

Are food cravings in humans determined by physiological processes?

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Abstract

Ultimately, all behavioral processes, including food selection, are governed by underlying physiological mechanisms. However, this presentation examines the general hypothesis that the food selected by humans is determined by physiological or biological need states. In that context, the presentation focuses on food cravings and the degree to which they are influenced by physiological need. It is suggested that three classes of evidence, not all equally compelling, are relevant to concluding that food cravings and food selection are determined by biological need. The first, and perhaps weakest evidence, seeks to show the correlation between a particular food craving or food selection and the existence of a specific need state. The second attempts to show the extent to which induction of a particular need state elicits a specific craving or selection of a particular food. The third class of evidence examines whether ingestion of the specific food craved, or presumed related to redressing the biological need state, satisfies the craving and eliminates the need state. Studies related to these three classes of evidence are reviewed. It is concluded that the evidence that cravings or food selection are directly related to need states is equivocal.

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Introduction

The central question investigated in this paper, as requested by the organizing committee, is whether food choices in humans are determined by physiological processes. The answer to this question, of course, must be yes. A fundamental philosophical underpinning of contemporary behavioural neuroscience is biological reductionism—the idea that behavioural events, such as food selection, can be reduced to their underlying physiological mechanisms. From this viewpoint, whatever one might promote as the controller of food selection—genetics, taste, habits or culture—must ultimately be reducible to physiological mechanisms. It cannot be that the organizers of this symposium were prepared to give me such a simple question that could be answered so briefly. And, of course, they were not. The question, as posed, is often code for another issue: are food choices in humans determined by biological need? The idea that what we choose to eat is intimately related to bodily needs is a recurring theme underlying investigations of ingestive behaviour (1).

Why is an examination of food cravings relevant to determining whether food choices in humans are determined by biological need?

There are several reasons why an examination of food cravings is a useful approach to revealing whether food choices are determined by biological need. First, food choices motivated by biological need should be easiest to reveal in situations where the desire to eat is intense and is targeted to a specific food item—exactly the eating instances defined as cravings (see 2,3,4 for reviews of food cravings). Second, most individuals (especially those in food companies) are primarily interested in the determinants of food selection in the normal population. Food cravings are highly prevalent, normative eating experiences (5,6), although the percentage of the population reporting cravings depends upon the population sampled and the definition of craving used (7,8). Finally, the idea that cravings are elicited by biological need has been a dominant and persistent hypothesis (3,4). Given these perspectives, one might predict that the food craving literature would offer the best examples of food selection determined by biological need. Conversely, if need-based food selection cannot be revealed in cases of food cravings, one might be pessimistic about the utility of the general proposition.

Harvey P. Weingarten

I propose that three questions allow an evaluation of the degree to which food cravings, and hence selection, are determined by biological need. First, do food cravings correlate with the existence of need states? Second, does the induction of a need state elicit a specific, relevant food craving? Third, does elimination or reduction of the need state eliminate or reduce the food craving? Each of these questions is considered in turn.

Do food cravings correlate with the existence of biological need states?

Analysis of this question requires a definition of “need” state. The concept of a need state is inextricably linked to the principle of homeostasis, the idea that critical internal variables must be maintained within strict physiological levels for the organism to survive (9). A “need state” is presumed to exist when some biological variable falls outside its acceptable range. It is easy to know that a “need state” exists when the level of a physiological response is so deviant that, in its persistence, the organism dies. One example is the need state presumed to exist for salt after experimental treatments (adrenalectomy or high dose diuretics) or adrenal (Addison's) disease, which deplete salt. Other examples are the need states presumed to exist for calories when glucose levels (or levels of glucose utilization) are driven pathologically low because of drugs or disease and for specific vitamins or micronutrients after chronic exposure to diets deficient in these items.

While the assumption that the body has “need” in these extreme cases appears reasonable, we must acknowledge that these obvious instances of need are rare. Most of those interested in the relationship between “need” and eating have more normative conditions in mind. But it is precisely in the more common cases, such as those considered in the food craving literature, where the concept of a “need state” gets quite fuzzy. Does dieting, restrained eating, or restriction of carbohydrate intake induce a “need” state? What “need state” erupts at specific points of the menstrual cycle? What is the need state associated with abstaining from chocolate? This is the first significant conceptual difficulty in the evaluation of any hypothesis that purports to link any aspect of ingestive behaviour to biological need—one rarely finds an articulation of the “need” state that is presumed to exist. A need state is assumed, but almost never documented.

This considerable conceptual difficulty notwithstanding, the idea that cravings are associated with need states is ubiquitous. Perhaps its earliest promoter was Richter (10,11), who championed the general idea that behavioural responses were part of the normal repertoire for maintaining homeostasis. He described cases of salt craving associated with Addison's Disease, chalk or plaster cravings in those with parathyroid deficiency and even cravings for liver in cases of anemia. It is significant, perhaps, that Richter said patients did not associate their cravings with the needed substance; it was just that foods with the presumably needed substances became quite palatable. So, even if a "wisdom of the body" was stimulating the craving, this association was not conscious or cognitively accessible.

Even if we concede that the descriptions of patient populations by Richter indicate an association between food cravings and biological need, we must also concede that such instances are rare and, perhaps, restricted to severely pathological states. For completeness, however, the robustness of even these observations has been questioned (see 12,13). In fact, it is the minority of patients with Addison's Disease who report salt cravings (14). It may be that specific appetites, and by extension cravings, elicited by biological need may only be apparent under defined situations (13).

The literature examining the correlation between dieting (or dietary restraint) and the incidence of food cravings is presented as relevant to the role of need in cravings. The logic is as follows: dieting represents caloric restriction that induces a need for calories. If cravings reflect need, then cravings should increase in cases of caloric restriction. The results of studies examining this correlation are equivocal. A minority of the studies report an association between dieting or restrained eating with increased cravings (15,16). The majority have failed to find such a correlation (5,6,17,18,19,20). In fact, subjects reporting higher levels of food craving are more likely to eat more calories daily than are those with fewer reports (19).

It is hard to imagine a more profound disturbance of energy balance in humans than anorexia nervosa. In fact, it is a clinical condition in which it is easy to imagine that subjects are in a state of biological need. Gendall et al. (21) compared food-craving reports in subjects with a previous diagnosis of anorexia nervosa (cases) to controls. The proportion of cases and controls reporting food cravings was not statistically different, although cases tended to have fewer experiences. These observations are inconsistent with the interpretation that need resulting from

Harvey P. Weingarten

severe caloric restriction or reduced body weight determines cravings. It is true that the cases in this study were “recovered” anorexics. Nevertheless, they exhibited lower current body mass indices and were more likely to have dieted.

If craving is a homeostatic response to combat caloric deprivation, one might predict that the food items most craved during food restriction would be high in fat, the densest source of calories. In fact, items high in fat and sweet-fat mixtures are the most frequently reported cravings (3,6). While this observation is consistent with a need-based origin of cravings, it escapes no one’s attention that craved foods are also the most hedonically pleasing. It seems reasonable to crave highly palatable foods, while broccoli cravings seem nonintuitive. More to the point, though, even in those studies that report increased cravings with dieting, there is no influence of restricted caloric intake on the type of food craved (16). Similarly, although the frequency of reported food cravings varies across the menstrual cycle, it does not appear that there is any systematic variation in the frequency of craving or the type of food craved to suggest that cravings are associated systematically with biological needs (8,13,22).

Some have suggested that diet monotony (lack of sensory variation of food intake)—a frequent correlate of dieting—is a better predictor of increased food cravings than dieting. It is unclear what biological need is induced by diet monotony; if any need state exists it is related to sensory, not homeostatic, requirements. In one study, Pelchat and Schaefer (24), the frequency of food cravings in an unrestricted feeding period was compared with their frequency in a feeding period in which subjects consumed an equivalent caloric intake but were restricted to ingestion of a monotonous vanilla beverage. Younger (but not older) subjects had increased reports of cravings during diet monotony, even though the level of caloric intake, and therefore biological state, during the period of diet monotony was equal to that during unrestricted eating. Yet, the dominance and tenacity of a homeostatic view of cravings is so apparent that even when the authors of the above paper demonstrate a clear dissociation between need and cravings, they maintain a homeostatic interpretation of the finding. Specifically, they suggest that “the cravings shown by these young adults in this study could be seen as a type of anticipatory homeostatic response to a diet that, by virtue of its lack of variability, is potentially nutritionally inadequate” (24, p. 358).

The data above also demonstrate that need is not essential for sweet cravings, as there were no differences in caloric load during the monotonous and varied feeding periods, yet changes in reported cravings were noted. This finding, that a need state is not required for cravings, is corroborated by the classic study of the effects of semi-starvation by Keys et al. (25). They reported an increase in many types of cravings during chronic caloric restriction, including salt cravings, even though the diet regimen did not result in salt depletion.

Does the induction of a need state elicit a specific, relevant food craving?

There does not appear to be a strong relationship between need and increased food cravings. But, even if compelling data did exist, these observations are merely correlational and, therefore, would not be strong evidence of a causal link. So, a more direct test of the question of whether biological need determines food choices must be a true experiment in which the degree of need state is manipulated and the consequent effects on craving observed.

In one such study, Harvey et al. (18) compared craving reports in obese, Type II diabetic subjects who were placed for over 20 weeks on either a 1000–1200 kcal/day or a 400 kcal/day diet. Overall, maintenance of these diets, and the consequent weight losses, resulted in a decrease in cravings, extending to all types of food craved. Furthermore, the reduction of cravings was greatest in subjects experiencing the greatest caloric restriction. The findings that dieting leads to decreased reports of craving and that the reduction is directly proportional to the amount of calorie restriction have been reported by others (20). These findings—that the imposition of caloric restriction decreases rather than increases cravings—are counter to the suggestion that needs determine cravings and food selection.

Hubert et al. (26) reported increased cravings in subjects on days in which they ingested a low-calorie breakfast compared with days in which they ate a higher-calorie breakfast. This observation is consistent with a conclusion that induction of a short-term energy deficit state may, in fact, induce food cravings. However, that same study found that another method of inducing an energy deficiency, high

Harvey P. Weingarten

levels of preprandial exercise, did not increase food cravings. As a minimum, therefore, anyone wishing to take this experiment as support for the relationship between need and cravings will need to refine the hypothesis. It must incorporate the finding that the method of inducing the need state affects this relationship (if, in fact, the single low-calorie meal or exercise bout used in this study can even be regarded as inducing a need state). Equally puzzling though, is the time at which the differential reports of craving between low- and high-calorie breakfasts were observed. They were reported not before lunch, when the differences in need because of the differential treatments would be most manifest, but at the end of the day, after the subjects had eaten an *ad libitum* lunch and, therefore, had the opportunity to mitigate the need state differences induced by the low- versus high-calorie breakfasts. The contrast between this finding and the reports described above, of decreased cravings with chronic dieting, could lead one, I suppose, to suggest that cravings are elicited by specific methods used to elicit short-term, but not long-term, need. But the qualifications apparently needed to maintain the hypothesis of a link between biological need and cravings begin to confuse; an alternative hypothesis might be more parsimonious.

The logical converse of the experiments that look for craving differences following treatments that induce differential need are investigations that permit an assessment of craving differences following treatments that attempt to equalize biological need. This class of studies is also not highly supportive of a need-craving linkage. For example, Gendall et al. (27) fed subjects equicaloric preloads that differed in macronutrient content. They found that high-protein meals resulted in significantly more postprandial reports of craving than did high-carbohydrate meals, even though the two meals were calorically equivalent and, therefore, induced no marked differences in energy levels.

One of the most direct tests of whether need stimulates cravings is provided by Beauchamp et al. (12) who induced extreme sodium depletion (clear evidence for the existence of a need state) in humans through a combination of very-low-sodium diet and diuretics. Sodium depletion did not result in clear cravings for high-salt foods, although a generalized increased desire for foods with higher salt content emerged during depletion. The observation that experimentally induced severe sodium depletion does not result in experiences of salt cravings is corroborated by other studies as well (12).

Does elimination or reduction of the presumed need state also eliminate or reduce the craving?

This question inevitably leads to an examination of chocolate cravings. The phenomenon of chocolate craving has achieved some prominence in the literature. Chocolate craving has become a “model system” in which many of the conceptual and empirical issues about cravings have been recently examined. The focus on chocolate craving results from several considerations. First, chocolate cravings appear to be the most ubiquitous, prevalent and intense food cravings, particularly among women (4,6,7,8,15,21,28)—although some cultural influences on this general conclusion have been noted (29). Second, chocolate contains a compelling constellation of components, such as high levels of xanthine, theobromine and magnesium and interesting sensory properties, that lend themselves to experiments assessing the role of these factors in the elicitation and satisfaction of chocolate cravings. Finally, there are theories linking chocolate craving with specific biological needs (see 28,31 for reviews).

If cravings result from biological need, then agents or treatments that redress or eliminate the need should also satisfy the craving. The most direct test of this prediction was an experiment conducted by Michener and Rozin (31). They tested the ability of six different experimental treatments to satisfy chocolate cravings in self-reported chocolate cravers. The treatments were designed to identify whether the basis for chocolate cravings was related more to the sensory properties, the nutritional (caloric) effects, the micronutrient (magnesium) component, or the pharmacological (e.g., phenylethylamine, theobromine) properties of chocolate. Milk chocolate was the stimulus that most effectively satisfied chocolate craving, followed by white chocolate or white chocolate plus cocoa capsules. Ingestion of cocoa capsules did not reduce cravings any more than placebo or no treatment. These findings are reinforced by another study showing that theobromine ingestion does not reduce cravings (32). These data provide no support for the idea that mimicking the physiological or pharmacological properties of chocolate satisfies a craving for it, thus mitigating the role of these factors in the determination of food cravings. Rather, these data point to a sensory-based determinant of cravings, a conclusion reinforced by the results of a more recent study investigating the ability of sensory events to elicit chocolate cravings (33).

Harvey P. Weingarten

If cravings result from specific biological needs, then cravings should be alleviated or satisfied by foods other than the ones specifically craved if they provide the item that replenishes the need. Yet this does not appear to be a feature of food cravings. For example, the majority of cravers of chocolate (15) and of other foods (6) report that there is no obvious "other food" that would satisfy their food cravings, even ones that share biological (or even sensory) properties to the specific item craved. Perhaps the most compelling example of the dissociation between replenished needs and cravings is related to the idea that menstrual-related chocolate cravings may result from magnesium deficiency. Chocolate is high in magnesium. But nuts are equally high (30). If cravings and food selection are determined by biological need, one is drawn to the prediction that eating nuts should satisfy menstrual-related chocolate cravings. I know of no direct empirical test of this hypothesis. However, I suspect that the thought experiment is easy for any chocolate craver and I believe I am prepared to place a small wager on the outcome that the eating of nuts does little to satisfy chocolate cravings.

What does the Internet say about the determinants of food cravings?

The review to date has been based on findings from the scientific literature. However, I suspect the general public obtains more information about food choices from popular media than through peer-reviewed journals. Imagine, then, an educated person who wishes to know how she or he should respond to their food cravings and what food choices to make in response to those cravings. If this individual consults the Internet using a popular search engine, what information would she or he obtain, especially if their primary interest was the topic of the current paper—the relationship between food cravings and biological need? (This discussion rests on the assumption that one purpose of our scientific investigations is to inform and influence the public about relevant and healthy food choices. With this assumption, we should not minimize the impact of the popular press in the dissemination of scientific information. As many of us know, a well-placed article or even reference to our work, especially in a high-prestige venue such as *The New York Times*, garners far more attention, interest and acclaim, and likely has far more impact, than even our highly-cited articles in the scientific literature.)

For the most part, the person searching the Internet would see a reflection of the ambivalence in the scientific literature about the relationship between food cravings and biological need. Some sites (a minority of those sampled) attempt a balanced presentation of the issues. For example, a site marketing products to pregnant women and new mothers discusses the uncertainty about the origin of cravings during pregnancy and suggests that they may, or may not, reflect biological need (www.babycenter.com/general/4444.htm). However, most individual sites present quite categorical opinions on this subject. Readers of the Web site of the College of Health and Human Performance at the University of Florida would learn that pre-menstrual cravings could be a way for the body to signal the need to replenish depleted brain serotonin. (www.hhp.ufl.edu/fit/article/mencrav.htm). From the Web site of a company, HEALTH-n-ENERGY, selling nutritional supplements, the reader would learn that "...our food cravings are largely caused by the body searching for missing nutrients, not for calories!" (www.health-n-energy.com/dietrept.htm). In contrast, from the Web site of a company targeting vegetarians, the reader learns that "...there is no evidence that we crave foods because we are deficient in the nutrients in that food", but that cravings more likely arise from monotonous diets, particularly of food items that people are denying themselves (www.vegan.com/issues/1999/feb99/messina.htm). Similarly, from the Cocoa, Chocolate and Confectionery Research Group at Penn State University, there are clear statements that chocolate cravings do not reflect biological need (www.psu.edu/dept/cccr/g/book2.htm). Finally, readers of the Web site of the American Dairy Association would learn that in a random sample of 1000 adult men and women, 61% rated cheese as their most often craved food (exceeding reports of cravings for chocolate and ice cream). They would also learn that cravings are most likely to be elicited by sensory events associated with cheese, that eating cheese induces positive affect, and that "Midwesterners are twice as likely as Northeasterners to crave cheddar." (www.ilovecheese.com/crave/htm). As noted earlier, it is clear that readers must exercise great caution when interpreting information on food cravings found on the World Wide Web.

Conclusion

This paper examines the idea that food selection is determined by biological need. It offers the suggestion that situations in which foods are craved should provide the easiest and best examples of this linkage. The review does not support the proposition that need (aka physiological processes) determines food selection. The idea of "need", as used in the literature, is not particularly clear. Notwithstanding this conceptual difficulty, there is much dissociation in the observed correlation between need and food cravings. A need state is not associated with increased cravings. Differential cravings are reported in equivalent need states. Cravings are reported in the absence of any clear need. In experimental investigations, induction of need states does not stimulate food cravings and actions that alleviate need do not reduce cravings.

It is customary in scientific circles to provide qualified or tempered conclusions to important sweeping questions. Nevertheless, in this instance, I believe it is appropriate and defensible to abandon the inclination toward caution. There is no compelling argument that biological need determines food selection except, perhaps, in contrived pathological situations (and even then the importance of need is suspect). This statement is no surprise in light of other analyses that minimize the importance of need and depletion in the determination of other aspects of ingestive behaviour (34, 35,36). It is time to move on to more productive conceptual frameworks that may help explain food selection, many of which are the subject of other talks at this symposium.

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Biography



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Dr. Weingarten was born and raised in Montreal, completing a Bachelor of Science at McGill University and three graduate degrees at Yale University – a Master of Science, a Master of Philosophy and a PhD in Psychology – before joining McMaster University in 1979.

He was appointed a full professor of psychology in 1990 and has a distinguished record of scholarship and teaching. His teaching has included lecture, seminar and inquiry courses for undergraduates and graduate students in a number of different areas of psychology including behavioural neuroscience and the controls of eating and its disorders. Dr. Weingarten's research examines psychological and biological controls of eating and has been supported by many grants from the Natural Sciences and Engineering Research Council and the Medical Research Council of Canada

Dr. Weingarten served as Chair of the Department of Psychology from 1989-92 and was appointed Dean of the Faculty of Science, serving from 1995 until 1996 when he accepted the appointment of Provost and Vice-President, Academic at McMaster University. Dr. Weingarten was one of the youngest provosts to be appointed at McMaster University. In September 2001, Dr. Weingarten was appointed as President and Vice-Chancellor and Professor of Psychology at the University of Calgary, a major research university in Canada.

