the effects of imagined food consumption by reducing impulse control after self-regulatory depletion alone (Baumeister et al., 1998; Epstein et al., 2009b). First, walnuts are not a product that is related to strong impulses as chocolate and sweets are. Second, if there were strong impulses to eat walnuts, and if individuals needed self-regulatory resources to limit themselves when eating walnuts, the depletion of self-regulatory resources should have increased food intake in both imagination conditions (walnuts and coins) and not only in the condition in which walnut consumption was imagined.

From a different theoretical perspective, other promising studies have also examined the effects of thoughts on food, satiety, and how much such foods are liked (Papies et al., 2012; Redden and Galak, 2013; Larson et al., 2014). Papies et al. (2012) argue, for example, that spontaneous mental images can lead to a more abstract representation of food with a reduced focus on eating; this in turn reduces appetite, liking, and automatic approach responses to food. We cannot rule out the possibility that repetition effects also lead to a different representation of food. However, the mentioned stream of research did not study repetition effects as we did in the current study, and they did not predict differences between a single instance of imagining and the repeated imagination of food consumption.

A strength of the current research is that we measured actual food intake. Indeed, we observed a reduction in actual food intake ranging from 20 to 25% from repeatedly imagining food intake.

LIMITATIONS

Although findings from both presented studies are intriguing, we want to mention that the interpretation of the results should be cautious because the interaction between self-regulatory depletion manipulation and the imaginary item was only marginally significant. The hypothesis that self-regulatory depletion reduces habituation effects after imagining the consumption of food is in line with models proposing that cognitive resources are needed for habituation effects to occur (Epstein et al., 2009b). Indeed, we suppose that the self-regulatory depletion task we applied in Study 2 slowed down the memory processes that are involved in habituation effects. However, at present, we cannot rule out the possibility that the self-regulatory depletion task reduced engagement in the imagination task or impeded attention allocation for the task (Friese et al., 2012; Inzlicht et al., 2014). Self-regulatory depletion might make it difficult for participants to imagine food consumption vividly, and one might speculate that a vivid imagination is a necessary precondition for habituation effects. In addition, it is possible that self-regulatory depletion amplifies processing at a lower level of brain processes but does not affect the memory processes that underlie habituation. Hence, on the basis of the present studies, we can conclude that self-regulatory depletion reduces the habituation effects of imagined food consumption.

But we can only speculate about the underlying processes. We would assume that the self-regulatory depletion decreased habituation effects in Study 2 by impeding the process of habituation. We assume that the self-regulatory task depleted cognitive resources (mainly memory) essential for habituation to take place and therefore habituation itself did not occur as a consequence. Apart from that, however, one might speculate that habituation is not only influenced by memory processes but also by other components of self-regulation leading to a reduced intake in participants with depleted self-regulatory resources. Beyond working memory, presumably disrupting self-regulation leads to a disruption of willpower resources, as well. Nevertheless, there is evidence that habituation enfolds slower in people who are allegedly weaker in self-regulation, such as people with obesity (Temple et al., 2007; Epstein et al., 2011), although cognitive resources are intact. Therefore, self-regulatory processes might influence habituation effects beyond just cognitive resources by additionally influencing resources of willpower. In fact, the depletion task used in Study 2 involved a component of extra self-control (balancing on one leg), which might have led to induce depletion of extra self-regulatory resources and thus those were responsible for reduced habituation. Future research might focus in more detail on the processes that underlie habituation effects after the imagination of food consumption and help to show which memory and brain processes are involved in such effects.

CONCLUSION

The findings of this paper further elucidate how cognitive processes interfere with and shape eating behaviors. The results suggest that habituation after the repeated imagination of food consumption is a stable phenomenon that needs self-regulatory resources to occur.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://www.frontiersin.org/journal/10.3389/fpsyg.2014.01391/abstract

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Pickles and ice cream! Food cravings in pregnancy: hypotheses, preliminary evidence, and directions for future research

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Women in the United States experience an increase in food cravings at two specific times during their life, (1) perimenstrually and (2) prenatally. The prevalence of excess gestational weight gain (GWG) is a growing concern due to its association with adverse health outcomes in both mothers and children. To the extent that prenatal food cravings may be a determinant of energy intake in pregnancy, a better understanding of craving etiology could be crucial in addressing the issue of excessive GWG. This paper reviews the available literature to corroborate and/or dispute some of the most commonly accepted hypotheses regarding the causes of food cravings during pregnancy, including a role of (1) hormonal changes, (2) nutritional deficits, (3) pharmacologically active ingredients in the desired foods, and (4) cultural and psychosocial factors. An existing model of perimenstrual chocolate craving etiology serves to structure the discussion of these hypotheses. The main hypotheses discussed receive little support, with the notable exception of a postulated role of cultural and psychosocial factors. The presence of cravings during pregnancy is a common phenomenon across different cultures, but the types of foods desired and the adverse impact of cravings on health may be culture-specific. Various psychosocial factors appear to correlate with excess GWG, including the presence of restrained eating. Findings strongly suggest that more research be conducted in this area. We propose that future investigations fall into one of the four following categories: (1) validation of food craving and eating-related measures specifically in pregnant populations, (2) use of ecological momentary assessment to obtain real time data on cravings during pregnancy, (3) implementation of longitudinal studies to address causality between eating disorder symptoms, food cravings, and GWG, and (4) development of interventions to ensure proper prenatal nutrition and prevent excess GWG.

Keywords: pregnancy, craving, restraint, eating disorders, food, chocolate, perimenstrual

OVERVIEW

Food cravings are a common phenomenon, especially in women in the United States (U.S.), and have been implicated in a range of weight- and eating-related pathology. Cravings in women have been shown to increase in frequency and intensity at two distinct times: during the perimenstrum (i.e., a period of about eight days around the onset of menstruation) and in pregnancy. Perimenstrual cravings for chocolate have been the focus of significant attention from researchers in recent years, resulting in enhanced insight into the mechanisms underlying craving etiology. Cravings in pregnancy, on the other hand, remain relatively understudied. This gap in the literature is especially striking given the steady rise in prevalence of excess gestational weight gain (GWG) during the end of the last century, which is related to adverse health outcomes in mothers and their children, along with a growing understanding of the causal role of food cravings in the etiology of overweight and obesity. Thus, a call for a renewed focus on research in this area is warranted.

This paper seeks to highlight the importance of gaining a better understanding of the mechanisms underlying food cravings as a potentially modifiable determinant of energy intake and nutritional quality in pregnancy. We will begin with a brief introduction to food cravings both in general and specifically in pregnancy, followed by an overview of the adverse health effects of excess GWG. We will then introduce a theoretical framework of craving etiology that integrates key results from work on perimenstrual chocolate craving and argue that this framework can serve as a useful blueprint for the study of food cravings in pregnancy. We will review major hypotheses regarding craving etiology and examine the extent to which they are supported or refuted by the existing literature on prenatal eating behaviors. We will conclude with thoughts on future directions for research in this area. It is important to note that an exhaustive review of the literature in this field is beyond the scope of the present paper. Instead, we aim to call attention to the importance of studying food cravings in pregnancy in so far as they may be implicated in the growing rates of gestational overweight and obesity and associated adverse health effects in U.S. mothers and their children. Our primary goal is to take advantage of the knowledge gained from the study of cravings in other domains to formulate testable hypotheses about the underlying causes of food cravings in pregnancy.

FOOD CRAVINGS: AN INTRODUCTION

Food cravings are strong urges for foods that are more specific than mere hunger and very difficult to resist (Gendall et al., 1997; Pelchat, 2002; Hormes and Rozin, 2010). Food cravings are a common phenomenon, at least in some areas of the world. Between 68 and 97% of college-aged men and women in North America report ever having experienced a craving for a specific type of food (Weingarten and Elston, 1990; Zellner et al., 1999). It is tempting to think of food cravings as far less harmful than strong urges for alcohol, tobacco, and other drugs, which are known to trigger relapse and interfere with successful abstinence from substance use (Bottlender and Soyka, 2004; Sinha et al., 2006; Ferguson and Shiffman, 2009; Evren et al., 2012). However, a growing body of research now points to a significant role of food cravings in the development and maintenance of eating- and weight-related pathology, including overweight, obesity, bulimia nervosa, binge eating disorder, and failure to sustain weight losses (Gendall et al., 1997; Lafay et al., 2001; Lowe, 2003; Lowe and Levine, 2005; Forman et al., 2007; Vander Wal et al., 2007). For example, food cravings have been identified not only as reliable predictors of subsequent consumption of the desired food (Forman et al., 2007), but also as potential triggers for episodes of binge eating, especially in bulimic and overweight individuals (Bjoervell et al., 1985; Kales, 1990). In spite of a steadily growing number of studies in this field, the exact mechanisms underlying the etiology of food cravings have yet to be elucidated. There has been a recent increase in efforts to develop interventions targeting food cravings and studies have tested the efficacy of diverse approaches, including brief guided imagery (Hamilton et al., 2013), use of self-help manuals (Rodriguez-Martin et al., 2013), acceptance based strategies (Forman et al., 2007; Alberts et al., 2010), and biofeedback (Meule et al., 2012) in preventing or reducing food cravings. It should be noted that most of these interventions were developed specifically for individuals who identify as strong cravers (Meule et al., 2012), non-clinical populations (Forman et al., 2007; Hamilton et al., 2013), or those enrolled in weight loss trials (Batra et al., 2013). More work to test the efficacy of these interventions specifically in clinical populations is warranted.

The prevalence and nature of food cravings varies significantly depending on the geographic region under investigation (Hormes and Rozin, 2010; Hormes, 2014). Food cravings seem to be most commonly reported by individuals in North America and chocolate has consistently been found to be the most commonly craved food in the U.S. (Rozin et al., 1991; Osman and Sobal, 2006). Within the U.S., the type, frequency, and intensity of reported food cravings vary markedly by demographic characteristics. Younger individuals are more likely to experience food cravings, with prevalence decreasing steadily with age (Pelchat, 1997). Women primarily report strong urges to consume sweets, while men typically crave savory foods, especially when stressed (Zellner et al., 1999, 2007). Women in the U.S. are twice as likely to experience cravings for chocolate as compared to men. This difference in prevalence appears attributable, primarily, to a pronounced increase in chocolate craving frequency and intensity during the perimenstrum, an eight days period beginning about four days prior to the onset of menstruation, for around half of female cravers (Rozin et al., 1991; Zellner et al., 2004; Hormes and Rozin, 2009). In addition to the characteristic perimenstrual rise in chocolate craving, it appears that many U.S. women may also experience an increase in food cravings during pregnancy (Pope et al., 1992). In spite of a growing interest in the study of mechanisms involved in the etiology of cravings in other domains, food cravings in pregnancy are poorly understood and widespread speculation about their meaning and significance by laypersons and the media stands in stark contrast to a lack of empirical research on the subject.

FOOD CRAVINGS IN PREGNANCY

An estimated 50–90% of U.S. women experience cravings for specific foods during pregnancy (Worthington-Roberts et al., 1989; Pope et al., 1992). Very few women report food cravings exclusively during pregnancy; most have a history of pregravid cravings for a variety of substances (Gendall et al., 1997). In terms of temporal patterns, it has been reported that food cravings typically emerge by the end of the first trimester. For example, among a sample of 400 white adult women 76% reported craving at least one food item by the 13th week of pregnancy (Tierson et al., 1985). The most common trajectory of food cravings across gestation shows a peak in frequency and intensity during the second trimester, followed by a subsequent decline as the pregnancy progresses to term (Pope et al., 1992; Bayley et al., 2002; Belzer et al., 2010). Research has also consistently documented a significant drop in cravings following delivery (Worthington-Roberts et al., 1989; Belzer et al., 2010).

A 1978 study retrospectively examined prevalence and types of cravings in a group of 250 pregnant women and demonstrated that the most commonly craved items included sweets (i.e., ice cream and candy), dairy, starchy carbohydrates, fruits, vegetables, and fast food (Hook, 1978). A 1992 survey of pregnant adolescents found frequent reports of cravings for sweets, fruits, fast foods, pickles, ice cream, and pizza (Pope et al., 1992). More recent studies showed similar cravings, with women endorsing a desire for fruit juice, fruit, sweets, desserts, dairy, and chocolate (Flaxman and Sherman, 2000; King, 2000). Prenatal cravings for salty or savory foods are somewhat less commonly reported (Hook, 1978; Pope et al., 1992; Bayley et al., 2002), with the notable exception of women who experience cravings exclusively during pregnancy (Gendall et al., 1997). This subset of women were found to endorse cravings for savory, rather than sweet foods (Gendall et al., 1997). Given the lack of current data on the nature of food cravings in pregnancy we recently conducted a small pilot study examining women's posts on pregnancy-related blog websites about the topic of food cravings[1]. Among 200 posts surveyed, the most

[1]This study sought to gather information on the types of food cravings currently reported by pregnant women in the U.S. by surveying women's posts on the topic of food cravings on two popular pregnancy-related websites: www.thebump.com and www.whattoexpect.com. Data were collected in the fall of 2012. We searched the "community" forums on the two websites for the term "craving" and examined responses contained in the first 20 message threads generated by that search, resulting in a sample of 200 unique posts. We excluded search results that were unrelated to

commonly reported cravings were for sweets, calorically dense savory carbohydrates like pizza or chips, animal proteins, and fruits (**Table 1**). Prior research also points to certain temporal patterns in the types of foods craved over the course of pregnancy. Cravings for savory substances appear to be strongest during the first trimester, with a tapering of urges during the later stages of peripartum (Belzer et al., 2010). In a large number of women, a preference for sweet foods reaches peak intensity during the second trimester (Bowen, 1992). Urges for salty substances tend to emerge later on in pregnancy, with preference for and intake of salty foods increasing in the later stages of gestation in both pregnant adults (Bowen, 1992; Crystal et al., 1999) and teens (Skinner et al., 1998).

It is important to distinguish food cravings in pregnancy from pica, a condition characterized by (1) persistent eating of non-nutritive substances such as soils and clay (geophagia), ice (pagophagia), and laundry or corn starch (amylophagia; Anderson, 2001; Corbett et al., 2003) for a period of at least one month, (2) consumption of non-nutritive substances in a manner that is inappropriate to the developmental level of the individual, and (3) eating of non-nutritive substances that is not part of a culturally supported or socially normative practice (American Psychiatric Association, 2013). The presence of pica is not exclusive to pregnant women and the condition can be diagnosed in non-pregnant individuals of all ages. A number of theories attempting to explain the etiology of pica have been discussed in detail elsewhere (Young, 2010) and typically implicate factors such as nutritional deficiencies, a preference for the taste, smell, or texture of the craved substances (Cooksey, 1995), or the consumption of non-food items as a coping mechanism to relieve stress (Mills, 2007). Estimates of prevalence of pica in the U.S. vary widely. In our convenience sample of women posting on pregnancy-related websites in the U.S. only 3.0% ($n = 6$) indicated strong urges for non-food substances, which is consistent with an early study citing prevalence rates of pica around 1.6% (Hook, 1978). However, since then it has been reported that as many as one fifth of women who are considered as having a high-risk pregnancy endorse pica behaviors (Mills, 2007). Pica in pregnancy is more common in certain demographic groups, with relatively higher prevalence in African–Americans, immigrants to the U.S., women living in rural areas, and those that have a family history of pica (Horner et al., 1991; Thihalolipavan et al., 2013). Of note, the practice of consuming non-nutritive substances is thought to be present in a number of different cultures across the world (Geissler et al., 1999) and the consumption of non-nutritive substances as part of culture-specific practices has been observed in countries like Kenya where pregnant women were found to eat clay on a regular basis because of beliefs about its impact on fertility and reproduction (Geissler et al., 1999).

food cravings, as well as posts that prompted women to comment on specific types of cravings (e.g., "Is anyone else craving lemonade?") so as not to skew our results in favor of any one type of food or beverage. We categorized responses according to specific categories (e.g., fast food, prepared dishes, pre-packaged foods) and types of foods (e.g., fruits, vegetables, sweets), as well as certain flavor profiles (e.g., sour, sweet, salty). We also coded responses noting cravings for beverages or non-food substances. In addition, we looked for mentions of specific hypotheses regarding the perceived causes of cravings, efforts to resist cravings, negative affect related to cravings, or the notion that pregnancy may serve as an excuse to consume otherwise forbidden foods.

Table 1 | Most common cravings (overlapping %) reported by pregnant women ($n = 200$) posting on popular pregnancy blogs.

Rank	Substance Craved	%
1	Sweets (e.g., chocolate, candy)	25.9
2	Carbohydrates, high-calorie, savory (e.g., pizza, chips)	19.3
2	Animal protein (e.g., steak, chicken)	19.3
4	Fruit	18.8
5	Dairy, high-calorie, savory (e.g., cheese, sour cream)	17.8
5	Carbohydrates, other (e.g., pretzels, cereal)	17.8
7	Fast food (e.g., Chinese, Mexican, falafel)	17.3
8	Cold foods (e.g., ice cream, slurpee)	13.2
9	Vegetables	12.2
10	Dairy, high-calorie, sweet (e.g., ice cream, milkshakes)	11.7

ADVERSE HEALTH EFFECTS OF EXCESS GESTATIONAL WEIGHT GAIN

Food intake in pregnancy has been the focus of increasing attention from researchers, health care providers, and policy makers alike due in part to a growing awareness of the rising prevalence and significant adverse consequences of excess GWG for the health of both mothers and their children. The Institute of Medicine (IOM) defines excess GWG in singleton pregnancies as 35+ pounds in women of normal pre-pregnancy weight, 25+ pounds in overweight women, and 20+ pounds in women who are obese (Rasmussen and Yaktine, 2009). While there are multiple components of GWG, including the weight of the fetus, placenta, and amniotic fluid, much of the variance in weight gained in pregnancy is accounted for by an increase in fat mass (Kaiser et al., 2008; Rasmussen and Yaktine, 2009). Despite efforts to combat obesity in the U.S., the prevalence of excess GWG is on the rise: according to the National Research Council (NRC) and the IOM there was a 20–25% increase in U.S. women gaining more than 40 pounds during pregnancy from 1990 to 2003 (National Research Council and Institute of Medicine, 2007), and around half of all pregnancies currently result in GWG that exceeds IOM guidelines (Oken et al., 2007; Wrotniak et al., 2008; Chu et al., 2009; Rasmussen and Yaktine, 2009).

While maternal underweight and insufficient GWG have long been known to have serious adverse effects on the health and growth of the fetus (Ehrenberg et al., 2003; Han et al., 2011), excessive gestational weight is emerging as a potentially even greater threat to the health and wellbeing of both women and children (Kaiser et al., 2002, 2008). Excess GWG has been linked to a number of adverse short- and long-term health outcomes in mothers and their offspring (Cox and Phelan, 2008), and excess weight is currently among the most common high-risk obstetric conditions (Galtier-Dereure et al., 2000). Overweight and obesity are linked to higher rates of cesarean sections and greater cost of obstetric care (Galtier-Dereure et al., 2000; Stotland et al., 2004; Vahratian et al., 2005). Additional complications associated with excess GWG have been described in detail (Rasmussen and Yaktine, 2009) and include increased risk of gestational diabetes, hypertension, preeclampsia, delivery complications, perinatal fatality, neural tube defects, neonatal hypoglycemia, and failure to initiate breast-feeding (Hilson et al., 1997, 2006; Galtier-Dereure et al., 2000; Kaiser et al., 2002, 2008; Thorsdottir et al., 2002).

By following guidelines for GWG women may be able to avoid excessive postpartum weight retention, which results in greater short- and long-term risk of maternal overweight and obesity (Rooney and Schauberger, 2002; Linne et al., 2004; Rooney et al., 2005; Amorim et al., 2007; Nohr et al., 2008). Interestingly, data suggest that the correlation between inadequate GWG and poor fetal growth is weaker than the relationship between excess weight gain in pregnancy and maternal postpartum weight retention (Scholl et al., 1995; Kaiser et al., 2002). Excess GWG is also a strong predictor of macrosomia (Stotland et al., 2004) and overweight/obesity in children and adolescents (Oken et al., 2007, 2010; Wrotniak et al., 2008), highlighting the potential impact of excess weight gain in pregnancy on risk for weight-related pathology across the lifespan.

Prior research has sought to identify risk factors for excessive weight gain in pregnant women. A range of physiological variables, such as insulin sensitivity and basal metabolic rate, have been hypothesized to influence GWG (Rasmussen and Yaktine, 2009). Environmental context, including lack of access to physical spaces for exercise (Laraia et al., 2007), and sociodemographic variables, such as race/ethnicity (Chu et al., 2009), higher levels of education (Chu et al., 2009), younger age (Howie et al., 2003), and food insecurity (Olson and Strawderman, 2008), have been shown to be at least weakly correlated with an increased risk for excess GWG. For example, white women in the U.S. gain on average 2.0 kg more than their African–American counterparts, which is an increase from a survey conducted at the same hospital three decades prior that showed only a 0.9 kg difference between the two (Eastman and Jackson, 1968; Caulfield et al., 1996). Psychosocial factors including depression, anxiety, stress, internal locus of control, and self-esteem have all been found to correlate with excess GWG (Abraham et al., 1994; Clark and Ogden, 1999; Gee and Troop, 2003; Hill et al., 2013).

There is also preliminary evidence to suggest that food cravings may be an important determinant of prenatal energy intake and risk factor for excess GWG. This assertion is supported in part by a recent study which found that cravings during pregnancy were the only significant predictor of excess GWG in a sample of overweight African–American women (Allison et al., 2012). As noted earlier, food cravings are known to lead to an increase in consumption of the desired foods in both the general and certain clinical populations. Research points to a similar effect of food cravings in pregnancy: cravings for sweets, desserts, and chocolates have been shown to result in a general increase in consumption of sugary foods and beverages and overall caloric intake in pregnant women (Tierson et al., 1985; Pope et al., 1992; Belzer et al., 2010). In order to be able to target food cravings as a means of preventing or minimizing excess GWG, a better understanding of the mechanisms underlying strong urges for specific foods specifically during pregnancy is critical.

Popular hypotheses regarding the causes of food cravings in pregnancy implicate hormonal fluctuations, changes in sensory perception, maternal and/or fetal nutritional needs and preferences, adaptive mechanisms protecting the fetus from toxins, cultural norms and practices, and cognitive or affective characteristics of the pregnant woman (King, 2000; Patil, 2012). In the small pilot study mentioned earlier we sought to gather qualitative information about pregnant women's own beliefs about the meaning and significance of their food cravings. Of the women who posted to the blog websites surveyed, 16.2% ($n = 32$) mentioned a perceived cause for their cravings. Responses varied widely but the more commonly cited hypotheses aligned closely with the existing literature: women speculated about cravings as a reaction to food restrictions (either self-imposed or prescribed by a physician, $n = 6$) or nutritional deficits ($n = 5$). Some postulated that cravings were indicative of the gender of the child ($n = 5$) or reflective of the parents' or fetus' food preferences ($n = 3$). A few women thought their cravings were largely due to external cues or triggers ($n = 3$) while others saw them as a byproduct of gestational diabetes ($n = 2$), a response to thirst ($n = 2$), a reaction to nausea or morning sickness ($n = 2$), or the result of changes in taste perception brought on by pregnancy ($n = 2$).

PERIMENSTRUAL CHOCOLATE CRAVING: A BLUEPRINT

In examining popular hypotheses regarding craving in pregnancy their close resemblance to the theorized causes of perimenstrual chocolate craving is striking. Chocolate, by far the most commonly craved food in the U.S., is unique in many ways: it has a very recognizable smell, high caloric density, and distinctive melt-in-your-mouth feel (Rozin et al., 1991; Hormes, 2014). The characteristic pattern of cyclically fluctuating chocolate craving in many U.S. women described earlier has motivated a body of research specifically examining perimenstrual chocolate craving. Major findings from this work have previously been summarized in some detail elsewhere (Hormes, 2014). Accounts regarding the etiology of perimenstrual chocolate craving can be categorized as focusing on biochemical/physiological versus contextual/psychosocial mechanisms. Popular hypotheses attribute craving to cyclic fluctuations in levels of ovarian hormones, pre- and perimenstrual nutritional deficits, and pharmacologically active ingredients in chocolate that serve to alleviate symptoms that arise specifically around the onset of menstruation. More recently, research has shifted toward exploring the role of cultural and psychosocial factors in the emergence of perimenstrual chocolate craving. These parallels suggest that existing research on the causes of perimenstrual chocolate craving may serve as a sort of blueprint for the study of cravings in pregnancy.

We have previously proposed a model that integrates findings regarding the role of contextual and psychosocial factors in craving etiology and provides a conceptual framework for the study of cravings across multiple domains, including food cravings in pregnancy (**Figure 1**; Hormes, 2014). The model postulates that craving results from ambivalence or a tension between approach (i.e., the desire to indulge) and avoidance (i.e., efforts to restrict consumption) tendencies toward highly palatable foods. It is

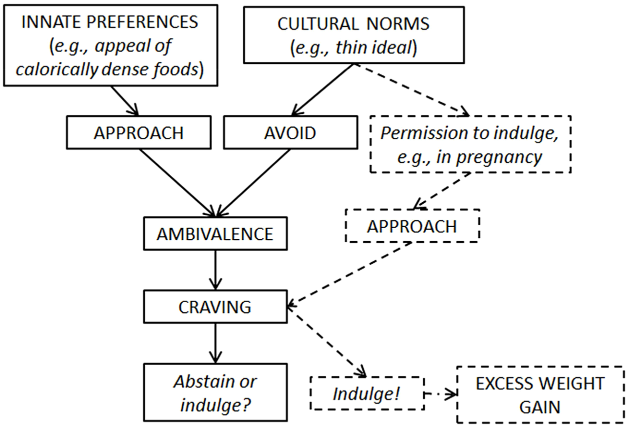

FIGURE 1 | Proposed model of craving etiology. Craving is hypothesized to be due to competing approach-avoidance conflicts brought about by exposure to foods that are perceived as being simultaneously appealing (due to an innate preference for high-calorie, sweet, and fatty foods) and forbidden (due to cultural norms prescribing restrained intake and a thin figure). While most individuals are thought to attempt to resolve the resulting ambivalence in favor of abstinence (represented by the solid lines), pregnancy is hypothesized to be a culturally sanctioned permissive factor, allowing women to circumvent their usual conflicting response and efforts to restrict intake and indulge in foods that they would otherwise avoid, resulting in increased intake and heightened risk for weight gain specifically during pregnancy (represented by the dashed lines).

assumed that most individuals – and U.S. women in particular – seek to resolve this ambivalence in favor of abstinence, thereby *de facto* increasing the likelihood that they will crave the avoided food due to an enhanced salience of relevant cues. The model furthermore proposes that certain culturally defined cues signal occasional permission to break restraint, resulting in episodic consumption (and, potentially, overconsumption) of craved foods. It is hypothesized that in the U.S., both the perimenstrum ("PMS") and pregnancy act as such culturally sanctioned disinhibitors, resulting in the characteristic patterns of increased craving frequency and intensity (and, as a result, consumption) specifically at these times. In other words, contrary to previous models of craving etiology, our model does not consider the perimenstrum and pregnancy a direct *cause* of cravings, but instead views them as a *catalyst* or permissive factor, allowing women to acknowledge and give in to otherwise unacceptable desires for highly palatable foods.

In the remainder of this paper we will examine major hypotheses regarding craving etiology in more detail, starting with a discussion of the role of hormonal, nutritional, and pharmacological factors, followed by an overview of evidence in favor of a role of cultural and psychosocial variables. We will review findings from research on perimenstrual chocolate craving and explore the extent to which the literature on eating behaviors in pregnancy supports or refutes translation of the proposed theoretical model into the domain of food cravings in pregnancy. We will attempt to point to gaps in the literature and outline directions for future research, keeping in mind the ultimate goal of identifying targets for interventions to reduce the prevalence of excess GWG and associated adverse health effects.

HYPOTHESIS 1: CRAVING IS CAUSED BY FLUCTUATING LEVELS OF HORMONES

Given the cyclic nature of perimenstrual chocolate craving, early hypotheses implicated fluctuations in the ovarian hormones estrogen and progesterone in craving etiology. Though initially quite compelling, there is generally a lack of empirical support in favor of this view. Levels of hormones involved in regulating the menstrual cycle are not significantly correlated with changes in the frequency or intensity of craving for chocolate (Rodin et al., 1991), and premenstrual administration of progesterone was not found to be effective in reducing cravings (Michener et al., 1999). A relatively high prevalence of women who continue to crave chocolate after menopause provides additional evidence against a significant causal role of hormonal fluctuations in craving etiology (Hormes and Rozin, 2009).

There is a lack of literature examining direct links between fluctuations in hormones and craving frequency and intensity in pregnancy; however, hormones have been implicated in prenatal craving etiology in more indirect ways. Pregnancy significantly alters sensory perception, possibly due to changes in secretion of hormones (Kuga et al., 2002; Nordin et al., 2004). When consuming plant products we ingest so-called "secondary compounds" that serve to fend off the plants' biotic enemies and, coincidentally, give them their distinctive and flavorful aroma. In small quantities these secondary compounds have little adverse – and potentially even beneficial – effects; however, consumed in large quantities they can be allergens, mutagens, carcinogens, teratogens, and abortifacients. Expectant mothers and fetuses may be especially susceptible to these harmful effects and it has been speculated that an increase in taste and olfactory sensitivity may serve to discourage consumption of potentially toxic foods in pregnancy (Nordin et al., 2004), and could also be responsible for changing food preferences and patterns of consumption.

As many as 26% of pregnant women report altered taste sensitivity (Nordin et al., 2004), and changes in olfactory perception were reported by 65.4% of pregnant women surveyed in one study, with 75% of these women adjusting their dietary habits due to their increased sensitivity to odors (Cantoni et al., 1999). In our pilot study 18.7% of blog posts ($n = 37$) mentioned cravings for foods that were disliked prior to pregnancy. Conversely, a vast majority of pregnant women quit drinking coffee due to a unique aversion to its taste (Lawson et al., 2004), possibly driven by an increase in bitter sensitivity (Nordin et al., 2004). Parallels in changes in taste perception and the trajectory of increasing craving intensity during the first trimester (Kuga et al., 2002) constitute preliminary evidence in favor of a connection between changing sensory perception and food cravings (and, possibly, aversions) in pregnancy, however the exact nature of this link remains to be elucidated. More research is also needed to link known fluctuations in levels of hormones across gestation with reported food cravings.

HYPOTHESIS 2: CRAVING IS A RESPONSE TO NUTRITIONAL DEFICITS

It has been speculated that perimenstrual chocolate craving is caused by a deficiency in certain nutrients that arises around the onset of menstruation and is alleviated by ingredients in the craved food. While it is possible that menstruation causes certain nutritional deficits such as low levels of iron due to blood loss (Harvey et al., 2005), it is unlikely that chocolate would serve to alleviate these needs more effectively than a variety of other foods that are not commonly craved perimenstrually (e.g., foods like red meat, egg yolks, or dark leafy greens, which provide large amounts of iron), effectively ruling out a causal role of nutritional deficits in the emergence of perimenstrual chocolate craving (Pelchat and Schaeffer, 2000; Hormes, 2014).

Fetal demands can double requirements for certain nutrients, and proper nutrition during pregnancy is critical in ensuring healthy fetal development (King, 2000). For example, a lack of adequate intake of iron can result in iron deficiency anemia and inadequate placental and fetal growth (Allen, 2000; Kaiser et al., 2008). Nutritional guidelines for pregnancy tend to highlight the importance of ensuring sufficient intake of a range of micronutrients, including iron, folic acid, B vitamins, zinc, magnesium, iodine, vitamin A, and calcium (Kaiser et al., 2002). It has been speculated that food cravings serve to prevent or alleviate nutritional deficits (or, perhaps, simply encourage the expectant mother to consume foods that provide added energy). This "nutritional deficits" hypothesis, which views craving as a mechanism to ensure adequate and balanced nutrition in pregnancy (Tierson et al., 1985), would predict that pregnant women primarily report urges for foods high in levels of micronutrients that are lacking and/or of particular importance during gestation. Such foods include dark leafy greens, which contain high levels of B vitamins, iron, magnesium and vitamin A, legumes, such as beans and lentils, which are a good source of folate, iron, and magnesium, as well as whole unrefined grains, which contain B vitamins and magnesium (Kaiser et al., 2002). Additionally, because the nutritional needs of the fetus increase as development progresses, the intensity of cravings should follow the same rising trajectory (Tierson et al., 1985).

A majority of studies found sweets, high-fat foods, and fast foods to be the predominately craved substances during pregnancy (Flaxman and Sherman, 2000; Fessler, 2002; Kaiser et al., 2002). Data from our pilot study of online posts about cravings in pregnancy suggests that while some women crave potentially beneficial proteins, fruits, or vegetables, many of the most commonly reported cravings are for high-calorie, sugary, and fatty foods (see **Table 1**). This data is largely consistent with previous studies examining cravings in a college population that found cravings for nutrient dense foods, such as fruits and vegetables, to be rarely reported (Weingarten and Elston, 1991). Thus, as is the case with perimenstrual chocolate craving, the foods typically desired by expectant women are unlikely to be the best source of nutrients needed in pregnancy. For example, an average serving of ice cream (1/2 cup, ~60g, ~230 calories) contains around 78 mg of calcium while the same serving size of tofu (~60g, ~90 calories) contains up to 160 mg of calcium and would thus constitute a much better source of nutrition. It should be noted that the available data appear to point to a higher prevalence of cravings for fruit in pregnant women, compared to other groups studied to date. More work is needed to systematically examine the seemingly higher prevalence and potential function of cravings for fruit specifically in pregnancy.

Prior studies found no evidence for a significant association between food cravings and dietary quality in pregnancy (Worthington-Roberts et al., 1989) and interestingly, potentially beneficial foods like meat and other high-protein foods appear to be among the most common aversions in pregnancy (Hook, 1978; Pope et al., 1992; King, 2000; Bayley et al., 2002). Research also suggest that the typical dietary intakes in middle- to upper-income pregnant women in the U.S. are likely to meet all dietary needs to the point where the widespread practice of prescribing prenatal vitamin supplements may lead to excessive nutrient intakes (Turner et al., 2003). Taken together, findings therefore do not support a nutritional deficits hypothesis for food cravings in pregnancy. Similarly, food cravings are unlikely to be due to a need for a general increase in caloric intake since they tend to emerge in the first half of gestation, long before a majority of fetal growth (and thus fetal demand for nutrients) takes place (King, 2000).

HYPOTHESIS 3: CRAVING IS DUE TO PHARMACOLOGICALLY ACTIVE INGREDIENTS IN THE DESIRED FOODS

Potentially pharmacologically active ingredients in chocolate have been implicated in perimenstrual craving etiology due to their hypothesized reinforcing effects or ability to alleviate physical – and perhaps psychological – symptoms associated with menstruation, such as fatigue, irritability, bloating, or cramps (Bruinsma and Taren, 1999). The methylxanthines, a group of compounds with potentially energizing effects, are one example of a hypothesized active ingredient in chocolate (Rogers and Smit, 2000; Smit et al., 2004). However, methylxanthines are not present in large enough quantities in a normal serving size of chocolate to have a noticeable effect on anyone but the most sensitive individuals (Mumford et al., 1994; Hormes, 2014): a 60 g serving of milk chocolate contains only around 12 mg of caffeine, which is far less than the amount found in a serving of coffee, and substantially below the reliable placebo-discriminable dose (Shivley and Tarka, 1984; Michener and Rozin, 1994; Mumford et al., 1994). Other potentially active ingredients are present in even smaller quantities in the amount of chocolate typically consumed in one sitting, making it highly unlikely that their effects would be causally involved in the emergence of cravings (Rogers and Smit, 2000). The study that perhaps most compellingly demonstrates that pharmacologically active ingredients do not play a key role in the satisfaction of cravings for chocolate (during the perimenstrum or otherwise) found that white chocolate (which contains none of the pharmacologically active ingredients of milk or dark chocolate, with the possible exception of the fat-soluble cannabinoid anandamide) is far more effective at alleviating cravings than capsulated cocoa powder, which contains all of the pharmacologically active ingredients of milk and dark chocolate, but in isolation of its oro-sensory properties (Michener and Rozin, 1994).

As is the case with the perimenstrum, a variety of unpleasant symptoms like aversions to specific foods, nausea, and vomiting are widely considered hallmarks of pregnancy and it has been theorized that food cravings serve to encourage intake of substances that may help alleviate these symptoms. Prevalence estimates are somewhat varied, but it appears that between 54 and 85% of expectant women report dislike of at least one specific food, 60–80% feel nausea, and around 55% experience vomiting (Tierson et al., 1985; Bayley et al., 2002). Pregnant women tend to identify a connection between food aversions and nausea and vomiting (Schwab and Axelson, 1984; Finley et al., 1985), a link that appears contingent on principles of classical conditioning (Bernstein, 1991), suggesting that a learned taste aversion may be a possible mechanism underlying the development of specific food avoidances in pregnancy (Bayley et al., 2002). In Pavlovian terms, the avoided food acts as the conditioned stimulus, while the nausea and/or vomiting acts as the unconditioned stimulus. Findings regarding demographic variables such as age or parity that may be predictive of a greater likelihood of morning sickness[2] have been largely inconclusive (Bayley et al., 2002).

It has been suggested that prenatal food aversions may serve the adaptive function of protecting the mother and fetus from foodborne illness. Indeed, nausea and vomiting have been associated with positive pregnancy outcomes, including lower risk of miscarriage and preterm or stillbirth (Sherman and Flaxman, 2002; Czeizel and Puho, 2004; Weigel et al., 2011). The "functional adaptation" hypothesis (largely synonymous with the Hook-Profet "maternal and embryo protection hypothesis") proposes that nausea and vomiting are a way for women to expel and learn to avoid food-borne teratogens and abortifacients, including certain toxins found in vegetables and beverages (Hook, 1980; Profet, 1992; Flaxman and Sherman, 2000; Bayley et al., 2002; Fessler, 2002; Fessler et al., 2005). The view of nausea and vomiting in pregnancy as a protective mechanism is supported by research showing that the common aversions in pregnancy are to foods high in levels of potentially teratogenic or abortifacient agents, such as bitter vegetables, eggs, meats, and dairy products (Profet, 1992; Fessler, 2002). In addition, the most pronounced periods of nausea coincide with peak vulnerability of the developing fetus to outside toxins (Profet, 1992; Flaxman and Sherman, 2000). However, emerging discrepancies between predictions of the functional adaptation hypothesis and the available research data have led some to suggest that this account is overly simplistic and insufficient in explaining food aversions in pregnancy (Weigel et al., 2011).

In light of the high prevalence of nausea and vomiting in pregnancy it has been speculated that cravings may have developed as a way to encourage consumption of foods known to prevent or alleviate these symptoms (Bayley et al., 2002). This view parallels the theorized "medicinal" effects of ingredients in chocolate in lessening perimenstrual symptoms and is supported to some extent by the fact that food aversions and cravings frequently co-occur (Bayley et al., 2002), with some indication that aversions precede the development of cravings (Tierson et al., 1985; Bayley et al., 2002). There is also evidence of a positive correlation between the occurrence of pregnancy sickness and the development of food cravings (Whitehead et al., 1992). It should be noted that the exact nature of a possible causal relationship between food aversions and cravings may be difficult to determine due to the fact that cravings for foods providing relief from nausea may not develop for up to 2 weeks after the initial onset of the illness (Bayley et al., 2002). More research is needed to assess the temporal dynamics in the relationship between food aversions and cravings and the hypothesized role of craved foods in alleviating prenatal nausea and vomiting.

HYPOTHESIS 4: CRAVING IS CAUSED BY CULTURAL AND PSYCHOSOCIAL FACTORS

Culture has long been known to be a powerful determinant of eating behaviors and our proposed model of craving etiology hypothesizes a key role of cultural norms in the emergence of food cravings (**Figure 1**). In the absence of strong evidence in favor of physiological and biochemical causes of perimenstrual chocolate craving, studies have consistently identified significant differences in the overall prevalence, types, and gender ratio of food cravings across various cultures. For example, while chocolate is by far the most commonly craved food in the U.S., hardly anyone in Egypt endorses strong urges for chocolate or general sweet cravings (Parker et al., 2003). Rice is the most widely craved food among women in Japan (Komatsu, 2008), a finding that highlights the strong influence of culture and culinary tradition on food-related preferences. As noted previously, American women are about twice as likely as U.S. men to crave chocolate (91 versus 59%), but men and women in Spain are almost equally likely to report strong urges for chocolate (90 and 78%, respectively; Osman and Sobal, 2006). The word "craving" does not translate into most languages outside of English, suggesting that the construct may be less important or altogether unknown in other cultures (Hormes and Rozin, 2010). Taken together these findings support the view that culture plays a central role in the emergence of perimenstrual chocolate craving and highlight the importance of studying the role of contextual and psychosocial factors in the etiology of cravings in other domains.

Conflicting attitudes toward foods like chocolate that are perceived to be simultaneously appealing and "forbidden" have recently been hypothesized to be associated with a greater likelihood of craving (Cartwright and Stritzke, 2008; Hormes and Rozin, 2011). Ambivalent feelings toward chocolate and similar foods are likely to be especially common in U.S. women who are exposed to a culture that promotes largely unrealistic ideals of female beauty (Thompson and Stice, 2001), while at the same time providing easy access to large quantities of highly palatable and calorically dense foods in what has been termed an "obesogenic" environment (Swinburn et al., 1999). Evidence suggests that efforts to avoid foods that cause these conflicting feelings may have the paradoxical effect of increasing the likelihood of craving. The result is a sort of "vicious cycle" of alternating restraint and overconsumption or binge eating. Multiple studies have demonstrated that dieting to lose weight and restricting intake of well-liked foods are associated with an increase in the salience of (internal and external) cues related to that food and, as a result, in the frequency of cravings (Placanica et al., 2002; Hill, 2007; Smeets et al., 2009; Kemps and Tiggemann, 2009; Hollitt et al., 2010; Durkin et al., 2012; Massey and Hill, 2012). A recent study found that U.S. women who experience cyclical increases in chocolate craving

[2] It should be noted that the term "morning sickness" is somewhat of a misnomer, with only about 17% of women who felt nausea and 31% of women who experienced vomiting during pregnancy reporting that symptoms occurred exclusively in the morning (Whitehead et al., 1992).

report significantly greater levels of dietary restraint, less flexible control over food intake, more guilt when consuming chocolate, and higher body mass indices (Hormes and Timko, 2011), supporting the notion that eating-related pathology may play a causal role in craving etiology.

Given these findings it seems warranted to examine cultural differences related to food cravings in pregnancy, and to try and identify contextual and psychosocial factors involved in their emergence. Evidence in favor of cross-cultural differences in craving prevalence and a causal role of psychosocial factors such as conflicting attitudes toward highly palatable foods, eating disorder symptoms, and dietary restraint would support the applicability of the proposed model in understanding food cravings in pregnancy. There is a small body of literature examining the prevalence, types, and correlates of prenatal food cravings and aversions as well as rates of nausea, vomiting, and pica in pregnancy in countries outside the U.S. Evidence suggests that all these phenomena exist in diverse cultures. For example, in a sample of 99 pregnant British women 61% reported experiencing strong urges for specific foods (Bayley et al., 2002). Between 64.9 and 79% of pregnant women in Tanzania have been found to experience food cravings, with craving intensity peaking in the first trimester (Nyaruhucha, 2009; Patil, 2012; Steinmetz et al., 2012). In India the term *dola-duka* is used to describe the experience of food aversions and cravings in pregnant women (Obeyesekere, 1963). *Duka* refers to the period in which a woman experiences nausea, vomiting, and weakness. *Dola* appears synonymous with what U.S. culture would deem a *craving* and refers to the desire to obtain a substance for consumption.

Prenatal cravings thus seem to exist outside the U.S. and prevalence appears fairly stable across the different countries surveyed to date. However, data also suggest that there are culture-specific differences in reported types, perceived meaning, and psychosocial correlates of cravings in pregnancy. An early study found that pregnant Indo-Ceylon women experience nausea, vomiting, and aversions associated with foods reflective of their traditional role as a wife and mother (e.g., time and effort spent preparing traditional foods like rice, everyday curries, tortillas from millet, and jiggery; Obeyesekere, 1963). Cravings reported by these women were categorized as childhood foods (e.g., sweets), foods expressing hostility, rare or expensive foods, festival foods, sour foods, male or phallic foods, and idiosyncratic foods (i.e., those that have personal significant meaning to the individual; Obeyesekere, 1963). Pregnant women in Nigeria proclaimed that their most craved foods (fruits, vegetables, and cereals) provide nutritional benefits, justifying their consumption with the belief that they are a good source of body building nutrients, serve as a mild laxative, and are easy to prepare (Olusanya and Ogundipe, 2009). The most common cravings reported by a sample of 545 Tanzanian pregnant women (i.e., reported by more than 25% of cravers) were meat and fish, vegetables, fruits, and grains (Patil, 2012). Provision of craved foods to pregnant women by their husband and his family is considered an expression of social support in rural Tanzania (Patil, 2012). In Indo-Ceylon cultures, the *dola* cannot be satisfied until the substance is consumed, and if it is not satisfied the woman is said to endure significant anxiety and stress until the compulsion is relieved (Obeyesekere, 1963). These data provide preliminary support in favor of a role of cultural associations in the types of food cravings in pregnancy, though more work is needed to systematically compare and contrast the nature, prevalence, and significance of food cravings in pregnancy across diverse cultures.

As noted previously, it has been speculated that food cravings may be a risk factor for excess weight gain in pregnancy. However, interesting cultural differences in the prevalence of excess weight gain in pregnancy suggest that a link between cravings and GWG may be unique to the U.S. (or perhaps North America)[3]: compared to more than 50% of U.S. women gaining too much weight prenatally, only 14.5% of obese and 30.4% of normal-weight women in Sweden were found to gain more than 16 kg (35.3 lbs) during singleton term pregnancies (Cedergren, 2006). Just over 20% of German mothers reported GWG of more than 17 kg (37.5 lbs; von Kries et al., 2011). In a prospective study of pregnant Vietnamese women, only 19.6% gained between 15 and 20 kg (33.1–44.1 lbs), and a mere 2.7% experienced GWG exceeding 20 kg (44.1 lbs; Ota et al., 2011). Based on these data it can be speculated that some factor that is unique to U.S. culture increases the likelihood that women gain excess weight in pregnancy. This hypothesis is supported by the finding that weight gain in pregnancy appears to be tied to a woman's level of acculturation to U.S. culture: Hispanic women who spent <10 years living in the United Sates were 50% less likely to gain above the threshold for GWG recommended by the IOM compared to third generation women (Chasan-Taber et al., 2008). Level of acculturation to U.S. culture in Hispanic women was also found to be a determinant of the types of foods consumed during pregnancy such that the less acculturated women reported consuming primarily traditional foods (Tovar et al., 2010).

A feeling of ambivalence toward highly palatable and calorically dense foods is a central aspect of the proposed model of craving etiology. It is thought that these ambivalent feelings heighten the salience of food-related cues, resulting in an increased likelihood of craving and subsequent consumption of the desired food (Hormes, 2014). There is some evidence for conflicting feelings related to food in pregnant women. For example, it has been argued that in U.S. women, the idea of "eating for two" takes on moral significance such that healthful eating in pregnancy is consistent with the perceived ideal of a good mother, while consumption of unhealthy foods is the cause of a considerably conflicting feeling (Copelton, 2007). Similarly, a survey of pregnant women with gestational diabetes in Canada found that cravings were frequently perceived to be specifically for "forbidden" foods, such as sweets (Hui et al., 2014).

[3]Of note, there are marked differences in guidelines for GWG in different countries. In a review comparing national GWG and energy intake recommendations (EIR), 13 of 22 countries surveyed had guidelines similar to those put forth by the IOM and adopted by the U.S., Canada, Finland, Italy, parts of Australia, and parts of Asia (specifically, Vietnam and Singapore). All either used the 2009 IOM or very comparable guidelines (Alavi et al., 2013). Parts of Western Europe recommend GWG in the lower end of the IOM suggestions (10–15 kg or 22–33 lbs). In India and Africa (8–10 kg or 17.6–22 lbs), the Phillipines (11–12.5 kg or 24.3–27.6 lbs), and Chile (12–13 kg or 26.5–28.7 lbs), official guidelines all suggest significantly lower weight gains for a normal weight expectant mother, compared to the thresholds recommended by the IOM (Alavi et al., 2013).

Menstrual cravings have previously been found to be associated with elevated levels of eating disorder symptomology (Hormes and Timko, 2011), and it can be hypothesized that maladaptive eating-related attitudes and behaviors may also increase the likelihood of prenatal cravings. It has been suggested that the presence of disordered eating behaviors could specifically heighten the risk of overconsumption in response to external and internal food-related cues in pregnancy (Fairburn and Welch, 1990; Abraham et al., 1994; Clark and Ogden, 1999). The prevalence of eating disorders in pregnant women (1%) is generally estimated to be equal to or perhaps even lower than that in the general population (1–3.5%; Hudson et al., 2007). In fact, a majority of women experience a decrease in dietary restraint and an increase in energy intake, weight, and overall body satisfaction during pregnancy (Fairburn and Welch, 1990; Wiles, 1993; Clark and Ogden, 1999). In a number of studies it has been found that for individuals diagnosed with bulimia nervosa, episodes of bingeing and purging decreased during pregnancy (Crow et al., 2004). However, for women with a history of problematic eating, pregnancy can trigger an increase in weight concern, sensitivity about body shape, and even maladaptive eating-related behaviors like bingeing and purging (Clark and Ogden, 1999). An early study suggests that both food cravings and aversions may be especially common in women who were particularly "picky" or had high levels of food faddiness as children, as well as those who endorse stress-induced appetite changes (Dickens and Trethowan, 1971). Women with a lower pre-pregnancy body mass index (BMI) and a history of disordered eating appear at greater risk to exceed guidelines for recommended GWG (Chu et al., 2009; Laraia et al., 2009). Pregnant women with a recent or past eating disorder were also found to be more likely to abuse laxatives, to engage in self-induce vomiting, and to exercise as compared to normal controls (Micali et al., 2007).

Episodes of binge eating are the most frequent disordered eating behavior in pregnant women (Fairburn and Welch, 1990; Abraham et al., 1994; Soares et al., 2009). The frequency of binge eating during pregnancy has significant effects on the mother's health, particularly regarding GWG (Soares et al., 2009). Caucasian women deemed restrained eaters (i.e., those who frequently think about their diet and weight and make attempts to restrict their dietary intake) are significantly more likely than unrestrained eaters to exceed guidelines for recommended GWG (Conway et al., 1999), a finding that supports the hypothesis that pregnancy acts as a time for women to legitimize seemingly excessive food intake, disregarding any previous attitudes and intentions to eat less (Clark and Ogden, 1999). Similar to restrained eaters, dieters[4] have also been found to endorse more episodes of overeating during pregnancy, compared to non-dieters (Fairburn and Welch, 1990). There are two possible explanations for this finding: women either (a) began dieting in response to already having gained excess weight, or (b) abandoned prior dieting attempts while pregnant and engaged in disinhibited eating, resulting in excess weight gain (Fairburn and Welch, 1990). Interestingly, for a sample of African–American women levels of restraint were relatively low and were not found to be predictors of excess GWG (Allison et al., 2012), suggesting that restraint may be more prevalent in certain cultures and ethnicities, and as a result have a different effect on GWG. The notion that pregnancy constitutes a culturally sanctioned excuse for dieters and women high in dietary restraint (and potentially eating disorder symptoms) to consume (and possibly overconsume) highly palatable foods that are otherwise perceived as taboo due to their high caloric content is consistent with the proposed model. Interestingly, the idea that pregnancy is a time when one does not need to feel accountable for one's food intake, (i.e., a time of disinhibition), has been found to be most commonly endorsed by women classified as habitual dieters prior to pregnancy (Fairburn et al., 1992; Clark and Ogden, 1999; Mumford et al., 2008). Of note, it has been suggested that continuous pregravid dieting may affect the women's ability to accurately distinguish hunger and satiety cues, which may contribute to excess energy intake in pregnancy (Mela and Rogers, 1998; Conway et al., 1999; Mumford et al., 2008).

Additional support for the view of pregnancy as a socially acceptable time for women to indulge comes from sociological research that finds that pregnant women take on a more functional view of their body, which legitimizes divergence from cultural ideals of thinness and restraint (Bailey, 2001; Dworkin and Wachs, 2004). In our qualitative pilot study, among the women posting about their cravings on the pregnancy-related blogs, negative affect related to cravings was rare and only mentioned by 6.1% ($n = 12$) of respondents. This low number may be due in part to the fact that the nature of the message board encouraged reports of cravings, but it may also reflect a more general sense that cravings in pregnancy are acceptable or maybe even enjoyable. Remarkably, only 4.5% ($n = 9$) of respondents described efforts to resist their cravings. These figures stand in stark contrast to the high levels of negative affect and conflicting approach-avoidance tendencies typically found to be associated with craving in the general population (Macdiarmid and Hetherington, 1995; Cartwright and Stritzke, 2008; Hormes and Rozin, 2011).

It thus appears that in the U.S., culture-specific norms, beliefs, and customs may allow or even encourage prenatal cravings and intake of foods that may otherwise be considered "taboo" (Snow and Johnson, 1978). As a result these views on cravings may leave pregnant women susceptible to overconsuming high calorie foods, resulting in excess weight gain, especially for women high in restraint and those with pre-existing eating disorder symptoms.

CONCLUSION AND DIRECTIONS FOR FUTURE RESEARCH

While some have argued that the mechanisms underlying food cravings in pregnancy differ from cravings experienced at other times (Gendall et al., 1997), we believe that the evidence presented here strongly supports the assumption that our proposed model of craving etiology applies to cravings in both the perimenstrum and pregnancy. We have reviewed evidence in favor of and against four major hypotheses regarding the etiology of perimenstrual and pregnancy cravings, implicating hormones, nutritional deficits, rewarding or reinforcing ingredients in the

[4]Individuals were classified as "dieters" if they gave a clear history of dieting prior to pregnancy. Of those assessed, 54% reported having dieted in the past to modify their shape and/or weight (Fairburn and Welch, 1990).

craved foods, and a complex set of cultural and psychosocial variables. Regarding perimenstrual chocolate cravings, evidence in favor of physiological/biochemical causes has been sparse. The literature on eating behaviors in pregnancy is largely consistent with these findings insofar as hormonally driven changes in sensory perception and the effects of potentially active ingredients in craved foods seem unlikely to be causally involved in the emergence of prenatal cravings. Prior research on the role of cultural and psychosocial factors in the etiology of food cravings in pregnancy is somewhat limited; however, existing studies point toward interesting cultural similarities in craving prevalence, as well as noteworthy differences in craving types and correlates that are consistent with the assumption that culture plays a key role in bringing about cravings in pregnancy. Furthermore, the observed link between food cravings and excess GWG gain may be unique to women in the U.S. or North America.

Factors influencing food cravings and weight gain in pregnancy are complex (Paul et al., 2013), and there are several important limitations inherent in existing research that must be addressed in future studies. For example, cross-cultural differences in prevalence of pregnancy cravings and GWG may simply be reflective of differences in the availability of and access to certain foods. The sample of Tanzanian pregnant women surveyed by one of the study referenced earlier was described as "marginally nourished," with food insecurity and hunger among the most common stressors faced by this group (Patil, 2012). Many of the key studies examining food cravings and aversions in pregnancy are somewhat dated. Assuming a key role of culture in craving etiology and given the fact that cultural norms and practices can change significantly over the course of even just a few decades it will be important to replicate some of the key studies cited here to determine if findings hold in current samples of pregnant women.

In addition to addressing these limitations we propose that future research in this field should focus on four specific areas of investigation: (1) validation of existing measures assessing food cravings and related behaviors and attitudes specifically in pregnant women, (2) real-time assessment of food cravings using ecological momentary assessment (EMA), (3) longitudinal tracking of eating disorder symptoms, food cravings, and GWG to determine causality, and (4) identification of targets for interventions to increase proper nutrition and decrease the risk of excess weight gain in pregnancy.

The failure of the term "craving" to lexicalize in most languages outside of English impacts the extent to which studies can accurately assess cross-cultural differences in the nature of food cravings in pregnancy (Hormes and Rozin, 2010). More work is needed to determine equivalence of terminology used by women in other countries to describe strong urges for specific foods. For instance, in one study a significant portion of the Hispanic women surveyed reported wanting to "eat junk food," and it can be speculated that these reports may be comparable to accounts of cravings in North American women (Tovar et al., 2010). There is also a lack of measures of food cravings and related attitudes and behaviors that have been validated specifically in pregnant women. Future studies should focus on determining the psychometric properties of key measures typically used in research on food cravings specifically in women in pregnancy[5]. Comparable efforts have previously been exerted in order to validate measures of anxiety specifically in the perinatal period (Meades and Ayers, 2011).

Many prior studies of food cravings in general, and specifically in pregnancy, are retrospective in nature (Nordin et al., 2004). Given the transient nature of the craving experience it is unlikely that craving episodes are accurately remembered following extended delays. Real-time neural correlates of food cravings are beginning to be examined using different forms of magnetic imaging (Pelchat et al., 2004; Frankort et al., 2014); however, this approach is not feasible in studying cravings in pregnancy due to the adverse effects of performing magnetic imaging on the health of the fetus. An area of research that has been receiving increasing attention and that is appropriate for the real time assessment of cravings in pregnant women is the use of EMA. For example, EMA has recently been utilized in studies of temptation and lapses in dieting (Carels et al., 2001), as well as cravings associated with smoking cessation (Waters et al., 2014), marijuana use (Buckner et al., 2011), and detoxification from substance use (Marhe et al., 2013). Real-time assessment of food cravings has also been used to examine the association between exposure to food cues in the external environments and craving and subsequent consumption in adolescents (Grenard et al., 2013). Compared to paper and pencil methods (i.e., those that provide the participant with the paper and pencil measures and cue them in advance to fill out the questionnaires at specific times throughout the day) electronic EMA (i.e., completion of measures in real time using an electronic device) was found to have a higher response rate when tracking food cravings and food intake (Berkman et al., 2014). Berkman et al. (2014) aimed to identify whether certain individual characteristics (i.e., BMI) increased or decreased responses using EMA technology. Findings showed that individuals with greater body mass indices were less likely to respond in the paper and pencil method as compared to the electronic EMA method. Furthermore, higher BMI was negatively correlated with latency response time in both groups. To the best of our knowledge, EMA has not yet been used to assess food cravings in real time in pregnant women. Thus, it is suggested that future research aim to implement the use of this technology to gage the intensity, frequency, types, and temporal patterns of food cravings specifically in this population.

The impact of GWG on maternal and child health has been deemed to be of great public health importance (Kaiser et al., 2009), and research to identify social, cultural, and environmental risk factors for excess GWG has been called for by the IOM (Rasmussen and Yaktine, 2009). Much of the work in this area has been cross-sectional in nature and there is an urgent need for longitudinal studies in order to determine with certainty the nature of the hypothesized associations between psychosocial risk factors, cultural variables, food cravings and consumption, and

[5]These measures include the Eating Disorder Diagnostic Scale (Stice et al., 2000), Dutch Eating Behavior Questionnaire (Van Strien et al., 1986), the Three Factor Eating Questionnaire (Stunkard and Messick, 1985), Food Craving Questionnaire (Cepeda-Benito et al., 2001), Food Craving Inventory (White et al., 2002), general psychosocial assessments like the Depression, Anxiety, and Stress, Scale (Henry and Crawford, 2005), and others.

weight gain in pregnancy (i.e., do cravers gain more weight in pregnancy than non-cravers, and if so, what are the causes of cravings?; Hook, 1978; Bayley et al., 2002). The ultimate goal of research in this area is to identify predictors of overweight and obesity in pregnant women in order to develop interventions that encourage good nutrition and healthy weight gain. Prior research on interventions targeting eating behaviors has had somewhat mixed results. Some studies implementing behavioral interventions for weight gain during pregnancy found that programs had a significant effect only on mothers with low socioeconomic status (Olson et al., 2004). However, there is also reason for optimism. For example, the Fit for Delivery program invites pregnant women to complete a face-to-face visit where guidelines for appropriate weight gain and behaviors related to proper nutrition are discussed. In one randomized controlled trial women ($n = 201$) were assigned to the intervention, which started between 10 and 16 weeks gestation. Following the face-to-face visit, women in the experimental group received postcards encouraging the continuation of healthy behaviors as well as (a minimum of) three phone calls from a dietician over the course of their pregnancy. Findings showed that the intervention reduced excessive GWG for normal weight women, as well as increased the likelihood that pregravid normal or over-weight women returned to their pre-pregnancy weight by six months postpartum (Phelan et al., 2011).

Thus, there is preliminary evidence in support of the effectiveness of behavioral interventions targeting weight and eating behaviors in pregnancy; nevertheless, research in this area remains lacking. It has been suggested that going forward, an emphasis on the prevention (as opposed to the treatment) of weight-related problems in pregnancy may be key (Cox and Phelan, 2008). We hope that the present discussion outlines avenues for identifying novel targets for future intervention programs. The adverse effect of excess weight gain in pregnancy on weight-related pathology across the lifespan is well documented. Importantly, however, it has also been shown that pregnancy is a "teachable moment," with implementation of behavior change during this time frequently resulting in especially long-lasting positive impact due to the mother's enhanced awareness of the effects of her behaviors on the health of the fetus (Phelan, 2010; Phelan et al., 2011). Targeting eating attitudes and behaviors in pregnant women may thus provide a unique opportunity to improve mothers' and children's weight-related health over the long term.

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A regulatory focus perspective on eating behavior: how prevention and promotion focus relates to emotional, external, and restrained eating

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By applying regulatory focus theory (RFT) to the context of eating behavior, the present research examines the relations between individual differences in the two motivational orientations as conceptualized in RFT, that is, prevention-focused and promotion-focused self-regulation and emotional, external, and restrained eating. Building on a representative study conducted in the Netherlands ($N = 4,230$), it is documented that individual differences in prevention focus are positively related to emotional eating whereas negligible associations are found in regards to external and restrained eating. Individual differences in promotion focus are positively related to external eating whereas negligible associations are found in regards to emotional and restrained eating. In relating RFT to different eating styles we were able to document significant relations of basic self-regulatory orientations with regard to essential daily behavior associated with health and well-being. The implications for changing eating styles are discussed.

Keywords: eating behavior, emotional eating, external eating, prevention focus, promotion focus, regulatory focus, restrained eating

INTRODUCTION

Humans differ substantially in terms of eating behavior. For instance, when having experienced negative events some individuals use eating as a strategy to cope with their negative emotions (Macht, 1999; Macht and Simons, 2000). Humans also differ in terms of how much they feel like eating when confronted with food that smells and looks good (Wardle, 1987). Additionally, some individuals have a strong focus on regulating food intake to control body weight (Van Strien et al., 1986). Basically, humans differ regarding both what they eat and how they eat (Young, 1941; Epstein et al., 2007) according to three central dimensions of eating behavior: (a) eating after experiencing negative emotions (i.e., emotional eating, also termed emotional food craving; Hill et al., 1991; Craeynest et al., 2008), (b) eating in response to positive external stimuli such as the smell, taste, and appearance of food (i.e., external eating), and (c) deliberately regulating food intake to control body weight (i.e., restrained eating; Van Strien et al., 1986).

Given that different eating styles are related to important health-related factors such as weight gain and obesity (e.g., Wilson, 1986; Snoek et al., 2007; Baños et al., 2014) it is essential to know *who* engages in what kind of eating styles. Prior research has linked different eating styles to personality dimensions (e.g., Heaven et al., 2001). However, different eating styles have not been analyzed from the perspective of individual differences in self-regulation as conceptualized by a prominent motivational approach: regulatory focus theory (RFT; Higgins, 1997, 1998). In the present contribution, we relate emotional, external, and restrained eating to individual differences in prevention- and promotion-focused self-regulation. In fact, with regard to practical interventions it seems important to know who engages in health-related eating styles, for instance whether emotional eating is likely to be executed by prevention-focused individuals. On this basis one can tailor interventions to fit individuals' basic self-regulatory orientations. We elaborate on this opportunity in the general discussion.

In the present work, the assumption was put to the test that individuals are more likely to engage in emotional eating the more vigilantly prevention-focused they are. Moreover, it was hypothesized that individuals are more likely to engage in external eating the more promotion-focused they are. No relation was likely to emerge between prevention or promotion orientation and restrained eating. The theoretical notions underlying these assumptions are discussed in the following sections.

REGULATORY FOCUS THEORY

Human beings (consciously and/or unconsciously) modify and adjust their own habits or actual states to bring these into alignment with a positive standard (e.g., a specific goal in life; Vohs and Schmeichel, 2003; Vohs and Baumeister, 2004). RFT (Higgins, 1997, 1998, 2012a; Scholer and Higgins, 2008, 2011) proposes that it is necessary to differentiate between specific standards (i.e., what is perceived as positive standard) as well as between specific preferred strategies in terms of *how* positively evaluated standards are approached and *how* negatively evaluated standards are avoided. Here, RFT proposes two distinct regulatory systems: a prevention-focused orientation and a promotion-focused orientation (Higgins, 1997, 1998, 2012a; Scholer and Higgins, 2008, 2011). The two basic motivational orientations of prevention focus and promotion focus represent the systems that include the strategies for how individuals approach pleasure and avoid pain. In other words, how individuals generally self-regulate movements toward goals. Prevention-focused individuals typically prefer avoidance strategies in goal striving whereas promotion-focused individuals typically prefer approach strategies (Scholer and Higgins, 2008, 2011; Higgins, 2012b)[1].

The input factors (i.e., valued standards or reference points) of a prevention focus are safety and security needs. Individuals in a prevention focus are oriented toward significant others, that is, they are concerned with fulfilling duties and responsibilities. Moreover, prevention-focused individuals are motivated to avoid losses and to approach non-losses. In doing so, prevention-focused individuals are sensitive regarding the presence or absence of negative outcomes and information (Scholer and Higgins, 2008, 2011; Higgins, 2012b). Neural correlates support this assumption indicating a greater activity in the amygdala, anterior cingulate, and extrastriate cortex for prevention-focused individuals when negative (vs. positive) information is presented (Cunningham et al., 2005). If a goal is reached, prevention-focused individuals experience quiescence/calmness-related emotions whereas if a goal is missed prevention-focused individuals experience agitation/anxiety-related emotions (Higgins, 1997; Molden et al., 2008).

The input factors of promotion-focused orientation are growth, advancement, and accomplishment. Individuals in a promotion focus are oriented toward ideals, wishes, and aspirations. Promotion-focused individuals are, moreover, motivated to avoid non-gains, and to approach gains. In doing so, promotion-focused individuals are sensitive with regard to the presence or absence of positive outcomes and information (Scholer and Higgins, 2008, 2011; Higgins, 2012b). Neural correlates also support this assumption indicating greater activity in the amygdala, anterior cingulate, and extrastriate cortex for promotion-focused individuals when positive (vs. negative) information is presented (Cunningham et al., 2005). If a goal is reached, promotion-focused individuals experience cheerfulness/happiness-related emotions whereas if a goal is missed promotion-focused individuals experience dejection/sadness-related emotions (Higgins, 1997; Molden et al., 2008).

Regulatory focus theory postulates that promotion focus represents a distinct orientation and is not the opposite orientation to prevention focus (Higgins, 1997, 2012a). This suggests that it is possible that one of the two orientations is associated with a certain external construct whereas the other orientation is not. This is relevant in the present context given that specific eating styles are expected to be related to one motivational orientation while the other motivational orientation may not be related.

REGULATORY FOCUS AND EATING BEHAVIOR

In the context of eating behavior, Florack et al. (2013) have shown that prevention-focused (vs. promotion-focused) individuals ensure appropriate eating behavior by following the eating behavior of others[2]. In another study it was found that prevention-focused individuals consumed more fruits associated with health precautions than associated with benefits (Spiegel et al., 2004). Joireman et al. (2012) documented that the more promotion-focused an individual was the more likely they were to report eating healthily in order to feel good. Recently, Pula et al. (2014) examined the relations of regulatory focus and food choice motives, showing that the prevention focus is associated with emphasizing mood, convenience, and familiarity. However, the relations between specific eating styles and chronic prevention and promotion focus have not been examined before. Therefore, we now outline in detail how different eating styles, in particular emotional, restrained, and external eating, are expected to be related to prevention and promotion focus.

Eating after experiencing negative emotions (i.e., emotional eating) is considered to be a response to cope with negative events and the resulting negative emotions when they cannot be appropriately regulated in a more adaptive way (Arnow et al., 1995; Macht and Simons, 2000; Evers et al., 2010). That is to say, emotional eating represents a coping style that reflects individuals' motivation to avoid a negative emotional state; so emotional eating is associated with the avoidance system (Cochrane et al., 1992; Spoor et al., 2007). Emotional eating is closely related to food cravings both conceptually and empirically (Hill et al., 1991; Craeynest et al., 2008; Rodríguez-Martín and Molerio-Pérez, 2014), especially the food cravings that occur after an individual experiences negative events and emotions (Nijs et al., 2007; Meule et al., 2012). Correspondingly, strong emotional eaters eat more snack foods compared with weak emotional eaters (de Lauzon et al., 2004), especially when in a state of distress or sadness (Van Strien et al., 2012, 2013).

Regarding the relation between emotional eating and regulatory focus, we build on the notion that emotional eating can be conceptualized as an avoidance strategy to cope with negative events and emotions (Cochrane et al., 1992; Spoor et al., 2007). Specifically, emotional eating reflects a tendency to avoid a negative emotional state in order to approach a more positive emotional state. This is particularly relevant in relation to

[1]As this work is situated in the context of food cravings and restrained eating it is important to distinguish between self-regulation as conceptualized by RFT and self-regulation in terms of self-control resources. Self-regulation in terms of self-control resources means that individuals forgo short-term gratification in service of higher ordered long-term goals. Closely related to this is research on ego-depletion showing when individuals' self-control resources are depleted they seek short-term gratification (e.g., Baumeister et al., 1998). That is to say, individuals regulate themselves using self-control resources. Our work, however, does not build on self-regulation in terms of self-control, ego-depletion, and appealing short-term gratification. The notion of self-control resources and ego-depletion is not explicitly implemented in RFT (see Higgins, 2012a). Rather, the present work focuses on the general strategies individuals use to approach pleasure and avoid pain, that is, how individuals generally regulate movements toward goals (Higgins, 1997). In contrast to the self-control resource approach (Baumeister et al., 1998), RFT does not emphasize a trade-off between short-term and long-term goals. One can use prevention and promotion strategies to move toward short-term and long-term goals. Additionally, RFT emphasizes that it is necessary to differentiate between specific standards, that is, what is perceived as a pleasure or positive standard (e.g., prevention-focused individuals emphasize safety and security needs). What is perceived as a pleasure or positive standard is not implemented in the self-control resource approach (Baumeister et al., 1998). Neither are basic needs and relevant standards implemented in this approach, in contrast to RFT. In sum, the two meanings of self-regulation represent distinct conceptualizations.

[2]We note that prevention focus is not the opposite of promotion focus. Therefore, one cannot conclude whether prevention or promotion focus drives the effects.

prevention focus given that prevention-focused individuals are typically sensitive to negative events and typically use avoidance strategies to cope and to approach a more general positive state (Scholer and Higgins, 2008, 2011; Higgins, 2012b; Keller and Pfattheicher, 2013; Pfattheicher and Keller, 2013; Cheung et al., 2014). In line with these considerations, Pula et al. (2014) showed that prevention-focused individuals emphasize the mood regulating function of food regarding negative states. On this basis we assume that prevention-focused individuals are most likely to engage in emotional eating, that is, a positive association between individual differences in prevention focus and emotional eating is expected.

External eating represents eating in response to positive external stimuli such as the smell, taste, and appearance of food. In short, external eating does not reflect a coping strategy for negative emotions (as emotional eating does) but rather an approach to attractive food when it is present that may result in over-eating (Van Strien et al., 2009). Building on the notion that external eating can be conceptualized as an approach strategy to attain positive external stimuli (i.e., favorable food), and promotion-focused individuals are typically sensitive to positive stimuli, and use approach strategies to ensure their wishes (Scholer and Higgins, 2008, 2011; Higgins, 2012b), we assume that promotion-focused individuals are more likely than others to engage in external eating. That is, a positive association between individual differences in promotion focus and external eating is expected.

Restrained eating implies that individuals regulate their food intake with regard to weight control. As such, restrained eating is more likely to be displayed by individuals with a relatively high BMI (Heaven et al., 2001; Provencher et al., 2003; Elfhag and Linné, 2005; Snoek et al., 2007, 2013; but see Baños et al., 2014). Also, restrained eaters eat more unhealthy food such as sweets (Elfhag et al., 2008).

Regarding the relation between restrained eating and regulatory focus, Vartanian et al. (2006) report no significant relations between restrained eating and individual differences in prevention and promotion focus. Indeed, it is not likely that the *general* notion of restrained eating reflects a *specific* orientation of regulatory focus. Restrained eating can be framed as approaching a positive outcome (losing weight), that is, it can fit a promotion-focused strategy. However, restrained eating can also be framed as avoiding a negative outcome (gaining weight), that is, it can fit a prevention-focused strategy. In the study reported below, however, only general restrained eating is assessed (e.g., "How often do you try not to eat over the course of an evening because you are dieting?") which does not include whether individuals focus on a positive outcome (approaching losing weight) or a negative outcome (avoiding gaining weight) when engaging in restrained eating. Accordingly, it seems unlikely for *general* restrained eating to be related to *specific* motivational orientations (i.e., prevention or promotion focus). These considerations are in line with the study by Vartanian et al. (2006) which documents null relations.

In sum, the current study investigated whether individuals are more likely to engage in emotional eating the more prevention-focused they are. Moreover, it was tested whether individuals are more likely to engage in external eating the more promotion-focused they are. In line with the findings of Vartanian et al. (2006), no relations were expected to emerge between prevention or promotion focus and restrained eating.

STUDY

METHOD

Participants

The study involves a representative study (the LISS panel) conducted in the Netherlands ($N = 4{,}230$; $M_{\text{age}} = 52.29$; 53.4% women). In this study, we took advantage of the panel-character of the LISS panel which allows the merging of several waves of the panel. In February 2011, individual differences in prevention and promotion focus were assessed; in July 2010, The Dutch Eating Behavior Questionnaire (Van Strien et al., 1986) was utilized to measure emotional, external, and restrained eating. Alpha reliabilities, means, and standard deviations are displayed in **Table 1**.

Regulatory focus

Chronic self-regulatory orientations were assessed using a Dutch version of the regulatory focus scale (RFS) developed by Lockwood et al. (2002). A sample item of the 9-item prevention focus subscale reads: "In general, I am focused on preventing negative events in my life." A sample item of the 9-item promotion focus subscale reads: "I frequently imagine how I will achieve my hopes and aspirations." The scale endpoints of the items were labeled "1" (not at all true) and "7" (completely true).

Eating behavior

The Dutch Eating Behavior Questionnaire (Van Strien et al., 1986) assessed emotional, restrained, and external eating. A sample item of the 13-item emotional eating subscale reads: "Do you have a desire to eat when you are emotionally upset?" A sample item of the 10-item restrained eating subscale reads: "Do you deliberately eat things that are good in terms of weight control?"[3] A sample item of the 10-item external eating subscale reads: "If you walk past the bakery do you have the desire to buy something delicious?" The scale endpoints of the items were labeled "1" (never) and "5" (very often).

BMI

The LISS panel also includes a self-report of height and weight on the basis of which participants' BMI was calculated. BMI was included because of its associations with different eating styles (e.g., Baños et al., 2014) and to show relations of regulatory focus and eating styles beyond BMI.

RESULTS

Zero-order correlations among the applied constructs are displayed in **Table 1**. These revealed significant positive associations ($p < 0.0001$) between emotional eating and restrained eating as well as external eating. External eating and restrained eating were negligibly correlated. The strength of these correlations was comparable to other research (e.g., Ellickson-Larew et al., 2013). In the present sample, BMI had the strongest positive correlation with restrained eating ($r = 0.19$; see also **Table 1**). BMI was less

[3]We note that one item of the scale is framed in a prevention-oriented way ("Do you deliberately eat less in order not to become heavier?"). Results remain exactly the same when excluding this item.

Table 1 | Alpha reliabilities, means, standard deviations (on the diagonal) and zero-order correlations.

	Prevention	Promotion	Emotional eating	Restrained eating	External eating	BMI
Prevention	1.00					
Promotion	0.54****	1.00				
Emotional eating	0.24****	0.16****	1.00			
Restrained eating	0.10****	0.09****	0.28****	1.00		
External eating	0.16****	0.23****	0.56****	0.11****	1.00	
BMI	0.00	−0.07****	0.13****	0.19****	0.01	1.00
Mean	3.25	3.86	2.02	2.74	2.67	25.63
SD	1.13	1.20	0.74	0.79	0.46	4.63
α	0.85	0.90	0.92	0.96	0.83	–

*****p < 0.0001; Prevention and Promotion were assessed on 7-point Likert scale, eating styles on a 5-point Likert scale.*

strongly correlated with emotional eating ($r = 0.13$) and was not significantly correlated with external eating ($r = 0.01$).

Regarding prevention focus, zero-order correlations revealed that prevention focus had the strongest correlation with emotional eating. Promotion focus had the strongest correlation with external eating. In this sample, individual differences in promotion and prevention were also correlated ($r = 0.54$, $p < 0.0001$)[4]. Thus, zero-order correlations with one self-regulatory orientation may be biased due to the shared variance with the respective other self-regulatory orientation. Therefore, multivariate analyses were applied. These analyses revealed that individuals are more likely to engage in emotional eating the more prevention-focused they are in their orientation ($\beta = 0.22$, $p < 0.0001$; see **Table 2**, Model 1). The relation between emotional eating and promotion focus was negligible ($\beta = 0.04$), although still significant ($p < 0.05$). For external eating, individuals are more likely to engage in this eating behavior the more promotion-focused they are in their orientation ($\beta = 0.20$, $p < 0.0001$). The relation between external eating and prevention focus was negligible ($\beta = 0.06$), although still significant ($p < 0.01$). No substantial (but still significant) relations between prevention focus or promotion focus and restrained eating were found ($\beta s < 0.08$). These relations also hold when including the BMI factor in the analyses (**Table 2**, Model 2) and when controlling for the respective two other eating behaviors (e.g., controlling for restrained and external eating when predicting emotional eating; see **Table 2**, Model 3).

[4]We want to point to the relatively strong positive correlation between prevention and promotion focus which is higher compared with other samples involving students (cf. Keller and Pfattheicher, 2013). This finding could be due to the specificity of this sample (representative sample with older adults instead of a student population) and speaks to the notion that prevention and promotion focus strategies are more strongly combined later in life and that older individuals are more likely to use prevention and promotion strategies in a more balanced way (resulting in a stronger positive correlation) whereas in younger individuals one strategy seems to predominate (resulting in a relatively weak positive correlation). In fact, using the younger respondents, that is, the age group of 16–25 results in a significantly ($p < 0.001$) weaker correlation ($r = 0.19$, $p < 0.001$; $n = 373$) compared to the entire sample ($r = 0.54$; $n = 4{,}230$). Additionally, we found a linear positive association between age and the strength of the prevention-promotion correlation (from 0.47, $p < 0.001$ in the age group of 35–45; $n = 563$ up to 0.63, $p < 0.001$ in the age group of 65–75; $n = 454$). Accordingly, the strong correlation seems to reflect an age effect. These findings are in line with previous research on regulatory focus and aging (Lockwood et al., 2005).

DISCUSSION

In relating RFT to different eating styles we were able to document significant relations of basic self-regulatory orientations with essential daily behavior associated with health and well-being (Van Strien et al., 1986; Wilson, 1986; Snoek et al., 2007; Alberts et al., 2012; Baños et al., 2014). Specifically, the present work examined the relation between different eating styles, in particular emotional, external eating, and restrained eating and prevention-focused and promotion-focused self-regulation. Analyses revealed that individual differences in prevention focus were positively related to emotional eating. In this regard, a medium effect size was found (Cohen, 1988). That is to say, the more individuals are chronically prevention-focused the more they use emotional eating to cope with negative emotions and events. Moreover, individual differences in promotion focus were positively related to external eating. Here, a medium effect size was found, too (Cohen, 1988). This strengthened the assumption that external eating reflects an approach type of behavior – behavior that is executed in particular by promotion-focused individuals. Regarding restrained eating, negligible associations with prevention and promotion focus are found. In sum, the present research contributes to the field of self-regulation, specifically to research on regulatory focus and extends existing knowledge about how basic motivation orientations as conceptualized in RFT relate to eating behavior (Spiegel et al., 2004; Joireman et al., 2012; Florack et al., 2013).

In critically reflecting upon the present work, we point to the fact that the reported data is of a correlational nature. Consequently, causation should not be assumed. Meanwhile, different directions of the observed correlations could be possible, for instance that prevention focus is the result and not the cause of emotional eating. That is to say, after engaging in emotional eating individuals may use vigilant, prevention-focused strategies to deal with the negative event of emotional eating which may have included over-eating and food cravings for unhealthy food.

Table 2 | Multivariate OLS regression analyses.

	Emotional eating						External eating						Restrained eating					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	B	β	B	β	B	β	B	β	B	β	B	β	B	β	B	β	B	β
Constant	1.46****		0.90****		−1.29****		2.30****		2.24****		1.97****		2.45****		1.60****		1.57****	
Prevention	0.14****	0.22	0.14****	0.21	0.11****	0.166	0.02**	0.06	0.02**	0.06	−0.02****	−0.06	0.06****	0.08	0.05****	0.07	0.01*	0.01
Promotion	0.03*	0.04	0.03**	0.05	−0.04****	−0.063	0.08****	0.20	0.08****	0.20	0.07****	0.17	0.03*	0.04	0.04***	0.06	0.38**	0.06
BMI			0.02****	0.133	0.01****	0.083			0.00	0.02	−0.00****	−0.04			0.03****	0.19	0.03****	0.15
Emotional eating											0.35****	0.57					0.30****	0.29
External eating					0.85****	0.525											−0.11****	−0.06
Restrained eating					0.19****	0.197					−0.03****	−0.05						
F	129.84****		114.90****		540.99****		120.47****		81.14****		437.62****		25.16****		70.57****		103.417****	
R	0.06		0.08		0.39		0.05		0.05		0.34		0.01		0.05		0.11	

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, $^{****}p < 0.0001$; all SEs were below 0.03.

Further research should address the causal nature of the associations by, for instance, manipulating the respective self-regulatory system (Shah et al., 1998; Friedman and Förster, 2001; Freitas et al., 2002).

Going back to the theoretical approach of RFT, the two modes of self-regulation (prevention and promotion) have been conceptualized as distinct orientations (Higgins, 1997, 2012a). Thus, prevention-focused self-regulation does not represent the opposite of promotion-focused self-regulation. This suggests that one of the two orientations can be associated with a certain construct whereas the other orientation is not, which is precisely what was found. Prevention focus predicted emotional eating whereas no substantial relation was found with promotion focus. Congruently, promotion focus predicted external eating while prevention focus was not substantially related to this eating style. That is to say, the present findings are in line with the distinctness assumption of RFT as documented in other research (e.g., Scholer et al., 2010; Keller and Pfattheicher, 2011).

We want to emphasize that the relation between prevention focus and emotional eating actually is not as straight-forward as it may seem. Prevention focus is occasionally conceptualized as a defensive mode of self-regulation sharing substantial communalities with behavioral avoidance and inhibition (e.g., Förster et al., 1998, 2001). This is especially the case if conceptualizing regulatory focus more concrete as self-regulation following the attainment of different standard (i.e., approaching a positive state, a 'gain,' in a promotion focus and avoiding a state, a 'loss,' in the prevention focus) as it relates promotion focus and approach and prevention focus and avoidance to some extent (see Summerville and Roese, 2008, for an overview). Yet, the present study suggests that prevention-focused individuals actively go for food in order to cope with negative emotions. Additionally, if prevention-focused individuals typically engage in behavioral avoidance and inhibition prevention focus should be positively related to the defensive eating style of restrained eating. This is, however, not the case. Prevention focus is very weakly related to restrained eating (see **Table 2**). These findings are incongruent to the notion that prevention focus mainly reflects behavioral avoidance and inhibition. As such, the present work also contributes to research on regulatory focus.

The present work is also relevant in terms of implications for changing eating styles. One can state that prevention-focused individuals are sensitive regarding the presence or absence of negative states and information (Scholer and Higgins, 2008, 2011; Higgins, 2012b). In order to reduce chronically prevention-focused individuals' emotional eating one could stress the negative consequences of emotional eating. In fact, it is documented that emotional eating results in weight-gain (Van Strien et al., 2012, 2013). In this way one may use prevention-focused individuals' sensitivity to negative information to reduce their use of emotional eating to cope with negative events. Regarding promotion focus, one can state that promotion-focused individuals are sensitive regarding the presence or absence of positive states and information (Scholer and Higgins, 2008, 2011; Higgins, 2012b). On this basis one could emphasize that external eating can lead to reduced healthiness (i.e., the absence a positive state). For instance, it is shown that external eating is related to overeating (Van Strien et al., 2009). In this way one may use promotion-focused individuals' sensitivity to the absence and presence of positive information to reduce their use of external eating.

Another possibility to change eating styles is offered by Evers et al. (2010) and Alberts et al. (2012). Alberts et al. (2012) reduced vigilant avoidance strategies through the use of a mindfulness intervention. Mindfulness fosters the acceptance of a current (negative) state thus reducing vigilance and avoidant goal striving. Results show that being mindful reduces food cravings when experiencing negative emotions, that is, mindfulness leads to less emotional eating (see also Alberts et al., 2010). Other work by Evers et al. (2010) shows that reappraisal rather than maladaptive suppression of negative emotions leads to less emotional eating. In sum, these studies show that reducing the vigilant avoidance system leads to less emotional eating. Building on our research, one could expect that these interventions would be particularly effective for individuals who actually use vigilant avoidance strategies (i.e., prevention-focused individuals). As such, mindfulness training and interventions to reappraise negative emotions can be especially useful for chronically prevention-focused individuals to regulate their food cravings.

Congruently, one might also aim to change external eating behavior, an important endeavor as external eating can result in over-eating (Van Strien et al., 2009) or maladaptive night eating (Nolan and Geliebter, 2012). In this regard, one can implement strategies for promotion-focused individuals to reduce external eating. Specifically, when aiming to reduce external eating one may focus on the reduction of promotion-focused individuals' approach tendencies when attractive food is present or can be reached. To this end, one could diminish the attractiveness of food (Visschers and Siegrist, 2009) so that chronically promotion-focused individuals' are less attracted by the food. In sum, we propose that interventions should be designed to fit individuals' basic self-regulatory orientations.

To conclude, the present work reflects a fruitful approach for future research examining the impact of self-regulatory orientations on emotional, restrained, and external eating. As such, the present work provides new impulses for the design of effective interventions aiming at reducing maladaptive eating styles.

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How relevant is food craving to obesity and its treatment?

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Cravings represent strong motivational states that are characterized by intense desires typically relating to the anticipation of consuming pleasure-producing substances or engaging in hedonic behaviors. In considering food craving and the extent of its applicability to food, a brief review of the history of craving within a culture-sensitive framework appears warranted. Many cultures appear to have considered cravings in different contexts over time, although it has been contended, based on analyses of translations and lexicalization across languages, that craving may fail to translate outside of Europe and North America, although there are similarities in the use of craving and addiction across domains of use (1). The word "crave" is derived from the Old English crafian meaning to beg[1]. Over time, the term craving became linked to excessive patterns of substance use. For example, in the early nineteenth century, in conceptualizing excessive patterns of alcohol consumption, the term dipsomania (translated from the German term *Trunksucht*, or drinking addiction) was described to define alcoholism as a condition characterized by a craving for continued intoxication (2). In Buddhism, the term taṇhā is commonly translated to mean craving (although its literal translation is "thirst"), with kāmataṇhā (sense-craving) describing strong motivations to experience pleasant feelings or sensory pleasures[2]. In Buddhism, taṇhā is seen as a type of ignorant desire and a cause of suffering and negative affective states, and some current approaches to understanding treatment mechanisms and promoting treatment development in addictions have involved considering craving within a Buddhist context (3, 4). Thus, links between cravings and negative processes including addictions have a longstanding history across multiple cultures.

In current psychiatric conceptualizations of addictions, cravings are considered an important component. Although substance-use disorders have been included in prior editions of the Diagnostic and Statistical Manual, a change from DSM-IV to DSM-5 involved the addition of an inclusionary criterion targeting craving in the diagnosing of substance-use disorders (5, 6). Despite the only recent addition of craving to the formal diagnostic criteria for substance-use disorders, craving has long been considered an important and clinically relevant feature of substance-use disorders. Craving has, for example, been linked in important fashions to treatment outcomes for both pharmacological interventions [e.g., naltrexone in the treatment of alcohol dependence (7)] and behavioral therapies [e.g., cognitive-behavioral therapies (8)] for substance addictions. Findings linking craving and treatment outcomes also appear applicable to non-substance or behavioral addictions; for example, in individuals with pathological gambling receiving opioid-receptor antagonists (naltrexone or nalmefene), individuals with strong gambling urges or cravings at treatment onset were more likely to demonstrate a better treatment outcome (9).

Despite the apparently widely appreciated relevance of craving to substance-use disorders and their treatment, the relevance of addiction features, including craving, to eating behaviors and conditions relating to excessive eating [e.g., obesity or binge-eating disorder (BED)] is more controversial and a topic of considerable debate (10–13). Some investigators have posited that energy balance remains central to obesity and that addiction or related aspects may represent a relatively minor component (13). Other investigators have suggested that a rapidly changing food environment may be contributing to the increases in obesity that have been observed over the past 30–40 years (14). Specifically, given the relative abundance and availability of inexpensive foods, it is possible that motivations to consume highly palatable foods, and perhaps large portions thereof, have taken a larger role in contributing to eating behaviors than in years past when the motivation to eat may have been more closely linked to energy restoration (15). Thus, examining other addiction-related constructs, such as food craving, as they relate to obesity and other food-related conditions seems relevant.

Multiple and diverse studies suggest that food cravings may be clinically relevant to understanding aspects of obesity and associated forms of disordered eating such as BED. Naturalistically and clinically, many individuals with overeating concerns and with BED report seeking

[1] http://www.thefreedictionary.com/crave
[2] http://en.wikipedia.org/wiki/Ta%E1%B9%87h%C4%81

and attending groups such as Overeaters Anonymous and other addiction-based 12-step programs (16). Researchers have developed specific measures to assess food addiction constructs [e.g., the Yale Food Addiction Scale, which has been investigated and validated to varying degrees across different clinical, age, racial, and cultural groups (17–22)] and, more specifically, various models and aspects of "food craving" (23–25) in order to investigate relationship with clinically relevant measures. For example, food craving has been linked to body mass index and consumption of multiple types of foods (sweet, high-fat, carbohydrate/starches, and fast-food) in community-dwelling individuals (26) and to various non-clinical and clinical study groups of individuals following dietary restrictions (27–29). Food cravings may also discriminate between successful and unsuccessful dieters (30, 31). Environmental factors like stress may induce food cravings and influence eating behaviors (32), and such effects may be particularly relevant to women (33, 34).

Importantly, relationships between food cravings and clinically relevant measures may differ in specific groups (25). For example, studies have reported significant differences in food cravings and associated clinical features between obese persons with and without BED (24, 25, 35, 36). As expected, individuals who endorse "food addiction" symptoms also report higher food cravings (37). Consistent with some research suggesting similarities in craving across different consummatory behaviors and addictions (38), research has found similarities in food cravings between women with obesity and women who smoke tobacco (39) and higher frequencies of substance-use disorders among obese women with BED who smoke than do not smoke (40).

Relationships between food cravings and various biological variables perhaps differing across specific groups have also been reported. For example, food-craving responses to favorite-food cues were associated with measures of insulin resistance in individuals with obesity but not in those of lean body mass, with thalamic brain activation mediating this relationship in the group with obesity (41). These findings suggest a biological mechanism linking insulin resistance and food cravings in obesity that might involve the thalamus, a region shown to differ in obese and lean humans in norepinephrine transporter availability (42). As such it is tempting to speculate that drugs targeting noradrenergic systems might be helpful in targeting food cravings in obesity, although this remains speculative and warrants further investigation. However, other systems [e.g., involving dopamine release (43)] appear differentially linked to food craving in obesity, suggesting contributions from multiple biological systems to food cravings. Additional, non-mutually exclusive pathways appear differentially linked to food craving and regional brain activations in obese and non-obese individuals. For example, the naturally occurring satiety lipid oleoylethanolamide appears differentially linked to body-mass-index measures in obese and lean individuals and to show different relationships with insular activations in response to food cues (44). Furthermore, molecular entities linked to appetite regulation and body habitus (e.g., leptin, ghrelin) appear differentially associated with regional brain activations to food cues in obese versus non-obese individuals and implicated in substance-use disorders (45, 46). These findings raise the possibility that common mechanisms may underlie craving states in obesity and substance-use disorders. Consistent with this possibility, meta-analyses of brain imaging data suggest common contributions of multiple brain regions to drug and food cravings (47). These commonalities have implications for treatment development in that treatments may be applicable to multiple disorders involving craving. Consistent with this idea, data suggest that manipulation of brain function (e.g., through neurostimulation of dorsolateral prefrontal cortex) may decrease food cravings like they do drug cravings (48).

Food cravings may be particularly relevant to individuals with obesity and eating disorders, and some interventions have targeted the management of food cravings. For example, food craving prior to food exposure has been linked to food consumption in obesity and to heightened levels in BED, raising the possibility that it has been targeted in treatment of the disorder (36). Notably, the Food and Drug Administration in the United States has recently approved a new medication combination of naltrexone and bupropion for the treatment of obesity. This follows several large studies reporting that the combination of these two medications, thought each to have some anti-craving effects, were effective in promoting weight loss in obese patients [e.g., Ref. (49, 50)]. However, to date, various other medications thought to reduce cravings have had limited effects on obese patients with BED (51–53). One study has found cognitive-behavioral therapy to be associated with better treatment outcomes and reduced food cravings in morbidly obese individuals undergoing bariatric surgery (54), and another study found that modifying a dialectical behavioral therapy by including appetite awareness and coping resulted in greater reductions in binge eating in patients with bulimia nervosa (55). Consistent with Buddhist views on craving described above, mindfulness-based approaches have shown promise with respect to reducing food cravings in some studies (56) and weight (57). However, other studies appear less promising (58), raising the possibility that there may exist individual differences with respect to who might respond favorably to these interventions [e.g., perhaps with respect to levels of food suppression thoughts (59) or susceptibility to the presence of food (60), with the possibility of gender-related differences also warranting consideration (61)]. The extent that behavioral techniques that target craving and methods of coping with craving are effective in the treatment of obesity and binge eating in different groups of individuals warrants additional investigation [e.g., (55)]. An alternate intervention, transcranial direct current stimulation of the prefrontal cortex, has been found in several studies to temporarily reduce craving (particularly in less impulsive individuals) and help them possibly resist food consumption (62, 63), although larger and more systematic studies are warranted to examine the clinical utility of this approach.

Food-craving states also warrant consideration within a developmental context. For example, upon food cue exposure in a group of children, adolescents and young adults, older age was associated with less craving, less recruitment of the striatum and greater recruitment of prefrontal cortex, and greater frontostriatal coupling

(64). Adolescents have also shown less cortical activation in response to favorite-food cues as compared with adults (41, 65), with certain vulnerable groups of youth (for example, those with prenatal cocaine exposure) showing differences in striatal responses to favorite-food cues (66). The implications of these neurodevelopmental findings that examine responses to favorite-food cues and subjective craving responses on subsequent weight gain and the development (or not) of obesity or eating disorders remains to be more precisely elucidated.

In summary, food craving appears to be an important construct to consider, particularly within the current food environment. Approaches that might effectively target food cravings hold significant implications for advancing public health and clinical concerns relating to overeating.

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Food cravings, appetite, and snack-food consumption in response to a psychomotor stimulant drug: the moderating effect of "food-addiction"

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There is mounting evidence that many highly processed foods have addictive properties, and that some cases of compulsive overeating resemble an addiction disorder. While support for the *Yale Food Addiction Scale* (YFAS) as a valid diagnostic tool has been impressive and continues to increase, to date, no research has examined the food-addiction construct in response to an actual food stimulus, and in relation to direct measures of appetite and food consumption. As part of a larger community-based study of overeating in healthy adults who were predominately overweight and obese (aged 25–50 years), 136 participants completed the YFAS, of whom 23 met the diagnostic criteria for food-addiction. They took part in a 2-day, double-blind, cross-over, single-dose drug challenge using a psychomotor stimulant (methylphenidate) and placebo. Participants were first assessed on ratings of appetite and food cravings after holding and tasting their favorite snack food, after which they were able to eat all or part of the snack, as they wished. Three separate repeated-measures analysis-of-variance procedures were carried out, each with two between-subjects factors (Diagnosis: food-addiction vs. non-food addiction) and (Sex: male vs. female) and 1 within-subjects factor (Days: drug vs. placebo). As anticipated, for all three dependent variables, there was a significant main effect for Days with a response decrease from placebo to the drug condition. With respect to *food cravings* and *appetite ratings*, results indicated that the food addiction group had significantly higher scores on both variables. For *food consumption*, there was a significant Days × Diagnosis interaction whereby the food-addiction group showed no food-intake suppression across days compared to the non-food-addiction group who demonstrated a significant decrease in snack-food consumption with methylphenidate. The finding that the food-addiction group was resistant to the food-intake suppression typically induced by a dopamine agonist supports evidence of dopamine signaling-strength differences in individuals with compulsive overeating compared to those without this disorder. This represents the first demonstration that individuals defined by their food-addiction status have a unique pattern of food-intake following a pharmacologic challenge with such agents.

Keywords: food cravings, appetite, food consumption, psychomotor stimulant, food-addiction

INTRODUCTION

In its recently released 5th edition, the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) has acknowledged the existence of behavioral addictions for the first time (American Psychiatric Association, 2013). Currently, however, pathological gambling is the only one listed in the newly labeled "non-substance-related disorders" category. Although other excessive behaviors related to sex, exercise, eating, and shopping had been considered for inclusion, none was deemed to have sufficient peer-reviewed evidence for identification as a mental health problem at the time of publication (Potenza, 2014). Of these conditions, the one receiving the most discussion and research investigation in recent years is *food addiction* – the rather unsuitably named[1] syndrome describing compulsive overeating accompanied by strong cravings and extreme difficulty in abstaining from highly palatable fare. To illustrate, a keywords search in *Web of Science* (an online scientific citation indexing service) for the year 2013 –

[1]There has been justified criticism of the contiguousness of the words "food" and "addiction" in this putative diagnostic label because the word "food" connotes substances essential for survival and fundamental to human existence, while "addiction" implies psychopathology and even antisocial behavior. More appropriate perhaps would be terms like "hyper-palatable processed food" or "high fat, sweet, and salty food" because those that are intensely craved and over-consumed, and that comprise most binge episodes are not grown or raised in nature. Instead they are highly processed foods, calorically dense in fat, sugar, and salt, and are almost universally perceived as very appetizing (Curtis and Davis, 2014).

using the terms "food addiction," "sex addiction," and "shopping addiction," consecutively – rendered 48, 8, and 0 citations, in that order.

The growing legitimacy of the food-addiction concept has been heavily influenced by the premise that hyper-palatable foods, rich in sugar, fat, and salt, have the potential to foster excessive consumption and a state of dependence (Gearhardt et al., 2011a; Davis and Carter, 2014), and that some cases of compulsive overeating have striking clinical and neurophysiologic similarities to drugaddiction (Davis and Carter, 2009; Davis, 2013). Compelling preclinical research laid the groundwork and a solid foundation of evidence for biobehavioral parallels between the excessive consumption of sugar and fat and that of addictive drugs like cocaine and heroin. Readers are referred to several excellent reviews of this body of research (Avena et al., 2008, 2012; Corwin et al., 2011). The systematic study of clinical cases of food addiction came somewhat later, but has increased rapidly. This work began to flourish with the development of the *Yale Food Addiction Scale* (YFAS; Gearhardt et al., 2009) – a diagnostic tool based on the seven DSM-IV (American Psychiatric Association, 1994) symptom criteria for substance dependence, with the word "food" substituting for drugs in the questionnaire items. To date, studies have found substantial co-morbidity between binge eating disorder (BED) and YFAS food addiction, in addition to many shared psychological and biological risk factors (Davis et al., 2011; Gearhardt et al., 2011b, 2012). An even greater overlap was found in an earlier study of women diagnosed with BED where 92% of the sample met the DSM-IV criteria for dependence during a structured telephone interview – again when food replaced the drug/substance nomenclature in the assessment questions (Cassin and von Ranson, 2007). A recent qualitative study also confirmed that a high proportion of obese women with and without BED endorsed DSM symptoms of substance dependence when food was the "substance" in question (Curtis and Davis, 2014). These women felt that "loss-of-control" overeating, the inability to stop this behavior despite strong wishes to do so, and extreme cravings were the characteristics of their disorder which most resembled an addiction.

The first case-control study of food addiction in obese men and women found that those who met the YFAS diagnostic criteria had a significantly greater prevalence of BED than their age- and weight-matched counterparts (Davis et al., 2011). They also reported more intense trait-related food cravings and greater emotional and hedonic overeating than the control participants. Other research has found similar results using the YFAS symptom score (Meule et al., 2012). In addition, preliminary genetic evidence demonstrated that a composite polymorphic index of elevated dopamine signaling strength was greater in those who met the YFAS criteria for food addiction, and this profile score correlated positively with binge eating severity, food cravings, and emotional eating (Davis et al., 2013). Together these results support the view that risk for food addiction is greater in those with a hyper-sensitivity to reward and a greater appetitive motivation for reinforcing stimuli. In a study of weight-loss treatment-seeking adults, YFAS-symptom scores were also associated with lower weight loss after several weeks of treatment, suggesting that food addiction, with related signs of tolerance and withdrawal, may undermine efforts to lose weight in those trying to adopt better eating habits (Burmeister et al., 2013). A later study, however, failed to replicate these results (Lent et al., 2014).

In a recent general-population study, adults who met the YFAS criteria for food addiction had significantly higher body mass index (BMIs) and a greater percentage of adipose tissue compared to their non-food-addicted counterparts (Pedram et al., 2013). They also self-reported eating more calories from fat and protein. In addition, it was found that overweight and obese women had a significantly higher prevalence of food addiction than weight-matched men. Interestingly, this sex bias reflects the pattern of findings from drug-addiction research. For example, while drug abuse has traditionally been more widespread in men than in women (Wittchen et al., 2011), the gap seems to be narrowing, suggesting that earlier differences may simply reflect variation in opportunity and gender-biased expectations rather than in vulnerability (Becker, 2009; Colell et al., 2013). Indeed, it appears that many addiction risk factors are greater in women than in men. Women tend to increase their rate of drug consumption more quickly than men, are more likely to relapse, and to have longer periods of drug use before their next attempt at abstinence (Elman et al., 2001; Evans and Foltin, 2010) – a phenomenon known as *telescoping*, which describes an accelerated progression from the commencement of drug use to the development of dependence and admission to treatment (Greenfield et al., 2010). Women who abuse drugs also report more severe cravings and subjective drug effects than their male counterparts (Back et al., 2011), and this pattern seems to be similar for most addictive substances (Becker and Ming, 2008).

There is now compelling evidence that the cravings for addictive drugs and for hyper-palatable foods are fostered by similar biological mechanisms whereby excessive consumption of either provokes neuro-adaptations resulting in a *blunted* dopamine signal in brain reward circuitry – in particular, the nucleus accumbens and the ventral tegmental area (VTA; Volkow et al., 2013). Excessive consumption also contributes to a heightened motivational salience for the reward, which, together with dopamine down-regulation, increases the "wanting," or an intense craving, for the substance in question (Robinson and Berridge, 2013). *Cravings* are therefore an important component of the addiction process, especially because they appear to increase the risk for relapse following abstinence (Sinha et al., 2006). In this context, it is noteworthy that conventional weight-loss programs, including dietary restriction and increased physical activity, are typically ineffective in the long term for patients with problematic overeating and obesity (Begin et al., 2006; Mann et al., 2007). Indeed, numerous obesity studies have linked cravings to overeating and weight gain, to the lack of success in attempts to restrict calories, and to early drop-out from bariatric treatment programs (Batra et al., 2013).

Not surprisingly, given the down-regulatory neurophysiologic processes in addiction, treatments that serve to increase dopamine signaling have shown some success in reducing episodes of overeating. For example, in a randomized-control trial, pharmacotherapy with an amphetamine-based stimulant medication was effective in lowering the frequency of binge episodes in those with compulsive overeating (Shaffer, 2012; Gasior et al., 2013). Similar medications have also been successful in producing weight loss in those with intractable obesity and co-morbid symptoms of attention deficit/hyperactivity disorder (ADHD; Levy et al., 2009). Likewise, laboratory studies of single-dose administrations of methylphenidate [a dopamine transporter (DAT) blocker] have also shown decreased food cravings and food consumption in obese adults and those with BED (Leddy et al., 2004; Goldfield et al., 2007; Davis et al., 2012). And finally, non-invasive dorsolateral prefrontal cortical (DLPFC) neurostimulation – a procedure which is believed to increase dopamine excretion via interconnections between the DLPFC and the VTA and nucleus accumbens – has also produced reductions in drug and food cravings (Jansen et al., 2013).

THE PRESENT STUDY

Although various studies have used food-related cues in their experimental paradigms (Gearhardt et al., 2011b; Meule et al., 2012), to the best of our knowledge, there are no *objective* food consumption studies in human food-addiction research. Since self-report measures of food intake may be subject to biased recall, it is also important to have objective food-intake data for a more complete understanding of the phenomenology of disordered (and other) eating behaviors. The purpose of the current study was therefore to compare appetite, cravings, and consumption between adults diagnosed with and without YFAS food addiction, in response to a snack-food challenge following a single-dose administration of methylphenidate versus placebo. Given the generally experienced, appetite-suppression, effects of stimulant drugs, and their suggested therapeutic use in reducing binge episodes (Levy et al., 2009; Shaffer, 2012; Gasior et al., 2013), the primary purpose for including the drug challenge in the study protocol was to identify possible factors moderating response magnitude to methylphenidate, given the considerable response variability among patients taking such medications[2].

Sex differences were also assessed in this 3-way mixed model, double-blind, cross-over design. It was anticipated that the food-addiction group would report greater appetite and food cravings and consume more of their favorite snack during the placebo condition than the non-food-addiction group. Another goal of this study was to investigate whether food addiction moderated the appetite-suppression effects typically found following administration of methylphenidate. It was speculated that the stronger appetitive responses to food associated with food-addiction (Davis et al., 2013) might buffer the normally experienced suppression effect from methylphenidate. Finally, and based on other sex differences in clinical and pre-clinical drug-response research, it was predicted that females would be more responsive to the appetite and food consumption suppression effects of methylphenidate than males.

[2]These potential moderators included genetic factors, results for which will be published elsewhere for the larger study.

MATERIALS AND METHODS

PARTICIPANTS

As part of a larger community-based study of overeating in healthy adults who were predominately overweight and obese and between the ages of 25 and 50 years, 136 participants (women = 92; male = 44) completed the YFAS, of whom 23 met the diagnostic criteria for food addiction. The food-addiction group had a mean BMI of 34.6 ± 7.0 and a mean age of 33.9 ± 5.9 years compared to the non-food-addiction group with a mean BMI of 33.8 ± 8.4 and a mean age of 32.4 ± 6.6 years. These values were not significantly different. Participants were recruited from posters, newspaper advertisements, and online sites like Craigslist and Kijiji. Inclusion criteria were residence in North America for at least 5 years and fluency in written and spoken English. Women were also required to be pre-menopausal as indicated by the reporting of regular menstrual-cycles. Exclusion criteria were a current diagnosis (or history) of any psychotic disorder, panic disorder, or substance abuse as diagnosed by the Structured Clinical Interview for DSM-IV (SCID), any serious medical condition like cancer, or heart disease, and any medications contraindicated for methylphenidate (e.g., certain antidepressants like Wellbutrin). Twenty-six percent of the food-addiction group, and 20 percent of the control group were regular smokers. Women who were pregnant or breast-feeding, or who had given birth within the past 6 months were also excluded. This study was approved by the institutional Research Ethics Boards and was carried out in accordance with the Declaration of Helsinki.

MEASURES

Food addiction

Food addiction was diagnosed by the 25-item YFAS (Gearhardt et al., 2009) – a self-report questionnaire measure – using the dichotomous scoring procedure proposed by its authors. Based on the DSM-IV (American Psychiatric Association, 1994) criteria for substance dependence, a diagnosis is given if the respondent endorses three or more of the symptom subscales "over the past year" and if s/he also confirms the "clinically significant impairment" criterion.

Food cravings

Food cravings were assessed by the 15-item *State* version of the *General Food Cravings Questionnaire* (Cepeda-Benito et al., 2000). This well-validated scale (Nijs et al., 2007) was personalized for each participant by replacing the general words "tasty food" with the specific snack-food each participant had identified. For example, where appropriate, item one was changed from "I'm craving tasty food" to "I'm craving potato chips," and so on. The alpha coefficients for Day 1 and Day 2 were 0.93 and 0.92, respectively.

Appetite ratings

Appetite ratings were assessed, after participants had been given their snack, by the sum of 3 Likert-scale questions, each scored from 1 ("not at all") to 10 ("a great deal"): (1) How hungry does it make you feel to see your favorite snack? (2) How much would you like to eat some of your favorite snack – even just a small portion? (3) Now that you've had a taste of your favorite snack, how strong is your desire to have some more? After the second question, participants were asked to take a few bites of their snack, before the third question was asked.

Snack-food consumption

Snack-food consumption was quantified as the weight of the snack (to the nearest gram) at the end of the session subtracted from the initial weight of the snack. The amount consumed was then converted to a percentage of the initial snack weight. For example, a score of zero indicated that none of the snack was eaten and a score of 100 indicated the entire snack was eaten.

PROCEDURES

The data reported in this study are part of a larger and more extensive protocol involving three separate assessment sessions. They comprise a sub-set of participants who were assessed on the YFAS. Using a randomized, double-blind, cross-over design, participants were administered either a dose of oral methylphenidate equivalent to 0.5 mg/kg body weight (to a maximum dose of 55 mg), or placebo, at the same time of day and the same day of the week, separated by 1 week. This dose was selected because it has been used successfully in other drug challenges with healthy adults (Volkow et al., 2001). Methylphenidate was titrated for BMI because of evidence-based recommendations that this compound should be prescribed on a weight-adjusted basis (Shader et al., 1999). Methylphenidate and placebo were packaged in identical colored capsules to prevent detection of the drug by taste or color.

Day 1

Demographic information was obtained, a psychiatric assessment was administered, and questionnaire measures were distributed to be completed at home and returned at the second assessment. Participants had height and weight measured, blood pressure was taken, and an electrocardiogram was carried out to confirm eligibility for the subsequent drug challenge sessions. Participants were also asked to indicate their "favorite snack food" in preparation for the food challenge taking place at the 2nd and 3rd session. The most commonly chosen snacks were potato chips, chocolate bars, and cookies. For a more detailed explanation of the protocol see Davis et al. (2012).

Days 2 and 3

Both 2.5-h sessions were scheduled at the same time of day and the same day of the week, separated by 1 week. Prior to each session, participants were told to eat a normal meal 2 h before their appointment and to abstain from drinking any caffeinated beverage or smoking nicotine on the day of, and prior to, their appointments. These dietary restrictions were confirmed on each testing day. Upon arrival at the laboratory, a 10-item, visual-analog, mood adjective scale was given at baseline and every 15 min after the ingestion of the capsule. The peak uptake for methylphenidate is approximately 1 h. During that time, participants were seated in a quiet area and encouraged to occupy themselves with reading materials. About an hour and 15 min after the ingestion of the capsule, participants were given their favorite snack-food to hold, and the appetite rating questions were asked, after which they were given the craving questionnaire to complete. Participants were then told that the study tasks were finished and they could eat as much of their snack as they wished. At this point more than 3 h had elapsed since their last meal.

RESULTS

In order to assess whether there were group differences in the initial weight of the snack food – since each participant chose his/her own – a 2 (Sex) × 2 (Diagnostic Group) analysis of variance (ANOVA) was carried out. Results confirmed there were no differences between men and women ($p = 0.828$) or between the food-addiction and the non-food-addiction groups ($p = 0.413$), and there was no significant interaction between these two variables ($p = 0.974$).

REPEATED MEASURES ANOVA

Three separate 2 × 2 × 2 mixed model, repeated measures ANOVAs were computed – one for each of the dependent variables: food cravings, appetite ratings, and percentage of food consumed. There was one within-subjects factor (Days: placebo vs. drug) and two between-subjects factors: (Sex: male vs. female) and (Diagnostic Group: food-addiction vs. non-food-addiction)[3].

With *food cravings* and *appetite ratings* as the dependent variables, there was a significant main effect for Diagnostic Group ($p < 0.0001$ for both: $\eta_p^2 = 0.157$ and 0.128, respectively) with the food-addiction group reporting higher scores than the non-food-addiction group. In both cases, there was also a significant main effect for Days, indicating a diminution in scores in the drug condition compared to the placebo condition ($p = 0.006$ and 0.031, and $\eta_p^2 = 0.056$ and 0.035, respectively), but these decreases on the drug day were not significantly different between those with and without food addiction. These results are presented graphically in **Figures 1** and **2**.

[3]Each of the three repeated measures ANOVAs was re-run with BMI included as a co-variate. In each case, BMI did not correlate with the dependent variable nor were the Days × BMI interaction terms statistically significant, indicating that BMI did not contribute to the variance in the appetite, cravings, and food-consumptions variables. Therefore it was removed from the models. The values reported in the Table and the Figures are the results without BMI.

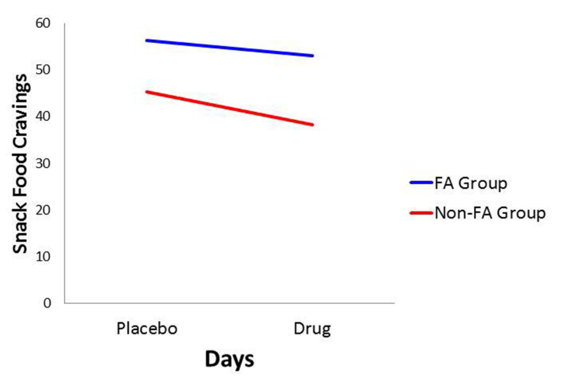

FIGURE 1 | Plot for the Diagnostic Group × Days interaction with food cravings as the dependent variable.

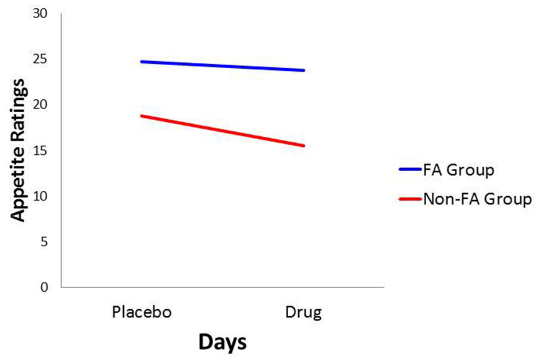

FIGURE 2 | Plot for the Diagnostic Group × Days interaction with appetite ratings as the dependent variable.

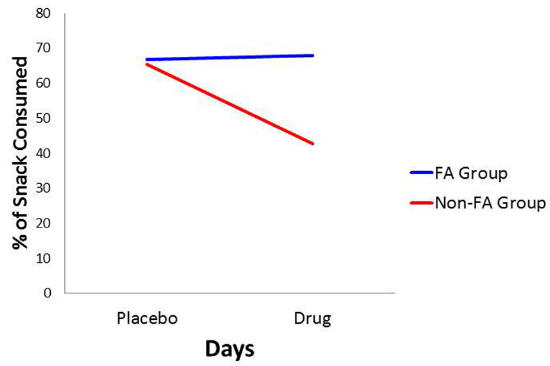

FIGURE 3 | Plot for the Diagnostic Group × Days interaction with percentage of snack-food consumption as the dependent variable.

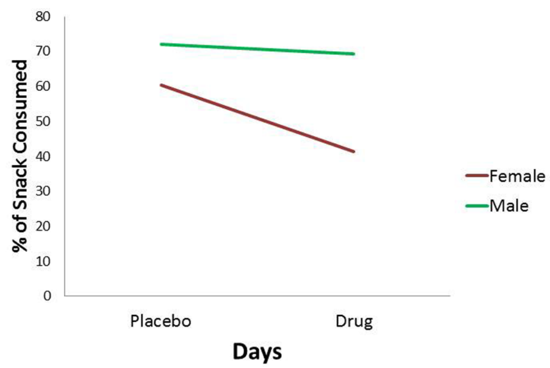

FIGURE 4 | Plot for the Sex main effect with percentage of snack-food consumption as the dependent variable.

In conformance with statistical convention, the absence of a significant interaction between the food-addiction and non-food-addiction variable and the placebo vs. drug variable precludes the legitimate testing of *post hoc* individual-Group comparisons across Days. It is important to note, however, that this interaction is testing the significance of the *difference in slopes* between the two groups. It is not testing whether either slope is different from zero. In this case, a slope not different from zero indicates no drug-suppression effect. Since the primary question of interest in the current study was whether one or both of the food-addiction groups displayed a suppression effect – not simply whether they differed from each other – a test of simple slopes was carried out for each group, strictly acknowledging that the results are investigational and preliminary. In the non-food-addiction group, the decrease from the placebo to the methylphenidate condition for appetite ratings and food cravings was statistically significant in both instances ($p < 0.0001$: $\eta^2_p = 0.260$ and 0.1.86, respectively). In the food-addiction group, neither comparison was statistically significant ($p = 0.257$ and 0.198, respectively).

There were no significant differences between men and women, nor did they differ on their food cravings and appetite ratings when they were taking the placebo or the drug.

For the *percentage of consumed snack-food*, there was a statistically significant interaction between Diagnostic Group and Days (see **Table 1**). As indicated in **Figure 3**, and according to *post hoc* comparisons, the food-addiction group showed no reduction in food-intake in the drug condition from the placebo condition, while there was a significant decrease in the non-food-addiction group ($p < 0.0001$: $\eta^2_p = 0.276$). There was also a significant main effect for Sex ($p = 0.022$: $\eta^2_p = 0.039$) with men consuming a greater percentage of their snack than women (see **Figure 4**)[4].

Table 1 | Summary statistics for the within subject contrasts for the 2 [Days] × 2 [Sex] × 2 [Diagnostic Group] ANOVA with Food Consumption as the dependent variable.

Source	Type III SS	df	*f*	*p* =
Days	1464.50	1	5.25	0.023
Days × Sex	833.22	1	2.99	0.086
Days × Diagnosis	1611.53	1	5.78	0.018
Days × Sex × Diagnosis	704.36	1	2.53	0.114
Error (Days)	36512.17	131	–	–

MOOD RATINGS

In light of the food consumption group differences in response to methylphenidate, it was decided to assess whether this finding reflected variation in subjective mood response to the drug, possibly as a result of differences in uptake or metabolism. The first item on the visual-analog scale, which was given every 15 min after ingestion of the capsule, asked participants whether they felt any mood or emotional changes that could be attributed to taking a stimulant medication. Participants indicated their response by making a pencil mark on a line 147 mm long, where the left

[4]As a *post hoc* analysis, we investigated whether the methylphenidate effect on food-intake was associated with its effect on food cravings and appetite ratings. We calculated a difference score (placebo – drug) for each of the three food-related variables and examined their bivariate inter-correlations. The food consumption difference score was moderately correlated with the cravings and appetite difference scores ($r = 0.39$ $p < 0.0001$, and $r = 0.35$ $p < 0.0001$, respectively), which were themselves highly correlated ($r = 0.76$, $p < 0.0001$).

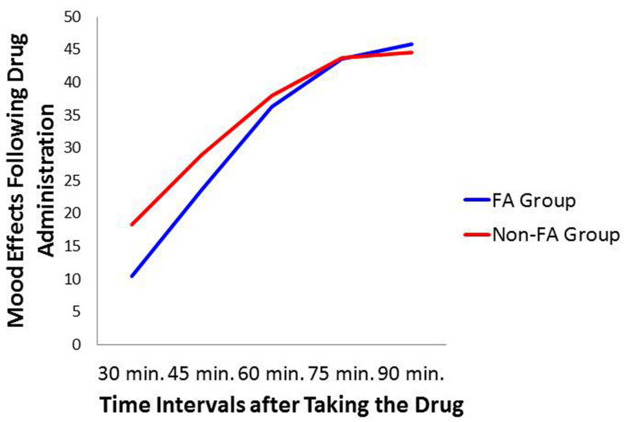

FIGURE 5 | Plot for the Diagnostic Group × Time Interval relationship with mood ratings on the drug day as the dependent variable.

end of the line indicated "no effect" and the right end of the line meant a "very strong" effect. Scores therefore varied between 0 and 147.

Repeated measure ANOVA was employed to assess the rating at time periods: 30, 45, 60, 75, and 90 min after ingestion of the capsule on the drug day. Similar to the previous analyses, between-subjects factors were Sex and Diagnostic Group. Results indicated a significant effect across time periods ($p < 0.0001$: $\eta_p^2 = 0.254$) with a linear increase which stabilized at 75 min post ingestion. There were, however, no differences between the food-addiction and the control groups, nor a difference between men and women. There was also no interaction between these two variables. **Figure 5** depicts the Time effect with separate lines for the food-addiction and the non-food-addiction groups. It is noteworthy that the peak subjective effect of the drug occurred at approximately 75 min after the capsule was taken – the time the snack-food challenge took place – after which the effect appeared to plateau in both groups.

DISCUSSION

This study represents the first empirical support for the food-addiction theory, based on *actual* food intake. Results demonstrated significant eating-related differences in response to a snack-food challenge between those diagnosed with YFAS food addiction and the non-diagnosed control group. The former reported stronger food cravings and greater appetite ratings following a taste of their favorite snack, and these differences remained stable in both the placebo and the methylphenidate conditions. While there was an overall diminution in these self-reports from placebo to drug, as was expected, this effect was driven primarily by a decrease in the non-food-addiction group, since there was no diminution among those with food addiction. With respect to food consumption, there was a significant interaction between Diagnostic Group and Days, again showing a substantial decrease in snack-food consumption in the non-food-addiction group, while there was no change in the food-addiction group.

Interestingly, and contrary to prediction, there was no difference between the food-addiction and the non-food-addiction groups in the percentage of food consumed in the placebo condition. Since appetite ratings and food cravings were both higher in the food-addiction group after the snack food was presented, it is difficult to explain why their food intake was also not greater on the drug-free testing day. One possibility is that a ceiling effect accounted for the null finding. Specifically, each participant was given a *single* snack item such as a chocolate bar, a cookie, or a small bag of chips. When analyzing the data, it was noted that a large proportion of the sample consumed the entire snack in the placebo condition – viz. 55% of the food-addiction group and 44% of the controls, compared to 45 and 25% respectively in the drug condition. If the size of the snack had been larger, thereby providing an opportunity for greater variability at the high-consumption end of the distribution, it is possible that placebo group differences may have emerged.

To summarize, in response to the methylphenidate challenge, the food-addiction group appeared resistant to the typical appetite-suppression effects of this drug. One can only speculate on the mechanisms underlying these results. Methylphenidate is lipophilic and therefore some of the drug may be sequestered in fat tissue. However, since the mean BMI values were equivalent in the two groups, differences in fat mass are unlikely to account for the observed group effects. In addition, the absence of any difference between the groups in the reporting of subjective drug effects, or on the timing of the peak subjective effects (see **Figure 5**), suggests that metabolic variation is unlikely to account for the appetite/eating group differences. Because methylphenidate's mechanism of action is very similar to that of cocaine – both block the DAT – some biological insights may be gleaned from preclinical research using a strain of cocaine-insensitive mice. The DAT-CI is a knock-in mouse line containing three point mutations in the DAT gene. This genetic alteration reduces DAT function and thereby leads to a hyper-dopaminergic state as reflected by heightened spontaneous locomotion in these animals compared to wild-type strains (O'Neill and Gu, 2013). Since inhibition of the DAT is necessary for a response to cocaine, as expected these genetically modified animals also do not display an increase in locomotion following cocaine administration, nor a conditioned place preference (O'Neill et al., 2013).

It is relevant that in previous human research we found evidence of an increased striatal dopamine signal – as indexed by a multi-locus genetic profile – in a group of adults diagnosed with YFAS food addiction compared to their age- and weight-matched counterparts (Davis et al., 2013). These findings are consistent with behavioral evidence that hyper-responsive brain reward mechanisms may serve as a risk factor for the tendency to over-consume highly palatable foods. Like the DAT-CI mice, individuals with a predisposition to elevated dopamine activity may also be relatively inured to the typical effects of stimulant drugs like cocaine and methylphenidate. Our results may therefore have potential clinical implications because methylphenidate is the first-line drug treatment for adults with ADHD, and similar stimulant drugs have recently shown some efficacy in reducing binge episodes in adults with BED (Shaffer, 2012; Gasior et al., 2013). Moreover, in light of the evidence that food addiction may reflect a more severe form of BED (Davis, 2013), the results of this study could assist in the development of personalized treatment management for patients with compulsive overeating. Indeed, many patients who use stimulant drugs therapeutically are non-responsive or discontinue treatment because of negative side effects – findings which suggest that pharmacogenetic research is needed to better understand the factors that influence drug effectiveness and toxicity. Regrettably, few adult studies have been conducted in this field, although some positive findings have identified influential markers on the DAT1 gene in relation to drug responsiveness (Contini et al., 2013).

With respect to sex differences, we found little support for our prediction that females would be more responsive to methylphenidate than males. Considering there were no Sex × Days interactions, our results do not mesh well with pre-clinical research demonstrating a stronger response to methylphenidate in females compared to males. For example, adolescent female rats showed a more robust sensitization to a dose of methylphenidate compared to their male counterparts (Brown et al., 2012), although later research found no sex differences in conditioned-place preference using the same drug (Cummins et al., 2013). It is also noteworthy that these drug effects were moderated by the strain of rats and by the drug dose (Chelaru et al., 2012).

Overall, the present study has added to the growing body of research supporting the validity of the food-addiction construct. To the best of our knowledge, this is the first study to use a well-controlled, laboratory-based, food challenge to make eating-related comparisons between adults with and without YFAS-diagnosed food addiction. In accord with our previous evidence of strong links between food addiction and trait-like food cravings (Davis et al., 2011), the current study also found elevated state-related food cravings in response to the physical presence of a highly palatable snack, which participants were asked to taste and invited to eat. Nevertheless, it is important to emphasize that replication is needed with larger samples of individuals meeting YFAS criteria for food addiction in order to improve confidence in the outcomes of this research. In the present study, the sample lacked adequate power to test the Sex × Diagnostic Group interaction due to small frequencies in some of the cells. Future researchers are also encouraged to provide a greater quantity in the snack-food challenge in order to increase the range of food-consumption scores. In addition, larger samples will allow researchers to take account of menstrual-cycle status in female participants since estrogen and progesterone levels are known to influence response to stimulant drugs (Evans and Foltin, 2010). And finally, we encourage studies going forward to search for mechanisms to explain the apparent food-related insensitivity to methylphenidate in those with YFAS food addiction by using sophisticated brain imaging techniques.

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