What Makes Ultra-Processed Food Appealing? A critical scan and conceptual model

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Abstract

There is growing evidence that consumption of ultra-processed food (UPF) has become a leading cause of global premature deaths and preventable diet-related diseases. To reduce consumption of UPF requires an understanding of the multiple forces behind it, including the understudied question of what makes UPF appealing. This critical scan of literature across multiple disciplines aims to fill this gap. We conclude that appeal is a multi-dimensional construct generated through the interplay of the products themselves, the people consuming them, and the practices of the corporations that manufacture, market, and distribute them. We argue that these relationships need to be unpacked to understand UPF appeal fully, and that public health interventions must take on the multiple dimensions of UPF appeal in an integrated way to effectively reduce its consumption. We propose a conceptual framework that can guide research to analyze the causes and consequences of UPF appeal and inform the development of policies and other interventions to reduce UPF appeal and consumption.

Keywords: ultra-processed foods, food choice, taste perception, Big Food, nutrition, dietary behavior, chronic disease

Introduction

In the past two decades, the proportion of calories in the human diet that comes from highly processed or ultra-processed food (UPF) has increased significantly.[1–3] In the same period, premature deaths and preventable illnesses from diet-related non-communicable diseases (NCDs) have also increased substantially.[4,5] While many factors including population aging have contributed to increases in NCDs,[6–8] a growing body of evidence suggests that UPF consumption has played a major role in this increased burden of disease.[9,10] As a result, several recent reports have called for developing public health strategies designed to reduce consumption of UPF and increase consumption of unprocessed or minimally processed foods.[11–13]

Devising such strategies requires an understanding of the multiple factors that have contributed to the increased consumption of processed foods. Scholars have investigated macrolevel changes in the global economy that have led to increased production and availability of highly processed food,[14–16] the changing composition of food consumed by different populations around the world,[3,17] and the complex psychology of food choice.[18] However, what makes UPF so appealing is a specific question in this body of evidence that requires deeper understanding. Why are people around the world compelled to obtain increasing proportions of their calories from UPF? What characteristics of these products, those who consume them, and the industries that produce, distribute, market, and sell them explain their appeal? How does appeal differ among populations and products?

In this critical scan, we seek to fill this gap in the literature. Our goal is to propose a comprehensive, integrated framework that can guide research to analyze the causes and consequences of UPF appeal and to inform the development of policies and other interventions that reduce appeal. In following the advice to make research questions a compass rather than an anchor,[19] we asked what bodies of knowledge could contribute to a deeper understanding of UPF appeal.

Methods

From recent reviews,[17,20,21] we identified three main relevant bodies of literature: 1) the characteristics of UPF products; 2) the knowledge, beliefs and behavioral patterns of the people who consume them; and (3) the practices of the corporations that manufacture, market, and distribute them. We then conducted a broad, critical scan of relevant literature, looking to identify common variables of interest and to summarize key findings across studies. To complete our scan of the literature we searched several databases including PubMed and Scopus for peer-reviewed studies related to the appeal of UPF that were published in English from any country between January 1, 2000 and April 30, 2021, since few studies on highly processed foods were published prior to that, with the exception of foundational food studies research. Search terms included “ultra-processed food” or “junk food”, “fast food”, “sugar-sweetened beverages”; “appeal” or “attraction”; and “drivers”, “determinants” or “causes”. We then extracted key study characteristics and findings from each source. Tables 1, 2 and 3 in the Appendix list the articles included in each section, including their study design; setting; product, people, or practice characteristics; and key findings.

With the variables identified through this process, we created a conceptual framework that posits relationships among the identified variables and constructs (Figure 1). The framework serves as a starting point for considering what is and is not known about drivers of the appeal of UPF

pertaining to the characteristics of the products, the people who consume them, and the practices of the companies that make them. After summarizing each body of literature separately, we use the conceptual framework as a guide to discuss the intersections among them and to highlight areas where further research is needed.

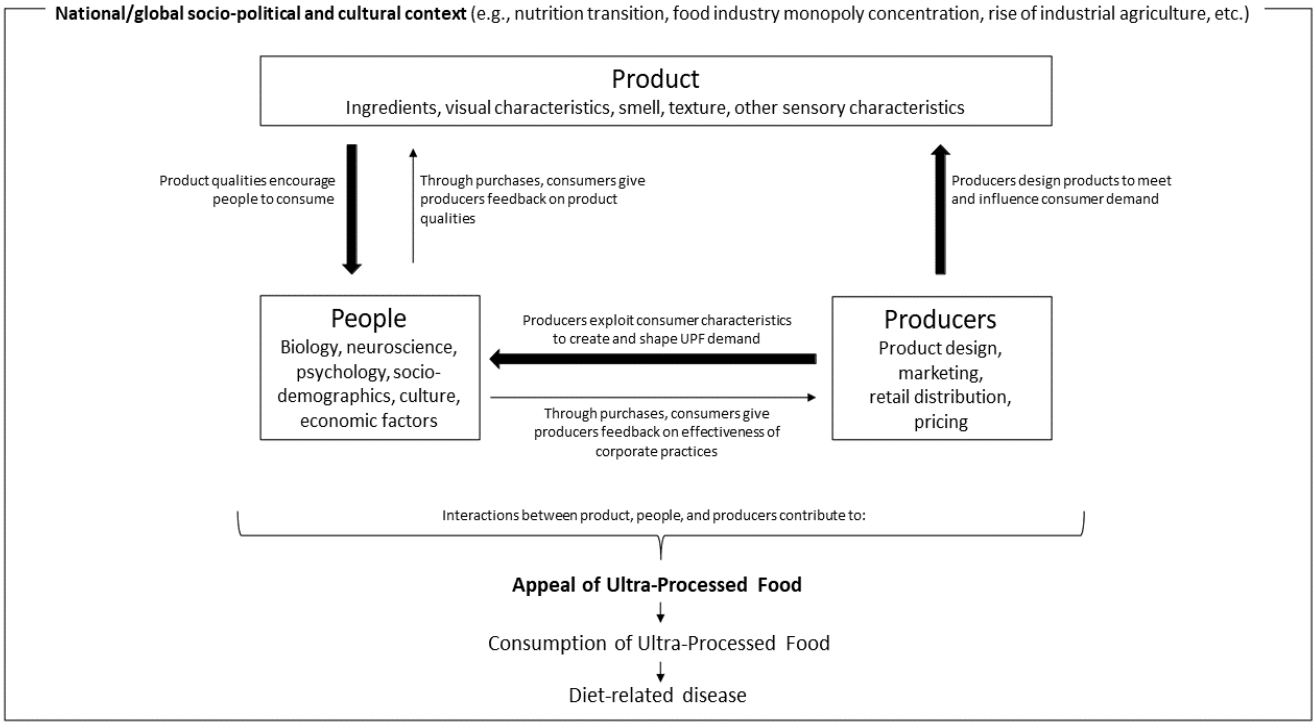

Figure 1. A conceptual framework for the study of the appeal of ultra-processed food

Definitions

The concept of *ultra-processed food* was first proposed in 2009 to describe products containing a mix of oils, fats, flours, starches and sugars, and little or no fresh meat and milk, grains, legumes, nuts, and fruits, vegetables, or roots.[22] These ingredients are combined with a sophisticated mix of additives designed to give these products a long shelf life and to make them attractive, palatable, and habit-forming. Examples include breads, cookies, ice creams, chocolates, confectionery, breakfast cereals, cereal bars, chips, savory and sweet snacks, sugared and other soft drinks, and meat products such as nuggets, hot dogs, burgers, and sausages made from processed or extruded remnants of meat. A food classification system called NOVA (a name not an acronym) defines a continuum of processing in which ultra-processed products are described as:

> formulated mostly or entirely from substances derived from foods. Typically contain little or no whole foods. Durable, convenient, accessible, highly, or ultra-palatable, often habit-forming. Typically, not recognizable as versions of foods, although may imitate the appearance, shape and sensory qualities of foods.[23]

Although the term ultra-processed came into common usage a decade ago, other terms that are often used to define similar categories are highly processed food, processed food, hyperpalatable

food, junk food, as well as specific categories such as fast food, sugary beverages, and snack food. Since there is not yet consensus on a single term and these terms are often used interchangeably, in this paper we use UPF to refer to the broad category of products that have undergone a significant amount of processing.

We define *appeal* as the power to attract consumers to purchase and consume certain products repeatedly. Based on our literature scan, we identified three broad categories of variables that influence appeal. First, characteristics of *products* influence appeal. The amount of sugar, fat and salt and the taste, color, odor, and texture of a product make it more or less appealing. Second, characteristics of *people* determine what they find appealing. These include biological affinities for salt, sugar, and fat; brain pathways that are activated by these ingredients; psychological dynamics and lived experiences influencing food choice; and socio-economic and cultural characteristics that affect the appeal of UPF. Finally, the *practices* of food manufacturers, distributors, and retailers – product design, marketing, retail distribution, and pricing – also influence appeal. In the real world, the three Ps of products, people, and practices intersect to shape the appeal of UPF and are not mutually exclusive categories. However, for purposes of organization, we summarize findings in each category separately, then consider how they have interacted to increase the appeal of these products over time and place.

Factors that influence appeal of UPF

Products

Product-level factors describe the composition of UPFs. What UPF looks like, how it smells, and how it tastes are all product-level characteristics. In examining product-level stimuli specific to UPFs, we considered several key factors related to their composition that contribute to their appeal, mainly in the context of their sensory attributes. While product composition is clearly the result of industry practices, we felt the complexity of the science involved and the individual-level behavioral influence of products warranted a separate section. We revisit this and other product design strategies, including product reformulation, in the Food Industry Practices section.

Industrial ingredients Most food components (ingredients) contribute to overall sensory characteristics and appeal, but what differentiates UPFs is the addition of industrial ingredients, those that are not available and have no equivalent in household settings.[24] For example, direct UPF additives to increase their sensory appeal include artificial and natural flavors, odorants, colorants, texturizers, and stabilizers. These may be utilized for a number of purposes, including to increase beneficial sensory characteristics, extend shelf life, mask unfavorable sensory characteristics, or offset the relatively higher costs of more expensive ingredients. Indirect additives, those that become part of the food usually in trace amounts due to contact with packaging or handling, may also be present in UPFs.[25] Describing health outcomes associated with UPF additives is beyond the scope of this review, but some evidence suggests links between additives found in UPFs and nutrition-related chronic disease outcomes.[26,27]

Visual characteristics "We eat with our eyes first" is supported by the peer-reviewed literature.[28,29] At the consumer level, color is one of the most significant factors associated with food choice and expectations.[30] Ultra-processed food manufacturers utilize colorants to replace the color in food products lost during processing, enhance existing colors, or add new colors to a

product.[31] Clydesdale (1993) reviewed the influence of color as a factor in food choice, concluding that, "Unquestionably color influences other sensory characteristics and, in turn, food acceptability, choice, and preference."[32]

Other research shows that color significantly influences consumers' ability to correctly identify flavor.[33] For example, when participants were given orange-flavored drinks that were purple in color with a label indicating grape flavor, they often reported that the drink was grape flavored. Authors found that, for the drinks tested, clear color had its own flavor expectations just as orange and purple colored drinks did, citing the market failure of the clear-colored Crystal Pepsi as an example of the importance of color-flavor-experience links. Spence et al (2010) conducted a review of empirical findings examining the impact of color on taste and flavor perception, finding strong and consistent evidence that food color, in general, influences the ability of consumers to identify flavor.[34] Similarly, Koch and Koch (2003) found that most colors were not associated with specific taste perceptions, but that color indirectly influenced consumers, especially when associated through experience.[35] As such, consumer expectations and previous experiences of foods and their color can play a key role in determining perception or appeal of new and unfamiliar foods. Other visual cues including portion size, number of products present, gloss, evenness, and shape also contribute to perception and liking of foods, whether highly processed or not.[36]

These visual cues are especially relevant in the context of UPFs, which consumers expect will remain uniform (in shape, color, taste, and texture) over time and occasion. Since the manufacturers of UPFs have free 'creative' reign to design products of any color, size, or shape, they have the ability to target any preference and continually create products that will be appealing to consumers. Indeed, color-food combinations that do not appear in nature (e.g., blue raspberry flavored drinks and candy) can attain market success, elicit consumer flavor expectations based on color alone, and even trigger brand expectations.[37]

Crossmodal correspondences and sensory interactions Sensory-stimulating characteristics of foods comprise perceptual interactions, sometimes referred to as crossmodal correspondences,[38] that are inextricably linked and that make studying individual sensory pathways nearly impossible.[39] Much of the recent research suggests that all five sensory pathways (gustation, olfactory, visual, auditory, and somatosensation) work in conjunction to produce a multisensory experience when eating.[40] According to Noble (1996), taste and aroma act in unison at the level of cognition to produce what is commonly referred to as flavor,[41] but flavor has also been modeled as the interactions between vision, olfaction, gustation, and oral-somatosensation.[34] Flavor tends to be one of the most conscious and lasting memories associated with food experiences, but crossmodal effects make it difficult to tease apart the effects of individual sensory components. Some sensory attributes are remembered less conspicuously, or perhaps even subconsciously, although their impact may not be any less significant.

Texture, for example, is most aptly examined as an oral-somatic sensation, but neurological studies suggest that taste, olfaction, and texture converge[39,42] and that texture plays a significant role in determining food acceptability.[43–45] Crispness, crunchiness, and chewiness are rated as highly important with most consumers,[46] whereas children and the elderly find some of those qualities difficult to manage in the mouth and prefer uniformity and smoothness. Tolerance to food texture has been shown to vary by time of day and eating occasion (least tolerance at breakfast, most at dinner) and consumer awareness of texture increases when expectations are

violated, such as when biting into a soft apple versus a crisp one. Some aspects of texture, such as crunchiness, also strongly influence the auditory stimuli emitted from foods, both internally and externally, as they are chewed, which also contributes to appeal.

Hedonic preference The key components of UPFs – sugar, salt, and fat – have been widely examined as moderators of UPF appeal or hedonic preference. Hedonic preference, an affect-level component of attitude (i.e., whether a person finds a food pleasant), is distinct from sensory evaluation of foods or intensity ratings of specific food characteristics (i.e., how a person rates one or more specific sensory aspects of a food such as sweetness), and these two may or may not be linked.[47] UPFs contain relatively higher proportions of these components,[48] which increases palatability of food products and aids in food preservation.[49] Addictive-like properties of UPFs have been described, with evidence suggesting that excess amounts of sugar, salt, and fat potentially "hijack" the brain's ability to make decisions.[50] Small (2019) provides a compelling model for the study of food appeal, eating addiction, and health outcomes by showing that the nutritional content of foods is not accurately conveyed to the brain, indicating processed foods may promote overeating and metabolic dysfunction.[51]

Universal appeal of UPFs: No competition Given the nearly infinite combination of food additives and processes associated with manufacturing UPFs, food companies can cater to any age-related phenomena or organoleptic preferences. Manufacturers of UPFs are able to control each of the five sensory stimuli precisely and independently, giving them unfettered flexibility in designing food products that provide the broadest possible appeal or even targeted appeal to certain populations. Therefore, unprocessed or minimally processed foods, those that are recommended for optimal health, cannot 'compete' with the massive range of sensory stimuli that UPFs can be designed to possess.

People

Literature from several disciplines including biology, psychology, public health, and social science suggests that certain characteristics of people, individually and in groups, influence the appeal of UPF.

Biological, neuroscience, and psychological factors Research from the fields of biology, neuroscience, and psychology highlight the bidirectional link between the UPF products described above, and people. Here we focus on human characteristics that both shape and are shaped by UPFs. One explanation for the appeal of UPF centers on the nutritional functions of the primary components of UPFs – salt, sugar, and fat – which are among the nutrients that humans need to survive.[52] Humans find the taste of all three pleasing, and research shows this is innate.[53] Researchers have used evolutionary perspectives to explain the universal fondness for sugar, salt, and fat. Throughout history, human taste has helped to evaluate the safety and nutritional content of foods available in our complex and changing environments.[54] Affinity for the tastes of sugar, salt, and fat made adaptive sense in context of scarce and uncertain resources, which remains the current reality for millions of people globally. However, in the increasing number of human environments with widely-available, highly-palatable UPFs, this taste-driven eating behavior can lead to disease.[54]

Another biological explanation for the appeal of UPF points to the relationship between diet and the microbiome. Consumption of UPF can result in harmful changes to the gut,[27,55] but there is also circumstantial evidence that the gut, once introduced to high-energy foods, which include

many UPFs, might become overtaken by specific microbes, which could then generate cravings for more high-energy foods.[56] This would not explain why people are first drawn to UPFs, but it may also contribute to the continued appeal of those products.

Research from the field of neuroscience suggests two possible pathways by which UPFs affect human brains in ways that link people and products to reinforce appeal. First, the taste of UPF activates the opioid circuitry – the brain's central reward pathway – which causes the release of endorphins, chemicals we perceive as pleasure. Endorphins also relieve pain and stress, another factor in UPF appeal: when one's emotional state amplifies the value of reward, as with depression, anxiety, or stress, the drive for that reward increases; sugary, salty, and fatty foods are often craved in times of stress.[57] The second pathway activated by UPFs is the dopamine system. Consumption of salt, sugar, and fat, and especially combinations of the three, results in release of dopamine, which drives a sense of desire. This encourages eaters to pay attention to these products and desire them the next time we perceive a relevant cue, such as an advertisement for UPF.[57] Brain activity in the opioidergic and dopaminergic systems in response to highly palatable food appears remarkably similar to brain activity following the consumption of drugs of abuse.[50] This has led some researchers to conclude that for some individuals UPF consumption can lead to cravings and other addictive-like behaviors,[50,58–61] a finding echoed in qualitative research.[62–64] Others have criticized use of the addiction model, suggesting it medicalizes food and goes beyond available evidence.[65]

Another explanation focuses on psychological attributes that make UPF more or less appealing. This research suggests complex emotions are associated with UPF. Those who find UPF appealing report positive affective reactions as motivators, i.e., enjoyment associated with its taste, happiness, and immediate satisfaction, at least at the beginning of the meal.[62,63] Some report that feeling depressed, stressed, or tired influences their decision to eat UPF,[62] perhaps making the expected immediate satisfaction more appealing. In the popular vernacular, comfort foods, as Romm (2015) put it, "promise solace as much as fuel."[66] However, studies of the characteristics of comfort food show not all are considered UPF,[67] suggesting the need for empirical investigation of the appeal of particular comfort foods.

UPF consumption can also elicit negative feelings, such as regret and guilt, though these typically arise only after UPF is consumed. Fear of being judged negatively by others for consuming UPF can also decrease its appeal.[62,63] The immediate satisfaction some derive from consuming UPF appears to overpower longer-term concerns about the health consequences of products high in salt, sugar, and fat,[62] which are typically more prevalent among women than men.[68] Concerns of weight gain and food poisoning from fast food can decrease its appeal,[63,64,69] though this does not always translate into reduced consumption.[70] Conversely, certain products such as diet soft drinks are perceived as being healthy, which can motivate their consumption.[71] In some places, bottled soda is perceived as and may be safer than tap water and packaged snack or fast food is similarly viewed as safer than home-cooked or street food.[72,73]

Other studies highlight the influence of memory and early life experiences on the appeal of UPFs. Acquired food preferences are strongly influenced by past experience, beginning in utero.[53] One influence on these preferences occurs through parental control over feeding, which has varying effects on attraction to UPFs in adulthood.[74,75] Among children and adolescents, modelling the eating and drinking behaviors of family members and friends can also influence preferences for UPFs.[63,71,76] This relationship can also work in the opposite direction, when

children influence their parents' purchasing or consumption of UPFs through so-called "pester power,"[62,64,77] again emphasizing the link between industry marketing practices and food choices.

Among adults and seniors, those who find UPFs less appealing report not having the habit of eating them.[64,78] This is likely the result of both age and cohort effects: older people have less innate preference for sweet and salty tastes compared to children (age effect), but they were also less exposed to UPFs as children, as these products have become more common with time (cohort effect).[78] On the other hand, for some adults, attraction to novel products or experiences, curiosity, and the desire for excitement, rather than routine or habit, is linked with an appreciation for UPFs, while traditionalist and do-it-yourself character traits are associated with negative attitudes towards UPFs.[62,79,80] Those who dislike cooking or who have limited physical ability to cook are more likely to find UPFs appealing, in part because it can satisfy their sense of achievement.[62,69,70,79]

Socio-demographic, cultural, and economic factors Another area of research focuses on socio-demographic determinants of UPF consumption, typically measured as the share of daily energy intake accounted for by UPFs or as frequency of UPF intake. While these studies do not explain the causes of UPF consumption, understanding which social groups are more likely to consume these products gives us clues into individual-level factors that explain the appeal of these products.

UPF consumption is negatively associated with age: children, adolescents and younger adults are more likely to consume these products compared to other age groups.[70,81–87] However, among older adults, preference for sweet and salty tastes increases, thought to occur because of the partial loss of taste and smell with age.[88] Evidence around gender consumption patterns are mixed, with some studies showing higher UPF consumption among males[70,71,83,85,89,90] while others find no gender differences.[81,87,91–93]

The relationship between social class and UPF consumption is also not clear-cut, depending in part on how class is measured (education, occupation, income, home ownership, etc.) but also on the cost and social value of UPFs in a given country. Data from the Global North suggest UPF consumption is higher among poor and working-class people,[81,83,90,94] though at least one study found the opposite (increased UPF consumption among the wealthier)[95] and others found no relationship.[83,89] In countries in the Global South, which are the fastest growing markets for UPF, consumption increases incrementally with income.[84,92,96,97] These findings suggest that sociodemographic factors may interact with national levels of economic development to influence UPF consumption.

Researchers primarily in the US have also investigated consumption patterns by race/ethnicity, deeply intertwined with social class, and have found UPF consumption to be higher among non-Hispanic black adults and non-Hispanic white adults than Hispanic[81,95] and Asian adults.[95]

Research in the Global North shows UPF consumption is higher in urban areas[87] or similar across urban and rural areas.[89,98] In the Global South, however, it is higher in urban areas but is increasing more rapidly in rural areas.[84,96,97] As we discuss in the Food Industry Practices section, socioeconomic variations in UPF consumption patterns may reflect differences in exposure to the marketing of these products.

In exploring broader socio-cultural and economic factors, a consistent finding is that those with time constraints, especially related to employment, find UPF appealing for its convenience, i.e., its ability to reduce time and effort in planning, purchasing, and consuming food.[62–64,70,77,90,99,100] The rise in demand for UPFs, and of prepared foods more generally, has been linked to the increase in women's participation in the labor force, highlighting the particular burden working women face as those most often responsible for feeding their families.[101] Attraction to convenience may also result from an interaction between consumers' time constraints and a 'convenience orientation,' the extent to which an individual values time and energy-saving in meal preparation.[102,103] Socio-cultural factors are likely at play, as convenience is valued as an end in and of itself in Western consumer culture.[104]

UPFs also carry symbolic value, and this research extends the well-known work of sociologist Pierre Bourdieu on the influence of economic, social, and cultural capital on food consumption.[105] Purchasing a candy bar for one's child or eating out in a fast food restaurant can provide relief from the stresses of low-wage work and poverty, or a rare moment of tranquility when tired working parents can enjoy a meal with their family.[106–108] For those experiencing homelessness, UPF consumption is driven by practical considerations such as lacking a space to cook or store food and limited resources to spend on food. However, UPFs can also offer a chance to exert control in context of the limited privacy and limited food choices in shelters.[109] Among adolescents, the appeal of UPF can be driven by the social interaction and independence it confers, while adolescents who value home-cooked meals with their families report finding UPF less appealing.[63,100,108] Other research examines the ways fast food establishments have been deliberately designed to function as 'third places,' i.e., spaces that are neither fully public nor private where people can socialize, found to be especially important for older people.[110,111] On the other hand, for some adults, eating alone facilitates the consumption of UPF,[62] perhaps because it requires less effort than cooking for oneself.

Explanations for the global spread of UPF consumption draw on the concept of the nutrition transition, according to which rising rates of urbanization, increases in income, changes in labor markets and family structure, and technological advances in work, leisure, and food production drive population shifts towards diets high in energy-dense, nutrient-poor products.[17,112,113] These social, economic, and technological influences, linked to globalization and neoliberal policies, create lifestyles and work conditions in which fast, cheap, and convenient foods become appealing. The nutrition transition is associated in some cases with concurrent shifts in eating culture, e.g., as seen in the US and Britain, characterized by increased availability and opportunities to eat, decline of collective meals, increased snacking, and larger portion sizes – all of which drive consumption and over-consumption of ready-to-eat, packaged foods.[114,115] Similar factors contribute to dietary 'acculturation' processes observed among multiple immigrant groups in the US and Europe.[116–119]

Finally, the attraction of UPF among populations from the Global South is also influenced by its positive associations with Western culture, modernity, and wealth.[100,120] However, the opposite has also been found, where UPF is considered unappealing because of its association with Western diet or culture viewed as unhealthy.[63,121] Aspects of traditional food may also influence the relative appeal of UPF, for example, with the logistical difficulty in transporting traditional food to school or work contributing to the appeal of UPF,[63] and cultural appreciation for traditional or indigenous food associated with reduced appreciation for UPF.[82,100,108] Some studies suggest that existing local traditions of indigenous fast food make the introduction of

foreign fast food easier.[120] These attitudes and perceptions also change over time, as UPF consumption shifts from something associated with special occasions to a more routine and normalized behavior.[80] A deeper understanding of the causes and dynamics of these changing perceptions could inform interventions.

Food Industry Practices

Food manufacturers play an important role in shaping the appeal of UPF. Their underlying motivation is to better achieve such basic business goals as increased sales, market share, profits, and return on investment.[122] To the extent that corporate decision-makers perceive that more appealing ultra-processed products will contribute to these aims, they will seek to increase their appeal. In this section, we provide a critical scan of the empirical literature on four corporate business practices that can contribute to appeal: product design, marketing, retail distribution and pricing. Our synthesis of the role of food industry practices is influenced by the growing body of work on commercial determinants of health, defined by West and Marteau (2013) as "factors that influence health which stem from the profit motive."[123]

Product design Food manufacturers produce or formulate products that are more appealing to consumers by adding or blending sugar, fat, and salt, substances known to increase the palatability of products, or by modifying product characteristics in other ways, as summarized in the Products section. We build on that section here by describing additional strategies used by food industries to manipulate product design with the goal of increasing their appeal. This includes changing the shape and color of existing products to cater to consumers drawn to novelty, as identified in the People section, and ensuring their products are easy to chew, a formulation that pleases both young children and older people. These companies also reformulate and "functionalize" their products to justify marketing claims about their healthfulness.[124,125] For example, adding vitamins or other micronutrients to UPF may increase appeal for some consumers through the "health halo" effect. In designing the composition and sensory characteristics of UPFs as described in the Products section, manufacturers incorporate the ingredients that seek to elicit sensations shown to increase appeal. Packaging, a design characteristic of products, has also been found to influence the appeal of UPF.[126,127]

Marketing Food producers and distributors market their products via mass media, digital media and social networks, store displays, peer influencers, and other routes. While the traditional rationale for advertising is that it provides consumers with information to make informed choices, in practice advertising seeks to speak to – and occasionally manipulate – cognitive, emotional, and cultural needs of potential customers. For UPF makers, marketing can be used to increase the appeal of the product by linking it to positive emotions or to counteract fears of adverse health consequences by giving the product a "health halo."[128] A key goal for marketers is to link a product and its brand to a core identity of the consumer, thus increasing appeal and ultimately brand loyalty. "Predatory marketing", defined as the practice of misleading, aggressive, pervasive, and emotional marketing of unhealthy products to vulnerable populations,[129] has often been used to promote purchase and consumption of ultra-processed products such as sugary beverages, fast food, and salty snacks to young people, people of color, and other groups at higher risk of dietary diseases.[122] Another well-known example is promotion of infant formula, not always recognized as UPF, to low-income mothers.

Retail distribution The goal of corporate retail distribution practices is to put their products within reach of as many potential customers as possible. In 1923, Coca Cola CEO

Robert Woodruff promised to put Coke's products "within arm's reach of desire" around the world.[130] In 2018, Coke's CEO James Quincey brought the slogan into the 21st century by amending the goal as being to put a Coca-Cola "within a click's reach of desire" of anyone in the world.[131]

By increasing the number and density of retail outlets where their products are available and now making home delivery more accessible, food producers make it easier for customers to act on their urges to purchase and consume products perceived as appealing. Evidence from other unhealthy products (e.g., alcohol and tobacco) has shown that retailer density can increase consumption.[132,133] While the links between availability and appeal are complex, if the appeal of a product is to have an influence on population health, many customers must be able to consume an appealing product, requiring its ready availability. Large multinational companies have the most resources to expand retail availability, further enhancing their capacity to bring their products into reach of billions of people.

As many populations around the world became confined to home during the Covid-19 pandemic, producers of UPF developed new strategies to make their products available through online purchasing and home delivery, further extending their market share and generating additional profits.[122]

Pricing Like other for-profit businesses, UPF manufacturers seek to offer prices that will maximize revenues and profits. Among the strategies they use to make their products more appealing are to offer discounts on volume, a strategy that is desirable for customers while generating higher revenues. By reducing the unit cost for customers while also increasing revenues for producers, super-sizing UPF products (e.g., selling discounted soda in containers of more than a liter) facilitates increased consumption.[134]

An opposing but also used strategy is selling smaller volumes at a lower cost but higher per unit price to make the products more affordable to low-income customers and also to appeal to health concerns about over consumption. For example, snack packs that provide 100 kcals are sold in multi-packs, which cost more than buying a bulk version of the same product. Other pricing strategies are to use some products as loss leaders to force competitors out of business, to collaborate with competitors to fix prices so as not to be underpriced (an illegal practice in some regulatory regimes), and to charge lower prices in new markets until customers have become loyal to the brand after which prices can be increased.[135]

Food producers, like other sellers of goods and services, generally recognize that lower prices increase sales and higher prices lower them. Low prices are especially important for low-income consumers, and UPF makers promote super-sized products in these communities to reduce unit costs and encourage additional purchases.[136] Evidence suggests that price promotions increase purchasing of sugary beverages and other unhealthy food.[137] Pricing also needs to recover production costs and return a profit. By calculating prices that maximize returns, companies seek to fulfill their mandate to investors and shareholders. In some cases, higher prices may bring added appeal as a luxury product, making a product more valued. Some studies suggest that higher costs of fast food in low- and middle-income countries may add to its appeal as a marker of higher income and status.[138]

In practice, these four strategies are integrated such that the corporate operations for designing, marketing, distributing, and pricing products operate in synergy to increase sales, market share,

and profit. In addition to these four market-oriented business practices, corporations that produce and distribute UPF engage in political practices such as lobbying, campaign contributions, sponsoring scientific research, and public relations. The goal of these political activities is to ensure that these companies can continue to increase the appeal of UPF and engage in their business practices without undue government interference. Several recent reviews summarize this body of work.[139–144] Together, these studies show that the food industry spends significant resources on seeking to reject, limit or delay proposals that would compromise their ability to produce, market and distribute more appealing highly-processed food. These include policies on package labeling, taxes on unhealthy products, product reformulation, mainstream and digital advertising, and outlet density zoning.[13] In the United States alone, for example, between 2011 and 2020, the food and beverage industry spent $293 million on federal lobbing and contributed $150 million to candidates in federal elections.[145] The vast majority of these contributions came from the largest corporate producers of UPF.

Discussion

Research on UPF has grown in recent years, marking its recognition as a major threat to population health. However, few studies have taken up the more focused goal of explaining the appeal of UPF and even fewer apply a multi-level, systems perspective on the intersecting forces driving the appeal of these products.[20,86] The goal of this critical scan was to describe current understanding of the multiple factors that contribute to the appeal of UPF, defined as the power of these products to induce consumers to purchase and consume them. We found that where UPF appeal is acknowledged, existing literature generally embraces the hypothesis that it is primarily a function of individual biological and psychological factors, or that it is driven solely by manufacturers who manipulate individuals' beliefs and attributes. We argue, based on our critical scan of the literature, that UPF appeal is a complex, multi-dimensional concept resulting from the interplay between these forces, and that the concept of appeal is key to understanding and ultimately reducing UPF consumption. We propose a conceptual framework integrating these multiple forces that can guide research to analyze the causes and consequences of the appeal of UPF and to inform the development of policies and other interventions to reduce that appeal. Furthermore, our categorization of the sources of appeal by product, people, and industry practices can help to identify various leverage points for interventions to reduce its attraction and thereby its consumption.

Though we have described factors specific to products, people, and practices separately, these three dimensions clearly intersect in shaping the appeal of UPF. For example, product stimuli such as color, odor, and texture are strong predictors of food preferences, but sensory testing protocols also typically include an array of data on people's sociodemographic factors, memories, feelings, experiences, and expectations, underscoring the importance of product-external variables in determining food preferences and appeal. Multi-sensory or crossmodal correspondences at the product-level are important determinants of appeal but are strongly linked to the context and characteristics of eaters. Food producers and advertising agencies create marketing strategies based on the knowledge of the specific messages, images, and product characteristics that will appeal to various target populations. For example, soda marketers have designed targeted ad campaigns for young people and for Black, Latinx, and LGBTQ[146] communities, seeking to increase their brand's appeal in these markets. These and other industry strategies manipulate the appeal of UPFs to respond to but also influence the needs of specific communities.

Jabareen (2009) defines conceptual frameworks as "interlinked concepts that together provide a comprehensive understanding of a phenomenon" and argues that by grounding and linking concepts to their intellectual and social origins, scholars can deepen our understanding of the "real world."[147] Our conceptual framework includes hypothesized mechanisms, based on our synthesis of the research summarized in this paper, through which products, people, and industry practices interact, with thicker arrows in Figure 1 highlighting the power of producers and products to meet and shape consumer demand for UPFs.[148,149] Additional research would help further clarify the nature of appeal as well as the links and feedback loops between the three dimensions in order to design strategies capable of reducing UPF appeal.

To what extent is appeal intrinsic, to what degree is it manufactured, and what is the potential for modification on either side? For example, the perception of UPFs as fun, time saving, or even healthy would seem more amenable to individual level change than humans' biological affinity for the tastes of salt, sugar, and fat. Taking this into account could allow public health professionals to create a portfolio of interventions that help individuals to change behaviors they have more control over while shifting more responsibility of action to producers, e.g., regulations limiting the amount of salt and sugar in commercial UPFs. The complexity of appeal suggests interventions that cut across product, people, and industry practices are more likely to be successful than interventions targeting a single dimension. For example, combining stronger industry regulation of what gets marketed, how, and to whom with policies that improve employment quality and strengthen the social safety net, making cheap and time-saving products less appealing, as articulated by Adams and colleagues (2020), might be more effective than any single strategy alone.[21] Evidence from initiatives to reduce tobacco use reinforce the hypothesis that multiple interventions are more effective than single ones.[150]

The conceptual model in Figure 1 also suggests the importance of overarching national socio-political and cultural contexts, including a country's stage in the nutrition transition and level of food industry monopoly concentration, in shaping the effectiveness of different interventions, a promising area for additional cross-national comparative research.

A focus on appeal raises important ethical and political debates about the relative merits of different strategies designed to raise prices, restrict choice, educate consumers or reduce availability. Debates on local and national taxation and product labeling rules around the world illustrate these controversies.[151] Acknowledging that UPFs are appealing and exploring avenues to make them less so in ways that consider the underlying drivers at the level of the products, people, and industry practices should be one of multiple public health approaches to reducing the burden of diet-related disease. As in tobacco control, re-framing individual choice (e.g., to smoke or not) to community choice (e.g., to assure the right to clean air or to protect vulnerable populations from predatory marketing) expands the ethical debates.[152]

A deeper analysis of appeal can also open the door to consideration of the role of social determinants of health in influencing perceptions of appeal. To illustrate, low prices make UPF appealing to some low-income populations, so increasing minimum wages and shrinking income inequality might reduce the attraction of this characteristic. The convenience of UPFs make them appealing to households where all adults need to work long hours to support the family, so shorter work weeks, higher wages, and reductions in gender disparities in responsibilities for household tasks such as meal preparation might limit this dimension of appeal. On another front, increased monopoly concentration of the food and beverage industry gives a handful of

transnational corporations added resources to devote to the product design, marketing, retail distribution, and pricing strategies that maximize appeal. Developing and enforcing new antitrust rules could limit their ability to exploit these appeal-generating strategies. By identifying and tackling the drivers of appeal – its more fundamental causes in an unequal, profit-driven global system[153] – public health professionals can develop innovative strategies to reduce the appeal and consumption of UPF.

Our review has several limitations. First, our inclusion of only English-language peer-reviewed articles may influence our conclusions about the appeal of UPF, particularly if experiences of countries with strong food cultures are not captured, though the articles included do present findings from a range of countries. Second, the choice of search engines resulted in a public health bent to the articles included, potentially excluding important evidence on the appeal of UPF as reported in other disciplines. Future research on this topic should aim to address both of these limitations by expanding both the languages and disciplines of focus. In addition, while we focused on the question of what makes UPF appealing, complementary questions to explore further are what makes UPF not appealing to some, and, relatedly, what makes unprocessed food less appealing to some?

In conclusion, the growing evidence of the role of UPFs in global premature deaths and preventable illnesses from diet-related NCDs requires new attention to reducing their consumption. By understanding the multiple sources of their appeal, public health professionals, researchers and advocates can contribute to controlling this growing threat to global health and health equity.

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Appendix

Table 1. References on product characteristics relevant to the appeal of ultra-processed food (UPF)

First author (year)	Study design	Setting	Characteristic	Key findings
Abbey (2014)	Review (encyclopedia)	n/a	Industrial ingredients	Widely utilized, some synthetic colorants are linked to health problems, though this remains controversial. Studies suggest a 1-5% rate of allergy and sensitivity reactions.
Avena (2008)	Review (animal model)	n/a	Hedonic preference	Under certain circumstances, rats may become dependent on sugar.
Cerf-Ducastel (2001)	Primary research (clinical)	12 adults in France, fMRI evaluation of sensory experiences	Crossmodal correspondences and sensory interactions	Taste and lingual somatosensory systems overlap widely, but perception can be discriminated by the brain.
Clydesdale (1993)	Review	n/a	Visual characteristics	Color of foods and beverages strongly influences sensory perceptions, food acceptability, choice, and preferences. Effects seem to be learned associations as opposed to 'inherent psychophysical characteristics.'
Delwiche (2004)	Review	n/a	Crossmodal correspondences and sensory interactions	All the sensory sensations are important to flavor experiences, and they interact strongly.
Delwiche (2012)	Commentary	n/a	Visual characteristics	Visual characteristics of food exert top-down influences on taste and flavor.
Drewnowski (1997)	Review	n/a	Crossmodal correspondences and sensory interactions	Taste responses are influenced by a range of genetic, physiological, and metabolic variables. Social, cultural, economic, and attitudinal factors impact preferences.
Garber (2000)	Sensory experiment	389 college students in Southeastern United States	Visual characteristics	Food color affects consumer ability to correctly identify flavor, form preferences, and dominates other flavor information sources such as labeling and taste.
Guinard (1996)	Review	n/a	Crossmodal correspondences and sensory interactions	Food preferences depend on physiological, social, cultural, economic, and psychological factors. For North Americans, most desirable textures are crispness, crunchiness, tenderness, juiciness, and firmness.
Koch (2003)	Primary research (survey)	45 college students in United States	Visual characteristics	Most colors are not positively associated with taste.
Martins (2016)	Review	n/a	Industrial ingredients	Most food colorants are synthetic and are linked to some negative health outcomes. Natural substitutions are increasingly in demand and employed.

Table 1. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Noble (1996)	Review	n/a	Crossmodal correspondences and sensory interactions	Taste and aroma interact strongly and affect flavor perceptions.
Small (2019)	Review (Perspective)	n/a	Hedonic preference	Proposed model for "reinforcing metabolic neural afferent (MNA) signals." Metabolic and hormonal signals to the brain are dependent on nutrient composition, quality, and proportion – and these systems may drive food choice and overeating.
Spence (2010)	Review	n/a	Visual characteristics	Consumer judgements of flavor identity are strongly influenced by color of food or beverage.
Spence (2016)	Review	n/a	Visual characteristics	The sight of appealing food is a powerful cue, especially among hungry people.
Spence (2015)	Review	n/a	Crossmodal correspondences and sensory interactions	Flavor is strongly affected by multi-sensory interactions, but should be considered in the wider context of cognitive factors.
Spence (2019)	Review	n/a	Visual characteristics, Crossmodal correspondences and sensory interactions	Bidirectional, crossmodal effects affect many taste/flavor interactions with other senses.
Spence (2021)	Review	n/a	Visual characteristics	Blue in natural foods is rare, so blue processed foods were once associated with artificiality, but dominant perceptions have changed. Blue is versatile and captures consumer attention.
Szczesniak (1971)	Review based on findings from interviews and surveys	Consumers, mostly homemakers, in United States	Crossmodal correspondences and sensory interactions	Awareness of texture may be subconscious and based on learned socio-cultural factors and expectations, but is important in determining people's feelings about food.
Szczesniak (1972)	Review and primary research (interviews)	Mothers and young consumers	Crossmodal correspondences and sensory interactions	Texture is an important determinant of food preference. Physiological factors are dominant, but modified by social, psychological, and cultural factors.
Szczesniak (2002)	Review	n/a	Crossmodal correspondences and sensory interactions	Texture is complex and there may no 'ideal' texture, as preferences vary by many factors, including age and occasion.

Table 1. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Tseng (2020)	Methods development	n/a	Industrial ingredients	Most of the nearly 300,000 branded foods evaluated contained at least one palatability-related industrial additive, most prevalent were flavors and texturizers.
Vaclavik (2014)	Review (textbook chapter)	n/a	Industrial ingredients	Reviews benefits of food preservation, the ingredients used to preserve food, and potential sensory outcomes.
Wadhera (2014)	Review	n/a	Visual characteristics	Visual cues from food can decrease neophobia in children, improve perceived flavors, and change estimations of food quantity, among other effects.

Table 2. References on individual and group characteristics relevant to the appeal of ultra-processed food (UPF)

First author (year)	Study design	Setting	Characteristic	Key findings
Alcock (2014)	Review	n/a	Biological	There are several mechanisms through which gut microbiota may influence eating behavior. Cravings for high-energy foods may be the result of reduced microbial diversity.
Almeida (2017)	Qualitative: semi-structured interviews	Adults in Brazil	Psychological, Socio-cultural, Economic	Barriers to UPF consumption include health concerns, not appreciating the taste, and not having the habit of eating it. Attraction to the taste, children's preference ("pester power"), convenience, addiction, and cost are facilitators to UPF consumption.
Askari Majabadi (2016)	Qualitative: semi-structured interviews	Adolescents in Iran	Psychological, Socio-cultural, Economic	There are facilitators and barriers to fast food consumption at the individual, interpersonal, and family levels. Facilitators include its convenience, a desire to conform to friends' behavior, and difficulty of transporting traditional foods. Barriers include views on its health threats, friends' negative attitudes towards fast food, and valuing eating with family members.
Ayala (2008)	Systematic review (qualitative and quantitative studies)	Latinos in United States	Socio-cultural	Acculturation is not associated with fat intake, but is associated with increased consumption of UPF.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Baker (2020)	Mixed methods synthesis review	Global	Socio-cultural, Economic	UPF sales are increasing globally but most rapidly in low- and middle-income countries. This is driven by food system industrialization and globalization, including the growth in market and political power of transnational food and beverage companies.
Baraldi (2018)	Quantitative: cross-sectional National Health and Nutrition Examination Survey	United States	Socio-demographic	UPF consumption is negatively associated with age and income level, is higher among non-Hispanic whites and non-Hispanic blacks than other race/ethnic groups, and is lower among college graduates compared to those with less formal education. No gender differences are observed.
Barrett (2017)	Quantitative: cross-sectional prospective cohort study	United Kingdom	Socio-demographic	Sugar-sweetened beverage consumption is higher among males and is negatively associated with income and home ownership. Artificially sweetened beverage consumption is higher among women, whites, and those with higher BMI, and is positively associated with income.
Batal (2017)	Quantitative: cross-sectional First Nations Food Nutrition and Environment Study	First Nations peoples in Canada	Socio-demographic	Lower UPF intake is associated with increasing age and household size, living in British Columbia, and eating traditional food.
Bere (2008)	Quantitative: cross-sectional analysis within randomized controlled trial	High school students in Norway	Socio-demographic, Psychological	Soft drink consumption is associated with taste preferences, attitudes about their healthfulness or value, modelling behaviors of parents and friends, and accessibility at home and in school.
Black (2015)	Quantitative: cross-sectional Canadian Community Health Survey	Canada	Socio-demographic	Fast food intake is highest among children and adolescents. Higher fast food consumption is associated with lower diet quality and higher BMI, but not with socioeconomic status, physical activity, smoking, or self-rated health.
Bleiweiss-Sande (2020)	Qualitative: focus groups	Low-income and immigrant parents in United States	Socio-cultural, economic	The meaning of processed food varies, but highly processed foods are commonly associated with convenience but limited healthfulness.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Botonaki (2010)	Quantitative: cross-sectional survey	Adult caregivers in Greece	Psychological	UPF consumption is reinforced by values that motivate people to seek new experiences, act independently, and enhance their personal interests. Use of "convenience food service" and use of "convenience food products" satisfy different needs.
Breslin (2013)	Review	n/a	Biological	Human taste has been shaped by evolutionary pressures to identify nutritious foods in different environments. Our biological affinity for energy-dense foods may result in nutrition-related diseases for those with ample access to those foods.
Brown (2004)	Quantitative: dyadic study using questionnaires	Parents and children in Southern England	Psychological	Snack intake, eating motivations, and body dissatisfaction among parents are correlated with those of their children, reflecting the modelling theory. Greater parental control of diet was correlated with children's higher intake of both healthy and unhealthy snacks, and children whose parents used food as a means of control reported greater levels of body dissatisfaction.
Candel (2001)	Quantitative: development and validation of scale using questionnaires	Netherlands	Psychological	Convenience orientation can be conceptualized as the extent to which an individual aims to save time and energy in meal preparation. Convenience orientation is negatively associated with pleasure derived from cooking and attraction to variety, and positively associated with role overload.
Cawley (2012)	Quantitative: longitudinal American Time Use survey	United States	Socio-cultural, Economic	Maternal employment is associated with less time spent grocery shopping, cooking, eating, playing, and supervising one's children. There is evidence of limited offsetting behavior by spouses. Time costs may explain the observed relationship between maternal employment and child obesity.
Cediel (2018)	Quantitative: cross-sectional national survey	Chile	Socio-demographic	UPF is an important contributor of total energy intake and total added sugars in the Chilean diet.
Chassaing (2015)	Experimental (animal model)	n/a	Biological	Dietary emulsifiers, a component of processed foods, alter the microbiome in ways that induce inflammation and metabolic syndrome.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Contini (2018)	Quantitative: test of structural equation model using online survey	Adults in Italy	Psychological, Socio-cultural, Economic	Intention to consume processed foods is correlated with social pressures, market availability, and individual traits, including time pressure and cooking skills.
Dave (2009)	Quantitative: cross-sectional survey	Adults in midwestern United States	Socio-demographic, Psychological	Of those with at least one fast food intake in the previous week, fast food consumption is more frequent among those who are younger, male, and single. Frequency of fast food consumption is associated with its perceived convenience and dislike of cooking, while it is not associated with perceived negative health impacts.
Davis (2008)	Mixed methods: cross-sectional nutrition screener and focus group study	Homeless women in transitional living center in United States	Socio-cultural, Economic	Women found shelter food to be of inadequate nutritional quality and considered shelter food to be contributing to poor management of chronic illness. Lack of agency in food choice, preparation, and storage in the shelter encouraged participants to seek comfort and "self-reward" in nearby fast food outlets.
Deglaire (2015)	Quantitative: web-based observational cohort	Adults in France	Biological	Preferences for salt and fat are associated with BMI. Preference for added sugar is linked with BMI in women but not men, while preference for natural sugar is linked with BMI in both genders. Preference for sweet and fat decreases with age in both men and women, while preference for salt increases slightly with age in men but not in women.
Devine (2003)	Qualitative: in-depth interviews	Low- and moderate-income adults in United States	Socio-cultural, Economic	Those who described their work as limiting experienced food choice as a cause for guilt and dissatisfaction. Those who described their work as manageable experienced food choice as a cause for pride and satisfaction.
Djupegot (2017)	Quantitative: cross-sectional study	Parents of school-age children in Norway	Socio-demographic, socio-cultural	Time scarcity is positively associated with UPF consumption. Men, those with lower education, those who are foreign born, and those with three or more children report higher UPF consumption.
Drewnowski (2007)	Review	n/a	Biological, Psychological	Sugar and sweet foods do not meet several criteria for substance dependence, including withdrawal, tolerance, and giving up other activities because of substance abuse.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Dunn (2008)	Qualitative: phone interviews, nested cohort study	Adults in Australia	Psychological	Positive affective reactions to fast food, convenience, and self-serving cognitions may overpower cognitive analyses of longer-term health risks of fast food.
Fielding-Singh (2017)	Qualitative: in-depth interviews and observation	Families in western United States	Socio-economic	Socio-economic position shapes the symbolic meaning given to food, which drives dietary disparities between socio-economic groups.
Fischler (2011)	Mixed methods: exploratory focus groups, phone interviews, survey	Multiple nations	Socio-cultural	In the United States and to some extent in the United Kingdom, eating is primarily an individual activity meant to meet nutritional requirements. In most European countries, eating is a social activity, and the concept of eating well includes eating with others.
Freeman (2016)	Review/ commentary	n/a	Socio-demographic, Psychological	Identity development and shifting interpersonal influences during adolescence shape eating behaviors. Adolescents are targeted aggressively through marketing campaigns. Greater focus is needed on adolescents in research, advocacy, and policy responses to consumption of energy-dense foods and beverages.
Fryar (2018)	Quantitative: cross-sectional National Health and Nutrition Examination Survey	United States	Socio-demographic	Between 2013 and 2016, 36% of adults consumed fast food on any given day. Fast food consumption decreased with age and increased with family income. Fast food consumption was higher among non-Hispanic black adults compared to other racial/ethnic groups.
Gilbert (2008)	Systematic review (qualitative and quantitative studies)	Multiple nations	Socio-demographic, Socio-cultural, Economic	Various ethnic groups living in Europe show dietary shifts towards increased consumption of energy-dense, nutrient-poor foods, associated with acculturation and adoption of Western lifestyle. Younger immigrants are more likely to adopt unhealthy diets, though income, education, religion, and food beliefs also influence dietary shifts.
Goodman (2003)	Book	Global	Socio-cultural, Economic	Reviews the history of global consumerism, global consumer patterns, and the effects of consumerism on society and the environment.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Hiamey (2018)	Quantitative: cross-sectional survey	Ghana	Socio-demographic, Socio-cultural	Consumers and non-consumers do not differ in their concerns over street food. Those with environmental, health, and food safety concerns were less likely to consume street food, while for consumers, concerns related to vendor appearance and practices were more important predictors of consumption.
Hoffman (2016)	Review (qualitative and quantitative studies)	Global	Biological, Socio-demographic	Sweet and salty preference is generally higher among children and adolescents than adults. Adolescents have a higher preference for sour and bitter tastes than children. A reversal is seen in older adulthood, with greater preference for intense sweet, salty, and sour tastes.
Janssen (2017)	Narrative review (qualitative and quantitative studies)	Global	Biological, Socio-demographic, Psychological, Socio-cultural	Determinants of take away, take-out, and fast food consumption include density of food outlets, taste preferences and neurochemical processes, individual preferences for convenience, and socio-cultural norms. There is an inconsistent relationship between demographic variables and consumption.
Jeffres (2009)	Quantitative: national telephone survey	Adults in United States	Socio-cultural	Nearly one third of respondents indicated they had no "third place" in their community. Of those who did, the most frequently cited locations were coffee shops and restaurants, including Starbucks and McDonald's.
Kennedy (2004)	Review plus 11 country case studies	Multiple low and middle-income countries	Socio-demographic, Socio-cultural, Economic	Globalization is associated with shifts in food availability, consumption, and security in urban settings in low and middle-income countries, with implications for shifts in malnutrition and burden of diet-related disease.
Kessler (2010)	Book	United States	Neuroscience, Psychological	Foods high in salt, sugar, and fat stimulate brain pathways in ways that make them difficult to resist. Corporations take advantage of this in their marketing and product design, but there are practical steps people can take to decrease overconsumption of these products.
Lean (2015)	Review	n/a	Biological	Humans require particular macronutrients and micronutrients for metabolism and tissue growth, for energy required of activity, and for compounds that we do not synthesize ourselves.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Louzada (2018)	Quantitative: cross-sectional food intake survey among sub-sample of National Household Budget Survey	Brazil	Socio-demographic	UPFs account for 20% of mean daily per capita energy intake. Higher UPF consumption is associated with worse diet quality, characterized by low consumption of fiber, protein, and many minerals and vitamins, but high consumption of free sugars and of total, saturated, and *trans* fats.
Lustig (2020)	Review (human and animal studies)	n/a	Biological, neuroscience	Existing evidence supports the claim that added sugar in UPF can lead to addictive-like behavior and is toxic. Combined with its ubiquity and negative societal externalities, this constitutes grounds for public health regulation.
Marrón-Ponce (2018)	Quantitative: cross-sectional food intake survey among sub-sample of Mexican National Health and Nutrition Survey	Mexico	Socio-demographic	UPFs account for 30% of mean dietary energy intake. UPF consumption is higher in young children, urban areas, the North and Central regions, and among groups with higher socio-economic status and education levels.
Martínez (2013)	Qualitative: exploratory situational analysis using in-depth interviews, observation, and content analysis	Multiple nations	Socio-cultural	Latino immigrants migrating to the United States from urban areas after 2000 engaged in unhealthy dietary practices prior to migrating, suggesting that modernization of food production and consumption, and transnational transmission of nutrition, are changing diets prior to migration, in contrast to the dominant explanation of acculturation once in the United States.
Murray (2015)	Review	Global	Biological	Patterns of addictive-like consumption of highly palatable foods among the elderly is poorly understood. Food addiction among older adults may increase as younger generations, with higher prevalence of food addiction, age, or older adults may "age out" of food cravings.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Olutayo (2009)	Qualitative: observation, in-depth interviews, document review	Ibadan, Nigeria	Socio-cultural	Fast food consumption is highly popular and is considered expensive and elegant, likely because of its Western association. It is consumed both by low-income and middle-class groups, particularly during special occasions, and is primarily observed among younger generations.
Peura-Kapanen (2017)	Qualitative: empathy-based stories and focus groups	Older adults in Finland	Socio-demographic, Psychological	Participants were critical of convenience food, though some saw it as useful when cooking for oneself is not possible. Participants indicated that taste, nutritional content, ease-of-use, and environmentally-friendly packaging were factors that increase acceptability of convenience food.
Popkin (2011)	Review/ commentary	Global	Socio-cultural, Economic	The global shift from undernutrition to overweight and obesity results from the collision between human biology and globalization, modern technology, public policies, and food industry practices. Intervention strategies aim to change social structures and individual behaviors.
Raynor (2001)	Review (human and animal studies)	n/a	Neuroscience	Evidence suggests greater dietary variety is associated with increased consumption and increased body weight, thought to occur because of oral habituation.
Ritter (2020)	Quantitative: difference-in-difference analysis	Peru	Economic	Regions with the largest drop in soda prices during the 1999 Price War saw increases in soda consumption, increases in obesity rates, and decreases in diarrhea prevalence among women without piped water at home. This suggests some women may have been substituting soda for contaminated water, facing a trade-off between diarrhea and obesity.
Saksena (2018)	Review (quantitative surveys)	United States	Socio-demographic	Spending on food away from home has increased over the past 30 years, with variations across socio-economic groups and age. Nutritional composition of food away from home is consistently lower than that of food at home. Public policies that influence consumption of food away from home include food assistance and menu labeling regulations.
Scholderer (2005)	Quantitative: development and validation of scale using questionnaires	France, United Kingdom	Psychological, Economic	Consumer interest in convenience food products is mediated first by perceived constraints in time and money, and then by individual orientation to effort-saving activities.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Schulte (2015)	Quantitative: cross-sectional study	United States	Biological	Highly processed foods share some characteristics with drugs and appear to be associated with food addiction.
Seale (2020)	Quantitative: cross-sectional survey	Canada	Socio-demographic	Younger adults and males consumed more types of UPF products than older adults and females, but UPF consumption is widespread.
Seubsman (2009)	Mixed methods: survey study using questionnaires and focus groups	Youth in northeastern Thailand	Socio-cultural	Over half of participants were aware of fast food health risks. Fast food consumption was driven by the appeal of modern lifestyles, social events and marketing, convenience, speed, and taste. Two thirds of participants thought local foods should be more popular, which may reflect an existing cultural resistance to fast food that should be supported.
Spence (2017)	Review	n/a	Socio-demographic, Socio-cultural, Psychological	What constitutes comfort food varies by gender, age, and culture, but comfort food tends to alleviate loneliness by eliciting past positive social interactions. There is limited empirical research that consumption of comfort food provides a psychological benefit.
Steele (2020)	Quantitative: National Health and Nutrition Examination Survey	United States	Socio-demographic, Socio-cultural	Measures of acculturation – place of birth, language spoken at home, and proportion of life in the United States – are associated with dietary share of UPF among foreign-born adults.
Thornton (2013)	Quantitative: cross-sectional survey part of Resilience for Eating and Activity Despite Inequality study	Australia	Socio-demographic, Socio-cultural, Economic	In neighborhoods with high density of fast food restaurants, barriers to limiting fast food consumption include lower self-reported ability to shop for and prepare healthy foods, less frequent family dining, lower family support for healthy eating, greater number of acquaintances who eat fast food regularly, and living further from supermarkets.
Tschirley (2015)	Quantitative: cross-sectional surveys	Multiple nations in East and Southern Africa	Socio-demographic, Economic	Demographic and food consumption patterns of the growing middle class suggest that this population resides in both urban and rural areas, and that purchase of highly processed foods is positively associated with income in both urban and rural areas.
Unger (2004)	Quantitative: longitudinal surveys	Asian-American and Hispanic adolescents in United States	Socio-cultural	Acculturation in the 6th grade is associated with lower participation in physical activity and higher consumption of fast food in the 7th grade.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Veeck (2020)	Quantitative: dual-period cross-sectional survey	China	Psychological, socio-cultural, economic	Surveys in 1996 and 2013 show that a traditionalist outlook is associated with negative attitudes towards processed food only at the second time point, once processed food consumption had become more routine. A do-it-yourself preference is associated with negative attitudes towards processed food at both time points, but this link was stronger in 1996, suggesting the desire to save money played a smaller role over time as spending power increased nationally.
Ventura (2013)	Review	n/a	Biological	Taste perception and preferences begin to develop early in development and are shaped by biological, social, and environmental factors throughout the lifespan.
Wadhera (2015)	Quantitative: online and web-based surveys	University students in United States	Psychological	Perceived memory of frequent food consumption in childhood was related to current liking for most foods. Parental encouragement and modeling was positively associated with current liking even for foods not liked in childhood, while both parental restriction and forced consumption were negatively associated with current liking.
Warde (2007)	Quantitative: cross-sectional time-use surveys	Multiple European nations and United States	Socio-cultural	Time spent on food preparation declined between the 1970s and 1990s. Time spent eating at home declined in all five countries except France, and the United States has the lowest time spent on food preparation and consumption at home.
Wardle (2004)	Quantitative: International Health Behavior Survey	University students in 23 nations	Socio-demographic, Psychological	Women's self-reported healthier food choices compared to men's appear to be partly attributable to their greater weight control and stronger beliefs around healthy eating.
Wexler (2017)	Review	n/a	Socio-cultural	Third places are public spaces intended to promote a sense of community. There are three distinct types of third places – communitarian, commercial, and digital – all of which serve important purposes in the private, public, and non-profit sectors.

Table 2. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Zhou (2015)	Quantitative: China Health and Nutrition Survey	China	Socio-demographic	Processed foods account for 28.5% of daily energy intake. Processed food consumption is highest among children and teenagers in urban centers, and those with higher incomes and education levels. Processed food consumption is negatively associated with BMI and risk of overweight among children and teenagers.
Zinöcker (2018)	Review (human and animal studies)	n/a	Biological	Consumption of UPF can result in harmful changes to the gut microbiome, including reduced microbial diversity, that promote inflammatory disease.
Zyl (2010)	Quantitative: cross-sectional questionnaire	South Africa	Socio-demographic	21% of participants consumed fast food at least once weekly, while 28% consumed it 2-3 times a week, despite high prevalence of health concerns. Fast food consumption was higher among males and those with lower socio-economic status. Drivers of consumption were time constraints, convenience, and taste.

Table 3. References on industry practices relevant to the appeal of ultra-processed food (UPF)

First author (year)	Study design	Setting	Characteristic	Key findings
Anderson (1999)	Quantitative: surveys	People's Republic of China	Marketing	Survey results explain frequency of purchasing fast food and distinguish between respondents preferring “fast” from those preferring “food” (taste and nutrition), and between younger and older consumers.
Baker (2016)	Quantitative: market data from Euromonitor International	Several Asian countries	Product design, Retail distribution, Pricing	UPF sales, particularly in carbonated soft drinks, have increased rapidly in most middle-income countries. Supermarkets, hypermarkets and convenience stores became dominant distribution channels for packaged foods; market concentration was increasing in the grocery retail sector; and food service sales are increasing in all countries. Transnational food and beverage corporations face strong competition from Asian firms in all sectors.

Table 3. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Bennett (2020)	Systematic review	Multiple nations	Marketing, Pricing	Price promotions are more common for unhealthy foods and beverages and a greater proportion of price-promoted purchases are for unhealthy products compared to healthy ones.
Dadhich (2018)	Commentary	n/a	Marketing	In the absence of effective global and national regulatory measures, manufacturers are promoting UPFs by influencing policymaking, consumer behavior and research.
Dobson (2010)	Quantitative: economic modeling	n/a	Pricing, retail distribution	Food vendors can profit by using supersizing strategies, where the cost of regular portions is set high and the cost of increasing portions is set low. However, these strategies can destroy social value, because the resource cost to provide increased portions can exceed consumer willingness to pay for it. Policies to tackle overeating unhealthy food can include supersizing bans, taxes, and warnings.
Gleeson (2020)	Review	Multiple nations	Retail distribution, Pricing	Tariff reductions can influence availability and price of tobacco, alcohol, and UPF. Trade challenges to regulation of product marketing and packaging can undermine public health policies. Investor-state dispute settlement processes have been used by the tobacco industry to challenge tobacco control efforts.
Hallez (2020)	Systematic review	Global	Product design, Marketing	Children and adults are influenced by packaging cues, especially visual ones. Children more frequently choose products that have a licensed endorser and eat more from packages depicting the product with an enlarged portion size. Adults are susceptible to other visual cues, such as package size and shape, and less by informational cues such as labels.
Harris (2018)	Quantitative: randomized controlled trial	United States	Marketing	Children who viewed a health halo commercial (a UPF ad with healthy messaging) rated the products as significantly healthier compared with children who viewed other commercials, but other commercials did not affect children's attitudes about advertised products.

Table 3. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Lavriša (2019)	Quantitative: database on prepacked foods	Slovenia	Marketing	"Breakfast Cereals", "Chocolate and Sugar Confectionery" and "Edible Ices" are the foods most promoted to children. 93% of products with child-directed promotions and 73% of products without such promotions were classified as "not permitted" according to the WHO nutritional profile.
Mialon (2019)	Qualitative: classification of corporate political activity in national websites and industry social media accounts	Latin America and Caribbean	Marketing	There are more than 200 examples of corporate political activity, including UPF industry lobbying of governments during the development of national health policies; attempts to forge alliances with policy makers, health professionals, and communities where they operate; and court challenges to regulation.
Mialon (2015)	Review	n/a	Marketing	Proposes a framework for categorizing corporate political activity of the food industry according to six strategies: information and messaging; financial incentive; constituency building; legal; policy substitution; opposition fragmentation and destabilization.
Moodie (2013)	Review	Multiple nations	Product design, Marketing, Retail distribution, Pricing	There is no evidence that industry self-regulation and public-private partnerships are effective. Public regulation and market intervention are the only evidence-based mechanisms to prevent harm caused by the unhealthy commodity industries.
Young (2021)	Analysis of portion size information	US	Pricing	Despite calls from public health authorities to reduce portion sizes, all US food companies included in the study still sold portions of up to 5-times-lager sizes compared to 2002.
Popkin (2021)	Review	Multiple nations	Product design, Marketing, Retail distribution, Pricing	There is a need for evidence-informed policy action to reduce consumption of UPF and increase consumption of healthy food, including taxes on sugary beverages, product warning labels and school food standards.
Riches (2018)	Rapid evidence review	Multiple countries	Retail distribution	Modelling studies, the most robust evidence on the topic, suggest that reducing tobacco outlet density can result in small to modest decreases in smoking prevalence in some situations.

Table 3. Continued

First author (year)	Study design	Setting	Characteristic	Key findings
Scrinis (2016)	Review	n/a	Product design	Food corporations engage in reformulation, fortification, and functionalization of products to nutritionally engineer and market their products. While presented as responses to the health issues of over and under-nutrition, corporations use these strategies to expand markets for their products.
Scrinis (2018)	Commentary	n/a	Product design	Reformulation of UPF products, whereby quantities of specific "nutrients-to-limit" are reduced, often misses other potentially harmful ingredients, may replace nutrients-to-limit with other highly processed ingredients and additives, and may legitimize UPF consumption levels in high-income countries and in the global South.
Sherk (2018)	Quantitative: Systematic reviews and meta-analyses	Multiple countries	Retail distribution	Most studies suggest that limiting availability of take-away alcohol leads to a reduction in alcohol consumption. Adding one additional day of alcohol sale was associated with per capita increases in alcohol consumption in meta-analyses.
Watt (2020)	Non-systematic review of quantitative studies	Multiple nations	Marketing, Pricing	Available evidence suggests that price promotions increase the purchase of unhealthy food.
West (2013)	Commentary	n/a	Product design, Marketing, Retail distribution, Pricing	Describes commercial determinants of health, the ways these drive the major causes of preventable disease globally, and strategies to improve health and combat climate change by reducing production and consumption of profitable goods.
Wood (2021)	Systematic review and document analysis	Multiple nations	Marketing, Pricing	Categorized market strategies of dominant processed food manufacturers according to six objectives: reduce competition with equivalent sized rivals and maintain dominance over smaller rivals; raise barriers to market entry by new competitors; counter threat of market disruptors and drive dietary displacement in favor of products; increase firm buyer power over suppliers; increase firm seller power over retailers and distributors; and leverage informational power asymmetries in relations with consumers.