



Digitalization of the Retail Food Environment: Modernizing Food Access, Highlighting Health Equity, and Identifying Opportunities for Future Research and Practice

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The digital transformation of the retail food environment is reshaping public health, producing both positive and negative impacts on how US consumers access food. This Research Report synthesizes these changes and explains why public health nutrition must modernize definitions and measures of food access, highlighting priority directions for new measurement approaches. Finally, we discuss future research and practice needs and directions, and describe how innovative nutrition education and behavior strategies, appropriate measurement, and policy, systems, and environmental (PSE) approaches can align public health and health equity efforts with the ongoing digital transformation of the food environment.

Key Words: digital, online grocery, food access, health equity, digital marketing (*J Nutr Educ Behav.* 2026;58:242–257.)

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INTRODUCTION

Digitalization is rapidly transforming the consumer retail food environment, defined as what consumers encounter within and around food outlets in which food and beverages can be purchased for immediate or later consumption.^{1–3} These environments are becoming increasingly digital (using technologies such as the internet, mobile, and cloud) and digitalized (leveraging digital data to transform operations and experiences).⁴ This digital transformation has created a fundamental shift in the retail food landscape in high-income countries and emerging markets, as well as in how customers access food, with significant public health

implications.^{5–9} This change is part of the emerging concept of the Digital Determinants of Health (any factor rooted in, contingent on, or inextricably linked to the digital world that can directly or indirectly influence health or well-being).^{7,10,11}

The transformation is characterized by a comprehensive shift in how retailers operate to meet customer expectations for digital food purchasing solutions and rapid technological advancements. Digital marketing is a significant aspect of this transformation,^{12–14} but there are also emerging interfaces (e.g., augmented reality [AR], digital kiosks) and server-side infrastructure, such as artificial intelligence (AI) (technology that enables computers and machines to simulate

human learning, comprehension, problem solving, decision making, creativity, and autonomy¹⁵), machine learning (a branch of AI focused on enabling computers and machines to imitate the way that humans learn, to perform tasks autonomously, and to improve their performance and accuracy through experience and exposure to more data¹⁶), big data (massive, complex datasets that traditional data management systems cannot handle¹⁷), and Internet of Things (a network of physical devices, vehicles, appliances, and other physical objects that are embedded with sensors, software, and network connectivity, allowing them to collect and share data).^{4,14,18} This transformation evolved from the expansion of online food ordering systems, the development of mobile food applications that simplified and enhanced the ordering process, and the integration of AI and automation into the retail food industry.¹⁹

There is a growing consensus in public health nutrition that digitalizing the retail food environment has both positive and negative effects on consumer decisions.^{14,20} Customers see the opportunity for convenience, reduced time burdens, and control.²¹ Digitalized food retail can free up time for consumers by replacing time

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spent grocery shopping (online groceries), creating shopping lists and meal planning, and food preparation (food delivery applications)—all of which can help to support healthier eating, and increase access to full-service grocery stores unavailable to some consumers.⁹ While online shopping has the potential to promote healthy food purchasing behaviors, it can also exacerbate unhealthy shopping behaviors. Research has shown that the highest proportion of promotions on online retailers' landing pages, search results, or emails is for unhealthy products (i.e., sugar-sweetened beverages, foods high in sodium, and saturated fats).^{22–24} Studies have also suggested that while online shopping reduces impulse purchases, it simultaneously reduces the variety of products and food categories within a grocery purchase compared with in-person shopping because of buy again options within online retailers that facilitate inertial purchasing behaviors.²⁵ This decreased variety is most concerning regarding fresh produce, as evidence suggests less purchasing of fresh produce online vs in person,^{26,27} often because consumers prefer to personally select their produce.^{27,28}

Retailers view digital transformation as an opportunity to better reach customers, focus on the customer experience, and gain a deeper understanding of shopping behavior, ultimately increasing revenue, consumption, and targeted product promotion.^{21,29} The commercial retail industry leverages online and digital marketing tactics to influence consumer behaviors. Their use of generative AI and machine learning allows companies to identify and target individuals,³⁰ consequently maximizing their ability to influence consumer purchases regardless of the nutritional content of products. More specifically, retailers and marketers can leverage data across multiple platforms to develop machine learning dashboards that leverage user and similar buyer data, thereby further enhancing consumer engagement and providing more relevant, tailored product recommendations.³¹ This mechanism heavily influences consumer shopping behaviors by highlighting certain

brands and products, reminding customers to make purchases, and triggering impulsive purchases based on an individual's profile and past shopping behaviors.³² These technologies may enable companies and retailers to treat customers differently based on certain demographics or characteristics, thus resulting in marketplace discrimination.³² Alternatively, if tailoring of products and product filtering could be used for more public health rather than profit priorities, they could help consumers meet their needs and preferences for healthier dietary choices (e.g., filters for low-sodium or diabetes friendly products).

In the US, government actions and policies have also shaped the digital transformation of the food environment.³³ As of June 2023, online grocery purchasing using *Supplemental Nutrition Assistance Program* (SNAP) benefits was available in all 50 states and Washington, DC.³⁴ Furthermore, as part of the *Special Supplemental Nutrition Program for Women, Infants, and Children* (WIC) ongoing modernization efforts, the US Department of Agriculture (USDA) has funded subgrants for states to implement online ordering solutions for WIC with retailers of various sizes.³⁵

This mix of opportunities and competing interests creates a dynamic ecosystem that forces the field of public health nutrition to understand how the retail food landscape has changed in high-income and emerging markets, what the impacts are on behaviors (particularly for groups with low income and who are marginalized who may be particularly vulnerable in this increasingly digitalized food environment^{36–38}), and what the implications of this change are for research and practice.

Thus, this paper aims to first clarify elements and terminology within the rapidly expanding digitalized retail food environment. For this paper, we will focus on digital interfaces that influence purchasing decisions in or in relation to the retail food environment. This is followed by a discussion of 3 important extension points: (1) connecting digital retail environment concepts to established food access frameworks (5A's:

availability, accessibility, affordability, acceptability, and accommodation), including relevant approaches to measure these revised concepts, (2) consider ways the digital environment may lead to widening inequities and undermine ethics and consumer protections, and (3) discuss future research needs and directions, including opportunities for innovative nutrition education and behavior strategies, and the need for strategic public health policies, systems, and environment approaches. The focus of this paper is on the US context, but it may have implications for other high-income and emerging countries.

DISCUSSION

Overview and Key Elements of the Digital Food Environment

The digitalized food environment encompasses a spectrum of digital immersion (the merging of the physical and digital worlds) and consumer interactive experiences, including digital elements being added to the physical environment (geotargeting/geofencing, AR, kiosks), digital advertising (affiliate marketing, remarketing, search engine optimization), digital platforms for food purchasing (applications, websites), and fully digital environments (virtual reality [VR] and immersive systems). The digital food environment often includes digitally designed components of the marketing mix that influence customers' decisions.^{9,39} Online grocery shopping, food delivery applications, and online meal planning are major categories in the digital retail environment,^{9,14} but this environment also includes digital elements meant to influence in-the-moment purchasing decisions within physical food retail outlets, including fast food locations and vending. In addition, emerging technologies, such as extended reality (VR, AR, and mixed reality), are creating dynamic food environment interaction points for customers.^{40,41} A summary of digital technologies arranged by their levels of digital immersion (sense of presence or engagement blurring the lines between the physical and digital

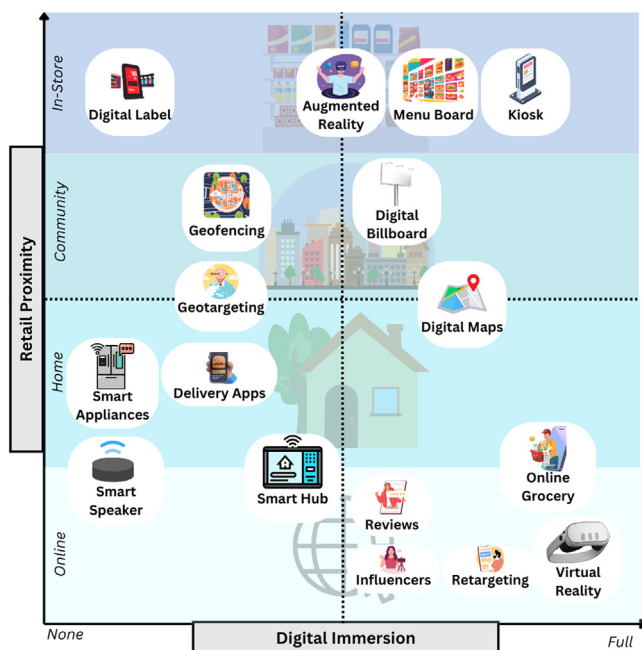


Figure. Summary of the emerging digitalized food environment arranged by level of digital immersion (none to full) and retail proximity (online, home, community, in-store).

worlds⁴²) (none to full) and physical retail proximity (online, home, community, in-store) can be found in the [Figure](#). The [Figure](#) represents the technology interfaces and digital retail strategies that customers may interact with in the digitalized retail food environment. Some of these interfaces are accessed in the online and home environment (smart speakers, smart hubs), home environment (smart appliances and delivery applications), the home and community environment (geotargeting), the community environment (geofencing, digital billboards), and some are mainly experienced within the retail environment (digital labels, menu boards, kiosks). The level of immersion also varies across different digital retail interfaces. Devices such as smart speakers have very low immersion and no physical retail proximity. Immersive digital menu kiosks, in which the consumer views a digital screen while still within the retail setting, represent a medium level of digital immersion. Online grocery shopping uses a digital screen interface, but the consumer is typically not present in the retail space. Interfaces such as VR have the highest levels of immersion as the retail environment is simulated or

modeled. The levels of retail proximity or immersion could influence how powerful the retail environment is in influencing consumer behavior.^{43–46}

Each of these technologies and promotion approaches comes with unique characteristics that make them suitable for different food environment uses and for different marketing approaches to influence customer shopping behaviors. Given this, each digital element comes with consumer benefits, drawbacks, public health opportunities (for research and practice), and threats to public health, summarized in [Table 1](#).

Modernizing The 5 A's of Food Access for the Digital Context

The retail food environment was far less digital when the 5 A's of food access (availability, accessibility, affordability, acceptability, and accommodation) were conceptualized initially.⁴⁷ As such, it is necessary to formally acknowledge the changing landscape and how public health researchers and practitioners can best evolve and modernize the food environment, considering necessary policy and system changes.

The commonly accepted dimensions of food access have revolved around the 5 A's.⁴⁷ Here, we attempt to modernize these dimensions and offer measurement approaches that encompass the digital evolution of food access and the food environment (summarized in [Table 2](#)). For example, availability, which traditionally evaluates the adequacy of the number of places to purchase foods as well as aspects (e.g., healthfulness, variety) of product availability,⁴⁷ might be modernized by also incorporating the presence of digital platforms for purchasing, pick up, broadband internet availability, and/or the presence and degree (or saturation) of digital food marketing happening in a particular area. This incorporation could help better understand how the presence or lack of digital platforms might facilitate or diminish food access. Accessibility or geographic access to the food supply, as well as the ease of reaching that location (including travel time and distance),⁴⁷ may be modernized by including access to online ordering pick-up sites, proximity to digital food ordering kiosks, service delivery range, or smartphone access. Factoring in accessibility to locations that are entirely a result of or heavily influenced by the digital retail food environment will help better understand how easily food sold in digital retail can be accessed. While online pick-up sites would be expected to enhance access, metrics to evaluate the time and distance burden remain important for assessing the actual improvements in convenience. Affordability might go beyond the food's relative value in the built environment (which is usually measured by store ads or regional price indexes)⁴⁷ to include AI and machine-learning-based pricing manipulation through digitally based dynamic pricing (a strategy that bases products or services' prices on evolving market trends such as supply and demand, competitor pricing, and inventory levels⁴⁸). Such dynamic pricing is now occurring or being tested in restaurants and grocery settings,⁴⁹ with some restaurants implementing surge pricing (changing the price of goods or services based on demand and supply at any given moment⁵⁰). Measuring the

Table 1. Summary of Elements of the Digitalized Food Environment, including Definitions, Consumer Interaction Points, and Consumer Benefits, Consumer Drawbacks, Opportunities (for Public Health Research and Practice), and Threats (to Public Health)

Element	Definition	Consumer Interaction	Analysis
Online			
Online grocery	E-commerce that includes online versions of grocery stores	Smartphone applications, websites	Consumer benefit: Convenience, time, curbside delivery Consumer drawback: Increased costs (delivery fees), customer disconnect (inability to handpick), inadequate substitutions Opportunity: Healthier swaps or alternative healthier products. Marketing of healthier items Threat: Algorithms can promote unhealthy foods and habits
Online food ordering/delivery application	Digital e-commerce platform connects consumers with local businesses	Smartphone applications, websites	Consumer benefit: Convenience, time, delivery, and real-time service information Consumer drawback: Delivery costs, food quality Opportunity: Promotion of healthier food options and support for healthier restaurants Threat: Algorithms can promote unhealthy foods and habits
Search engine optimization/re-targeting	Digital advertisement strategy that shows ads to consumers who previously visited a website or application	Websites, applications, email, social media	Consumer benefit: Building off previous consumer behavior. Consumer drawback: Privacy concerns, ad fatigue, timing, site relevance, ad blockers, competition Opportunity: Cost-effective way to boost brand awareness Threat: Industry promotion of unhealthy items
Digital maps	Digital mapping web services and mobile application interfaces provide detailed location information	Electronic devices (smartphones, computers, tablets, etc.)	Consumer benefit: Real-time updates, identification of new locations, location sharing, menus and store visuals/photographs, reviews, popular/busy times, connecting to ordering services Consumer drawback: Oversaturation of options, ads, and optimization can make navigation challenging Opportunity: Searching for stores with healthier options, promotion of stores that offer healthier items, health-centric reviews, promotion of healthier menu items Threat: Algorithms promote less healthy restaurants
Affiliate marketing	A digital marketing tactic that compensates affiliates for business generated from the affiliate's marketing	Websites, applications, social media, Short Message Service messaging, and video streaming platforms	Consumer benefit: Related product reviews, targeting recommendations, exclusive deals/discounts Consumer drawback: Deceptive marketing, unwanted advertising Opportunity: Promotion of healthier foods Threat: Reinforcement of less healthy foods, exacerbating unhealthy habits, and false or misleading information about foods, leading to less healthy behaviors
Influencer marketing	Marketing of products through collaboration with social media influencers with a large following	Social media and video streaming platforms	Consumer benefit: Product reviews and recommendations from individuals they follow and trust, exposure to new and relevant products, and informed decision making Consumer drawback: Advertising fatigue, authenticity of endorsements, and social manipulation Opportunity: Influencers promoting healthy eating and healthy foods, and locations Threat: Industry sponsoring influencer content and endorsements that promote less healthy habits among socially vulnerable consumers, such as teens and children
Crowdsourcing and/or reviews	Reviews of restaurants and food items posted on internet websites and mapping platforms	Electronic devices (smartphones, tablets, etc.), mapping web services, websites, applications, social media, Short Message Service messaging, and video streaming platforms	Consumer benefit: Food venue and item reviews to inform choices Consumer drawback: Oversaturation of opinions, skewed results Opportunity: Promotion of health-centered food reviews, encouraging people to leave positive reviews for healthier food locations Threat: Paid/manipulated reviews can influence public opinion
Virtual reality	Computer-generated simulation of food purchasing and retail venues in a 3-dimensional image or environment that can be interacted with physically by a person using devices such as a head-mounted device	Virtual reality headset operating system	Consumer benefit: Immersiveness in a food-related experience, customer engagement with digitalized retail spaces, and food retail marketing Consumer drawback: Equipment and experience cost, access, head-mounted devices, motion sickness isolation, and learning curve Opportunity: Building health-promoting experiences, incorporation of health into existing experiences Threat: Seamless and immersive incorporation of unhealthy products into the virtual world. Sedentary behaviors
Home			
Smart appliances	Appliance devices connected to the internet and controllable by		Consumer Benefit: Convenience to control appliances remotely with a smartphone application Weakness: Cost, glitches/security breaches.

(continued)

Table 1. (Continued)

Element	Definition	Consumer Interaction	Analysis
Smart hub	consumer devices (smart-phones, etc.) A central control device with digital features (screen and speaker) and a voice assistant that can be controlled by voice commands	Home appliances (refrigerators, microwaves, ovens, air fryers, etc.) Home device	Opportunity: Promotion of healthy shopping, healthy food use, inventory tracking, meal planning, reminders/alerts Threat: Automated and personalized functions encouraging overeating and sedentary behaviors Consumer Benefit: Convenience to centrally and remotely controlled connected devices, gather information audibly, and watch videos Weakness: Compatibility with devices, dependence on the internet, glitches, and privacy concerns Opportunity: Convenient educational resources (video and audio), smart assistance, choice architecture/nudging Threat: Recommendations of less healthy foods or cooking habits, video and audio marketing of less healthy foods, and sedentary behavior
Smart speaker	A device with a speaker and a voice assistant that can be controlled with voice commands	Home device	Consumer Benefit: Convenient way to obtain audible, hands-free information, smaller size for counter space Weakness: Dependence on the internet, no video, glitches, and privacy concerns Opportunity: Convenient educational resources, smart assistance, choice architecture/nudging Threat: Recommendations of less healthy foods or cooking habits, audio marketing of less healthy foods
Community environment Geotargeting	Location-based marketing based on consumer location (e.g., city, zip code) and homing in on a specific consumer criterion (demographic, behavior, interest)	Physical retail food environment	Consumer benefit: Personalization is more effective for behavior change Consumer drawback: Currently used to promote sales of all foods, regardless of health Opportunity: Ability to opt in to healthy food marketing and opt out of unhealthy marketing Threat: Without regulation, complex algorithms could override behavioral interventions
Digital Maps	Digital mapping web service and mobile application interfaces providing detailed location information	Electronic devices (smart-phones, computers, tablets, etc.)	Consumer benefit: Real-time updates, identification of new locations, location sharing, menus and store visuals/photographs, reviews, popular/busy times, connecting to ordering services. Consumer drawback: Oversaturation of options, ads, and optimization can make navigation challenging Opportunity: Searching for stores with healthier options, promotion of stores that offer healthier items, health-centric reviews, promotion of healthier menu items Threat: Algorithms can promote less healthy restaurants as top options
Digital billboards	A billboard that displays digital images	Built environment, roadways, and entertainment areas	Consumer benefit: Highly visible, potentially timely information in the community environment. Consumer drawback: Limited engagement Opportunity: Promotion of healthy food options and healthy diet messages Threat: Promotion of less healthy foods/restaurants
In and around the store Geofencing	Location-based proximity marketing creates a virtual boundary around a more specific location (e.g., store), triggering an action (notification or advertisement) when a customer moves in or out of the boundary	Smartphone application notifications and ads, tablet, and desktop devices. Physical retail food environment	Consumer benefit: Personalization is more effective for behavior change Consumer drawback: Customers must opt in, dependent on signal strength (Bluetooth and global positioning system), drain battery life, push notification fatigue, and privacy (with location tracking) Opportunity: Promoting healthy items at retail venues. Discouraging less healthy items Threat: Retail can promote unhealthy items when consumers are most primed to purchase
Digital menu boards	An electronic display that shows a menu to customers at a retail food outlet, and can be adaptive and easily updated	Retail food restaurant	Consumer benefit: Improve customer experience, easily updated Consumer drawback: Overstimulation, technical issues Opportunity: Promotion of healthier items, nutrition information Threat: Allows opportunity for dynamic/surge pricing of healthier items to change prices at different times. Unhealthy product promotion can be easier and more dynamic
Self-ordering kiosks	Digital terminal for customers to order food without staff assistance	Retail food restaurant	Consumer benefit: Improve customer experience, easily updated, and the ability to review orders more easily Consumer drawback weakness: reduced social experience, technical issues, and wait lines

(continued)

Table 1. (Continued)

Element	Definition	Consumer Interaction	Analysis
Augmented reality	Enhances the real world by overlaying computer-generated information onto a user's environment	Smartphones, tablets, smart glasses, and headsets in the physical retail food environment	Opportunity: Order review for health, promotion of healthier items, and nutrition information Threat: Allows opportunity for surge/dynamic pricing of healthier items to change prices at different times Consumer benefit: Adding things to the environment, customer engagement, marketing, and smartphone features Weakness: Equipment and experience cost, technological challenges of spatial computing, and learning curve Opportunity: Building health-promoting experiences for retail environments Threat: Promotion of unhealthy items
QR codes	A digital barcode that a digital device can read	Posted in physical food retail locations and online locations. Scannable by smartphones, scanning devices, and smart glasses	Consumer benefit: Quick and convenient access to information and transactions with fewer copying and typing errors. Weakness: Scanning issues, need a smart device to scan, broken links to information, fake QR codes can be easily created, leading to malicious content or phishing Opportunity: Increasing access to information on food packaging can lead to healthier purchasing decisions. Promotion of healthier food/menu items Threat: QR codes could be used to promote less healthy foods or shopping patterns by retailers or the industry
Digital front-of-package labels	Digital labels that are dynamic	Physical food retail stores, online retail environments	Consumer benefit: Increased information, facilitating product comparison, and overcoming low food literacy. Weakness: Potential consumer confusion, space constraints Opportunity: Design the digital front-of-package labels to provide clearer, more real-time information on products and their potential impact on health, including personalized information Threat: Manufacturers and retail stores might easily manipulate the dynamic digital labels to promote less healthy foods or change aspects of the marketing mix

impact of adaptive digital pricing on consumers' purchasing behaviors is essential to understanding affordability in an environment in which prices can be more (immediately) manipulated than in the past. The growing use of real-time pricing and its impact on equitable pricing for consumers is prompting consumer protection actions in some states.⁵¹ Acceptability could include not only customer attitudes, preferences, and standards for the built environment,⁴⁷ but also for digital services, as well as objective audits of online and digital shopping components/features and the performance of the user interface. Understanding the acceptability of digital food shopping could help us understand the potential adoption and use of digital food retail platforms and approaches. Finally, accommodation, which reflects how well food retailers accept and adapt to consumer needs,⁴⁷ might now require evaluating retailers' adaptability to consumer digital needs, including whether digital services are set up to make it easier for shoppers to choose healthier food items and avoid less healthy items. Understanding how well retailers accommodate consumer health needs on digital platforms and how they can improve this will help identify opportunities to make healthier shopping easier.

Challenges of Measuring and Evaluating the Digital Retail Food Environment

There are many challenges to measuring and evaluating the digital retail food environment. One challenge is the lack of a clear definition of what the digitalized retail food environment encompasses, as well as of metrics and best practices for evaluating it. A comprehensive definition will help determine what needs to be measured and how. Table 1 lists many digital retail approaches and consumer interfaces, but it is not exhaustive. As technology continues to rapidly develop, new interfaces may emerge. For example, many see the potential of robots in the grocery and retail space.^{52,53} As new technologies emerge, an expanding

Table 2. Reconceptualized 5 A's of Food Access in a Digitally Transformed Food Environment: Reconceptualization, Potential Measurement Approaches, and Policy and Systems Considerations

Access Domain	Reconceptualization	Measurement	Policy and Systems Considerations
Availability: Adequacy of the supply of healthy food The presence of places to purchase food or The number of places to purchase food in a region Whether healthy food and sufficient variety are represented	The presence or number of places offering digital platforms for purchasing in a certain location, or the degree of digital food marketing in a region	• Presence or total count for an area of online or digital ordering opportunities; derived from corporate websites, food delivery sites, business databases, mapping interfaces, crowd-sourced data, or on-the-ground audits • Availability of items in the online ordering system vs actual/in-store availability • Assessment of the presence of digital advertising • Availability of in-store digital shopping support	• Incentivizing retail to expand the availability of online services, including SNAP and WIC online ordering • Incentivize or require retail to have consistent online and in-store item availability • Incentivize businesses to have consistent availability of in-store digital services • Restricting location and degree of exposure to digital food marketing
Accessibility: Geographic access, or the location of the food supply, and ease of getting to that location (including travel time and distance)	Geographic access or location of the digital food supply, and ease of getting to physical locations connected to digitized experiences	• Travel time, distance, temperature, and restrictions for online ordering, pickup, and food delivery • Broadband internet access and cellular service • Proximity to geofencing and geotargeted marketing, and the ability to avoid it	• Expanding access to broadband high-speed internet, particularly in rural areas • Satellite/remote pickup spots for online orders to reduce travel burden, particularly communities that are rural/remote and with low income
Affordability: Food prices and people's perceptions of worth relative to the cost, usually measured by store ads or regional price indexes	Digitization of food prices and AI and machine-learning-based manipulation	• Audits of online/applications (grocery, food delivery) and digital food prices (e.g., kiosks) pulled from websites, in-store audits, and regional price indexes • Fees for online ordering services (commissions/service fees, tips), delivery fees, and surge pricing	• Subsidizing online grocery delivery in communities that are rural/remote and with low income • Regulation of dynamic pricing • Support for consistent pricing in areas that are rural and with low income
Accommodation: How well local food sources accept and adapt to residents' needs (e.g., store hours, types of payment accepted, arrangement	How well online and digital interfaces and in-store connections accept and adapt to residents' needs	• Online ordering, pickup and delivery hours, ease of pickup, and payment method • Quality of vendor selection and food transfer from digital orders • Intuitiveness of digital experiences • Ease of using SNAP or WIC benefits	• System efficiencies to ensure quality during food transfer • Healthy defaults in digital spaces • Making SNAP or WIC benefits easy to use

(continued)

Table 2. (Continued)

Access Domain	Reconceptualization	Measurement	Policy and Systems Considerations
of goods in the environment)		• Accessibility of digital ordering and support for populations experiencing disabilities • Visibility of nutrition information on digital ordering platforms	• Ensuring accessibility to consumers with disabilities beyond the required legal regulations • Requirements to make nutrition information visible
Acceptability: People's attitudes about attributes of their local food environment and whether an available product meets their personal standards	Consumer attitudes and standards about attributes of their digitized food environment	• Self-reported customer satisfaction with digital services • Quality of product (e.g., produce) and substitutions • Online ordering system accuracy on availability • Objective audits of online and digital shopping components/features	• Policies or systems that support standards for cultural acceptance • Policies that promote high-quality produce availability online • System supports that make online ordering systems in areas that are rural and with low income work as effectively as in urban areas

AI indicates artificial intelligence; SNAP, Supplemental Nutrition Assistance Program; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

definition of the space and new measurement approaches will be needed. Another challenge is the dynamic nature of the data, as most aspects of the marketing mix (price, product, and promotions) can shift constantly, and personalized algorithms create nonstandardized consumer experiences. These nonstandard experiences need to be considered for the reliable measurement of this environment. Exposure and attribution can also be challenging to track, as the rapid, evolving nature of many digital interfaces and experiences, along with the interconnectedness of multiplatform approaches, makes it hard to attribute exposure to decision making. Data access also makes measurement challenging, as most digital retail platforms are not transparent about the data they hold, which may be proprietary, limiting access to data that could be useful for measuring or evaluating impact. Understanding the impact of geographic access is also more complicated, as the impact, location, and accessibility of food must now be further conceptualized based on the availability of delivery services, delivery coverage areas and costs, and access to pick-up sites. The influence of digital retail on geographic access will necessitate a shift in the understanding of food swamps (areas with a high-density of establishments selling high-calorie fast food and less healthful food, relative to healthier food options)⁵⁴ and food deserts (neighborhoods and communities that have limited access to affordable and nutritious foods),⁵⁵ as accessibility must no longer be entirely based on access to traditional brick-and-mortar retail locations or traditional retail experiences.⁵⁶ In the future, purchasing could be made in VR-based grocery stores with home delivery. Finally, because of the nature of digital data and its interconnectedness across platforms, there are ethical and privacy concerns about measuring behavior across devices and platforms. Public health researchers could use measurement approaches such as cookies (small files of information that a web server generates and sends to a web browser),⁵⁷ bots (a software program that operates on the internet and performs repetitive

tasks),⁵⁸ or screen recording, particularly if used to monitor retail changes, but bring ethical and privacy concerns when tracking individual behavior. Protocols and privacy safeguards need to be developed.

Equitable and Ethical Challenges of the Digitalized Food Environment

Inequitable access to healthy, nutritious foods has long afflicted Black, Indigenous, and People of Color, rural populations, and those with low incomes in the US.^{59,60} While digital retail was initially promoted as a promising strategy to address inequitable access among populations with low income, the digitalized food environment may undermine equity because of who can access such services in certain contexts (e.g., high delivery fees reducing access, broadband access).^{27,36,61} In addition, digital retail can raise ethical concerns about predatory marketing and data privacy that affect all who interact with the platform, potentially widening health inequities.⁶²

Multiple studies have found disparities in access to online grocery services across rural-urban areas and low and high-income areas, including delivery, SNAP acceptance, and the availability of fruits and vegetables.^{63–65} In addition to the reduced availability of online grocery services, rural residents are also less likely to have access to home broadband than urban and suburban residents, although this has improved in recent years,⁶⁶ and rural residents may depend on cellular internet for internet access despite limited cell coverage.⁶⁷ A much lower percentage of Americans in rural and tribal areas (vs urban) have access to adequate broadband coverage needed for online ordering, smart devices, and VR functionality, according to the US Federal Communications Commission.⁶⁸ Some research suggests that these disparities may be wider because of the undercounting of need in certain rural areas.⁶⁹ These disparities in broadband availability may limit rural residents' ability to leverage digital technologies,

including online ordering, smart devices, and high-bandwidth devices (VR/AR headsets). The rise in the potential of low Earth orbit satellite-based internet (a constellation of satellites orbiting closer to Earth than traditional satellite internet systems, resulting in lower latency and faster speeds, and making internet available in remote areas) could help overcome the broadband internet gap.⁷⁰

A second contributor to amplifying disparities is the cost of online grocery services, which may impede affordability for lower-income households. While the SNAP Online Purchasing Pilot allows participants to use SNAP benefits online, benefits cannot be used for delivery, service fees, or tips; these must be paid out of pocket.³³ Some online retailers or delivery services waive delivery or service fees, but only if the shopper meets a minimum purchase requirement, which may exceed what the shopper has available to spend with their benefits. In addition to the fees, prices online may be higher than in the same store,⁷¹ compounding the costs of online grocery shopping and reducing affordability.^{27,28,36} Moreover, aversion to the risk of a bad buy may disproportionately affect households with low income.

Accommodations for individuals with disabilities in the digitalized environment may also be inadequate, leading to additional disparities.^{72,73} Many individuals with disabilities lack access to the internet at home and are less likely to have mobile devices.⁷³ In addition, many online food websites do not meet web content accessibility guidelines (e.g., providing alt text, keyboard navigation, and compatibility with assistive technologies),⁷³ and kiosks may not meet Americans with Disabilities Act standards.⁷⁴ This is concerning, given that there are many potential benefits of online services for people with disabilities, including reducing transportation, mobility, and navigation barriers they may experience when in-store shopping, and providing independence and flexibility in purchasing food.⁷⁵

Older adults (aged ≥ 60 years) also face specific challenges with the digitalized food environment. Many

older adults have less experience and comfort with online shopping and digital ordering systems.^{75,76} These comfort issues may be related to reduced hand dexterity, cognitive skills, and eyesight quality as people age.^{76,77} Older adults may also face restraints related to a fixed income, making affordability and access to up-to-date devices and high-speed internet more challenging.^{76–78}

In addition to equity concerns, digital retail also raises ethical challenges for those who interact with the online platform. First are data privacy concerns, which involve the unclear terms users largely agree to that allow companies to collect, track, store, use, and share the personal information of their consumers and their purchases.^{37,79} Company practices of collecting and sharing private data have “evolved in a largely unregulated environment, where no... policies provide adequate protections for consumers” [p.3].³⁷ This context has resulted in limited transparency of privacy policy disclosures by using long, complicated legalese and excessive data collection of private shopper information such as their social networks, demographics, household size, geolocation, purchasing patterns, and cross-device use.^{37,80} This leaves a black box of what data is collected, who else it is shared with, and how it is used to manipulate consumer purchasing.

Given the numerous data points collected on consumers, it is unsurprising that companies use this information to tailor their marketing content and approaches to influence consumers to certain purchases in the digital retail space—resulting in a second ethical concern.³⁷ Companies have designed sophisticated algorithms that offer consumers a wider range of products, product swaps, add-ons, and cross-promotions based on their data profiles, including current and past selections.^{79–81} Moreover, the continued integration of AI into these marketing strategies means the content is more personalized and thus engaging, further driving the sales of products that companies want to promote and prioritize.⁸¹ While such marketing strategies have the potential to improve

the diet quality purchased,⁸² their increasing and poorly transparent use by the leading global food and beverage companies⁸¹ suggests a continued promotion of unhealthy products and poor diet-related outcomes.⁸⁰

Notably, while data privacy concerns and tailored marketing approaches are used with all customers, how these practices are ultimately implemented can also contribute to widening nutrition-related health inequities. Past purchasing is an example, as digital retail marketing algorithms can reinforce unhealthy defaults and expand the range of unhealthy suggestions.⁸² In addition, companies' segmentation and profiling algorithms allow them to group customers with similar affinities and purchasing patterns and then rank these groups based on their likelihood to be profitable marketing targets, leading to further customer profiling, targeted marketing, and exclusive product promotion among groups with similar characteristics.^{32,80} The degree to which these digital marketing strategies rely on overt demographic features, such as race/ethnicity, income, and gender, raises questions of discriminatory practices. Targeted marketing of unhealthy foods to Black and Latino individuals has been well-documented,⁸³ but pairing this with extensive amounts of digital data only provides the opportunity to amplify the nutrition-related health disparities.⁸⁰ As Barnhill et al. (2022) clarify, marketers do not "need it to be motivated by any discriminatory intent... [to] exacerbate health disadvantage" [p.54].⁸³

IMPLICATIONS FOR RESEARCH, PRACTICE, AND POLICY

Given the growing mediums of the digitalized food environment, the modernization of the 5 As, and the key equity and ethical implications that need to be considered, we offer several implications for research, practice, and policy. This section highlights gaps and opportunities for informing future research and practice related to the digitalized food

environment presented in [Tables 1 and 2](#).

Measurement of the Digital Retail Environment

A detailed summary of potential measurement approaches is listed in [Table 2](#). To enhance our understanding of the digitalized food environment and to help evaluate changes over time, there is a need to develop a suite of valid and reliable assessment tools. These tools can be modified versions of existing food environment assessment tools, such as the Nutrition Environment Measurement Survey,⁸⁴ and/or be based on key factors related to retail food marketing. For example, Moran et al (2022)²³ developed a coding instrument to examine the marketing mix strategies (i.e., product, placement, promotion, and pricing) and the nutritional quality of marketed products among online grocery retailers. Emerging evaluation and assessment tools and approaches could be tailored to other specific digital retail food environments and be flexible, given the rapidly evolving nature of these environments. While traditional approaches have leveraged person-power to collect and code food environment assessment data, the digitalization of the food environment space creates opportunities for more efficient digital evaluation approaches, including web scraping, sourcing datasets from data servers, and AI-based methods.

Intervention in the Digitalized Food Environment and Behavior Change Tools

Potential intervention strategies for different digital applications are identified in [Table 1](#). While many digital interventions may resemble those implemented in the physical environment (choice architecture, nudging, education), the digital application offers the potential for a broader reach through more mediums of delivery (applications, websites, kiosks, VR, etc.), higher personalization, more adaptive and continuous feedback, more interactivity through gamification and

nudges, and potentially more scalable and cost-effective approaches.

Public health interventions in the digitalized food environment have thus far focused on choice architecture techniques that seek to predictably influence choices without dictating the ultimate choice.^{85,86} The strategies used in these studies can be categorized as making information visible (e.g., using labels indicating low or high-calorie products; multiple traffic lights or Nutri-score labels; less healthy food or ingredient warning labels^{87–90}) or invisible (e.g., removing less healthy options),⁸⁹ changing option consequences (e.g., imposing 20% to 25% taxes on unhealthy products and/or 10% to 50% discounts for healthy ones), changing choice defaults (setting no-action defaults), or providing nudges highlighting healthy products, and changing option-related efforts (e.g., providing a prefilled cart with healthy products that participants can still modify as desired).⁹¹

There is a need to equip consumers to interact successfully with this digitalized environment. One way is to develop and disseminate consumer tools that directly promote healthier behavioral habits within the digitalized food environment. Theoretically driven and practice-based tools could help consumers navigate the digital retail environment.⁹² These tools may be designed to directly combat the unhealthy influences of digital advertising and machine learning algorithms within or outside the digital food environment platform. These tools might instead use similar tactics or leverage existing platforms used by retail actors to promote healthier behaviors. Tools could also be developed to help older adults use technology platforms for online grocery shopping, such as larger fonts, simpler flows to reduce cognitive demand, and assistive features.⁷⁷

One example of public health nutrition digital retail technology is the WICShopper application,⁹³ which helps WIC participants manage their benefits and make informed food choices through functions such as scanning barcodes to check if items are WIC-approved, viewing current benefit balances, and

accessing WIC-approved food lists. Other research has examined approaches to healthier online purchasing among individuals with low income. Coffino et al⁹⁴ and Melo Herrera et. al (2024)⁹⁵ have demonstrated the potential of online default healthy grocery carts, and McGuirt et al (2024),⁹⁶ reported the potential of embodied conversational agent online grocery shopping assistants.

Future research could explore expanding these approaches with AI and extended reality. Future research could also explore digital reward programs, health-based digital restaurant reviews (integrated into common review sites such as Google Maps and Yelp), and real-time feedback on food choices. Digital healthy food maps could be created to help navigate the built environment more effectively, including by avoiding areas with heavy digital marketing. A combination of approaches may be necessary; thus, investigators must leverage study designs to disentangle the multiple effects on outcomes. Frameworks such as the multiphase optimization strategy⁹⁷ or sequential, multiple assignment, randomized trial⁹⁸ will be essential to evaluate and refine combined interventions.

Significant capital investments and strategic funding will be needed to develop tools and bring them to scale. Given rapid changes within the digital transformation, these funding mechanisms need to be expeditious and flexible to keep pace. Cross-disciplinary collaboration with coders and Big Tech (the largest and most influential technology companies) will be essential, leveraging the knowledge and skills needed to combat food industry algorithms and strategies.

Education for the Consumer

Interviews with SNAP program participants suggest making nutrition education publicly available to promote healthy behaviors in the digitalized retail food environment, via tutorials and related resources, as an equity-promoting strategy, especially for households of low income, while considering digital literacy, language barriers, and limited budgets.⁶¹ Education could start early in kindergarten to 12th-grade educational

environments, given the increasing youth engagement with the digital food environment. Similarly, federal nutrition programs could develop and promote dedicated educational programs to help consumers navigate the digitalized food environment, including older populations. While there are opportunities within federal nutrition programs and alternative, evidence-based nutrition education programs to promote healthier purchasing in the digital retail food environment, these programs face constraints and challenges in working within and navigating digital environments. Online shopping and digital literacy may be a new addition to many educators' curricula, so support is needed for curriculum development, materials, and training.^{99,100}

Specifically, curricula might focus on raising awareness of how digital tactics influence consumers in the digitalized retail food environment, which companies are most engaged in these tactics, and improving their self-efficacy for identifying, avoiding, or overcoming these tactics and strategies. Instruction might be based on emerging theoretical models, such as the food and beverage cues in digital marketing model,¹² which specifies key marketing elements and marketing integration strategies common on digital platforms. The digital food environment brings several important differences compared with traditional marketing: it is cheaper and therefore more ubiquitous, uses a wider range of strategies to maximize impact, including graphics and visuals designed to appeal to the consumer, cartoons and brand equity characters, influencers, and more opportunities for engagement (e.g., likes, comments, and shares).^{12,101} Consumers could be educated on these marketing techniques to understand how they are being targeted and how they can develop resilience to marketing strategies that may lead to less healthy behaviors.

Policy and Systems-level Support

Policies could help provide a formal framework via laws and regulations to help support healthy shopping in this digitalized environment. Policies

may also help facilitate the specific intervention strategies listed above. A list of potential policies and system-level support for each food access domain is presented in Table 2. While many of these are aspirational, speculative, or prospective, some pilots and initiatives offer the potential to examine the impact of some of these approaches on food shopping behaviors (expanding access to broadband internet,^{68,70,102,103} remote pickup locations for online grocery orders,^{104,105} and retailers offering free or discounted delivery fees for SNAP users¹⁰⁶).

Per previous literature, policy-level pathways to prevent harm, promote health, and protect against predatory digital environments exist, including for the online grocery retail, online restaurant ordering, and social media marketing.¹⁰⁷ In this Research Report, we include these ideas and expand them to the broader digitalized retail food environment. Policy changes that frame transparency in marketing regulations and marketing business practices are needed at all levels to protect consumers against the potential and real harms of predatory marketing tactics used on online food delivery platforms. These policies could be paired with systems-change commitments to promote social responsibility.

For instance, voluntary corporate policies (not legally required) may include transparency in nutrition information of marketed products, dedicating 85% to 95% of the positive space on webpages for healthier options (e.g., fresh, frozen, or canned produce, water, formula) on all digital platforms, limiting digital marketing to adult users, and a policy that at least 85% of digital menu offerings will be aligned with the Dietary Guidelines for Americans.¹⁰⁸ Federal policies involving legally mandated actions could include expanding food manufacturer marketing regulations, regulating digital advertising and deceptive practices, standardizing nutrition disclosures on digital platforms, and reducing the digital marketing of unhealthy foods to children.

At the federal level, efforts could also be made to expand and facilitate

online ordering and food delivery for SNAP and WIC, including delivery support (lowering or subsidizing delivery fees) and pickup. In addition, urgent policy action is needed to protect consumers against the adverse effects of digital marketing. In the US, food manufacturers are subject to limited marketing regulations because of judicial interpretation of the First Amendment, which protects commercial free speech by extending rights to industry and companies, not just US citizens. Within a framework that prioritizes commercial interests over public health, policymakers could be encouraged to develop guidance on digital promotion and incentives for healthy products, mandatory advertising disclosures, and other consumer protections against discriminatory practices.^{109,110}

To prevent predatory food marketing, which might exacerbate health disparities, federal benefits programs (SNAP, WIC) with online shopping options could consider consumer protections on the type of data collected, how it is shared, and making the default not to opt in to user agreement terms. These protections may require stronger federal regulations or new legislation if retailer data practices exceed current regulatory reach. While the USDA oversees the SNAP and WIC programs and authorizes retailers,¹¹¹ online data practices are typically governed by privacy and consumer protection laws, regulated by the Federal Trade Commission.¹¹² In the built retail environment, policies could regulate the content of digital billboards and ordering kiosks. Policies could also help ensure that digital platforms are accessible to consumers with disabilities, focusing on user-centered design to create positive experiences in online and digitalized retail environments.

Summary

The retail food environment's rapid digitalization and transformation require the field of public health nutrition to modernize its conceptualization of food access and the food environment, adapt its measurement and research approaches accordingly,

and refine its approaches to health promotion efforts. Researchers and practitioners must understand and identify the elements, opportunities, and threats of this digitalized food environment. This paper highlights the growing need for new measurement approaches, consumer nutrition education, innovative interventions, and policy and systems-level support for this digitalized food environment. There is a clear need for focused efforts and resource investments to equip public health researchers and practitioners to support consumers in this digitalized retail food environment.

CONFLICT OF INTEREST DISCLOSURE

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