Digital Nudges within Recommendation Systems for Improving Eating Behavior towards Healthier Options: State of the Art

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Abstract. Digital nudges are subtle interventions designed to influence people's behavior in a non-intrusive way, through elements such as reminders, suggestions or strategic incentives. In the context of healthy food recommendation systems (FRS), these nudges are used to encourage more health-beneficial choices, such as highlighting foods that are low in calories, rich in nutrients, or with specific properties, highlighting their health benefits, and provide personalized Recommendations based on user preferences. This document presents the results of research based on the analysis of the state of the art, synthesizing the most relevant findings on digital nudges and recommendation systems in the field of healthy eating. The Systematic Literature Review (PRISMA-ScR) methodology was used, which made it possible to identify trends, challenges and opportunities in this area. Among the main conclusions, the importance of developing and implementing new healthy recommendation systems that combine the use of digital nudges with advanced artificial intelligence technologies stands out. This approach promises to personalize recommendations, improve user experience, and have a positive impact on promoting healthy eating habits. Furthermore, the need to adapt these tools to various cultural and social contexts to maximize their effectiveness is highlighted.

Keywords: Digital nudges, eating behavior, recommendation systems, artificial intelligence.

1 Introduction

Poor eating habits contribute to affecting our long-term health. If poor eating habits are established from a very young age, they can last into adulthood, which can increase the risk of developing non-communicable diseases such as obesity, diabetes, and hypertension [1]. The correct correlation between nutrients, foods and dietary patterns can be very relevant in terms of prevention of the diseases mentioned above [2].

The food choices made throughout life are mainly influenced by family, peers and social environment [3]. Typically, parents provide food to eat according to their

Table 1. A systematic review of the literature**.**

Research Questions	What are the most used techniques in health and nutrition recommendation systems? What Artificial Intelligence (AI) tools, methods and algorithms are useful in recommendation systems in the field of healthy eating? What are the types of pushing techniques that are most relevant in these domains?
Protocolo de búsqueda	
Search string	"Health recommendation systems", "Healthy eating recommender systems" or "Healthy food recommender systems through digital nudges".
Metadata Search	Title, Abstract, Keywords
Selecting Libraries	PubMed, Google Scholar, Scopus y ScienceDirect.
Criterios de selección	
Inclusion criteria	The work must have been published within the last 5 years. The work includes documentation on aspects related to health and nutrition recommendation systems. The article describes the characteristics and main AI techniques of health and nutrition recommendation systems. Describe aspects related to the outstanding techniques of digital push in healthy food recommendation systems. Presentations in English and Spanish. Articles, publications in conferences, theses and in indexed journals.
Exclusion Criteria	The work is not recent. The work is not related to the domain. Only the summary is displayed.

preferences and experiences, regardless of age, gender, socioeconomic status, country, etc. [4]. Despite this, studies show that eating behavior that is modified during childhood can promote health [1]. Currently, there is a large amount of information on the internet that can apparently be useful to improve eating habits, there are websites that provide information about the nutrients of food, shared diets, and the like; However, in many cases, this information is not usually adapted to the nutritional needs or preferences of the users.

There are software systems that specialize in this domain, such as recommendation systems (SRs) which, according to [5], are defined as software designed to interact with large volumes of information, but which only provide the elements that are relevant to the user. These SRs are used in many areas, such as health and nutrition. Modern SRs use algorithms and models from Artificial Intelligence and machine learning, among other techniques, to analyze ingredients, based on various factors such as dietary restrictions, ingredient compatibility, and user preferences [6], to provide them with much healthier suggestions and avoid long-term health problems.

Today's technologies are providing a new landscape that allows us to intervene in improving eating behavior and habits in support of classic recommender systems. Such as digital nudges, which are elements of the user interface that allow certain options to be established in digital environments to channel users' choices, without interfering with their freedom of choice [7]. In recent years, this novel technology has been reinforced as a strategy to promote the selection of healthier products [8], being used as a healthy choice strategy within food recommendation systems (FRS).

The main objective of this research is to synthesize the main findings about digital nudges and their use within SRs to improve eating behavior towards healthier options.
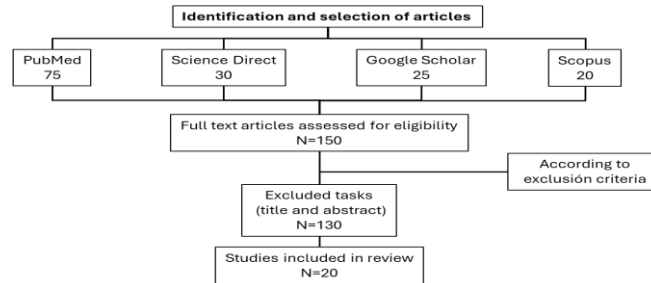
Fig. 1. Item Identification and selection.

Table 2. Search strings.

Research Question	ID	String
What are the most used techniques in health and nutrition recommendation systems?	1	HRS Tools
What Artificial Intelligence (AI) tools, methods and algorithms are useful in recommendation systems in the field of healthy eating?	2	AI tools, methods, and algorithms
What are the types of nudging techniques that are most relevant in the selected domain?	3	RS and digital nudges

Table 3. Classification of selected articles.

ID	PubMed	Science Direct	Google Scholar	Scopus
1	4	1	0	0
2	1	1	3	1
3	3	2	1	3

Likewise, the specific objectives are the three: 1) To select from the technical literature those associated with the central theme. 2) Apply inclusion and exclusion criteria according to the literature review methodology and systematic mapping based on the PRISMA-ScR protocol. [9], 3) To synthesize the findings, according to authors, reference, year of publication, contribution and techniques used.

2 Methodology

Following the PRISMA-ScR protocol, Preferred Reporting Items for Systematic Reviews of Meta-Analysis for Scoping Review (PRISMA-ScR), we developed our Systematic Literature Review, which allows mapping the existing literature related to the implementation of digital nudges and Intelligence tools. in the field of health, especially in recommendation systems focused on nutrition, as a strategy to improve

Table 4. Recommendation systems in the field of health and nutrition.

Authors	Contributions	Basic HRS Techniques
Abhar et. al, 2019. [10]	They conducted a systematic review based on PRISMA and found that hybrid and knowledge-based techniques are more widely used.	Hybrid and knowledge-based techniques.
Rya, Hyu-ho, Won-jin & Jae-dong,2019.[11]	They proposed an intelligent SR based on hybrid learning methods.	Hybrid models and machine learning.
Cai, Yu, Kumar Gladney &Mus-tafa. 2021. [12]	They focus on five aspects: The field of health, nutrition, recommended elements, recommendation technique and evaluation.	Knowledge-based approach.
Sun, Zhou, Ji,Pei and Wang, 2023. [13]	They provided 23 studies, where they reported that hybrid SRs are the most widely used in the healthcare field and the most used interfaces are usually mobile apps.	Collaborative filtering; Content-based filtering; Knowledge-based filtering; SR hybrids.
Year, Alzahrani, Martínez &Ro-dríguez 2023 [1]	A study on FRS for diabetic patients was presented within the framework of PRISMA 2020	Content-based recommendations; collaborative filtering, hybrid recommendation.

people's eating behavior, towards healthier options. This methodology consists of the following phases:

Phase 1. Planning the Review

In this phase, the title, abstract and keywords of various works related to the domain of this work were reviewed, within the main libraries selected (PubMed, Science Direct, Google Scholar and Scopus), as the most used databases currently.

Establish of research questions:

Because this work aims to find current evidence that digital nudges are useful in improving eating behavior towards healthier choices within SRs, the research questions are: 1) What are the most commonly used techniques in recommendation systems in the field of Health and Nutrition? 2) What Artificial Intelligence (AI) tools, methods and algorithms are useful in recommendation systems in the field of healthy eating? 3) What are the types of pushing techniques that are most relevant in these domains?

Protocol Review: Following the research questions of the previous phase, a search strategy was developed in the libraries, using the keywords: "Health recommendation systems", "Healthy eating recommendation systems", "Digital nudges", "Digital nudges in food recommending systems" or "Recommendation system with digital nudges". The search retrieved articles from 2018 to date.

Validation of the revised protocol: To validate the review protocol for each article, it was developed under certain selection and quality criteria. Articles were eligible to be included in this paper if: their publication was within the period range, their information was related to healthy food recommendation systems, their content has information related to digital nudges and artificial intelligence tools, they are in English or Spanish, and if their paper is complete and contains the abstract. On the other hand,

Table 5. AI algorithms and technological tools used in nutrition recommendation systems.

Authors	Contributions	Techniques & algorithms
Ganju, Tan, et al. & Menezes 2020. [2]	They created the Saathealth Android mobile app that provides low-income families in India with health and nutrition content, which evolves thanks to scalable predictive models like Random Forest.	Machine learning. Logistic Regression Methods, Decision Trees, Random Forest
Chava,Thoms& Isaacs, 2021[5]	They adopt the standard cross-industry process for data mining (CRISP-DM), to create a recommendation system.	Collaborative content-based filtering, hybrid recommendation model.
Yi-Ying, Su-cheng, Pal-anisamy, El-ham Abdul-wahab & Hairulnizam, 2023. [6]	They point out that FRS are generally classified into 4 types: the one of users' previous preferences, the one of nutritional needs based on their health conditions, the one that focuses on balancing nutritional needs and preferences, and the one that recommends foods for certain users or groups.	Collaborative filtering, AI techniques: Matrix factorization algorithm, classification machine learning algorithms.
Abhari et al.,2023 [3]	They created a healthy food recommendation system for Iran, implemented as a website and mobile app.	Content-based, collaborative filtering, knowledge-based, hybrid. & AI Techniques: K-means, rules-based ontologies
Chen, Guo, Fan, Dong & Dong, 2023 [4]	They performed a consistent health FRS, using knowledge graphs and multitasking learning in a convolutional neural network.	Score-based method, collaborative recipe knowledge graph using TransD. AI techniques: convolutional neural network
Forouzandeh, Rostami, Berahmand &Sheikhpour, 2024[5]	They developed an HFRS-DA framework, a healthy recipe SR with heterogeneous information networks that establish links between users and recipes based on shared ingredients and nutritional content.	AI Techniques: Graphic neural networks. Deep learning. Convolutional neural networks.

the exclusion criteria for each article were: the recommendation system was not related to human health, whether the recommendations did not contain AI technological tools or contained digital nudges. Table 1 shows a summary of the information obtained in phase 1 of this methodology.

Phase 2. Conducting the Review

For each article found, a review was carried out at the abstract level, the full text and the keywords and, following the proposed inclusion and exclusion criteria, all the selected citations, the documents that successfully met them were added to Mendeley Reference Manager. To this end, the following tasks were carried out:

Identification of sources: The largest possible number of primary studies related to the research questions were identified and it was verified that the documents were in the selected period, with good spelling, with all their bibliographic sources, that they were accessible on the web and that their hypotheses were relevant to the topic addressed. In this activity, around 150 documents were found.

Selection of primary studies: After reviewing all primary studies, those that met the inclusion and exclusion criteria described in phase.

Table 6. Digital nudges techniques in recommendation systems.

Authors	Contributions	Digital nudges techniques
Karlsen & Andersen, 2019 [6]	They compare the digital nudge with HRS models.	Personalized and transparent nudge.
Dolgopolova, Toscano & Roosen 2021 [7]	Results of an experiment to encourage young people to reduce calories in fast food orders are presented.	Ordering nudges.
Starke, Majjodi & Trattner, 2022 [8]	In their study, they found that placing nutrition labels in the shape of a traffic light, along with an explanation, helps users make healthier choices	Traffic light labels to support offline choice.
Majjodi, Starke & Trattner. 2022.[9]	They conducted a study with 6 different recommendation interfaces with personalized and non-personalized recipe tips and 3 labels: no label, multiple traffic light, and nutritional score. They reveal that the digital nudge reduces difficulty of choice.	Multiple pushes of traffic lights.
Yi, Kanetkar & Brauer, 2022 [10]	They designed and implemented 5 interventions to promote fruits and vegetables in university canteens implementing Digital Nudges.	Selection of Architecture Techniques.
Castiglia, et. al. 2023 [11]	They examine the influence of multimodal interactions on a conversational food recommendation system, obtaining as a result that the chatbot is more effective when accompanied by nutritional labels.	Forms of interaction: exact, multimodal (text and images), and multimodal complemented by nutritional labels.
Ytreberg, Alfnes and Oort. 2023 [12]	Based on the taxonomy of Münscher et al. (2016) and nudges, they propose three choice architecture techniques: Decision Information, Decision Structure, and Decision Assistance.	Options Architecture Techniques: Decision information, decision structure and assistance. The decision structure is the most used technique, as a promotion of products.
Mazzori, Starke, Elahi & Tratner, 2023 [`13]	They created an experiment for a SR Online Prescriptions	Cognitive Digital Nudges (Food Labels)
Chiam et al., 2024. [14]	They designed and implemented an AI-powered platform for digital algorithms and nudges, enabled by a graph neural network (GNN)-based recommendation and granular health behavior data from wearable fitness devices	Personalized pushes that adapt to the behavior and preferences of the participants. Gamification, Reminder and social influence.

Evaluation of the quality of the studies: The process of selection and evaluation of the works was carried out by a doctoral researcher, a doctoral student and us. We only assess the quality of the studies to identify in detail the inclusion and exclusion criteria and to be able to filter out the relevant documents for this work. Therefore, out of 150 documents found and reviewed, we are left with only 20. Figure 1 shows a diagram of the identification and selection carried out.

Data extraction and synthesis: Of 20 articles selected in the previous step, we classified them according to the topic they addressed in Table 2. Subsequently, they were categorized according to the library where they were found (see Table 3) to have details of which library contains the largest number of documents belonging to this work domain.

Phase 3. Document the Review

The most relevant findings in this literature review were in three tables: the first (Table 4) contains information related to SRs in the health and nutrition domain, the second (Table 5) contains information on the main artificial intelligence techniques, methods, and algorithms implemented in SRs, and the last (Table 6), it addresses everything related to the main digital nudging techniques used in FRS.

3 Summary of the Results

Recommendation systems use a variety of techniques to suggest products, services, or information that users are likely to be interested in. The main techniques implemented in these systems are collaborative filtering, content-based filtering, and hybrid models. In this regard, Table 4 shows an overview of these techniques used in recommendation systems in the field of health, where hybrid models are proving to be more useful as they take advantage of both explicit data (ratings, clicks) and implicit data (browsing history, time of use).

It is very important to know the algorithms, methods and technological tools of AI that are used in this field, as they allow us to understand the impact of the implementation of these technologies within recommendation systems and to be able to identify areas for improvement, evaluate the quality of recommendations, among other things. Table 5 shows an overview of the findings found on the AI techniques most used in the development of recommendation systems in the field of healthy eating.

According to the reviewer's work, the nearest neighbor technique (it's great for quick recommendations), matrix factorization (it handles large volumes of data and discovers patterns between user-item interactions), and neural networks (due to their ability to capture complexities and continuously learn to provide more accurate recommendations), are showing good results.

Knowing digital push techniques allows users to be supported in decision-making, evaluate possible biases and, in addition, improve recommendations, aligning them with health and well-being needs. Table 6 shows the most recent information on the types of common nudges used in the design of healthy FRS, with personalized options being much more effective as they significantly improve the effectiveness of the recommendation, adapting to the individual preferences of users, allowing them to

improve their experience since recommendations can be more intuitive and less intrusive.

4 Discussion

This review, which systematically identified and analyzed 20 articles published between 2018 and 2024, adds to the existing research literature on HRS in several ways. First, it provides an overview of the recent research landscape on the main techniques of personalized health recommendation in HR.

Second, compared to previous review studies on HRS, this study is more comprehensive and rigorous in terms of literature search, study selection, and analysis of key HRS constructs. We focused on looking for jobs that implement AI tools, and, above all, use digital nudges, since these allow guiding and motivating users towards much healthier choices, improving their experience and satisfaction when interacting with the User Interfaces, although their effects were short-term.

They have been studied and used by various authors, for example, by (15, 16, 17, 18,19), according to [20] the long-term effects of digital nudges are incredibly unknown, which is a major gap that needs to be addressed in future studies because there is no standardization of nudges yet, making it difficult to compare multiple studies.

5 Conclusions

Healthy FRSs are currently having a great boom, as they provide personalized and useful information according to the specific needs and preferences of users, the findings of this review are quite useful to show which Artificial Intelligence technologies are currently used to provide highly personalized and accurate recommendations, considering the nutritional needs of people and the dietary restrictions. Highlighting convolutional neural networks, graphic neural networks and Machine Learning techniques.

Digital nudges, on the other hand, play a very important role, as they can remind users of the importance of choosing nutritious options, encourage moderation in the consumption of unhealthy foods and serve as tools to re-educate the population and improve their quality of life.

Among the main findings, it was found that one of the most widely used digital nudge techniques in recommendation systems in the nutrition domain is the Decision Structure Technique, where cognitive and personalized digital nudges are very useful, and that multiple traffic light tags have been shown to be effective in supporting offline choices.

Today, digital nudges can be found in a variety of recommendation systems, to offer relevant and timely suggestions. This research will support software developers to design healthy FRS to improve the user experience, personalizing content to their specific needs, and thus contribute to the improvement of eating habits.

The key is to use a combination of visual, informational, and motivational techniques to make healthy choices more appealing and accessible. By doing so, these systems can help promote better eating habits and improve the overall health of users.

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