

Smartphone Apps for Food Purchase Choices: A Scoping Review of Designs and Opportunities and Challenges

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Abstract

Background: Smartphone apps can aid consumers in making healthier and more sustainable food purchases. However, there is still limited understanding of the different app design approaches and how they might impact food purchase choices. An overview of existing food purchase choice (FPC) apps, and an understanding of common challenges, can help speed up effective future developments.

Objective: We scope the academic literature on FPC apps and provide an overview of a) design characteristics, and b) opportunities and challenges for effective implementation. Thus, we contribute to an understanding of how the technologies can effectively improve FPC behavior and recommendations for future design efforts.

Methods: Following the PRISMA guidelines for scoping reviews (PRISMA-ScR), we consider peer-reviewed literature on FPC apps within IEEE Explore, Pubmed, Scopus, and Science Direct. We inductively coded and summarized design characteristics. Opportunities and challenges were addressed from both a quantitative and a qualitative perspective. From the quantitative perspective, we coded and summarized outcomes from comparative evaluation trials. For a qualitative perspective, we performed a qualitative content analysis of commonly discussed opportunities and challenges.

Results: We retrieved 55 articles and identified 46 unique apps and grouped them into five distinct app types (ATs). Each AT supports a specific stage of the purchase choice and shares a common functional design. Most apps support the stage of product selection (Selection Apps; ~60%), commonly by scanning the barcode and displaying a nutritional rating. Eight out of 12 evaluation trials report significant findings and indicate the potential for FPC apps to support behavior change. However, relatively few evaluations covered selection app type and these studies showed mixed results. We found that a common opportunity is found in apps contributing to learning (knowledge gain), while infrequent engagement presents a common challenge. The latter was associated with a perceived burden of use, trust, and performance, as well as with learning. Also common were technical challenges in establishing comprehensive product information databases or achieving performance accuracy with advanced identification methods like image recognition.

Conclusions: Our findings suggest that designs of FPC apps do not encourage repeated use and long-term adoption, compromising the effectiveness of behavior change through nudging. However, we find that smartphone apps can enhance learning, which plays an important role in behavior change. Compared to nudging as a mechanism for behavior change, this mechanism is less dependent on continued use. We argue that designs that optimize for learning within each interaction will have a better chance of achieving behavior change. This review concludes with design recommendations, suggesting FPC app designers a) anticipate the possibility of early abandonment as part of their design process and b) design apps that optimize the

learning experience.

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Original Manuscript

Review

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Keywords: behavior change; mobile apps; food choices; grocery shopping; sustainability; healthy eating, digital health

Introduction

Background

Recent reports suggest that current consumer patterns, particularly in Western societies, have a

significant impact on health and pose a considerable burden on the natural environment [1]. There is increasing evidence that the food production systems and processes enabling current diets contribute to biodiversity losses, water scarcity, and climate change [2]. Also, obesity and food-related health diseases affect a significant proportion of the global population [3], leading to an increasing economic and social burden, both at individual and aggregate levels [1].

While many people claim to have values that align with healthy and environmentally sustainable diets [8], actual consumption patterns are often inconsistent with such stated preferences [9,10]. Research finds that people often struggle to select suitable products to support a healthy or sustainable diet [11]. Diet choices are impacted by factors such as broader values, preferences, prices, availability, social pressure, and socioeconomic constraints [11,12]. This frequently leads to inconsistencies and compromises between competing priorities [13]. Moreover, bounded rationality (i.e., the limited capacity for rational decision making) and heuristic biases (i.e., rational errors in the way we make quick decisions) often lead to sub-optimal choices.

Digital technology—particularly smartphone technology—can support people in making suitable diet purchases [6,14] that align with their values. Smartphone technology (further referred to as apps, but not excluding any smartphone technology that is not strictly considered as an app) can provide rapid access to information, can summarize large amounts of data, and can present this in personally meaningful ways. With smartphones being omnipresent, these capabilities are available at nearly any time and place; alleviating the need for retailers to make financial investments which could hold back the implementation of alternative systems [15,16]. In the last decade, several software and hardware mobile technologies emerged to support consumers in making better—i.e., healthier, sustainable—diet choices. This is particularly the case for healthy diet support apps which have received much interest in recent years, particularly in the form of diet tracking technologies (e.g., [6,17–19]).

While a large body of research examined digital technology for consumption tracking of different products (e.g., [17–19]), the research on smartphone apps that support food purchase choices (FPC) is still limited [6,14]. Responding to Flaherty et al. [6] and Chan et al. [14], who call for further research on developments of FPC apps and to support the development of effective FPC app designs, we conducted a comprehensive review of the research on such developments to date.

Related reviews

Our scoping review complements previous exercises. Mauch et al. [20] reviewed popular apps for healthy food provision available in the Android and iOS app stores. They downloaded 51 apps, assessed the app quality (following the mobile app rating scale, MARS [21]), and identified the behavior change techniques (BCTs) present in the design. They classified most apps as recipe, meal planning, or shopping list apps. Two were classified as food choice apps. They found that apps cover relatively few BCTs and that while the apps generally score well on functionality, the apps score poorly on engagement. They recommend that future developments employ a range of features to simplify healthy food shopping and maximize the use of BCTs.

Chan et al. [14] conducted a systematic review to assess the efficacy of point-of-sale nutrition information interventions. They included 26 studies that report on comparative evaluations, five of which used digital technology as an intervention medium. Three of the five digital technology intervention studies showed a positive health impact, and the authors conclude that digital point-of-sale information interventions can improve healthy diet purchasing. However, they note that, compared to shelf labels, the requirement to scan products to retrieve information may have posed a

barrier that has led to inconsistency in the results. They found no relationship between intervention effectiveness and the number of identified BCTs.

Objective

To the best of our knowledge, Mauch et al. [20] and Chan et al. [14] are the only reviews of FPC apps to date. However, they are incomplete. Mauch et al. provide a catalog of publicly available health and diet apps, without much appraisal of their use. Chan et al. survey evaluations of FPC apps but limit the scope of their review to five apps that follow a comparative evaluation design. Thus, our review aims to complement their work by compiling a comprehensive overview of the academic literature on apps for FPC published to date. Specifically, we aim to (1) describe common design characteristics of the retrieved apps, and (2) describe opportunities and challenges to effective implementation as they are observed in the literature.

To address these objectives, we chose to conduct a scoping review. Like meta-analyses, scoping reviews are systematic, yet they are less restrictive in scope. They are suitable for mapping the knowledge on a topic and the characteristics of the evidence [23], which makes them well suited for our aims.

This work contributes an overview of existing food purchase choice (FPC) app characteristics, unpacking how and with what effect different design approaches might impact food purchase choices (FPC). Moreover, it frames common challenges in the implementation of these apps. Finally, it frames design considerations that could support future effective FPC app developments.

Methods

Overview

We conducted a scoping review of published literature on smartphone-compatible digital technology for food purchase choices (FPC apps). The review follows the guidelines covered by the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) [23] (Multimedia Appendix 1).

Information Sources

We scanned for peer-reviewed articles in four libraries that were selected to provide coverage of digital health and wellbeing technologies from an empirical, as well as technical perspective: IEEE, PubMed, Scopus—which covers the ACM library—and Science Direct. The most recent database search happened on 10 July 2023. Together, the libraries cover a broad range of literature, with research around mature as well as emerging technologies, and publications from the fields of behavioral science, economics, and computer science. We further scanned included works for references to articles that would fit our inclusion criteria.

Search

We scanned the four libraries with the keyword combination: “(mobile OR smartphone OR app) AND (purchase OR shopping) AND (food OR grocery OR supermarket)”. We limited our search to articles published from 2008 onwards. We chose this date limit in consideration of the introduction of the iPhone—the first widely adopted consumer smartphone with a noteworthy ecosystem of apps—in January 2007 and the time required for app development to pick up.

Selection

For selecting the articles, we applied a stepwise process that involved three reviewers (RBG, JH, and

GM). RBG exported the search results from the individual database searches, imported these into the article selection tool Rayyan [24], and removed duplicates. We then proceeded with the selection of articles along the eligibility criteria as described in Table 1. First, we filtered articles based on title, and—if the title left uncertainty about inclusion or exclusion—the abstract. RBG scanned the full set of articles. JH and GM scanned approximately half of the set each. This way, each article was scanned, independently, by at least two authors. We then compared results and discussed any differences until we reached a mutual agreement. RBG then read the full text of all the articles that remained for another round of filtering. JH and GM together read 17 full-text articles, so that a subset of full-text articles was read and selected by multiple researchers. Any differences in selection were discussed until mutual agreement was reached.

Table 1. Eligibility criteria for article selection.

Inclusion criteria (all must apply)	Exclusion criteria (any of these causes exclusion)
<i>App design characteristics</i>	
- Designed for, or compatible with, smartphones (like smartphone apps, web apps, or SMS). - Designed to support grocery choices by considering non-commercial product information (PI) types, like nutritional value and social or environmental impact.	- Does not address diet choices. - Does not have an apparent influence on the decision process (e.g., if the technology focuses on automatic billing). - Is exclusively designed for online grocery purchases.^a - Recipe recommenders (that recommend recipes rather than products). - Diet tracking apps (unless specifically tracking purchases rather than consumption). - Designed specifically to provide support around physical disabilities (e.g., mobility and eye-sight disabilities). - Designed around exclusive programs (e.g., exclusive voucher programs available only in restricted areas). - Technology purely designed and intended as a study support tool.
<i>Article characteristics</i>	
- Primary works in peer-reviewed journals.	- Literature reviews.^b - Not in the English language.

^a Most purchases are still made in brick-and-mortar grocery stores [25], and interventions for brick-and-mortar and online stores involve rather different interaction challenges. Designs for purchases in brick-and-mortar stores need to address transitions between the physical and digital spaces [26,27], while designs for online purchases do not need to address this transition.

^b In case relevant reviews were retrieved through the literature search they have been covered as related work in the introduction of this article.

Data Charting

The data charting process (also, 'data extraction') was iterative, and the coding of several items was inductive.

Step 1, open coding. Open coding was done by following an instruction manual and inserted in a Microsoft Excel spreadsheet that served as the charting form. The instruction manual was drafted by RBG and subsequently verified for comprehensiveness and clarity of instruction by duplicate coding of a test set of seven articles by RBG, JH, and GM. For verification, the three coders met to compare and discuss differences in coding, and minor adjustments to the instruction manual were made. The three coders then continued to code the remaining articles. JH and GM each coded another 5 articles each, and RBG coded the remaining articles. Open coding at this stage aimed to cover relevant information at a high level of detail, such that this could facilitate the inductive process. Variables that were coded at this stage were app variables: (a) description of the app description, including the user interaction, (b) functions, (c) required technical infrastructure, (d) considered product information; evaluation variables: (e) study design, (f) participants, (g) findings (h) reported challenges and opportunities; and article variables: (i) publisher and (j) publication year. In case the same app was discussed in multiple articles, the information for app variables was combined.

Step 2, collaborative identification of patterns. After completion of open coding, the coders met for a workshop meeting to identify patterns in several of the data items from step 1 (items a, b, g, and h) to determine app types (AT), a harmonized collection of functions, and topics of opportunities and challenges. Miro [28], a digital whiteboard for collaborative note-taking, was used for this workshop. Post-it notes with the initial codes for several of the data items (excluding the article items) were added to the whiteboard. A complete set of these notes was copied for each of the three coders, which they could reorganize to aid the process of exploring and identifying patterns. Workshop participants also had access to a PowerPoint slide deck with images and descriptions of each app and the spreadsheet with the complete coding from step 1. Pattern exploration was done in six rounds. In each round, a subset of step-1 items were explored, first independently by each of the participants, then collectively.

Step 3, final coding. RBG updated the charting form with the outcomes from the workshop. Several data items were replaced such that new data items aligned with the patterns from the workshop. Additionally, the full text of articles was scanned for references to the patterns of opportunities and challenges that were identified in the workshop (aka *indirect* opportunities and challenges).

Data Items

The final set of charted data items included the following:

Article characteristics. We charted publication year (i) and publisher (ii). Classification of study types (iii) is coded along the classification adapted from Bardus et al. [29]. We classify article types as (a) *design and development*: articles that describe the design of an app (b) *feasibility*: articles reporting procedural outcomes such as use, acceptance, and retention, as well as articles reporting outcomes of experiments that are performed under restrictive conditions (e.g., laboratory setting or a pre-determined selection of products to choose from), (c) *evaluation*: reporting effectiveness of a technology intervention trial on FPC, (d) process evaluations and causal-comparative studies (*process evaluations* in short): reporting effects on socio-cognitive factors that are related to FPC, or reporting on comparisons to alternative interventions. A fifth type (e) was reserved for *app store reviews*. Combination types are also possible, e.g., an article could cover both a feasibility and evaluation study and would then be assigned both codes.

Design characteristics. We recorded the *app name* (iv). The variables *App Type* (AT) (v) and *functions* (vi) were charted in correspondence to the patterns that evolved from the workshop (cf. Data Charting, step 2). *Product Information* (PI) (vii) represents the type of information that the app uses to support the product choice. This covers nutrition information (e.g., calories, allergens, and macro-, and micro-nutrients), diet balance (or food group; information of food groups¹ of purchases concerning recommendations for a balanced diet, like MyPlate [30], or the Eatwell Guide [31]), environmental impact (e.g., carbon footprint, food-miles), societal impact. *Retailer Dependency* (RD) (viii) was classified as ‘dependent’ in case the article mentioned the use of data infrastructure that is controlled by the retailer (e.g., the retailer product database, loyalty card data, or beacons for indoor navigation), ‘independent’ in case the article stated that only crowd-sourced or open-access data was used, or ‘unknown’ when this information was unavailable.

Study characteristics (with ix-xii for evaluation studies only). We recorded the *study design* (i.e., cohort or control group design) (ix), the Evaluation period (*duration*) (x), the number of participants in each study group (*participants*) (xi), and primary findings (*findings*) (xii). Topics of *opportunities and challenges* (xiii) were coded in correspondence to the patterns from the workshop. Here we distinguished between *direct* (reported as a challenge or opportunity in the article) and *indirect* (not reported as a challenge to the design and identified in the second pass of the article).

Synthesis of Results

We count the frequencies at which values are observed and provide narrative summaries of the findings. Specifically, to synthesize the findings on apps, we group observations (i.e., apps) by AT and summarize the design characteristics for each group. We supplement this with a narrative summary in which we focus on common patterns and salient exemptions to those patterns. We furthermore visualize the frequency of functions per AT in a bar chart.

Next, we investigate opportunities and challenges from a quantitative as well as qualitative perspective. For the quantitative perspective, we count significant and insignificant primary evaluation outcomes and provide a narrative summary of dominant patterns in the results. From a qualitative perspective, we provide a qualitative content analysis of the charted opportunities and challenges. Meaning, we tabulate an overview of counted topics of opportunities and challenges and elaborate on these topics with a narrative summary that is supported by specific observations in the articles.

Results

Overview of Included Articles

The database searches returned a total of 1353 articles. Another 11 articles were added from references. After screening we kept 57 articles for this review. Figure 1 provides an overview of the reason and number of articles excluded at each step of the selection process.

¹ Information about food groups is provided to convey diet balance. While the term *food group* is more accurate, we choose to use the term *diet balance*, wherever possible, for the purpose of clarity.

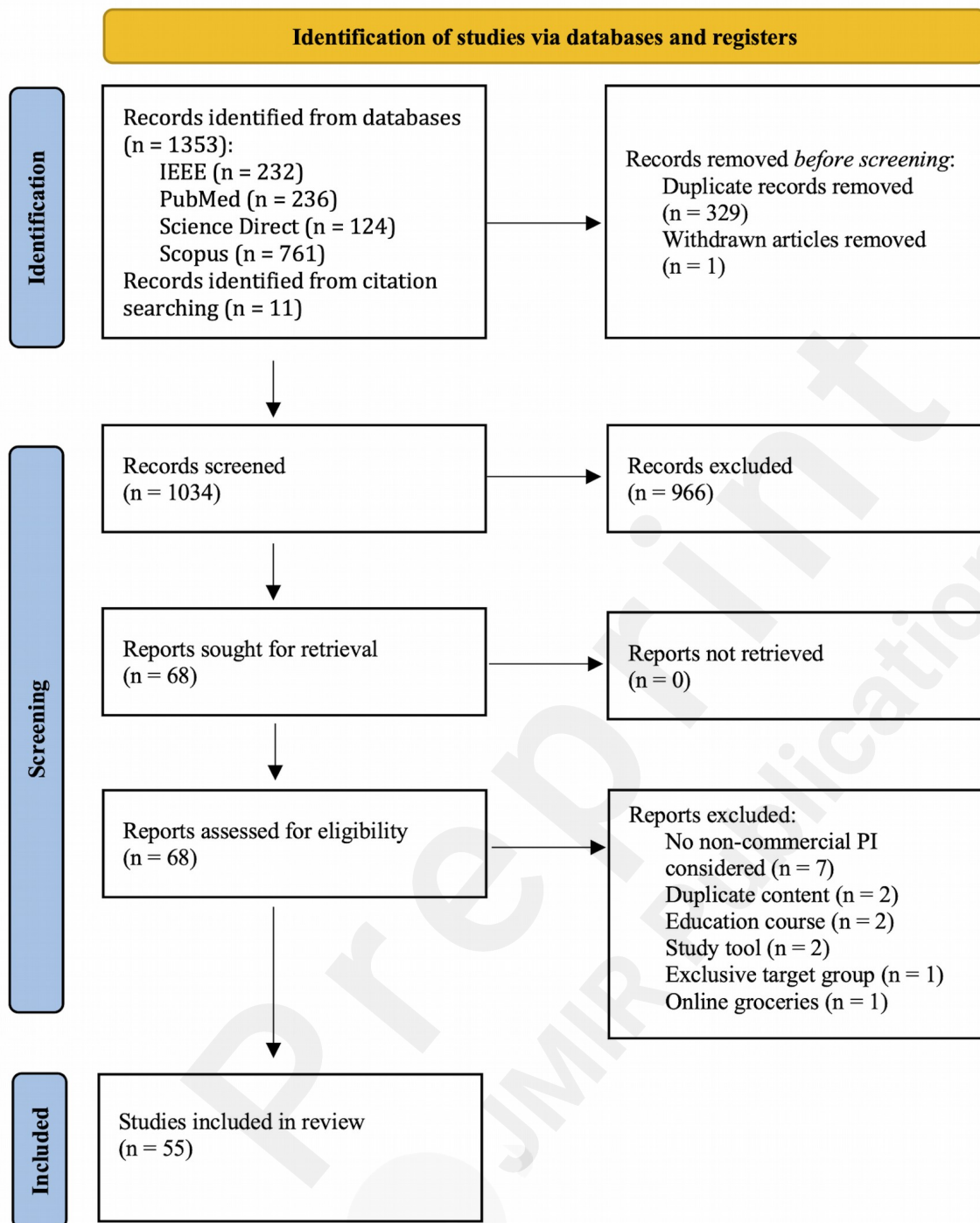


Figure 1. Results of articles search and screening.

Amongst the 55 articles that remained after filtering, we identified 41 design and development studies, 32 feasibility studies, 13 evaluations, and 3 process evaluations. Two articles were classified as app store reviews. These counts do not sum up to 55, as articles often covered a combination of classifications. Dominant publication venues were IEEE (engineering, 13), ACM (computer science, 13), Elsevier (7), JMIR (5), and Springer (5). A complete overview of the included publications is available (Multimedia Appendix 2).

Overview of apps

We charted characteristics for 46 unique FPC apps (see Multimedia Appendix 3 for a complete overview). Three articles [6,20,32] provided insufficient information on their covered apps for us to

chart these apps. We identified 9 main functions. For three of these, we distinguished different implementations of the functions, creating a total of 21 different function labels (see Error: Reference source not found for counts and descriptions). Most apps provide health-relevant information ($n = 37$), with 32 apps returning nutritional content and 6 apps providing information on diet balance (one provides information on both). Twelve (12) apps provide information on environmental impact. Other product qualities were societal impact (3), product freshness (1), and one product authenticity (whether the provided origin and product type were genuine, 1). About a quarter ($n = 12$) of apps were found to be dependent on the retailer.

We categorized the apps into six app types (ATs). We observed that all—except one [33]—of the covered apps provide support to a distinct moment, or stage, around the product choice. We therefore named each AT by the stage that it addresses. We find apps that address (in chronological order) structured purchase *planning* (7), *contemplation* (2), *approaching the product* (6), physically *selecting the product* (27), and *reflecting on the purchases* (7). One app addresses a combination of these stages². Below we describe these ATs along common functions (see Figure 2) and examples.



Figure 2. Frequency of functions by AT. Separate panels for each AT are scaled to the total number of apps within the AT. An overview of function descriptions is provided in Multimedia Appendix 4.

² This combines the planning, contemplation, selection, and reflection type. For calculations and graphical mappings, we do not count this towards the individual ATs. In those cases, we include a separate multi-stage AT.

Purchase Planning Apps

These apps support the planning shape around the use of a shopping list. This can either be done by automatically generating a shopping list [34], suggesting a goal for the shopping list content [33,35], or providing feedback about product characteristics within the shopping list [36,37].

For example, Hedin et al. [36] use an autocomplete algorithm that lists items of food from a carbon footprint database while the user types. The carbon footprint value per 100g is then presented next to the list item.

Contemplation Apps

The Contemplation App has a mostly practical educational characteristic and provides knowledge and tips that help the user make decisions about food purchases while shopping.

For example, Bangia et al. [38] introduce a podcast series that informs the listener about the benefits of omega-3, the types of products in which it is found, and practical considerations, like the affordability of different forms of omega-3. The podcast series has short episodes, one each covering products that are typically found in the same shopping aisle, so that it can be played when visiting the specific aisle.

Approach Apps

Product Approach Apps use the live search function to provide information about nearby products. Options are visualized on the device screen together with suitability ratings for each product. Apps were found to provide nutrition and environmental, but not diet balance information.

For example, the app described by Isley et al. [39] uses AR to project semi-transparent traffic-light-color frames and A-to-F tailored ratings over breakfast cereal boxes as the user views the respective shelf section through the phone camera.

Special cases: Two apps use indoor position data to provide the user with information about nearby products but rely on the retailer for this data.

Selection Apps

Selection Apps (SA) provide the user with an evaluation of the product after it has been identified. *Barcode scanning* (n = 13) is the most common type of identification. *Normative ratings* (n = 8) and *tailored ratings* (n = 12) are the most common types of evaluation. Many of these apps also recommend alternative products from the same product category (n = 10; e.g., the category of milk and dairy-free milk alternatives).

For example, upon barcode scanning, FoodSwitch [40], shows the product name and traffic-light nutrition label for the identified product and lists same-category alternatives, ordered from more to less healthy, below the identified product.

Special cases: While Selection Apps rely on the active pursuit of product information, one SA makes an exception and allows the user to be passive in the information pursuit. Customers use the retailer-dependent Dirk app [41] to scan articles as they go around the store as part of a checkout-free automated payment process. In case the user scans an unhealthy item, the app provides a pop-up with information and an alternative.

Also, one SA, Nutriflect mobile [42] is designed to be used in combination with a Reflection App

(RA), Nutriflect home, that records the diet balance in diet purchases. This is the only selection app that provides feedback on diet balance (see also the visual in Multimedia Appendix 5).

Reflection Apps

These apps rely on monitoring purchases to provide the user with feedback in an aggregated data visualization. Some of these apps are intended to be used in the store [16,33,35], tracking items as they are added to the shopping basket and providing the user the opportunity to make adjustments before leaving the store. Other apps provide feedback based on a record of purchases, e.g. from loyalty card data, and support intention formation for the next purchase.

For example, Bird et al. [16] let the user scan the barcodes of products as they are added to the shopping basket to receive diet balance information. The app interface provides visual feedback about the content of the basket along five food groups (grains, meat, dairy, fruit & veg., and treats) through a pie chart. Each slice of the pie chart has a size that is proportional to the recommended number of purchases for that food group and each slice could be partly filled, by using e.g., light green to represent the remaining amount to be added to the basket, and dark green representing the amount already added.

Multi-stage Apps

One app was found to address multiple stages of the purchase process. Bomfim et al. [33,35] propose an app, PBGA, that covers the planning, contemplation, selection, and reflection stages to support users in a balanced diet. PBGA supports users in creating a shopping list in line with a healthy diet balance (planning), provides users tips for identifying healthy options in various aisles (contemplation), provides nutrient information upon scanning the barcode of a product (selection), and monitors the scanned items to recommend purchases in each of five food groups.

Challenges and Opportunities

In the following sections, we explore the opportunities and challenges to the effective implementation of FPC apps. For this purpose, we summarize results from evaluation studies and report a qualitative content analysis of common challenges.

Study Outcomes

Table 2 provides an overview of the 12 evaluation studies. These evaluation studies cover 24% of all 46 apps: 7% of the selection apps (lowest), and all reflection apps (highest). Eight studies (66%) report a significant behavior impact. Mixed results are observed for the two evaluated selection apps. Otherwise, no clear patterns between AT and study outcome can be observed. Three studies report outcomes (findings) towards a diet balance, all showing significant results (see also Multimedia Appendix 6 for grouping of evaluations by PI).

Table 2. Summary of evaluation studies, organized by AT.

	App	Design/duration/participants	Findings
Planning Apps			
	GreenCobra [36]	cohort/2 wks/30p	n.s. ^b change in the carbon footprint of purchases.
	MyNutriCart [43]	cohort/8 wks/27p	sig. healthier diet balance of

			purchases.
Contemp. Apps			
	AppX05 [38]	cohort/6 mnt/251p	sig. ^a increase in omega-3-rich purchases.
Approach Apps			
	AppX08 [44]	cohort/7 mnt/69p + 323p ^c	sig. increase higher-rated purchases.
Selection Apps			
	Dirk app [41]	3 UI variations (1x with and 2x with health note and 1x without) vs. control/5 wks/1783 scans ^d	(1) sig. healthier purchase when presenting alternatives without health info, (2) n.s. when adding health info.
	Foodswitch [45]	app vs. no app/4 wks/33p + 33p	sig. reduction sodium concentration in purchases.
	Foodswitch [46]	app + reduced sodium salt vs. no app/12 wks/84p + 84p	n.s. change sodium intake.
Reflection Apps			
	AppX13 [47]	cohort/2 wks/31p	n.s. change in the healthiness of purchases.
	EcoPanel [48]	app vs. no app/5 mnt/65p + 2587p	sig. increase organic purchases.
	FutureMe [49]	app + future-self simulation vs. app without/12 wks/42p + 53p	n.s. difference in the healthiness of purchases.
	Healthy Shopping App [16]	cohort/4 wks/7p	sig. healthier diet balance of purchases.
	Nutriflect Home [42]	cohort/4 wks/21p	sig. healthier diet balance of purchases.

^aSig. = significant.

^bN.s. = non-significant.

^cxp + yp = Participants in the intervention group + participants in the control group.

^dParticipant counts are unknown. Only the number of scans that triggered information prompts are however available.

Table 3 provides an overview of the six process evaluations and causal-comparative studies. Knowledge gain was the most commonly reported socio-cognitive outcome factor (n = 4). All these

studies report significant knowledge gain.

Table 3. Summary of process evaluations and causal-comparative studies.

	App name	Design/duration/ participants	Findings
Planning Apps			
	GreenCobra [36]	cohort/2 wks/30p	sig. knowledge gain
	MFG [35]	cohort	sig. knowledge gain
	MyNutriCart [43]	app vs. education/ 8 wks/27p + 24p ^c	n.s. ^b difference in healthiness of purchases vs. education
Selection Apps			
	EDO App [50]	cohort/12 wks/143p	(1) sig. ^a knowledge gain, (2) sig. gain in self-efficacy
Multi-stage Apps			
	PBGA [35]	cohort ^d	sig. knowledge gain
	PBGA [35]	PBGA vs. MFG/3 wks/12p + 12p ^d	sig. reduction of ultra-processed food purchases

^aSig. = significant.

^bN.s. = non-significant.

^cxp + yp = Participants in the intervention group + participants in the control group.

^dKnowledge gain is assessed with a pre-test and post-test design, while behavior change is assessed by comparing the effect of different apps. We therefore list the results in separate table rows, even though the two evaluations are done in the same study.

Qualitative Content Analysis of Challenges and Opportunities

Table 4 provides counts of common topics of challenges and opportunities as they were identified through a qualitative content analysis. We elaborate on these topics in the sections below.

Table 4. Common challenges topics found in the articles.

	Topic	Direct ^a	Indirect ^b	Total
Behavior change		8	10	18
	barriers to change	5	4	9
	scope of impact	3	6	9
Interaction		23	20	43
	engagement	12	2	14
	trust	5	7	12
	burden of use	5	4	9
	learning	1	7	8
Tech. Feasibility		13	7	20
	source data ^c	8	3	11
	performance	5	4	9

^a The authors of the publication recorded the topic as a challenge to the implementation of the app.

^b The authors address the topic, but not directly as a challenge to the implementation of the app.

^c Source data: the data that underlies the information that is viewed in the app. This is typically a database of product information.

Behavior Change Challenges

Barriers to change. Behavior change is hard, and participants struggle to achieve diet goals [16,35]. Conflicting priorities complicate adopting changes [13,36,51]. The user may not like suggested products [51], or perceive the pursuit of adopting changes as too time-consuming [13,36]. Participants look for ways to prioritize their efforts but may find support for this lacking [36]. Zapico et al. [48] argue that reflection of prior behavior helps people in prioritizing behavior change and developed a reflection app [48,52]. Apps can also support prioritization by providing salient reminders of past behavior, as memories of past behavior may not be accurate [42]. Reitberger et al. [42] supported this by linking a selection app with the behavior monitoring data from a reflection app. This allowed the selection app to assess the suitability of products from the perspective of past behavior.

Scope of impact. While a benefit of mobile apps lies in their scalability [6], the impact is limited to the users who choose to adopt the technology [10,40]. This is often only a small proportion of the population [40]. However, Reitberger et al. [42] note that this impact can be extended to household members by monitoring household purchases, using a reflection app. Reflection on household behavior can spark conversation and lead to social facilitation.

Retailer dependency can also restrict the scope of impact. Information about purchases is available only at specific stores [52]. The app may have little value for people who purchase much of their food at other retailers [49]. The commercial interest of retailers may also lead them to restrict the

information that is provided. For example, retailers may be interested in providing data that encourages the purchase of organic products but may be less inclined to provide data on other indicators of sustainability [52]. Retailers may also choose to withhold negative information or withhold information altogether, as negative information was found to have a stronger impact on rejecting a product than positive information has on choosing a product [53].

Interaction Challenges

Engagement. Engagement issues (limited use and abandonment) were frequently reported [6,13,20,32,45,46,49,51,54–57]. Engagement issues are seen as a barrier to behavioral impact [20,32,46,49,55] and two studies attribute insignificant findings to the issue [46,49]. Zapico et al. [48] however did not observe a correlation between frequency of engagement and behavioral impact. They reported significant behavior impact despite a low engagement frequency in their EcoPanel reflection app. Engagement issues may result from knowledge gain (learning) [50,58], a perceived burden of app use [46,57,58], performance [6,49], and trust issues [49], while tailored, or personalized, feedback can increase engagement [49,55]—although personalized feedback can negatively affect engagement when the data is not trusted [49]. Normark and Tholander [59] found that when technology doesn't perform as expected, this leads to frustration and rejection of the technology.

Burden of use. The use of the technology may be found effortful and disruptive to the shopping routine [42,44,60] or shopping list creation [13] and therefore less acceptable for frequent use [58,59]. Studies instead indicate that technology is used as an infrequent lookup, and to explore new products [13,44,58], which may not have been the intended use [13]. However, one study [58] was found to consider the likelihood of infrequent use as part of their design process.

Learning. Learning (knowledge-gain) was framed as a challenge from the viewpoint of some authors, as they perceive it might hinder repeated use of the application and contribute towards its abandonment. Indeed, as people gain knowledge about products through the use of the application, they may perceive less need to use the application again [50,58]. Knowledge gain (i.e., increasing food literacy) through digital interaction was however frequently highlighted as an important mediator for behavior change [33,35,36,38,50]. This means that learning was viewed as a challenge for the FPC app's adoption, but not necessarily for achieving behavior change. Moreover, knowledge gain was generalized beyond the products that were evaluated with the app [58], and even the food group [50]. Some authors suggest that, because of rapid learning, initial app interactions may be the most important for guiding change [48,58], and, in some cases, further engagements may have little incremental impact on further behavior change [48]. Also, Bangia et al. [38] observed a significant behavioral impact from a one-off intervention with their app six months after the intervention had taken place; pointing out that repetition is not an essential mechanism to achieve knowledge gain and to mediate behavior impact.

Trust. Issues with trust were also flagged as negatively affecting engagement with technology. Involvement of the retailer in the app source data is noted as a potential source for distrust [13,16,58], leading to efforts to develop technology that can work independently of the retailer [16]. Commercial interests may restrict transparency [52], involve advertisement in the form of recommendations to influence purchases [61], or restrict product information unfavorably [53]. Even when the motives of influence are genuine, external influence may result in reactance (the resistance against a persuasive intent that is however perceived as manipulation). Van der Laan and Orcholska [41] show how a persuasion attempt to choose a healthier alternative can be nullified when external motives are exposed.

Commercial interests may also make demands on privacy protection, particularly when personal data is shared [44]. As many of the devices are designed to be used in non-private environments, privacy concerns are also relevant for the mode of feedback, particularly when the feedback is not well concealed (e.g., when using audio feedback [60]), or when the phone camera is used for recognition of products and personal identifiable features may be exposed [36].

Technical Feasibility Challenges

Source data. Acquiring and maintaining (accurate) source data may also present feasibility issues. For example, when using location information for recognizing products [44,62,63]. Acquiring and updating source data to achieve the required performance was found to be very challenging [63,64]. Also, some data, like data on environmental sustainability data and data on social impact may be difficult to acquire [36,44,58,65]. This can pose significant implementation challenges.

Performance. Technical challenges may stand in the way of a practical implementation of an app. For example, performance issues may limit the app of approaches using image recognition. Studies that report on recognition performance find that not all products could be identified [66,67] and no evaluation studies were found for apps that use image recognition to identify products. Indeed, Isley et al. [39] note that water bottles could not be detected by camera, and QR labels on shelves were needed to assist their study. They also report that cereal boxes were not always accurately detected or not detected at all.

Field trials were not found when NFC/RFID was used as a detection method. While no performance issues were reported, it was noted that NFC/RFID labels were not (yet) provided for the grocery products in the study supermarket [42], which made practical implementation of this strategy unfeasible at the time of the study.

Even when a product is correctly scanned, product data may not be returned. We find various studies that note issues with missing or faulty data for products, particularly in the case of retailer-independent designs [46,47,54,55], although also faulty data could be observed for retailer-dependent designs [13].

Discussion

Principal Results

We systematically scoped the academic literature on FPC apps and inductively charted common design characteristics, and opportunities and challenges for their effective implementation. We identified five distinct app types (ATs), each supporting a specific stage of the FPC. The most common AT (over 60%) was the Selection App (SA). Most selection apps identify products by barcode scanning and evaluate the product by returning a (tailored or norm-based) rating of nutritional contents without any dependence on a specific retailer. Other types of apps and product information (PI) were less present.

We investigated opportunities and challenges by charting quantitative results from evaluation trials and qualitatively exploring patterns in authors' observations. Similar to Chan et al. [14], we observe that results from 12 comparative evaluation trials indicate the potential for FPC apps to support behavior change. However, the proportion of evaluated Selection Apps (SA) is notably small (2/26, 7% vs. 9/19 (47%) for other types); moreover, the results for this AT are mixed, suggesting potential efficacy challenges with this approach [68,69]. Notably, all three comparative evaluations that

provided diet balance information showed a positive impact. Evaluation trials also indicated the potential of FPC apps to contribute to knowledge gain, with all four respective evaluations reporting significant findings.

Qualitative findings based on content analysis of authors' observations highlighted opportunities and challenges around FPC apps. In FPC apps, engagement issues such as repeated use and long-term adoption present a common challenge. Findings indicate that engagement challenges frequently result from a perceived burden of use. These results are in line with research on abandonment of behavior change technology [70,71]. We also observed broader challenges relevant to the pursuit of behavior change (e.g., people may struggle to identify which efforts to prioritize), trust toward retailer motives, and technical feasibility. Learning was observed as a common opportunity derived from the use of FPC apps. Opportunities for addressing various challenges were repeatedly found in apps that apply behavior monitoring (Reflection Apps).

Implications

Consideration of Mechanism of Technology-Mediated Change in Design Thinking

Selection Apps (SA) address *the moment* of product selection and appeared particularly popular for supporting food purchase choices (FPC). SAs provide support 'just-in-time' (at "exactly the right moment") [55]—see 'just-in-time' intervention literature [72,73]; i.e. the moment a choice is translated into action in-store, and a product is either added or not added to the shopping basket. There is no need to rely on—potentially inaccurate—memories [42]. Rather than relying on rational thinking, this approach allows the user to be guided by a gentle push (nudge) in the direction of healthy or sustainable choices on the spot [41,55,74]—see [75–77] for frameworks of nudging. As such, the approach aligns with a growing acknowledgment that most decisions during in-store grocery shopping, are not made by deliberate, rational, decision-making processes, but rather through heuristics [78] ('mental short-cuts', or 'snap decisions' based on less conscious evaluations of the available information [76,79]). It can be argued that conscious decision-making is not the design aim of a nudge-driven system; but it can be a side outcome. Along these lines, behavior change beyond a single purchase relies on the repeated exposure to these nudges; and on the repeated use of the FPC app that utilizes nudges to achieve impact.

Despite their claimed benefits, we observed frequent reporting of engagement challenges with Selection Apps (SA), and FPC apps in general. Users perceive the use of the SA as interruptive or burdensome [46,58,80], leading them to slowly abandon its use over time; which jeopardizes the intended behavior-change goal of such apps. These findings align with Vhaduri and Prioleau [81], highlighting that infrequent engagement with digital health technology jeopardizes the potential health benefits. Similarly, Ni Mhurchu et al. [80] found that the healthiness of food purchases only increased for people who frequently used the SA.

Several studies attempt to characterize the causes that underlie these engagement issues [70,71,81,82] and propose design modifications that may improve long-term engagement. Kalnikaite et al. [27,79] and Todd et al. [26] highlight the importance of causing minimal disruption to the shopping routine and providing 'just enough information, in the right form'. A variety of product identification and evaluation approaches may be driven by the premise of minimal disruption in the selection of Apps that we found through our literature search. However, these approaches sustain the focus on nudge-based systems. The questions remain open with regards to improving nudge-based systems enough to accomplish long-term use to achieve behavior impact.

Related to this, we observe two important shortcomings in the attempt to improve behavior change impact through designing FPC apps with the premise of repeated use. First, we find that engagement

challenges are common across various domains of digital technology (e.g., for just-in-time (JIT) digital health interventions [83,84], online diet interventions [85] self-tracking apps [70,82] wearables [86], and IoT [87]). The widespread presence of engagement issues suggests that these are hard to solve and results of efforts to achieve engagement for extended periods are likely to be modest at best. Short periods of engagement may better be understood as the rule, than the exception [70,82].

Second, the proposal to improve nudge-based systems for improved engagement reflects the prioritization of quantity over quality of the engagement. A focus on engagement quantity aligns with a nudge-mediated mechanism of behavior change—i.e., the app redirects automatic behavior by changing the choice environment, without significant involvement of conscious decision-making [76,79]. However, findings from our study challenge this prioritization of quantity over quality and suggest that other important mechanisms are at play.

Our findings suggest that learning (knowledge gain) plays an important mediating role in the impact of FPC apps on FPC behavior. In their study with a Reflection App (RA), Flaherty et al., [78] found that behavior feedback can spark learning through critical reflection on products and one's beliefs about products, and influence future purchases. Reitberger et al. [42] and Zapico et al. [48] observed the use of an RA to contribute to positive change in FPC. Also indicative of learning, Bangia et al. [38] observed a positive change in FPC, 6 months after using an information-rich FPC APP during one shopping trip.

The mechanism of learning-mediated changes appears to depend more on the quality than quantity of FPC APP engagements. Few interactions may suffice for learning to happen [38,48,58]. A single interaction may even suffice for a significant impact on behavior [38,48]. In their research with Selection Apps, Samoggia et al. [50] and Herbig et al. [58] noted that Learning can even reduce the likelihood of future use as the perceived value of the information diminishes; findings that align with Epstein et al., [2016], who find that internalization of the learnings from the use of diet trackers can be a cause of abandonment of the technology. As such a mechanism of learning-mediated change can intervene with a mechanism of nudge-mediated change.

While the described mechanism of learning involves conscious reflection, it does not conflict with an appreciation for the role of heuristics in grocery shopping. Flaherty et al., [2020] observe that conscious reflection serves to update beliefs that drive heuristics-based FPC. After a period of conscious reflection on purchases, routinized, heuristics-based, shopping is continued.

Summarizing, we observe that there is an important role for learning in behavior change supported by FPC apps and that—contrary to a mechanism that relies on nudging—learning is relatively robust against disengagement, as it does not necessarily rely on continued engagement with the app. This has important implications for the design of FPC apps. Opportunities exist to design apps that can be effective despite potential abandonment, that designers may want to pursue. In the next section, we will provide some practical suggestions for designing with learning in mind, alongside other suggestions for the future design of FPC applications.

Suggestions for Future Design

The purpose of this section is to formulate, briefly, some practical suggestions for the design of FPC apps that follow from the contents of this review.

Optimize for learning. As discussed in the previous section, learning appears to play a key role in the potential behavioral impact of FPC apps. We propose that key elements of learning-oriented FPC app

design include information clarity; information contextualization (i.e., providing informative context to support decisions); and an emphasis on rich information—elements that we observed in the use of functions like *tips and tricks* and *background information*. Key elements also include: design with a view for minimal interactions as opposed to repeated use; design to support reflection on information and rational thinking which extends beyond the app's use; design to support user autonomy and gradual abandonment of the app.

This proposal aligns with our observations that behavior monitoring can benefit learning [47,48,78], and that the use of knowledge tips and background information is also associated with knowledge gain [38,58]. Importantly, the optimization of designs for a nudging effect (see [26,27]) may conflict with efforts to optimize designs for learning.

Formalize assumptions of app use over time. Many FPC app designs seem to be developed on the unspoken premise of continued engagement to achieve behavior impact; although this is not a given. We have observed that it is uncommon for designers to articulate expectations towards the regularity and nature of engagement within the design process (an exception is [58]). Yet, our findings suggest that early abandonment appears to be common and can have a detrimental impact on the potential of an app to impact behavior. To mitigate unforeseen impact, we suggest that designers should view abandonment as a key element of their design strategy and formulate engagement expectations early in the design process. It is recommended that designers include considerations about engagement over time, and possible abandonment, into design thinking. By bringing transparency on the matter, designers can then develop diverse mechanisms to address abandonment.

Overcome biases and norms when selecting design characteristics. Although we observed a wide range of design characteristics (ATs, functions, and PIs); FPC app designers seem biased towards selecting a set of characteristics – see for instance, Selection Apps (SA) and the use of barcode scanning and normative of tailored ratings of nutrition information. We found that other ATs and PIs may have more potential. We therefore encourage designers to explore other options for the design of SAs and broadly FPC apps. Some suggestions include the use of diet balance as PI, and Reflection Apps (RA) as AT; which are further addressed below.

Use diet balance as PI. This PI was commonly associated with significant behavior impact (cf. Study Outcomes). Achieving a balanced diet can be framed as goal setting, which is considered an effective behavior change technique [88–90]. Also, the simplicity of categorizing choices into five categories may be beneficial for facilitating behavior change. Goal setting requires a form of monitoring and is, therefore, suitable for reflection apps—for which monitoring is a key function. Goal setting is also compatible with planning apps (see e.g., [35]) based on purchase intention monitoring. However, the need to define quantities for the intended purchases may present a barrier [13,36,91], which may make this a less suitable option.

Consider behavior monitoring (Reflection Apps). We have observed that various opportunities for addressing common challenges with FPC apps are found in Reflection Apps; framed around behavior monitoring. Behavior monitoring is considered one of the more impactful BCT techniques [88,89]. Behavior monitoring can help prioritize actions [48], which is a common barrier to achieving behavior change. Behavior monitoring can be resistant to engagement issues [48] particularly related to missing product data [47]; as it does not depend on the information of a single product (as opposed to many SAs and nudging approaches). It also provides opportunities for providing feedback on diet balance, a PI that was commonly associated with significant behavior impact. Moreover, as reflection is independent of the point of purchase (usually happens after the purchase), the interaction with Reflection Apps is likely to be less time-pressured than with those designed to be used during

shopping (e.g. SAs, nudging systems); which can provide better learning opportunities.

Practical limitations and future opportunities for Reflection Apps. Relevant to the above, it must be noted that most Reflection Apps included in this study used loyalty card data or receipt scanning; approaches that facilitated easy data recording [42,47,49,52]. Still, practical implementation of these approaches can present difficulties. Applicability of loyalty card data is limited to the people who use loyalty cards, and availability depends on the retailers that make this data available. While Swiss law seems to require retailers to make this data available through an API [49], such regulations may not apply in other countries; which can pose constraints to designers who want to pursue such approaches. Moreover, receipt scanning requires trained machine learning algorithms and may not work optimally [47,52]; but given alternatives like barcode scanning are often perceived as too effortful [70], receipt scanning seems a promising avenue for future designs. These limitations can be framed as opportunities for further research for developing effective FPC apps.

Limitations

We acknowledge several limitations to our decisions for executing and reporting this review. We report these in no specific order.

The use of digital technology for behavior change can raise important ethical concerns [92–94], as these technologies have the potential to be manipulative. This review did not systematically assess the ethical concerns that might be associated with the app designs, nor the approaches that were taken to mitigate manipulative potential (i.e., design approaches that respect individual needs and priorities like participatory design [95–97] or user-centered design). Such an assessment was beyond the scope of the current article. However, designers of technology must be respectful of individual needs and priorities and follow user-centered approaches.

We did not calculate a meta-statistic estimate of the effect of FPC apps. Appropriate reporting of this statistic relies on the stringent review procedure of a meta-analysis. We provided a simple summary analysis of study findings that provided context to the opportunities and challenges that were reported in the literature. Calculating a meta-statistic would be beyond this means not our objective, and following the requirements for a meta-analysis would have compromised our ability to report on the objectives that we did formulate. Moreover, with the current body of literature, we see little justification for conducting a meta-analysis to calculate the impact of FPC apps. The variety in reported outcome measures together with a modest number of studies reporting evaluation results complicates the calculation of a meta-statistic and restricts the conclusion that can be drawn.

Final charting was done only by one person. This limited the rigor in establishing exact counts of observed codes. However, the main function of observation counts was to indicate the magnitude of common patterns in designs, opportunities, and challenges. Establishing exact counts for each observation was less important. Importantly, the identification of the common patterns themselves played a superior role in addressing the study objectives. Multiple reviewers were involved in the identification of patterns in the literature.

We acknowledge that apps could have been described along with additional characteristics. We have listed the characteristics that appeared most salient in describing the variations in apps without much interpretation. Apps could have been characterized by mapping techniques from the Behavior Change Technique Taxonomy BCTT [98]. However, we had several reasons not to characterize apps by BCTs. First, mapping along the BCTT requires a firm understanding of the various techniques, as well as a firm understanding of the intervention that applies the techniques [99]. Comprehensiveness and clarity of app descriptions in the articles varied considerably and it was not feasible to download

and investigate the apps, because most apps were not deployed in app stores. This limited our abilities to perform accurate mapping of BCTs, with the potential of misleading interpretations that are drawn from this mapping. Second, the value of mapping BCTs is expected to be moderate. BCTs have been associated with the efficacy of behavioral intervention [88–90] and counting BCTs in apps is used as a practice to estimate the potential of an app to impact behavior (e.g., [14,20]). However, several studies fail to find a relationship between the number of applied BCTs and behavioral outcomes (e.g., [14,100,101]). As a binary mapping approach, mapping along the BCTT does not consider the intensity or fidelity of the BCT app. For these reasons, we decided not to prioritize the mapping of BCTs.

Conclusions

This scoping review examined the a) design characteristics, and b) opportunities and challenges of food purchase choice (FPC) apps. Most FPC apps are designed to help users select healthier products by scanning the barcode and displaying a nutritional rating. The value of this design comes from its potential to influence (nudge) users' decisions at the point of purchase (just-in-time) with little demand for conscious decision-making. However, our findings suggest that this design approach does not encourage repeated use and long-term adoption, which limits opportunities for behavior change through nudging. Instead, our results indicate that learning plays an important role in behavior change and that this mechanism is less dependent on continued use. We argue that designs that optimize learning within each interaction will have a better chance of achieving behavior change. This review concludes with design recommendations, suggesting FPC APP designers a) anticipate the possibility of early abandonment as part of their design process and b) design apps that optimize the learning experience.

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Authors' Contributions

As the main author, RBG designed the scoping review and had the lead in data collection and analysis. GM and JH contributed to article selection, data charting, and data analysis. CB, DSM, JS, and LM contributed by editing the manuscript. All authors reviewed the final manuscript.

Data Availability

All data generated or analyzed during this study are included in this published article and its supplementary information files.

Conflicts of Interest

None declared.

Abbreviations

ACM: Association for Computing Machinery

AR: Augmented reality

AT: App type

BC: Behavior change

BCT: Behavior change technique
BCTT: Behavior Change Technique Taxonomy
FPC: Food purchase choice
IEEE: Institute of Electrical and Electronics Engineers
JMIR: Journal of Medical Internet Research
MARS: Mobile app rating scale
NFC: Near-field communication
PI: Product information
RA: Reflection App
RD: Retailer dependency
RFID: Radio frequency identification
SA: Selection App
ST: Smartphone technology

Multimedia Appendix 1

Completed PRISMA-ScR Checklist.

Multimedia Appendix 2

Overview of included articles.

Multimedia Appendix 3

Overview of apps.

Multimedia Appendix 4

Function descriptions.

Multimedia Appendix 5

Sankey diagram of app designs grouped by AT, PI, RD.

Multimedia Appendix 6

Overview of evaluation studies by PI.

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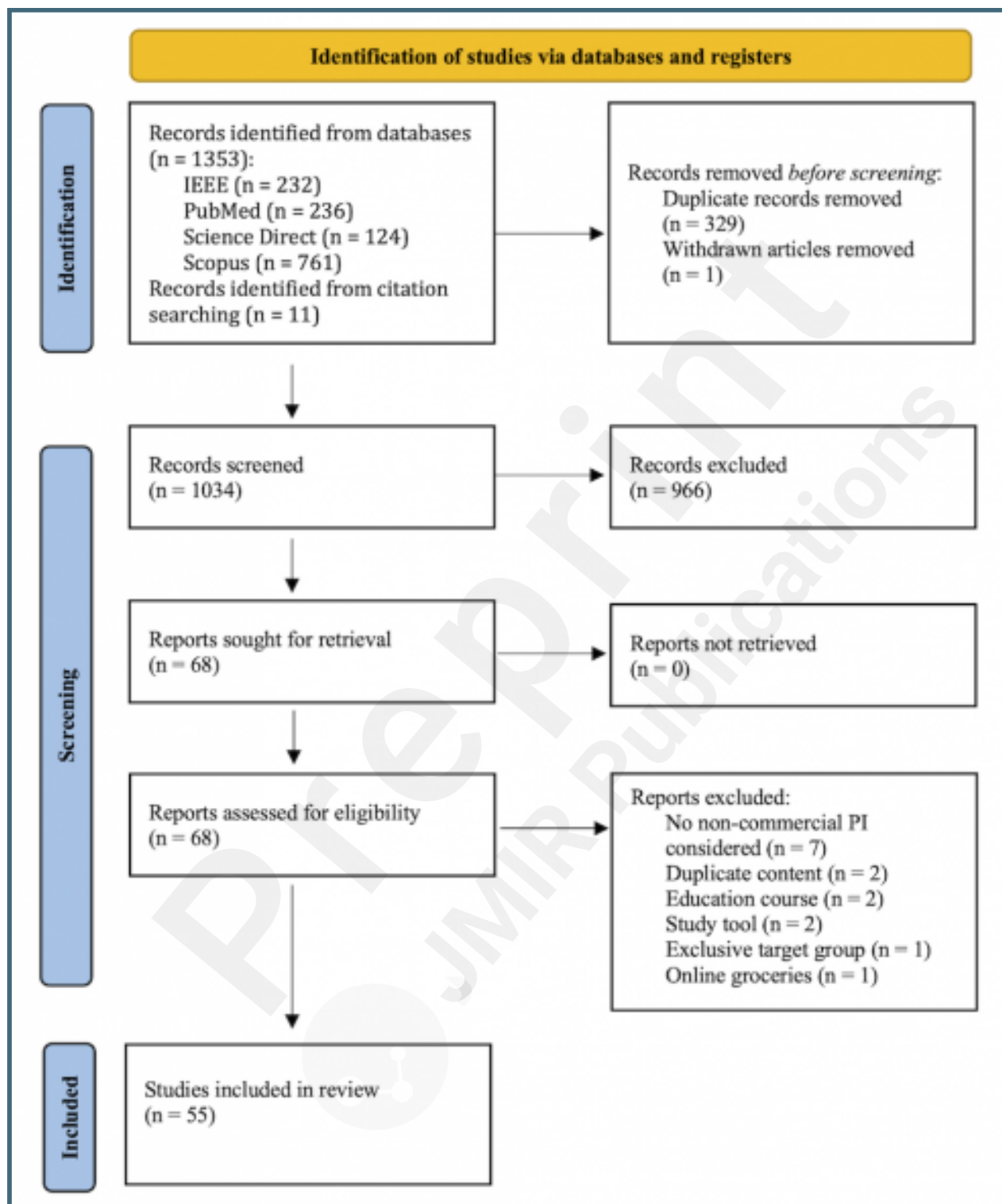
Supplementary Files

Untitled.

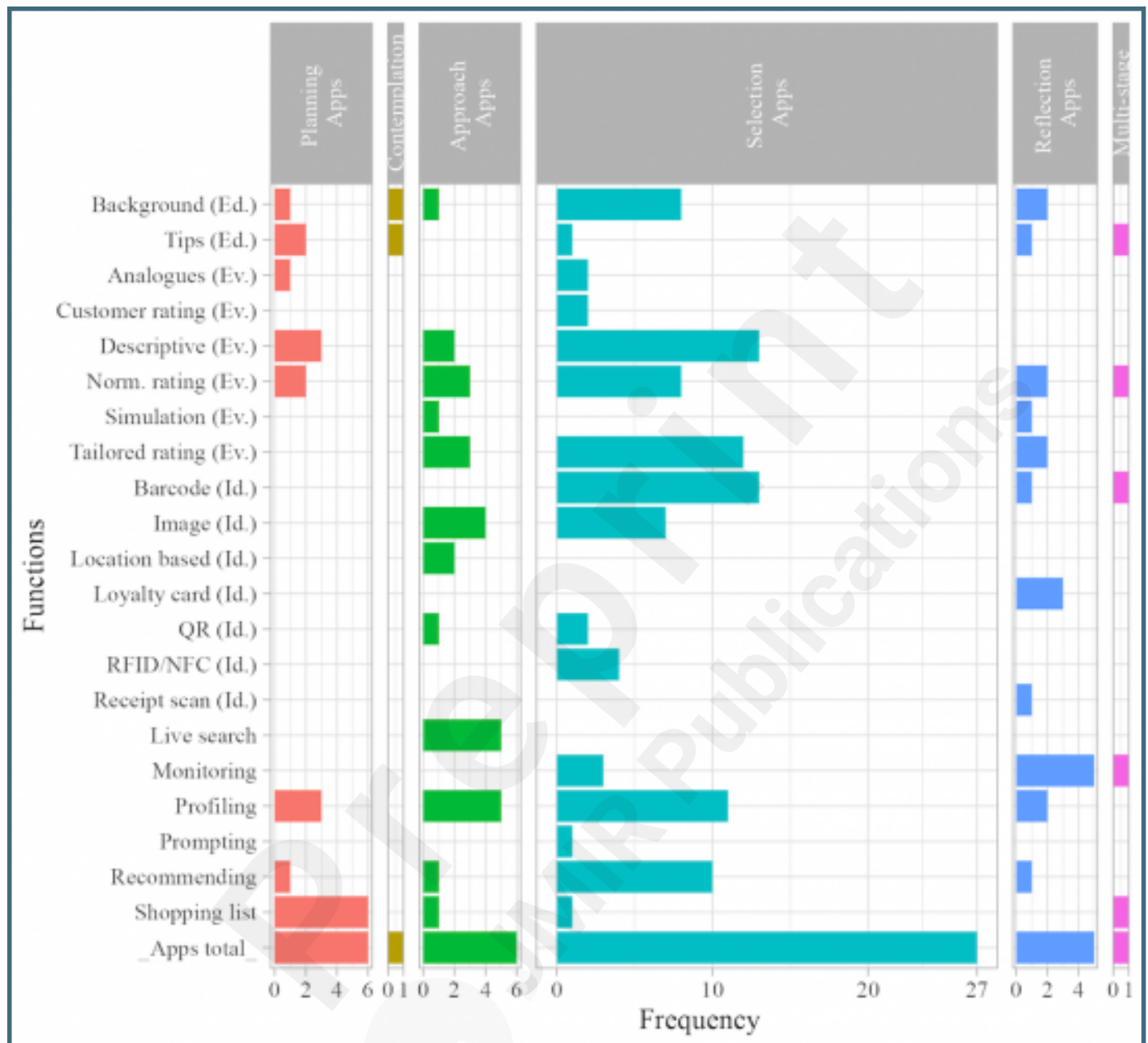
URL: <http://asset.jmir.pub/assets/b46eca5f426e1b357df20f3f51d25f4b.docx>

Figures

Results of articles search and screening.



Frequency of functions by AT. Separate panels for each AT are scaled to the total number of apps within the AT. An overview of function descriptions is provided in Multimedia Appendix 4.



Multimedia Appendixes

Completed PRISMA-ScR Checklist.

URL: <http://asset.jmir.pub/assets/c78394d486069f0070b87378b6101e9a.pdf>

Overview of included articles.

URL: <http://asset.jmir.pub/assets/62dfca4e0c1ccb6495ce74ad8d8f9d.docx>

Overview of apps.

URL: <http://asset.jmir.pub/assets/00d2b533546b11a739a552f365bbe9ac.xlsx>

Function descriptions.

URL: <http://asset.jmir.pub/assets/97ef37618200c631c3989cf89d29f6ef.docx>

Sankey diagram of app designs grouped by AT, PI, RD.

URL: <http://asset.jmir.pub/assets/4f83db49cf0cf5168438afe38e3ec00f.png>

Overview of evaluation studies by PI.

URL: <http://asset.jmir.pub/assets/ddb241e4ff0c830c19759c98b2fdcbcd.docx>