THE MILBANK QUARTERLY
A MULTIDISCIPLINARY JOURNAL OF POPULATION HEALTH AND HEALTH POLICY

Original Research

From Tobacco to Ultraprocessed Food: How Industry Engineering Fuels the Epidemic of Preventable Disease

ASHLEY N. GEARHARDT,* KELLY D. BROWNELL,† and ALLAN M. BRANDT‡

**University of Michigan; †Sanford School of Public Policy, Duke University; ‡Harvard Medical School, Harvard University*

Policy Points:

- Ultraprocessed foods (UPFs) are engineered to heighten reward and accelerate delivery of reinforcing ingredients, driving compulsive consumption and disrupting appetite regulation. This is a growing challenge for health policy.
- UPFs share key engineering strategies adopted from the tobacco industry, such as dose optimization and hedonic manipulation. These parallels should inform how we classify and regulate UPFs.
- Policy tools that helped reduce tobacco-related harm, including restrictions on child-targeted marketing, taxes, improved labeling, limits on availability in schools and hospitals, and litigation, should be adapted to address the public-health threat posed by UPFs.

Context: Ultraprocessed foods (UPFs) now dominate the global food supply and are strongly associated with risks for heart disease, cancers, metabolic disease, diabetes, and obesity. UPFs are likely associated with rates of neurologic issues such as dementia and Parkinson's disease and predict premature death. Drawing on the history of tobacco regulation, we examine how the design, marketing, and distribution of UPFs mirror those of industrial tobacco products. Such information speaks to the sophistication and aims of food product manipulation and its consequences.

Methods: This review synthesizes findings from addiction science, nutrition, and public health history to identify structural and sensory features that increase the reinforcing potential

The Milbank Quarterly, Vol. 00, No. 0, 2026 (pp. 1-40)

of both cigarettes and UPFs. We focus on five key areas: dose optimization, delivery speed, hedonic engineering, environmental ubiquity, and deceptive reformulation.

Findings: Cigarettes and UPFs are not simply natural products but highly engineered delivery systems designed specifically to maximize biological and psychological reinforcement and habitual overuse. Both industries have used similar strategies to increase product appeal, evade regulation, and shape public perception, including adding sensory additives, accelerating reward delivery, expanding contextual access, and deploying health-washing claims. These design features collectively hijack human biology, undermine individual agency, and contribute heavily to disease and health care costs.

Conclusions: UPFs should be evaluated not only through a nutritional lens but also as addictive, industrially engineered substances. Lessons from tobacco regulation, including litigation, marketing restrictions, and structural interventions, offer a roadmap for reducing UPF-related harm. Public health efforts must shift from individual responsibility to food industry accountability, recognizing UPFs as potent drivers of preventable disease.

Keywords: ultraprocessed foods, cigarettes, tobacco regulation, addiction, public policy, commercial determinants of health.

Engineered Addictions

Ultraprocessed food (UPFs) and beverages now dominate the food supply in many industrialized nations and are rapidly spreading across the globe.[1,2] These products are not simply modified foods—they are carefully engineered to maximize hedonic impact, consumption, and profitability through industrial processing.[3,4] A growing body of evidence links UPFs to the global rise in diet-related diseases,[5] and many individuals report difficulty moderating their intake, often describing behaviors consistent with addiction.[6] Despite this, scientific and public health responses to UPFs remain fragmented, in part owing to controversy and industry-driven doubt that obscure both the risks and the mechanisms underlying these products' appeal.[7,8] This dynamic has hampered effective policy action and delayed meaningful intervention.

Tobacco cigarettes and UPFs share many key features: both are industrially engineered substances that deliver powerful sensory experiences and have been, in some cases, produced or owned by the same corporations.[9–11] Tobacco companies (R.J. Reynolds and Philip Morris) acquired companies such as Kraft, General Foods, and Nabisco and were top manufacturers and marketers of UPFs from the 1980s through the mid-2000s.[10–11] The science around UPFs has been primarily shaped by nutrition science, which often frames food in terms of nutrients and physiological needs. However, UPFs may be viewed as well through the lens of addiction science, which considers how processed substances are optimized for compulsive consumption.

The history of tobacco regulation offers a compelling parallel for understanding UPFs. Reducing cigarette use stands as one of the most significant public health achievements of the 20th century, but it required decades of scientific advance, advocacy, policy change, and litigation against a powerful industry determined to evade accountability and protect its profits.[12] In the decades between known harm and meaningful action, millions more became addicted, and rates of preventable disease soared. These patterns are now echoed in the proliferation of UPFs.[13] In the sections that follow, we examine how UPFs are deliberately engineered for maximum appeal and profitability, often using strategies analogous to those employed to optimize cigarettes. We propose that these parallels offer unique insight into how UPFs have come to dominate modern diets and why so many consumers struggle to moderate their intake. Based on this analysis (Table 1), we argue that many UPFs share more characteristics with cigarettes than with minimally processed fruits or vegetables and therefore warrant regulation commensurate with the significant public-health risks they pose.

There is ongoing debate about whether UPFs should be considered addictive.[9] Our analysis contributes to this debate by demonstrating how UPFs meet established addiction-science benchmarks, particularly when viewed through parallels with tobacco. By situating UPFs within this framework, we provide clarity on how their design features can drive compulsive use and inform both scientific and policy discussions. As with tobacco, recognizing addiction can shift the focus from individual blame to corporate accountability, providing the basis for policies that constrain manufacturers, restrict marketing, and prioritize structural interventions. We emphasize, however, that the harms of UPFs are clear irrespective of their addictive nature.

Conceptual Analysis

This article is a conceptual analysis that integrates historical, epidemiologic, and addiction science literature rather than a systematic review. The comparison is anchored in *The Cigarette Century*,[12] which provides a detailed historical account of how cigarettes were engineered for addictiveness. From this foundation, a framework of industrial strategies—such as dose manipulation, delivery speed, use of additives, and health washing—was developed as the basis for comparison with UPFs. To extend the analysis, key literature from addiction science on mechanisms of dependence (e.g., reinforcement, tolerance, withdrawal, and cue reactivity) was reviewed alongside epidemiologic and public health research on UPFs. Relevant sources were identified through targeted searches in PubMed and Google Scholar, using terms such as "food addiction," "ultra-processed foods," and "tobacco industry practices." Additional references were drawn from foundational works and the bibliographies of key studies. The analysis is organized thematically around mechanisms of addictive potential and industry strategies to illuminate both parallels and distinctions between tobacco and UPFs.

Table 1. **Comparison of Ultraprocessed Cigarettes, UPFs, and Minimally Processed Foods**

Design Element	Ultraprocessed Cigarettes	UPFs	Minimally Processed Foods
Primary reinforcer	Nicotine, optimized for rapid delivery	Refined carbohydrates and fats, often in potent combinations, optimized for rapid delivery	Naturally occurring nutrients like fiber, vitamins, and minerals; no concentrated reinforcers
Dose optimization	Nicotine dose standardized (1.0%-2.0%) to balance reward and aversion	Precise calibration of refined carbohydrates and added fats to maximize hedonic impact	No engineered dose; nutrient density and energy content vary naturally
Speed of delivery	Nicotine is rapidly absorbed through inhalation; industrial processing breaks down the tobacco plant matrix and uses freebasing (e.g., with ammonia) and additives to enhance nicotine's bioavailability and speed of delivery	Refined carbohydrates and added fats are rapidly digested; industrial processing breaks down the food matrix and uses additives to increase speed and efficiency of absorption	Slower digestion and absorption owing to intact food matrixes (e.g., fiber, protein, water)
Short hang time	Cigarettes produce a quick hit of reward nicotine that fades quickly, leading to a desire for more	Carbohydrates, fats, and flavor compounds in UPFs produce a quick hit of reward that fades and leads to a desire for more	Longer-lasting flavors; satiety signals reduce further intake

Continued

Table 1. (Continued)

Design Element	Ultraprocessed Cigarettes	UPFs	Minimally Processed Foods
Additives and hedonic engineering	Flavorants, menthol, and sweeteners added to reconstituted tobacco to enhance appeal	Artificial flavors, sweeteners, emulsifiers, colorants added to processed ingredient bases to amplify appeal	No added flavorants; sensory cues aligned with nutritional content
Engineered convenience	Shelf-stable, portable, and easily ignited; integrated into daily routines	Shelf-stable, portable, microwavable, and omnipresent in daily life	Perishable, require preparation; often consumed in structured settings
Health washing	"Light" cigarettes and filters marketed as safer but still addictive	Low-fat, sugar-free, vitamin-enhanced foods often maintain addictive profiles	No health claims needed; nutritional integrity is apparent
Spectrum of risk	Tobacco products vary in risk; cigarettes are most addictive and harmful	UPFs vary in risk; high refined carbohydrate-added fat products are most addictive and harmful	Low risk of addiction or overconsumption; support satiety and health

UPFs, ultraprocessed foods.

Addiction science is particularly valuable for understanding UPFs because it goes beyond identifying a single addictive agent (e.g., nicotine) to examine the entire engineered delivery vehicle (e.g., cigarette). Addiction science emphasizes how reinforcement, craving, and compulsive use are deliberately cultivated by product design.[9] Food industry documents make this intent explicit. A recent trade advertisement boasted about "turning consumer cravings into commercial wins,"[14] while a leading food industry newsletter noted that "for decades, indulgence has been the profit engine."[15] These statements highlight that the industry itself sees its profitability as dependent on engineering reward dysfunction, which is a central focus of addiction science. By making these mechanisms visible, addiction science provides critical insights that can extend beyond nutrition science and have informed life-saving policies in domains ranging from tobacco control to opioids.

From Plant to Product: The Power of Industrial Processing

The human reward and motivation system has been shaped by evolutionary pressures to identify and pursue substances and behaviors that promote survival.[16] These include essentials like water and nutrient-rich foods as well as socially and reproductively beneficial behaviors such as bonding and mating. At the center of this system lies the mesolimbic dopamine pathway, which is a neural circuit that assigns value to stimuli by releasing the neurotransmitter dopamine, enhancing the salience of cues and motivating organisms to repeat the behaviors that lead to a reward.[17–19] This process, known as reinforcement learning, has been critical in guiding adaptive behaviors throughout our evolutionary history. This neurobiological architecture allowed early humans to efficiently find resources and build social networks that supported survival. However, the same system is also susceptible to being hijacked by modern, industrially engineered products, like cigarettes and UPFs, that deliver intensely rewarding effects with both speed and precision.[16]

In the case of cigarettes, the primary reinforcing agent is nicotine, a psychoactive compound that binds to nicotinic acetylcholine receptors, preferentially activating dopaminergic neurons in the posterior ventral tegmental area.[20,21] This interaction triggers a surge of dopamine in the nucleus accumbens and prefrontal cortex, brain regions central to reward.[22] This release has been shown to be between approximately 150% and 250% above baseline in basic science animal models,[23–25] which is sufficient to contribute to compulsive patterns of intake characteristic of nicotine addiction.

Interestingly, nicotine's ability to activate the dopamine system may be a maladaptation of mechanisms that once helped early humans and other animals identify nutrient-rich plant sources.[26] Nicotine belongs to a class of compounds called alkaloids, which are bitter tasting chemicals produced by plants as a defense against herbivores.[27] Although toxic at high doses, many alkaloid-containing plants, such as tomatoes, potatoes, eggplants, and peppers, are also rich in nutrients.[28] These foods contain only trace amounts of nicotine (up to-100 ng/g, compared with more than 7 mg/g in many varieties of tobacco),[29,30] which are absorbed through the gut and metabolized in the liver.[28] The capacity to tolerate small doses of alkaloids may have conferred a survival advantage in food scarce environments, enabling early humans to access these valuable resources.[26] Moreover, the mild dopaminergic response elicited by such plants may have helped reinforce foraging behavior and memory, encouraging return to these food sources.[26]

Although nicotine's effects on the dopamine system may be incidental from an evolutionary standpoint, the system itself evolved to promote survival by reinforcing behaviors that ensured caloric and nutrient sufficiency.[31,32] Carbohydrates have long been a primary energy source, in part because they deliver fuel more quickly than fats or proteins and are also the preferred source of fuel for key tissues, such as the brain.[33,34] Simple carbohydrates, like sucrose, produce dopamine responses that are comparable with those triggered by nicotine, typically increasing levels by about 150% above baseline (with some studies showing up to 300% increase, depending on sugar concentration).[35–37] This strong dopaminergic response reflects an evolutionary adaptation: humans are born with a preference for sweet flavors, a trait believed to encourage the intake of energy-dense breast milk in infancy and to support survival in environments where calories were scarce.[38]

This quick energy return may contribute to the high level of carbohydrates consumed in many primate and early human diets.[34] Nonhuman primates, our closest evolutionary relatives, primarily subsist on natural carbohydrate sources such as grasses, tubers, and fruits.[39] High carbohydrate foods like ripe fruit and honey are especially prized but can be more difficult to obtain in the wild.[40] Similarly, archaeological and historical data suggest that early human hunter-gatherers relied heavily on wild plants rich in carbohydrates.[41] The agricultural revolution marked a shift toward cultivated staple crops like wheat, rice, and corn, further entrenching carbohydrates as dietary mainstays.[41]

Fat, another vital calorie source, provides more than twice the energy per gram as carbohydrates (9 kcal vs. 4 kcal), but it is digested and metabolized more slowly.[33,42] Fat also releases dopamine (around 120%-140% of baseline when consumed orally or 200% of baseline upon gastric infusion) but possibly at a slower rate than sucrose.[43,44] Although most nonhuman primates rely heavily on carbohydrates, many also consume some fats through insects, seeds, or small animals.[40] Early humans likely consumed more fat than primates, especially from nuts, seeds, insects, fish, and game, with the domestication of animals in the postagricultural era making fat more accessible via meat and dairy.[41]

Taken together, the ability to consume nicotine, carbohydrates, and fat appears to have important evolutionary advantages when ingested in minimally processed, naturally occurring forms. This highlights that it is not merely the presence of these reinforcing substances that leads to addiction. The form, dose, and delivery mechanism matter tremendously. The trace nicotine in eggplants and tomatoes, for example, is far too low to cause addiction. Similarly, the carbohydrates and fats in whole foods like bananas, corn, or avocados do not typically lead to compulsive overconsumption.[6,45,46] The problem arises when these substances are industrially processed and concentrated into forms that deliver unnaturally high and rapid rewards. Ultraprocessing transforms natural ingredients (e.g., tobacco leaves or corn) into products like cigarettes or UPFs, optimized for maximum palatability, reinforcement, and profitability. These products hijack ancient reward systems in ways that evolution could not have anticipated. In the following section, we will explore how industrial processing has created public-health crises around tobacco and UPFs and how understanding the underlying link may help guide effective responses to minimize the impact of these market-driven epidemics.

Reinforcing Ingredients and Dose Optimization

Tobacco and UPFs share a common origin story: both begin as natural, plant-based substances that demonstrate little addictive potential in their unprocessed forms. For centuries, tobacco leaves, corn, sugarcane, grains, and oil seeds played roles in human life without causing public health crises. What transformed these materials into major drivers of disease was not their inherent properties but the way they were industrially reengineered to enhance reinforcement, maximize both want and need, increase accessibility, and maximize profit.[3,4,12]

This transformation is characteristic of many addictive substances: the harm does not stem from the plant itself but from the ways humans alter it. In the case of tobacco, the raw leaf of the *Nicotiana* genus contains much higher levels of nicotine than related plants like tomatoes or eggplants.[47] Yet in its unprocessed form, tobacco is too potent for safe consumption with direct exposure causing nausea, poisoning, or even death. To make it consumable and pleasurable, the leaf must undergo extensive processing that carefully modulates dose and delivery.[12]

Humans have cultivated tobacco for over 2,500 years, initially for use in chewing or pipe smoking.[12,47,48] Traditional methods included drying the leaves through air, sun, or fire curing, aging them to reduce harshness, removing the central veins, and cutting the leaves into strips.[12,48] Varieties were often blended to optimize flavor and burn characteristics.[12,48] Over time, additional substances such as sugar, licorice, and cocoa were introduced to mask bitterness and enhance palatability, setting the stage for even more sophisticated forms of product engineering in the modern era.[12]

In the 17th century, the development of rolling papers allowed for hand-rolled cigarettes, which offered a more rapid and intense nicotine delivery than chewing or pipe smoking.[12,49] Relative to pipes, cigarettes provided a consistent burn, were easier to inhale, and allowed nicotine to reach the brain faster.[49] The invention of flue curing in the 1800s (i.e., applying controlled heat to dry tobacco leaves) made the resulting processed tobacco leaves more combustible, ideal for cigarette use.[12,48] However, production remained slow until the 1881 patent of a mechanized cigarette rolling machine, capable of producing thousands of cigarettes per day.[12,49] This technological leap set the stage for mass-produced, ultraprocessed cigarettes that could be produced cheaply, sold widely, and consumed easily.[12] However, modern cigarettes are not simply dried tobacco rolled into paper. Rather, they are chemically engineered products, optimized for appeal, convenience, and profitability.

As with tobacco, the foods driving modern epidemics of obesity, diabetes, and metabolic disease are not inherently harmful in their natural form. Humans have refined and processed plant and animal foods for millennia.[50] Traditional methods such as stone grinding grains, fermenting milk, cold pressing oil, or boiling sugarcane juice to make crystals produced more usable and palatable forms of food.[51,52] However, these processes were labor intensive, time consuming, and retained much of the food's original structure and nutrient complexity.[51,52] For example, flour was once coarse and perishable, sugar was expensive to extract, and butter took significant effort to churn from cream.[51,52]

The Industrial Revolution fundamentally reshaped the food landscape. By the late 19th century, new machinery, chemical processes, government subsidies, and trade liberalization enabled the mass production and sale of refined carbohydrates and fats, including roller-milled white flour from whole wheat, crystalline sugar from sugar beets and sugarcane, and hydrogenated or solvent-extracted oils from nuts and seeds.[52] These ingredients were stripped of fiber and micronutrients, rendered shelf-stable, and made available at a scale and price point never before seen.[52] As a result, the sources of carbohydrates and fats used in UPFs became markedly more potent, inexpensive, and easily manipulated compared with their minimally processed counterparts. For example, high-fructose corn syrup is produced by enzymatically converting glucose into fructose, yielding a sweeter and more stable compound ideal for sodas and snack foods.[53,54] Refined oils such as soybean or palm oil offer greater shelf stability and a more neutral flavor than less-processed fats like butter or olive oil, making them ideal delivery devices for engineered flavors.[55] These industrial ingredients are then combined with extreme precision to achieve optimized taste, mouthfeel, and longevity.[56,57] Much like the cigarette, these innovations did not merely accelerate production—they enabled the creation of an entirely new class of ultraprocessed substances, carefully designed for maximal hedonic impact.[4]

Dose: Hitting the Sweet Spot

Both cigarettes and UPFs are engineered with remarkable precision to deliver a "just right" dose of reinforcing substances: nicotine in the case of cigarettes, and refined carbohydrates and fats in the case of UPFs.[9,12] The goal in each case is to optimize reward that is potent enough to produce highly pleasurable and reinforcing effects but not so strong as to provoke aversion or overwhelm the user.

In cigarette design, this pharmacological balance is central to sustaining regular use. If there is too little nicotine, the smoker may not experience the stimulation, relaxation, or cognitive enhancement that reinforces smoking behavior.[58] If there is too much nicotine, the effects can quickly become unpleasant, causing nausea, dizziness, or a sense of being overwhelmed.[58,59] To avoid this, modern cigarettes are engineered precisely, with most containing between 1.0% and 2.0% nicotine by weight.[60] This tightly controlled range is made possible through aggressive selective breeding of high-nicotine strains like *Nicotiana tabacum*, combined with industrial blending and processing techniques.[47,48]

UPFs are similarly optimized, but their reinforcing ingredients—refined carbohydrates and fats—allow for greater variation. If there are too little of these ingredients, the product may fail to satisfy. If there are too much, the product can become greasy, cloying, or physically unpleasant.[56] The objective is to strike a sensory "sweet spot" that maximizes pleasure and craving while minimizing aversive responses. Unlike cigarettes, which must maintain a narrow nicotine concentration to balance reward and tolerance, UPFs operate across a much broader hedonic range. For example, sugar can be appealing at a wide range of concentrations, with some commercially available preparations as low as 10% (as in soda) or as high as 99% (as in hard candy).[61–63] This flexibility allows for endless product variation, enabling companies to fine tune combinations for every age group, context, and craving.

These products do not merely mimic the taste of whole foods, they surpass them. Basic science models show that liquid sugar concentrations around 10% by weight—comparable with Coca-Cola, Pepsi, and Mountain Dew—can reliably trigger addictive behaviors in animals, including bingelike consumption, withdrawal, and dopamine system alterations.[37] In contrast, naturally sweet liquids like cow's milk (∼4.8% lactose)[64] and breast milk (∼7% lactose)[65,66] are both typically less sweet and less rapidly absorbed than sodas, which deliver about 10% to 12% sugar, primarily in the form of high-fructose corn syrup.[67]

The disparity is even greater in solid foods. Candies like plain M&M's and Starburst fruit chews are approximately 55% sugar by weight, whereas marshmallow Peeps and candy corn can reach as high as 81%.[68] Even savory snacks like saltines and pretzels deliver roughly 70% carbohydrates (although their sugar concentrations are low).[66] By contrast, carbohydrate-rich whole foods, bananas (∼22%-23%), mangoes (∼15%-20%), potatoes (∼17%-20%), and corn (∼19%-25%), contain far lower levels.[68] In effect, UPFs can deliver more than three times the carbohydrate content of naturally occurring foods.

Interestingly, UPFs that deliver primarily fat with little carbohydrate are relatively rare and typically less popular. Fat-only beverages have little consumer appeal, and even high-fat solids like ultraprocessed cheddar cheese (~32% fat; ~3% carbohydrates)[68] or bacon (~34% fat; ~1% carbohydrates)[68] are usually consumed alongside refined carbohydrate-containing foods like crackers or bread. It is in combination with refined carbohydrates that fat becomes especially reinforcing: fat is a potent vehicle for delivering flavor.[43,69,70] Industry scientists precisely blend refined carbohydrates and fats to elicit the maximally pleasurable response without sensory overload.[56,71,72] This combination can result in UPFs with carbohydrate levels ranging from 25% to 50% carbohydrates and from 10% to 35% fats by weight, which is represented in the foods most commonly reported as addictive (i.e., chocolate, ice cream, potato chips, pizza).[6,45]

On a biological level, carbohydrates and fats activate separate gut–brain reward pathways. Refined carbohydrates stimulate dopamine release via the vagus nerve, whereas fats do so through intestinal lipid sensing and cholecystokinin signaling.[43,73] When consumed together, their effects are supra-additive: the mesolimbic dopamine response can rise to 300% above baseline, compared with 120% to 150% for fat alone.[43] This makes UPFs with high levels of refined carbohydrates and added fats some of the most potently rewarding substances in the modern diet. Notably, this refined carbohydrate-fat combination is almost nonexistent in nature. Whole foods typically contain one macronutrient in high concentration, not both.[9,74]

Speed of Delivery: Engineering for Rapid Reward

An underappreciated aspect of addictiveness is the speed at which a product delivers its rewarding ingredients. The faster a reinforcing substance reaches the brain, the steeper the rise is in dopamine and the more addictive the product becomes.[75] Both cigarettes and UPFs are engineered for delivery speed, employing sophisticated industrial innovations to accelerate the delivery of their active compounds and maximize reinforcement.

Cigarettes are designed to deliver nicotine to the brain within seconds. Inhaled smoke produces an immediate psychoactive effect, rapidly stimulating dopamine release and reinforcing use almost instantaneously.[58,76] To intensify this effect, the tobacco industry developed methods to strip tobacco from its natural plant matrix and reconstitute it into chemically uniform sheets.[77] These reconstituted tobacco sheets, known as "recon," are created by grinding tobacco leaf scraps into a pulp, combining them with additives and binders, and forming them into sheets that are rolled and cut like paper.[77,78] Recon enables precise control over nicotine levels, burn characteristics, and additive content, and it provides a consistent base for further chemical modification.[77]

One of the most significant of these modifications is the use of ammonia to "freebase" nicotine, increasing its bioavailability.[79] Freebased nicotine is thought to be absorbed more efficiently through the lungs, crosses the blood–brain barrier more readily, and is significantly more potent in triggering dopamine release than the nicotine naturally occurring in tobacco.[79] Manufacturers also manipulate the particle size of both tobacco and its additives. Smaller smoke particles have a relatively high surface area to mass ratio, facilitating absorption and delivery of gases in the lungs.[80] Additionally, these smaller particles penetrate deeper into the lungs where efficient clearance mechanisms are lacking.[81] Although this can intensify the pleasure of smoking, it can also increase health risks, delivering more toxins to sensitive lung tissue.[81] Taken together, these innovations reflect a deliberate engineering of cigarettes to maximize the speed, efficiency, and reinforcing effects of nicotine delivery.[12,79,82]

A parallel strategy is evident in the design of UPFs, which are engineered to accelerate the digestion, absorption, and metabolism of refined carbohydrates and fats. Just as tobacco's natural structure is dismantled to enhance delivery, UPFs undergo extensive processing that strips away fiber, protein, and water—elements that normally slow digestion.[3,9,74] By breaking down the food matrix, UPFs become softer, more easily consumed, and rapidly digested, which speeds the delivery of reinforcing ingredients like sugar and fat.[83,84] In addition, manufacturers can include enzymatic additives, such as amylases and proteases, that mimic the effects of saliva and digestive enzymes by breaking complex molecules into simpler, more rapidly absorbable forms.[85] For example, products like ready-to-eat cereals and puffed savory snacks use enzymatic processing to break down starches (much like saliva does) to produce smaller molecules that yield a crispy, melt-in-the-mouth texture. By breaking down the food matrix and enhancing bioavailability, UPFs could be considered "prechewed," "presalivated," and "predigested" to enable the delivery of refined carbohydrates and fats with enhanced speed and potency.

In stark contrast, minimally processed foods retain their natural structure, which includes intact fibers, proteins, and water content that slow the process of digestion and absorption.[4,83] These foods typically require more oral and gastrointestinal processing, leading to a more gradual rise in blood glucose and potentially a slower, more sustained dopamine response.[84,86,87] This moderated pace of digestion and absorption supports satiety, reduces reward-driven overconsumption, and aligns more closely with the body's evolved regulatory mechanisms.[82,88] In comparison, the rapid nutrient delivery of UPFs overwhelms these mechanisms, likely contributing to their high addictive potential and widespread overuse.[3,88]

Short Hang Time: Engineering "Moreish-ness"

One of the defining features of both cigarettes and UPFs is the fleeting nature of the pleasure they provide.[12,56] This brief hang time plays a critical role in sustaining compulsive use by delivering a rapid sensory peak followed by a swift decline, which, in turn, triggers renewed craving.[58,89]

The pleasurable effects of smoking can be intense but are notably short lived. Subjective sensations such as relief, enhanced focus, or mild euphoria begin within seconds and typically peak within minutes.[20] However, these effects fade quickly, reinforcing the urge to smoke again soon after.[58,90] Biologically, nicotine inhaled through cigarette smoke reaches the brain within seconds, rapidly stimulating dopamine release within the mesolimbic pathway.[59] This near-instantaneous neurochemical response strengthens the association between the act of smoking and its perceived reward.[20] As nicotine is cleared from the body, withdrawal symptoms such as irritability, fatigue, and mood dysregulation may emerge, prompting the individual to seek another cigarette.[58] This cycle of craving, brief stimulation, subsequent crash, and repeated use is a hallmark of addictive intake patterns.[16,91]

Likewise, UPFs are designed to deliver a similarly transient pattern of sensory stimulation. A frequently overlooked feature of these products is the deliberate engineering of flavor bursts that fade rapidly through flavor engineering.[92] Industry professionals have openly acknowledged the intentional engineering of flavors to fade rapidly to encourage continued consumption. In a *60 Minutes* segment titled "The Flavorists,"[93] flavorists Dawn Streich and Jim Hassel from Givaudan (one of the world's largest flavor companies) discussed with correspondent Morley Safer how flavor design is optimized for short sensory duration to encourage compulsive intake:

Streich: We want a burst in the beginning. And maybe a finish that doesn't linger too much so that you want more of it.
Hassel: You don't want a long linger, because you're not going to eat more of it if it lingers.
Safer: Aha. So I see, it's going to be a quick fix. And then—
Hassel: Have more.
Safer: And then have more. But that suggests something else?
Hassel: Exactly.
Safer: Which is called addiction?
Hassel: Exactly.
Safer: You're tryin' to create an addictive taste?
Hassel: That's a good word.[93]

The initial sensory burst can be achieved by concentrating refined carbohydrates and fats in combination with synthetic or enhanced flavor compounds that amplify taste intensity.[94–101] These compounds, particularly volatile aroma compounds, are rapidly detected by the olfactory system but dissipate quickly,[101] especially when not embedded in the fibrous matrixes typical of minimally processed foods.[102] Texture also plays a critical role. Many UPFs are designed to break down easily or melt rapidly, producing dynamic contrast (i.e., combinations of sensory opposites like crunchy and creamy) and delivering flavor-laden particles quickly.[103,104] Emulsifiers and stabilizers facilitate these rapid transitions in mouthfeel, enabling smooth, palatable textures that fade shortly after swallowing.[68,99,103–105] Plain M&M's illustrate this process well: high levels of sugar and fat are amplified by flavor enhancers, while the hard shell is engineered to shatter quickly and release a creamy chocolate center stabilized with emulsifiers that promote a melt-in-the-mouth experience. In contrast, minimally processed foods tend to require more chewing and release flavor compounds more gradually, promoting a prolonged sensory experience.[102] This more sustained sensory experience may diminish the drive for more, thus reducing the likelihood of impulsive, repetitive intake.

Physiological mechanisms further reinforce the sensory crash associated with UPFs. These products often lead to rapid spikes in blood glucose because of their high content of quickly absorbed carbohydrates.[84] Within one to two hours, this spike may give way to a compensatory drop—mild hypoglycemia—resulting in fatigue, irritability, and renewed cravings.[86] This physiological crash mirrors the nicotine withdrawal response, which similarly follows a sharp rise in dopamine and subsequent decline in mood.[58] Notably, even mild hypoglycemia has been shown to enhance reward-related brain responses to high-calorie food cues, further perpetuating the cycle of consumption.[86]

By contrast, minimally processed foods tend to release nutrients more gradually.[4] The carbohydrates found in fruits, vegetables, and whole grains digest at a slower pace, thereby stabilizing blood sugar and promoting satiety.[84] In contrast, both cigarettes and UPFs are intentionally engineered to do the opposite: they deliver intense, immediate gratification that fades rapidly. This contributes to a feedback loop of craving and consumption. Crucially, this short hang time is not a design flaw but rather a feature, strategically implemented to encourage repeated use.[56,57,93,106]

Additives and Hedonic Engineering: Optimizing Sensory Cues for Craving

Both cigarettes and UPFs exploit the human brain's sensitivity to sensory cues (e.g., taste, smell, mouthfeel, visual presentation) to create products that are not only pleasurable but also deeply reinforcing.[20,56,57,77,107–111] These sensory cues evolved to help early humans identify nutrient-rich, energy-dense, and nontoxic foods.[112] For example, sweetness and signaled ripeness, umami suggested easily digestible protein, and vibrant colors indicated essential micronutrients.[112,113] In environments of scarcity and risk, these cues guided adaptive foraging behaviors.[112]

In contemporary food and tobacco products, however, these same perceptual pathways are strategically manipulated. Additives such as flavor enhancers, preservatives, emulsifiers, stabilizers, humectants, and colorants are used not only to improve nutritional value or safety but to intensify sensory appeal, override satiety cues, and extend shelf life.[4,12,108]

In cigarette manufacturing, sensory additives are central to product appeal. Traditional ingredients like sugar, cocoa, and licorice have been supplemented with complex proprietary flavor blends developed by industrial flavor houses.[12,114,115] These formulations serve not only to enhance palatability but also to differentiate brands in a market where nicotine content is largely uniform. Because most cigarettes contain approximately 1% to 2% nicotine by weight, brand identity and consumer preference are shaped primarily through sensory design: carefully controlled combinations of flavor, texture, and aroma.[12,107,116]

Manufacturers use reconstituted tobacco (recon) as a flexible base for embedding a wide array of additives, allowing for precise control over a cigarette's taste, mouthfeel, aroma, and burn characteristics.[108] This process enables consistent sensory effects across products and supports extensive customization without altering nicotine dose.[108] Innovations such as flavor capsules—crushable beads embedded in cigarette filters—further allow users to release menthol or fruit flavors on demand, enhancing novelty and control.[114,115] Menthol, in particular, reduces throat irritation and facilitates deeper inhalation, increasing nicotine delivery and reinforcing use.[114] Importantly, menthol use has also been associated with greater difficulty quitting, highlighting the potent behavioral impact of sensory cues.[114,117]

Modern UPFs follow a similar trajectory. Just as recon enables customization in cigarettes, food additives allow precise manipulation of flavor, texture, and aroma in UPFs.[4,83,101] Compounds developed for tobacco are now deployed in food manufacturing.[11] The use of sensory additives can lead to the creation of products that are portrayed as naturally occurring foods but are predominantly delivery vehicles for reinforcing ingredients like sugar.[3,118] For instance, strawberry-flavored foods often contain no real fruit but simulate a strawberry's sensory profile using synthetic flavors, emulsifiers that produce a creamy mouthfeel, and vibrant red dyes.[110,111,119,120] These components can decouple taste from nutrition, overriding natural feedback systems and promoting continued intake.[106]

UPFs also mirror tobacco in manipulating physical and chemical sensations. For example, additives such as organic acids and sugars lower the pH of aerosols and convert nicotine to its salt form, reducing harshness while increasing blood nicotine yield.[121] In parallel, UPFs use emulsifiers, stabilizers, and thickeners to produce textures that mimic richness, such as creaminess or smoothness, while dissolving quickly and leaving little aftertaste.[48,105,111,122] This engineered ease of consumption reduces oral and digestive effort and diminishes natural signals of fullness (i.e., vanishing caloric density), signaling to the brain that fewer calories are being consumed and encouraging greater intake.[56,123–125]

Both industries also exploit the brain's dual evolutionary drives for familiarity and novelty. Familiarity promotes safety and comfort, and novelty fosters exploration and dietary diversity.[26,112,126,127] UPF manufacturers capitalize on this tension by producing endless variations on the same base product. Minor tweaks to flavoring agents, aroma compounds, or texture modifiers yield a wide range of seemingly new products—such as sour cream and onion chips, barbecue chips, or hot honey chips—that share nearly identical macronutrient profiles.[106] Brand mash-ups like Coca-Cola-flavored Oreos or Oreo-flavored Coca-Cola stimulate human curiosity for new products all while leveraging the familiarity of popular brands. Thus, modern UPFs hijack evolutionary drives for novelty and familiarity to encourage further intake of their products.

Brand loyalty is deeply anchored in sensory experiences. Many smokers develop lasting preferences for the sensory cues of their brand of cigarettes, which is often initiated in adolescence.[12,107,116] The flavor and mouthfeel cues associated with specific cigarette brands become embedded in memory and reward systems, sometimes proving more reinforcing than nicotine itself.[114,116,128] Similarly, UPF consumers form strong attachments to specific combinations of flavor, texture, and aroma, even when the core ingredients (e.g., sugar, fat) are chemically similar across brands.[106] For example, although most sodas contain around 10% sugar, brand preferences are driven by proprietary variations in acidity, carbonation, and flavoring.[129,130] However, people develop strong brand loyalty to specific types of even very similar sodas (e.g., Coca-Cola vs. Pepsi loyalists), which can be established in childhood and persist through adulthood.[129,131,132]

Visual cues further enhance these engineered experiences. As a recent article for an industry-focused newsletter stated, "Before we even take a bite, colour tells our brain what to crave."[113] Evolutionarily, humans have learned to equate colors with beneficial properties like flavor or nutrient profile. In whole foods, bright colors signal the presence of beneficial nutrients: orange for carotenoids, red and purple for polyphenols, green for chlorophyll.[133,134] Modern products exploit this learned behavior, using bright artificial colorants to signal flavor and intensity.[135] Bright reds, yellows, and greens now appear in everything from cereals and fruit snacks to cigarette packaging, and these colors are particularly prevalent in foods targeted at youth.[120,136] These visual signals are not merely decorative; they shape perception, expectations, and behavior.[113,135] Research has shown that increased visual variety heightens food appeal and increases consumption.[135] The use of vibrant coloring in UPFs can also become a key component of brand identity (e.g., the specific green of Mountain Dew, the colorful array of Froot Loops),[113,135] which may contribute to the industry's resistance to attempts by the government to ban certain artificial color additives from food.[113,137]

Critically, information on the extent of this sensory manipulation is not disclosed to consumers. Additive formulations are frequently protected as proprietary trade secrets, and product labels typically use vague descriptors such as "natural flavors," "artificial flavors," or "color added" without disclosing specific chemical names.[138,139] Federal regulations in the United States permit these generalized terms to protect industry formulas, limiting consumer transparency.[138–140] Many of these additives are designated as "generally recognized as safe" (GRAS), a classification that allows companies to bypass the formal food additive petition process of the US Food and Drug Administration (FDA).[138–140] Manufacturers often conduct their own safety assessments or outsource them to consultants with potential conflicts of interest, and notification to the FDA remains voluntary rather than required.[138–140] These GRAS determinations usually focus on short-term toxicity and rarely consider long-term, cumulative, or behavioral impacts, especially for vulnerable populations such as children.[138–140]

In both cigarettes and UPFs, these additives simulate rather than satisfy. They hijack evolved reward systems, generating sensations of pleasure that are immediate, intense, and short lived.[12,45,106] The outcome is a carefully engineered sensory experience that compels use not because of physiological necessity but because of desire.[9,56,57,74] By contrast, in whole foods, flavors and textures are tightly coupled with their nutritional value. These foods typically take longer to eat and digest, promoting satiety through intact feedback loops.[83,84,141] Their appeal lies in their alignment with evolved regulatory systems rather than their ability to hedonically override them.

Delivery Mechanics: Consistency and Density

A defining feature of both cigarettes and UPFs is the precision with which they are engineered to deliver a predictable experience.[12,56,129] This reliability is not incidental. It is a core mechanism by which both industries cultivate consumer loyalty and sustain habitual use. Through industrial processing and design, these products are optimized not only for sensory appeal but also for uniformity in delivery, ensuring that each use feels familiar, satisfying, and reinforcing.

Cigarettes, for example, are calibrated with extraordinary care to maintain a steady burn and tightly regulated nicotine delivery.[12,77,142] Burn enhancers, such as nitrates, and additives in cigarette papers, such as alkali citrates, help cigarettes stay lit and influence burn rate.[77] Cigarette circumference and tobacco density (i.e., how tightly the cigarette is packed) influence burn rate, draw resistance, and the number of puffs per cigarette.[143–145] More tightly packed cigarettes burn more slowly and yield more puffs, whereas longer cigarettes act as larger "portion sizes," increasing nicotine exposure and reinforcement per unit.[145]

These physical characteristics are refined through mechanized mass production, allowing manufacturers to deliver a highly standardized product.[12] Each cigarette in a pack is designed to burn the same way, taste the same, and offer the same throat sensation and mouthfeel.[12] This sensory consistency becomes integral to brand identity, as smokers come to rely on their preferred brand for a specific combination of burn rate, flavor, draw resistance, and tactile effects.[107,116,142,146] Over time, this predictability transforms the cigarette from a simple habit into a precision drug delivery device.[147]

Similarly, UPFs mirror these strategies in how they deliver reinforcing ingredients. These products often have higher energy density than naturally occurring foods, packing more "reward" into every bite,[148] which parallels how densely packed cigarettes deliver more puffs. Over time, portion sizes of UPFs have increased substantially,[149] paralleling the evolution of cigarettes from shorter sticks to longer, more potent units. By contrast, minimally processed foods such as fruits, vegetables, and legumes have not increased in size to the same extent. Natural foods typically induce satiety over time, limiting intake.[83,141] By contrast, UPFs are formulated to override satiety signals, making it easy to consume large quantities without feeling fullness.[56,57,150]

The sensory engineering of UPFs also extends into the auditory domain.[151] Increasingly, sound is used as part of the consumption experience and brand identity, which is a strategy known as sonic branding.[152] The crisp crunch of a potato chip, the fizz of a freshly opened soda, or the snap of a chocolate bar are not incidental. These acoustic cues can be deliberately engineered to signal freshness, texture, and indulgence.[152,153] For example, snack food manufacturers can optimize the fracture structure of chips to produce a high-frequency crunch associated with satisfaction and freshness.[154,155] Carbonated beverages are designed to deliver not just mouthfeel but also an auditory pop and hiss that evoke intensity and refreshment.[156] Even the sound of packaging (e.g., crinkling of wrapper, pop of a potato chip canister) can be selected or engineered to make distinct sounds that build anticipation and strengthen brand associations.[152,156,157] These sounds are amplified in advertisements and standardized in production to become part of the product's sensory signature, reinforcing both emotional connection and brand recognition.[158]

Although cigarettes do not offer the same range of audible consumption cues, auditory elements still play a subtle but meaningful role. The flick of a lighter, the snap of a flip-top box, the crinkle of cellophane, and the sound of a deep inhale all contribute to a smoker's ritualized sensory experience.[82] These cues become conditioned signals that enhance anticipation and reinforce the behavior.[159] However, it is within the UPF domain that sonic branding has become more deliberate, flexible, and commercially potent, which is an additional sensory lever used to shape perception, signal pleasure, and drive habitual intake.[152]

Like cigarettes, UPFs are optimized delivery packages that are precisely engineered to activate reward pathways, strengthen learned associations, and increase the likelihood of repeated use. Both cigarettes and UPFs are mass-produced products that consistently deliver optimized density, portion size, and sensory characteristics intended to drive consumer appeal and company profit. In contrast, minimally processed foods offer little in the way of engineered sensory amplification. Their density, size, sounds, textures, and flavors emerge naturally from their biological composition, which supports more gradual, regulated intake rather than compulsive overconsumption.

Engineering Convenience: Frictionless Access and Embedded Use

The widespread and habitual use of cigarettes and UPFs has been shaped not only by their chemical and sensory properties but also by the infrastructure built around them. Both products have been transformed from relatively perishable, occasionally consumed goods into durable, ultraconvenient staples embedded in daily routines. This shift was enabled by a combination of chemical additives, packaging innovations, and technological advancements that collectively removed barriers to access and facilitated seamless, habitual consumption.[12,56,57] Convenience, in this context, is not incidental but engineered to minimize friction at every point from product formulation to environmental availability.[12,160]

In tobacco, the use of preservatives and humectants marked a significant turning point in product design.[145,161] Compounds such as glycerol and propylene glycol retained moisture in the tobacco, preventing it from drying out and making for a more pleasurable smoking experience.[162,163] These additives also maintained humidity of tobacco during transportation and storage,[108] thus allowing these products to remain on the shelf for months across variable storage conditions (e.g., vending machines, gas station checkout counters, grocery store shelves). The result is a cigarette engineered to be highly accessible and convenient across a wide variety of contexts while increasing industry profitability.

Of note, many of these additives are also employed in UPFs to achieve similar effects. For example, propylene glycol is used to thicken, emulsify, and maintain moisture in a wide range of food products including ice cream, salad dressings, and processed snacks.[164] Similarly, sorbitol and guar gum can be used to extend shelf life and prevent spoilage of certain foods, such as baked goods.[105,165] These additives are often used with the same functional intent as cigarettes—to extend product shelf life and durability—making UPFs widely accessible and convenient across many of the same contexts where cigarettes are sold (e.g., vending machines, gas stations, grocery stores).

Packaging innovations have further reinforced stability, portability, and brand visibility in both industries. Cigarettes are enclosed in foil-lined packs, vacuum-sealed cartons, and crush-proof boxes that maintain product integrity while projecting brand identity.[12] Likewise, UPFs are stored in vacuum-sealed bags, plastic wrappers, and multilayered packaging designed to protect flavor, mouthfeel, and visual appeal.[166,167] In the context of UPFs, packaging is designed to embed artificial smells that will release at the moment of opening to deliver a pleasant, brand-associated olfactory cue with the product.[168] For both cigarettes and UPFs, packaging serves a dual role: preserving sensory quality and serving as a highly visible platform for marketing and brand recognition, which further reinforces consumer loyalty and impulse purchasing.[169–171]

Collectively, innovations in product formulation, production, and packaging have removed the practical barriers that once limited use of both cigarettes and UPFs. Smokers no longer must roll their own cigarettes or consume them before they go stale. They can carry packs in their pockets, keep them in desk drawers, and light up almost anywhere with minimal effort. Similarly, UPFs are easy to store, portion, and consume on demand, transforming them from occasional treats to daily fixtures in car consoles, office drawers, and kitchen cabinets. This seamless access has helped to normalize both products as routine rather than exceptional, embedding them within the rhythms of modern life.

Technological advances have also played a central role in promoting frictionless use. In tobacco, innovations in ignition devices (e.g., matchbooks, disposable butane lighters) transformed the act of smoking into portable, effortless behavior. Lighting a cigarette became a ritual, tightly coupled with daily activities such as meals, work breaks, or commutes.[172–175] Over time, smoking was no longer confined to specific settings: it became ubiquitous.[12]

A parallel infrastructure has been developed for UPFs. The microwave oven revolutionized food preparation, enabling frozen and packaged meals to be ready in minutes.[176] Drive-thru windows, vending machines, and delivery apps further reduced time and energy costs, allowing consumers to obtain UPFs without leaving their homes or vehicles.[177,178] These tools functioned much like the lighter in tobacco use, by removing the steps between desire and consumption, and removing barriers that could reduce intake.

Packaging design in UPFs also mimicked the portability and convenience of cigarette packs. For example, patented one-hand food packaging technology is designed to be easy to tear open, eat with one hand, and store in a cup holder for snacking on the go.[179] Automated snack dispensers in schools, offices, and gyms paralleled cigarette vending machines of earlier decades,[180] providing unexamined access that normalized consumption and bypassed social scrutiny.

Perhaps most consequentially, the ubiquity of cigarettes and UPFs has reshaped the contextual landscape of consumption. Neuroscience research demonstrates that cue-induced dopamine signaling can be highly context dependent. The presence of a cue is less likely to elicit craving unless the environment also signals that consumption is possible and appropriate.[181–183] For example, being in a no-smoking zone (e.g., flying on a plane) may suppress cravings associated with common triggers, whereas the same cue in a permissive context can lead to intense desire for the substance.[184] However, at its peak, the saturation of cigarettes across settings (e.g., offices, restaurants, even hospitals) transformed nearly every environment into a smoking-related context. Rather than tobacco use being restricted to certain contexts, most settings would facilitate cigarette cravings and make it harder to resist their use.[12] Therefore quitting smoking required extreme individual effort in the face of everpresent triggers and permissive contexts.[181,185]

A similar process has occurred with UPFs. Historically, eating was bounded by time, location, and social norms. Meals were prepared and consumed at home, often in a shared context, and snacking was discouraged.[186] Today, UPFs can be purchased from mobile apps, vending machines, and gas stations and consumed alone in bedrooms, cars, or workplaces. Foods that were once associated with celebration or rarity (such as cake) are now available anywhere at any time. This erosion of contextual boundaries eliminates natural points of inhibition, leaving individuals continuously exposed to cues and opportunities to consume.[187] This has reduced the ability of environmental context to assist individuals in resisting UPFs and instead placed the entire onus on the individual to resist constant bombardment by appealing cues.

Taken together, the chemical, mechanical, and environmental strategies employed by both the tobacco and UPF industries created a culture of frictionless use. Through innovations in shelf stability, packaging, and access infrastructure, both products became routine, impulse-driven, and omnipresent. The goal was not merely to extend shelf life but to engineer enduring habits by maximizing convenience. As a Coca-Cola executive famously put it, "The goal was to keep Coke within arm's reach of desire—to make sure it was always available, always present, always tempting."[129] Technological advances of the modern era have brought that vision to life with unprecedented success. In stark contrast, minimally processed foods perish more quickly, require active preparation, and are typically consumed in defined contexts.[88] They lack the infrastructure of instant access and engineered cues that promote compulsive engagement, and as a result, their use remains more naturally bounded—reinforcing satiety and intentionality rather than overconsumption.

Health Washing: Reformulation to Reduce the Appearance of Harm

Both the tobacco and food industries have long employed a strategy known as "health washing," in which products are reformulated and marketed in ways that create the illusion of reduced harm while preserving their core addictive properties.[188,189] These tactics are designed to manipulate public perception, reassure health-conscious consumers, and delay regulatory and legal action all while sustaining profit margins and levels of consumption.[13]

For tobacco, health washing gained traction in the 1950s with the introduction of cigarette filters, which were advertised as protective innovations that could trap tar and particulates before reaching the lungs.[12] In practice, filters offered little meaningful benefit. Many smokers adapted by inhaling more deeply or smoking more frequently, effectively offsetting any reductions in toxin exposure.[60,190,191] The subsequent emergence of "light" and "low-tar" cigarettes followed the same logic. Although marketed as safer options, these products prompted compensatory behaviors, such as more frequent or deeper puffs, without reducing actual harm.[189]

These changes created confusion among consumers and successfully stalled regulation, allowing the tobacco industry to retain consumers for decades.[190] More recently, this strategy has reemerged in the form of alternative nicotine-delivery systems, including e-cigarettes, synthetic nicotine products, and oral nicotine pouches.[192–194] Marketed as "smoke-free" or "tobacco-free," these products are frequently framed as cleaner or safer alternatives, despite limited evidence regarding their long-term health effects.[192–194] Synthetic nicotine, often labeled as "lab-created" or "pharmaceutical grade," is increasingly used to evade tobacco-specific regulations while still delivering potent, addictive effects.[194,195]

Some e-cigarette and vape manufacturers have taken these tactics further by incorporating additives like vitamins, essential oils, B12, or melatonin.[196] These so-called "functional" ingredients borrow the language of supplements to suggest therapeutic or health-promoting properties despite a lack of evidence.[197] This mirrors earlier industry efforts to rebrand cigarettes as "mild" or "clean"—framing changes that failed to reduce harm but effectively preserved market share, especially among young and health-conscious consumers.[48,198]

The food industry has adopted nearly identical strategies. Labels such as "low fat" and "sugar free" are widely used to market UPFs that still contain highly reinforcing combinations of ingredients.[199] These reformulations are often superficial, offering a cosmetic appearance of health while leaving the product's addictive structure and metabolic harms intact. Food products are also increasingly fortified with trending nutrients, such as added fiber or protein, which align with dominant health narratives and distract from the concentration of processed ingredients. Protein-enriched UPFs provide a salient example: although marketed as healthier options, clinical trials suggest they continue to promote overeating and carry similar health risks as conventional sweets.[200]

Just as vitamin-infused vapes aim to reframe nicotine delivery, functional additives in UPFs (such as probiotics or added vitamins) are used to elevate the health image of products that bear little resemblance to whole foods—for example, probiotic sodas.[201]

These ingredients contribute to a veneer of wellness while preserving and sometimes enhancing the product's appeal.[201]

The use of nonsugar sweeteners (NSS) represents another major front in the food industry's health-washing toolkit.[202] Once limited primarily to diet sodas, NSS are now added to a wide array of products—yogurts, condiments, and even children's snacks—to reduce "added sugar" while maintaining palatability through combinations with fat and other reinforcing ingredients.[99] Their widespread use in children's products is particularly concerning because the long-term effects of early NSS exposure remain poorly understood.[203,204] Whereas some studies suggest that NSS may modestly reduce short-term weight gain, others raise concerns about gut microbiome disruption, increased inflammation, and altered brain signaling.[202–205] In some animal studies, NSS are preferred over drugs like cocaine,[206,207] and recent neuroimaging research in humans suggests they may interfere with appetite regulation particularly among individuals with obesity.[208]

Despite these risks, NSS-containing products continue to proliferate, often positioned as healthier or more responsible choices, particularly when naturally derived (e.g., monk fruit extract, stevia). However, like filtered or "light" cigarettes, these reformulated foods are typically introduced without adequate long-term safety data.[209] Their primary function is not to improve public health outcomes but to preserve consumption patterns and forestall regulatory scrutiny, repeating a dangerous playbook already well-established in the history of tobacco.[13]

The UPF industry also employs another strategy: green washing. Products are marketed as environmentally friendly despite many UPFs contributing to environmental harm.[210] For example, sugar-sweetened beverages are packaged in plastics that pollute ecosystems and require large quantities of water for production.[211] Cigarettes are a major source of pollution, and no environmentally friendly version exists.[212] Thus, tobacco companies do not have the same opportunity to present a "green" alternative. This provides the UPF industry with a unique avenue to portray products as more beneficial than they truly are, enhancing their social legitimacy while distracting consumers from both health and ecologic harms.

In contrast, minimally processed foods rarely require such marketing tactics. Whole fruits, vegetables, legumes, and grains do not depend on fortified claims or engineered additives to convey value.[213] They are generally not accompanied by health-washing strategies because their nutritional integrity is apparent and their risks are negligible.[213,214] Moreover, they tend to have far lower environmental costs compared with UPFs and modern tobacco products.[215] Unlike UPFs and modern tobacco products, minimally processed foods do not need to be reinvented or disguised to appear wholesome.

Complexity and Spectrum of Risk: Identifying the Worst Offenders

One of the most common critiques of the UPF classification system is its breadth. Critics argue that the category is overly heterogeneous, encompassing a wide array of products—from plant-based milks to candy bars—that differ in nutritional quality and health impact.[216] This criticism merits serious consideration. However, such heterogeneity is not unique to UPFs: it is also a defining characteristic of the processed tobacco and nicotine product landscape, which spans a similarly wide spectrum of harm and addictive potential.

The FDA currently recognizes nearly 17,000 unique tobacco products, yet not all of them carry the same level of risk.[217] For example, nicotine replacement therapies, such as transdermal patches, often contain more nicotine than a single cigarette but have minimal addictive potential.[218,219] This is because they deliver nicotine slowly and steadily and lack the reinforcing sensory cues such as heat, flavor, and the hand-to-mouth ritual that characterize combustible cigarettes.[218,219] Processed tobacco products range from culturally embedded forms like hookah to loosely regulated items such as cigars, as well as emerging products like e-cigarettes and nicotine pouches. Many of these products occupy regulatory and scientific gray areas with unresolved questions surrounding dose-response thresholds, nicotine absorption rates, and the long-term effects of hundreds of chemical additives.[220–222] Despite this complexity, public-health efforts have advanced by identifying and prioritizing regulation of the most harmful and addictive products.[12] Cigarettes' precise combination of rapid nicotine delivery, potent sensory appeal, and cultural normalization have made them uniquely reinforcing and a persistent focus of prevention and control efforts.[12]

A similar spectrum of risk exists within the category of UPFs.[223] Not all UPFs are equally harmful. Some, like almond milk and some jarred pasta sauce, are highly processed but do not always contain the engineered combinations of refined carbohydrates and fats that drive compulsive intake. Similar to tobacco products, UPFs likely vary widely in terms of their health impact and addictive potential. Despite this complexity, it remains both possible and essential to identify those UPFs that pose the greatest risk. Products high in refined carbohydrates and added fats, such as soda, sweets, and fast food, are among the most addictive and disease-promoting items in the modern diet.[45,47,224,225] These should be prioritized in public-health messaging, consumer education, and regulatory policy. However, it is important to note that the strongest evidence linking UPFs to disease comes from dietary pattern research: populations with high UPF intake experience greater risks across multiple health outcomes.[5] This evidence suggests that policy should not only target specific high-risk products but also strive to reduce dependence on the UPF-dietary pattern as a whole.

Conclusion: Lessons From Tobacco for Confronting UPFs

Cigarettes are not merely nicotine-delivery devices but engineered delivery systems created for maximum appeal,[12] and UPFs are not just nutrients but intentionally designed, highly engineered and manipulated, hedonically optimized products.[3,88] Although food, unlike tobacco, is essential for survival, this distinction should not preclude meaningful action. In fact, it emphasizes the necessity because opting out of the modern food supply is difficult. When cigarette use was common and unrestricted, avoiding the harms of secondhand smoke was virtually impossible. Today, exposure to a food environment dominated by UPFs is relentless.[226] The tobacco industry demonstrated how a plant that is toxic in its raw form could be processed into one of the most addictive and lethal products in history. Applying the same levers of dose, delivery, and sensory engineering to UPFs has yielded similarly compulsive intake and disastrously harmful outcomes. UPFs should thus be viewed less as food and more as hedonically optimized consumables akin to cigarettes. In industries where product innovation outpaces long-term safety research, especially for children, precautionary principles are justified.[227] A large body of epidemiologic research from more than 50 countries now links high UPF consumption to rising rates of obesity, metabolic dysfunction, and neurobehavioral changes,[5] with recent estimates indicating that one American dies every four minutes from preventable disease associated with these products.[2]

Tobacco provides a warning, and tobacco control provides a source of hope. It is easy to forget how deeply cigarettes were once woven into American life, marketed as symbols of modernity, embedded in social rituals, and celebrated as an economic boon.[12] However, in the past 50 years, smoking rates in the United States have fallen by 73% among adults and 86% among youth.[228] This transformation was not accidental: targeted public-health campaigns reshaped cultural views of tobacco and eroded trust in the industry. Litigation exposed internal documents that revealed deliberate deception and paved the way for regulation. Taxation was particularly effective in altering the price point of cigarettes, which motivated many people to quit and prevented many children from starting to smoke.[229] At the same time, tobacco's history offers a stark warning. As domestic markets contracted, the industry expanded aggressively into countries with weaker public health infrastructures and exported addiction and disease worldwide. UPFs are now following this same trajectory. The time to act is not only in nations where UPFs already dominate but also in those where their market share is still expanding. Unlike tobacco, however, the solution is already in our hands: minimally and traditionally processed foods that have sustained human health for millennia. Legal action against health damages and misleading health claims, restrictions on UPF advertising, taxation of nutrient-poor UPFs, markedly reducing UPFs in schools and hospitals, and clearer labeling of ultraprocessing could all serve as next steps. Similar to tobacco, voluntary reform of the industry will not be sufficient. Policies that confront UPFs with the same seriousness that once applied to tobacco, while actively promoting real food, offer the most promising path out of the current crisis.

References

1. Monteiro CA, Levy RB, Claro RM, de Castro IRR, Cannon G. Increasing consumption of ultra-processed foods and likely impact on human health: evidence from Brazil. *Public Health Nutr*. 2011;14(1):5-13.
2. Nilson EAF, Delpino FM, Batis C, et al. Premature mortality attributable to ultraprocessed food consumption in 8 countries. *Am J Prev Med*. 2025;68(6):1091-1099.
3. Monteiro CA, Cannon G. The foods that are addictive. *Addiction*. 2023;118(4):603-604.
4. Monteiro CA, Cannon G, Levy RB, et al. Ultra-processed foods: what they are and how to identify them. *Public Health Nutr*. 2019;22(5):936-941.
5. Lane MM, Gamage E, Du S, et al. Ultra-processed food exposure and adverse health outcomes: umbrella review of epidemiological meta-analyses. *BMJ*. 2024;384:e077226.
6. LaFata EM, Gearhardt AN. Ultra-processed food addiction: an epidemic? *Psychother Psychosom*. 2022;91(6):363-372.
7. Mozaffarian D. The dietary guidelines for Americans—is the evidence bar too low or too high? *Am J Clin Nutr*. 2025;121(1):3-4.
8. Hunt D. How food companies use social media to influence policy debates: a framework of Australian ultra-processed food industry Twitter data. *Public Health Nutr*. 2021;24(10):3124-3135.
9. Gearhardt AN, DiFeliceantonio AG. Highly processed foods can be considered addictive substances based on established scientific criteria. *Addiction*. 2023;118(4):589-598.
10. Nguyen KH, Glantz SA, Palmer CN, Schmidt LA. Transferring racial/ethnic marketing strategies from tobacco to food corporations: Philip Morris and Kraft General Foods. *Am J Public Health*. 2020;110(3):329-336.
11. Nguyen KH, Glantz SA, Palmer CN, Schmidt LA. Tobacco industry involvement in children's sugary drinks market. *BMJ*. 2019;364:l736.
12. Brandt AM. *The Cigarette Century: the Rise, Fall, and Deadly Persistence of the Product That Defined America*. Basic Books; 2007.
13. 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(1):259-294.
14. Spiring J, Peruzzi C, Newland F, Chappell C, White G. Sweetest innovations 2025. Confectionery News. July 10, 2025. Accessed September 20, 2025. onlinexperiences.com/scripts/Server.nxp?LASCmd=AI:4;F:QS!10100&ShowUUID=F374CF17-3395-4C4E-

9C83-44D96A70063A&GroupID=Onyx&AffiliateData=Web-Webbox-SWCN2525_CN25

15. Hyslop G. The snackdown: are GLP-1s really killing snacks or is it just all hype? Bakery and Snacks. Updated August 6, 2025. Accessed September 20, 2025. bakeryandsnacks.com/Article/2025/08/26/are-glp-1s-really-the-end-of-bakery-snacks-and-confectionery/
16. Substance Abuse and Mental Health Servies Administration, Office of the Surgeon General. *Facing Addiction in America: The Surgeon General's Report on Alcohol, Drugs, and Health*. US Department of Health and Human Services; 2016.
17. Berridge KC, Kringelbach ML. Pleasure systems in the brain. *Neuron*. 2015;86(3):646-664.
18. Robinson TE, Berridge KC. The incentive-sensitization theory of addiction 30 years on. *Annu Rev Psychol*. 2025;76(1):29-58.
19. Schultz W. A dopamine mechanism for reward maximization. *Proc Natl Acad Sci USA*. 2024;121(20):e2316658121.
20. Rupprecht LE, Smith TT, Schassburger RL, Buffalari DM, Sved AF, Donny EC. Behavioral mechanisms underlying nicotine reinforcement. *Curr Top Behav Neurosci*. 2015;24:19-53.
21. Zhao-Shea R, Liu L, Soll LG, et al. Nicotine-mediated activation of dopaminergic neurons in distinct regions of the ventral tegmental area. *Neuropsychopharmacology*. 2011;36(5):1021-1032.
22. Mansvelder HD, De Rover M, McGehee DS, Brussaard AB. Cholinergic modulation of dopaminergic reward areas: upstream and downstream targets of nicotine addiction. *Eur J Pharmacol*. 2003;480(1-3):117-123.
23. 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 USA*. 1988;85(14):5274-5278.
24. 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(7):1465-1472.
25. Pontieri FE, Tanda G, Di Chiara G. Intravenous cocaine, morphine, and amphetamine preferentially increase extracellular dopamine in the "shell" as compared with the "core" of the rat nucleus accumbens. *Proc Natl Acad Sci USA*. 1995;92(26):12304-12308.
26. Davis C. Evolutionary and neuropsychological perspectives on addictive behaviors and addictive substances: relevance to the "food addiction" construct. *Subst Abuse Rehabil*. 2014;5:129-137.
27. Steppuhn A, Gase K, Krock B, Halitschke R, Baldwin IT. Nicotine's defensive function in nature. *PLoS Biol*. 2004;2(8):E217.
28. Chen C, Lin L. Alkaloids in diet. In: Xiao J, Sarker SD, Asakawa Y, eds. *Handbook of Dietary Phytochemicals*. Springer Singapore; 2021:1595-1629.
29. Blakely T, Bates M. *Nicotine and tar in cigarette tobacco: a literature review to inform policy development*. Ministry of Health of New Zealand; 1998.
30. Moldoveanu SC, Scott WA, Lawson DM. Nicotine analysis in several non-tobacco plant materials. *Beitr Tab Int*. 2016:27(2), 54-59.

31. de Araujo IE, Ferreira JG, Tellez LA, Ren X, Yeckel CW. The gut-brain dopamine axis: a regulatory system for caloric intake. *Physiol Behav*. 2012;106(3):394-399.
32. Minère M, Wilhelms H, Kuzmanovic B, et al. Thalamic opioids from POMC satiety neurons switch on sugar appetite. *Science*. 2025;387(6735):750-758.
33. Singh P, Kesharwani RK, Keservani RK. Protein, carbohydrates, and fats: energy metabolism. In: *Sustained Energy for Enhanced Human Functions and Activity*. Elsevier; 2017:103-115.
34. Hardy K, Brand-Miller J, Brown KD, Thomas MG, Copeland L. The importance of dietary carbohydrate in human evolution. *Q Rev Biol*. 2015;90(3):251-268.
35. Hajnal A, Smith GP, Norgren R. Oral sucrose stimulation increases accumbens dopamine in the rat. *Am J Physiol Regul Integr Comp Physiol*. 2004;286(1):R31-R37.
36. Hajnal A, Norgren R. Accumbens dopamine mechanisms in sucrose intake. *Brain Res*. 2001;904(1):76-84.
37. Avena NM, Rada P, Hoebel BG. Evidence for sugar addiction: behavioral and neurochemical effects of intermittent, excessive sugar intake. *Neurosci Biobehav Rev*. 2008;32(1):20-39.
38. Mennella JA, Bobowski NK, Reed DR. The development of sweet taste: from biology to hedonics. *Rev Endocr Metab Disord*. 2016;17(2):171-178.
39. Milton K. Nutritional characteristics of wild primate foods: do the diets of our closest living relatives have lessons for us? *Nutrition*. 1999;15(6):488-498.
40. McLennan MR. Is honey a fallback food for wild chimpanzees or just a sweet treat? *Am J Phys Anthropol*. 2015;158(4):685-695.
41. Pontzer H, Wood BM. Effects of evolution, ecology, and economy on human diet: insights from hunter-gatherers and other small-scale societies. *Ann Rev Nutr*. 2021;41:363-385.
42. Flatt JP. Use and storage of carbohydrate and fat. *Am J Clin Nutr*. 1995;61(4 Suppl): 952S-959S.
43. McDougle M, de Araujo A, Singh A, et al. Separate gut-brain circuits for fat and sugar reinforcement combine to promote overeating. *Cell Metab*. 2024;36(2):393-407.e7.
44. Leslie EH, Kelly A, DiFeliceantonio AG. Dopamine magnitude and timing. In: Gearhardt AN, Brownell KD, eds. *Food and Addiction: A Comprehensive Handbook*. 2nd ed. Oxford University Press; 2024:139.
45. Gearhardt AN, Schulte EM. Is food addictive? A review of the science. *Ann Rev Nutr*. 2021;41:387-410.
46. Schulte EM, Avena NM, Gearhardt AN. Which foods may be addictive? The roles of processing, fat content, and glycemic load. *PLoS One*. 2015;10(2):e0117959.
47. Dewey RE, Xie J. Molecular genetics of alkaloid biosynthesis in Nicotiana tabacum. *Phytochemistry*. 2013;94:10-27.
48. Slade J. The tobacco epidemic: lessons from history. *J Psychoactive Drugs*. 1989;21(3):281-291.

49. Goodman J. *Tobacco in History: the Cultures of Dependence*. Routledge; 2005.
50. Silva VL, Sereno AM, do Amaral Sobral PJ. Food industry and processing technology: on time to harmonize technology and social drivers. *Food Eng Rev*. 2018;10:1-13.
51. Geissler C, Powers HJ. *Human Nutrition*. Oxford University Press; 2023.
52. Huebbe P, Rimbach G. Historical reflection of food processing and the role of legumes as part of a healthy balanced diet. *Foods*. 2020;9(8):1056.
53. Casey JP. High fructose corn syrup. A case history of innovation. *Starch*. 1977;29(6):196-204.
54. Parker K, Salas M, Nwosu VC. High fructose corn syrup: production, uses and public health concerns. *Biotechnol Mol Biol Rev*. 2010;5(5):71-78.
55. Gharby S. Refining vegetable oils: chemical and physical refining. *ScientificWorldJournal*. 2022;2022:6627013.
56. Moss M. *Salt, Sugar, Fat: How the Food Giants Hooked Us*. Random House; 2013.
57. Moss M. *Hooked: Food, Free Will, and How the Food Giants Exploit Our Addictions*. Random House; 2021.
58. Benowitz NL. Nicotine addiction. *N Engl J Med*. 2010;362(24):2295-2303.
59. Benowitz NL. Pharmacology of nicotine: addiction, smoking-induced disease, and therapeutics. *Annu Rev Pharmacol Toxicol*. 2009;49:57-71.
60. Kozlowski LT, Mehta NY, Sweeney CT, et al. Filter ventilation and nicotine content of tobacco in cigarettes from Canada, the United Kingdom, and the United States. *Tob Control*. 1998;7(4):369-375.
61. Petty S, Salame C, Mennella JA, Pepino MY. Relationship between sucrose taste detection thresholds and preferences in children, adolescents, and adults. *Nutrients*. 2020;12(7):1918.
62. Ozel B, Kuzu S, Marangoz MA, Dogdu S, Morris RH, Oztop MH. Hard candy production and quality parameters: a review. *Open Res Eur*. 2024;4:60.
63. The Coca-Cola Company. The Coca-Cola company website: products. Accessed June 2025. coca-cola.com/us/en/brands/coca-cola/products/original
64. US Food and Drug Administration. Raw milk misconceptions and the danger of raw milk consumption. FDA.gov. Updated March 5, 2024. Accessed June 2025. fda.gov/food/buy-store-serve-safe-food/raw-milk-misconceptions-and-danger-raw-milk-consumption
65. Romero-Velarde E, Delgado-Franco D, García-Gutiérrez M, et al. The importance of lactose in the human diet: outcomes of a Mexican consensus meeting. *Nutrients*. 2019;11(11):2737.
66. Jenness R. The composition of human milk. *Semin Perinatol*. 1979;3(3):225-239.
67. Ventura EE, Davis JN, Goran MI. Sugar content of popular sweetened beverages based on objective laboratory analysis: focus on fructose content. *Obesity (Silver Spring)*. 2011;19(4):868-874.
68. US Department of Agriculture, Agricultural Research Service. FoodData Central. 2019. Accessed June 21, 2025. fdc.nal.usda.gov/

69. DiFeliceantonio AG, Coppin G, Rigoux L, et al. Supra-additive effects of combining fat and carbohydrate on food reward. *Cell Metab*. 2018;28(1):33-44.e3.
70. Mao L, Roos YH, Biliaderis CG, Miao S. Food emulsions as delivery systems for flavor compounds: a review. *Crit Rev Food Sci Nutr*. 2017;57(15):3173-3187.
71. Guinard JX, Zoumas-Morse C, Mori L, Uatoni B, Panyam D, Kilara A. Sugar and fat effects on sensory properties of ice cream. *J Food Sci*. 1997;62(5):1087-1094.
72. Biguzzi C, Lange C, Schlich P. Effect of sensory exposure on liking for fat- or sugar-reduced biscuits. *Appetite*. 2015;95:317-323.
73. Small DM, DiFeliceantonio AG. Processed foods and food reward. *Science*. 2019;363(6425):346-347.
74. Gearhardt AN, Bueno NB, DiFeliceantonio AG, Roberto CA, Jiménez-Murcia S, Fernandez-Aranda F. Social, clinical, and policy implications of ultra-processed food addiction. 2023;383:e075354.
75. Samaha AN, Robinson TE. Why does the rapid delivery of drugs to the brain promote addiction? *Trends Pharmacol Sci*. 2005;26(2):82-87.
76. McKinney DL, Vansickel AR. Nicotine chemistry, pharmacology, and pharmacokinetics. In: Preedy VR, ed. *Neuropathology of Drug Addictions and Substance Misuse*. Vol 1. Elsevier; 2016:93-103.
77. Hoffmann D, Hoffmann I. The changing cigarette, 1950-1995. *J Toxicol Environ Health*. 1997;50(4):307-364.
78. Wu L, Wang B, Zhang L, et al. Determination of routine chemicals, physical indices and macromolecular substances in reconstituted tobacco using near infrared spectroscopy combined with sample set partitioning. *J Near Infrared Spectrosc*. 2020;28(3):153-162.
79. Stevenson T, Proctor RN. The secret and soul of Marlboro: Phillip Morris and the origins, spread, and denial of nicotine freebasing. *Am J Public Health*. 2008;98(7):1184-1194.
80. Anderson PJ, Wilson JD, Hiller FC. Particle size distribution of mainstream tobacco and marijuana smoke. Analysis using the electrical aerosol analyzer. *Am Rev Respir Dis*. 1989;140(1):202-205.
81. Wayne GF, Connolly GN, Henningfield JE, Farone WA. Tobacco industry research and efforts to manipulate smoke particle size: implications for product regulation. *Nicotine Tob Res*. 2008;10(4):613-625.
82. Wayne GF, Carpenter CM. Tobacco industry manipulation of nicotine dosing. *Handb Exp Pharmacol*. 2009;(192):457-485.
83. Hall KD. From dearth to excess: the rise of obesity in an ultra-processed food system. *Philos Trans R Soc Lond B Biol Sci*. 2023;378(1885):20220214.
84. Fardet A. Minimally processed foods are more satiating and less hyperglycemic than ultra-processed foods: a preliminary study with 98 ready-to-eat foods. *Food Funct*. 2016;7(5):2338-2346.
85. Motta JFG, de Freitas BCB, de Almeida AF, de Souza Martins GA, Borges SV. Use of enzymes in the food industry: a review. *Food Sci Technol (Campinas)*. 2023;43:e106222.

86. Lennerz BS, Alsop DC, Holsen LM, et al. Effects of dietary glycemic index on brain regions related to reward and craving in men. *Am J Clin Nutr*. 2013;98(3):641-647.
87. Konanur VR, Hurh SJ, Hsu TM, Roitman MF. Dopamine neuron activity evoked by sucrose and sucrose-predictive cues is augmented by peripheral and central manipulations of glucose availability. *Eur J Neurosci*. 2024;59(10):2419-2435.
88. Popkin B, Ng SW, Taillie LS. The mismatch between biological needs and the modern food industry. *Nat Food*. 2025;6(3):216-219.
89. Benowitz NL. Clinical pharmacology of nicotine: implications for understanding, preventing, and treating tobacco addiction. *Clin Pharmacol Ther*. 2008;83(4):531-541.
90. Cosci F, Nardi AE, Griez EJL. Nicotine effects on human affective functions: a systematic review of the literature on a controversial issue. *CNS Neurol Disord Drug Targets*. 2014;13(6):981-991.
91. Volkow ND, Michaelides M, Baler R. The neuroscience of drug reward and addiction. *Physiol Rev*. 2019;99(4):2115-2140.
92. Queiroz LP, Nogueira IBR, Ribeiro AM. Flavor engineering: a comprehensive review of biological foundations, AI integration, industrial development, and socio-cultural dynamics. *Food Res Int*. 2024;196:115100.
93. CBS News. The flavorists: tweaking tastes and creating cravings. cbsnews.com. November 27, 2011. Accessed June 2025. cbsnews.com/news/the-flavorists-tweaking-tastes-and-creating-cravings-27-11-2011/
94. Bolhuis DP, Newman LP, Keast RSJ. Effects of salt and fat combinations on taste preference and perception. *Chem Senses*. 2016;41(3):189-195.
95. Drewnowski A. Taste preferences and food intake. *Annu Rev Nutr*. 1997;17:237-253.
96. Drewnowski A, Mennella JA, Johnson SL, Bellisle F. Sweetness and food preference. *J Nutr*. 2012;142(6): 1142S-1148S.
97. Folkenberg DM, Martens M. Sensory properties of low fat yoghurts. Part B: hedonic evaluations of plain yoghurts by consumers correlated to fat content, sensory profile and consumer attitudes. *Milchwissenschaft*. 2003;58(3):154-157.
98. Hutchings SC, Low JYQ, Keast RSJ. Sugar reduction without compromising sensory perception. An impossible dream? *Crit Rev Food Sci Nutr*. 2019;59(14):2287-2307.
99. Grumezescu AM, Holban AM. *Natural and Artificial Flavoring Agents and Food Dyes*. Academic Press; 2017.
100. Ciobanu MM, Flocea EI, Boişteanu PC. The impact of artificial and natural additives in meat products on neurocognitive food perception: a narrative review. *Foods*. 2024;13(23):3908.
101. Huang L, Dai Y, Zhang F, Zhang L, Zheng B, Zhang Y. Insights into the enhancement of food flavor perception: strategies, mechanism and emulsion applications. *Food Sci Hum Wellness*. 2024;13(5):2410-2424.
102. Guichard E, Salles C. Retention and release of taste and aroma compounds from the food matrix during mastication and ingestion. In: Etiévant P,

Guichard E, Salles C, Voilley A, eds. Flavor: From Food to Behaviors, Wellbeing and Health. Elsevier; 2016:3-22.
103. Premjit Y, Pandhi S, Kumar A, Rai DC, Duary RK, Mahato DK. Current trends in flavor encapsulation: a comprehensive review of emerging encapsulation techniques, flavour release, and mathematical modelling. *Food Res Int*. 2022;151:110879.
104. Hyde RJ, Witherly SA. Dynamic contrast: a sensory contribution to palatability. *Appetite*. 1993;21(1):1-16.
105. Bacak A. Flavors, colors, thickeners, and emulsifiers. In: Conto F, ed. *Advances in Dairy Products*. CRC Press; 2017:132-145.
106. Schatzker M. *The Dorito Effect: the Surprising New Truth About Food and Flavor*. Simon and Schuster; 2015.
107. Carpenter CM, Wayne GF, Pauly JL, Koh HK, Connolly GN. New cigarette brands with flavors that appeal to youth: tobacco marketing strategies. *Health Aff (Millwood)*. 2005;24(6):1601-1610.
108. Rabinoff M, Caskey N, Rissling A, Park C. Pharmacological and chemical effects of cigarette additives. *Am J Public Health*. 2007;97(11):1981-1991.
109. 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(1-2):1-10.
110. Mosia S, Sukdeo N, Pradhan A, Ramdass K. A comparative analysis of natural and artificial flavorings through analytical methods and flavor additive regulations. Proceedings of the 7th North American International Conference on Industrial Engineering and Operations Management; June 12-14, 2022; Orlando, FL.
111. Sandall A, Smith L, Svensen E, Whelan K. Emulsifiers in ultra-processed foods in the UK food supply. *Public Health Nutr*. 2023;26(11):2256-2270.
112. Breslin PAS. An evolutionary perspective on food and human taste. *Curr Biol*. 2013;23(9):R409-R418.
113. Hyslop G. Hue got it: the colour psychology behind top snacks. Bakery & Snacks. 2025. Accessed June 25, 2025. https://bakeryandsnacks.com/Article/2025/05/22/how-colour-sells-snacks-psychology-packaging-power/
114. Bold KW, Kong G, O'Malley SS. The scientific basis for the regulation of flavors in tobacco products. *Annu Rev Clin Psychol*. 2024;20(1):381-406.
115. Krishnan-Sarin S, O'Malley SS, Green BG, Jordt SE. The science of flavour in tobacco products. *World Health Organ Tech Rep Ser*. 2019;1015:125-142.
116. DeCicca P, Kenkel D, Liu F, Somerville J. Quantifying brand loyalty: evidence from the cigarette market. *J Health Econ*. 2021;79:102512.
117. Foulds J, Hooper MW, Pletcher MJ, Okuyemi KS. Do smokers of menthol cigarettes find it harder to quit smoking? *Nicotine Tob Res*. 2010;12(Suppl 2):S102-S109.
118. Tseng M, Grigsby CJ, Austin A, Amin S, Nazmi A. Sensory-related industrial additives in the US packaged food supply. *Front Nutr*. 2022;8:762814.
119. Ulloa AM. The aesthetic life of artificial flavors. *Senses Soc*. 2018;13(1):60-74.

120. Stevens LJ, Burgess JR, Stochelski MA, Kuczek T. Amounts of artificial food dyes and added sugars in foods and sweets commonly consumed by children. *Clin Pediatr (Phila)*. 2015;54(4):309-321.
121. Talhout R, Leventhal AM. Coolants, organic acids, flavourings and other additives that facilitate inhalation of tobacco and nicotine products: implications for regulation. Tob Control. Published online September 27, 2024. doi: 10.1136/tc-2024-058738
122. Mouritsen OG. Texture: how texture makes flavour. In: *Handbook of Molecular Gastronomy*. CRC Press; 2021:585-591.
123. Forde CG. From perception to ingestion: the role of sensory properties in energy selection, eating behaviour and food intake. *Food Qual Prefer*. 2018;66:171-177.
124. de Graaf K. Sensory responses in nutrition and energy balance: role of texture, taste, and smell in eating behavior. In: Meiselman HL, ed. Handbook of Eating and Drinking: Interdisciplinary Perspectives. Springer Cham; 2020:641-658.
125. Forde CG, de Graaf K. Influence of sensory properties in moderating eating behaviors and food intake. *Front Nutr*. 2022;9:841444.
126. Cordain L, Eaton SB, Sebastian A, et al. Origins and evolution of the Western diet: health implications for the 21st century. *Am J Clin Nutr*. 2005;81(2):341-354.
127. Cross GS, Proctor RN. *Packaged Pleasures: How Technology and Marketing Revolutionized Desire*. University of Chicago Press; 2020.
128. 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):1-12.
129. Carpenter M. *Sweet and Deadly: How Coca-Cola Spreads Disinformation and Makes Us Sick*. MIT Press; 2025.
130. Dubow JS, Childs NM. New Coke, mixture perception, and the flavor balance hypothesis. *J Bus Res*. 1998;43(3):147-155.
131. McClure SM, Li J, Tomlin D, Cypert KS, Montague LM, Montague PR. Neural correlates of behavioral preference for culturally familiar drinks. *Neuron*. 2004;44(2):379-387.
132. Sheth J, Koschmann A. Do brands compete or coexist? How persistence of brand loyalty segments the market. *Eur J Mark*. 2019;53(1):2-19.
133. Minich DM. A review of the science of colorful, plant-based food and practical strategies for "eating the rainbow." *J Nutr Metab*. 2019;2019:2125070.
134. Sharma S, Katoch V, Kumar S, Chatterjee S. Functional relationship of vegetable colors and bioactive compounds: implications in human health. *J Nutr Biochem*. 2021;92:108615.
135. Spence C. On the psychological impact of food colour. *Flavour*. 2015;4(21):1-16.
136. Batada A, Jacobson MF. Prevalence of artificial food colors in grocery store products marketed to children. *Clin Pediatr (Phila)*. 2016;55(12):1113-1119.
137. Crawford E. *Where is the line for the ingredient bans and when should companies comply vs. pusback?* Food Navigator USA. April 28, 2025. Accessed

June 25, 2025. foodnavigator-usa.com/Article/2025/04/28/navigating-state-ingredient-bans-when-to-push-back-and-what-comes-after-colors/

138. Maffini MV, Neltner TG, Vogel S. We are what we eat: regulatory gaps in the United States that put our health at risk. *PLoS Biol*. 2017;15(12):e2003578.
139. Center for Science in the Public Interest. Secret ingredients lurk in food, hidden as 'artificial flavor,' 'natural flavor,' and 'spices.' CSPI.org. Updated March 19, 2024. Accessed June 25, 2025. cspinet.org/article/secret-ingredients-lurk-food
140. Faustman C, Aaron D, Negowetti N, Leib EB. Ten years post-GAO assessment, FDA remains uninformed of potentially harmful GRAS substances in foods. *Crit Rev Food Sci Nutr*. 2021;61(8):1260-1268.
141. Hall KD, Ayuketah A, Brychta R, et al. Ultra-processed diets cause excess calorie intake and weight gain: an inpatient randomized controlled trial of ad libitum food intake. *Cell Metab*. 2019;30(1):67-77.e3.
142. de Granda Orive JI, Solano-Reina S, de Granda-Beltrán C, Jiménez-Ruiz CA. Cigarette: perfect engineering product to inhale but not safe. *Open Respir Arch*. 2019;1(1-2):5-6.
143. Zemann A. Components of a cigarette. In: Bernhard D, ed. *Cigarette Smoke Toxicity: Linking Individual Chemicals to Human Diseases*. Wiley; 2011:17-35.
144. McAdam K, Eldridge A, Fearon IM, et al. Influence of cigarette circumference on smoke chemistry, biological activity, and smoking behaviour. *Regul Toxicol Pharmacol*. 2016;82:111-126.
145. Geiss O, Kotzias D. Tobacco, cigarettes and cigarette smoke: an overview. *JEUR-Sci Tech Res Ser*. 2007;73:21.
146. Bernat JK, Jackson KJ, Krüsemann EJZ, Boesveldt S, Rudy SF, Talhout R. Sensory methods to evaluate perception of flavors in tobacco and other nicotine-containing products: a review. *Tob Control*. 2023;32(e1): e95-e102.
147. Kessler DA, Witt AM, Barnett PS, et al. The Food and Drug Administration's regulation of tobacco products. *N Engl J Med*. 1996;335(13):988-994.
148. Gupta S, Hawk T, Aggarwal A, Drewnowski A. Characterizing ultra-processed foods by energy density, nutrient density, and cost. *Front Nutr*. 2019;6:70.
149. Young LR, Nestle M. Portion sizes of ultra-processed foods in the United States, 2002 to 2021. *Am J Public Health*. 2021;111(12):2223-2226.
150. Williams DM. Ultra-processed foods and the strategic manipulation of our evolved motivational tendencies. *Prev Med Rep*. 2024;47:102902.
151. Velasco C, Obrist M, Petit O, Spence C. Multisensory technology for flavor augmentation: a mini review. *Front Psychol*. 2018;9:26.
152. Spence C, Keller S. Sonic branding: a narrative review at the intersection of art and science. *Psychol Mark*. 2024;41(7):1530-1548.
153. Hyslop G. *The science of sound: what is it about the crunch that keeps snackers dipping in for more?* Bakery and Snacks. June 18, 2024. Accessed June 25, 2025. bakeryandsnacks.com/Article/2024/06/18/the-science-of-sound-what-is-it-about-the-crunch-that-keeps-snackers-dipping-in-for-more/

154. Salvador A, Varela P, Sanz T, Fiszman SM. Understanding potato chips crispy texture by simultaneous fracture and acoustic measurements, and sensory analysis. *LWT-Food Sci Technol*. 2009;42(3):763-767.
155. Lee III WE, Schweitzer MA, Morgan GM, Shepherd DC. Analysis of food crushing sounds during mastication: total sound level studies 1. *J Texture Stud*. 1990;21(2):165-178.
156. Spence C, Wang Q. Sensory expectations elicited by the sounds of opening the packaging and pouring a beverage. *Flavour*. 2015;4(35):1-11.
157. Spence C, Shankar MU. The influence of auditory cues on the perception of, and responses to, food and drink. *J Sens Stud*. 2010;25(3):406-430.
158. Elder RS, Krishna A. The effects of advertising copy on sensory thoughts and perceived taste. *J Consum Res*. 2010;36(5):748-756.
159. Lazev AB, Herzog TA, Brandon TH. Classical conditioning of environmental cues to cigarette smoking. *Exp Clin Psychopharmacol*. 1999;7(1):56-63.
160. Vignola EF, Nazmi A, Freudenberg N. What makes ultra-processed food appealing? A critical scan and conceptual model. *World Nutr*. 2021;12(4):136-175.
161. Wigand JS. Additives, cigarette design and tobacco product regulation. A report to: World Health Organization, Tobacco Free Initiative, Tobacco Product Regulation Group. 2006.
162. Gaworski CL, Oldham MJ, Coggins CRE. Toxicological considerations on the use of propylene glycol as a humectant in cigarettes. *Toxicology*. 2010;269(1):54-66.
163. Heck JD, Gaworski CL, Rajendran N, Morrissey RL. Toxicologic evaluation of humectants added to cigarette tobacco: 13-week smoke inhalation study of glycerin and propylene glycol in Fischer 344 rats. *Inhal Toxicol*. 2002;14(11):1135-1152.
164. Center for Science in the Public Interest. Propylene glycol. CSPI.org. Updated February 4, 2022. Accessed June 25, 2025. cspi.org/article/propylene-glycol.
165. Triyannanto E, Lee KT. Evaluation of honey and rice syrup as replacements for sorbitol in the production of restructured duck jerky. *Asian-Australas J Anim Sci*. 2015;29(2):271-279.
166. Yates J, Kadiyala S, Deeney M, et al. A toxic relationship: ultra-processed foods & plastics. *Glob Health*. 2024;20(1):74.
167. Brody AL, Bugusu B, Han JH, Sand CK, McHugh TH. Scientific status summary. Innovative food packaging solutions. *J Food Sci*. 2008;73(8):R107-R116.
168. Spence C. Leading the consumer by the nose: on the commercialization of olfactory design for the food and beverage sector. *Flavour*. 2015;4(31):1-15.
169. Deliza R, MacFie H. Product packaging and branding. In: Frewer LJ, Risvik E, Schifferstein H, eds. *Food, People and Society: a European Perspective of Consumers' Food Choices*. Springer, Berlin, Heidelberg; 2001:55-72.
170. Hawkes C. Food packaging: the medium is the message. *Public Health Nutr*. 2010;13(2):297-299.

171. Gallopel-Morvan K, Moodie C, Hammond D, Eker F, Beguinot E, Martinet Y. Consumer perceptions of cigarette pack design in France: a comparison of regular, limited edition and plain packaging. *Tob Control*. 2012;21(5):502-506.
172. Chandra S, Shiffman S, Scharf DM, Dang Q, Shadel WG. Daily smoking patterns, their determinants, and implications for quitting. *Exp Clin Psychopharmacol*. 2007;15(1):67-80.
173. Shiffman S. Responses to smoking cues are relevant to smoking and relapse. *Addiction*. 2009;104(10):1617-1618.
174. Shiffman S. Assessing smoking patterns and motives. *J Consult Clin Psychol*. 1993;61(5):732-742.
175. Shiffman S, Dunbar M, Kirchner T, et al. Smoker reactivity to cues: effects on craving and on smoking behavior. *J Abnorm Psychol*. 2012;122(1):264-280.
176. Richardson S, Phillips JA, Axelson JM, Lovingood RP, Pearson JM, Saltmarch M. Cost of preparing convenience and home-prepared foods with an electric range and a microwave oven. *Home Econ Res J*. 1985;14(1):29-40.
177. Allon G, Federgruen A, Pierson M. How much is a reduction of your customers' wait worth? An empirical study of the fast-food drive-thru industry based on structural estimation methods. *Manuf Serv Oper Manag*. 2011;13(4):419-563.
178. Vincent DC, Joy J, Mathew PD, Thomas P, Rahul P, George HM. Optimizing operational cost and delivery of online food delivery apps using high-tech vending machines. In: Karras DA, Oruganti SK, Ray S, eds. *Emerging Trends and Innovations in Industries of the Developing World: A Multidisciplinary Approach*. 1st ed. CRC Press; 2023:42-46.
179. Classic snacks debut new, on-the-go snack packaging format. Packaging Strategies. June 28, 2013. Accessed June 27, 2025. packagingstrategies.com/articles/86373-classic-snacks-debut-new-on-the-go-snack-packaging-format.
180. Hasan H, Faris MAIE, Mohamad MN, et al. Consumption, attitudes, and trends of vending machine foods at a university campus: a cross-sectional study. *Foods*. 2021;10(9):2122.
181. Crombag HS, Bossert JM, Koya E, Shaham Y. Context-induced relapse to drug seeking: a review. *Philos Trans R Soc Lond B Biol Sci*. 2008;363(1507):3233-3243.
182. Fraser KM, Collins V, Wolff AR, et al. Contextual cues facilitate dynamic value encoding in the mesolimbic dopamine system. *Curr Biol*. 2025;35(4):746-760.e5.
183. Moore SR, Depue RA. Neurobehavioral foundation of environmental reactivity. *Psychol Bull*. 2016;142(2):107-164.
184. Dar R, Rosen-Korakin N, Shapira O, Gottlieb Y, Frenk H. The craving to smoke in flight attendants: relations with smoking deprivation, anticipation of smoking, and actual smoking. *J Abnorm Psychol*. 2010;119(1):248-253.

185. Conklin CA. Environments as cues to smoke: implications for human extinction-based research and treatment. *Exp Clin Psychopharmacol*. 2006;14(1):12-19.
186. Higgs S. Social norms and their influence on eating behaviours. *Appetite*. 2015;86:38-44.
187. Brownell KD. Does a "toxic" environment make obesity inevitable? *Obes Manag*. 2005;1(2):52-55.
188. Ares G, Natero V, Gugliucci V, et al. Health-washing of ultraprocessed products on Instagram: prevalence and strategies in an emerging market. *J Nutr Educ Behav*. 2023;55(11):815-822.
189. Yong HH, Borland R, Cummings KM, et al. Impact of the removal of misleading terms on cigarette pack on smokers' beliefs about 'light/mild' cigarettes: cross-country comparisons. *Addiction*. 2011;106(12):2204-2213.
190. Evans-Reeves K, Lauber K, Hiscock R. The 'filter fraud' persists: the tobacco industry is still using filters to suggest lower health risks while destroying the environment. *Tob Control*. 2022;31(e1):e80-e82.
191. Kozlowski LT, O'Connor RJ. Cigarette filter ventilation is a defective design because of misleading taste, bigger puffs, and blocked vents. *Tob Control*. 2002;11(Suppl 1):I40-I50.
192. Denlinger-Apte RL, Pacek LR, Ross JC, et al. Risk perceptions of low nicotine cigarettes and alternative nicotine products across priority smoking populations. *Int J Environ Res Public Health*. 2021;18(10):5311.
193. Morean ME, Bold KW, Davis DR, Kong G, Krishnan-Sarin S, Camenga DR. "Tobacco-free" nicotine pouches: risk perceptions, awareness, susceptibility, and use among young adults in the United States. *Nicotine Tob Res*. 2023;25(1):143-150.
194. Kowitt SD, Seidenberg AB, O'Shea NCG, et al. Synthetic nicotine descriptors: awareness and impact on perceptions of e-cigarettes among US youth. *Tob Control*. 2024;33(6):713-719.
195. Jordt SE. Synthetic nicotine has arrived. *Tob Control*. 2023;32(e1):e113-e117.
196. da Silva ALO. E-cigarettes with vitamins and nutrients: where quackery and technology meet. *Cad Saúde Pública*. 2024;40(1):e00024223.
197. Kassem NOF, Strongin RM, Stroup AM, et al. A review of the toxicity of ingredients in e-cigarettes, including those ingredients having the FDA's "generally recognized as safe (GRAS)" regulatory status for use in food. *Nicotine Tob Res*. 2024;26(11):1445-1454.
198. Giovino GA. Epidemiology of tobacco use in the United States. *Oncogene*. 2002;21(48):7326-7340.
199. Taillie LS, Ng SW, Xue Y, Busey E, Harding M. No fat, no sugar, no salt… no problem? Prevalence of "low-content" nutrient claims and their associations with the nutritional profile of food and beverage purchases in the United States. *J Acad Nutr Diet*. 2017;117(9):1366-1374.e6.
200. Hägele FA, Herpich C, Koop J, et al. Short-term effects of high-protein, lower-carbohydrate ultra-processed foods on human energy balance. *Nat Metab*. 2025;7(4):704-713.

201. Kellershohn J. Marketing probiotic beverages. In: Panda SK, Kellershohn J, Russell, I, eds. *Probiotic Beverages*. Elsevier; 2021:427-440.
202. Russell C, Baker P, Grimes C, Lindberg R, Lawrence MA. Global trends in added sugars and non-nutritive sweetener use in the packaged food supply: drivers and implications for public health. *Public Health Nutr*. 2023;26(5):952-964.
203. Rother KI, Conway EM, Sylvetsky AC. How non-nutritive sweeteners influence hormones and health. *Trends Endocrinol Metab*. 2018;29(7):455-467.
204. Sylvetsky AC, Reddy A, Wang Y, et al. Associations between non-nutritive sweetener consumption, metabolic risk factors, and inflammatory biomarkers among US adults. *Curr Dev Nutr*. 2024;8:103305.
205. Suez J, Cohen Y, Valdés-Mas R, et al. Personalized microbiome-driven effects of non-nutritive sweeteners on human glucose tolerance. *Cell*. 2022;185(18):3307-3328.e19.
206. Ahmed SH, Guillem K, Vandaele Y. Sugar addiction: pushing the drug-sugar analogy to the limit. *Curr Opin Clin Nutr Metab Care*. 2013;16(4):434-439.
207. Lenoir M, Serre F, Cantin L, Ahmed SH. Intense sweetness surpasses cocaine reward. *PLoS One*. 2007;2(8):e698.
208. Chakravartti SP, Jann K, Veit R, et al. Non-caloric sweetener effects on brain appetite regulation in individuals across varying body weights. *Nat Metab*. 2025;7(3):574-585.
209. WHO Scientific Group, WHO Guidelines Development Group. Use of non-sugar sweeteners: WHO guideline. World Health Organization. 2023. Accessed September 20, 2025. who.int/publications/i/item/9789240073616
210. Nugraha WS, Szakos D, Süth M, Kasza G. Greenwashing in the food industry: a systematic review exploring the current situation and possible countermeasures. *Clean Responsib Consum*. 2024;15:100227.
211. Cotter T, Kass D. Big soda's plastic waste is at the heart of planetary health's decline. Vital Strategies. April 19, 2024. Accessed September 20, 2025. vitalstrategies.org/big-sodas-plastic-waste-is-at-the-heart-of-planetary-healths-decline.
212. No Tobacco, World Health Organization. Tobacco: poisoning our planet. World Health Organization. 2022. Accessed September 20, 2025. who.int/publications/i/item/9789240051287
213. Dicken SJ, Batterham RL. Ultra-processed food: a global problem requiring a global solution. *Lancet Diabetes Endocrinol*. 2022;10(10):691-694.
214. Pollan M. In *Defense of Food: An Eater's Manifesto*. Penguin; 2009.
215. Fardet A, Rock E. Ultra-processed foods and food system sustainability: what are the links? *Sustainability*. 2020;12(15): 6280.
216. Duan MJ, Vinke PC, Navis G, Corpeleijn E, Dekker LH. Ultra-processed food and incident type 2 diabetes: studying the underlying consumption patterns to unravel the health effects of this heterogeneous food category in the prospective Lifelines cohort. *BMC Med*. 2022;20(1):7.
217. US Food and Drug Administration. Clarification of when products made or derived from tobacco are regulated as drugs, devices, or com-

bination products; amendments to regulations regarding "intended uses". *Fed Regist*. 2017;82(5):11639-11642. 21 CFR §201,801,1100. federalregister.gov/documents/2018/03/16/2018-05347/clarification-of-when-products-made-or-derived-from-tobacco-are-regulated-as-drugs-devices-or

218. Henningfield JE, Keenan RM. Nicotine delivery kinetics and abuse liability. *J Consult Clin Psychol*. 1993;61(5):743-750.
219. West R, Hajek P, Foulds J, Nilsson F, May S, Meadows A. A comparison of the abuse liability and dependence potential of nicotine patch, gum, spray and inhaler. *Psychopharmacology (Berl)*. 2000;149(3):198-202.
220. Ettelt S, Hawkins B. Scientific controversy, issue salience, and e-cigarette regulation: a comparative study of policy debates in Germany and England. *Eur Policy Anal*. 2018;4(2):255-274.
221. Peitsch MC, Polosa R, Proctor C, et al. Next-generation tobacco and nicotine products: substantiating harm reduction and supporting tobacco regulatory science. *Toxicol Res Appl*. 2018;2. doi: 10.1177/2397847318773701
222. Moysaenko D. When tobacco-free products are tobacco products: major questions behind FDA regulation of synthetic nicotine e-cigarettes. *Case W Res L Rev*.2023;74:487. scholarlycommons.law.case.edu/caselrev/vol74/iss2/10
223. Fang Z, Rossato SL, Hang D, et al. Association of ultra-processed food consumption with all cause and cause specific mortality: population based cohort study. *BMJ*. 2024;385;e078476.
224. Neri D, Martinez-Steele E, Monteiro CA, Levy RB. Consumption of ultra-processed foods and its association with added sugar content in the diets of US children, NHANES 2009-2014. *Pediatr Obes*. 2019;14(12):e12563.
225. Rosenheck R. Fast food consumption and increased caloric intake: a systematic review of a trajectory towards weight gain and obesity risk. *Obes Rev*. 2008;9(6):535-547.
226. van Tulleken C. *Ultra Processed People: the Science Behind Food That Isn't Food*. W.W. Norton & Company; 2023.
227. Goldstein BD. The precautionary principle also applies to public health actions. *Am J Public Health*. 2001;91(9):1358-1361.
228. American Lung Association. Overall smoking trends: trends in cigarette smoking rates. lung.org. 2024. Accessed September 20, 2025. lung.org/research/trends-in-lung-disease/tobacco-trends-brief/overall-smoking-trends
229. Chaloupka FJ, Straif K, Leon ME; Working Group, International Agency for Research on Cancer. Effectiveness of tax and price policies in tobacco control. *Tob Control*. 2011;20(3):235-238.

Acknowledgments: We are grateful to Alyssa Moran for her thoughtful feedback and contributions to earlier drafts of this work. We would like to acknowledge Ingrid Worth and Jacki Zhang for their assistance with formatting citations. We would also like to transparently acknowledge that we used generative AI technology to assist in improving the clarity, organization, and consistency of the manuscript. All AI-assisted outputs were carefully reviewed and revised by the authors to ensure accuracy and alignment with current evidence, given known limitations of these tools.

Funding/Support: This manuscript was supported by funding from Vital Strategies. Vital Strategies' Food Policy Program is supported by a grant from Bloomberg Philanthropies. The funder had no role in the design, analysis, interpretation, or writing of this manuscript.

Conflict of Interest Disclosure: Dr. Gearhardt has provided paid and unpaid consultation to public health nonprofits and law firms on matters related to ultraprocessed food and public health. These activities did not influence the content, analysis, or conclusions of this manuscript. The other authors declare no conflicts of interest relevant to the content of this article.

Address correspondence to: Ashley N. Gearhardt, Department of Psychology, University of Michigan, 530 Church St, Ann Arbor, MI 48109 (agearhar@umich.edu).