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Food Craving and Food "Addiction": A Critical Review of the Evidence From a Biopsychosocial Perspective

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ROGERS, P. J. AND H. J. SMIT. *Food craving and food "addiction": A critical review of the evidence from a biopsychosocial perspective.* PHARMACOL BIOCHEM BEHAV **66**(1) 3–14, 2000.—Although certain commonalities exist between eating and drug use (mood effects, external cue-control of appetites, reinforcement, etc.), it is argued that the vast majority of cases of (self-reported) food craving and food "addiction" should not be viewed as addictive behavior. An explanation is proposed that instead gives a prominent role to the psychological processes of ambivalence and attribution, operating together with normal mechanisms of appetite control, the hedonic effects of certain foods, and socially and culturally determined perceptions of appropriate intakes and uses of those foods. Ambivalence (e.g., "nice but naughty") about foods such as chocolate arises from the attitude that it is highly palatable but should be eaten with restraint. Attempts to restrict intake, however, cause the desire for chocolate to become more salient, an experience that is then labelled as a craving. This, together with a need to provide a reason for why resisting eating chocolate is difficult and sometimes fails, can, in turn, lead the individual to an explanation in terms of addiction (e.g., "chocoholism"). Moreishness ("causing a desire for more") occurs during, rather than preceding, an eating episode, and is experienced when the eater attempts to limit consumption before appetite for the food has been sated. © 2000 Elsevier Science Inc.

Addiction Craving Moreishness Chocolate Mood Ambivalence Attribution Food Eating Appetite Dieting Conditioning

FOOD cravings and the related concept of food "addiction" are widely discussed in the popular media, and have also received a considerable amount of attention in the scientific literature. Chocolate is the food most typically associated with reports of food craving and food "addiction," although other energy dense foods, including cakes, biscuits, and various salty and savory "snack" foods, also usually appear high on lists of craved foods [e.g., (81,123)]. Usually, the subject has been viewed primarily from a biological perspective. For example, it has often been suggested or assumed that cravings are an expression of an energy or specific nutrient requirement, or that addiction is explained by the presence of a naturally occurring psychoactive compound in the food. In fact, despite the interest that these ideas generate, they appear to be based more on speculation than substantial research findings.

This article critically reviews the scientific evidence on food craving and addiction, focusing primarily on chocolate as a case study. It first briefly discusses current views on the criteria for drug addiction, and it then examines eating behavior and the effects of eating (e.g., on mood) in the light of these criteria. This is followed by an overview of appetite control and dietary restraint as background to an integrated "biopsychosocial" perspective on food craving and addiction (and particularly so-called "chocoholism"). The latter develops arguments made elsewhere (68,84,85), but not previously brought together as a comprehensive review.

WHAT ARE CRAVING AND ADDICTION?

Finding an agreed definition of cravings is much easier than defining addiction, or at least this is the case if it is assumed that craving is a subjective state that individuals can recognize and report on. Among the definitions of craving offered by the Collins English Dictionary (21) are "to long for" and "to desire intensely." The latter is closest to the meaning typically

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used or implied in studies of food craving [i.e., food craving is an intense desire to eat a particular food (52,69,94,123)]. That said, there is much less agreement on the role of craving in influencing the choice and consumption of foods, and the use of drugs (41,80,108). This is discussed in detail below, although it is worth noting here that there would appear to be an important difference between what is suggested by the statements: "I often get a strong desire to eat chocolate;" "I often get a craving for chocolate." The second statement seems to more strongly suggest an addiction to chocolate, and this is also implied by another dictionary definition of craving—"to need greatly or urgently" (21).

The question "Is chocolate addictive?" can be answered in different ways. If it is considered in terms of personal discourse, then the statements that "I'm addicted to chocolate" or "I am a chocoholic" could be taken as evidence that chocolate is indeed addictive. Alternatively, it could be argued that chocolate is not addictive because, as discussed below, there is no convincing evidence that eating chocolate leads to physical dependence on one or more of the substances it contains. Another answer might be that addiction is an unhelpful term [a "troublesome concept" (1)], which should be abandoned, and therefore, the question needs to be rephrased, perhaps replacing "addiction" with "dependence" [see (41)].

It is not really possible, however, to dispense with the term addiction altogether, because it will continue to used in everyday discourse and by scientists and other authorities concerned with highlighting the harmful effects of drug abuse. In any case, the existence of concepts such as "chocoholic," "chocolate addiction," and more generally "food addiction," needs to be explained. In particular, these terms are potentially very revealing about an individual's relationship (attitudes, experience, etc.) with chocolate and other foods, even if she or he is not seriously affected by that relationship.

Historically, and more recently, the concept of addiction has undergone considerable revision. This has occurred in the light of new scientific knowledge and due to political and social pressures (1,75). Although current definitions or criteria for drug addiction differ, in some cases quite substantially, almost all emphasize compulsion or loss of control and the discomfort of drug withdrawal, with positive psychoactive effects, and harm caused to health and personal social and economic functioning, as further important factors [e.g., (1,2,38,40,43,55,59,80,102,113)]. For example, a major recent review of the biological and psychosocial bases of drug addiction used to following definitions [(2), p. 287]: "*Addiction* is restricted to the extreme or psychopathological state where control over drug use is lost. *Dependence* refers to the state of needing a drug or drugs to function within normal limits; it is often associated with tolerance and withdrawal (symptoms), and with addiction as defined above. *Tolerance, sensitization, withdrawal* and *craving* are phenomena that may accompany dependence."

In turn, tolerance, sensitization, and withdrawal are due to "neuroadaptive" effects induced by the drug, although associative learning processes play a significant role as well. Tolerance is decreased sensitivity to a drug that comes from its repeated use, so that the drug user must take larger and larger amounts of the drug for it to be effective. Repeated use can also result in increased sensitivity to the drug, or sensitization. Withdrawal symptoms can occur when drugs use ceases, and they are primarily the opposite of the effects of the drug itself. Withdrawal from heroin produces dysphoria, agitation, nausea, and cramping. Avoidance of withdrawal can be an important motive for continued drug use; however, the capacity of psychoactive drugs to produce positive or pleasurable effects is also an important determinant of addiction risk (39).

Some authors have argued, though, that these biological consequences of drug use provide an insufficient explanation of addiction. For example, Heather (43) summarizes the view that addiction is best defined by repeated failures to refrain from drug use despite prior resolutions to do so. This is consistent with the original, pre-19th century meaning of addiction, which was "given over" to something [addicted = devoted, wholly given over to (21)], and sees decision making, ambivalence, and conflict as central features of the addict's behavior and experience [see also (75)]. It potentially broadens addiction to include behaviors not involving the ingestion of a substance, as well as to the consumption of substances having mild biological effects.

From the preceding discussion it is clear that there is a fair degree of consensus as to what addiction is. However, it is equally clear that there is a lack of agreement as to what substances (and activities) are "addictive," so, for example, claims that caffeine, nicotine, and cocaine are addictive have all been disputed (1,53,55,79,80,102,113,117). At least part of the problem here is that there is a tendency to treat addiction and addictiveness as all or nothing phenomena, which they are not. Individuals vary in their vulnerability to addiction due to factors such as socioeconomic circumstances and inherited traits [e.g., there is evidence of genetically determined predisposition to alcoholism (18)], and substances vary in their addictive potential according to their capacity to produce, as outlined above, positive psychoactive effects and neuroadaptive changes that occur with continued substance use (including, tolerance and withdrawal effects). Accordingly, the next section reviews evidence concerning possible psychoactive and other effects of eating, and especially the consumption of chocolate and chocolate constituents, which bear on this question of addictive potential.

PSYCHOACTIVE (MOOD) EFFECTS OF EATING: IMPLICATIONS FOR FOOD "ADDICTION"

Chocolate and Mood

It appears to be widely believed that an important motive for eating chocolate is to improve mood. Consistent with this is evidence from scientific studies showing that the consumption of chocolate does indeed significantly influence mood, generally leading to an increase in pleasant feelings and a reduction in tension, although increased "guilt" may be a penalty for some individuals [e.g., (7,49,51,52,65)]. Also, self-reported appetite and craving for various foods, including chocolate and other confectionery, have often been found to be associated with negative moods, including boredom, tension, anger, depression, and tiredness (7,52,87,97,98).

On their own, these observations do not make a strong case for the addictiveness of chocolate, because positive shifts in mood may occur merely because eating chocolate, or for that matter any liked food, is pleasurable. What is needed is an understanding of the mechanisms underlying such effects and the extent to which they can lead to pathological changes in behavior and a loss of control over eating. It is obvious that very many people eat chocolate regularly without leading to this outcome; however, a variety of ideas have been put forward to explain why chocolate and certain other foods might have a relatively high addictive potential.

Possible Psychoactive Constituents of Chocolate

A common argument found in the popular media is that chocolate "addiction" can be explained by the presence of

psychoactive or mood-altering compounds in cocoa-containing products. This idea was recently given renewed impetus by a widely publicized report published in *Nature* (28) claiming to find "brain cannabinoids in chocolate." We have examined these speculations in the light of what is known about the concentrations of potentially psychoactive compounds in the products that are most widely eaten, and their likely effects on the brain when administered orally, and have concluded, as have other serious reviewers (36,67,70,94,106), that such constituents play little or no role in chocolate "addiction" and craving, or indeed in influencing appetite or liking for chocolate. For example, although chocolate can contain relatively high concentrations of theobromine, this is a relatively weak central nervous system stimulant and does not have strong subjective effects (74). The related methylxanthine, caffeine, is also found in chocolate, but in much lower concentrations. Compared with coffee and tea, chocolate is an insignificant source of dietary caffeine (37). There also appears to be a lack of any generally significant relationship between reported chocolate craving and the liking and consumption of other xanthine-containing foods and drinks (94). Other substances present in chocolate that have been discussed as potentially pharmacologically significant include phenylethylamine, tyramine, serotonin, tryptophan, and magnesium [e.g., (19,70)], but many of these compounds exist in higher concentrations in other foods with less appeal than chocolate. The same is true for certain bioactive peptides, such as casomorphins, which can act as opioid agonists and occur in a variety of food sources, for example, milk and gluten (35,73).

Di Tomaso et al. (28) identified anandamide in chocolate and cocoa powder, but not in white chocolate or coffee. This suggests that the presence of this endogenous cannabinoid (26) is relatively unique to cocoa products [but see (27)]. However, the conclusion that these findings "point to an unexpected link between non-drug craving and the endogenous cannabinoid system" [(28), p. 678] seems unjustified, given the extremely low concentrations that were detected. Even with generous assumptions, including assuming a potency of orally consumed anandamide equal to Δ^9-THC, the most psychoactively potent plant-derived cannabinoid, our calculations show that a 70-kg person would need to eat about 25 kg of chocolate to ingest sufficient anandamide to achieve a noticeable "high." This conclusion is supported by results showing that amounts of anandamide several orders of magnitude higher than those present in cocoa products are required to produce significant cannabimimetic behavioral effects in mice (27). [A more detailed version of this review of some of the potentially psychoactive minor constituents of cocoa-containing products and other foods is available from the authors (e-mail: Henk.Smit@bristol.ac.uk)].

A further crucial issue here, and one that is usually overlooked, is that identifying a compound in a food is only a first step towards demonstrating that this can have psychoactive effects as consumed in everyday life, and that, in turn, these effects play a role in influencing consumption of the food. Recent research on caffeine has demonstrated significant preference-reinforcing effects, at least at the levels of caffeine found in coffee and tea (91,134), but this method has not yet been applied widely in the investigation of other psychopharmacologically active constituents of foods and drinks. Furthermore, it is perhaps significant that, while regular caffeine consumers do become mildly dependent on caffeine [withdrawal results in headache and fatigue (88)], people tend not to describe cravings for caffeine-containing drinks. We argue that this is because the urge to consume, for example, tea or coffee is rarely resisted (see below). In fact, even when caffeine intake is reduced due to changes in daily routines, such as occurs at weekends, the "need" for caffeine is often not recognized (88).

Of course, this review of the psychoactive effects of various minor constituents of chocolate is not exhaustive; nor realistically could it ever be, because there will always be potentially potent substances contained in chocolate that are undiscovered. Also, we have not discussed the possibility that interactions between two or more constituents will produce effects not predicted from their individual actions [see, e.g., (6)]. A different approach to this problem is to directly test the mood and psychostimulant effects of, for example, cocoa powder in double-blind, placebo-controlled studies. Results from such a project showed small, but significant alerting effects of cocoa powder at a dose level equivalent to a typical serving of dark chocolate (100). A full report on these studies is currently in preparation.

The only relevant study published to date on this subject took a less direct approach. Michener and Rozin (70) provided chocolate "cravers" (individuals who reported having a craving for chocolate at least once per week) with sealed boxes containing either a milk chocolate bar, a bar of white chocolate, capsules containing cocoa (and, therefore, many of the presumed psychoactive ingredients of chocolate), placebo capsules, white chocolate plus cocoa capsules, or nothing. The subjects consumed, in random order, the contents of one of these boxes when they experienced a craving for chocolate, and just before, just after, and 90 min after doing this they rated the intensity of their craving. The results showed that only consumption of chocolate itself, either white or milk chocolate, substantially reduced the craving, suggesting that there is "no role for pharmacological effects in the satisfaction of chocolate craving" [(70), p. 419].

Finally, another observation is that the most widely consumed chocolate is milk chocolate and chocolate-covered confectionery (5). This is also true for self-reported chocolate "addicts" (49). Compared with dark chocolate, these contain a lower amount of cocoa solids, and therefore, a lower concentration of many of the potentially psychoactive compounds unique to chocolate. It is far more plausible to suggest, therefore, that liking for chocolate, and its effects on mood, are due mainly to its principal constituents sugar and fat and their related orosensory effects (67,70,84,100).

Serotonin, Mood, and "Craving" for Carbohydrates

"The carbohydrate cravers were significantly less depressed after snacking, whereas noncravers experienced fatigue and sleepiness. These findings suggest that carbohydrate cravers may eat snacks high in carbohydrates in order to restore flagging vitality, much as some people will pour another cup of coffee when they feel that their energy level or attention span is flagging" [(131), p. 53].

This quote relates to the development of a theory concerning dietary influences on mood based on the suggestion that the balance of protein and carbohydrate consumed in a meal can affect brain serotonin neurotransmission (130). One prediction from this theory is that meals high in protein will increase alertness. A second is that carbohydrate-rich snacks and meals will relieve depressed mood, especially as occurs in "carbohydrate-craving obesity" (CCO), premenstrual syndrome (PMS), and seasonal affective disorder (SAD), which it is argued are characterized by depressed mood and a craving for and increased intake of high-carbohydrate foods (131).

Together with evidence implicating altered serotonergic function in the aetiology of depression [e.g., (66,72)], this has led to the suggestion that the increase in carbohydrate intake constitutes self-medication to relieve the depression. In the case of CCO, the sustained increase in carbohydrate and fat intake causes obesity (although, as discussed below, many "craved" high-carbohydrate foods are also high in fat, fat is claimed to have a neutral effect on serotonergic function). In other words, CCO is "a disease of mood, in which appetite control is sacrificed to affective state" [(132), p. 152].

Like the claims relating to psychoactive constituents of chocolate, this proposed link between serotonin, mood and "craving" for carbohydrates (or even carbohydrate "addiction") has become part of the folklore of the psychology of eating; however, the actual evidence for such a link is weak and contradictory. We have reviewed this evidence in detail elsewhere [(68,85), see also (42,135)], and crucially, it appears that the variations in protein and carbohydrate intake achieved by eating real foods actually have very little effect on brain serotonergic function. Furthermore, even extreme "dietary" manipulations of tryptophan availability produce physiological changes that are too slow to account for mood effects occurring during and soon after eating (136). There is also a fundamental problem concerning the use of the term carbohydrate "craving" in the studies of CCO, PMS, and SAD, because it was defined primarily on the basis of the frequent consumption of snacks high in carbohydrate and fat, but low in protein. For example, in a study by Wurtman et al. (129) the carbohydrate cravers ate on average seven such snacks per day. In the same study there was also a smaller number of obese "noncarbohydrate cravers" who acted as a control group. They had a similar frequency of snacking, divided about equally between high-protein and high-carbohydrate snacks. The question is whether craving is the appropriate term to describe the CCO subjects' behavior, because no information was provided about their subjective experience of appetite for high-carbohydrate foods, or how this experience contrasted with that of the obese noncarbohydrate cravers, whose actual eating behavior did not differ very much from the so-called carbohydrate cravers.

Sugar, Fat, and Endogenous Opioids

The existence of carbohydrate craving has also been challenged on the grounds that high fat content is itself an essential feature of frequently craved foods [(31), see also (29,48,51,115)]. Craving for foods high in fat and/or (sweet) carbohydrate has, moreover, been linked with activity of the endogenous opioid system rather than serotonergic mediation (29). Thus, Drewnowski (29) has argued that overeating and reported cravings for such foods may share a common mechanism with opiate drug addition. Similarly, Blass (10) suggested earlier that consumption of sweet and other palatable foods may be motivated in part by their capacity to relieve stress. These ideas are supported by results indicating that opioids are released in response to the ingestion of sweet and other palatable foods (11,34), and the finding that the opioid antagonist drug naloxone is highly effective in reducing food intake in binge eaters, due largely to an effect on the consumption of sweet, high-fat foods such as chocolate and biscuits (30). It is also claimed that opioid antagonists suppress stress-induced overeating (34).

There is good evidence that endogenous opioid peptides are involved in mediating hedonic responses during eating (58). However, whether or not an exaggeration of activity of these same systems is implicated in the development of food craving, compulsive eating, or obesity (69) is less certain. Compared with opioid agonist drugs, food consumption has relatively weak effects on endogenous systems. An alternative view of what makes palatable, sweet, high-fat foods such as chocolate, cakes, ice-cream, and biscuits special, is the role these foods are perceived to have in the diet (84). We discuss this in detail below.

Menstrual Cycle-Related Food Cravings

Reports of food cravings increase during the premenstrual phase of the menstrual cycle and during pregnancy, and craving for chocolate can show particularly marked fluctuations across the menstrual cycle [e.g., (94)]. One idea, as discussed above, is that altered nutrient intakes may act to ameliorate the negative shift in mood that is experienced during the premenstrual phase by at least a significant proportion of women (131). Currently, however, there is no clear consensus concerning the interrelationships between mood and eating during the menstrual cycle. Some researchers have concluded that menstrual cycle effects on mood and eating occur largely independently [e.g., (4,20)]. These studies, however, relied on daily ratings of mood and behavior, and therefore, may have lacked sufficient resolution to detect the subtle mood changes that are associated with individual eating episodes (25,52).

Perhaps the most consistent finding is that energy intake is relatively higher during the premenstrual phase, although the exact timing and size of this increase differs considerably between studies [reviewed in (16,57)]. In her careful analysis, Jas (57) found for women not using the contraceptive pill that the most striking variation in energy intake was a fall during the follicular (i.e., preovulatory) phase. In contrast, for a group of PMS sufferers, intake peaked during the premenstrual phase. In these women, premenstrual increases in energy intake were found to be due predominantly to increases in fat intake, accompanied by increases in preference for high-fat as well as high-carbohydrate foods [see also (50)]. Other studies, with women not diagnosed as suffering from PMS, indicated that chocolate is a frequently craved food during the premenstrual phase (94,111), and again, that increases in fat intake accounted for the premenstrual increases in energy intake (105). On the other hand, non-PMS sufferers showed no evidence of cyclic changes in intake of fat vs. carbohydrate vs. protein (57). Furthermore, in these same studies, although the women reported that they often craved chocolate premenstrually, they did not eat more chocolate at this time (57).

From the discussion above it is apparent that the relationships between food preference, mood, and the menstrual cycle are not well understood. Ovarian hormones may exert a direct action on appetite and food intake, but it is unlikely that this alone can fully explain either the cyclic fluctuations in total energy intake or the more variable changes in food choice (16,57,63). Other explanations include the possibility that altered food choices function to alleviate negative mood states, not via a nutritional–physiological mechanism (131), but through the hedonic effects accompanying eating. In other words, consumption of pleasant-tasting foods might provide at least temporary escape from deteriorated mood. Negative mood might also be implicated as a factor precipitating a loss of motivation to limit food intake and avoid certain "forbidden" foods viewed as fattening or "diet breaking." In laboratory studies, induction of negative mood has been reported to trigger overeating in dieters and highly restrained

eaters (45,95). Furthermore, because dieting itself is a source of stress (46), it is possible that premenstrual changes in mood are exacerbated in dieters. As far as we are aware, however, there have been only two studies that have attempted to examine the interaction between menstrual cycle effects and dietary restraint, neither of which found support for this hypothesis (20,57).

Another underresearched issue concerns the role of individual expectations and attributions in influencing mood and behavior in relation to the menstrual cycle. Ussher (114), for example, has pointed out that there is great variability in mood changes associated with the premenstrual phase, with some women reporting predominantly negative moods, including tension and anxiety, irritability, and depression, but other women reporting improved mood, in particular, increased feelings of "energy." Ussher argues that underlying these different experiences is a premenstrual increase in arousal or activation [see also (107)], which can be interpreted by individual women in different ways. Furthermore, it appears that negative mood changes are more likely to be attributed to biological factors, whereas positive moods are likely to be attributed to personality or situational factors (114). Similarly, the premenstrual state might also be used as an attribution (personal explanation or "excuse") for the relaxation of dietary restraint.

Bulimia and Compulsive Eating

The primary symptom of bulimia or bulimia nervosa is binge eating, that is, the "rapid consumption of a large amount of food in a discrete period of time" accompanied by the feeling that the eating is "out of control" (3). Typically, extremely large amounts of food (>12.5 MJ (>3,000 kcal)) are consumed during bulimic episodes, with most items being palatable, energy dense, high-fat, high-carbohydrate foods [e.g., (48,71,115)]. Bingeing is also usually followed by purging, for example, self-induced vomiting, abuse of laxatives, and/or compulsive exercise, which is aimed at avoiding weight gain. The highest incidence of bulimia occurs in young women, and a majority of these women with bulimia are of normal weight. Similar recurrent episodes of binge eating associated with feelings of lack of control and distress occur in binge-eating disorder, but without the regular use of compensatory behavior such as self-induced vomiting (3).

Bulimia often begins during a time of personal stress. In addition, many reports indicate that it is very common for actual bulimic episodes to be preceded by dysphoric mood states, and that mood is improved during bingeing [e.g., (22,48,71)]. For example, Cooper and Bowskill (20) found a strong association between deterioration of mood and the onset of self-reported episodes of overeating in patients with bulimia, and also in women students who were highly restrained eaters and were on a diet. This relationship was much weaker in nondieting highly restrained eaters. These observations have led to the suggestion that bingeing is negatively reinforced by the temporary emotional relief provided by eating [e.g., (71)].

However, whether or not such a mechanism does operate in bulimia and other examples of mood- and stress-associated eating, on its own this would seem to be insufficient to account for the very intense and excessive character of bulimic eating behavior. Furthermore, after bingeing, bulimics frequently experience a rapid deterioration in mood, including guilt, self-disgust, fear of weight gain, and depression. Purging, in turn, can reduce these negative emotional states [thus, purging may also be negatively reinforced (71)]. It is also difficult to establish the exact causal relationships between the different features of the psychopathology of bulimia. For example, some authors have suggested that the overeating and depression, as well as other symptoms that coincide with bulimia such as substance abuse and impulsive behavior, share a common pathology (altered brain serotonergic function), but that they are not necessarily functionally interdependent (93,124). Various approaches have been taken in the search for explanations and treatments for bulimia, and increasingly, these have made connections with the mood (affective) disorders. Mood and overeating are closely associated in bulimia, but the development and maintenance of bulimic behavior will depend on a complex network of influences, including primary etiological factors and the biological and learned effects of bingeing and purging (14).

In several ways, the binge eating described above has features that can reasonably allow it to be labelled as "food addiction" [see also (38)]. It is a severe psychopathological state in which control over eating is lost, and it causes harm to the individual who typically attempts unsuccessfully to refrain from the behavior. Binge eating also alters mood, perhaps mainly by providing escape from distress, even if only temporarily. In part, this distress may be caused by the aftermath of a previous binge episode and associated low self-esteem. Finally, a variety of physiological adaptations are likely to be important in the binge eater's capacity to accommodate or "tolerate" the very large meals [cf. (127)].

FOOD CRAVING, FOOD "ADDICTION," AND MOREISHNESS: A BIOPSYCHOSOCIAL HYPOTHESIS

Most of the preceding discussion has considered potential biological bases of food cravings, food "addiction," and mood effects of eating. However, we also noted that dieting and attitudes towards food and eating appear to play a critical role in influencing relationships between mood and eating, for example, across the menstrual cycle and during bulimic bingeing and purging. Below, we develop this idea further by making the case that food craving and self-reported food addiction are best understood in terms of cognitive influences on eating. Specifically, we suggest that it is ambivalence about certain foods that leads to attempts to resist eating them and the need to provide an explanation (e.g., in terms of "addiction" or "chocoholism") of why this is difficult and sometimes fails. This does not mean that we regard biological effects of eating as unimportant, but merely that these form only part of the determinants of human eating behavior and the experiences accompanying eating. Indeed, the nature of the basic mechanisms underlying appetite and weight control forms a key part of our argument.

Biological and Learned Influences on Appetite

Biological perspectives on eating behavior often assume that appetite and food choice is controlled by physiological mechanisms that serve to maintain steady states of energy and nutrient balances (homeostasis). However, evidence from a wide variety of sources fits better with the idea that the appetite control system is actually fairly permissive in its response to overeating and undereating, because it originally evolved to solve the problem of unevenness of food supply across time (42,68,83). In other words, eating motivation is not regulated according to a simple cycle of depletion and repletion. At the very least it is also necessary to consider the motivational effects of the presence of food and the quality or palatability of that food and the effort required to obtain it,

which additionally influence the decision to eat and how much is eaten [e.g., (110)].

"Depletion" is, nevertheless, an important stimulus for meal initiation. This is demonstrated, for example, by observations on the relationships between meal size and intermeal interval, which can be accounted for very well by models based on estimates of stomach capacity and emptying rates, or energy flows from the intestines (13,24). Put another way, it can be said that the initiation of eating is increasingly likely to occur as the inhibitory effects of repletion dissipate, in which case hunger equates to the absence of satiety [cf. (103)]. Although there is perhaps no real distinction here, this avoids the use of the term "depletion of reserves" and emphasizes that a dominant influence on satiety (absence of hunger) is the amount and composition of the food consumed in the previous meal. Note that the energy economy of the whole body probably has little impact in the short term, because for adult humans depletion from one meal to the next is typically very small compared with total bodily energy reserves. The level of these reserves (body fat content) does exert an influence on appetite, but the action of this relatively weak negative feedback is only apparent over the longer term (68).

Experience strongly suggests that hunger can be aroused by external cues. For example, our appetite is stimulated by someone offering us an unexpected treat, or it can fade in the afternoon even though we were too busy to eat lunch. As well as the obvious effects of the sight and smell of food, eating can be motivated by learned contextual cues such as place and time of day. This has been confirmed experimentally in studies showing that arbitrary external stimuli previously associated with food consumption reliably stimulated eating in the absence of immediate deprivation or apparent nutritional "need" (9,120), although both the acquisition and expression of this behavior is also influenced by the individual's internal state of repletion (36,120).

A question arising from these observations concerns the specificity of the effects of external stimuli conditioned to eating. One possibility is that exposure to such stimuli triggers physiological responses in preparation for eating, including salivation, insulin release, and gastric acid secretion (the so-called cephalic phase of digestion), the consequences of which feed back to the brain where they are interpreted as an internal signal for hunger. Against this, though, is the finding that blockade of cephalic-phase responses does not disrupt the initiation of eating in response to learned cues (121). Alternatively, rather than a general state of hunger, the presentation of stimuli that have become associated with consumption of a food may elicit a desire to eat that specific food (122). An analogy for this question is to consider visiting the cinema where in the past you have usually eaten popcorn. What is the effect of exposure to this eating-related setting? Does it trigger a general feeling of hunger, or a specific desire to eat popcorn? Recent results from studies on rats do indeed suggest that eating-related stimuli have specific effects on food choice [(23), see also (109)].

Another issue, which is of particular interest here, concerns the possibility that specific appetites might also become conditioned to salient internal stimuli, for example, accompanying particular emotional states. Actually, this would probably involve associations formed between eating and a configuration of both internal and external stimuli evoking the emotional response (15,78,119). Such a mechanism might underlie mood- and stress-induced eating, and in turn, would help explain effects of mood on eating at an individual level, because these relationships would be shaped according to a person's own unique learning history. Furthermore, if specific appetites are based on learned associations then presumably they can be unlearned (i.e., extinguished), for instance, through unreinforced exposure to the context in which the appetite or "craving" is experienced. This technique of "cue exposure" has shown some success in the treatment of binge eating in bulimia nervosa (56).

During a meal, eating is controlled moment to moment predominantly by the oro-sensory and postingestive effects of the food consumed. These influences can be modelled as positive and negative feedbacks, respectively; the overall contribution of the effects in the mouth usually being stimulatory, while the net effect of the entry of food into the stomach and intestines being inhibitory (12,68,83,101). The positive feedback is the stimulation of eating by eating, and its strength is influenced by food palatability [e.g., (133)], which is defined as the individual's hedonic or affective response to the taste, flavor, texture, etc., of a food or drink (82). Palatability, in turn, is determined both by innate responses (e.g., there is an inborn liking for sweet tastes and dislike of bitter tastes) and learning (68,99). Underlying the operation of negative feedback during the meal are pre- and, to a lesser extent, postabsorptive effects of food including filling of the gastrointestinal tract, release of regulatory hormones such as cholecystokinin, insulin, and glucagon, and the detection of nutrients absorbed into the systemic circulation [e.g., (33)].

If it assumed that the orosensory effects of eating operate maximally almost as soon as eating starts, and are maintained more or less at the same level throughout the meal, and that the postingestive effects increase only gradually with the amount eaten, these influences can be combined to produce an S-shaped cumulative intake curve (68,83,101) similar to that observed in studies of the microstructure of human eating (125). Eating finally stops when the negative postingestive effects outweigh the positive orosensory effects.

Dietary Restraint and the Cognitive Control of Eating

Against the background of imprecise physiological control of energy intake in relation to expenditure, there has been a recognition of the critical role played by dieting and dietary restraint in influencing human eating behavior. Weight loss or the avoidance of weight gain can be achieved through the deliberate control of food intake. Indeed, an individual's preferred weight, shape, waist size, etc. (derived from cultural norms) can be viewed as a "cognitive set point" (13). Deviations from this set point are detected when the individual notices, for example, a change in the fit of their clothes or an increase in measured weight, causing her or him to try to eat less in an attempt to eventually restore weight to the desired level. However, dieting can sometimes undermine successful eating control.

This was first shown in studies carried out during the 1970s [reviewed in (45,96)]. Classifying individuals according to their degree of dietary restraint measured by the Revised Restraint Scale (RRS) was found to predict a very striking phenomenon: highly restrained individuals ate more instead of less following a food preload (the preload was a fixed amount of food that subjects were required to eat as part of their participation in the experiment). This counterregulatory behavior was interpreted in terms of a process of disinhibition. The preload, by forcing the perceived intake of calories above a critical threshold or "diet boundary," supposedly causes normally restrained eaters to suspend their self-imposed restraint, thereby releasing their underlying desire to eat. Other

disinhibitors of eating in restrained eaters have also been identified, including emotional events, the consumption of alcohol, the behavior of others, and even anticipated overeating later in the same day. Partly on the basis of these results it was argued that restrained eating plays a direct role in the aetiology of binge eating and bulimia nervosa (77).

Subsequent psychometric analysis of the questions making up the RRS has shown that these measure principally "concern with dieting" and "weight fluctuation" (118). In later research two other questionnaires, the Three-Factor Eating Questionnaire [TFEQ, (104)] and the Dutch Eating Behavior Questionnaire [DEBQ, (116)], were developed with items that relate more directly to restrained eating and the conscious restriction of food intake. Crucially, individuals scoring high on the TFEQ and DEBQ were found to be relatively less susceptible to disinhibited eating, leading to the suggestion that the RRS tends to identify unsuccessful dieters, whereas the TFEQ and DEBQ restraint scales identify more successful dieters, or at least a mixture of some successful and some unsuccessful dieters (44,64,68). An explanation for this predictability of successful vs. unsuccessful dietary control is that these outcomes are due to certain self-perpetuating patterns of eating behavior (68). Thus, hunger tends to be diminished during strict, unbroken dieting, but increased in individuals having a highly variable eating pattern, for example, as occurs when eating is frequently disinhibited (47,61,68).

Ambivalence and Affect

When the terms "craving" and "addiction" are used, the existence of certain underlying biological mechanisms that support addictions is usually also implied. But, as suggested above, addiction is not defined by these effects alone, so that, for example, problem drug use cannot be explained without reference to individual and social perceptions of the behavior, and attempts to refrain from it [e.g., (43)]. In the case of reported craving and addiction for chocolate and other similar foods, these perceptions and their consequences may be particularly critical.

Earlier in our discussion of the cue control of eating we argued that the experience of the desire to eat specific foods in particular contexts or in relation to particular feelings can be regarded as a feature of normal appetite (rather than being indicative of eating pathology). One of the questions that this then raises is exactly what experiences are regarded as food cravings. The desire to eat cereal at breakfast and the desire to eat chocolate when relaxing and watching television in the evening may both be examples of learned specific appetites. However, very few people are likely to label the desire to eat cereal as a food craving (unless perhaps this occurred in the evening, which culturally is a less appropriate time for eating breakfast cereal).

This suggests that attitudes to food and eating play a fundamental role in the experience of food craving. Chocolate is a highly palatable food typically consumed in addition to main meals, and valued as a treat and a reward more than for its dietary value. Thus, chocolate is not regarded as a staple food, and indeed, its nutritional content (high sugar, fat, and energy content) is often viewed negatively—as the penalty for indulging in the enjoyment of the sensory pleasure it evokes (i.e., "nice but naughty"). In other words, chocolate is a highly desirable food, but which, according to social norms, should be eaten with restraint (54,84). However, attempting to resist the desire to eat chocolate only causes this desire to become more prominent (salient), and in turn, the experience is labelled as craving, rather than say hunger, because of the attitude that chocolate is an indulgence.

In several respects this is similar to Tiffany's (108,109) account of drug craving in which he proposes that drug use is largely controlled by automatic processes and involves no noticeable urges or cravings, except when drug use is prevented or *resisted*. Drug use is viewed as the performance of a series of cognitive and motor tasks that, with repeated practice, become increasingly effortless, efficient, and stimulus bound (i.e., triggered by external cues), and that are carried out with little or no awareness. However, attempts to resist drug use cause the activation of nonautomatic processing, along with accompanying behavioral and emotional responses, including reports of cravings and urges to eat. In other words, Tiffany argues that the processes controlling cravings and urges are largely separate from the immediate cause of drug use. [Actually, this view of craving perhaps applies better to some types of habitual substance "use," including smoking and eating (86), than to others such as heroin abuse, where more effort is required to obtain supplies of the substance.]

The conflict or ambivalence experienced when eating chocolate and other "treat" foods, such as cakes, biscuits and also savory "snack" foods, is confirmed by a number of results. For instance, in an investigation of the relationship between dieting and food craving, subjects kept detailed diaries of their food intake, hunger, mood, and food cravings (52). Chocolate was specified as the craved food on nearly 60% of all occasions on which a craving was noted. Furthermore, dysphoric mood often the preceded occurrences of craving, and for the subjects who invariably acted on their craving (i.e., ate the craved food) there was a positive shift in mood after eating, for example, toward feeling calm and relaxed. Significantly, however, subjects who attempted to resist their cravings tended to report a negative shift in mood after eating the craved food.

Ambivalent responses to chocolate are also indicated by results from a study in which "chocoholics" were presented with chocolate to smell and taste in a brief laboratory test [(87), see Figure 9.1 in (68)]. The chocoholics were "self-diagnosed," being recruited through a newspaper advertisement that began simply "Are you a chocoholic?" Compared to a group of age- and sex-matched controls, the chocoholics showed a greater liking for and desire to eat chocolate, but a smaller increase in salivation when exposed to chocolate. This is in contrast to the usual finding of a positive relationship between food-induced salivation and hunger (desire to eat) and food palatability (128), but is similar to other findings that suggest that confronting dieters with palatable, "diet-prohibited" foods can provoke anxiety that, in turn, inhibits their salivary output (89,92). In other words. these results are consistent with the possibility that for chocoholics, chocolate is a source of both pleasure and anxiety.

In another study, men and women rated the "appropriateness" of 50 foods and beverages on 50 attributes or uses (P. J. Rogers & H. G. Schutz, unpublished). Among these attributes/uses were, "when I am unhappy," "when I want something I really like," "when I want something nutritious," and "a food difficult to resist." Chocolate ranked highest on the attribute "difficult to resist," although it ranked only 17th in terms of frequency of consumption. Foods that were scored high on "difficult to resist" were also highly liked, and they were rated as appropriate for the mood "when I am unhappy," indicating, presumably, that eating these foods can improve mood. However, there was a low correlation between "difficult to resist" and perceived nutritional value, with chocolate ranked 39th out of 50 on the use "when I want

something nutritious." This again demonstrates the existence of ambivalent attitudes toward such foods.

Additionally, eating a food to alter mood (affect) rather than to remove hunger may itself be a source of conflict—this is perceived as an inappropriate use of a food, leading to concerns about lack of self-control and self-efficacy. It is noteworthy that in this study on food appropriateness, tea and coffee were not rated highly on the attribute "difficult to resist" (rank orders 18th and 25th, respectively), but these were the most frequently consumed items. Therefore, there would appear to relatively little ambivalence associated with tea and coffee drinking. Indeed, their use as a source of pharmacological stimulation is openly acknowledged and regarded as acceptable. In contrast to drinking tea and coffee, eating chocolate has many negative connotations. In particular, chocolate may be *perceived* as an unhealthy food, lacking in nutritional value and is stigmatized by associations with overeating, overindulgence, and obesity.

Attribution

This leads on to a further, closely related aspect of food craving and addiction that concerns the use of these terms, or the ideas that they convey, to give a particular explanation of behavior. By saying that "I crave chocolate," or confessing that "I am a chocoholic," the individual is able to explain why she or he eats chocolate frequently and why she or he finds it difficult to resist. Attributing what is perceived as excessive consumption of chocolate, or the use of chocolate as a mood modifier, to an addiction provides a more socially (and personally) acceptable explanation for this behavior, and thereby helps to remove individual responsibility for the difficulty. On the basis of the publicly accepted model of addictions, it implies that eating chocolate is outside the person's control, and alternatively attributes the problems of control to biological effects of the food (e.g., it contains a dependence-forming substance), or possibly to an individual pathology, thus invoking a medical model (32,76).

Attributions are commonsense explanations made in an attempt to understand and sometimes to excuse personal behavior. Notions such as compulsive eating and food craving indicate an addiction model. Given the widespread salience of the concept of addiction (76), it is not surprising that this concept is applied to food-related behavior. Moreover, this attribution may provide a basis for individual action, which in turn, will help to confirm the model. For instance, the belief that abstinence is required for recovery from addiction will lead to exactly the sort of conflict described above—between the desire to eat a food and the desire to maintain (complete) restraint. Similarly, as discussed above, it has been argued that attributions are significant determinants of menstrual cycle-related changes in mood and behavior, including reports of food craving and premenstrual increases in food intake (90,114).

Relationship Between Dietary Restraint and Food Craving and Food "Addiction"

A consistent finding from studies of food cravers and self-reported chocolate "addicts" is that these individuals score only slightly, and not significantly, higher than noncravers and nonaddicts on measures of dietary restraint (36,52, 65,87,112). At first sight this appears to contradict our view that craving arises as a result of attempting to resist eating [or more generally as a result of dieting and low energy intake (52)]. However, all these studies used either the DEBQ or TEFQ to assess restraint, which tend to identify successful restrained eaters or dieters. Crucially, the eating attitudes and behavioral strategies (e.g., "If I overeat now, I know I can compensate later today or tomorrow") and the eating patterns (e.g., low eating variability) associated with high scores on the restraint scales of these questionnaires predict no very strong negative perceptions of particular foods and relatively low externally cued eating (hunger) (see above). This is in contrast to less successful dieters whose eating restraint is prone to disinhibition, showing eating patterns and eating and body-shape attitudes more similar to the bulimic profile (60), which, in fact, characterizes food cravers and chocolate "addicts." In the above studies (36,52,65,87,112) this is demonstrated by the cravers and "addicts" significantly elevated "disinhibition" and "hunger" scores on the TEFQ, high "external eating" scores on the DEBQ, and high body shape dissatisfaction. In addition, they also scored very high on the "emotional eating" scale of the DEBQ, a finding that is fully consistent with our suggestion of a link between affect-driven eating and the attribution of craving and addiction.

Moreishness

Chocolate is sometimes described as "moreish." Although this is not a very commonly used term, its meaning and the experience it describes appear to be widely understood, at least in the UK. The Collins English Dictionary (21) defines moreish as an adjective, usually applied to food, meaning "causing a desire for more." Our view is that moreishness is closely related to food craving, in terms of both subjective experience and underlying processes, the main distinction between moreishness and food craving being that moreish labels an experience that occurs during an eating episode, whereas craving is experienced during abstinence from eating. Like food craving, moreishness is usually associated with eating and attempts to refrain from eating snack and treat foods: "Lay's potato chips—nobody can eat just one" (advertising slogan from the USA for potato "crisps").

One feature of these foods is that they are highly palatable. However, although it is unlikely that a food can be moreish without being highly palatable, it is not clear that high palatability is in itself a sufficient explanation of this phenomenon. Instead, we suggest that the two essential components of moreishness are palatability and self-imposed eating restraint. This can be illustrated by considering the positive and negative feedback influences controlling appetite during a meal described earlier. According to this simple model, food intake in a meal is controlled both by positive feedback from orosensory stimulation and negative feedback, which represents the postingestive effects of food. Moreishness, in turn, is a function of the strength of positive feedback relative to the strength of negative feedback. One possibility, therefore, is that moreish foods produce weak or delayed negative feedback. However, there is no reason to believe that, for example, chocolate lacks satiating efficiency, because the high-fat and high-carbohydrate content of chocolate should produce a strong satiating effect.

A more compelling hypothesis has to do with the fact that the appropriate (i.e., socially defined) portion sizes of "treat" foods are small compared with typical meals (84). This is simply another aspect of the expectation that restraint should be shown by everyone (dieters and nondieters alike) when eating chocolate, crisps, cakes, biscuits, confectionery, etc. A typical, moderately filling meal might contain around 900 kcal. The same energy intake could be achieved by consuming three average bars (3×50 g) of milk chocolate or 14 chocolate coated

("digestive") biscuits, but this would normally be regarded as excessive. Nonetheless, intakes less than this will fail to generate strong satiety signals (negative feedback), and instead, conscious restraint is required to limit intake to a personally and socially acceptable level. In other words, in order not to exceed an "appropriate" intake, external restraint is imposed that curtails eating before physiological satiety inhibits appetite, consequently leaving the eater wanting more.

Note that, consistent with this view, feelings of satiety and fullness associated with eating chocolate are quite likely to be reported with disgust rather than satisfaction. A possible exception would be when chocolate is eaten as an energy-boosting snack. According to the present analysis, moreishness (and craving) should not be associated with this particular use of chocolate. This prediction is supported by the results of a recent study conducted by Benton et al. (7). Factor analysis of an "attitudes to chocolate questionnaire" showed that statements related to craving for chocolate loaded together with liking for chocolate and a tendency to use chocolate to improve negative mood, and separately from a factor that indicated a "functional approach" to chocolate, which included statements that chocolate was used to give energy when taking exercise or if a meal was missed.

CONCLUSIONS

This review has identified certain commonalities between eating and drug use. These include psychoactive (mood) effects, the external cue (environmental) control of appetites, and the cognitive factors of restraint, ambivalence, and attribution [see also, e.g., (38,62,126,127)]. There is also a wide overlap of the brain mechanisms underlying the rewarding effects of foods and drugs (8,80), and foods are, like drugs of abuse, strong reinforcers. However, although it may be reasonable to label the compulsive eating seen in bulimia and binge-eating disorder as food addiction [along with very rare instances of food-specific compulsions (17)], we suggest that the vast majority of cases of self-reported food "addiction," "chocoholism," and food craving should not be viewed this way. Crucially, eating does not appear to produce the powerful neuroadaptive effects, including associated withdrawal effects, which are central to drug addiction. Labelling the *perceived* overconsumption of chocolate as "chocolate addiction" [e.g., (49,112)], even if this is associated with high levels of comfort (emotional) eating and somewhat unstable eating patterns, risks trivializing serious addictions. In fact, self-reported chocolate "addicts" and chocolate "cravers" generally eat fairly moderate amounts of chocolate (36,49,65). For example, in the study recording the highest average intakes (mean of 12.5 bars per week), only 15% of the 50 chocolate "addicts" surveyed reported eating three or more bars of chocolate per day, and 17 percent reported eating less than one bar per day (49). These are not excessive intakes. On the other hand, consumption of 70 bars per week, as reported by one individual in this study (49), is very extreme, and if confirmed, would clearly represent pathological eating behavior very probably having a highly compulsive component.

Such extremes apart, our explanation of self-reported food craving and "addiction" (and moreishness) gives a prominent role to the psychological processes of ambivalence and attribution, operating together with normal mechanisms of appe-

FIG. 1. Cartoon depicting an extreme case of moreishness. (Reproduced with the permission of the author.)

tite control, the hedonic effects of certain foods, and socially and culturally determined perceptions of the appropriate intakes and uses of those foods. Several of these elements, including ambivalence, attempted eating restraint, and attribution (in this case, attribution of another's inadequate will-power) can be seen in Fig. 1, which appears to be an extreme case of moreishness, rather than an example of food addiction as the headline suggests.

SUMMARY

A popular idea is that chocolate craving and "addiction" might explained, at least in part, by the presence of psychoactive substances in cocoa-containing products. However, based on what is known about the concentrations of such substances in the products that are most widely eaten, and their probable effects on the brain when administered orally, it is concluded that there is no convincing support for these speculations. Similarly, the balance of evidence is against this and other examples of food craving and food "addiction" being linked specifically to the effects of eating on the activity of brain serotonergic or endogenous opioid systems. Primarily biologically based explanations also fail to account for premenstrual food cravings. Certain commonalities exist between eating and drug use (mood effects, external cue-control of appetites, reinforcement, etc.), but it is argued that, apart from the compulsive eating seen in bulimia and binge-eating disorder, the vast majority of cases of (self-reported) food craving and food "addiction" should not be viewed as addictive behavior. Crucially, eating does not appear to produce the powerful neuroadaptive effects, including associated withdrawal effects, which are central to drug addiction. Why then do some people claim to crave chocolate and even to be addicted to it (e.g., "chocoholics")? The answer proposed here gives a prominent role to the psychological processes of restraint, ambivalence, and attribution, operating together with normal mechanisms of appetite control, the hedonic effects of certain foods, and socially and culturally determined perceptions of the appropriate intakes and uses of those foods. Ambivalence (e.g., "nice but naughty") about chocolate arises from the attitude that while this is a highly palatable food, it is not a staple component of the diet but instead a "treat" that should be eaten with restraint. However, attempts to restrict intake only cause the desire for chocolate to become more salient, and this experience is then labelled as a craving. This, together with the need to provide a reason for why resisting eating chocolate is difficult and sometimes fails, can, in turn, lead the individual to an explanation in terms of addiction (e.g., "chocoholism"). According to this view, chocolate is the most frequently craved food because it is the food that people most often try to resist eating. In contrast to craving, moreishness ("causing a desire for more") occurs during rather than preceding an eating episode. Nevertheless, restraint is again an essential feature, because moreishness is experienced when the eater attempts to limit consumption before appetite for the food has been sated.

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