

# Social, clinical, and policy implications of ultra-processed food addiction

Conceptualising ultra-processed foods high in carbohydrates and fats as addictive substances can contribute to efforts to improve health, argue **Ashley Gearhardt and colleagues**

**T**he scientific understanding of addiction is evolving. Although addiction to certain foods is not included in diagnostic frameworks such as the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), research on this topic has grown rapidly in the past 20 years. Much of this research uses the Yale Food Addiction Scale (YFAS), which was developed to measure food addiction by assessing DSM-5 criteria for substance use disorder in the context of food intake (box 1).<sup>14</sup>

A recent analysis of two systematic reviews including 281 studies from 36 different countries found the overall pooled prevalence of food addiction using YFAS was 14% in adults and 12% in children.<sup>8,9</sup> This reported prevalence is similar to the levels of addiction seen for other legal substances in adults (eg, 14% for alcohol and 18% for tobacco),<sup>10,11</sup> but the level of implied addiction in children is unprecedented. In populations with defined clinical diagnoses, YFAS identified prevalence of food addiction reaches 32% in people with obesity having bariatric

surgery,<sup>12</sup> and over 50% in those with binge eating disorder.<sup>8</sup> Food addiction based on the YFAS is also associated with core mechanisms of addiction, such as reward related neural dysfunction, impulsivity, and emotion dysregulation, as well as poorer physical and mental health and lower quality of life.<sup>13-15</sup> Thus, there is converging and consistent support for the validity and clinical relevance of food addiction; what remains a more open question is the types of foods that are addictive. Despite the uncertainty, classifying foods as addictive could stimulate research and shift attitudes to regulation.

## What types of foods can be addictive

Not all foods have addictive potential. The YFAS asks people to report on intake of foods with high levels of refined carbohydrates or added fats, such as sweets and salty snacks.<sup>14</sup> These types of foods are most strongly implicated in the behavioural indicators of addiction, such as excessive intake, loss of control over consumption, intense cravings, and continued use despite negative consequences.<sup>16-19</sup> Refined carbohydrates or fats evoke similar levels of extracellular dopamine in the brain striatum to those seen with addictive substances such as nicotine and alcohol.<sup>20-25</sup> Based on these behavioural and biological parallels, foods that deliver high levels of refined carbohydrates or added fats are a strong candidate for an addictive substance.<sup>16,17</sup>

Ultra-processed foods (UPFs)—industrially produced foods containing ingredients not available in home

kitchens—are the main source of source of refined carbohydrate and added fats in the modern food supply.<sup>26-28</sup> While natural or minimally processed foods typically contain either carbohydrates or fat, they rarely contain both—for example, 100 g of apple has 55 kcal from carbohydrates and 1.5 kcal from fat (roughly 36:1) and 100 g of salmon has 0 kcal from carbohydrates and 73 kcal from fat (roughly 0:1). By contrast, many UPFs contain much higher levels of both carbohydrates and fats in more equal proportions. For example, 100 g of a chocolate bar contains 237 kcal from carbohydrates and 266 kcal from fat (1:1). The combination of refined carbohydrates and fats often found in UPFs seems to have a supra-additive effect on brain reward systems,<sup>29</sup> above either macronutrient alone, which may increase the addictive potential of these foods.

The speed at which UPFs deliver carbohydrates and fats to the gut may also be important to their addictive potential. Drugs and routes of administration that affect the brain more quickly have a higher addictive potential.<sup>30,31</sup> This is the rationale behind substitution therapies and why a cigarette, which rapidly delivers nicotine to the brain, is more addictive than a slow release nicotine transdermal patch. The food matrix is altered in UPFs, which makes them easier and faster to consume, have greater bioavailability, and potentially allows them to affect the brain more rapidly.<sup>32</sup> The intact food matrix of minimally processed foods slows down their rate of consumption and reduces bioavailability. For example,

## KEY MESSAGES

- Ultra-processed foods high in refined carbohydrates and added fats are highly rewarding, appealing, and consumed compulsively and may be addictive
- Behaviours around ultra-processed food may meet the criteria for diagnosis of substance use disorder in some people
- Ultra-processed food addiction is estimated to occur in 14% of adults and 12% of children and is associated with biopsychological mechanisms of addiction and clinically significant problems
- Understanding of these foods as addictive could lead to novel approaches in the realm of social justice, clinical care, and policy approaches

## Box 1: Yale Food Addiction Scale (YFAS)

- The Yale Food Addiction Scale assesses all 11 symptom criteria for substance use disorder in DSM-5, including diminished control over intake, cravings, withdrawal, and continued use despite negative consequences<sup>12</sup>
- A substance use disorder is defined as the presence of two or more symptoms in the past year and clinically significant impairment or distress<sup>23</sup>
- The YFAS has undergone rigorous psychometric testing and has strong internal consistency and test-retest reliability, as well as convergent, discriminant, and incremental validity<sup>14</sup>
- It has been translated into over 12 languages, such as Spanish, Persian, and Chinese, and these versions also show strong psychometric properties<sup>5-7</sup>

**Box 2: Future directions in the science of ultra-processed food addiction**

- Evaluate how complex features of ultra-processed foods (eg, combinations of rewarding ingredients, flavour additives, altered food matrixes) combine to increase addictive potential
- Clarify the boundaries at which foods can be considered addictive and based on what attributes
- Identify the level of UPF intake at which risk for addiction may increase
- Investigate how levels of UPF addiction may differ by country based on the availability of ultra-processed foods in their food supply
- Assess the disproportionate impact of UPF addiction on disadvantaged communities
- Test the value of industry focused public health messaging to reduce UPF addiction
- Develop empirically supported clinical guidelines for the treatment, management, and prevention of UPF addiction
- Consider whether the scientific literature supports the recognition of an official diagnosis reflecting UPF addiction
- Further probe the overlap between UPF addiction, obesity, and eating disorders
- Evaluate the ability of multipronged litigation, regulatory, and policy efforts to reduce addictive patterns of UPF intake

nuts have a relatively high amount of fat compared with other minimally processed food (100 g of almonds provides 86 kcal from carbohydrates and 449 kcal from fat (roughly 1:5) but a lower addictive potential than UPFs). This is likely to be because nuts have a high ratio of fat to carbohydrate than most UPFs and the fats remain encapsulated in cell walls after chewing, making them unavailable, especially at the early stages of digestion.<sup>33</sup> This is especially important as signalling from the upper intestine (duodenum) but not the lower portion of the digestive track evokes dopamine in the striatum.<sup>34 35</sup> Thus, the ability of UPFs to rapidly deliver bioavailable rewarding substances may contribute to their increased addictive potential.

Additives may also be contributing to the addictiveness of UPFs. Many UPFs have flavour additives that increase sweet and savoury tastes, as well as texturisers that improve the mouthfeel.<sup>28 36-39</sup> Additives that aim to improve flavour and mouthfeel are also common in cigarettes, including sugar, cocoa, menthol, and alkaline salt.<sup>40</sup> These additives and flavour profiles are important for establishing brand loyalty and become potent secondary reinforcers, so much so that people prefer to smoke denicotinised cigarettes than receive an intravenous injection of nicotine.<sup>41 42</sup> Similarly, while food additives are not likely addictive on their own, they could become powerful reinforcers of the effects of calories in the gut.

Other additives can enhance the effects of a drug; menthol, for example, increases nicotine evoked dopamine in the striatum.<sup>43</sup> Artificial sweeteners in UPFs

bind to receptors in the gut, increasing glucose transporter isoform 1 (SGLT1) and glucose transporter 2 (GLUT2) expression, increasing the capacity to absorb glucose.<sup>44 45</sup> In the United States there is a proposal to remove menthol flavoured cigarettes and flavoured cigars from the market because of their role in increasing addictive liability. Such a ban is expected to lead to hundreds of thousands of people to quit smoking.<sup>46</sup> A similar level of rigour in research and policy needs to be applied to UPFs to determine the role of additives in potentiating and maintaining UPF intake.

It is clear not all foods trigger addictive behaviours, just as not all drugs are addictive. Currently, of the foods available for consumption, UPFs seem to be the best candidate for an addictive substance. While further careful research is needed to determine the exact mechanism by which these foods trigger addictive responses, UPFs high in refined carbohydrates and fats are clearly consumed in addictive patterns<sup>16 17</sup> and are leading to deleterious health outcomes.<sup>28</sup> Therefore, we will use the term UPF addiction here to reflect those substances most strongly implicated in addictive eating.

**Critiques of UPF addiction**

While there are notable parallels between addictive substances and UPFs, there are also unanswered questions. Critics of the UPF addiction perspective have noted that specific addictive chemicals, such as nicotine for tobacco addiction, have not been identified for foods. Addictive chemicals potently activate endogenous reward systems, triggering addiction in some people. Although refined carbohydrates and fats

do not act on reward systems directly, they seem to activate neural reward systems to a similar magnitude as nicotine and ethanol.<sup>20-25</sup> However, the presence of an addictive chemical is not sufficient to render a substance addictive—for example, aubergines contain nicotine. Dose and route of administration matter.

Even with well studied addictive substances such as nicotine, the exact dose and intake level at which addiction occurs is unknown. Similarly, the additive potential of UPFs is unlikely to be determined by the presence of a single chemical such as sucrose. Research has generally focused on single ingredients in UPFs, and further study is needed to investigate how UPF ingredients interact to increase addictive potential. It will also be important to explore at what dose and at what level of intake rewarding chemicals in UPFs are most addictive (box 2).

A crucial point of debate is the criteria by which to categorise addictive foods. We have focused on UPFs, as this is the major source of refined carbohydrates and added fats.<sup>26-28</sup> One tool for classifying foods, NOVA, defines a category for UPFs as NOVA 4, focusing mainly on industrially created foods.<sup>26-28</sup> The UPF category in NOVA is broad and captures foods that may be unlikely to have strong addictive potential, such as meat alternatives.<sup>47</sup> Homemade foods made from processed ingredients such as sugar and butter may also be addictive (eg, homemade cookies)<sup>48</sup> but would not be considered a UPF based on the NOVA classification. UPFs with high levels of refined carbohydrates and fats are more accessible, convenient, and heavily marketed than homemade versions and are therefore likely to be a more potent driver of addictive food intake. Similarly, processed tobacco leaves have been available for hundreds of years for people to make their own addictive tobacco products. However, the invention of the cigarette roller in the 1880s<sup>49</sup> made mass produced cigarettes more accessible, convenient, and heavily advertised<sup>50</sup> and contributed to an over 1000% increase in cigarette smoking.<sup>51</sup> As with industrial cigarettes, higher consumption of highly rewarding UPFs is likely to make them a more effective target for intervention.

**Social justice implications of UPF addiction**

Unique social justice issues need to be considered with UPF addiction. Addictive drugs are not necessary for survival; eating is. In some countries UPFs are an important source of calories for many people.<sup>52</sup> It will

**Box 3: Policy approaches to tackle ultra-processed food addiction****Ultra-processed food (UPF) and beverage taxes**

103 countries around the globe passed sugar sweetened beverage (SSB) taxes,<sup>83</sup> with several more also taxing UPFs. A meta-analysis estimates that such taxes are associated with an average decline of 15% in SSB sales ( $P<0.001$ ) and 18% in SSB intake ( $P=0.07$ ), though most intake studies are limited by small samples.<sup>84</sup> Preliminary evidence has also linked such taxes with reductions in body mass index among adolescent girls in Mexico<sup>85</sup> and declines in dental caries among people with low incomes in a large US city.<sup>86</sup> Further, the revenue generated by these taxes is being invested in other health promoting initiatives.

**Mandatory or voluntary front-of-pack or shelf labelling systems**

Nutrition labels on the front of UPFs have been implemented in over 20 countries. Meta-analyses of short-term experimental studies on nutrition warning labels estimate that they significantly reduce purchases of labelled products, including SSB's, snack foods, and alcohol.<sup>87-89</sup> One quasi-experiment in a hospital cafeteria found that pictorial warnings (but not text-only warnings) reduced purchases of SSB's compared with calorie labels.<sup>90</sup>

**Mandatory or voluntary reformulation of the food supply**

Evaluations of the UK's salt reduction programme estimate that it was associated with 15% reduction in sodium intake and 42% and 40% reduction in stroke and ischaemic heart disease mortality, respectively.<sup>91</sup> Similarly, New York City's trans-fat ban was associated with 4.5% reduction in cardiovascular disease mortality.<sup>92</sup> Reductions in heart disease were also linked with Denmark's trans-fat ban.<sup>93</sup> In addition, the implementation of healthier nutrition standards in US schools was associated with reductions in body mass index among youth.<sup>94</sup>

**Suite of policies targeting UPFs are needed**

No one food policy will transform unhealthy food environments. Countries such as Chile and Mexico have implemented a bundle of healthy food policies, including taxes, nutrition labels, and marketing regulations on UPFs. An evaluation of Chile's law found that it was associated with average reductions of 7.4 kcal/person/day (-7.5%) from beverage purchases<sup>95</sup> and 16.4 kcal/person/day (-3.5%) from food purchases. The policies were also associated with declines of 10.2%, 3.9%, and 4.7% in sugar, saturated fat, and sodium purchased, respectively.<sup>96</sup>

be essential to understand the levels of UPF addiction with changes in UPF marketing and consumption globally, particularly in low and middle income countries. Even within countries, the food environment is not equitable, and food outlets in disadvantaged neighbourhoods are often dominated by UPFs, with limited access to minimally processed foods.<sup>53-55</sup> People facing food insecurity are more reliant on UPFs to meet their daily energy needs<sup>56</sup> and are more likely to exhibit higher levels of UPF addiction.<sup>57</sup>

It will take courageous action to change these and other economic and structural factors that drive people towards UPFs. Increasing the accessibility, affordability, and convenience of minimally processed foods is necessary but not sufficient. Stress amplifies the appeal of addictive substances,<sup>58</sup> and food insecurity is a stressful experience.<sup>59</sup> UPFs already have heightened appeal, and combined with their low cost, convenience, and marketing, it is hard for minimally processed foods to compete, particularly for those facing the stress of structural disadvantages. Policy approaches that combine increased access to convenient, affordable, and tasty minimally processed meals, while also limiting industry practices that inequitably promote UPFs to disadvantaged communities could help reduce UPF addiction.

A potential concern with conceptualising UPFs as addictive is that it may increase

stigma, particularly within already stigmatised communities. However, experimental studies find that the addiction model of excessive food intake seems to reduce stigma towards people with obesity,<sup>60</sup> while a framework that focuses on deficits in personal responsibility is reported as increasing stigma.<sup>60</sup> This aligns with evidence that public messaging campaigns highlighting practices of the tobacco industry such as predatory marketing and engineering addictive products were effective in driving public attitudes against tobacco.<sup>61</sup> The effect of similar industry focused public health messaging in the context of UPFs needs to be tested.

**Clinical implications of UPF addiction**

The presence of UPF addiction in people with obesity or eating disorders is associated with more severe clinical presentations, including higher levels of diet related disease, higher general psychopathology, lower cognitive functioning, and worse treatment outcomes.<sup>62-66</sup> Despite the potential relevance of UPF addiction for clinical care,<sup>67</sup> the scientific literature on the treatment, management, or prevention of UPF addiction is sparse. Most research has focused on evaluating the validity of UPF addiction as a concept, with work on development of clinical guidelines for UPF addiction just beginning.<sup>67</sup>

UPF addiction is not currently an official diagnosis,<sup>68</sup> but such recognition

would be likely to promote research into its clinical management. Although it has been suggested that existing eating disorder diagnoses obviate the need for making UPF addiction a diagnosis,<sup>69</sup> there are substantial differences in estimated prevalence (14% for UPF addiction and around 1% for binge-type eating disorders<sup>8 70</sup>). This discrepancy suggests that a substantial proportion of people with problematic eating are being missed in current diagnostic frameworks.<sup>71</sup> This is concerning given that many individuals with UPF addiction report clinically significant problems and demonstrate neurobiological differences from those without food addiction, even when they do not meet criteria for an eating disorder.<sup>72-74</sup> The inclusion of a UPF addiction diagnosis in clinical care would be likely to improve access to support and enable the development of treatments to reduce compulsive patterns of UPF intake.<sup>68</sup>

Several promising treatment directions for UPF addiction need further evaluation. Preliminary evidence suggests that drugs used to treat substance use disorders, such as naltrexone and bupropion, may reduce symptoms of UPF addiction.<sup>75</sup> New glucagon-like peptide (GLP)-1 agonists seem to reduce food craving and may reduce desire for addictive drugs,<sup>76 77</sup> suggesting a potential treatment for UPF addiction. Twelve step addiction treatment models (eg, Overeaters Anonymous) have been available since the 1960s but have



rarely been studied. Given that abstinence from UPFs is unfeasible or unnecessary for many, it will be important to investigate the utility of harm reduction treatments for UPF addiction. Further research will be needed to identify the optimal timing and clinical threshold for different approaches to tackle UPF addiction.

### Policy implications of UPF addiction

The misclassification of addictive substances as non-addictive can delay necessary policy action. Tobacco companies minimised the addictive nature of their products by focusing on users' personal responsibility.<sup>50</sup> However, people find it challenging to reduce intake of addictive substances even when highly motivated, which challenges the personal responsibility narrative used by industry.<sup>78 79</sup> Appropriately classifying cigarettes as addictive increased the focus on industry culpability<sup>78 80</sup> and supported litigation, regulatory, and policy efforts that have been effective in reducing tobacco use globally.<sup>81 82</sup>

If the science supports reclassifying UPFs as addictive substances, it may support the use of similar approaches to address UPF addiction (box 3). This would particularly highlight the need for regulatory safeguards to curtail industry practices such as the creation of UPFs that maximise "craveability" by hitting consumers' "bliss point," and the aggressive marketing of such products to children.<sup>97 98</sup> As past addiction epidemics have shown, multipronged action will be needed to address the factors that allow the spread of potentially addictive UPFs to occur unchecked.

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Ashley N Gearhardt, professor<sup>1</sup>  
Nassib B Bueno, professor<sup>2</sup>

Alexandra G DiFelicantonio, assistant professor<sup>3</sup>  
Christina A Roberto, associate professor<sup>4</sup>  
Susana Jiménez-Murcia, professor<sup>5,6,7</sup>

Fernando Fernandez-Aranda, professor<sup>5,6,7</sup>  
<sup>1</sup>Department of Psychology, University of Michigan, Ann Arbor, Michigan, USA

<sup>2</sup>Faculdade de Nutrição, Universidade Federal de Alagoas, Maceió, Brazil

<sup>3</sup>Fralin Biomedical Research Institute at VTC, Department of Human, Nutrition Foods, and Exercise, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA

<sup>4</sup>Department of Medical Ethics and Health Policy, Perelman School of Medicine, University of Pennsylvania, Philadelphia, USA

<sup>5</sup>Department of Clinical Psychology, University Hospital of Bellvitge-IDIBELL, Barcelona, Spain

<sup>6</sup>Department of Clinical Sciences, School of Medicine and Health Sciences, University of Barcelona, Barcelona, Spain

<sup>7</sup>Ciber Fisiopatología Obesidad y Nutrición, Instituto Salud Carlos III, Barcelona, Spain

Correspondence to: A N Gearhardt  
ageahar@umich.edu



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- Gearhardt AN, Schulte EM. Is food addictive? A review of the science. *Annu Rev Nutr* 2021;41:387-410. doi:10.1146/annurev-nutr-110420-111710
- American Psychiatric Association. *Diagnostic and statistical manual of mental disorders (DSM-5)*. APA, 2013.
- Gearhardt AN, Corbin WR, Brownell KD. Development of the Yale Food Addiction Scale Version 2.0. *Psychol Addict Behav* 2016;30:113-21. doi:10.1037/adb0000136
- Meule A, Gearhardt AN. Ten years of the Yale Food Addiction Scale: a review of version 2.0. *Curr Addict Rep* 2019;6:218-28. doi:10.1007/s40429-019-00261-3.
- Granero R, Jiménez-Murcia S, Gearhardt AN, et al. Validation of the Spanish version of the Yale Food Addiction Scale 2.0 (YFAS 2.0) and clinical correlates in a sample of eating disorder, gambling disorder, and healthy control participants. *Front Psychiatry* 2018;9:208. doi:10.3389/fpsy.2018.00208
- Haghighinejad H, Tarakemehzadeh M, Jafari P, Jafari M, Ramzi M, Hedayati A. Persian version of the Yale Food Addiction Scale 2.0: psychometric analysis and setting cutoff point for the food cravings questionnaire-trait-reduced. *Psychiatry Investig* 2021;18:179-86. doi:10.30773/pi.2020.0198
- Li S, Schulte EM, Cui G, Li Z, Cheng Z, Xu H. Psychometric properties of the Chinese version of the modified Yale Food Addiction Scale version 2.0 (C-mYFAS 2.0): prevalence of food addiction and relationship with resilience and social support. *Eat Weight Disord* 2022;27:273-84. doi:10.1007/s40519-021-01174-9
- Praxedes DRS, Silva-Júnior AE, Macena ML, et al. Prevalence of food addiction determined by the Yale Food Addiction Scale and associated factors: a systematic review with meta-analysis. *Eur Eat Disord Rev* 2022;30:85-95. doi:10.1002/erv.2878
- Yekaninejad MS, Badrooj N, Vosoughi F, Lin CY, Potenza MN, Pakpour AH. Prevalence of food addiction in children and adolescents: a systematic review and meta-analysis. *Obes Rev* 2021;22:e13183. doi:10.1111/obr.13183
- Grant BF, Goldstein RB, Saha TD, et al. Epidemiology of DSM-5 alcohol use disorder: results from the national epidemiologic survey on alcohol and related conditions III. *JAMA Psychiatry* 2015;72:757-66. doi:10.1001/jamapsychiatry.2015.0584
- WHO. *WHO report on the global tobacco epidemic, 2019: offer help to quit tobacco use*. World Health Organization, 2019.
- Praxedes DR, Silva-Júnior AE, Macena ML, Gearhardt AN, Bueno NB. Prevalence of food addiction among patients undergoing metabolic/bariatric surgery: a systematic review and meta-analysis. *Obes Rev* 2023;24:e13529. doi:10.1111/obr.13529
- Minhas M, Murphy CM, Balodis IM, Samokhvalov AV, MacKillop J. Food addiction in a large community sample of Canadian adults: prevalence and relationship with obesity, body composition, quality of life and impulsivity. *Addiction* 2021;116:2870-9. doi:10.1111/add.15446
- Horsager C, Bruun JM, Færk E, Hagstrøm S, Lauritsen MB, Østergaard SD. Food addiction is strongly associated with type 2 diabetes. *Clin Nutr* 2023;42:717-21. doi:10.1016/j.clnu.2023.03.014
- Horsager C, Færk E, Lauritsen MB, Østergaard SD. Food addiction comorbid to mental disorders: a nationwide survey and register-based study. *Int J Eat Disord* 2021;54:545-60. doi:10.1002/eat.23472
- Schulte EM, Avena NM, Gearhardt AN. Which foods may be addictive? The roles of processing, fat content, and glycemic load. *PLoS One* 2015;10:e0117959. doi:10.1371/journal.pone.0117959
- Schulte EM, Smeal JK, Gearhardt AN. Foods are differentially associated with subjective effect report questions of abuse liability. *PLoS One* 2017;12:e0184220. doi:10.1371/journal.pone.0184220
- Allison S, Timmerman GM. Anatomy of a binge: food environment and characteristics of nonpurge binge episodes. *Eat Behav* 2007;8:31-8. doi:10.1016/j.eatbeh.2005.01.004
- Meule A. Twenty years of the food cravings questionnaires: a comprehensive review. *Curr Addict Rep* 2020;7:30-43. doi:10.1007/s40429-020-00294-z
- Di Chiara G, Imperato A. Drugs abused by humans preferentially increase synaptic dopamine concentrations in the mesolimbic system of freely moving rats. *Proc Natl Acad Sci U S A* 1988;85:5274-8. doi:10.1073/pnas.85.14.5274
- Bassareo V, De Luca MA, Aresu M, Aste A, Ariu T, Di Chiara G. Differential adaptive properties of accumbens shell dopamine responses to ethanol as a drug and as a motivational stimulus. *Eur J Neurosci* 2003;17:1465-72. doi:10.1046/j.1460-9568.2003.02556.x
- Hajnal A, Smith GP, Norgren R. Oral sucrose stimulation increases accumbens dopamine in the rat. *Am J Physiol Regul Integr Comp Physiol* 2004;286:R31-7. doi:10.1152/ajpregu.00282.2003
- Bassareo V, Di Chiara G. Differential influence of associative and nonassociative learning mechanisms on the responsiveness of prefrontal and accumbal dopamine transmission to food stimuli in rats fed ad libitum. *J Neurosci* 1997;17:851-61. doi:10.1523/JNEUROSCI.17-02-00851.1997

- 24 Bassareo V, De Luca MA, Di Chiara G. Differential expression of motivational stimulus properties by dopamine in nucleus accumbens shell versus core and prefrontal cortex. *J Neurosci* 2002;22:4709-19. doi:10.1523/JNEUROSCI.22-11-04709.2002
- 25 De Luca MA. Habituation of the responsiveness of mesolimbic and mesocortical dopamine transmission to taste stimuli. *Front Integr Neurosci* 2014;8:21.
- 26 Martínez Steele E, Baraldi LG, Louzada ML, Moubarac J-C, Mozaffarian D, Monteiro CA. Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study. *BMJ Open* 2016;6:e009892. doi:10.1136/bmjopen-2015-009892
- 27 Martínez Steele E, Popkin BM, Swinburn B, Monteiro CA. The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence from a nationally representative cross-sectional study. *Popul Health Metr* 2017;15:6. doi:10.1186/s12963-017-0119-3
- 28 Touvier M, da Costa Louzada ML, Baker P, Juul F, Srouf B. Ultra-processed foods and cardiometabolic health: public health policies to reduce dietary intake cannot wait. *BMJ* 2023;383:e075294.
- 29 DiFeliceantonio AG, Coppin G, Rigoux L, et al. Supra-additive effects of combining fat and carbohydrate on food reward. *Cell Metab* 2018;28:33-44.e3. doi:10.1016/j.cmet.2018.05.018
- 30 Nelson RA, Boyd SJ, Ziegelstein RC, et al. Effect of rate of administration on subjective and physiological effects of intravenous cocaine in humans. *Drug Alcohol Depend* 2006;82:19-24. doi:10.1016/j.drugalcdep.2005.08.004
- 31 de Wit H, Bodker B, Ambre J. Rate of increase of plasma drug level influences subjective response in humans. *Psychopharmacology (Berl)* 1992;107:352-8. doi:10.1007/BF02245161
- 32 Kelly AL, Baugh ME, Oster ME, DiFeliceantonio AG. The impact of caloric availability on eating behavior and ultra-processed food reward. *Appetite* 2022;178:106274. doi:10.1016/j.appet.2022.106274
- 33 Grundy MML, Lapsley K, Ellis PR. A review of the impact of processing on nutrient bioaccessibility and digestion of almonds. *Int J Food Sci Technol* 2016;51:1937-46. doi:10.1111/ijfs.13192
- 34 Zhang L, Han W, Lin C, Li F, de Araujo IE. Sugar metabolism regulates flavor preferences and portal glucose sensing. *Front Integr Neurosci* 2018;12:57. doi:10.3389/fnint.2018.00057
- 35 Han W, Tellez LA, Perkins MH, et al. A neural circuit for gut-induced reward. *Cell* 2018;175:665-678. e23. doi:10.1016/j.cell.2018.08.049
- 36 Monteiro CA, Cannon G, Levy RB, et al. Ultra-processed foods: what they are and how to identify them. *Public Health Nutr* 2019;22:936-41. doi:10.1017/S1368980018003762
- 37 Yunker AG, Patel R, Page KA. Effects of non-nutritive sweeteners on sweet taste processing and neuroendocrine regulation of eating behavior. *Curr Nutr Rep* 2020;9:278-89. doi:10.1007/s13668-020-00323-3
- 38 Yunker AG, Alves JM, Luo S, et al. Obesity and sex-related associations with differential effects of sucralose vs sucrose on appetite and reward processing: a randomized crossover trial. *JAMA Netw Open* 2021;4:e2126313. doi:10.1001/jamanetworkopen.2021.26313
- 39 Torii K. Brain activation by the umami taste substance monosodium L-glutamate via gustatory and visceral signaling pathways, and its physiological significance due to homeostasis after a meal. *J Oral Biosci* 2012;54:144-50. doi:10.1016/j.job.2012.03.005
- 40 Rees VW, Kreslake JM, Wayne GF, O'Connor RJ, Cummings KM, Connolly GN. Role of cigarette sensory cues in modifying puffing topography. *Drug Alcohol Depend* 2012;124:1-10. doi:10.1016/j.drugalcdep.2012.01.012
- 41 DeCicca P, Kenkel D, Liu F, Somerville J. Quantifying brand loyalty: evidence from the cigarette market. *J Health Econ* 2021;79:102512. doi:10.1016/j.jhealeco.2021.102512
- 42 Rose JE, Salley A, Behm FM, Bates JE, Westman EC. Reinforcing effects of nicotine and non-nicotine components of cigarette smoke. *Psychopharmacology (Berl)* 2010;210:1-12. doi:10.1007/s00213-010-1810-2
- 43 Zhang M, Harrison E, Biswas L, Tran T, Liu X. Menthol facilitates dopamine-releasing effect of nicotine in rat nucleus accumbens. *Pharmacol Biochem Behav* 2018;175:47-52. doi:10.1016/j.pbb.2018.09.004
- 44 Margolskee RF, Dyer J, Kokrashvili Z, et al. T1R3 and gustducin in gut sense sugars to regulate expression of Na<sup>+</sup>-glucose cotransporter 1. *Proc Natl Acad Sci U S A* 2007;104:15075-80. doi:10.1073/pnas.0706678104
- 45 Pepino MY. Metabolic effects of non-nutritive sweeteners. *Physiol Behav* 2015;152(Pt B):450-5. doi:10.1016/j.physbeh.2015.06.024
- 46 Cadham CJ, Sanchez-Romero LM, Fleischer NL, et al. The actual and anticipated effects of a menthol cigarette ban: a scoping review. *BMC Public Health* 2020;20:1055. doi:10.1186/s12889-020-09055-2
- 47 Messina M, Sievenpiper JL, Williamson P, Kiel J, Erdman JW Jr. Perspective: soy-based meat and dairy alternatives, despite classification as ultra-processed foods, deliver high-quality nutrition on par with unprocessed or minimally processed animal-based counterparts. *Adv Nutr* 2022;13:726-38. doi:10.1093/advances/nmac026
- 48 Delgado-Rodríguez R, Moreno-Padilla M, Moreno-Domínguez S, Cepeda-Benito A. Food addiction correlates with emotional and craving reactivity to industrially prepared (ultra-processed) and home-cooked (processed) foods but not unprocessed or minimally processed foods. *Food Qual Prefer* 2023;110:104961. doi:10.1016/j.foodqual.2023.104961
- 49 Cross GS, Proctor RN. *Packaged pleasures: How technology and marketing revolutionized desire*. University of Chicago Press, 2020.
- 50 Brownell KD, Warner KE. The perils of ignoring history: Big Tobacco played dirty and millions died. How similar is Big Food? *Milbank Q* 2009;87:259-94. doi:10.1111/j.1468-0009.2009.00555.x
- 51 Burns DM, Lee L, Shen LZ, et al. Cigarette smoking behavior in the United States. In: National Cancer Institute. Changes in cigarette-related disease risks and their implications for prevention and control. Smoking and Tobacco Control Monograph No 8, 1997:13-42. [https://cancercontrol.cancer.gov/sites/default/files/2020-08/m08\\_2.pdf](https://cancercontrol.cancer.gov/sites/default/files/2020-08/m08_2.pdf)
- 52 Dicken SJ, Batterham RL. Ultra-processed food: a global problem requiring a global solution. *Lancet Diabetes Endocrinol* 2022;10:691-4. doi:10.1016/S2213-8587(22)00248-0
- 53 Fagerberg P, Langlet B, Oravsky A, Sandborg J, Löf M, Ioakimidis I. Ultra-processed food advertisements dominate the food advertising landscape in two Stockholm areas with low vs high socioeconomic status. Is it time for regulatory action? *BMC Public Health* 2019;19:1717. doi:10.1186/s12889-019-8090-5
- 54 Cooksey-Stowers K, Schwartz MB, Brownell KD. Food swamps predict obesity rates better than food deserts in the United States. *Int J Environ Res Public Health* 2017;14:1366. doi:10.3390/ijerph14111366
- 55 Serafim P, Borges CA, Cabral-Miranda W, Jaime PC. Ultra-processed food availability and sociodemographic associated factors in a Brazilian municipality. *Front Nutr* 2022;9:858089. doi:10.3389/fnut.2022.858089
- 56 Leung CW, Fulay AP, Parnarouskis L, Martinez-Steele E, Gearhardt AN, Wolfson JA. Food insecurity and ultra-processed food consumption: the modifying role of participation in the Supplemental Nutrition Assistance Program (SNAP). *Am J Clin Nutr* 2022;116:197-205. doi:10.1093/ajcn/nqac049
- 57 Parnarouskis L, Gearhardt AN, Mason AE, et al. Association of food insecurity and food addiction symptoms: a secondary analysis of two samples of low-income female adults. *J Acad Nutr Diet* 2022;122:1885-92. doi:10.1016/j.jand.2022.04.015
- 58 Sinha R, Jastreboff AM. Stress as a common risk factor for obesity and addiction. *Biol Psychiatry* 2013;73:827-35. doi:10.1016/j.biopsych.2013.01.032
- 59 Martin MS, Maddocks E, Chen Y, Gilman SE, Colman I. Food insecurity and mental illness: disproportionate impacts in the context of perceived stress and social isolation. *Public Health* 2016;132:86-91. doi:10.1016/j.puhe.2015.11.014
- 60 Latner JD, Puhl RM, Murakami JM, O'Brien KS. Food addiction as a causal model of obesity. Effects on stigma, blame, and perceived psychopathology. *Appetite* 2014;77:77-82. doi:10.1016/j.appet.2014.03.004
- 61 Sly DF, Hopkins RS, Trapido E, Ray S. Influence of a counteradvertising media campaign on initiation of smoking: the Florida "truth" campaign. *Am J Public Health* 2001;91:233-8. doi:10.2105/AJPH.91.2.233
- 62 Munguía L, Gaspar-Pérez A, Jiménez-Murcia S, et al. Food addiction in eating disorders: a cluster analysis approach and treatment outcome. *Nutrients* 2022;14:1084. doi:10.3390/nu14051084
- 63 Camacho-Barcia L, Munguía L, Gaspar-Pérez A, Jimenez-Murcia S, Fernández-Aranda F. Impact of food addiction in therapy response in obesity and eating disorders. *Rev Addict Rep* 2022;9:268-74. doi:10.1007/s40429-022-00421-y
- 64 Hilker I, Sánchez I, Steward T, et al. Food addiction in bulimia nervosa: clinical correlates and association with response to a brief psychoeducational intervention. *Eur Eat Disord Rev* 2016;24:482-8. doi:10.1002/erv.2473
- 65 Treasure J, Leslie M, Chami R, Fernández-Aranda F. Are trans diagnostic models of eating disorders fit for purpose? A consideration of the evidence for food addiction. *Eur Eat Disord Rev* 2018;26:83-91. doi:10.1002/erv.2578
- 66 Fielding-Singh P, Patel ML, King AC, Gardner CD. Baseline psychosocial and demographic factors associated with study attrition and 12 month weight gain in the DIETFITS trial. *Obesity (Silver Spring)* 2019;27:1997-2004. doi:10.1002/oby.22650
- 67 Wiss D. Clinical considerations of ultra-processed food addiction across weight classes: an eating disorder treatment and care perspective. *Curr Addict Rep* 2022;9:255-67. doi:10.1007/s40429-022-00411-0
- 68 Schulte EM, Wadden TA, Allison KC. An evaluation of food addiction as a distinct psychiatric disorder. *Int J Eat Disord* 2020;53:1610-22. doi:10.1002/eat.23350
- 69 Meule A. A critical examination of the practical implications derived from the food addiction concept. *Curr Obes Rep* 2019;8:11-7. doi:10.1007/s13679-019-0326-2
- 70 Udo T, Grilo CM. Epidemiology of eating disorders among US adults. *Curr Opin Psychiatry* 2022;35:372-8. doi:10.1097/YCO.0000000000000814
- 71 LaFata EM, Gearhardt AN. Ultra-Processed Food Addiction: an Epidemic? *Psychother Psychosom* 2022;91:363-72. doi:10.1159/000527322
- 72 Gearhardt AN, Boswell RG, White MA. The association of "food addiction" with disordered eating and body mass index. *Eat Behav* 2014;15:427-33. doi:10.1016/j.eatbeh.2014.05.001

- 73 Schiestl ET, Wolfson JA, Gearhardt AN. The qualitative evaluation of the Yale Food addiction scale 2.0. *Appetite* 2022;175:106077. doi:10.1016/j.appet.2022.106077
- 74 Gearhardt AN, Yokum S, Orr PT, Stice E, Corbin WR, Brownell KD. Neural correlates of food addiction. *Arch Gen Psychiatry* 2011;68:808-16. doi:10.1001/archgenpsychiatry.2011.32
- 75 Carbone EA, Caroleo M, Rania M, et al. An open-label trial on the efficacy and tolerability of naltrexone/bupropion SR for treating altered eating behaviours and weight loss in binge eating disorder. *Eat Weight Disord* 2021;26:779-88. doi:10.1007/s40519-020-00910-x
- 76 Klausen MK, Thomsen M, Wortwein G, Fink-Jensen A. The role of glucagon-like peptide 1 (GLP-1) in addictive disorders. *Br J Pharmacol* 2022;179:625-41. doi:10.1111/bph.15677
- 77 Eren-Yazicioglu CY, Yigit A, Dogruoz RE, Yapici-Eser H. Can GLP-1 be a target for reward system related disorders? A qualitative synthesis and systematic review analysis of studies on palatable food, drugs of abuse, and alcohol. *Front Behav Neurosci* 2021;14:614884. doi:10.3389/fnbeh.2020.614884
- 78 Henningfield JE, Rose CA, Zeller M. Tobacco industry litigation position on addiction: continued dependence on past views. *Tob Control* 2006;15(Suppl 4):iv27-36. doi:10.1136/tc.2005.013789
- 79 Hurt RD, Robertson CR. Prying open the door to the tobacco industry's secrets about nicotine: the Minnesota Tobacco Trial. *JAMA* 1998;280:1173-81. doi:10.1001/jama.280.13.1173
- 80 Marks JH. Lessons from corporate influence in the opioid epidemic: toward a norm of separation. *J Bioeth Inq* 2020;17:173-89. doi:10.1007/s11673-020-09982-x
- 81 Warner KE, Mendez D. Tobacco control policy in developed countries: yesterday, today, and tomorrow. *Nicotine Tob Res* 2010;12:876-87. doi:10.1093/ntr/ntq125
- 82 Warner KE, Tam J. The impact of tobacco control research on policy: 20 years of progress. *Tob Control* 2012;21:103-9. doi:10.1136/tobaccocontrol-2011-050396
- 83 Hattersley L, Mandeville KL. Global coverage and design of sugar-sweetened beverage taxes. *JAMA Netw Open* 2023;6:e231412. doi:10.1001/jamanetworkopen.2023.1412
- 84 Andreyeva T, Marple K, Marinello S, Moore TE, Powell LM. Outcomes following taxation of sugar-sweetened beverages: a systematic review and meta-analysis. *JAMA Netw Open* 2022;5:e2215276. doi:10.1001/jamanetworkopen.2022.15276
- 85 Gračner T, Marquez-Padilla F, Hernandez-Cortes D. Changes in weight-related outcomes among adolescents following consumer price increases of taxed sugar-sweetened beverages. *JAMA Pediatr* 2022;176:150-8. doi:10.1001/jamapediatrics.2021.5044
- 86 Petimar J, Gibson LA, Wolff MS, et al. Changes in dental outcomes after implementation of the Philadelphia beverage tax. *Am J Prev Med* 2023;65:221-9. doi:10.1016/j.amepre.2023.02.009
- 87 An R, Liu J, Liu R, Barker AR, Figueroa RB, McBride TD. Impact of sugar-sweetened beverage warning labels on consumer behaviors: a systematic review and meta-analysis. *Am J Prev Med* 2021;60:115-26. doi:10.1016/j.amepre.2020.07.003
- 88 Clarke N, Pechey E, Kosite D, et al. Impact of health warning labels on selection and consumption of food and alcohol products: systematic review with meta-analysis. *Health Psychol Rev* 2021;15:430-53. doi:10.1080/17437199.2020.1780147
- 89 Grummon AH, Hall MG. Sugary drink warnings: a meta-analysis of experimental studies. *PLoS Med* 2020;17:e1003120. doi:10.1371/journal.pmed.1003120
- 90 Donnelly GE, Zatz LY, Svirsky D, John LK. The effect of graphic warnings on sugary-drink purchasing. *Psychol Sci* 2018;29:1321-33. doi:10.1177/0956797618766361
- 91 He FJ, Pombo-Rodrigues S, Macgregor GA. Salt reduction in England from 2003 to 2011: its relationship to blood pressure, stroke and ischaemic heart disease mortality. *BMJ Open* 2014;4:e004549. doi:10.1136/bmjopen-2013-004549
- 92 Restrepo BJ, Rieger M. Trans fat and cardiovascular disease mortality: evidence from bans in restaurants in New York. *J Health Econ* 2016;45:176-96. doi:10.1016/j.jhealeco.2015.09.005
- 93 Restrepo BJ, Rieger M. Denmark's policy on artificial trans fat and cardiovascular disease. *Am J Prev Med* 2016;50:69-76. doi:10.1016/j.amepre.2015.06.018
- 94 Chandran A, Burjak M, Petimar J, et al. Changes in body mass index among school-aged youths following implementation of the Healthy, Hunger-Free Kids Act of 2010. *JAMA Pediatr* 2023;177:401-9. doi:10.1001/jamapediatrics.2022.5828
- 95 Taillie LS, Reyes M, Colchero MA, Popkin B, Corvalán C. An evaluation of Chile's law of food labeling and advertising on sugar-sweetened beverage purchases from 2015 to 2017: a before-and-after study. *PLoS Med* 2020;17:e1003015. doi:10.1371/journal.pmed.1003015
- 96 Taillie LS, Bercholz M, Popkin B, Reyes M, Colchero MA, Corvalán C. Changes in food purchases after the Chilean policies on food labelling, marketing, and sales in schools: a before and after study. *Lancet Planet Health* 2021;5:e526-33. doi:10.1016/S2542-5196(21)00172-8
- 97 Moss M. *Hooked: food, free will, and how the food giants exploit our addictions*. Random House, 2021.
- 98 Moss M. *Salt, sugar, fat: How the food giants hooked us*. Random House, 2013.
- 99 Roberto CA, Ng SW, Ganderats-Fuentes M, et al. The influence of front-of-package nutrition labeling on consumer behavior and product reformulation. *Annu Rev Nutr* 2021;41:529-50. doi:10.1146/annurev-nutr-111120-094932

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