Persuasive Design for Healthy Eating: A Scoping Review

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Abstract. In this scoping review, we aimed to summarize and analyze the latest research developments of persuasive design for healthy eating behavior and explore future design opportunities. This paper initially collected 1231 papers from 2011 to 2021 in three different databases: the Association for Computing Machinery (ACM) digital library, IEEE Xplore and SpringerLink databases. Based on a selection process, 28 papers that mainly focused on addressing dietary health by persuasive designs were eventually included in final analysis. These 28 papers were sorted by three characteristics: research specifications, methodologies, and design rationales. Our data analyses revealed that the reviewed papers primarily utilized persuasive technologies for eating behaviors monitoring, recording, and healthy eating suggestion. Moreover, six types of design applications were commonly implemented, including mobile applications, persuasive messages, digital products and service systems, wearable devices, chatbots/assistants, and public devices. Our review showed that persuasive design, as a generic approach for promoting healthy eating, lacked research investigations on personalized solutions for particular user groups such as office workers and teenagers. Future works could explore persuasive design strategies by applying the research factors of user experience and examining the efficacy of persuasive technology tools to effectively promote healthy eating behaviors for various user groups in different contexts.

Keywords: Persuasive design · Healthy eating · Health-promoting technology · Review

1 Introduction

According to Fogg [1], persuasive technology can be regarded as an interactive system that achieves the goal of changing people's behavior and attitudes based on the principles of psychological theories and computing engineering. It is also known as "behavior design", which refers to shaping user behaviors through persuasion and social influence in design, rather than through coercive methods [33]. Persuasive technology was deemed as a beneficial approach to solve health problems, while the rapid development of ICTs made it widely applied in various fields [2].

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Given the fact that persuasion is meant to change people's behavior, it is widely used to achieve public goals and support self-management, such as improving people's awareness of sustainability, lowering the risk of developing chronic diseases, and enhancing work efficiency [32]. In this light, persuasive design has been increasingly developed to encourage behavior changes on a wide range of human vitality, including physical activity [10, 11, 34], oral health [35], mental health [36, 37], and diet [3–31], etc.

In this paper, we reviewed recent design research that employed persuasive technologies to solve eating problems or promote healthy eating behaviors. The scoping review summarized research from 2011 to 2021 on persuasive design for the purpose of healthy eating. Rather than focusing on the outcomes of designs and technologies, this review aims to provide an overview of the design considerations for healthy eating and the development processes of these design proposals. Based on this scoping review, we hope to discover the research gap in the persuasive design for promoting healthy eating and identify design opportunities accordingly. In particular, our research questions are threefold:

- How have persuasive designs been applied to the research domain of healthy eating?
- How have persuasive strategies been employed to intervene users' behaviors related to diets?
- What are the design opportunities of future health-promoting tools that can support healthy eating practices?

2 Methods

2.1 Search and Selection

The scoping review was conducted according to the following procedure: 1) identifying research questions, 2) searching for related papers, 3) selecting papers, 4) drawing data charts, 5) sorting, summarizing and reporting results. The full papers published in related conferences and journals were searched mainly in two databases, namely Association for Computing Machinery (ACM) Digital Library. In addition, IEEE Xplore and SpringerLink databases were used as supplementary sources. Based on our research questions, the search keywords were identified as: health* AND (eat* OR diet) AND (persuade OR persuasive OR persuasion) AND design. The publication date of the article is limited to the period from 2010 to 2021.

After receiving 1231 papers based on our searching criteria, we screened those papers with the following steps. To start, we excluded copies of the same research papers and experimental studies derived from the same study in different groups or cultural contexts, based on the title and abstract of the searched papers. 773 related papers were obtained for the next step of paper screening. Then, we reviewed the full text of the papers due to the following criteria for the final paper selection:

- Objective: Healthy eating must be the main application objective. We excluded articles that target health management purposes such as exercise, sleep and rest, or research on diet as an influencing factor on emotions and well-being of special groups.

- Theoretical grounds: We excluded papers that did not apply persuasion design theory, or persuasion techniques were only applied to study economics behavior and other related literature.
- Methods: Articles that did not conduct empirical studies and did not design and develop technical solutions were excluded.

After the screening process as described above, a total of 28 papers were finally selected for this scoping review.

2.2 Paper Coding

The selected papers were focusing on user studies and technology evaluations, the 28 selected papers were coded (shown in Table 1), sorted by three types of characters: research specifications, methodologies, and design practice.

Table 1. Paper coding

Primary	Secondary	Coding status
Research specifications	Target user	People with health problems such as alcoholism; older people, children, office workers, younger people such as diabetics and university students, without differentiating between user types
	Intervention area	Promotion of healthy eating choices and nutritional mix, control of snacking and emotional eating, aid in diet monitoring and recording, aid in the eating process, management of other health indicators in an integrated manner
Methodologies		User-centered approach, theory-based approach, context-driven approach, technology-driven approach
Design rationales	Type of application	Mobile applications, information, smart products and complex product systems, wearable devices, chatbots or virtual assistants
	Design evaluation	Qualitative, quantitative, mixed method

3 Results

3.1 Research Specifications

In order to examine the specific application objectives of the persuasive design in the selected papers, the application objectives were divided into two dimensions: 1) the

Table 2. Target users in the included technologies and designs

Target users	Included papers
Patients	[3–7, 16]
Older adults	[17, 18]
Children	[10–13, 15, 16]
Office workers	[19, 22]
Teenagers	[23]
No specification of users	[8, 9, 19–21, 24–28]

target user, and the branch of the healthy eating problem in which they are located, and the distribution of the study objectives are shown in Tables 2 and Table 3.

Target Users. *Patients.* As shown in Table 2, healthy diet management for patients with diabetes and obesity is an important application research field of persuasive design. Using persuasive designs can help patients with the process of self-regulation [3–7, 16], reduce the burden on processing information [3, 5, 7], improve the efficiency of dietary supervision [3, 4, 6], and increase their motivation for healthy living [3–7, 16]. For example, strategies such as transforming weight management goals into game challenges [3–5, 16] can encourage users with diabetes mellitus to learn nutritional knowledge and make healthy diet choices. Smart technologies with self-monitoring mechanisms [4, 6] can automatically track the diet status of users with metabolic syndrome (i.e., eating speed, food ratio control, and calorie and sodium intake management), and can do the same for people with emotional eating problems. Additionally, metaphoric designs [5] could help patients with difficulties in processing information easily understand the relevant information.

Older Adults. Persuasive design has been applied to support healthy eating for older adults in several recent research projects [17, 18]. The benefits of persuasive design could be helping the older adults know the nutrients of their body needs in time and to offering suitable dietary guidance for them. For example, the elderly could use the tablet application of persuasive communication [17] and the smart foodbox [18] to record dietary intake, get reminders and suggestions of protein intake and prevent malnutrition.

Children. Persuasive design has been widely used to form children's healthy eating habits and prevent childhood obesity symptoms. For children, persuasive design could teach them healthy eating knowledge, motivate them to change their behaviors and develop healthy habits. For example, a mobile game called MACO [11] was designed to educate children to eat healthy foods and engage in physical exercises. The designed verbal and bodily features of the social robots [12] could motivate children to increase vitamin intake. A gamified chatbot was developed [13] to help children obtain personalized healthy eating recommendations. There are also tools designed as aids to parents in educating children, such as the digital enhanced food [14] and the smart tableware products [15], which could encourage children to eat healthy food in a joyful eating process.

Office Workers. There have been office-based health management systems using wearable devices and mobile applications. Such systems were created for diet tracking and promoting exercise in the workplace scenarios [22].

Teenagers. For teenagers, a persuasive toolkit [23] composed by an awareness video and a text messaging campaign could prompt healthy food choices, through elevating awareness about the importance of proper dieting during adolescence.

Table 3. Intervention areas of the paper included in the analysis

Intervention areas	Included papers
Healthy food choices and nutritional combinations	[4, 5, 11, 12, 13, 14, 18, 23, 24, 25, 27, 28, 30]
Snacking and emotional eating	[6–9]
Diet supervision and documentation	[3, 10, 18–23]
Eating process	[4, 14, 29, 30]

Intervention Areas. *Healthy Food Choices and Nutritional Combinations.* As shown in Table 3, persuasive design has been widely used for a healthy food choice of nutritional eating in different settings. For example, an information system was designed to enable reflection about nutrition by showing the collective food consumption patterns of a family [28]. Similarly, a personalized shopping assistant could provide guidance to users on healthy food product purchases [26]. A gamified online shopping service could promote the reflection on nutritional choices [25]. It has been explored the embodiment of music in the food information interfaces could influence users' meal choices for health promotion [29]. There are also controls for the intake of a specific nutritional element. For instance, *Nutritionavatar* [27] is an intention for low-sodium dieting, which was designed to supporting people gain awareness of high blood pressure risk.

Snacking and Emotional Eating. For emotional eating issues, persuasive design aims to intervene users' behavior with a light burden. For example, through a just-in-time intervention system with playful notifications and visual reports, users were encouraged to moderate emotions and control themselves to avoid unhealthy eating conditions [6]. For excessive drinking, [7] investigated an empathic virtual agent that can send messages with emoticons to improve the interventional efficiency. To address unhealthy snacking, [8] has provided empirical evidence that tailored persuasive text messages may have effects on influencing users to reduce snacking. Additionally, heuristic information design has been proved to be effective in prompting users to choose lower-calorie healthy snacks [9].

Diet Supervision and Documentation. To support diet managements, design studies have increasingly employed persuasive strategies in recent years. For example, a sensor network [10] has been designed and implemented to automatically detect eating and

exercise of obese children under clinical treatment. In collective settings, through sharing eating records with each other in a social network [19–21], users were motivated to achieve healthy eating goals with this type of social support.

Eating Process. Among papers published in recent years, several persuasive designs for optimizing the eating process have been proposed to support eating speed and food portion control. For instance, *Foodworks* [14] was designed to digitally augment a plate of food and provide rewards upon the completion of a meal, encouraging children to eat vegetables. *Eat2pic* [30] uses a pair of chopsticks with sensor modules to collect food data for generating visual pictures during eating process to motivate users to slow their eating pace down for a balanced diet. Similarly, *Eco-meal* [4] based on a smart tray and a smartphone application was designed for eating speed and food portion control, as well as managing calorie/sodium intakes.

3.2 Methodologies

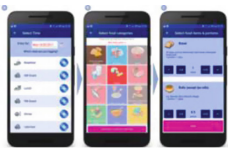
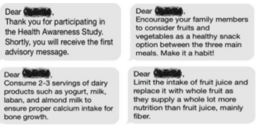
According to the description of characteristics, 28 included papers adopted 4 different design approaches, namely *user-centered approach*, *theory-based approach*, *context-driven approach*, and *technology-driven approach* (see Table 4).

Table 4. Design approaches mentioned in the included papers

Approches	Included papers
User-centered approach	[3–7, 9–18, 20–23, 26, 27]
Theory-based approach	[7, 8, 10, 22, 25–27, 29, 30]
Context-driven approach	[3, 8, 19, 20, 24]
Technology-driven approach	[4, 8, 10, 14, 20, 28, 30]

On the one hand, twenty-one included papers used a user-centered approach. Specifically, six papers [4, 6, 10, 13, 14, 20] combined with a technology-driven approach to make intervention of food choice and eating process in specific groups such as children with obesity problem and people with emotional eating problems. Six papers [7, 8, 10, 13, 22, 26] combined with theory-based approach during the whole process, which focus on the result of related framework experiment. For example, [7] used a virtual counselor to deliver Brief Motivational Interventions for behavior change for avoiding excessive drinking. Other papers [5, 9, 12, 15, 17, 18, 21, 23] developed mobile software and multimedia such as game and video based on the user-centered approach to achieve behavior change.

Table 5. Distribution of papers for different design types

Types	Included papers	Picture examples
Digital apps	[3, 5, 6, 11, 16, 21, 22, 24, 25, 26, 27]	 Food record and avatar intervention UI [27]
Social media	[8, 9, 23]	 Text messages [23]
Smart products service systems	[4, 14, 15, 18, 28, 30]	 prototype design [15]  EcoMeal prototype [4]
Wearable devices	[6, 10]	 Sensor placement outline [6]
Conversational agents	[7, 12, 13]	 paper sheet for children [12]  The CiboPoli Conversational UI [13]

(*continued*)

Table 5. (*continued*)

Types	Included papers	Picture examples
Public services	[19, 20, 29]	 [29]  [19]

On the other hand, for the rest eight included papers, four papers [8, 25, 29, 30] adopted theoretical models to guide to present related application example and testing which mainly used a theory-based approach. Three included papers [8, 28, 30] take the technology-driven approach to increase the effects of persuasive technologies. Five included papers [3, 8, 19, 20, 24] applied the context-driven approach that focuses on e.g., daily mealtime [19] and snacking [8], etc.

3.3 Design Rationale

Type of Application. As shown in Table 5, the included persuasive designs of all the reviewed papers could be classified into six different types of applications, including digital apps, social media, smart product service systems, wearable devices, conversational agents, and public services. Specifically, the majority of persuasive designs were mobile apps that designed to change users' attitudes and behaviors via data visualizations and motivational elements. For example, gamification of shopping platform was designed in [25] to influence food choice. Additionally, several studies combined smart products and wearable devices with mobile apps for promoting healthy eating behaviors [4, 14, 15, 18, 28, 30]. e.g., *Healthy Cradle* [15] realizes a smart tableware with an associated mobile app to improve the experience of the eating process.

Design Evaluation. As shown in Table 6, eight included papers present qualitative results as the design evaluation and nine had quantitative data analysis from the user survey or data from the persuasive design application. Six included papers applied mixed method to show both quantitative and qualitative results to verify their designs. Nevertheless, studies from two papers did not evaluate their design outcomes.

Table 6. Design evaluations mentioned in the included papers

Approches	Included papers
Qualitative	[3–5, 11, 21, 23, 25, 28]
Quantitative	[6, 8–10, 12, 16, 17, 24, 26]
Mixed method	[7, 13, 18, 19, 22, 27]
Not evaluated	[29, 30]

4 Discussion and Conclusions

This scoping review is set out to summarize and analyze the latest research developments of persuasive design for healthy eating behavior promotion. Through a literature search from three databases across a span of ten years, we selected and analyzed 28 selected papers published between 2011 and 2021. This scoping review provided a holistic view of paper characteristics, including their research specifications, methodologies, type of design applications and evaluations. The narrative analysis revealed the following two gaps in current research direction.

Firstly, we found that persuasive design, as a generic approach for promoting healthy eating, lacked personalized applications for specific user type and focused scenes. Personalization is of great importance in intervening unhealthy behaviors, especially on the food choices and nutritional combinations. Only recording personal eating patterns and exercise data can lead to improved nutrition and diet recommendations. E.g., Nutritionavatar [27] is a future-self avatar-based sodium reduction intervention; Lubbe et al. [18] have a proposal of personalized suggestions for older adults based on their protein intake. In addition, for snacking and emotional eating, detection of related data (i.e., emotion curve, snack time) could help reflections and self-management in a personalized way. Moreover, technologies (i.e., wearable sensors, chatbots, smart tableware) play an essential role in personalized persuasion. Thus, it is crucial to utilize user experience design that incorporates a variety of design approaches like user-centered design and data-driven innovation.

Secondly, from our review we learned that the major user groups in persuasive designs for healthy eating are patients and children. In contrast, relatively few studies were designed for teenagers (1/28), office workers (2/28), and older adults (2/28). However, it has been increasingly suggested to investigate technologies for encouraging these different user groups to reduce their unhealthy diet. As revealed by [17, 22, 23], healthy eating promotion is essential to address the increase of suboptimal health problems among vulnerable people like teenagers, older adults, and workers with heavy mental workload. Therefore, design researchers of future design studies could dedicate efforts to persuasive designs of healthy eating promotion for special user groups such as teenagers, office workers, and older adults.

In addition, most of the selected papers have created complete designs to promote healthy eating but did not pay attention to their feasibility to be easily adopted in the real-life setup. There is a growing tendency of persuasive design in avoiding complexity to incentivize users through easy tasks. As a support for this principle, Reinhardt et al.

[9] proved that simple heuristic information design is effective in prompting users to choose lower-calorie healthy snacks.

Based on this scoping review, we suggest future studies to explore the user experience factors for categorizing user according to the application contexts to achieve the personalized persuasion. Meanwhile, future work should also focus on simple forms of persuasive design application to promote healthy eating behavior in different contexts by expanding research on factors affecting user experience, experimenting with new technologies and materials, exploring innovative solutions to specific problems.

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