CHAPTER 4

Craving Chocolate?

A Review of Individual Differences, Triggers, and Assessment of Food Cravings

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Food cravings are ubiquitous in the modern human experience, yet they appear to differ between people in many ways. Are one person's cravings qualitatively and biologically similar to another's? What makes some people's cravings so strong, irresistible, and chronic, leading to, for example, finishing the box of chocolates, despite their strongest intentions not to do so?

Food cravings are a common experience among the majority of people struggling with regulating their eating, and a major barrier to diet adherence.[1] Although food cravings play a critical role in what many researchers now refer to as "compulsive eating" or "food addiction,"[2] food cravings are reported among individuals who do and do not meet criteria for DSM-IV (*Diagnostic and Statistical Manual of Mental Disorders, Edition IV*) eating pathology—from individuals trying to lose a few pounds, to those who describe an excessive drive to eat causing undesirable weight gain. Behavioral and biological overlaps between food and drug addiction,[3] and emerging data linking increased food cravings to greater insulin resistance among obese individuals,[4] underscore the potential utility of food cravings as an intervention target in the treatment of obesity.

Better understanding of food-craving experiences—individual differences in intensity and frequency, contextual triggers, and how craving is conceptualized and assessed—would shed light on mechanisms that underlie problematic and reward-based eating in response to food cravings. This, in turn, would better clarify targets for intervention.[5] In this chapter, we examine food cravings along different dimensions. We first discuss definitions and prevalence of food cravings.

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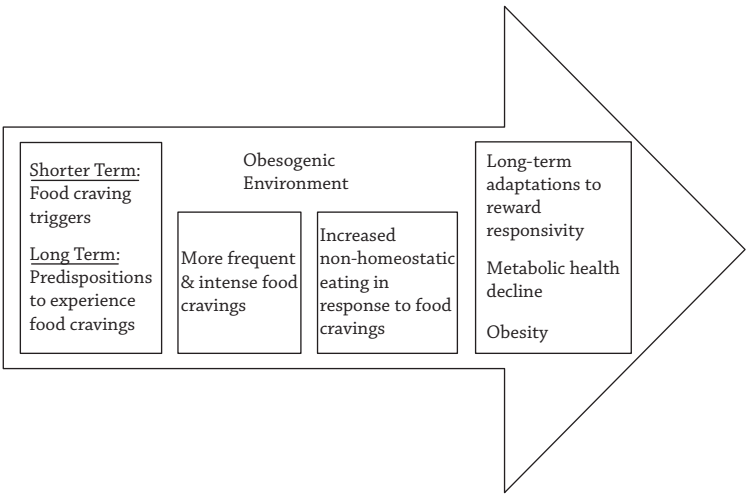

Figure 4.1:
This chapter reviews the effects of predispositions to experience food cravings and food craving triggers on food craving triggers and predispositions to experience food cravings on food craving experiences. Make the decision, craving experiences.

We then review individual differences in, and common triggers of, food cravings, with a special focus on the roles of stress and mood. As shown in Figure 4.1, there are longer-term individual predispositions to experience and indulge in food cravings, and shorter-term common triggers that may interact with these predispositions. Last, we review methods used to assess food cravings and close with a brief overview of future directions.

DEFINITIONS AND PREVALENCE

Food craving is most often defined as an *intense desire or longing to eat a specific food*.[6,7] Studies report a wide range of food-craving prevalence, with rates as high as 90%–100% of individuals sampled reporting food cravings of some type.[1,8–10] People vary in the intensity of their food cravings; in one study, among women between the ages of 18 and 45, approximately 58% reported ever having experienced a food craving, and of these, 42% of young and 21% of middle-aged women reported having had moderate-to-strong and strong cravings.[11]

Food craving fits into Berridge's "food reward framework" as a type of *wanting*, or appetitive motivation to seek out a particular food, which differs from *liking*, or the pleasure derived from eating a particular food.[12] Although liking may play a crucial role in the development of a motivational (wanting) state, individuals with pathologically elevated levels of wanting in the form of food cravings (due to predisposition or adaptation) may be at greater risk of overeating in a food-rich environment.[13] Thus, the motivational state of wanting dictates food-craving experiences that lead to overeating and the resulting overweight state.

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Food craving differs from *hunger* in terms of specificity: Although a variety of foods may satisfy one's hunger, an arguably narrower repertoire of foods may satisfy one's food craving.[14] Some researchers assert that "craving a food differs from simply deciding, for example, to have a certain food for dinner—unless that decision is based on a desire so strong that you would go out of your way to satisfy it."[15, p. 355] In humans, food cravings are generally for calorically dense, highly palatable foods that are often high in fats and sugars;[8,16,17] however, cross-cultural data suggest that food cravings can be culture-specific.[18–20] For example, surveys of North Americans indicate food cravings for pizza, ice cream, chips, pies, and especially chocolate;[19,21] whereas surveys of Japanese populations report cravings for rice and sushi to be most common.[18,22] Greater craving intensity is strongly associated with greater intake of sweet and high-fat foods.[8] Accordingly, some researchers have posited that food cravings may be considered a conditioned expression of hunger: in one study, women instructed to eat chocolate only when hungry reported increased chocolate cravings over a two-week period, whereas chocolate cravings decreased among participants instructed to only eat chocolate when sated.[23]

INDIVIDUAL DIFFERENCES IN FOOD CRAVINGS

Sex and Age Differences

Food cravings vary greatly according to a number of individual differences, and sex differences are among the most commonly examined factors. Several studies,[7,24] though not all,[15] have supported the popular notion that women experience more frequent or more intense food cravings than men.[1,7] More women (91%) than men (59%) report ever having experienced a chocolate craving,[25] and 45% of women report regularly experiencing chocolate cravings.[20] Qualitatively, women tend to crave sweet foods more often, whereas men tend to crave savory foods more often.[26] Some data suggest that men and women indulge their food cravings equally often, but may experience indulgence differently. For example, in one study women reported more tiredness, boredom, and depression when indulging their cravings, whereas men reported more happiness and relaxation upon indulging their cravings.[24] Although men and women report reduced cravings as they age, this reduction is more pronounced for women, with 100% of young women and 70% of young men reporting experiences of food or drink cravings, and 66% of older women and 62% of older men reporting these experiences.[1,15] Thus, in older age, men and women are similar in the frequency with which they experience food cravings.

Overweight Status

Relative to normal-weight people, overweight and obese people report more frequent and intense cravings for highly palatable food (high-fat, high-sugar), and will work harder in laboratory tasks for food.[8,27,28] Weight gain impacts hormone and peptide action (e.g., leptin and insulin resistance) that can shape reward-seeking

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behavior by increasing food cravings and decreasing satiety.[29,30] Additionally, repeated exposure to highly palatable foods upregulates dopamine release and downregulates dopamine-receptor sites (D_1, D_2) in the nucleus accumbens.[31] The decreased activation of D_1 and D_2 receptors may blunt individuals' sensitivity to experiences of neural reward, and increase the frequency of and indulgence in food cravings, especially in the case of sugar.[32] (See elsewhere in this chapter for a discussion how hyper- and hypo-responsivity to reward can be conceptualized as operating in tandem to exacerbate overeating.) This in turn may make it more difficult for overweight individuals to adhere to and benefit from lifestyle interventions targeting weight loss. This hypothesis fits with data collected from participants in the Diabetes Prevention Program lifestyle intervention, which targeted overweight adults with impaired glucose tolerance, a likely result of overeating calorically dense, highly palatable foods. In this sample, greater food cravings at baseline were associated with more previous weight-loss attempts, greater binge-eating severity, less weight-loss efficacy, and greater non-adherence to a low-fat diet. Baseline food cravings did not predict successful weight loss, and unfortunately the authors did not report data addressing changes in cravings.[33,34]

Surgical obesity treatment and lifestyle modifications targeting weight loss have both resulted in reduced food cravings. Although bariatric surgery requires a non-trivial amount of lifestyle modification, findings hint that food cravings can be reduced by weight loss in itself, or changes in gut peptides, and not solely by the behavioral change that is generally required for weight loss. In one study, 44 obese individuals received obesity surgery that resulted in a 20% weight loss by six months post-surgery. These participants reported significant reductions in the frequency of cravings for sweet, starchy, and high-fat foods, including high-fat fast food, at six-month follow-up.[35] Another study examined self-reported changes in eating behavior in 40 patients 12 months after bariatric surgery, and reported significant reductions in food cravings.[36]

Studies of diet interventions for obese individuals also report that reductions in weight coincide with reductions in food cravings. In an analysis of 270 participants assigned to either a low-carbohydrate or a low-fat diet, participants in each group evidenced similar weight loss over time, and both groups reported similar reductions in food cravings for carbohydrates, sweet-tasting food, and fast-food fats, at two-year follow-up.[16] Thus, bariatric surgery and lifestyle interventions for weight loss suggest that reducing body fat in a variety of ways may lead to decreased food cravings.

Food cravings probably play a role in the subtype of obesity characterized by high reward drive.[37] To better assess subclinical, more normative levels of disordered eating behavior, we developed the Reward-based Eating Drive (RED) scale, which gauges individuals' trait-like tendencies to eat in response to factors presumably reflecting strong reward drive—feeling a lack of control over eating, lacking satiety response, and feeling preoccupied with food.[38] We have found that, among overweight women, those who endorse greater reward-based eating drive also experience greater daily food-craving intensity, based on naturalistic daily reports.[39] Brief self-report assessment measures such as RED may help to identify individuals

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at greater risk for problematic food cravings, which is an important symptom to address in weight-loss interventions and prevention of obesity.

Eating Disorders and Compulsive Eating

Compared to normal eaters, individuals with disordered eating patterns report more intense food cravings when exposed to food cues.[40] Data have indicated that individuals who periodically binge eat,[41,42] or who meet criteria for binge-eating disorder,[43] bulimia,[44] or night eating syndrome,[42,45,46] report more frequent or intense food cravings. Bulimia, and to a lesser extent, binge-purge type anorexia, are associated with an increased drive to eat, which correlates with food cravings.[47,48] One recent review of food cue processing among individuals diagnosed with eating disorders such as anorexia, bulimia nervosa, or eating disorder not otherwise specified, concluded that individuals with eating disorders evidence attentional biases for food cues across different experimental paradigms.[49] A full discussion of the complex associations among disordered eating and food cravings is beyond the scope of this chapter, and we refer the interested reader to recent reviews on this topic.[50,51]

Dietary Restraint

Broadly, *dietary restraint*, or *restrained eating*, refers to the tendency to restrict food intake consciously with a goal of weight maintenance or reduction. Dietary restraint is commonly assessed in various self-report measures, such as the Revised Restraint Scale,[52] Three-Factor Eating Questionnaire,[53] and the Dutch Eating Behavior Questionnaire.[54] Food-craving experiences (frequency, and type) do not tend to score higher on self-report measures of dietary restraint,[55] and self-reports of dietary restraint do not appear to predict weight gain over time.[56]

Dietary restraint, however, may be an important characteristic in terms of reward drive. In laboratory reactivity situations, individuals with higher dietary restraint report more intense food cravings and greater appetitive responses upon exposure to food cues. This may help explain why many individuals who report higher dietary restraint are more likely to fail in achieving a weight-loss, diet-related goal: People with high restraint may be more likely to *eat in response* to food cravings.[57] For example, in one study wherein women restricted carbohydrate or protein intake for a three-day period, the authors found that individuals assigned to the carbohydrate-restriction condition who also reported greater dietary restraint reported *greater cravings* for carbohydrate during the restriction period. Similarly, among women deprived of chocolate for three days, those who reported greater dietary restraint (relative to those who reported lower dietary restraint) ate significantly more chocolate after the deprivation period.[58] Thus, data suggest that trait-like dietary restraint may increase food cravings, but only in response to observable cues.

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How might we explain why longitudinal and cross-sectional data do not show that higher dietary restraint is contemporaneously or prospectively associated with increases in weight?[55,56,59] At present, the literature is lacking a complete picture of the factors that determine successful long-term restraint. Recent data suggest that dispositional self-control moderates an association between increased dietary restraint and increased appetitive responses to food cues. In one study, individuals high in both dispositional self-control and restrained eating had normal body mass indices (BMIs), whereas women low in dispositional self-control and high in restrained eating had overweight BMIs.[60] Of note, the authors reported cross-sectional associations and called for longitudinal studies to understand how associations between self-control and dietary restraint affect weight over time. These findings are reminiscent of data that have differentiated between rigid and flexible dietary restraint. Rigid dietary restraint reflects an "all-or-nothing" attitude toward dieting, characterized by excessive self-control of eating behavior that is often punctuated by failures, which are then difficult for individuals to overcome when resuming their diet. In contrast, flexible dietary restraint reflects a more balanced approach that is more forgiving of lapses that are not as difficult for individuals to overcome in resuming their diet. One recent study reported that food cravings mediated an association between rigid restraint (but not flexible restraint) and perceived self-regulatory success in dieting, suggesting that rigid restraint decreases perceived dieting success via increased food cravings. In this study, flexible restraint predicted perceived dieting success.[61]

Indeed, restrained eaters who are successful in controlling their body weight report fewer cravings for highly palatable food,[62] and although this may be due to greater levels of dispositional self-control, there are other possibilities. Some restrained eaters may be more self-aware of their difficulties with eating in response to food cravings, and may use this self-knowledge to be more effective in reducing environmental cues that trigger food cravings, rather than directly suppressing thoughts or responses when cravings occur. For example, several studies have documented that simple environmental changes, such as moving a candy dish as few as two meters further from one's work desk or placing candy in an opaque dish, decreases wanting for and consumption of that candy.[63,64] In contrast, restrained eaters who attempt to suppress thoughts about foods that they crave tend to eat *more* of this food, suggesting that for these individuals, dietary restraint *does* contribute to weight gain.[65] Similarly, relative to individuals with lower dietary restraint, individuals with higher dietary restraint ate significantly less chocolate before a thought-suppression task and more chocolate after the suppression task.[66]

Implications of these data are that, although dietary restraint may promote maladaptive eating behavior (especially in response to food cues), dietary restraint can also be adaptive when paired with high trait self-control. Thus, we cannot interpret the impact of high dietary restraint on eating behavior without the context of other individual differences. Additionally, it is important to consider rigid and flexible restraint as differentially affecting eating behavior. Researchers assessing dietary restraint should do so in tandem with assessments of self-control, self-regulation

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capacities, and the types of strategies individuals use to address cravings in real-life situations. Moreover, researchers should be aware that, rather than restrained eating leading to problematic eating behavior, it may well be the case that individuals who gain weight subsequently attempt to restrain their eating. That is, rather than playing a mechanistic or causal role, restrained eating may be a marker for tendencies to overeat.[59]

Sensitivity to Reward

Researchers agree that abnormalities in the pathways that shape the neural experience of reward in response to eating can disrupt normative eating patterns; however, these abnormalities may follow from a variety of situations. Researchers have pointed to behavioral pathways (e.g., repeated overeating), genetic influences (e.g., the TaqIA A1 allele), biological factors (e.g., dopamine-receptor site availability), and conditioning processes (e.g., emotional memories linking food intake to positive affect) as potential causes of such abnormalities. What sorts of abnormalities might underlie a dysregulated reward system that leads people to eat in ways that promote obesity and other metabolic consequences? Here, we review models of hypo- and hyper-responsivity to food reward in the context of obesity, and how food cravings fit within each model. We then review the recently posited dynamic vulnerability model that incorporates both models.

Hypo-Responsive Model of Neural Reward

The *hypo-responsive* theory reflects the *reward deficiency syndrome* model and suggests that obese individuals experience less neural reward in response to eating, potentially due to sluggish neural reward circuitry, and therefore overeat in an effort to counteract this deficiency.[67] Certain genetic predispositions, such as presence of the TaqIA A1 allele, have been associated with decreased neural reward responsivity, decreased reinforcement valuation of food, and increased weight gain.[27,68] It is also possible that overconsumption of highly palatable food downregulates dopaminergic activity, resulting in reduced neural experience of reward.[69] It is unclear what role, if any, food cravings may play in this profile. While this model focuses on overeating behavior as a causal factor in neural adaptation, it may be that the blunted response to eating is preceded by an excessive reward drive and associated food cravings that motivate individuals to seek highly palatable food in the first place. Further research should utilize longitudinal designs to assess temporal associations between food-craving intensity, neural reward circuitry, and subjective reports of wanting and liking.

Hyper-Responsive Model of Neural Reward

The *hyper-responsive* theory reflects the *reinforcement sensitivity model* of substance abuse, and posits that obese individuals are more sensitive to the rewarding

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aspects of eating, and therefore eat more to heighten their experience of reward.[70,71] Self-report measures of general reward sensitivity that have been commonly used in research on eating behavior include the Physical Anhedonia Scale,[72] the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ),[73] and the Behavioral Activation System (BAS) component of the Behavioral Inhibition System (BIS)/BAS scales.[74] Greater reward sensitivity, as indexed by these self-report measures, has been associated with higher BMI and greater trait food craving.[70,75]

A growing body of literature highlights important distinctions between the hyper-responsivity to reward when anticipating versus when consuming palatable food. *Incentive salience* theory suggests that anticipatory and consummatory reward have temporal associations that lead to increases in the reinforcement value of food. This increased valuation leads to increased anticipatory reward (i.e., motivated craving, or *wanting*) and decreased consummatory reward (i.e., hedonic pleasure, or *liking*).[76] These increases in anticipatory reward, or motivated craving, may lead to greater food intake, suggesting that individuals conditioned to experience greater anticipatory reward may be at a heightened risk for weight gain.[77]

Dynamic Vulnerability Model of Neural Reward

Burger and Stice[78] recently proposed an integration of evidence for each the hyper- and hypo-responsive models of neural reward, theories of anticipatory and consummatory reward, and conditioned behavior that shapes the reward experience. They proposed that individuals at risk for obesity might initially experience hyper-responsivity to reward in response to eating, which leads to subsequent overeating. Repeated overeating (1) increases the reinforcing value of food and strengthens conditioned associations surrounding eating; and (2) dampens dopaminergic action in response to food intake. These two processes form a positive feedback loop that maintains overeating so as to experience a dopamine-driven neural reward experience. Behavioral responses to food cravings are key components in this developmental model, given their importance in initiating and maintaining conditioned food cues. Findings suggest that this model may more accurately depict how the associations between reward responsivity and eating behavior change.[78]

TRIGGERS OF FOOD CRAVINGS

A biopsychosocial model (e.g., Rogers & Smit, 2000) of food craving posits important roles for conditioning, dieting status and dietary restraint, food environment, health behavior (e.g., sleep), biological factors (e.g., hormones and nutrient deficiencies), and psychological factors (e.g., stress and mood) in triggering food cravings. Below, we review empirical support for several of these triggers.

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Pavlovian Conditioning

The pairing of consumption of a given food with a rewarding consequence increases the *incentive value* of a given food. This incentive valuation, or rendering of certain food cues as highly desirable, results from a Pavlovian conditioning process.[79] According to this conditioning model, the development of a craving for a given food requires familiarity with this food and the rewarding consequences of ingesting it, meaning that individuals do not crave highly rewarding *novel* foods. This behavioral model maps onto dopamine action, which is considered to be a primary determinant of food-seeking behavior[80] and is discussed in depth elsewhere in this volume (Chapter 3). Briefly, eating stimulates dopaminergic release, and over the course of repeated pairings of eating with an environmental cue, that environmental cue alone may come to stimulate dopamine release. Upon observing and attending to this cue, dopamine may then bind to D_2 receptors in the nucleus accumbens and stimulate strong motivational states of wanting, or food craving (for a review, see[81]). Therefore, researchers have recommended that individuals who endorse problematic craving-related eating limit the places in which they eat, and the activities in which they engage while eating, in order to reduce the development of environmental cues to eat. A person attempting to lose weight, or avoid future weight gain, might consider bypassing the delicious smells wafting from a local bakery while walking to work, and might try to avoid the office kitchen until he or she can be reasonably certain that the morning doughnuts have vanished.

Dieting Status and Diet Interventions

Data addressing the impact of dieting on food-craving experiences are mixed. Here, we refer to "dieting" as the state of currently being on a diet, rather than dietary restraint, which is most often not correlated with actual caloric intake and therefore not reflective of dieting status.[82–84] The "deprivation hypothesis" holds that individuals will more often crave the foods they are deprived of, and short-term laboratory data support this hypothesis. In one study, women deprived of carbohydrate or protein for a three-day period reported increased cravings for these macronutrients during the restriction period.[85] More studies, however, report that dieting in the form of low-calorie diets or macronutrient restriction (e.g., low-carbohydrate or low-fat diets) can reduce the frequency and intensity of food cravings.[86–88] In one study that assigned individuals to either a low-carbohydrate or a low-fat diet regimen, individuals reported reductions in food cravings specifically for the macronutrient they were assigned to limit.[16] Similarly, diet interventions that instruct individuals to restrict caloric intake also lead to reductions in food cravings.[88]

In addition to reducing food cravings, diet interventions may reduce the frequency with which individuals "give in" to their food cravings: prior to a six-month diet intervention, overweight women reported "giving in" to their cravings 64% of the time, and following the intervention, they reported "giving in" 27% of the

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time, and this reduction was unrelated to the amount of weight lost.[10] Data highlighting associations between dieting status and food cravings tend to suggest that dieting may reduce the frequency and indulgence of food cravings, which theoretically should be critical to the regulation of eating. However, the status of simply being on a diet introduces many other vulnerability factors that prevent weight loss maintenance over time: a recent review of prospective studies examining the impact of dieting status on future weight gain found that 75% (15) of the reviewed analyses found a positive association between currently dieting and prospective weight gain.[56] Thus, while short-term dieting status may be helpful for reducing cravings, dieting behavior is notoriously difficult to maintain. Food cravings may play a key role in individuals' inabilities to maintain successful weight loss, as some research has indicated that those who successfully maintain their weight loss report using coping strategies that do not involve eating in response to food cravings.[89,90]

Food Environment

The modern food environment is oft-termed "obesogenic" due to the widespread availability of food and drinks that are calorically dense, non-nutritious, highly palatable, and often highly processed.[91,92] We are constantly surrounded by external cues to eat when not in a state of energy depletion, and these cues affect our eating behavior even when we do not consciously attend to them.[93–95] This environment is surely a mismatch for humans' innate response patterns to the biological need to eat. Researchers have argued that in the context of the modern food environment, homeostatically based hunger and satiety cues play a lesser role in determining eating behavior than environmental cues to eat.[96] Sounds, colors, food packaging, smells, plate shape, lighting, socializing, and a myriad of other environmental factors influence motivations to eat by inhibiting physiological cues of caloric deficit and suggesting alternative reasons for consumption.[97]

Individual differences, such as reward processing, impulsivity, and dietary restraint,[98,99] shape attention to cues indicating the availability of highly palatable food and also render certain individuals more susceptible to the influence of these cues on eating behavior.[70] In one study, overweight individuals, relative to lean individuals, reported greater increases in the desire to eat pizza when exposed to the sight and smell of pizza.[100] Another study found that food cues can exert larger effects on the eating behavior of individuals who report greater dietary restraint. Researchers presented restrained and unrestrained eaters with smells and verbal descriptions of pizza, and found that restrained eaters reported more intense cravings than unrestrained eaters.[98] Individuals who report greater susceptibility to the impact of living in a food-abundant environment as indexed by the Power of Food Scale[101] experience stronger food cravings in response to environmental food cues and endorse increased desire to eat when in the presence of highly palatable food.[102]

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Sleep Deprivation and Disorders

The past two decades have seen a wealth of data linking dysregulated sleep to weight gain and overweight and obese status.[103,104] Sleep deprivation and disruption can alter diurnal rhythms of appetite-regulating hormones operating in endocrine and metabolic pathways in ways that increase caloric intake. Few studies, however, have specifically unpacked how sleep affects food cravings. In a sample of adolescents, greater daytime sleep (for any reason, such as napping to compensate for insufficient nocturnal sleep) was associated with greater total food cravings, as indexed by a food-craving inventory.[105] In another study, men deprived of sleep (from ten hours per night to four hours per night) reported increases in desire for high-carbohydrate, sweet, salty, and starchy foods, as well as changes in the peptides that regulate hunger, specifically, decreased leptin and increased ghrelin.[106] Similarly, in a study of individuals with obstructive sleep apnea (OSA), which leads to reduced or disrupted nighttime sleep, individuals with greater disease severity selected dinner items off of a menu that were higher in fat and carbohydrate content (e.g., French fries) than those with lesser disease severity.[107] If sleep curtailment is a causal factor that increases food cravings, increasing sleep time should reduce cravings. Indeed, recent intervention data show that increasing bedtime duration to 8.5 hours each night resulted in decreased cravings for salty and sweet foods, such as cake, candy, cookies, and ice cream.[108] In sum, a growing literature suggests that sleep restriction may increase cravings, and that interventions targeting increased sleep duration may reduce food cravings.

Hormones

Gender differences in food cravings implicate non-trivial roles of sex hormones in eliciting craving experiences. Under normal conditions of reproductive cycling, pre-menopausal women undergo increases in estrogen and progesterone during the periovulatory and midluteal phases, with a peak estrogen level at ovulation that is followed by a drop in estrogen and progesterone. The ovarian hormone hypothesis of food cravings suggests a direct link between hormonal shifts and food cravings such that women experience more food cravings during the luteal phase.[109] Data do not uniformly support this hypothesis, with some reporting no differences in craving across the menstrual cycle.[93] The majority of studies, however, appear to report an impact of the menstrual cycle on food cravings. In one study, nearly 68% of women reported chocolate cravings around the time of menstruation.[110] Women report food-craving experiences to be a core component of premenstrual syndrome (PMS),[111] and those diagnosed with premenstrual dysphoric disorder(PMDD) endorse more cravings during the luteal phase.[112]

Furthermore, there is a significant decrease in chocolate cravings between pre- and post-menopausal women, although this difference is probably not large enough to support a *purely* hormonal explanation for chocolate cravings.[113] Laboratory studies have yet to manipulate sex hormones to impact food cravings.

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Furthermore, estradiol, a common component of oral contraceptives, has not been found to be significantly associated with frequency of food cravings,[114] and oral contraceptives have not been found to alter food cravings across the menstrual cycle.[115,116] Thus, while there are often small main effects of cycle and menopausal status across women on cravings, it appears that only a subgroup of women are particularly vulnerable to problematic hormone-related cravings—such as those with Premenstrual dysphoric disorder (PMDD). The individual differences that predict which women are more sensitive to hormone-induced cravings are unknown.

Nutrient Deficiencies and Orosensory Experience

Though popular, the hypothesis that food cravings result from nutrient deficiencies has garnered little empirical support. For example, one hypothesis is that chocolate, an oft-craved food among women, may restore magnesium during menstruation.[7] Others suggest that carbohydrates may increase brain serotonin levels[117] and that sweet foods may restore blood glucose levels.[118] Data, however, do not appear to support these nutrient deficiency hypotheses. One study fed women variations of chocolate, including an orally ingested capsule of cocoa with cocoa equivalent to a serving of chocolate, an actual chocolate bar, or a serving of white chocolate, which lacks commonly cited pharmacological components of chocolate (e.g., theobromine, magnesium). This study design allowed researchers to disentangle the orosensory components of eating chocolate—the smells, texture, and tastes—from the nutritional content of cocoa, so that they could better understand if cocoa was indeed craved due to a nutritional deficiency. Data indicated that cocoa capsules did not satisfy chocolate cravings, white chocolate partially satisfied chocolate cravings, and chocolate itself reduced chocolate craving. The authors concluded that although aroma, sweetness, texture, and calories may lead to satisfaction of chocolate cravings, the lack of reduction in chocolate cravings following ingestion of the cocoa capsules fails to provide evidence for pharmacological effects in the satisfaction of chocolate cravings.[119] In another study, young adults eating a monotonous, though nutritionally adequate diet (a single sweet nutritional supplement beverage) reported sizeable increases in food cravings relative to when they consumed a varied diet at baseline.[15] This, too, suggests that the orosensory components of eating play a key role in the satisfaction of cravings.

In contrast to the idea that decreasing a nutrient will lead to increased craving for it, some data show that food cravings for restricted foods decrease in the context of diet interventions (e.g., decreased carbohydrate cravings on a low-carbohydrate diet).[120] Additionally, food cravings are often for nutrient-poor foods (e.g., pizza, ice cream).[1,7] In sum, it has been difficult to demonstrate an association between nutritional deficiencies or macronutrient compositions and increased food cravings in laboratory settings, and data thus far suggest that food cravings may primarily arise due to orosensory factors and dietary monotony.

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One emerging theory hints that the gut microbiome may play a role in eating and obesity. Researchers have hypothesized that gastrointestinal microbes may stimulate cravings for foods that either enhance their survival or suppress their competitors; a fascinating concept, but one that awaits experimental data in humans.[121]

Stress, Mood, and Food Cravings

Stress has powerful effects on eating behavior, but we know little about the mechanisms linking stress to experiences of and indulgence in food. To complicate things, stress can dampen the appetite and hedonic response to stimuli including food,[122–124] although here we focus on the more common pattern of stress-enhanced appetite. Stress may increase the intensity or frequency of cravings, particularly for people with eating issues in a broad sense—such as obesity, high dietary restraint, emotional eating, or dysregulated eating behavior. Could the effects of stress on overeating and weight gain be in part due to increases in the reward value of food and the intensity of cravings under stress? Here we review what is known about associations between stress, food craving, and eating.

Stress can increase incentive salience and cravings for substances.[125] It appears that stress can also increase the rewarding value of food.[126–128] However, as is commonly the case with the multifaceted constructs of acute and chronic psychological stress, stress more often strengthens the association between vulnerability factors and resulting behaviors, rather than increasing the behaviors across the board. Acute stress, such as exposure to a laboratory stressor, affects people differently depending on their level of chronic or daily stress. Acute stress differentially impacts individuals' appetites, with some individuals reporting decreased appetite and some reporting increased appetite. A growing body of data suggests that these differential effects may depend in part on levels of background chronic stress and biological predispositions (e.g., level of hypothalamic-pituitary-adrenal [HPA] axis responsiveness) or appetitive predispositions to engage in dysregulated eating patterns in times of emotional chaos.

To date, the most dramatic effects of stress on reward drive have been shown in non-human animals. For example, rats presented with highly palatable food tend to eat beyond their homeostatic needs. Rats conditioned to binge eat through cyclic caloric restriction (which may be thought of as an analogue to dietary restraint in humans), however, eat significantly more highly palatable food when administered an acute stressor (footshock).[129] Administering the opioid antagonist naloxone to these rats blocks this effect, which suggests that binge eating in rats with histories of caloric restriction is mediated by the opioidergic system. Data have shown that this pattern of neural adaptation is robust, and that rats conditioned to binge (via caloric restriction and stressor exposure) will withstand greater aversive stimuli (e.g., stronger footshock) in order to obtain a food reward.[130] Thus, conditioned eating in response to stress appears to be a robust response that is likely to be difficult

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to extinguish—we are unaware of rodent designs that have successfully reversed conditioned binge eating.

Human laboratory data also underscore impacts of acute stressors on food cravings and the consumption of highly palatable food. Several paradigms have exposed women to acute stress so as to examine changes in cortisol, food cravings, and eating of "comfort food" (which is often highly palatable) in response to the stressor. In one study, women who evidenced higher cortisol reactivity in response to an acute standardized stressor ate more calories from comfort foods after the stressor, and reported eating more sweet foods,[131] but this study did not examine interactions with chronic stress or other eating-relevant moderators. A few recent studies have characterized women by level of chronic stress, which appears to heighten sensitivity of the reward center and increase appetitive drive. In one study, women endorsing higher (relative to lower) chronic stress at study intake evidenced blunted cortisol responses to an acute stressor and reported significantly more emotional eating.[132] Similarly, another study assessing eating in response to an acute stressor found that women who reported greater trait emotional eating *and* who evidenced a blunted cortisol in response to the acute stressor ate significantly more comfort food after the stressor task.[133] In contrast, another study reported that greater chronic stress was associated with greater trait-level food craving after an acute stressor, but only for women who showed an *increased*, rather than a blunted, cortisol response.[134]

On the surface, these studies suggest two phenotypes—that women who have hyper- or hypo-responsive HPA activation may experience more frequent or intense cravings for highly palatable food after an acutely stressful experience. Why might these women evidence different patterns? Stress-induced increases in cortisol are thought to induce increases in appetite—and thus it is not surprising that high reactivity can increase the drive to eat palatable food.[131,135,136] In contrast, chronic stress coupled with repeated overconsumption of highly palatable food suppresses HPA reactivity, turning the drive to eat palatable food into a habit-based behavior.[137] Animal models suggest that chronic stress and intermittent access to highly palatable food may instantiate neural adaptations that more tightly couple the eating, the reward system, and HPA axis activity. Thus the hypo-responsive profile may be a proxy for people who have undergone neural adaptation to chronic stress. That is, as described above, a greater motivational drive for highly palatable food may in turn lead to a downregulated HPA axis. In this way, cortisol reactivity may prove an integral puzzle piece in understanding neuronal adaptations to chronic stress.

Laboratory stress studies find that biological (cortisol reactivity), behavioral (eating in response to stress), and stress-related (chronic stress) factors may render individuals more susceptible to eating in response to food cravings. Thus, understanding individuals' phenotypes as indexed by self-reported stress-related eating, chronic stress, and trait food craving, as well as objective measures of cortisol reactivity to acute stress and of eating in response to acute stress, will further elucidate associations between stress, food cravings, and eating. Future research should expand upon the laboratory and short-term animal and human laboratory studies

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in order to create and test longitudinal models of associations between stress, food cravings, and eating in response to food cravings.

Although a body of literature has laid the groundwork for unpacking associations between stress and food cravings, associations between mood disorders and food cravings are less abundant. One study reported that, across a large sample of undergraduates, greater negative affect was associated with greater intensity of cravings, but only for those who self-identified as "carbohydrate cravers."[9] Several studies have manipulated state emotions, such as positive and negative affect, to better understand associations between food cravings and food consumption. These studies may offer clues about how mood affects food craving and incentive salience of food. People who identify as "emotional eaters" show greater neural responsivity when anticipating and consuming palatable food, but only when induced to experience negative mood.[138] In contrast, non-emotional eaters evidenced reduced activation in the reward system when induced to experience negative mood (relative to a neutral mood). Studies in rats and humans have demonstrated that induction of depressive mood can increase chocolate cravings.[139] Among women with bulimia, greater negative affect was associated with greater neural reward activation when anticipating palatable food, suggesting that negative affect may prime the reward drive in these women. In contrast, women's neural activation in response to *consuming* palatable food was uncorrelated with affect.[140] In another study of bulimic women, negative affect was a more potent trigger of cravings that led to a binge episode than was biological hunger. Furthermore, cravings alone did not typically lead to binges, but cravings in the context of negative affect did.[141] Similarly, obese people exposed to a negative mood induction, or a relived favorite food cue, both evidenced greater corticolimbic-striatal activation, a motivation-reward region of the brain. Activation in this area mediated an association between insulin sensitivity and food craving, suggesting that improving insulin sensitivity and reducing reactivity to food- and stress-related cues may improve eating behavior in the context of obesity.[4] These studies support the idea that negative affect can increase neural reward drive and the experience of strong cravings.

FOOD-CRAVING ASSESSMENT

Food cravings are a common experience, and may or may not lead to overeating. It is critical to assess them in ways that will allow us to identify risk factors that predict the problematic overeating that may result without intervention. Once these patterns of habitual eating in response to food cravings have already developed, reversal of the neural, metabolic, and behavioral patterns that promote weight gain is very difficult to achieve and maintain. Here we review commonly used measures and suggest study conditions in which they are most applicable.

Pelchat (2002)[158] asserts, "Craving, as a psychological experience, is best measured by self report" (p. 350). There are several self-report methods of measuring food cravings (for reviews, see[120,142]). Most self-report measures of food cravings assess either *state* or *trait* food craving. "State food craving" refers to food

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cravings in response to specific, momentary situations, psychological states, or physiological states, and these measures can be repeatedly administered over the course of various interventions. "Trait food craving" refers to aspects of food craving that are stable within an individual across time and situations, and are less likely to change over time. Whereas state measures of food craving may elucidate changes in food cravings due to study manipulations, trait measures of food craving may be more useful in predicting outcomes related to eating behavior and food choice.

The original Food Craving Questionnaires (FCQ) for each state (FCQ-S) and trait (FCQ-T) food craving[143] ask respondents to think of a specific food that one craves while completing the measures, and have been subsequently modified to reflect general trait food cravings (G-FCQ-T[144]); they also target specific foods, such as chocolate.[145] Variations of the FCQ have been validated in several languages, such as German, Spanish, and Korean.[146–148] Authors of the original FCQ-T and FCQ-S found that participants' scores on the FCQ-S differed considerably across fasting and sated states, whereas participants' scores on the FCQ-T did not.[143] Furthermore, all nine subscales within the FCQ-T correlated with measures of hunger and disinhibited eating, as indexed by the Three-Factor Eating Questionnaire (TFEQ),[53] while only one of five subscales within the FCQ-S correlated with both hunger and disinhibited eating on the TFEQ. Thus, the state and trait versions of this scale appear to tap distinct facets of food craving.

Self-report inventories of commonly craved foods, such as the Food Craving Inventory, are often administered pre- and post-interventions, and are designed to measure changes in food craving as a function of an intervention. Food-craving inventories also allow the assessor to conceptualize the respondents' cravings in terms of broad categories, such as sweets, starches, and fats. This type of scale is probably most helpful for understanding the specific types of cravings an individual is having, and for tailoring specific interventions.

Alternatives to multi-item, validated measures of food craving include face-valid, individual items asking respondents to rate their craving intensity using visual analogue or Likert scales. For example, in one study targeting reductions in food cravings by using imagery techniques, the authors used a single-item craving intensity measure, asking participants to rate the intensity of their cravings on a ten-point Likert scale.[149] Assessing cravings qualitatively may also yield rich data: Dressler and Smith used open-ended questions to interview women living in low-income environments about their food cravings, and found that overweight/obese and lean/normal-weight reported that health and cost were significant determinants of food choices, respectively.[150]

Assessing food cravings in terms of individuals' relationship to the experience of cravings may index individuals' abilities to experience, but not act on, food cravings. A novel measure of food-craving experience, the Food Craving Acceptance and Awareness Questionnaire (FAAQ) was developed to assess acceptance of food-craving experiences and the extent to which individuals attempt to control these experiences.[151] The psychological ability to experience food cravings and

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not act on them may prove critical for healthy eating and weight loss, although no large-scale studies have tested this. Juarascio and colleagues reported that, among a sample of 29 overweight or obese women enrolled in a weight-loss program, greater acceptance of food-craving experience as indexed by the FAAQ predicted greater weight loss.[151]

In addition to self-report measures of cravings that are generally completed before and after given interventions, recent investigations of food cravings have turned to ecological momentary assessments (EMA) as a method of capturing food-craving experiences in real time. For example, Berkman and colleagues (2014) developed a text-messaging program that allows individuals to receive and respond to text messages asking them about their experiences of hunger, craving, and eating.[152] This methodology may be more sensitive to acute changes in situational (state) food cravings and allow researchers to understand the daily impact of interventions. Additionally, EMA of food cravings allows the assessment of transient craving experiences in the context of social, behavioral, or environmental antecedents of cravings, as well as the aftermath of craving experiences (i.e., whether one satisfied the craving, waited for it to pass, or responded in some other fashion).

In sum, researchers should employ diverse methodologies when assessing food cravings. Food cravings are not static traits, but dynamic experiences that unfold in very specific contexts with sensitive timeframes. Trait craving assessments may reveal important individual differences that indicate who will benefit from particular interventions. State craving assessments, such as food inventories and measures of frequency and intensity, would allow researchers to ascertain impacts of interventions with more sensitive information. Such measures would allow researchers to unpack how, for example, weight-loss protocols alter cravings for particular foods, or alter the frequency or intensity with which individuals experience food cravings. EMA methodologies enable fine-grained analyses targeting associations between food cravings and a variety of daily events, such as exposure to food cues while spending the day at a bakery café with friends, or during an argument with a spouse. Using a multimethod approach to assess food cravings, and tailoring the measures of food craving to answer key research questions about food cravings, will undoubtedly increase our knowledge of how food cravings impact health.

CONCLUSION

When does a craving become pathological, putting one at risk of repeated overeating and obesity-related metabolic dysregulation? The modern food environment, replete with easily accessible, highly palatable food, can promote persistent overeating in response to food cues in certain individuals. Here we have emphasized that frequent and intense food cravings may play a key role in the growing obesity epidemic and are thus critical to investigate as potential

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targets of intervention. Furthermore, cravings may potentiate or otherwise significantly affect eating-disorder symptomology;[141] thus they are implicated in the development of obesity and eating disorders, pointing to potential for prevention.

Cravings are a key component of addiction processes, and are experienced by chronic dieters, individuals with clinical eating disorders (e.g., bulimia and binge eating), and individuals who do not identify their behavioral responses to food cravings as contributing to their overweight. Each of these patterns is alarming and must be attended to. Chronic unsuccessful dieting may lead people to seek treatment that involves dietary, behavioral, and emotional supports, such as Weight Watchers,[153] and individuals with eating disorders may be less likely to seek treatment. Overweight individuals who frequently experience and indulge food cravings and are either not aware that, or do not believe that, their eating in response to food cravings may contribute to their overweight status, may be at heightened risk for obese status over time. Therefore, it is critical to identify people at risk for overeating in response to food cravings and to develop interventions that target behavioral responses to food cravings and triggers for food cravings.

Most lifestyle interventions that address food cravings identify obesity as the target outcome variable; however, some researchers have begun targeting food cravings as an independent study outcome. The past decade has witnessed a surge in behavioral treatments for food cravings, including mindfulness and acceptance-based treatments,[86,102,154] cognitive and behavioral treatments,[98,155] nutritional interventions,[16,88] and suggestions for possible environmental interventions.[156,157]

We have found that a ten-item self-report assessment of reward-based eating drive to eat predicts daily cravings[39] as well as weight gain over time.[38] Other craving measures appear helpful in predicting how people fare in weight-loss programs. Here we have reviewed many factors that put one at risk for more food-craving experiences (see Figure 4.1). Better understanding of how these psychological, behavioral, and neurobiological constructs shape cravings will allow us to develop targeted interventions for craving-related eating behavior. Chronic stress and dysregulated HPA axis responsivity appear important in laboratory studies, and may be key players in identifying a risk profile for reward-based eating, especially in times of high negative affect. It appears that interventions for reward-based eating that target behavioral responses to cravings are not only warranted but also are necessary to curb the tide of obesity. Future research will hopefully shed further light on the types of cravings that lead to overeating, and how to prevent and reduce them.

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