Food Literacy while Shopping: Motivating Informed Food Purchasing Behaviour with a Situated Gameful App

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ABSTRACT
Establishing healthy eating patterns early in life is critical and has implications for lifelong health. Situated interventions are a promising approach to improve eating patterns. However, HCI research has emphasized calorie control and weight loss, potentially leading consumers to prioritize caloric intake over healthy eating patterns. To support healthy eating more holistically, we designed a gameful app called *Pirate Bri's Grocery Adventure* (PBGA) that seeks to improve food literacy—meaning the interconnected combination of food-related knowledge, skills, and behaviours that empower an individual to make informed food choices—through a situated approach to grocery shopping. Findings from our three-week field study revealed that PBGA was effective for improving players' nutrition knowledge and motivation for healthier food choices and reducing their impulse purchases. Our findings highlight that nutrition apps should promote planning and shopping based on balance, variety, and moderation.

Author Keywords
food literacy; situated app; gameful design; grocery shopping

CCS Concepts
•Human-centered computing → User studies; Field studies;

INTRODUCTION
Developing the knowledge and motivation for healthy eating early in life remains a challenge. While eating patterns tend to form before and during young adulthood, individuals may have little opportunity to develop their food literacy until they

Figure 1. In *Pirate Bri's Grocery Adventure*, players scan products while grocery shopping to visualize nutrition information, engage with weekly food challenges, and make more informed shopping decisions.

begin to live independently [13, 17]. As a consequence, sub-optimal eating patterns may persist into later life, affecting long-term health [2, 11, 14, 38, 64]. In addition, the ease of access to ultra-processed and ready-to-eat foods provides a challenge to anyone wanting to practice food literacy, which requires time, effort, skills, and confidence to select and prepare healthy meals [13, 17]. This is specifically the case for young adults transitioning into independent living situations where they often have budgetary and time constraints. Food literacy, defined as the interconnected combination of food-related knowledge, skills, and behaviours that empower an individual to make informed food choices [15, 61], may hold the key to changing people's eating patterns.

Mobile technology has great potential for supporting interventions that encourage healthy eating. However, existing mobile applications like Weight Watchers, MyFitnessPal, and FitBit have limitations in how they foster healthy eating patterns. First, they tend to focus on weight loss and calorie control [26, 27, 34, 58], which emphasizes quantity instead of quality, leads consumers to optimize caloric intake over a nutritious diet [62], and is associated with negative body image [47] and eating disorders [20], especially among youth [47]. Indeed, evidence on diet and health increasingly points to the importance of overall diet quality [21]; illustrated by recent food-based guidelines such as Canada's Food Guide [9]. Second, these mobile apps are designed to track consumed foods, instead of supporting planning and/or selecting foods at the grocery store [4], and thus fail to prevent impulse purchases [57]. Finally, approximately half the people who start using self-tracking apps stop using them because of loss of interest and a high data-entry burden [32]. Studies suggest that many young adults do not feel they have the time to participate in food interventions such as nutrition education classes [13, 59].

To address the food literacy gap among young adults, we designed and studied the use of a gameful situated mobile app to promote informed food purchasing (Figure 1). Situated interventions are applied at the moment a behaviour occurs, such as when purchasing foods. Mobile technology is an ideal fit for this situation. Our approach has three main advantages: 1) we designed our custom app with a focus on promoting healthy eating patterns through food literacy instead of calorie control for weight loss, 2) the app can be used while grocery shopping, reducing the time and effort required to participate, and explicitly linking the information and activities to the target behaviour of food purchasing, and 3) using gameful design elements motivates healthy behaviours effectively (e.g., [18, 30, 41]). Our gameful app, *Pirate Bri's Grocery Adventure (PBGA)*, incorporates gameful design elements, such as *challenges*, *personalization*, and *meaningful choices* to motivate young adults to develop food literacy and increase awareness and improve choices at the grocery store.

To investigate the effectiveness of our gameful situated app (PBGA) to promote food literacy in young adults, we conducted a three-week exploratory field study with PBGA compared to an existing nutrition planning app (My Food Guide [8]). Our results suggest that while both apps increased participants' general nutrition knowledge and attitude towards healthy eating, those who played PBGA made fewer impulse purchases. Our findings contribute four important insights: (1) the importance of promoting healthy eating patterns in an app's design, (2) the effectiveness of situated interventions which can help individuals better understand the nutrition information on product labels, (3) how interventions relate to people's needs when they shop, and (4) the strength of gameful design in motivating healthy food purchases.

RELATED WORK

A problematic feature of popular mobile applications like MyFitnessPal and FitBit is that they focus on calorie control rather than promoting a nutritious diet [26]. This focus can lead to poor nutritional choices and consumers prioritizing caloric intake instead of a healthy diet [62]. It can also have negative effects on people with eating disorder behaviours [20] or a negative body image, especially among young adults [47].

These interventions also fall short because they concentrate on logging meals after consumption instead of promoting healthier food choices through planning days in advance [57]. Choices made at the grocery store have a direct and crucial impact on those made at home—you cannot eat those potato chips if they never come home from the store. Further, a recent survey by Rahman et al. [49] shows the general public's interest in food planning apps. Although having a plan before going shopping can help consumers avoid impulse purchases [4], grocery stores have their layouts designed to influence consumers' decisions and stimulate impulse purchases [19]. Thus, situated interventions are needed to counteract the negative influences of retail food environments.

Food Literacy

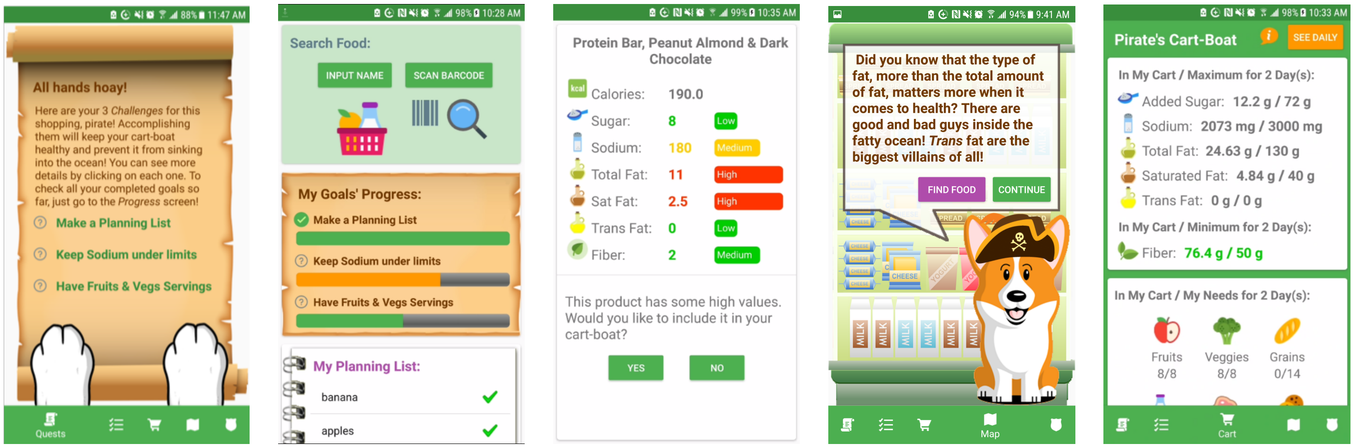
In response to these limitations, the nutrition community has called for technologies that promote *Food Literacy* instead of short-term weight loss and calorie control [26]. Food Literacy [48] comprises the knowledge and awareness of foods within the different food groups; of nutrients and their relevance to our health and wellbeing; the ability or self-efficacy to choose healthy foods; and the desire or motivation to engage with food to achieve a nutritious diet. Food Literacy skills have been shown to enable individuals to make informed food choices and facilitate healthier dietary behaviours [15, 60, 61].

A lack of time to participate in educational classes [13, 16, 59] and the effort required to understand nutritional labels on packages [7] are common barriers to motivating young adults to develop their Food Literacy. Human-Computer Interaction (HCI) research has explored different technologies to help consumers overcome these barriers, like Augmented Reality to reduce the time required to find healthy items [1], scanning devices to quickly identify suitable items for a specific diet (e.g., [36]), interactive displays to calculate serving sizes and compare products (e.g., [3]), and games played in store to promote healthy snack choices (e.g., [44]). These approaches lower barriers to healthy eating through automation of tasks that require time and effort at the grocery store, but fall short of developing Food Literacy, and the knowledge and motivation to continue healthy eating behaviours for the long-term.

In this work, we approach Food Literacy through Sizer et al.'s [55] key factors of a nutritious diet: consuming a *balance* of foods from all four food groups (Fruits & Vegetables, Grains, Milk & Alternatives, Meat & Alternatives); consuming a *variety* of different foods from within each group; and *moderating* consumption of foods to sustain your body—while not exceeding recommended amounts of nutrients like sugar, fat, and sodium. To address these limitations, we investigated how mobile devices can help develop the knowledge, awareness, and motivation young adults require to make informed food decisions when grocery shopping. We were particularly interested in the opportunity to explore situated and gameful design to promote internal motivation and self-efficacy.

Gameful Situated Design for Nutrition

Gameful design has been shown to be an effective way to change overall health attitudes or behaviours (e.g., [18,30,41]), particularly when applied in the field of nutrition [29]. For instance, gameful design elements such as progress feedback and incremental challenges have helped people achieve their health goals [29]. Games are a potentially effective way to motivate young adults to improve their Food Literacy because this population represents the biggest portion of video game players (40%) [56].



(a) (b) (c) (d) (e)

Figure 2. (a) Brigitte, the Pirate Dog Nutritionist, presents the 3 Food Literacy *challenges* to be completed in the current shopping trip. (b) As players put food in their cart, they visualize the *progress feedback* towards each goal (challenge). (c) Players can make meaningful choices of which products to buy, by visualizing each item's nutrients using colours that highlight low, moderate, or high amount. (d) As players enter each section, they *learn* from Brigitte about the types of food they will encounter there. (e) Pirate's Cart-Boat shows a summary of *personalized* nutrients and servings for each food group in the cart versus how much is needed for the total trip.

The use of simulation, where players develop food knowledge and self-efficacy without real-life consequences, has been found to be a promising approach to gameful design by the research community. Games that simulate real-world decisions have been found to increase players' nutrition knowledge and/or self-efficacy (e.g., [24,33,41,42,46]). However, simulations also have drawbacks. For instance, Silk et al. [54] found that participants preferred and acquired more knowledge from an educational website instead of their game. Further, simulations do not account for many factors that impact real-life food choices, such as taste, availability, affordability, level of hunger, or cravings. That is, one might know the healthier food choice when shopping, but decide to buy an alternative based on impulse, availability, affordability, or emotional factors (e.g. selecting "comfort foods").

To address this shortcoming, researchers have begun to explore how integrating virtual worlds with real life can help players take these factors into account when selecting foods. For example, SpaPlay [53] differs from the previous games by integrating a simulated resort with real-life activities (e.g., eating a salad, taking the stairs) that need to be developed and maintained to make players progress in the game. Shiyko et al. found that players experienced an increase in nutrition knowledge and decrease in Body-Mass Index (BMI) after three months. However, the game focused on weight loss rather than Food Literacy, and lacked a control group to determine whether the outcomes were caused by the game or selecting a population already committed to weight loss. We address these limitations in our work.

Based on the potential of simulations, but a lack of research that examines their use in real-life, we explore how gameful design can be used to promote food literate purchasing behaviour while shopping. Situated interventions are an effective way to promote healthy behaviour [43], also overcoming the challenge of lack of time because they can be incorporated in daily routines. We developed our app, PBGA, from the perspective of meaningful gamification [37,50], which posits that gameful design should add game elements with meaning and purpose, that educate the player, help them understand their actions, and internalize content. The gameful app combines elements from the above research, is played at the store, and was developed with a focus on Food Literacy.

PIRATE BRI'S GROCERY ADVENTURE

We developed a gameful app to be played at home and in the grocery store over a series of shopping trips to help players learn, internalize, and maintain healthy shopping behaviour [37]. We designed the gameful app to be played over a three week period for three different shopping trips. This design applies the concept of slow technology [25], by giving players time to reflect upon new content, apply the knowledge, and to discover the consequences of their actions.

Our gameful app was developed using Android Studio, and is compatible with Android versions 4.0 or above. We now provide a walkthrough, with a particular focus on how its design supports the development of Food Literacy. An in-depth description of the gameful app and its development is provided by Bomfim and Wallace [5].

Planning for Shopping

When starting PBGA for the first time, players create a character based on their personal information (i.e. gender and age), to assess their nutritional needs [10], and food preferences (e.g., salty or sweet). After creating their character, the player is introduced to Brigitte the Pirate Nutritionist (Figure 2, a), who serves as a guide for the remainder of the gameful app. Brigitte then asks how many days they will be buying groceries for, and encourages the player to plan and create a grocery list before going to the store. Creating a grocery list has been shown to be the most effective means of minimizing waste and maintaining a budget [9]. Maintaining a budget is particularly important, as financial constraints are common among post-secondary students [39].

To develop a player's sense of competence and progress over the three week period, Brigitte then presents players with three challenges (goals) per shopping trip, with increasing difficulty each week (Figure 2, b). For instance, a player with a preference for sweet foods would be challenged to choose products with less sugar [28], whereas one with a preference for salty food would be challenged to keep their sodium intake within daily recommended limits [65].

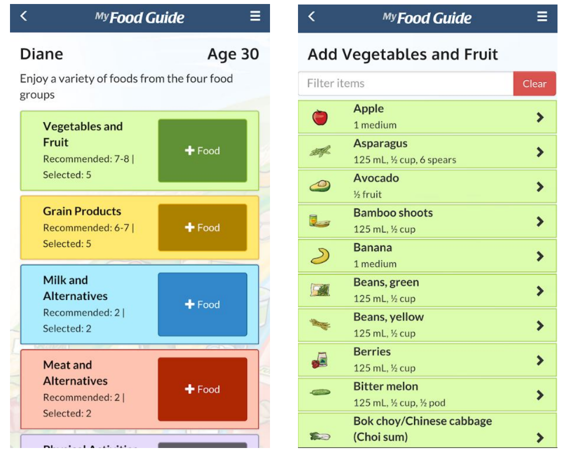
At the Grocery Store

After creating a grocery list, players head to the store for the next phase (It's time to go shopping!). While in the store, players navigate using a map that shows a top-down view of a common supermarket layout. The player then manually chooses the sections they want to go to, depending on their shopping list. When the player enters each section, Brigitte presents an important tip related to the types of foods found there (Figure 2, d). For instance, when entering the bread section, she explains the importance of selecting whole wheat options and dietary fibre. When entering the centre aisles, she explains common issues with ultra-processed foods, such as misconceptions about the nutritional value of fruit juice.

As the player selects foods from the grocery store shelf, they have two options to add it to their virtual shopping cart: scan the barcode, or manually input the product's name, as not all products have barcodes. This screen also shows the player's progress towards each of their current challenges, so they can keep track of their progress (Figure 2, b). After finding a specific product, the app visualizes the product's nutrients using traffic light colours, which highlights whether each nutrient is in low, moderate or high amounts (Figure 2, c). If the product has fibre, the bar is always green, but the length of the line changes to reflect high/med/low levels. This visual information helps the player reflect on the implications of adding a product to their cart, particularly within the context of their current challenges. This feature offers the player the opportunity to learn about the products and think about their decisions, developing their own understanding of what is healthy [23].

As products are added to the player's cart, they must also select the number of servings of the product to its food group to encourage players to select products that will fulfill the distribution of a balanced diet. For instance, it is possible to visualize how many servings of fruits and vegetables the player should aim to meet a healthy intake for the next days. After each item is added to the cart, a summary screen (Figure 2, e) helps players learn about their daily needs. That is, if the player is shopping for 5 days of groceries, and 2 servings of meat and alternatives per day are recommended to the player, their cart requires 10 servings for this food group. The player can also switch to this view for a single day, to aid with comparisons for a specific product.

We intentionally do not include the recommended number of calories, because they can be a poor predictor of healthy foods [62]. Instead, we encourage the consumption of more fibres, fruits, and vegetables and the careful monitoring of nutrients such as added sugar, sodium and trans fat. As the user adds products while shopping, the app helps to visualize how much of each nutrient and servings of each food group is in the cart and how much is still needed (or exceeded).



(a) (b)

Figure 3. My Food Guide: (a) Shopping list is separated into food groups. (b) As shoppers add food items, a list of foods under the chosen food group is displayed for selection.

Checking Out

Finally, when a player checks out of the grocery store, Brigitte presents a summary of completed and uncompleted challenges, and gives the player an opportunity to reflect on their goals and return to the aisles to complete a challenge. For example, if they did not meet the required servings of fruits and vegetables, they can return to this section to buy more produce before checking out. If a player completed all three challenges, they are rewarded by unlocking a new member of their crew. Each crew member was a different type of animal, serving as an acheivement/goal and as an incentive to foster their curiosity for the next shopping trip.

EXPLORATORY FIELD STUDY

Having designed PBGA to promote Food Literacy, we sought to understand the strengths and weaknesses of its design through an empirical study. In particular, we wanted to understand how it promotes skills like food planning and selection, provides nutrition knowledge, and motivates healthy eating behaviour. To answer these questions, we conducted an exploratory field study in which participants used either PBGA or a commercially-available, non-gameful nutrition app over a 3-week period. The 3-week study period provided participants an opportunity to use their assigned app during multiple shopping trips to their preferred grocery store, and is consistent with other recent studies of technologies to support healthy behaviour promotion (e.g. [24, 42]).

We compared PBGA to a non-situated, non-gameful nutrition app called My Food Guide (MFG) (Figure 3), which was developed by Public Health Canada, endorsed by Registered Dietitians, and is available for free on the Google Play Store. We considered comparisons to other popular commercial mobile apps, such as MyFitnessPal, but our review found that they primarily focus on calories and are designed to input foods by meals, serving as food diaries of consumed foods.

Instead, MFG was designed to create food plans based on food groups instead of meals, that can serve as guides for grocery shopping. Thus, the MFG app targets much of the same Food Literacy content as PBGA, without placing an emphasis on situated learning [8]. MFG organizes food plans along the four food groups, and users add foods to a grocery list using a comprehensive set of suggested items (Figure 3). For the purpose of this study, each food plan was created as a grocery list, serving as a reference for a shopping trip.

Participants and Recruitment

We recruited 24 Participants (M=11; F=13) from a local university, aged 18 to 31. Of these, 16 participants identified as Asian, 4 as Middle Eastern, and 4 as Caucasian. Most (21/24) participants rated their health as 'good', 'very good', or 'excellent', with 9/24 having a BMI greater than 25 based on reported heights and weights. Participants were randomly assigned to use each app over the 3 week period, with 12 participants in each group. To be eligible for the study, participants had to own a mobile phone with Android 4.0 or higher. All 24 participants completed the study, and each received a $30 honorarium.

Study Design & Procedure

Our 2 $\times$ 2 study design included the app used (either MFG or PBGA) as a between-subjects independent variable, and time (pre-/post-intervention) as a within-subjects independent variable. At the beginning of the study, each participant was randomly assigned to use either the MFG or PBGA app. Participants had two sessions, one at the beginning of the study, and one after using the app for a 3-week period.

During the first session, participants completed a background survey to collect demographic information as well as preferences regarding use of mobile games, shopping and cooking habits, and confidence in selecting and preparing foods. Participants also completed the General Nutrition Knowledge Questionnaire (GNKQ) [31], an extensively validated nutrition knowledge instrument that captures an individual's general knowledge in the area of nutrition, and the Health Belief Model Survey (HBMS) [51], that captures beliefs around healthy eating. The GNKQ is separated into four sections: 1) Dietary Recommendations given by experts, such as the number of recommended servings for different food groups and what types of nutrients we should include in our daily diet; 2) Food Groups, which includes the different food groups and the nutrients they contain; 3) Healthy Food choices covers shopping at the supermarket, choosing meals in restaurants, and food preparation; and 4) Diet and disease management covers health problems or diseases related to diet.

The HBMS [51] is frequently used in the design and evaluation of health behaviour interventions (e.g. [40,42,46]). The model posits that an individual's likelihood of engaging in a healthy behaviour is defined by their perception of perceived susceptibility, perceived severity, perceived benefit, perceived barrier, cue to action, self-efficacy and intention. Examples of questions from the HealthHealth Belief Model Survey (HBMS) are: "Selecting healthy products most of the time would be beneficial to me" (perceived benefit); "It is hard to find a snack that is tasty and healthy" (perceived barrier); "If I do not eat healthily, I will be at high risk of some dietary-related diseases" (perceived susceptibility); "The thought of ending up in the hospital due to dietary-related diseases scares me" (perceived severity); "I would make healthier food choices if I had a better knowledge of the healthier options" (cue to action); "I am confident that I can eat healthily during the next three weeks" (self-efficacy); "I intend to eat more fruits and vegetables during the next two weeks" (intention).

After all surveys were completed, the MFG or PBGA app was installed on the participant's mobile phone and they were asked to use the app to both plan (at home) and select foods (in the grocery store) for the following 3-week period, on three different days of their regular grocery shopping.

After three weeks, participants were contacted by email to schedule the second session, which also included a semi-structured interview to gather information about their experience using the app focusing on their perceptions of the app and its features. For the second session, the order of questions on the GNKQ and the HBMS were changed to avoid memorability. During the interview, participants were asked to reflect on how they used the app during the past three weeks and explain how the app affected their understanding and behaviour in planning and purchasing foods.

Data Collection & Analysis

All interactions with PGBA were recorded directly to app logs. Because we did not have access to usage data for MFG, we asked participants assigned to MFG to send screen shots of their shopping lists and receipts for the foods they bought. We collected the following information for each participant: age, gender, food preferences, name of products added to the shopping list, name of products added to purchase, number of times they used the app and days for each shopping trip, values of nutrients for each shopping trip, number of servings for each food group for each shopping trip and the names of completed challenges.

We performed a mixed Analysis of Variance (ANOVA) to compare the mean differences between participants that played PBGA and the control group that used MFG, and their scores of the pre- and post- GNKQ and HBMS to investigate differences in nutrition knowledge and health beliefs ($\alpha < 0.05$).

To compare how participants changed their shopping behaviour, we compared the items from the "Fruits and Vegetables" food group as well as the "Ultra-Processed" foods not included in the four food groups, such as pastries, chocolate and candies, ice cream, and potato chips. Ultra-processed products are made from processed substances extracted or refined from whole foods. They are typically energy-dense, with a high content in total, saturated and trans-fats, added sugars and sodium, and little or no fibre or micronutrients [35]. There is no recommendation for those foods and they should be eaten sparingly, with moderation, due to the high values of added sugar, sodium, and fats.

Audio files from the interview in the second session were transcribed, and then analyzed using thematic analysis [6]. We grouped discussions according to users' descriptions of

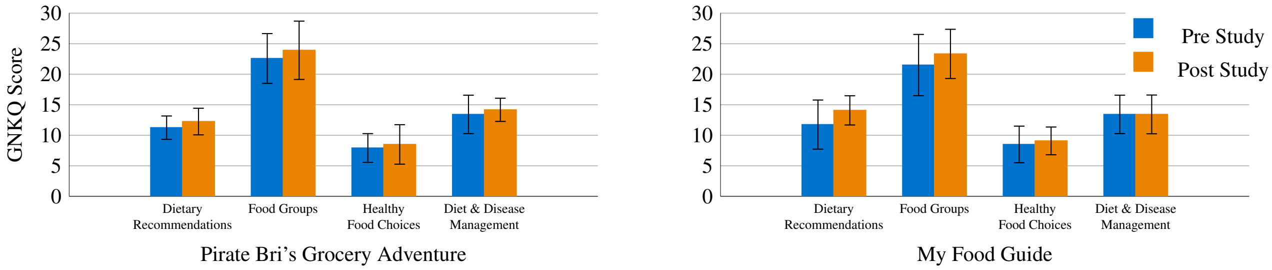


Figure 4. General Nutrition Knowledge Questionnaire scores increased for both PBGA (left) and MFG (right) over the course of the study.

how they used each app and what features they would like to better plan and select foods while grocery shopping. We then developed initial codes, searched for themes, and reviewed and grouped them together, which led to the final themes.

QUANTITATIVE RESULTS

Over the three-week study period, logged data indicated that participates used PBGA as expected for planning meals before shopping, scanning groceries as they shopped, and checking goals before they paid. We now present results related to nutrition knowledge, health beliefs, and purchasing behaviour. After, we present and discuss the main themes that emerged from our qualitative analysis of participant responses during the post-study interviews.

General Nutrition Knowledge

Our mixed-factorial ANOVA revealed no significant difference between apps for pre scores on the General Nutrition Knowledge Questionnaire, ($F_{1,21} = .000, p = 1.000, \eta_p^2 = .00$). The general nutrition knowledge of participants increased for both groups. Our mixed-factorial ANOVA revealed a main effect for pre- and post-intervention scores on the GNKQ ($F_{1,22} = 15.93, p = .001, \eta_p^2 = .42$), with participants scoring on average 55.17/88 before the study, and 59.38/88 after the study. We found no significant mean difference for app ($F_{1,22} = 0.26, p = .613, \eta_p^2 = .01$): PBGA (Pre M = 55.17, SD = 7.21; Post M = 58.83, SD = 8.41) and MFG (Pre M = 55.17, SD = 12.58; Post M = 59.92, SD = 9.58).

We also examined each section of the GNKQ separately, to discern differences in the types of content that participants learned (Figure 4). Section 1 (Dietary Recommendations) had a significant increase with MFG, ($F_{1,11} = 8.69, p = .013, \eta_p^2 = .44$), but had no significant increase with PBGA ($F_{1,11} =, p = .060, \eta_p^2 = .29$). Section 2 (Food Groups) had a significant main effect, ($F_{1,22} = 5.25, p = .032, \eta_p^2 = .17$), but no significant differences between apps. Section 3 (Healthy Food Choices) had no significant main effects ($F_{1,22} = 3.00, p = .097, \eta_p^2 = .12$). Finally, Section 4 (Diet and Disease Management) had a significant increase with PBGA, ($F_{1,11} = 5.21, p = .043, \eta_p^2 = .32$), but we found no significant increase with MFG ($F_{1,11} = .00, p = 1.00, \eta_p^2 = .00$).

Health Belief Model

Our analysis of the HBMS revealed significant differences pre and post scores for Self-Efficacy, ($F_{1,22} = 10.28, p = .004, \eta_p^2 = .32$) for PBGA (Pre M = 3.28; Pre SD = 0.82; Post M = 3.86; Post SD = 0.94) and for MFG (Pre M = 3.64; Pre SD = 0.48; Post M = 3.86; Post SD = 0.66) with no significant mean differences between apps. We also found a significant difference pre and post intervention for Perceived Susceptibility, ($F_{1,22} = 7.04, p = .015, \eta_p^2 = .24$) for PBGA (Pre M = 4.04; Pre SD = 0.83; Post M = 4.54; Post SD = 0.45) and for MFG (Pre M = 3.87; Pre SD = 1.11; Post M = 4.33; Post SD = 0.65), with no significant mean differences between apps. There was no significant difference between apps for pre scores on Self-Efficacy, ($F_{1,21} = .171, p = .204, \eta_p^2 = .07$), or Perceived Susceptibility, ($F_{1,21} = .172, p = .682, \eta_p^2 = .01$). We found no significant increase for either app for the Determinants of Likelihood of Healthy Behaviour, Cue to Action, Perceived Severity, Perceived Benefit, and Perceived Barrier.

Food Purchases

Fruits and Vegetables

We found that across all participants, there was a trend of purchasing more fruits and vegetables (Bought: M = 15.83, SD = 8.82) than they had planned on before going to the store (Planned M = 11.17, SD = 7.38) ($F_{1,21} = 12.34, p = .002, \eta_p^2 = .37$). However, our mixed-factorial ANOVA revealed no significant differences between apps ($F_{1,21} = 2.72, p = .114, \eta_p^2 = .12$) (Figure 5). A simple effect for each app showed a significant increase in the amount of fruits and vegetables purchased compared to what was planned for PBGA, (Planned M = 8.83, SD = 5.67; Bought M = 15.42, SD = 7.65), ($F_{1,11} = 13.46, p = .004, \eta_p^2 = .55$), but no significant increase for MFG, (Planned M = 13.73, SD = 8.40; Bought M = 16.27, SD = 10.31), ($F_{1,10} = 1.83, p = .206, \eta_p^2 = .16$).

Ultra-Processed Foods

Our analysis also found a significant difference between the amount of ultra-processed foods that participants planned to buy (M = 1.17, SD = 1.78) and those that they ultimately bought (M = 2.74, SD = 2.78), ($F_{1,21} = 8.65, p = .008, \eta_p^2 = .29$). There was a significant interaction of interval by app, ($F_{1,21} = 7.79, p = .011, \eta_p^2 = .27$). A simple effect for each app showed a significant increase in ultra-processed foods bought compared to planned for MFG, ($F_{1,10} = 9.00, p = .013, \eta_p^2 = .47$), but no significant increase for PBGA, ($F_{1,11} = .037, p = .851, \eta_p^2 = .00$).

A one-way ANOVA showed a significant difference ($F_{1,13} = 6.377, p = .025, \eta_p^2 = .33$) between total servings of ultra-

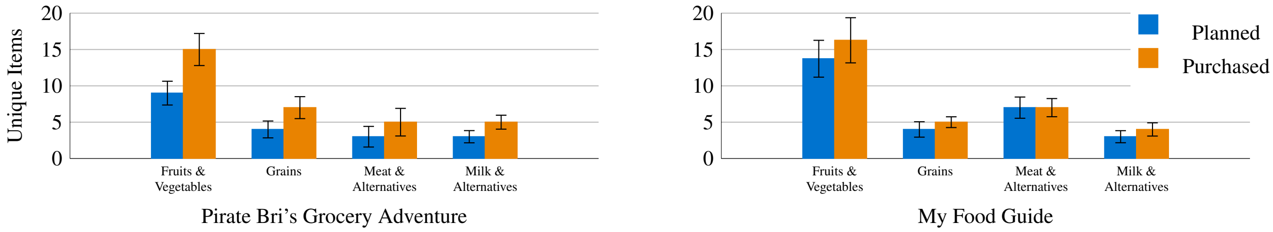


Figure 5. Number of items planned and purchased for each food group. Participants using both PBGA and MFG purchased more fruits and vegetables than they had planned to before going to the store.

processed items bought between PBGA (M = 6.13, SD = 4.91) and MFG (M = 18.86, SD = 13.32) (Figure 6). Levene's test revealed that the homogeneity of variances was not assumed, $(F_{1,13} = 5.46, p = .036)$; However, the differences in means remain significant with a Welch correction applied, $(W_{1,7.422} = 5.714, p = .046, est.\omega^2 = 0.24)$. Four participants from PBGA and four participants from MFG did not add ultra-processed foods to their carts. One participant from MFG did not submit the information of foods planned and bought.

QUALITATIVE RESULTS

Our results show that both PBGA and MFG improved participants' Food Literacy over the 3-week study period, as demonstrated through GNKQ responses, as well as participant planning and shopping behaviours, which is consistent with their focus on nutrition content and advice. Overall, these results demonstrate the potential for apps to motivate in-depth healthy behaviour promotion based on Food Literacy, beyond the calorie approach demonstrated in previous research (e.g., [27,45,46,62]).

Further, participants who used PBGA for the 3-week study period demonstrated healthier shopping behaviour, compared to those who used MFG. Specifically, participants who used MFG bought nearly three times as much ultra-processed food than those who used PGBA (Figure 6). We now explore reasons for these differences based on our thematic analysis of participant responses during post-study interviews. In particular, we discuss how gameful design choices influenced participants' decisions to purchase a balanced diet, and to moderate consumption of unhealthy foods.

Balance and Variety

A core component of Food Literacy is ensuring that an individual's dietary needs are met, that they purchase a variety of foods, and that those foods cover all food groups in a balanced way. Participants reported that both PBGA and MFG

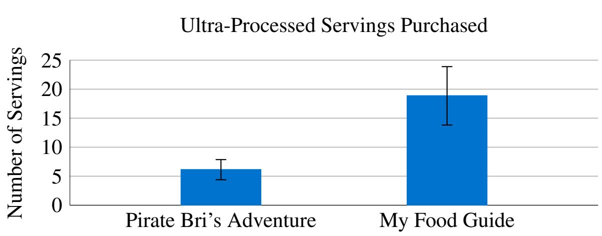


Figure 6. Participants who used PBGA purchased a lower number of servings of ultra-processed foods than those who used MFG.

ultimately promoted balance and variety in food purchases, but that different features of each app were responsible for this behaviour. Figure 5 shows that both PBGA and MFG promoted purchases of foods with balance and variety, as different items within each food group were added to participants' carts.

Many participants indicated that they particularly liked MFG's planning feature, and how it highlighted alternative food choices for more variety, with an emphasis on purchasing foods from all food groups for better balance. Participants frequently mentioned MFG's visualization of all products from a specific food group, with pictures for each food. This visualization served to suggest items to include in their lists, and at times provided inspiration and motivation to try foods that might not be included regularly, or that they may never have tried before. For example, P25 (MFG) described one such experience as: "Quinoa, I didn't know what was that, but I saw on the app and then saw on Wikipedia that it was good for you then I bought to try ... like many things in the list I don't have in my home country, so seeing in the app I see the name of the products and I could understand and it gives me ideas of what to buy". She also tried to buy a larger variety of fruits and vegetables: "Squash was something that I never had before, but I looked at what kind of meal could be made by that and it gave me ideas." Over the 3-week period she was inspired to purchase many new foods like cabbage, eggplant, and figs. This knowledge was also reflected in increased GNKQ scores on dietary recommendations for participants who used MFG.

On the other hand, PBGA encouraged balance and variety through its in-store features: its food balance visualization (Figure 2, e) provided feedback on the recommended number of servings of each food group. Participants frequently mentioned discovering that they needed to purchase more fruits and vegetables, and that PBGA nudged them towards making those purchases before leaving the store. For instance, P13 described their experience as "I know I have less fruits and vegetables than I need and it was just nice to see how much I needed and that encouraged me to buy more." P10 described how PBGA served as a reminder at the end of his trip, "As soon as I finished my shopping for the first time, I used to see that screen and remember like 'Oh, shi*, this is not complete!' like for fruits and vegetables, so I wasn't able to complete that, so I just go and buy one more." He was also encouraged to have more salads and look for recipes: "In three weeks I ate more fruits than I previously [ate]. I used to have more snacks, but now I started having more fruits, basically. I also had more vegetables, salads, I watched some videos of recipes as well."

Moderation

Moderation of nutrients, such as sugar, fat, and sodium, is also a core component of Food Literacy. Three features from PBGA were mentioned by participants as being particularly effective in moderating purchases of foods high in those nutrients: the visualization of nutrition facts, the summary of the nutrients in their shopping cart, and weekly challenges. Participants who used PBGA also demonstrated higher scores for knowledge about Diet, and Disease Management from GNKQ, which might also have influenced the moderation of ultra-processed foods. These topics were primarily featured in Bri's in-game tips, and the increased scores indicate that this feature was effective, despite participants not specifically mentioning it during interviews.

Visualization of Nutrition Facts

All 12 participants who used PBGA reported that the visualization of nutrition facts (Figure 2, c) was easier to understand than the food's physical packaging, and helped them understand the healthiness of the products as they shopped. For instance, P15 explained that "I don't usually read [nutrition facts on packages], because I look at the label and I don't really understand, so that's why I liked this screen, because it says this is low, this is high, and then I have a sense. Because the numbers don't mean anything to me, but with this screen I can see." P21 (PBGA) felt that the visualization provided a straight-forward way to understand healthiness of a product even if you are a non-specialist: "You don't need to know about food and nutrition, you just have to see that this is high (in the visualization), and you see sodium, sugar high, you don't need [prior] knowledge to understand."

Visualizing the amounts of nutrients in products sometimes surprised participants, raised awareness about foods that they were buying, and identified products they should have in moderation: "Like people always tell me that cheese is really bad and then I scanned and then I saw the high values and I was like 'Oh my God, it really is really bad.' So I really liked that screen, I think it was the best part." (P15). Cereal was also mentioned with surprise by participants, "I thought cereals to be healthier, but it said that cereal had added sugar." (P12).

Notably, participants also reported that the visualization helped them to moderate *consumption* of processed foods: "It was easy to understand and helpful to determine how many servings I should eat. When you look for a product and see how much sodium is there in the things I had to buy, like soy sauce, it had too much sodium. I always knew that soy sauce was high in sodium, but now I can use it a little bit less" (P5, PBGA); "Seeing how much fat you have in a milk made me think oh God, I should drink more water instead of milk all the time ... Seeing that a certain product has 35g of sugar might make you think that's a lot, but when you see a red, it makes you sad (laughs)" (P13, PBGA). Another participant mentioned that this feature did not discourage buying a product that he already intended to buy, but visualizing high values made him buy fewer units and eat less of it afterwards: "It didn't change what I bought but certainly made me more aware ... I bought the cheese, but I thought to myself, I should eat less of those. And that's what I've been doing." (P15, PBGA)

Visualizing the Pirate's Cart-Boat

The summary of nutrients (Figure 2, e) was also reported by participants to be helpful when shopping, and in particular helped moderate consumption of sugar, fats, and salt. For example, P21 described their use of this visualization: "I think having your daily nutrients versus just counting calories is pretty interesting because I know a lot of people that just do this thing that they got to eat whatever they want as long as they're under their calories limit, like you're eating MacDonald's or you're eating things like processed foods. But this screen is like, you're getting all the actual nutrients that you need to have a healthy lifestyle" (P21, PBGA).

Another participant highlighted how focusing on monitoring calories can be an unhealthy approach in nutrition apps: "Before, when I used to count calories I was more obsessed with checking labels, but I found that, for me, it leads you to unhealthy eating behaviour, so I just didn't want to look at nutrition label in packages anymore. I think a lot of people who are concerned about weight checks just for calories, which was what I was doing, but it's also important to check for sodium and fat contents and other things besides calories. So now I check for those other things besides calories" (P17, PBGA). When asked why she changed that habit, she added: "Because I had a negative perception of how I looked, so I wanted to keep my calories for 1100 calories a day, but I think I had a lot of unrealistic goals for myself that were not healthy. So afterwards I was like 'I don't wanna look at that anymore'." (P17, PBGA). This quote from P17 shows how tracking calories can lead to unrealistic goals and how tracking nutrients are perceived as more meaningful for creating healthy habits.

Challenges

Challenges were frequently mentioned by participants as a strong motivator while shopping, particularly for moderating purchases of items high in sodium, fat, and sugar. We also noticed that challenges aimed at promoting balance and variety tended to be more difficult for participants than those targeted at moderating consumption of nutrients. For example, challenges for purchasing recommended amounts of fruits and vegetables (33%) or fibre (42%) were completed by far fewer participants than those for reducing intake of sugar (83%), saturated fat (92%), or sodium (92%).

Participants' success in meeting these challenges was varied, ranging from balancing constraints of an individual's lifestyle, to lack of awareness of their importance in a healthy diet. For example, participants described a variety of difficulties when trying to meet the sodium challenge. P10 related this difficulty to their student lifetyle, "Sodium was very difficult, because since I'm a student, generally I cannot cook every day, so sometimes I'm busy with my work and I generally prefer eating chips and processed food" (P10, PBGA). On the other hand, P12 described a tension between lowering sodium and maintaining a vegetarian diet, "I usually choose foods with high protein, because I'm vegetarian and thus cannot have meat. But now I'm looking at sodium as well" (P12, PBGA). Other participants mentioned that sodium was simply something that they did not think about when shopping, "sodium was the most interesting challenge to me. Sodium is something that I don't really think about when I'm planning in general. After that I tried to minimize the canned beans I bought. I paid an extra 50 cents to get the low sodium version." (P19, PBGA).

Despite these obstacles, participants largely met the nutrient-related challenges while in-store. In post-study interviews, they frequently mentioned that they served as a 'nudge' towards the end of a shopping trip to revisit their dietary needs.

DISCUSSION & IMPLICATIONS

Our study shows that designing for Food Literacy can improve people's nutrition knowledge, health beliefs, and in-store shopping behaviour. Both PBGA and MFG demonstrate how organizing food items into food groups encourages shoppers to make adjustments and fill their carts with balance and variety. We observed that this behaviour was more prominent in planning with MFG (because of the list of suggestions) compared to being more prominent in selecting foods in stores with PBGA (because of the Challenges, the Visualization of Nutrition Facts, and the Visualization of Pirate's Cart-Boat). On the other hand, participants who used PBGA moderated their intake of ulta-processed foods more successfully than those who used MFG. Participant responses suggest that this success was supported by features that helped them visualize the nutrients in different foods while in the store, and was motivated by gameful design elements like challenges. We now reflect on these aspects of PBGA's design.

More Informed Decisions

Our field study shows that Food Literacy apps can be used by young adults to increase their nutrition knowledge, motivate themselves towards healthy eating, and to purchase a variety of fruits and vegetables, and fewer ultra-processed foods. Participants who used both PBGA and MFG increased their nutrition knowledge (GNKQ) and motivation towards healthy eating (HBMS), and purchased groceries that were balanced across the four food groups. Together, these results demonstrate the benefits of promoting Food Literacy, a focus on interventions that take place before consuming foods, and the potential to help individuals make more informed food choices.

We also found that PBGA's design was particularly effective in promoting certain aspects of Food Literacy. For example, participants' increased knowledge around diet and disease management can be directly linked to content provided by Bri (Figure 2, d). Motivation towards healthy eating was increased for both groups (i.e., HBMS), but impulse purchases were significantly lower for those using PBGA. This reduction in impulse purchases is particularly notable, because we found no difference between groups' planned purchases of any food group. That is, participants' initial intention to purchase healthy foods was similar for both groups, but those using PBGA left the store with fewer unhealthy foods. Thus, the gameful situated app motivated participants to follow the key factors of a nutritious diet: balance, variety, and moderation.

Many participants also mentioned that PBGA helped them recognize products with high values of nutrients that they were not aware of before, and that learning that while shopping later influenced how they *consumed* their food. After making purchases high in nutrients, such as soy sauce that is high in sodium or cheese that is high in saturated fats, many of our participants decided to limit their intake to better match daily recommendations. We take this feedback as indicative that participants were internalizing lessons learned in the store, and practising Food Literacy skills later at home.

Situated Interventions

Situated interventions for groceries are particularly important to counteract the negative influence of the retail food environment on consumers. This is because grocery stores are carefully designed to influence a shopper's behaviour [63]. Staples like milk and bread are placed in the back, requiring shoppers to walk by other products. Eye-level shelf space is used to promote ultra-processed cereals and snacks, often the most profitable for retailers, that are packaged in bright boxes that draw an individual's attention. And candy and chocolate bars tempt customers at the checkout, where impulse can quickly translate into a sale. These engineered retail environments work against a shopper's balanced diet [12], and in-store supports like nutrition labelling can be difficult to interpret, even for those who are health conscious [7].

Our work demonstrates the importance of this situated approach, and how smartphones can help shoppers act in their self-interest in this complex and hostile environment. PBGA's situated features address many barriers to informed shopping: the map feature makes users aware of the grocery store layout, and asks them to consider their needs as they walk between the different areas; The food scanning feature and traffic-light colours visualization helps users understand the nutrients in each food as they consider the purchase, and the cart-boat visualization helps them monitor their overall intake of nutrients and balance of each food group. Critically, these activities take place when purchases are made, with real foods. Participants were enthusiastic about having a tool that helped them make sense of nutrition information in the grocery store, and to avoid impulse purchases of unhealthy items.

Motivation from Gameful Design

PBGA's gameful design elements were widely praised by participants as engaging, informative, and motivating. Participants were particularly enthusiastic about the weekly challenges, and reported that they often stopped in the midst of a shopping trip to make sure that their goals were within reach. The impact of challenges is perhaps most apparent by the difference between planned and purchased foods (Figure 5); even though participants did not initially create ideal shopping lists with PBGA, they ultimately purchased a balanced group of foods, and moderated purchases of ultra-processed foods. This motivation was often described by participants during interviews, such as: "It is very motivating to see the quests that I completed" (P16, PBGA), and "When I saw the salt quest, I said 'Yeah, I do wanna get less salt, that's cool!"' (P13, PBGA). PBGA's overall design was also reported to be a motivator by participants, e.g. "The design was like a theme of a game, which was helpful in getting motivation" (P12, PBGA), and was reflected in increased Self-Efficacy on the HBMS, where self-efficacy is associated with a higher likelihood of achievement [52].

While participants frequently mentioned enjoying the challenges, some were found to be particularly difficult, such as the Fruits & Vegetables challenge, which was only completed by 4/12 participants, and the Fibre challenge, completed by 5/12 participants. A potential improvement to make these challenges more attainable would be to provide increasing levels of difficulty that build a participant's competencies more smoothly, and that encourage smaller changes in their eating patterns. For example, bronze, silver and gold medals could be awarded based on performance. Additionally, showing all challenges at once instead of three each week would give players a more personalized approach and support their autonomy.

It's also important to recognize that gameful elements were not designed in isolation, and that elements like personalization, meaningful choices, and learning [18] also contributed to PBGA's design. While it's difficult to determine the impact of any one of these design elements independent from one another, our research points to their combined effectiveness in motivating informed food purchases.

Planning for the Win

Finally, we learned that MFG's list of suggestions for each food group helps shoppers be prepared at the grocery store, and to purchase foods with balance and variety. However, some participants mentioned that design improvements could be made to help shoppers purchase foods with moderate amounts of saturated fats, sugar, and sodium. To help with these decisions, a nutritious shopping list could highlight and order foods under each food group from the healthier options to the unhealthier option. For example, white bread and whole wheat bread are both considered 'grains', but an app that encourages healthier options could place whole wheat bread higher on the list. Linking with local flyers could also help participants plan within their budget. However, many flyers are loaded with unhealthy options, and thus care would need to be taken to filter out many promotions. Suggestions based on nutritional needs, preferences, and past purchases would also support healthier and personalized planning.

LIMITATIONS AND FUTURE WORK

Our study identified new opportunities for improving the design of gameful nutrition apps to develop Food Literacy in the context of shopping. However—like any single study—our results should be interpreted within the context of their limitations. As exploratory work, a limitation of our study design is that we cannot make any conclusions about the clinical effectiveness of PBGA as an intervention for promotion of Food Literacy. Our intention was to explore the potential of situated and gameful apps from an HCI perspective, and to identify features like narrative, challenges, and meaningful decisions, for motivating people to use such apps. Our decision to study use of the app over 3 weeks, and to compare to My Food Guide were driven by this choice, and the ability to elucidate strengths and weaknesses of our design. A different design, such as a long-term randomized controlled trial, is required to provide formal validation of long-term behaviour change.

Another limitation was our choice to not address the issue of budgeting. Food insecurity, defined as uncertain or insufficient access to food because of financial limitations, is a widely identified issue for students in the nutrition literature [22]. In our own study, 9 participants mentioned cost as one of the most important factors when shopping for groceries, and two participants declared spending as little as $10–50 CAD in groceries a month. Despite the importance of cost, neither MFG nor PBGA directly address food insecurity.

However, both apps encourage planning as a means of maintaining a budget, and present advice to the user to help plan based on cost. The results of our study suggest that this approach can be effective: participants who used PBGA purchased about one third as much ultra-processed food as those who used MFG. We expect that additional features, such as helping students identify items that are in season—and thus less expensive—or that are on sale through links to local flyers, would be beneficial. Gameful design may also be effective, such as providing shoppers an opportunity to 'trade' one expensive, unhealthy item in their cart for an in-season fruit or vegetable, in exchange for an in-game reward. For now, we simply acknowledge the importance of designing for food insecurity, and that balancing the cost of a healthy diet is a critical area for future research, particularly for vulnerable populations like students.

CONCLUSION

Our work is the first to use gameful design and situated learning to develop the Food Literacy skills of planning and selecting foods when grocery shopping. We took this approach with the goal of moving beyond counting calories and short-term weight loss, and to place an emphasis on developing long-term Food Literacy skills. Results from our three-week field study show that our app increased participants' food knowledge and encouraged balanced food purchased across all four food groups. We also found that the app helped shoppers moderate purchases of sugar, fat, and sodium. Practising these skills in the grocery store provides a meaningful learning experience, helps individuals internalize the skills as they develop, and improves confidence and self-efficacy.

This research is a first step towards developing Food Literacy skills more broadly, which includes skills for planning and selecting foods, but also for preparing meals and enjoying them with friends and family at home. Our app shows how this approach can effectively support food purchasing behaviour, and contributes insights into how gameful design can be used to develop Food Literacy in the grocery store. We envision that future work will extend this research to develop the full range of Food Literacy skills.

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