

# Emotional influences on food choice: Sensory, physiological and psychological pathways<sup>☆</sup>

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## Abstract

Sensory, physiological and psychological mechanisms are reviewed that underlie emotional influences on food choice. Both moods and emotions are considered. Eating a meal will reliably alter mood and emotional predisposition, typically reducing arousal and irritability, and increasing calmness and positive affect. However, this depends on the meal size and composition being close to the eater's habit, expectations and needs. Unusual meals – e.g. too small, unhealthy – may negatively affect mood. Sweetness, and sensory cues to high energy density, such as fatty texture, can improve mood and mitigate effects of stress via brain opioidergic and dopaminergic neurotransmission. However, adaptation in these pathways, perhaps enhanced by inherited sensitivity, with chronic exposure to such sensory qualities, could lead to overeating of energy-dense foods and consequent obesity. Sweet, fatty foods low in protein may also provide alleviation from stress in vulnerable people via enhanced function of the serotonergic system. Moreover, in rats, such foods seem to act as part of a feedback loop, via release of glucocorticoid hormones and insulin, to restrain activity of the hypothalamic pituitary adrenal axis during stress. However, this effect is also associated with abdominal obesity. In humans, a number of psychological characteristics predict the tendency to choose such foods when stressed, such as restrained or emotional eating, neuroticism, depression and premenstrual dysphoria, all of which could indicate neurophysiological sensitivity to reinforcing effects of such foods. Greater understanding of such predictive traits and the underlying mechanisms could lead to tailoring of diet to meet personal emotional needs.

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## 1. Introduction

Let me have men about me that are fat; Sleek-headed men, and such as sleep o' nights: Yond Cassius has a lean and hungry look; He thinks too much: such men are dangerous. Caesar in W. Shakespeare's "Julius Caesar", Act 1, Scene (ii).

Observers have noticed over the ages that emotions, mood and food choice can clearly interact with each other, in ways that

vary from strong and overt to subtle and subconscious. For example, mood and emotion could influence food choice via physiological effects that change appetite, or by changing other behaviour that constrains or alters food availability. On the other hand, alteration of mood may be an outcome of food choice, deliberate or otherwise. Thus, mood or emotions could provide an internal stimulus or state that elicits a beneficial, corrective food choice. Furthermore, eating a particular food, or combination, can alter mood via sensory (including hedonic) effects, associated social context, cognitive expectations, psychological distraction, changes in appetite, or nutritional modulation of brain function for example. These sensory, physiological and psychological pathways are considered in more detail below.

Here, both moods and emotions are considered in relation to food, since there is evidence for involvement of both types of affect, as well as instances where the distinction is unclear.

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## 2. Defining mood and emotion

Moods have been distinguished from emotions, in that emotions can be defined as short-term affective responses to appraisals of particular stimuli, situations or events having reinforcing potential, whereas moods may appear and persist in the absence of obvious stimuli, and may be more covert to observers [1,2]. Mood is typically characterised as a psychological arousal state lasting at least several minutes and usually longer, e.g. circadian changes in arousal, with interacting dimensions related to energy, tension and pleasure (hedonic tone) [1,3]. Other mood concepts can be characterised in terms of these dimensions: for instance, positive affect and pleasant mood are related to low tension and higher energy, whereas negative affect, unpleasant mood, depression and anxiety are related to high tension and lower energy [1].

Relationships between mood, emotions and physiological arousal are likely to be complex: it has been argued that the affective significance of a given level of arousal will depend on the person's current subjective and motivational state [4], as well as their personality [1,5], which can interact with mood and responses to emotional stimuli [6]. Thus, personality and cognitive factors could substantially modulate any impact of physiological change induced by food.

## 3. General effects of eating on mood

The commonest way in which food can affect behaviour is the change in mood and arousal that occurs from before to after eating a meal. This general meal effect is probably the most reliable example of an effect of diet on behaviour. Many animals, including human beings, tend to be aroused, alert and even irritable when hungry. This encourages their search for food. After eating a satiating meal, we and other animals typically become calm, lethargic and may even sleep, and mood is more likely to be positive than negative [7]. Nutrient absorption is rapidly detected by the brain, as afferent information is conveyed by the vagus nerve from the gut and liver. The potential influence of this internal information route on emotional behaviour is beginning to be acknowledged [8].

### 3.1. Meal size, timing and habit

The impact of a food or drink will depend on the person's initial state, expectations and attitudes. For example, thirsty people improved their vigilance when allowed to drink water, whereas when people were asked to drink when not thirsty, their performance deteriorated [9]. One might predict a similar result for eating when hungry versus full: similarly, eating more than one's habitual intake may reduce arousal and impair vigilance [10]. In general, meal size per se has little impact on mood unless too little is eaten [11].

There are circadian rhythms and sleep–wake cycles in arousal and performance, which complicate interpretation of meal effects: for example, levels of arousal and alertness tend to rise during the morning, reaching a peak near midday [12]. Breakfast might help to control this arousal, so that attention can

be successfully focused on the task in hand, whereas omitting breakfast may increase autonomic reactivity [13].

The drop in arousal and attention after the midday meal has been termed the 'post-lunch dip' [14]. However, this may not simply be an effect of eating, because vigilance has also been found to decline from late morning to early afternoon in subjects not eating lunch [15]: there is a confounding underlying circadian rhythm. Also, a stressful environment or anxiety prevents any decline in performance due to the meal [15]. Stable extraverts may be more easily calmed by lunch than neurotic introverts, but their post-lunch performance can suffer [15,16]. This is in line with recent evidence that brain activity related to working memory interacts with emotional state and these personality traits [17], and emphasises the importance of individual differences and context in predicting meal effects.

## 4. Sensation, expectation and mood

The sensation of sweetness is innately pleasant, whereas some other sensations derived from tasting food are innately aversive, such as bitterness and sourness. It is relevant that, together with evidence of ingestion or ejection, these conclusions depend on observing facial expressions in newborn babies that we adults interpret as reflecting positive or negative emotions. Yet sensory qualities of foods do not have invariant hedonic attributes; rather, these are dependent on context and experience: within a given context, one can make predictions about the hedonic reactions to different foods or tastes, but even then there will be variation due to differential experience and attitudes among the eaters [18].

Expectations about food are personal predictions of the consequences of eating a food that depend on experience with that food in a variety of contexts. Such expectations are not impotent psychology, but can have real influence on both behaviour and physiology, probably through altering cephalic phase responses: for instance, at the group level, labelling a drink of glucose solution as placebo prevented any beneficial effects of the glucose load on mental performance [19]. In another study, at the individual level, changes in plasma glucose after a zero-energy aspartame-sweetened drink (i.e., no glucose was ingested) were correlated with perceived sweetness of the drink — falls in blood glucose being associated with greater perceived sweetness [20].

Emotional responses to food are sensitive to expectations based on the sensory qualities of a single taste. Women rated various emotions immediately after tasting nine different foods, three being low in energy, three medium and three high in energy (in counterbalanced order) [21]. Intensity of negative moods (sad, ashamed, anxious, sleepy) increased with increasing energy density of the foods, and more so for overweight than normal weight women. Moreover, medium- and high-energy foods were rated less healthy and more dangerous than low-energy foods. These psychological effects were independent of rated pleasantness of the foods. The negative effects of the high-energy foods presumably reflected concerns about their impact on health and weight gain. Furthermore, stronger increases in negative mood were seen for women reporting

greater tendencies to eat in response to emotional state. So any reinforcing effect of eating such foods on prior emotional state must be independent of these emotional reactions to brief tastes — a beneficial effect of a real meal would not have been detected by this design.

Similarly, self-identified female chocolate ‘addicts’ felt more guilty after eating chocolate than did a control group [22]. The chocolate ‘addicts’ also reported lower positive and higher negative affect prior to eating. By contrast, in healthy men, experimental induction of sadness decreased appetite, whereas when cheerful, chocolate tasted more pleasant and stimulating, and more of it was eaten [23]. This gender difference is likely to be confounded by dispositional differences (Section 6).

Nevertheless, there is evidence that sweetness, perhaps together with fatty tastes, in particular may have an ability to influence mood, at least in some individuals some of the time, and might be a key determinant of affective influences on food choice. This evidence is considered in the next sections.

## 5. Neural substrates of sensory reward and stress alleviation

Eating when hungry is both pleasurable and rewarding. Research has shown that eating activates neural substrates in a similar manner to drugs of abuse, although with important differences of degree [24]. The most evidenced neural substrates of reward are the dopamine, opioid and benzodiazepine/GABA neurotransmitter systems: there may be a dissociation of these systems, such that dopamine underlies motivational aspects of eating (‘wanting’), whereas opioid and benzodiazepine systems may mediate hedonic evaluation of food sensory stimuli (“liking”) [25].

Endogenous opioid neuropeptides are involved in reward processes in eating behaviour, such as stimulation of appetite by palatable foods, as well as adaptive responses to stress and discomfort [26,27]. One might therefore expect a link between opioid action, mood and food choice, and in animals and human infants, the ingestion of sweet and fatty foods, including milk, alleviates crying and other behavioural signs of distress [28,29]. This effect depends on sweet taste rather than calories, as non-nutritive sweeteners reduce crying too [30], and it can be blocked by opioid antagonists, which also reduce consumption of more preferred foods [28,31–33].

Interestingly, as babies grow older, sweet taste becomes less effective at calming than does pacifier sucking, which might reflect a maturational separation of taste and emotion [34], or a difference in opportunities to learn the instrumental emotional value of the two experiences. Furthermore, the extent to which adults (whether rat or human) retain an analgesic effect of sweet taste remains controversial, but this might again reflect variation in retention of this phenomenon, through a combination of predisposition and experience.

Using the cold pressor test (holding the hand in very cold water), pain threshold latency (but not tolerance) was extended by concurrent sweet taste in 8–11-year old children [35]. In adults, pain tolerance, not threshold, was increased by prior tasting of a sucrose solution [36]. Perceived palatability (liking)

may be important, as well as gender, and duration and timing of exposure [37]. For example, in one study it was found that only a highly liked food (chocolate chip cookies), and not bland or disliked foods, was able to increase pain tolerance in female students when eaten beforehand [38]. One may speculate that adults select sweet, fatty, palatable foods for opioid-mediated relief of stress. However, repeated intake of a sweet, fatty energy-dense food was found to downregulate an opioid pathway (ventral striatum) involved in food reward in rats, suggesting an adaptation to chronic activation of this appetitive pathway [39].

Similarly, overconsumption of palatable energy-dense (e.g. high-fat, high-sugar) food may downregulate dopamine ( $D_2$ ) receptors, since their availability in the striatum has been shown to be inversely correlated to BMI, and a questionnaire measure of ‘sensitivity to reward’ was found to be lower in obese than in overweight people [40]. This latter finding was interpreted as suggesting that chronic overeating may eventually induce a more anhedonic state (i.e. less sensitivity to reward), although this measure was also correlated to emotional eating. However, obese respondents might report less pleasure from various activities as a result of social stigma and physical disability. The findings could indicate a neurochemical predisposition that may cause overeating of palatable foods so as to enhance dopamine release [41]. In support of this, energy-dense snack food appears to reinforce greater effort to obtain it in obese than non-obese women [42], and young children of obese parents showed greater ‘enjoyment of food’ as well as higher preference for high-fat energy-dense foods, than did the offspring of non-obese parents [43]. It may also be relevant that sufferers of binge eating (particularly associated with obesity), and other eating disorders, are at greater risk of substance abuse, as well as susceptibility to negative affect [44], given that dopamine also mediates stress sensitivity and depression [45].

## 6. Negative affect, stress, comfort eating and food choice

Studies of the impact of stress on eating have emerged in part from animal studies of psychopathology, especially depression [46,47], as well as human studies testing effects of negative affect on eating. Most of this work addresses whether stress alters overall food intake, but this section concentrates on studies that investigate effects on food choice.

A distinction needs to be made between acute and chronic effects of diet on mood and neurophysiological mechanisms. For example, after an overnight fast, a carbohydrate preload, but not protein or fat load, enhances stress-induced release of cortisol [48]. By contrast, over 10 days, a carbohydrate-rich diet was associated with lower average plasma cortisol than a high-protein diet [49]. This may reflect an adaptive change in hypothalamic pituitary adrenal (HPA) axis function: in rats, drinking sucrose solution for several days inhibits production of corticotrophin releasing hormone (CRH) in the brain, and appears to mimic glucocorticoid replacement in adrenalectomised rats [50]. Moreover, rats allowed a choice of lard (pork fat) and chow for a week showed substantially reduced HPA axis activation to stress, yet greater insulin levels, than rats having to eat the same amount of lard mixed with chow [51]. It has been

proposed that cortisol and insulin may stimulate ingestion of energy-dense “comfort foods”, which then protects the HPA axis from stress-induced dysfunction and associated depression and anxiety [50]. It may be relevant that patients with Seasonal Affective Disorder show increased insulin resistance in the winter, together with a greater predilection for sugar-rich foods [52].

### 6.1. Naturalistic studies of stress and food choice

Naturally occurring stressful circumstances, such as examinations or periods of high workload, can provide a predictable context in which to study stress-related variations in diet. Such studies have found that periods of high workloads are associated with greater energy and fat intake [53], or higher fat, sugar and total energy intake, but only in people who habitually restrained their food intake [54]. In students, exams or high workload have been associated with higher energy intake [55] or less healthy diets [56]. However, a number of studies have failed to find any changes in diet under these circumstances, despite evidence for increased stress and negative affect [57–60]. Nevertheless, negative findings may not be too surprising, given the difficulty of reliable dietary data collection, particularly during demanding times, and the notoriously mediocre quality of students’ diets at the best of times. Moreover, an unchanged mean intake may disguise wide variation in intake in response to stress between individuals [61].

In US teenagers, depressive symptoms were associated with perceived barriers to healthy eating, meal skipping and more disordered eating, although the only significant change in diet appeared to be increased consumption of sweet soft drinks in more depressed school children [62]. In a study of health behaviours in 11–13-year old school children in London, UK, greater perceived stress was associated with eating more fatty food and snacks, but less fruit and vegetables, and less likelihood of breakfast [63]. In a Finnish adult population-based study, ‘stress-driven eaters’ ate more energy-dense high-fat foods and had higher body mass indices [64]. Smaller but more intensive studies have also found associations between negative affect and stress and increased intake of high-fat snack or convenience foods [65,66]. Inevitably it is difficult to interpret these findings in terms of mechanisms, since a number of social and psychological pathways is possible [67].

So far as overall food intake is concerned, surveys of self-reported changes in eating behaviour reveal a bidirectional effect across the samples, but consistency within individuals. Thus, 38% to 72% of sampled populations reported eating less when stressed, whereas slightly fewer, 28% to 50%, reported eating more, with a minority in each survey believing stress did not alter their food intake [68–71].

One survey of perceived changes in intake of a number of food categories during stress revealed an interesting pattern, which was partly independent of whether participants were grouped as reporting eating more, the same or less overall when stressed [68]. That is, sweets and chocolate were reported to be eaten more under stress by all groups, even those eating less overall; conversely, intakes of fruit and vegetables, and meat

and fish, were reported as less or unchanged under stress in all groups (Fig. 1). The changes for the staple food, bread, matched the overall group self-perceptions of changes in eating due to stress. These data imply that mechanisms governing effects of stress on food choice may be somewhat separate from those influencing overall appetite under stress, and that foods such as sweets and chocolate may be particularly useful in ameliorating stress.

### 6.2. Dietary restraint, emotional eating and stress

An important question is whether certain psychological or physiological characteristics predispose a person to change their food choice in an unhealthy direction. For example, students who reported eating more when stressed were more likely to be dieters or restrained eaters (i.e. consciously restricting intake) [68,70]. This is consistent with a number of experimental studies in which it appears that normally dominant cognitive strategies for restraint may be disinhibited or overridden during negative affect or stress [72,73], leading to increased eating. The implication is that restrained eaters may be unresponsive to their internal physiological influences on appetite [74–76]. Certainly, cognitively demanding situations, which may be stressful, lead

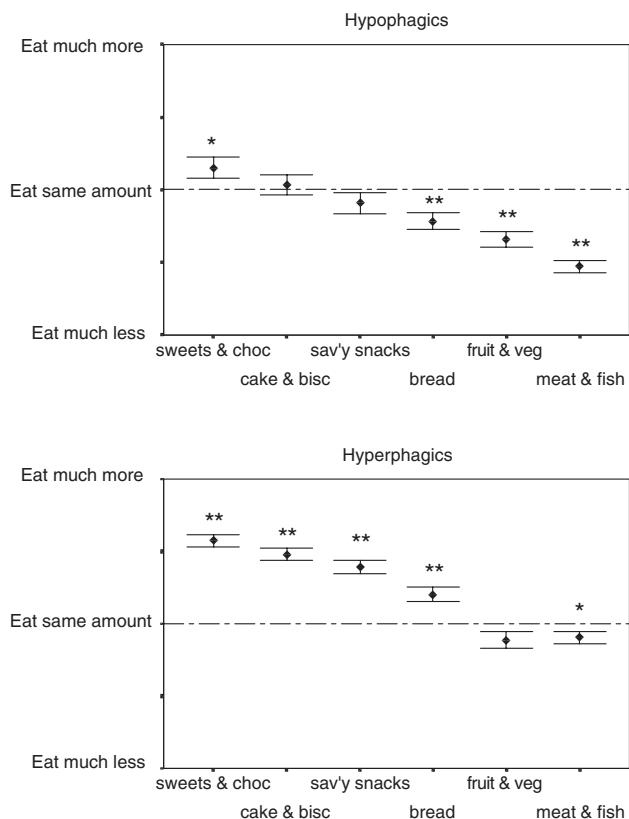


Fig. 1. Self-reported changes in intake (y-axis) of six food categories (x-axis) during stress, for people who perceive eating less overall (hypophagics, upper panel, 38% of sample) or those who report eating more overall (hyperphagics, lower panel, 42% of sample) under stress (212 students). Note that intake of sweets and chocolate is significantly raised by stress even in the group who perceived their overall intake to be less under stress. Data are expressed as mean rating  $\pm$  SE. Asterisks indicate statistically significant perceived changes in intake when stressed. Reproduced from [122].

to disruption of restraint and so overeating, especially of sweet fatty foods [77–80].

Although dietary restraint may be an important predictor of overeating during stress, many previous reports did not distinguish between restrained and emotional eating [81–83]. Restraint was measured in most studies by the Restraint Scale [84], which includes the tendency for eating to be disinhibited by emotional states. When separate scales were used to measure restraint and emotional eating (Dutch Eating Behaviour Questionnaire, [85]), the latter was the better predictor of stress-induced eating [86]. In that study, stress (threat of public speaking) did not alter overall intake of a buffet meal. However, stressed emotional eaters ate more sweet high-fat foods (chocolate and cake), and a more energy-dense meal, than either unstressed emotional eaters or non-emotional eaters in either condition. Moreover, emotional eaters may be more susceptible to effects of stress: women who ate more from a selection of snack foods after a stressful task also showed the greatest release of the stress-sensitive hormone, cortisol [87], and more stress-induced negative affect. These high reactors also showed a preference for sweet foods. So it seems that emotional eaters may be more likely to experience mood disturbance when challenged, and to seek solace from food in these circumstances, whereas, in restrained eaters, stress can alter eating via cognitive routes.

## 7. Meal composition and effects of specific nutrients

This section considers how the nutrient content of foods might act to alleviate stress, and in particular why sweet fatty foods might be preferentially chosen during stress. Sensory explanations have already been considered, but there could also be nutritional or metabolic effects of high-sugar or -fat content.

### 7.1. Carbohydrate vs. protein

Synthesis of the neurotransmitter serotonin (or 5-hydroxytryptamine; 5-HT) depends on dietary availability of the precursor essential amino acid, tryptophan (TRP) [88]. High-sugar, low-protein foods might influence mood via increased synthesis of 5-HT, at least relative to effects of low-carbohydrate high-protein meals. The former foods raise, and the latter lower, the plasma ratio of TRP to several large neutral amino acids (LNAA), with which it competes for entry into the brain. Such effects also depend on the interval since, and nutrient content of, the last meal [89].

This evidence is particularly relevant to dietary effects on mood and arousal, because 5-HT has long been implicated in sleep, as well as affective disorders such as depression and anxiety [90]. There is experimental evidence that people feel more calm and sleepy after snacks or meals rich in carbohydrate but virtually free of protein (an unusual situation) than after protein-rich meals with little carbohydrate (reviewed by Ref. [91]). This is compatible with changes in 5-HT function, but typically these studies did not determine whether this was due to an increase in 5-HT after the carbohydrate-rich meal, or a decrease after the protein meal, which could prevent the post-

prandial sleepiness. Furthermore, adding more than 5% or 6% protein (of total energy) to the carbohydrate meal prevents the increased synthesis of 5-HT seen with pure carbohydrate, relative to fasted levels, in both rats and people [89,92].

Another difficulty in comparing effects of carbohydrate and protein intake is that relative changes in mood and performance might be due to protein-induced raised plasma tyrosine (TYR) [93,94], the precursor amino acid for synthesis of the catecholamine neurotransmitters, dopamine, adrenaline and noradrenaline. Such an effect might contribute to the acute increase in positive affect after a protein-rich (39%) lunch, relative to a low-protein (5%) lunch, at least by 2 h after eating, although a meal-induced rise in cortisol could also be involved [95]. Indeed, after 5 days on a low-protein diet, a protein-rich meal induced a substantial increase in positive affect 2–3 h later, which correlated with the amount of cortisol released after the meal [96]. Because the change in mood occurred 2 h after eating, it is not likely to be due to immediate appraisal of the meal, but rather to some postigestive consequence. This increase in well-being may be related to the reinforcing effect of eating a good source of protein when it is a needed nutrient [97].

Chronic intake of high or low ratios of carbohydrate to protein may also affect mood, but the effects appear to be the converse of those seen acutely. When mood was averaged over 9 days, a higher proportion of protein predicted greater depression, whereas a higher proportion of carbohydrate predicted less depression [98]. In obese women eating their regular diet freely, lower levels of anxiety and depression at baseline predicted greater intake of carbohydrate and less protein over 4 days [99]. Causality cannot be determined from these studies. However, chronic changes in 5-HT function might be involved: in an intervention study, after 6 weeks on either a high- or low-carbohydrate diet, mood in women had deteriorated on the latter diet, and better mood was associated with higher average 24-h plasma TRP/LNAA ratio [100]. It may be relevant that chronic changes in 5-HT activity are necessary for the antidepressant action of selective serotonin reuptake inhibitors [90].

It is notable that milk chocolate, often chosen during stress, is high in sugar and fat, and stimulates insulin release [101], but has only 3–6% of energy as protein. Thus, if eaten in sufficient amounts on an empty stomach, chocolate might increase TRP availability to the brain, and so enhance 5-HT-mediated mood. However, the mood-enhancing actions recently demonstrated for caffeine and theobromine in chocolate [102], together with sensory and social reinforcement, are more probable mechanisms.

### 7.2. Effects of dietary fat

On balance, high-fat meals appear to increase subsequent fatigue and reduce alertness and attention, relative to equicaloric high-carbohydrate/low-fat meals (reviewed by Refs. [11,103]). Effects of fat on postdigestive mood are not dramatic, and in general fat produces less substantial changes in postprandial physiology than carbohydrate or protein [104].

In many of these studies, the meals were designed to disguise variation in fat level from participants. Mood may be adversely affected by meals that differ substantially in macronutrient composition from habitual ones. So, effects on mood may have resulted from discrepancies between subjects' expectations of certain postigestive effects, and the actual effects that resulted from neurohormonal responses to detection of specific nutrients in the duodenum and liver. This could explain the increase in tension, 90 min post-lunch, with increasing fat intake, reported by predominantly female subjects [105], which might reflect an aversive reaction to (unexpected) fat-related postigestive sensations.

### 7.3. Wellbeing from nutrient replenishment

In principle, food choice could at times be driven by the need to replenish a particular essential nutrient, such as a vitamin, mineral, fatty acid, or amino acid (or at least protein; see above). There is certainly a long history of evidence that animals can learn to select diets for just these reasons [106,107]. The assumption is that eating a diet that replenishes a nutritional need reinforces liking for the flavours of that diet. Therefore, one might expect that such an experience would be rewarding, and may involve some sense of positive affect or well-being. The evidence in rats for a reinforcing action of nutrient replenishment is strong, but scarce in human beings, aside from the evidence for protein discussed above.

There is growing interest in a possible effect on mood of a number of essential micronutrients, especially the omega-3 and omega-6 essential fatty acids, B vitamins including thiamine, B<sub>6</sub> and B<sub>12</sub>, and the essential mineral co-factor selenium [92]. However, despite the likelihood that these nutrients can influence brain function, the evidence for their effects on mood via dietary intake remains equivocal [11,108]. Furthermore, it is not known whether such micronutrients have any influence on human food choice.

## 8. Individual susceptibility to mood enhancement by diet

A key developing area of research concerns predictors of individual differences in susceptibility to nutritional effects on mood, emotion and other aspects of brain function [11]. In particular, recent evidence suggests that some types of personality or those with emotional disorders may be susceptible to beneficial effects of specific proportions of macronutrients, especially in coping with stressful challenges.

The possibility that a carbohydrate-rich low-protein meal could raise 5-HT function gave rise to the proposal that some depressed people may self-medicate by eating high proportions of carbohydrate [109]. Although that theory and its evidence have been strongly criticised [92,106], it is clear that severe reduction in plasma TRP by feeding a TRP-free diet acutely can induce depressed mood in those with a history of or genetic predisposition to depression or bipolar disorder [110,111]. Moreover, this treatment induces greater negative mood in healthy adults with no psychiatric history exposed to uncontrollable noise stress [112].

Conversely, short-term dietary manipulations that raised plasma TRP/LNAA ratios, have been found to block subsequent task-induced depressive feelings and release of cortisol, but only in the high stress-prone (neurotic) group [94,113]. It was argued that, because stress increases 5-HT activity, the poor stress-coping of this sensitive group might indicate a deficit in 5-HT synthesis that is improved by such dietary interventions. Stress causes both worsening of mood and reduced TRP/LNAA ratio [114], perhaps due to greater diversion of TRP to peripheral metabolism by cortisol [115]. Interestingly, human breast milk, which clearly calms the stressed infant, is rich in TRP [116].

Women suffering from the luteal phase-dependent mood disorder, Premenstrual Syndrome (PMS) may also be sensitive to dietary manipulation of 5-HT function [117,118]. Pharmacological activation of the central serotonin system appears to reduce PMS dysphoria [119], and women may be more physiologically reactive to stress during the luteal phase [120]. Thus, food choice during the late luteal phase of the menstrual cycle, could, in some women, be motivated by a need to improve their mood, although evidence for such menstrual cycle-dependent self-medicating food choice is equivocal [121].

## 9. Conclusion

Mood can alter food choice, and food choice can alter mood, for a variety of reasons. Where this relationship is consistent, predictable, perhaps habitual, then the effect of one on the other likely involves some reinforcing outcome. This might be a reduction in negative mood, e.g. by assuaging hunger, or an increase in positive mood through sensory pleasure; or it might be mediated by enhanced resilience under stress, or the removal of aversive physiological symptoms. The direction of an association between mood and food choice, or whether it exists at all, will depend upon an individual's psychological and neurohormonal dispositions.

Thus, the eater will often have learnt, consciously or subconsciously, their best food choice strategy depending on their current mood and the outcome sought. An obvious example is the lifting of mood, or calming of stressed 'nerves', by eating foods having hedonic sensory (or nutritional) qualities that elicit pleasure and activation of its palliative neural substrates: chocolate may spring to mind for most people.

Future research should try to characterise more reliably the predictive traits, and psychophysiological mechanisms, underlying the link between food choice and mood. This may allow development of foods tailored to personal emotional needs.

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