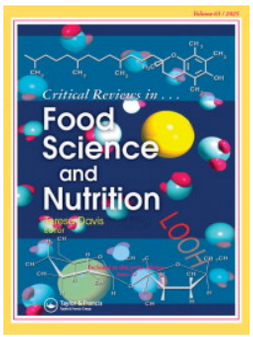

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REVIEW ARTICLE

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Nudging and food shopping: A review of technological interventions within the grocery environment

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ABSTRACT

Food choice decisions and dietary habits contribute significantly to the current global epidemic of obesity. Designing healthful shopping environments is key to supporting consumers in making informed food choices and addressing diet-related health issues such as obesity. This systematic review aimed to consolidate and synthesize extant literature on nudging and the role of technology on healthy food choice decisions and address the research question of how nudging techniques, particularly those enabled by technologies, are used to influence healthy decisions in food retail environments. The review included studies published between 2011 and 2024 across five databases. It followed the PRISMA structure to systematically identify, screen, and synthesize, the literature. Through the searches, 11,662 papers were identified. Overall, twenty-five papers met the inclusion criteria and are included within this review. Three contributions are made. First, a novel and rigorous systematic literature review process synthesizes studies of nudging techniques in shaping food choice with gaps in knowledge for further research highlighted. Second, the review identifies the importance of nudging interventions on consumers' health-related food choices in retail environments. Existing nudging taxonomies are introduced to provide new frameworks for future research. Third, the review provides new insights and future research opportunities pertaining to digital technology-enabled nudging for consumer food choice decisions. Examples of technology include virtual reality, mobile applications, and augmented reality.

KEYWORDS

Behavioral science; choice architecture; decision making; food choice; systematic literature review; technology

Introduction

Consumer behavior plays a critical role in understanding the prevalence of dietary related diseases (Maninder 2022). Specifically, understanding the food choice and dietary habits of consumers could help to mitigate the rise in health conditions such as cardiovascular disease and diabetes. By understanding food choice decisions, prevention as opposed to treatment of such dietary-related diseases could alleviate strain on healthcare services globally (Baker et al. 2022). By prioritizing preventative measures associated with better food choice, both economic and health burdens associated with health-related diseases can be decreased (Wang et al. 2011). The implementation of nudging techniques offers potential in this regard for food retailers to address unhealthy food consumer behaviors (Trafford and De La Hunty 2021). Nudging is defined as, "*any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives*" (Thaler and Sunstein 2008, p.6). It refers to subtly guiding individuals' food choices, without limiting or restricting options, or significantly changing consumer economic incentives and draws on insights from behavioral economics and psychology, using cognitive biases and heuristics to influence decision making processes (Schmidt and Engelen 2020; Thaler and Sunstein 2008). Health nudging therefore is a promising, preventative technique to encourage consumers to make healthier choices through salient cues and other changes to the presentation of food products (Hollands et al. 2013). Moreover, the concept of nudging to guide consumer behavior is increasingly located in digital environments.

The core steps of the nudging process, outlined in Figure 1, include: (1) Identifying the target behavior, (2) mapping the behavioral process to uncover frictions (barriers) such as limited visibility of health options, as well as fuels (enablers) such as consumers' health goals, and (3) designing and implementing the nudges that make the desired behavior easier, more attractive, social, and timely (EAST framework) (Hallsworth and Kirkman 2020). In a food retail setting, this might translate into repositioning healthier items to eye level

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Figure 1. Illustrtaes the process of applying behavioral nudges in public health through the three steps of: (1) identifying the target behavior, (2) mapping the behavioral process, and (3) designing and implementing the nudge.

(easy), adding appealing signage (attractive), highlighting popular healthy purchases (social), or offering real-time feedback via digital kiosks (timely). This systematic approach enables retailers to tailor interventions based on behavioral insights, improving the likelihood of sustained change. As Kim, Kim, and Lee (2023) argue, integrating behavioral mapping with EAST principles ensures that nudges are not only theoretically sound but also practically relevant and context-sensitive, which is crucial in dynamic retail environments. This aligns with prior research emphasizing the importance of understanding decision points and context in nudge effectiveness (Hummel and Maedche 2019; Thaler and Sunstein 2008).

Digital nudging involves the use or changing of interface design elements to subtly influence consumer food choice decisions (Schneider et al. 2020). Furthermore, digital nudging can also provide personalized prompts such as pop-up reminders or using visual cues such as colors and fonts to draw attention (Mirsch, Lehrer, and Jung 2018). The use of interactivity and real-time feedback enables nudges to be modified in response to consumer behaviors, creating adaptable and context-sensitive nudging techniques that optimize digital advancements (Schneider, Weinmann, and Vom Brocke 2018). One example of this is the use of push messages, which are delivered at the point of decision. These interventions, often referred to as just-in-time nudges, have demonstrated positive effects on consumer behavior change (Van der Laan and Orcholska 2022). These changes not only support healthier consumer food choice decisions but also contribute to improved health outcomes by encouraging better dietary habits and reducing the risk of health-related diseases.

Overall, technological advancements are transforming food choice in terms of the environment, interactions, and behaviors (Mancuso, Petruzzelli, and Panniello 2023). Blending behavioral insights with digital technologies enables nudging strategies to become more impactful and context-sensitive (Ewert 2020). However, studies of nudging to create healthier consumer food choices are fragmented, with a lack of clarity pertaining to the role of digital technologies (Bergram et al. 2022). Investigating the context of nudging alongside the role of digital technology as an emerging field of consumer behavior research, provides a basis for more targeted future studies. The aim of this systematic review, therefore, was to consolidate and synthesize extant literature on nudging and the role of technology on healthy consumer food choice decisions, and answer the research question of how nudging techniques, particularly those enabled by technologies, are used to influence healthy food choice decisions in foot retail environments.

This systematic review draws together pertinent literature to better understand nudging in the context of healthier food choice while identifying gaps for further research. It also considers the increasingly important role of digital technology in the retail context of consumer food choice decisions.

In the following sections, we first discuss the theoretical underpinning of nudging in the context of food consumer behavior and food choice decisions in retail environments. We then present the intensive and systematic method used in the review process. Next, we explain the key findings of the systematic review in terms of effective nudging techniques for shaping food choice decisions and the role of digital technologies. We conclude by introducing a framework of combined nudging techniques and the role of digital technology, reflecting on future research directions as well as managerial implications and limitations.

Theoretical background

Consumer behavior is a complex field in relation to food consumer choice and is heavily influenced by attributes and features of food products and social, economic, psychological, and environmental cues (Chen and Antonelli 2020). The DONE framework (Determinants of Nutrition and Eating), provides a comprehensive understanding of these influences, emphasizing the complexity and interplay between social, environmental, and individual factors within food consumer choice decisions (Stok et al. 2017).

Figure 2 illustrates the DONE Framework, which categorizes key influences into three areas: (1) Food choice, which encompasses preferences, purchasing behavior, and food preparation; (2) Eating behavior, which includes eating habits, portion control, and dieting; and (3) Dietary intake/nutrition, which highlights meal patterns, nutrient intake, and dietary healthiness. The framework underscores the importance of the food environment in shaping decision-making (AbuKhousa, El-Tahawy, and Atif 2023). Not just consumer behavior toward food purchasing, but also their reasoning behind making decisions to purchase certain products (Solomon, Russell-Bennett, and Previte 2012).

Nudging is defined as, "*any aspect of the choice architecture that alters consumers' behaviour in a predictable way without preventing options or significantly changing economic incentives*" (Thaler and Sunstein 2008, p. 4). In food retail settings, the theory of nudging recognizes that consumers often make food choice decisions based on efforts rather than health considerations. Therefore, the concept of nudging aims to promote healthier choices by ensuring they are more accessible and prominently placed through modifying the environment strategically (Kroese, Marchiori, and De Ridder 2016). Ensaff (2021) outlines that some straightforward nudges being applied frequently throughout food retail, such as placement, which refers to the location of the food product close to the consumer, close to the till, or at eye-level. This nudge is often successful in creating a healthier food choice when assessing the placement or proximity of food products (Bucher et al. 2016). Default nudges, where

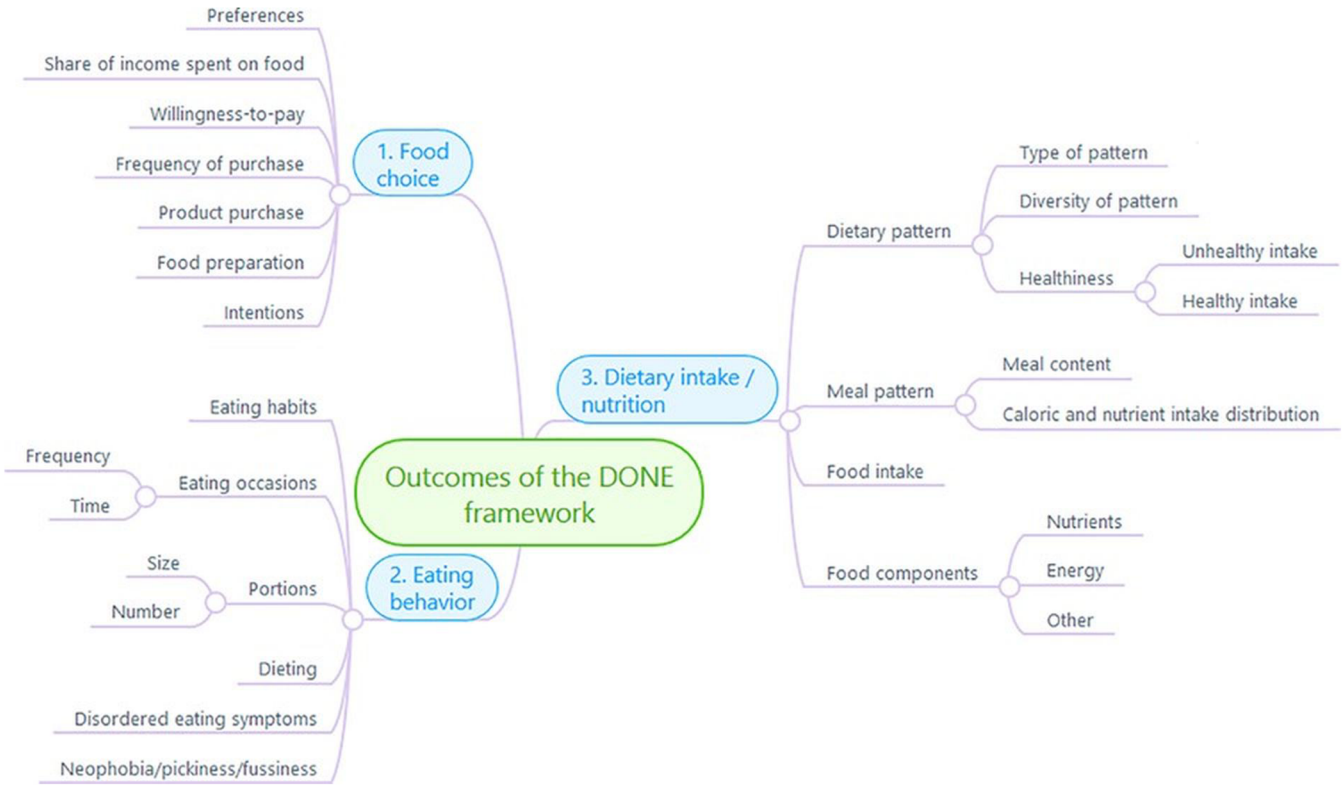

Figure 2. illustrates the DONE Framework (Determinants of Nutrition and Eating), which outlines key factors influencing consumer behavior related to food choice, eating behavior, and dietary intake/nutrition. The framework categorizes these influences into three main areas: (1) Food choice, which encompasses preferences, purchasing behavior, and food preparation; (2) Eating behavior, which includes eating habits, portion control, and dieting; and (3) Dietary intake/nutrition, which highlights meal patterns, nutrient intake, and dietary healthiness. The framework emphasizes the complexity of consumer food decision-making, shaped by psychological, social, and environmental factors (Stok et al. 2017).

a better option is predetermined, are another common nudging strategy outlined by Ensaff (2021). They have been shown to shift consumers toward healthier and more sustainable food choices, for example, pre-selecting options such as a plant-based meal on online forms, can effectively nudge consumers to appropriate these choices (Vecchio and Cavallo 2019). User interfaces can aid food choice, both positively and negatively, as they can provide default options. However, food retailers may not always choose the healthiest version of a food product as a default and should be encouraged to design interfaces that promote healthier food choices as opposed to sales (Valenčič et al. 2023).

Decision-making can be simplified using decisional heuristics which involve mental shortcuts that help consumers navigate complex environments (Tversky and Kahneman 1974). For example, availability heuristics influence how consumers recall familiar brands, often favoring recognizable labels (Collins et al. 2015). Decisional heuristics also align with two modes of thinking: system one and system two. Recently, this theory has been developed further by Kahnemann (2017) who outlined that system one (automatic thinking) is fast and intuitive, reiterating that consumers take mental shortcuts and often make subconscious decisions, selecting healthy food products based on instinct, familiarity or habit. System two is more deliberative and analytical, meaning that choice can be reasoned and logical and can override emotions and impulses (Leng et al. 2021; Kahnemann, 2017). This means that consumers may plan their food choices, read nutritional labels, or even consider health impacts when making decisions. However, in terms of food choice, most decisions are system one as they are driven by automatic preferences formed through repeated exposure (Monterrosa et al. 2020), but health-related nudges aim to shift behavior by activating either or both systems (Ensaff 2021). The food retail environment plays a key role in this cognitive dynamic, as its layout, design, and informational cues can prime system 1 responses through convenience and visibility or engage system two thinking through nutritional content and labeling (Cohen and Babey 2012). From a technical standpoint, certain food attributes, e.g., sustainable or ethical sourcing, typically require cognitive elaboration and therefore activate system two (De-Magistris and Gracia 2016), whereas inherent physical traits like color, freshness, or product placement are more likely to influence system one due to their immediate and observable nature (Wansink 2004). Understanding how these attribute types interact with cognitive processing systems can support more tailored nudging interventions that align with both the consumer's values and cognitive tendencies (Schäufele and Janssen 2021).

Building on this dual-process perspective, the Integrated Dual-Process Nudging Model (IDPNM), detailed in Figure 3, provides a structured framework to understand how different nudges engage distinct cognitive mechanisms. System one nudges, such as visual cues, defaults, and social norms, target automatic processes, often used in online retail environments, for example, using subtle design modifications by

placing healthier options at the top of search results (Jäger and Weber 2020). Conversely, System two nudges, including nutritional labeling, real-time feedback, and comparative product information, engage deliberate processing which prompts consumers to actively evaluate their choices before making a food choice (Hummel and Maedche 2019). Encouraging system two engagement through educational campaigns or labeling can then balance quick instincts with conscious, reasoned choices to target long-term healthier consumer behavior. While these nudges require greater cognitive effort, they play a crucial role in health-related food choice by fostering awareness and self-regulation (Eyles et al. 2023). Furthermore, hybrid nudges using new technologies, such as gamification and real-time interactive prompts, combine both to increase immediate influence and sustained engagement (Casado-Mansilla, López-de-Armentia, and Emaldi 2024; Ghosh, Das, and Gupta 2021). Therefore, understanding the interplay between cognitive processes and digital choice architecture is critical for designing effective nudging interventions that balance intuitive guidance with informed decision-making, ultimately fostering sustained healthier food choices in retail environments.

Figure 3 illustrates the IDPNM, which aligns nudging strategies with cognitive processes. System one nudges rely on intuitive decision-making (e.g., visual cues), whilst system two nudges require active evaluation (e.g., informational prompts). Hybrid nudges combine elements of both, such as real-time feedback and personalized recommendations, optimizing influence on consumer behavior in food retail settings (Hummel and Maedche 2019; Jäger and Weber 2020; Thaler and Sunstein 2008).

The use of technology regarding nudging can therefore serve two distinct roles: (1) as a tool for implementing nudging strategies, for example, using augmented reality labels to promote healthier food choices in a retail setting; (2) as a means for testing the effectiveness of these nudging interventions, for example, using a virtual reality supermarket to track changes in food consumer behavior (Hertwig and Grüne-Yanoff 2017). Digital technologies can be used to present visual cues to highlight the preferred food choice, using a range of methods such as different fonts, colors, icons, or labels, or repositioning the food product to a more prominent location such as top of the category page (Thorndike et al. 2014). The display and timing of prompts should be carefully considered as research outlines this can impact food consumer choice (Valenčič et al. 2024). For example, pop up reminders can be programmed to appear at point of decision, or when consumers add food products to their cart, pop up messages could suggest a healthier alternative (Kallbekken and Sælen 2013). These techniques are considered digital nudges because they require modifications within the user interface to subtly guide food choice decisions (Petersson 2022).

The use of technology can be used to create an immersive and real-time experience that directly influences consumer behavior (Patel, Asch, and Volpp 2015). Such technologies include wearable devices that can provide alerts to nudge a consumer to move or stand up after sedentary behavior or periods of inactivity (Toner, Allen-Collinson, and Jones 2022). Similarly, virtual or augmented reality (VR and AR) can insert a label overlay or score to deem foods as unhealthy, nudging consumers toward a healthier option (Fuchs et al. 2020). However, consumers are often cynical when faced with new technologies and equally have a fear of being nudged (Elliott 2024). The Early Adopters Marketing Theory for New Products (Frattini et al. 2014) explains these concerns and suggests the identification of early adopters such as technologically savvy consumers to generate interest and awareness and socially accept these new technologies.

Furthermore, technology such as VR and AR can be used to provide immersive food shopping or dining experiences and provide controlled environments to apply nudging principles, enhancing customer experience (Batat 2021). The Lambent shopping trolley is another innovative technology being used as a "fast and frugal" nudging technique where LED lights will flash green, amber, or red, to give immediate visual feedback to indicate the environmental impact of a product's food miles (Bachour et al. 2012). This type of "smart nudging" is scalable and adaptable across variables

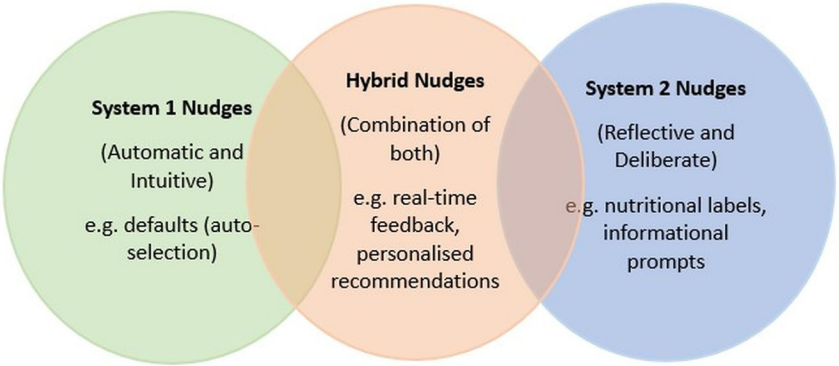

Figure 3. illustrates the Integrated Dual-Process Nudging Model (IDPNM), which categorizes nudging interventions based on their alignment with cognitive mechanisms. System 1 nudges operate on automatic and intuitive decision-making processes, requiring minimal cognitive effort (e.g., default selections and visual cues). System 2 nudges engage reflective and deliberate thinking, prompting consumers to actively evaluate choices (e.g., nutritional labels and informational prompts). Hybrid nudges combine elements of both, such as real-time feedback and personalized recommendations. This model highlights how nudging strategies can be designed to align with cognitive processes, influencing consumer behavior in food retail settings (Hummel and Maedche 2019; Jäger and Weber 2020; Thaler and Sunstein 2008).

such as calories or sugar content, supporting healthier decision-making in real time (Mele et al. 2021).

The literature reviewed above provides a basis for the systematic review of literature conducted in this study. There is a need to further consolidate and synthesize studies of nudging techniques and the role of new digital technologies in shaping food consumer behavior. Of interest is nudging interventions on consumers' health-related food choices in retail environments. And the role of digital-technology-enabled nudging that is emerging in terms of food choice decisions. The next section develops the systematic literature review approach adopted by this study.

Review methodology

Systematic literature reviews are designed to identify, appraise, and synthesis all relevant empirical evidence to answer a clearly defined research question, thereby informing practice, policy, or future research (Munn et al. 2018). The systematic review conducted in this study was completed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines, which ensures a rigorous and systematic approach (Mohamed Shaffril, Samsul, and Abu Samah 2021). A PRISMA diagram outlines the identification, screening, eligibility, and inclusion/exclusion criteria used. Overall, there were five stages of this systematic review (Figure 4).

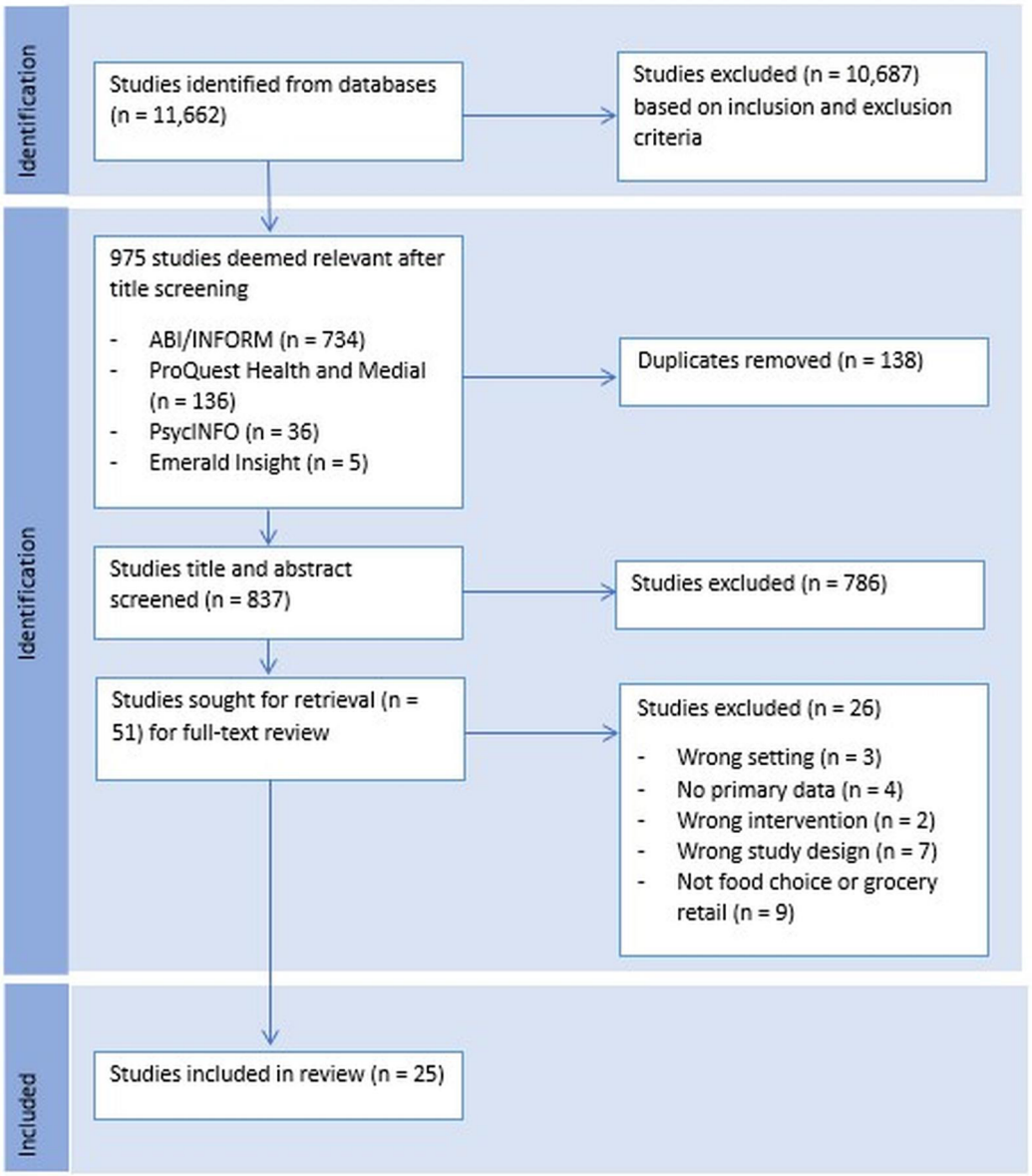

Figure 4. illustrates a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram illustrates the systematic review process, detailing the identification, screening, eligibility, and inclusion/exclusion of studies. A total of 11,662 studies were identified through database searches, with 10,687 excluded based on inclusion and exclusion criteria. After removing duplicates ($n = 138$), 837 studies were screened based on title and abstract, resulting in 786 exclusions. Of the 51 studies retrieved for full-text review, 26 were further excluded due to reasons such as incorrect study setting, lack of primary data, or irrelevance to food choice and grocery retail. Ultimately, 25 studies were included in the final systematic review. This structured process ensures methodological rigor and transparency in study selection (Mohamed Shaffril, Samsul, and Abu Samah 2021).

This PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram illustrates the systematic review process, detailing the identification, screening, eligibility, and inclusion/exclusion of studies. A total of 11,662 studies were identified through database searches, with 10,687 excluded based on inclusion and exclusion criteria. After removing duplicates ($n = 138$), 837 studies were screened based on title and abstract, resulting in 786 exclusions. Of the 51 studies retrieved for full-text review, 26 were further excluded due to reasons such as incorrect study setting, lack of primary data, or irrelevance to food choice and grocery retail. Ultimately, 25 studies were included in the final systematic review. This structured process ensures methodological rigor and transparency in study selection (Mohamed Shaffril, Samsul, and Abu Samah 2021).

Table 1. Inclusion and exclusion criteria used to determine papers included within the review.

Inclusion criteria	Exclusion criteria
English language	Not related to food
Peer-reviewed	Related to shopping generally as opposed to food shopping
Full-text access	Systematic reviews to avoid overlapping or redundant information
Between January 2011 and December 2024	Medical health trials as they are typically focused on clinical outcomes rather than behavioral outcomes
Include either primary or secondary research (review papers excluded).	Did not occur within the grocery retail setting (e.g., food service, restaurants, leisure centres)
Include technology e.g., mobile applications either as part of the nudge itself or as a methodological tool for testing or measuring the effects of the nudge. However, if the intervention was specifically a nudging intervention related to food shopping or food choice, e.g., changes in product placement such as the positioning of healthy snacks at the till checkout, it was deemed relevant and included.	Grey literature (media/government reports, conferences reports, and industry studies) was not considered to ensure a timely completion of this review and has low quality relevance to this systematic review.
Be conducted within a grocery store or online retail environment	
Include an intervention within food retail	

Firstly, a scoping study was conducted to identify the overarching research question and identify keywords and strings to be used in this systematic review. The scoping study also helped collate eligibility criteria. Inclusion criteria were agreed to limit the theoretical boundaries of the research question, which ensures a rapid, streamlined, and focused review process. The timeframe for journal articles used was between January 2011 and December 2024 to enable searching for recent developments in key concepts (i.e., choice architecture). Whilst these terms are still not standardized within food choice and food retail, they gained clearer definitions and usage in this context within the timeframe. This time-period also reflects the significant increase in technological innovations and applications within food retail environments (Table 1).

The second stage involved a thorough literature search across five databases (ABI/INFORM Collection, Emerald, Proquest Health and Medical, PsycInfo, and Scopus). The search terms included thesaurus terms, controlled terms, and free text terms to ensure comprehensive searching across all databases. To facilitate the systematic review, the search was based on three concepts: (1) choice architecture; (2) health intervention; (3) technology. A range of free-text and index terms were used, along with synonyms and truncation to include alternative terminology. These terms were generated based upon the *population, intervention, comparison, outcome, study design* (PICOS) framework. Intervention was searched using terms such as "choice architecture", with the comparison condition specifically an intervention and outcome (e.g., "health behavior"). Population and study design were manually verified. The key terms were used across all databases.

Figure 5 presents the key search terms used in the systematic review to identify relevant studies. The search strategy was structured into three main categories: (1) Choice architecture, including terms related to behavioral economics, nudging strategies, and health interventions; (2) Food behavior, encompassing terms related to food choice, purchasing behavior, motivation, and decision-making in grocery shopping; and (3) Technology, incorporating search terms related to virtual and augmented reality, eye-tracking, EEG brain function, and persuasive technology. The use of truncation (e.g., * OR operators) ensured comprehensive coverage of relevant literature.

Choice architecture	Choice architecture OR health nudg* OR libertarian paternalism OR behavio* economics OR behavio* change OR nutrition intervention OR health intervention OR BCT OR behavio* taxonomy OR nudg* strateg*
Food behaviour	Food choice OR food preference OR food selection OR food purchas* OR food behavio* OR healthier choices OR choice behave* OR purchas* decision*" OR grocery shop* habit* OR motivation* OR decision making OR supermarket
Technology	Technology OR virtual reality OR VR OR augmented reality OR eye track* OR EEG brain function OR persuasive technolog* OR eye movement measurement*

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The lead author conducted this search across the databases, identifying a total of 11,662 studies, 975 of which were deemed relevant after title screening based on the inclusion and exclusion criteria. This search ended on December 15, 2024. Furthermore, titles and abstracts were dual-screened, where two authors (KG and LH) individually screened each article and those relevant to the research question progressed for further analysis.

The third stage involved uploading all articles ($n=975$) onto a system called Covidence which organized the articles, allowing collaboration amongst the reviewers. A total of 138 articles were removed automatically from Covidence as they were duplicates, with 837 studies remaining. Two authors independently screened the title and abstract discussing any conflicts ($n=79$) in which they consulted a third reviewer if necessary (GS). Prior to reviewing each conflict, inclusion and exclusion criteria were reiterated in detail. This approach highlighted that one reviewer included food retail settings only, and the second reviewer included all shopping studies. Upon agreement that the review was to focus solely on the food grocery retail context this resulted in a remaining 28 conflicts to be discussed against the inclusion criteria, resulting in 51 studies qualifying for full-text review.

The fourth stage focused on the 51 articles, where two authors (KG and LH) reviewed the full text against the eligibility criteria. A further 26 articles were excluded, and therefore, 25 articles were deemed appropriate and were included within the review. Disagreements were resolved through discussion where appropriate. Studies were excluded, if they were within the incorrect setting ($n=3$), had no primary data ($n=4$), had inappropriate study design, for example, not an intervention study ($n=7$), or irrelevant interventions, for example, studies unrelated to technology, nudging, food, or grocery ($n=2$). Or finally, were not within food choice or grocery retail ($n=9$).

The fifth stage of the process was to conduct a quality assessment (see Supplementary Appendix 1). The Mixed Methods Appraisal Tool (MMAT) (Hong, Gonzalez-Reyes, and Pluye 2018) was used to assess the quality of included studies to outline internal validity and risk of bias. There was no scoring involved as the checklist was developed as a pedagogic tool. Firstly, the two screening questions were answered by ticking "yes", "no", or "can't tell". If the answer was no or can't tell, to these two questions, further appraisal may not be feasible, and the study would be deemed as extremely low quality. Once answered, the study progressed to the applicable category based on the type of study. The five categories selected were qualitative, quantitative randomized controlled trials, quantitative non-randomized, quantitative descriptive, and mixed methods. There were five questions to answer in each category. CASP (Critical Appraisal Skills Programme 2022) was also considered, however, this tool considers randomized control trials only.

The quality of the studies was generally high, containing clear research questions and the data included addressed the research question adequately. Some of the studies were quantitative non-randomized ($n=9$), and nine of the studies were quantitative randomized controlled trials. The remaining studies were mixed methods ($n=6$) or qualitative ($n=1$). Five studies scored 5/5, with a further ten studies scoring 4/5. The lowest score was 2/5, however this study would still be deemed medium quality as one of the answers was "no" and there remaining two answers were "can't tell". The results are presented in Supplementary Appendix 1 (Table 2).

Findings

Identification of nudging techniques and consumer choice architecture

From the twenty-five studies, nine different types of nudging techniques were identified and tailored to retail contexts based on a nudging framework by Ensaff (2021). Supplementary Appendix 2 details the nudge type and the number of studies associated with each. The most frequently used nudging type was "labeling", which was deployed by eight studies. Information provision came close second as it was used eight times in total. One example is Rummo et al. (2024), where digital nudges like product placement and healthier swap suggestions led to a significant reduction in sugary drink purchases, demonstrating the power of combined nudging techniques in digital environments. Information provision was used as a single nudging technique ($n=4$) and in a further four studies in combination with another nudging technique. Labeling was used singly a total of five times, and in combination with other techniques four times. Other important nudging types were "timing and framing" ($n=6$), "incentives and rewards" ($n=5$), "socials norms" ($n=2$), "feedback" ($n=3$), "choice architecture" ($n=3$), "digital nudging" ($n=5$), and "self-commitment" ($n=1$). As a result of this systematic review, a distinctive identification of nudging techniques was formed using techniques identified from the literature. This consolidation of techniques is a relevant output of this review as to the best of the authors knowledge, there is no definitive list or model of effective nudging strategies used in the literature.

Figure 6 illustrates the nine different types of nudging techniques identified from the systematic review, adapted from Ensaff (2021). These nudging strategies include social norms, feedback, information provision, salience, timing, positioning, availability, choice architecture, default settings, labels, incentives and rewards, and self-commitment. This framework consolidates various nudging strategies, providing a structured approach to understanding how behavioral interventions influence food choices in retail settings.

Information provision and labeling were the most used nudging techniques from the twenty-five studies, presented in an array of forms. For example, textual information presented on labels, signs, or LED lights informing consumers if something was high, medium, or low in food miles. One study by Bleich et al. (2014) highlighted nutritional properties of food products and conveyed these through signs. This intervention was successful in a study of adolescents, offering an opportunity to further explore the nudging technique with other demographic groups. One study that implemented information provision simply used textual material to relay information to participants regarding obesity (Djupegot 2019). Whilst another nudged sustainable choice by examining food miles (Kalnikaite, Bird, and Rogers 2013). Some

Table 2. Nudging technique used within studies included within the review.

Author, Year	Social norms	Feedback	Information provision	Timing/ Framing	Incentive/ Rewards	Labeling	Choice architecture	Digital nudging	Self-commitment
Agyemang et al. (2024)		X			X	X		X	
Berger (2019)	X								
Bird et al. (2013)	X	X							
Bleich et al. (2014)						X			
Bogomolova et al. (2021)		X		X		X			
Bushong et al. (2010)				X	X				
Casado-Mansilla, López-de-Armentia, and Emaldi (2024)									
Djupegot (2019)			X						
Dunford et al. (2014)						X			
Egnell et al. (2019)						X			
Enax, Krajbich, and Weber (2016)						X			
Eyles et al. (2023)							X		
Guan et al. (2023)									
Hoenink et al. (2020)					X				
Jäger and Weber (2020)				X		X		X	
Bird Jernigan et al. (2019)			X	X	X				
Kalnikaite, Bird, and Rogers (2013)			X						
Labban, Ma, and Dube (2021)				X	X				
Lee and Hammant (2024)			X			X	X	X	
Meijers et al. (2022)			X					X	
Mönninghoff et al. (2022)			X						
Reitberger, Spreicer, and Fitzpatrick (2014)			X						
Rummo et al. (2024)				X			X	X	
Talati et al. (2019)						X			
Van der Laan et al. (2017)			X						X
Total	**2**	**3**	**8**	**6**	**5**	**9**	**3**	**5**	**1**

nudging techniques were using in conjunction with other nudges, for example, information combined with timing and framing as products were presenting in prominent locations. Information and timing/framing were used in conjunction with incentives or rewards in one study (Bird Jernigan et al. 2019). This study brought together several marketing techniques: placement, price, and promotion to create a successful intervention. Bogomolova et al. (2021) used a combination of labeling, feedback, and timing and framing together to promote healthy food choice. However, discerning the effectiveness of individual nudges within this multi-faceted approach can be challenging. Notwithstanding, the success of these interventions emphasizes the versatility of nudging, despite the variables or context, presenting an opportunity for further research to focus on the most effective nudging strategies. Studies that analyzed environmental or sustainable nudging techniques (Berger 2019; Jäger and Weber 2020; Kalnikaite, Bird, and Rogers 2013), could be replicated to encourage consumers toward healthier food choices and to compare the nudging techniques across different variables.

Three studies (Egnell et al. 2019: Enax, Krajbich, and Weber 2016; Talati et al. 2019) deployed nudging techniques that used nutritional information in the form of traffic light labels, warning labels, and organic labels. Study results proved these to be an effective way to nudge food consumers toward specific food choices. Specifically, a study by Enax, Krajbich, and Weber (2016) confirmed that nudging through labels led to a higher percentage of participants opting for healthier food products when labels were color-coded as opposed to numerical figures. These labels portrayed easy to understand nutritional information and particularly when used in conjunction with a mobile app, where two studies (Dunford et al. 2014; Eyles et al. 2023) used the SaltSwitch app, which enabled consumers to scan the food product. It then presented nutritional information through traffic light labels and ranked the product based on the nutritional content or for example, salt content. This seamless app presented consumers with information in a hierarchy, allowing them to effortlessly identify which food products were deemed a healthier choice. Additionally, another study

Figure 6. illustrates the nine different types of nudging techniques identified from the systematic review, adapted from Ensaff (2021). These nudging strategies include social norms, feedback, information provision, salience, timing, positioning, availability, choice architecture, default settings, labels, incentives and rewards, and self-commitment. This framework consolidates various nudging strategies, providing a structured approach to understanding how behavioral interventions influence food choices in retail settings.

(Reitberger, Spreicer, and Fitzpatrick 2014) used the Nutriflect system to outline shopping habits and breakdown nutrition to provide consumers with an easy-to understand chart detailing the specific food groups. This supports the broader literature on the effectiveness of choice architecture in simplifying decision-making processes and reducing cognitive load for consumers (Weber and Johnson 2009).

Findings also showed that nudges paired with pricing strategies outperformed nudges alone, for instance, one study found that a healthy-eating nudge by itself didn't change behavior significantly, but when combined with price discounts or price salience, participants chose healthier products (Hoenink et al. 2020). This suggests that monetary incentives or disincentives can strengthen the impact of behavioral nudges.

Utilization of technology for nudging

Almost half of the nudging studies using technology were conducted in an online setting ($n = 11$), a further ten in a physical retail setting, two within a virtual supermarket, and one was conducted in a laboratory setting. There were no notable challenges raised within the online, virtual, or laboratory studies. The two studies that were undertaken within a virtual supermarket setting concluded that virtual reality was an accurate representation of a physical food retail environment and offered positive consumer choice decisions when combined with nudging strategies.

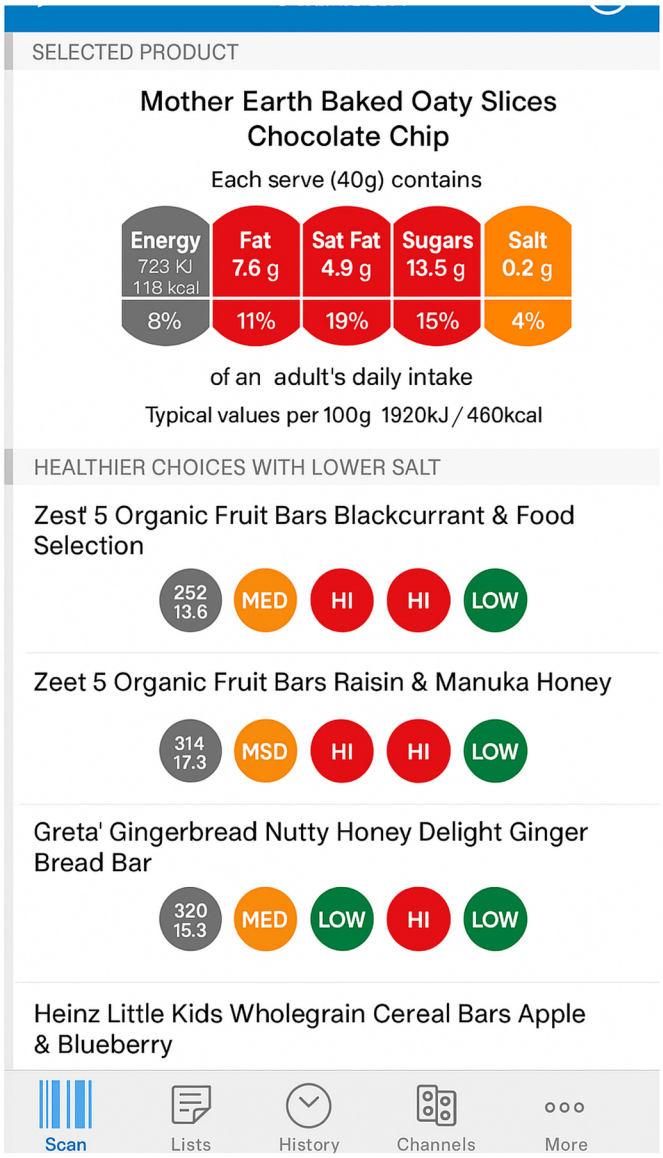
The outcomes from these studies indicate that virtual supermarkets, when integrated with nudging strategies, can effectively stimulate a real-world shopping environment, enabling accurate analysis of food choice data. Whilst there were limitations reported within these studies; few difficulties were reported in the use of VR. One study suggested repeating the same research within an actual store as opposed to the virtual supermarket as consumer choice decisions may differ due to extrinsic cues within the actual environment (Meijers et al. 2022). Another study by Jäger and Weber (2020), nudged organic food choices with the addition of timing and framing, through message framing and digital signage. Finding that the use of AR did not directly boost sales. However, both studies concluded that VR offered a promising and effective tool for analyzing food consumer behavior and deploying nudging techniques.

Incentives and rewards were used individually in one of the studies (Hoenink et al. 2020), where participants were asked to perform one food shop per week for five weeks. Each week, they were exposed to a different condition, control, nudging, pricing, price salience, and price salience with nudging. The results revealed that non price related conditions did not significantly encourage consumers toward healthier food choices, however, when combined with price, participants purchased healthier products overall. Social norms and feedback mechanisms were also effective in altering consumer behavior, particularly when integrated with real-time feedback at the point of decision-making.

From the twenty-five studies, the most popular technology used within nudging interventions was an online setting, with eleven utilizing online platforms throughout their methods. Additionally, seven studies used a mobile app, two used VR technology, one used AR, and one used eye-tracking technology. The remaining three did not use any notable technology. From the seven studies that used a mobile app, two implemented the SaltSwitch smartphone app (Dunford et al. 2014; Eyles et al. 2023) which enabled the consumers to scan the product barcode, providing a traffic light label to assess salt levels and suggest lower salt alternatives. Additionally, Casado-Mansilla, López-de-Armentia, and Emaldi (2024) highlighted the potential of citizen science combined with AI to nudge healthier and more sustainable shopping habits by analyzing food receipts and providing tailored recommendations through a conversational interface.

Figure 7 showcases the SaltSwitch smartphone app, a mobile-based nudging intervention designed to help consumers make healthier food choices by assessing salt levels and providing lower-salt alternatives. The app allows users to scan product barcodes, displaying a traffic light nutrition label that highlights key nutritional values, including energy, fat, saturated fat, sugar, and salt content. Additionally, the app suggests healthier alternatives with lower salt content.

One of the studies found no significant differences upon implementation of the SaltSwitch app over a 12-week period (Eyles et al. 2014). However, another study which employed the same app as its sister apps (FoodSwitch and GlutenSwitch), showed positive associations with the app due to the easy-to-understand information presented to consumers. An innovative app called Future Me featured throughout one study (Mönninghoff et al. 2022), adopting an avatar to provide participants with a personalized food basket, shopping tips, daily step count, and nutritional information of food



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choices. This app was marginally effective in both food purchases and physical activity levels, seeing small improvements across the nudging intervention. A further study applied the Nutriflect system (Reitberger, Spreicer, and Fitzpatrick 2014), which collates shopping data onto the app to produce a chart outlining users' household shopping information. Participants within this study did look at the chart, specifically when displayed on their mobile or iPad devices as opposed to a computer/website and reflected upon this to determine how they could improve their next food shop. Eye-tracking was used within a study (Van der Laan et al. 2017) as a methodological tool to understand visual attention to food products, and the effect priming, and presentational nudging strategies had on consumers focus and dwell points. The addition of health and dieting words, and recipe banners were deemed effective primes as participants chose lower energy foods. Moreover, augmented reality was used in another study (Jäger and Weber 2020) to present advertisements and messages. However, whilst the use of AR interested more shoppers, it did not significantly increase sales of healthier food, which is surprising to note.

Two studies used a mobile app in conjunction with the "Lambent shopping trolley". The Lambent shopping trolley, provided immediate feedback through colored lights based on the environmental impact of selected products, demonstrated the power of combining social norms with feedback to influence purchasing decisions. These studies aligned with social cognitive theory, which posits that individuals are influenced by their perception of what others do or approve of Bandura (1991). Bird et al. (2013) used the technology-based trolley to nudge consumers into selecting products which had less food miles. This study applied the idea of social norms but also required feedback from participants on the functionality of the app, which was also compared with other apps. The app led to significant changes in participants' shopping habits and an improvement in the nutritional balance of their diets, specifically they purchased more milk and alternatives, and secondly, the amount of fruit and vegetables purchased doubled. They concluded that once participants seen their lights flash amber or red, they scanned alternative products to decrease the total number of food miles. The nudge type used within this study was social norms, as when participants realized their product selection food miles was above the norm, they pursued an alternative. Another study adopted the Lambent shopping trolley in conjunction with a mobile app (Kalnikaite, Bird, and Rogers 2013), however, this study analyzed if it could be used to nudge shoppers toward environmentally friendly products. This study was highly successful as when using the lambent shopping trolley, 72% of products selected had lower food milage when compared with using a regular shopping trolley and concluded that the lambent trolley had an "immediate nudge effect" on participants as the lights lit up (Kalnikaite, Bird, and Rogers 2013). The same study noted that the mobile app was not effective due to issues when scanning products. Both studies incorporated instantaneous feedback for consumers whilst making purchasing decisions, indicating that behavior change can be successful when providing information or feedback at the point of food choice decision making. One study conducted online for example implemented feedback on the environmental impact of foods (Berger 2019), through use of an arrow called a "Green Meter".

Additionally, interventions within digital environments versus physical retail settings showed differing outcomes, for example, Augmented Reality (AR) attracted user attention but did not significantly boost healthy food sales, whereas simple cues such as labels or signage often influenced choices comparably well.

High-tech interventions (AR/VR, mobile apps) introduced novelty but faced practical challenges. Some app-based nudges yielded mixed results, for instance, one study's nutrition-scanner app showed no significant change over 12 wks, whilst a similar app did prompt healthier choices when

its interface was user-friendly and information easy to interpret. This indicates an important nuanced finding: the usability and simplicity of a digital nudge (not just the technology itself) determine its success in that a simple, well-timed SMS or intuitive app might outperform a complex VR simulation if the latter isn't seamlessly integrated into the shopping experience.

Scale and sampling

Overall, most of the studies were quantitative in nature ($n = 16$). Seven studies used mixed methods, which contained both quantitative and qualitative elements. The studies provide a wide range of sample sizes, varying from small-scale studies with fewer than 100 participants, to large-scale studies involving over 11,000 participants. Out of the twenty-five studies, eleven were deemed large-scale containing samples of between 107 and 11,000. The study with the highest number of participants was conducted across twelve different countries. The remaining ten studies were classified as smaller scale, containing less than 100 participants. Within the smaller studies, the number of participants extended between 0 and 57, with the average number of participants across these ten studies equating to 26 participants. Larger-scale studies, particularly those conducted across several countries, offered robust insights into food consumer behavior across different contexts (Hennekens and DeMets 2009). The smaller studies, with an average of 26 participants, provide detailed, context-specific insights that are valuable for understanding the nuances of food consumer behavior. The relevant sample size is mostly determined by the study design. Experimental studies are small, however, they can contribute strong evidence because they make casual inferences, whereas large studies are mainly cross-sectional. Notably, Guan et al. (2024) conducted a usability study for a mobile app leveraging cognitive-behavioral theory, which, despite a small sample size, demonstrated high user engagement and potential scalability.

Geographical distribution of studies

Studies were conducted in the United States ($n = 5$), Germany ($n = 3$), Netherlands ($n = 2$), Australia ($n = 3$), Switzerland ($n = 2$), UK ($n = 2$), and 1 in each of the following countries: Austria, Canada, China, France, New Zealand, and Norway. Additionally, one study was conducted across two countries in Europe (Spain and France), and another conducted across 12 different countries. Overall, most studies took place within Europe ($n = 13$). Six were conducted in North America, four in Oceania, and one in Asia. Results showed that all studies were derived from developed countries. Interestingly, no studies were identified from developing countries or innovation hubs such as Hong Kong and Japan, where advanced technological nudging interventions may be expected. The geographic finding suggests that the existing body of research on nudging in food retail environments is predominantly Eurocentric, which may pose a limitation of findings to different cultures and economic contexts. This aligns with broader observations within the literature, where research on consumer behavior and health interventions often focuses on developed countries due to increased funding opportunities and more advanced research infrastructure (Ginsburg et al. 2017). However, recent studies emphasize the scalability of nudges such as product placement and healthier swap in low-income households (Rummo et al. 2024), providing a pathway for adaption in lower-resource settings. The absence of studies from developing countries highlights a gap in understanding how nudging interventions in food choice decisions could be adapted and implemented in regions with different socio-economic conditions and consumer behavior patterns.

Distribution and emerging trends

Most studies ($n = 17$) were published in 2019 or later (4 in 2019, 3 in 2020, 2 in 2021, 2 in 2022, 2 in 2023, and 4 in 2024). The remaining studies ($n = 7$) were published in 2010–2017 (1 in 2010, 2 in 2013, 3 in 2014, 1 in 2016, 1 in 2017). This significant increase in the number of studies from 2019 onwards suggests a rapidly developing interest in digital technology-driven nudging interventions, which may have stemmed from the increase in research, affordability, and availability of digital tools, or also because of Covid-19 and the virtual focus. In turn, expanding the potential for more innovative approaches within consumer health and food choice (Michie, Van Stralen, and West 2011). This rise in research corresponds with the global impulse toward incorporating technology within public health initiatives, reflecting a shift in research focus from traditional to digital nudging strategies. For example, the DISH dashboard developed by Agyemang et al. (2024) combines gamification with metrics like "minutes of healthy life gained or lost," showing how digital nudging can align with sustainability goals while promoting healthier eating habits.

Study design

Different study designs were associated with particular nudging strategies and target groups. Digital interventions (online grocery platforms or smartphone apps) often employed tech-enabled nudges like personalized recommendations, real-time feedback, or "smart" labels, and tended to recruit participants comfortable with technology (e.g., young adults or smartphone users). In contrast, traditional in-store experiments used physical cues such as shelf labels, signage, product placement, or default product arrangements, targeting general shoppers in supermarkets.

Small-scale studies (including lab experiments or VR simulations) frequently tested novel and complex nudges, for example, immersive VR shopping experiences or AI-driven apps, usually with specific populations like students or people with defined health goals, to observe mechanism-focused effects in a controlled setting. Large-scale studies and field trials, on the other hand, favored simpler, easily scalable nudges such as traffic-light nutrition labels or price incentives, and involved broad consumer samples, providing

evidence of effectiveness in real-world, diverse contexts. Even VR-based studies versus physical store studies showed this pattern: VR simulations allowed researchers to experiment with innovative nudges in a risk-free virtual environment, often confirming that these virtual nudges elicited similar choices to real stores, while physical store studies had to account for real-world complexities (noise, distractions, varying store layouts) and thus often implemented more straightforward interventions. In summary, technology-oriented and smaller-scale designs leaned toward personalized, complex nudges aimed at specialized groups, whereas larger or more traditional setups leaned toward universally applicable nudges for general populations.

Participant characteristics and inclusion

Diverse participant characteristics were observed across the studies. Whilst some studies did not require specific characteristics, others had detailed conditions such as an intention to pursue eco-friendly diets (Berger 2019), living alone (Bird et al. 2013), or having high blood pressure (Eyles et al. 2014). However, only four studies out of twenty-five (?) required participants to be the primary food shopper within their household. Though one study did require participants to own a supermarket loyalty card, and one study required participants to be over the age of 23. In addition, two studies required participants to own a smartphone to comply with study procedures such as ensuring compatibility with using and downloading a mobile app. Few studies had age-specific requirements such as being a teenager (Bleich et al. 2014), while others targeted specific demographic groups such as university students (Bushong et al. 2010; Dunford et al. 2014; Meijers et al. 2022). There was a variety of characteristics amongst participants across the studies, meaning that research explored an array of behaviors to understand different aspects of food choice, decision making, and acceptance of technology. This also enables a broad understanding of the factors influencing food consumer choice decisions. One study by Lee and Hammant (2024) stands out for involving community stakeholders in understanding supermarkets' roles in community well-being, thereby broadening the scope of participant demographics and exploring the intersection of consumer behavior with societal impacts. However, the limited focus on primary shoppers highlights a potential oversight in capturing the decision-makers who are most likely to influence household food choices. Overall, the characteristics of participants were diverse showing that there is research exploring different segments of the food consumer population, as some studies were behavioral focused, for example, wanting to become eco-friendly (Berger 2019), and some studies are health focused, for example, focusing on blood pressure (Eyles et al. 2014). The introduction of age and demographic specific characteristics such as being an adolescent, or currently attending a university, outlines the interest in understanding how different types of food consumers respond to different interventions and allows analysis into a range of consumer behavior.

Discussion and implications

This systematic review draws together pertinent literature on nudging and the role of digital technology in the retail context of healthy consumer food choice decisions. Three contributions are made to the consumer behavior literature. Three contributions are made. First, a novel and rigorous systematic literature review process consolidates and synthesizes studies of nudging techniques in shaping food consumer behavior. Gaps in knowledge for further research are highlighted. For example, a prevalence of studies conducted in developed regions of the world is identified, primarily Europe and North America. The notable absence of research from developing countries may hinder the applicability of nudging to diverse socio-economic and cultural settings. Second, the review identifies the importance of nudging interventions on consumers' health-related food choices in retail environments. Existing nudging taxonomies, such as those by Thaler and Sunstein (2008), are introduced to understand areas such as setting defaults, and providing feedback from a healthy food choice perspective. We identify nine different nudging techniques and how they are implemented from a healthy food choice perspective in food retail settings. And gaps where further research is required. Third, the review provides new insights and future research opportunities pertaining to digital technology-enabled nudging for consumer food choice decisions. Examples of technology include virtual reality, mobile applications, and augmented reality. This is identified as a crucial setting for future research on nudging and the role of technology in the context of contemporary food consumer behavior areas of interest such as health and sustainability. With specific research areas highlighted.

First, a rigorous systematic literature review process consolidates and synthesizes studies of nudging techniques in shaping food consumer behavior, bringing together results from twenty-five studies. The food retail environment forms a distinct and pertinent focus to identify developing areas of interest with opportunities for future research. The prevalence of studies conducted in developed regions of the world is notable, primarily Europe and North America, which collectively account for most of the research. However, the notable absence of research from developing countries or innovation hubs such as Japan and Hong Kong highlights regions for further research. This geographical imbalance may hinder the applicability of nudging to diverse socio-economic and cultural settings, where consumer behaviors and the effectiveness of interventions could differ significantly. This limitation aligns with broader observations in behavioral research, where developed nations are often prioritized due to more substantial funding opportunities and advanced research infrastructure (Ginsburg et al. 2017). By highlighting this geographic and demographic skew, the review identifies clear gaps in the current literature, guiding future research to broaden the scope and improve the applicability of healthy food choice nudges across different populations and settings.

Previous research also suggests that whilst nudging techniques are largely applicable to healthy food choice

decisions, their effectiveness may vary depending on the participant's role in household food decision-making and shopping habits.

Consumer behavior is influenced by a multitude of personal and contextual factors, suggesting that more effective nudging strategies are those that align with the unique traits and motivations of primary food shoppers (Noar, Benac, and Harris 2007). This is particularly relevant given that only four out of the twenty-five studies specifically required participants to be the primary food shopper within their household. Furthermore, smaller-scale studies targeting specific demographics, such as those focusing on university students or individuals with health conditions (e.g., high blood pressure), while providing valuable context-specific insights, were limited in the generalizability of their findings to household decision-makers. Therefore, future research could be scaled up to explore effectiveness and draw further conclusions based on consumer households as opposed to in-store food choice decisions only.

A significant increase in studies post-2019 suggests a shift toward technology-driven nudging interventions that are scalable in developing health and dietary benefits for populations, likely driven by the growth in digital tools and the impact of the pandemic, which accelerated online behaviors (Lynch and Nieto-Gomez 2024). This transition from traditional to digital nudging reflects a global trend toward leveraging technology in public health initiatives that can impact food choice in retail environments. The study by Agyemang et al. (2024) highlights how advanced tools like the DISH dashboard can be leveraged to integrate environmental and health-related nudges, paving the way for cross-cultural and scalable implementations. Guan et al. (2024) further supports this trend, demonstrating the importance of user-centred design in mobile applications for promoting adherence to dietary guidelines. However, whilst these developments indicate promising nudging techniques, there is variability in their effectiveness. Studies employing mobile applications, such as the SaltSwitch app, highlighted mixed outcomes: some demonstrated positive behavior change due to easy-to-understand nutritional labeling, while others found limited impact over extended periods. This discrepancy may be attributed to differences in user engagement in retail settings, study duration, or the complexity of the nudging interventions. Studies such as Rummo et al. (2024) demonstrate clear benefits, with digital nudges reducing caloric intake from sugary drinks in low-income households, but challenges remain, and opportunities present in scaling these interventions in retail settings to reflect diverse socio-economic contexts.

Second, review highlights how certain nudging interventions can influence consumers' health-related food choices in retail environments, though effectiveness varies depending on context, delivery, and user engagement. We align this area of research with existing nudging taxonomies, such as those by Thaler and Sunstein (2008), who classify nudges into categories such as setting defaults, and providing feedback. This comprehensive categorization fills a gap by mapping real-world interventions onto established nudging frameworks, such as Thaler & Sunstein's taxonomy, showing which tactics are well-studied and which are underutilized. It contributes to academic theory by confirming that common nudges align with behavioral economics principles, and it informs policy by indicating that simple, low-cost nudges (e.g., clear labeling) can be as effective as high-tech approaches, while also noting the need to test unexplored strategies for influencing healthy choices.

Techniques like information provision and labeling resonate with the taxonomy's use of simplification strategies to guide consumer behavior by making information more accessible and easier to interpret (Thaler and Sunstein 2008). Similarly, the use of incentives and rewards aligns with nudges that encourage positive health-related reinforcement and motivation in food decision choices (Kahneman and Tversky 1979; Sunstein 2016). However, there were certain nudges from established taxonomies not prominently featured in research, such as the "use of defaults" and "pre-commitment strategies". For instance, default options (e.g., setting healthier food options as the default in meal kits) could be highly effective in food settings but were not identified from previous studies. Defaults have been shown to significantly influence consumer choices, as demonstrated by the success of default enrollment in workplace retirement plans (Madrian and Shea 2001). While defaults and pre-commitment strategies were absent from the reviewed studies, their demonstrated success in other behavioral domains suggests a promising avenue for future research in food choice contexts (Charness and Gneezy 2009). These are potential knowledge gaps for future research on how nudging can promote sustainable and healthy food choices and eating habits (Dolan et al. 2012; Hummel and Maedche 2019).

More specifically, we identify nine different nudging techniques from a healthy food choice perspective in food retail settings, with information provision and labeling being the most prevalent. These techniques were employed individually, but also combined with other strategies, demonstrating the versatility of nudging. For example, the use of traffic light labels, particularly when integrated with mobile applications, has been effective in steering consumers toward healthier choices. Studies incorporating real-time feedback, such as the Lambent shopping trolley, also showed positive results, emphasizing the importance of immediate information at the point of food choice decision-making. This finding supports the broader literature on choice architecture, which highlights its role in simplifying decisions and reducing cognitive load (Weber and Johnson 2009). Despite these advancements, challenges remain in establishing the standalone effectiveness of specific nudging techniques, particularly when used in combination. For example, studies that combined information provision with incentives or social norms showcased more comprehensive intervention strategies, but discerning the unique impact of each nudge has proved difficult. This suggests a need for future research to isolate and assess the individual and combined effects of nudging strategies to refine best practices. Additionally, preliminary results suggest that innovative technologies like the Lambent trolley can be effective, although further research is needed to confirm scalability and impact across diverse settings.

Indeed, whilst innovative technologies like VR and AR hold promise for encouraging healthier food choice in retail environments, traditional nudging methods, such as information provision through signage or labels, were found to be equally effective in many cases. For example, Reitberger, Spreicer, and Fitzpatrick (2014) showed that traditional nudging methods can be just as effective when using contextually situated displays. This suggests that the effectiveness of a nudge may be more dependent on its simplicity and relevance to the consumer rather than the sophistication of the technology used. This aligns with Thaler and Sunstein (2008) argument that nudges should be easy and cost-effective to implement. This review indicates that while technological tools like mobile apps, augmented reality (AR), and virtual reality (VR) show potential for enhancing health-based nudging in food retail environments, their use in the studies was not without limitations. AR, for instance, attracted attention but failed to significantly boost sales of healthier foods, revealing that novelty alone is insufficient for driving behavior change. Moreover, while VR was shown to replicate real-world decision-making contexts effectively, its practical application in everyday settings remains limited. The mixed results underscore the importance of contextual factors and user engagement in the success of technology-based nudges.

One key limitation of existing nudging research from a healthy food choice perspective is its over-reliance on descriptive classifications without deeper engagement with cognitive and behavioral mechanisms (Ewert 2020). By integrating dual-process theories of decision-making (Kahneman, 2011) with digital nudging interventions, findings suggest that the effectiveness of nudges may relate to their ability to engage automatic (ystem one) or deliberative (System two) decision processes, aligning with dual-process theory. Framing nudges, such as visual or textual primes, showed promise in some online environments by reducing cognitive effort, although further evidence is needed to confirm their consistent effectiveness (Hummel and Maedche 2019). For example, studies using real-time visual prompts (System 1) in online food retail platforms have successfully increased healthier food selections, but when paired with informational labeling (System 2), long-term purchase patterns improve (Bogomolova et al. 2021). We highlight interplay between digital choice architecture and cognitive engagement, identifying the need for further empirical research on how the sequencing and combination of nudges that could influence healthier food choices by consumers. Future research could explore whether technology-enabled personalization, for example, AI-driven nudging, enhances the transition from intuitive to deliberate decision-making and therefore sustain long-term healthy eating behavioral change (Ghosh, Das, and Gupta 2021).

Third, the review consolidates evidence on digital technology-enabled nudging and highlights key gaps in existing research, particularly regarding underexplored tools and participant targeting strategies. The importance of new digital technologies is identified in developing tailored nudging interventions targeting the characteristics and motivations of food consumers. Previous research highlights the variety of participant characteristics targeted by different studies, including health-related factors (e.g., high blood pressure), eco-friendly diet intentions, and demographic-specific characteristics such as age or being a university student. For instance, studies involving mobile apps, such as the SaltSwitch app, were found to be effective when they provided easy-to-understand nutritional information, appealing to consumers' health-conscious motivations (Dunford et al. 2014; Eyles et al. 2014, 2023). Similarly, interventions like the Lambent shopping trolley leveraged immediate feedback to promote sustainable choices, showcasing how real-time, context-specific nudges can motivate behavior change (Bird et al. 2013; Kalnikaite, Bird, and Rogers 2013). However, while tailored nudges are effective, there remains a gap in research specifically targeting primary household decision-makers, who play a pivotal role in shaping food choice and consumption habits. The variation in outcomes from studies using different approaches, such as in-store versus online or mobile app-based interventions, suggests that the most impactful strategies may be those that not only consider the individual's preferences but also integrate into their broader food choice decision-making environment.

Studies have highlighted a range of technologies, including mobile apps, virtual reality (VR), augmented reality (AR), and eye-tracking tools, yet there are still numerous technological tools that could be leveraged to enhance nudging techniques within food retail contexts. For example, smart personalization technologies, which use machine learning algorithms to tailor messages and recommendations based on individual preferences and purchase history, could offer a new dimension of targeted nudging (Ghosh, Das, and Gupta 2021). Such technology can adapt to consumer behavior over time, ensuring that interventions remain relevant and effective (Ghosh, Das, and Gupta 2021; Jannach, Adomavicius, and Sankaranarayanan 2019). Additionally, chatbots integrated into mobile platforms or grocery store apps could provide real-time, conversational nudges, offering product recommendations or providing instant feedback based on user queries (Dastgeer, Bandyopadhyay, and Monwar 2020; Moor, Sanderson, and Lewis 2021). Emerging tools such as chatbots, real-time analytics, and personalized nudging platforms were not represented in the reviewed studies but present exciting opportunities for future intervention design. These devices could provide timely reminders, track health metrics, and suggest healthier choices while consumers are shopping (Hossain and Lemoine 2022; Schmidt, Meier, and Wong 2019). Incorporating these advanced technologies into food choice nudges could lead to more adaptive and engaging consumer experiences that are capable of influencing purchasing behavior over time, presenting a new frontier for future research and intervention design (Robinson and Roberts 2020; Kolb, Miller, and Andersen 2021).

It was perhaps surprising to note that only two studies (Hoenink et al. 2020; Meijers et al. 2022) were conducted within a virtual supermarket despite the search to include these studies specifically, and as this evolving technology lends itself particularly to nudging techniques. This is an evident area of future research opportunity in nudging and consumer choice. However, the use of mobile apps is useful to direct consumer choices toward certain food products are

point of purchase, such as the Nutriflect system, and can also ensure cross-cultural validity as alternative languages can be provided, and furthermore, personalization. These studies could be implemented to scan and provide color-coded lights based on the calorie content of food as opposed to food milage, as a new and innovative way to nudge healthier choices at point-of-decision. However, advanced technologies will not always be accepted within society and traditional methods may be more effective for certain segments of food consumers.

By pointing out the use of digital innovation and personalization, the review opens a new frontier for research and practice: it suggests harnessing emerging digital technologies to tailor nudges to individual consumers' habits and preferences, which could enhance effectiveness and scalability. This claim of contribution underlines how the review's insights can drive innovation in nudging design, bridging to human-computer interaction and AI fields, and encourages policymakers to consider integrating personalized, real-time feedback mechanisms into public health interventions, all whilst cautioning that one must match the approach to the target population's needs.

Limitations and future research

In conclusion, this review contributes to the body of knowledge by categorizing and synthesizing various nudging techniques, demonstrating their varied effectiveness, and illustrating the growing role of technology in influencing food consumer behavior. However, to extend the relevance of these findings, future research should focus on studying diverse populations in different cultural and economic contexts, standardizing methodologies for better comparability, and assessing the isolated impact of specific nudging strategies. This will not only enhance the robustness of the field but also provide insights into adapting interventions for varied global settings, thereby addressing the current Eurocentric bias. Overall, the studies included within the review highlight the positive relationship between effectively nudging consumer choices and presenting information that is easily accessible and convenient for the shopper, as the presence of information provision and labels were the most used type of nudging strategy.

This systematic literature review also demonstrates that nudging techniques backed by new technologies are effective tools for encouraging healthier choices across various food retail settings such as physical stores, virtual stores, and online platforms. One potential limitation associated with this study is that it excludes grey literature due to concerns about quality and timeliness, however, grey literature can sometimes provide valuable insights or data that are not captured within peer review journals. Additionally, this review does not explicitly focus on terms such as "optimisation" which are common in systems design and information technology, nor does it include computer science databases that publish full conference papers relevant to this domain. The process involved subjective judgments during the title and abstract screening and full-text review stages. Conflicts between reviewers were resolved through discussion, which introduces potential for reviewer bias. There might be variability in how studies were assessed, which could affect the consistency and reliability of the inclusion criteria application. The process involved subjective judgments during the title and abstract screening and full-text review stages.

The review suggests that there is a clear gap in nudging interventions using up-to-date and innovative technologies despite the development of such equipment, for example, virtual supermarkets and eye-tracking devices. Innovative technologies such as VR and mobile apps simulate real-world shopping environments and therefore there is potential to use advanced technologies as tools for nudging consumer behavior. In particularly, VR provides an immersive, controlled environment which, due to the accurate representation of physical stores, can enable research to observe consumer behavior whilst implementing nudging techniques to gain insight on reactions. Meanwhile, eye-tracking could provide additional insights into eye gazing patterns and delve into how information is presented to further maximize the impact of nudging interventions. Overall, there is a need to integrate these new technologies and modern nudges to elevate the link between food consumption and consumer health. However, future research areas could include investigating how VR or AR nudging interventions affect a range of demographic groups, specifically in terms of the promoting healthier food choices. Furthermore, studies could examine if certain nudges work better with VR or AR due to the immersive nature. Emerging technologies could also be used to create new ways to nudge, alongside enhancing current nudging techniques. Overall, the use of technology within nudging is a promising but underdeveloped field, with nudging techniques, driven by technology advancements, offering potential for encouraging healthier consumer food choices.

Despite the growing research on strategies to nudge healthier food choices, various notable gaps within the literature persist. Predominantly, there is a requirement for comprehensive examination into the long-term nudging effects on consumer behavior and their dietary habits. Studies within this review have outlined the short-term efficacy, however, the endurance of these interventions in adopting healthier habits remains unclear. Cost is also a factor involved and so, there is a gap for research evaluating the cost-effectiveness of nudging implementation within physical, real-world environments, or virtual environments, to ensure stakeholders and policymakers are presented with the key understandings and insights to implement evidence-based nudging interventions and policies to encourage healthier food choice.

Finally, most of the nudging studies reviewed were quantitative in approach. Only two studies used a mono-method qualitative data approach, which outlines a gap and an opportunity for future intervention studies. This methodological preference reflects a broader trend in consumer behavior research, where quantitative methods are often favored for their ability to produce generalizable results (Creswell and Creswell 2017). However, the low usage of qualitative approaches across these studies highlights a missed opportunity to gain deeper insights into the contextual and psychological factors that underpin food consumer

responses to nudging interventions. Mixed methods approach, though less common, offer a valuable means of triangulating data and capturing the complexity of consumer behavior. Future research could benefit from a more balanced methodological approach, incorporating qualitative insights to complement quantitative findings and provide a more holistic understanding of nudging effectiveness.

This review identifies several gaps which persist within the current literature and suggests direction for future research. In essence, attempts have been made in understanding short-term nudging efficacy and technological applications, however, significant gaps remain prominent, beckoning further inquiry into long-term and sustained impacts (Bogomolova et al. 2021). Furthermore, there is a need for cost-effectiveness analysis within the empirical studies focusing on food choices. This review highlights the need for further research within diverse cultural contests, and the integration of innovative technologies such as virtual reality and eye-tracking devices to explore their full potential in influencing consumer behavior. The development of more holistic and evidence-based nudging interventions to promote healthier food choices should remain an ongoing imperative.

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Authors contributions

The following authors agree to be accountable for all aspects of the work, and were involved in the conception and design, or analysis and interpretation of the data; the drafting of the paper; revising it critically for intellectual content; and the final approval of the version to be published: Kerri Grant (corresponding author), Professor. Lynsey Hollywood, Professor Geoff Simmons, Professor Tamara Bucher, and Dr. Amy Burns.

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