Development, usability, formative assessment, and story immersion of Nutrigame, a mHealth nutrition education app

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Abstract

The replacement of unprocessed and minimally processed foods with processed and ultra-processed ones can be a contributor to the increased prevalence of obesity amongst adults and adolescents. Mobile health (mHealth) innovations, such as mobile applications (apps), especially games, can be used to improve health behaviors and increase adolescent knowledge. The aim of this qualitative research was to describe the development, assessment, and story immersion of a mHealth nutrition education app developed to improve the food knowledge of adolescents. This study employed the stepwise approach model to the mHealth app development, according to the person-based approach and evidence-based behavior change techniques. The mHealth app was based on the concepts of the NOVA system food classification, present in the Brazilian dietary guidelines. The developed app, Nutrigame – your food guide, is a story-based serious game set in the food routine of an adolescent who needs to choose what to eat, when, where, and with whom the meals are taken. The first version of the app was tested by a group of adolescents (convenience sample, n=6, mean age: 15.8 ± 0.9 years) for 30 days. To assess usability, feasibility, engagement (user testing), and formative evaluation from the user's perspective, five individual interviews. After the last interview, the participants were required to complete a 13-item immersion scale, adapted from the narrative transportation scale to assess story immersion game. The final version of the game was adapted to meet the suggestions presented by the adolescents. All steps used for the app development are described. The gamification elements chosen led to the comprehension of the main learning contents. The mean story immersion score (30.3 ± 1.9) demonstrates the participant's involvement with the game's narrative. This study can provide useful insights to public health researchers and nutrition educators who are planning to develop a mHealth nutrition education app from a practical perspective.

Keywords: Food knowledge, NOVA classification, Dietary Guidelines, Serious game, Game for health, Nutrition education

1 Introduction

Overweight and obesity are major public health problems worldwide, mainly due to the prevalence increase in different age groups in recent years. From 1975 to 2016, obesity prevalence among children and adolescents (5 to 19 years old) increased more than four times (from 4% to 18%) (Abarca-Gómez et al. 2017). This is an alarming scenario, as adolescents with obesity are five times more likely to have obesity in adulthood (Simmonds et al. 2016). The replacement of unprocessed (natural) and minimally processed foods with ultra-processed ones is a major contributor to diet nutritional low quality and thus to the increased prevalence of obesity (Lane et al. 2021).

Unprocessed and minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods are the four groups of the NOVA food classification system. It classifies foods according to the nature, extent, and purpose of the industrial processing they undergo. Food processing according to NOVA involves physical, biological, and chemical processes used after foods are separated from nature, and before being consumed or prepared as meals (Monteiro et al. 2016). The 2014 Dietary Guidelines for the Brazilian Population gained notoriety in the international media and the scientific community as its recommendations are not based on nutrient sources and food calorie content. Contrariwise, it has adopted qualitative, dietary guidelines based on the extension of food processing. The Brazilian guideline golden rule claims that natural or mini-
nally processed foods and freshly made meals must be preferred over ultra-processed foods (Brasil 2015). However, for this rule to be complied with, knowledge and understanding of food processing, as well as the identification and recognition of NOVA food classification, are required.

Knowledge is one of the attributes of food literacy. It is a collection of interrelated knowledge, skills, and behaviors required to obtain, process, and understand basic information about food and nutrition. Additionally, it includes the competence to use the information to make appropriate decisions that lead to dietary behavior changes (Vidgen et al. 2014).

Adolescents’ food knowledge has proven to be an important determinant of healthy food choices. Adolescents with low food knowledge showed less adherence to healthy eating habits (Tsartsali et al. 2009; Vaitkeviciute et al. 2015; Drywien et al. 2021). It has been shown that Brazilian adolescents had insufficient knowledge about the new dietary guidelines, especially about the NOVA classification (Chagas et al. 2018; Fonseca et al. 2019; Chagas et al. 2020). Therefore, the challenge of translation and teaching dietary guidelines to achieve effective changes in health behavior remains.

In this sense, mobile health (mHealth) innovations, such as the use of mobile applications (apps), represent novel opportunities to address public health challenges. According to the World Health Organization (WHO), the union of mobile technology with health and healthy eating practices can improve communication, increasing knowledge and awareness (WHO 2016; 2019). Currently, there is consistent evidence of the benefits of using mHealth apps, especially games for children and adolescents, to improve health behaviors, including initiating behavior change, increasing motivation for small changes, and increasing knowledge (Johnson et al. 2016; Dias et al. 2018; Belghali et al. 2021). Therefore, games can be considered promising tools for nutritional interventions, especially among youth (Amaral et al. 2017).

Games designed to improve cognitive and intellectual skills are called educational games, learning games, or serious games. Serious games, when created with well-crafted stories, may facilitate nutritional education. Stories can include initiating behavior change, increasing motivation for small changes, and increasing knowledge (Johnson et al. 2016; Dias et al. 2018; Belghali et al. 2021). Story immersion refers to the experience of being absorbed and engaged by it. The players may experience psychological immersion while being fully engaged in the game story, thereby paying close attention to embedded messages, and taking on a leading role in the learning process (Baranowski et al. 2012; Thompson et al. 2012; Wang et al. 2015; Wang et al. 2017). The development of mHealth interventions must be based on evidence, behavior change theories, and taxonomies. Also, the person-centred approach recommends using qualitative and iterative research to explore and test intervention with the end-user before implementation (Ferdig 2009; Czajkowski et al. 2015; Yardley et al. 2015).

Whereas adolescents generally have greater autonomy in food decisions, it is important to increase the adoption of healthier food behaviors, so they will be more likely to be sustained into adulthood. Although serious games, when created with well-crafted stories, may facilitate nutritional education, in Brazil, it is still an unexplored area. Few mHealth apps were found whose aim is to increase adolescents’ food knowledge (Chagas et al. 2018; Ribeiro et al. 2019; Brito et al. 2020; Fossari et al. 2023). Therefore, this study describes the development, usability, formative assessment and story immersion of a mHealth nutrition education app to improve the food knowledge of adolescents. The mHealth app is based on the concepts of the NOVA classification, the foundation of the 2014 Dietary Guidelines for the Brazilian Population. In this sense, the authors should better present the article’s objectives, methodology, main results, and contributions to the scientific community in this section.

2 Method

2.1 Study Design

The game was idealized by researchers in the field of nutrition and human health (researchers: CSC, BCCG, EAE and ER-V). Game development and design were conducted by a game company (Glitch Factory), under the supervision of the researchers. For the development of the app we used a step-wise, person-based approach, guided by the Obesity-Related Behavioral Intervention Trials (ORBIT) (Ferdig 2009; Czajkowski et al. 2015; Yardley et al. 2015) (Table 1). The study was approved by the Research Ethics Committee of the Universidade Federal dos Vales do Jequitinhonha e Mucuri and all the participants provided written informed consent (# 12218819.0.0000.5108).

2.1.1 Step 1 - Theoretical underpinning and conceptualization

Based on literature and taxonomy; based that the knowledge is an attribute of food literacy that has been identified as a gap in the ability of youth to make healthy eating choices: the learning goal, the learning approach, the learning content, the behaviour change techniques, and the communication's way were determined (Michie et al. 2009; Michie et al. 2013; Brasil 2015; Ivens et al. 2016; Johnson et al. 2016; Amaral et al. 2017; Chagas et al. 2018; Dias et al. 2018; Simons et al. 2018; Fonseca et al. 2019; Brown et al. 2020; Chagas et al. 2020; Belghali et al. 2021).

2.1.2 Step 2 - Developing the mHealth nutrition education app

Naming process. The mHealth app name creation process involved 8 steps, according to Wheeler (2013).

Dimensions and gamification elements. An analysis was carried out in the Google Play and Apple Store to identify the

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most popular caring games, which were used as a reference to explore the gamification dimensions and the more attractive and currently acceptable elements of user's interest. The games chosen as references were: Bubbu My Virtual Pet® (Pilcom), Plant Nanny® (Fourdesire), and Pou® (Paul Salameh). These 3 games exceed 10 million downloads. Based on these games and the Taxonomy of Gamification Concepts for Health Apps (Schmidt-Kraepelin et al. 2018), the team defined the dimensions and gamification elements of the concepts of art and design that would best deliver the content to be taught to adolescents: narrative, plot, and user identity; gameplay; player advancement; and reinforcement.

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<td>Usability: refers to the technical aspects of the app and the interface with the game.</td>
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<td>Feasibility: refers to how the strategy is realistic</td>
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<tr>
<td>Engagement: refers to how the target audience interacted with the app</td>
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<td>Formative assessment: refers to the interaction between gameplay, narrative and content. It allows a preliminary evaluation of the game learning objective achievements</td>
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<tr>
<td>Story immersion: refers to the experience of being absorbed and engaged by narrative</td>
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</table>

### 2.1.3 Step 3 - User testing, formative evaluation, and story immersion

The first version of the mHealth app was evaluated by the team and approved for step 3. In this step, a convenience sample of adolescents (n=6), consistent with the game's target audience, was selected to test the mHealth app for 30 days. The aim of this step was to assess usability (download and install; correction and understanding; visibility and structure; avatar; gameplay; overall impression), feasibility (completeness; relevance), engagement (user testing), and formative evaluation (about gamification elements and dimensions used) from the user's perspective. So, five individual interviews with each adolescent were conducted (Maramba et al. 2019). To stimulate the participants’ communication (Charters 2003), an interview protocol, based on the Iterative Convergent Design for Mobile Health Usability Testing approach was developed (Alwashmi et al. 2019). The interview was composed by questions adapted from questionnaires used in similar studies (supplementary appendix 1) (Wang et al. 2015; Simons et al. 2018). After the last interview, the participants were required to complete a 13-item immersion scale, adapted from the narrative transportation scale to assess story immersion game (supplementary appendix 2) (Green et al. 2000). The adolescents rated their levels of agreement with statements on a 3-point Likert scale (1 = do not agree; 2 = somewhat agree; 3 = agree a lot). The score was summed, and the possible scores ranged from 13 to 59.

### 2.2 Data Analysis

Continuous data were presented as mean and standard deviation or median, minimum, and maximum range. All interviews were recorded in audio and video and transcribed verbatim.

Qualitative content analysis was carried out by means of a systematic floating, reading of all the transcribed material, and the answers were then grouped according to each question of the interview protocol. This methodological approach was based on the content analysis technique (Bardin 2010). The main answers were compiled, then aligned by question and presented in a tabular form. To preserve the anonymity of the participants, each adolescent was assigned a code (A1 through A6) for the description of the results.

### 3 Results

#### 3.1 Step 1

**The learning goal.** The goal was to improve the adolescents’ food knowledge about the 2014 Dietary Guidelines for the Brazilian Population. Knowledge is an attribute of food literacy that has been identified as a gap in the ability of youth to make healthy eating choices (Chagas et al. 2018; Fonseca et al. 2019; Chagas et al. 2020).

**The learning approach.** Gamified mHealth apps are a promising way to pursue food literacy (Johnson et al. 2016; Amaral et al. 2017; Dias et al. 2018; Belghali et al. 2021). However, game immersion has received scant empirical investigation in mHealth intervention research. Thereby, a game with an immersive story and characters similar to the adolescent was chosen as the learning approach to the mHealth app to improve food knowledge.
The learning content. The content was defined based on five from the ten recommendations of the 2014 Dietary Guidelines for the Brazilian Population (Brasil 2015) (Table 2).

Communication. The app uses pieces of information, instructions, and prompts/cues, in text form, to increase knowledge and to encourage the next proper choice during the game. The text development was guided by the best practices for translating scientific knowledge for dietary guidelines. The text was short (≤ 3 sentences long), concise, direct, and employed simple language. It conveyed the most important information at the beginning (anticlimactic) and was explicit in the information released (Ivens et al. 2016). A communication specialist reviewed the text and integrated colloquial terminology without compromising the precision of the communicated information. In addition, when necessary, message length was condensed or divided into two or more sentences to make it simpler for reading. A communication specialist reviewed the text and integrated colloquial terminology without compromising the precision of the communicated information. In addition, when necessary, the message length was condensed or divided into two or more sentences to make it simpler to read.

Selecting behaviour change techniques. The evidence-based behaviour change techniques were incorporated into the mHealth app to illustrate how the knowledge acquired could be applied to real-life dietary decisions and increase the attitude related to these decisions. These techniques were identified as a replicable and potentially effective approach to include in mHealth apps (Michie et al. 2009). Therefore, based on literature and taxonomy, five behaviour change techniques were chosen: feedback on behaviour; feedback on the outcome of behaviour; instruction on how to perform the behaviour; prompts/cues and associative learning (Michie et al. 2013; Simons et al. 2018; Brown et al. 2020) (Table 3).

3.2 Step 2

3.2.1 The naming process

Nutrigame – your food guide (from Portuguese, Nutrigame – seu guia alimentar) was the chosen name. The word “nutri” comes from nutrition, which is more popular and used in colloquial language as a synonym for food. The word “game” was chosen to literally represent the mHealth app type. It was adopted in English because it is a word incorporated into the colloquial Brazilian vocabulary. The use of the grammatical apposition “— your food guide” was chosen to summarize the content of the game while emphasizing the 2014 Dietary Guidelines for the Brazilian Population (Brasil 2015).

3.2.2 The narrative, plot, and user identity

Nutrigame – Your food guide is a story-based game set in the food routine of an adolescent who needs to choose what to eat, when, where, and with whom the meals will be taken. The plot is driven when the adolescent consults with a dietitian who provides guidance on how to choose healthy foods and have healthy eating attitudes. After an interval of 6 days, the adolescent returns to the dietitian to get feedback on food choices and how they have affected health. To initiate the game, the player needs to choose a female or male avatar and name it. The avatar is an adolescent character created to have diverse appearances with different racial backgrounds and facial features (Figure 1). Population (Brasil 2015).

3.2.3 Gameplay - feeding the avatar

To feed the avatar, the player assembles a meal from a menu with 40 food options. The foods and homemade culinary preparations presented on the list were strategically chosen to teach about how foods are classified according to the extent of processing, based on the concepts of the NOVA food classification system (Monteiro et al. 2016).
and if the avatar

The location choice was not appropriate (i.e.: the TV room),

player is free to continue with the choice or to change it. If

food, instructions on how to make healthy changes. Then the

ation with culinary ingredients; (d) A tip on how to combine

importance of homemade food and its balanced combina-

food, to teach the player NOVA classification. When the pla-

brief explanation of the processing extent of

parations (you made an excellent choice); a recommendation

foods, and homemade culinary pre-

3.2.4 Gameplay – location, company, and

mealt ime

Every time the player feeds the avatar, he can choose be-

between three locations: the kitchen, the living room with the

TV on, and the cafeteria. The player can also choose whether

or not the meal will be enjoyed in a company. The passage

time also counts. The clock marks the avatar's fasting

time.

3.2.5 Reinforcement

At each gameplay, through direct dialogue, the players are

repeatedly exposed to information, instructions, and

prompts/cues via text. The dialogues communicate, teach

and allow avatar development as it is possible for the player

to improve future choices along with the narrative. At the

beginning of the game, a dietitian explains how to play and

gives all instructions and recommendations. At the end of

the game, the avatar is referred to the dietitian again who gives

feedback on food decisions based on the food log. The food

log provides health long-term indicators and a food choice

analysis according to NOVA classification.

For each food chosen to compose the meal, a text box

with 4 pieces of information appears. (a) The food classifica-

tion, according to NOVA. (b) A reinforcement or an instruc-

tion: a positive reinforcement for choosing unprocessed fo-

oods, minimally processed foods, and homemade culinary

preparations (you made an excellent choice); a recommendation

for choosing processed food (should be consumed in modera-

tion) and for ultra-processed food (should be avoided); (c)

a brief explanation of the processing extent of the chosen

food, to teach the player NOVA classification. When the player

chooses a culinary preparation, an explanation highlights the

importance of homemade food and its balanced combination

with culinary ingredients; (d) A tip on how to combine

the chosen food with others, or when it is an ultra-processed

food, instructions on how to make healthy changes. Then the

player is free to continue with the choice or to change it. If

the location choice was not appropriate (i.e.: the TV room),

and if the avatar ate alone, a tip/instruction pops up after the

meal, to show the player the best choices for the next meal.

Table 3. Relationship among learning content, gamification elements and dimensions used, and the behavior change techniques implemented in the Nutrigame.

<table>
<thead>
<tr>
<th>Learning content</th>
<th>Gamification elements and dimensions</th>
<th>Behavior changes techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOVA classification</td>
<td>Tutorial with the dietitian</td>
<td>4.1. Instruction on how to perform the behavior</td>
</tr>
<tr>
<td>Act of eating and commensality</td>
<td></td>
<td>7.1. Prompts/cues</td>
</tr>
<tr>
<td>NOVA classification</td>
<td>Food menu with descriptions, positive and negative reinforcement, instructions</td>
<td>2.2. Feedback on behavior</td>
</tr>
<tr>
<td>Act of eating and commensality</td>
<td>Location, company, and time</td>
<td>4.1. Instruction on how to perform the behavior</td>
</tr>
<tr>
<td>NOVA food classification system</td>
<td>Short-term indicator</td>
<td>7.1. Prompts/cues</td>
</tr>
<tr>
<td>Short-term impact of food choices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOVA food classification system</td>
<td>Long-term indicator</td>
<td>2.2. Feedback on behavior</td>
</tr>
<tr>
<td>Long-term impact of food choices</td>
<td></td>
<td>7.8. Associative learning</td>
</tr>
<tr>
<td>Long-term impact of choices</td>
<td>Avatar's physical form and mood</td>
<td>7.8. Associative learning</td>
</tr>
<tr>
<td>Act of eating and commensality</td>
<td>The avatar's faint</td>
<td>7.8. Associative learning</td>
</tr>
<tr>
<td>NOVA food classification system</td>
<td>Food log</td>
<td>2.7. Feedback on behavior outcome(s)</td>
</tr>
</tbody>
</table>

3.2.6 Player advancement

The players’ advancement and performance are presented via

the qualitative progress indicators. The short-term indicator

(feed indicator) reflects the impact of feeding choices during a

single day. When the player chooses meals containing un-

processed foods, minimally processed foods and homemade

culinary preparations it goes up. Otherwise, the indicator

goes down when processed and ultra-processed foods are chosen.

When the avatar spends a long time without being fed, this indicator also goes down. It is reset every morning, allowing the player to change food choices. There is no connection between food calorie content and the indicator modification. Food quality, according to the processing extension, is what matters (Monteiro et al. 2016).

The long-term indicator is the overall health indicator. It changes gradually over the days according to gameplay, and in the end, it reflects the sum of choices the player has made throughout the game. Alterations in this indicator are accompanied by a change in the avatar's physical form and mood. As health improves, the indicator goes up and the avatar loses weight and improves mood. As health worsens, the indicator goes down and the avatar gains weight and worsens mood. According to the 2014 Dietary Guidelines for the Brazilian Population, controlling body weight instead of counting calories is a simple and efficient way to know if the amount of food consumed is adequate or not (Brasil 2015).

The two possible game outcomes depend on the progress of this indicator: when not reset, at the end of the 6 days the avatar will be evaluated by the dietitian. When reset, the avatar passes out and goes to the hospital, ending the game. Hence, the goals are to allow the player to understand how food choices impact the avatar's health, that food impact on health is gradual, and to teach the player how to make better food choices.
Figure 1. Screenshots of the mHealth app: Nutrigame - your food guide

Translation
Okay, now you have received all the guidelines to take care of your diet and your health. In 7 days, we will meet again to analyze your food choices. See you soon!

Menu with 40 food options and homemade culinary preparations.

Game day 1

Game day 6

Translation
Banana. Unprocessed food. You made an excellent choice! Fruits come directly from nature, ready to be consumed. Fruits such as bananas, apples, oranges, pears, persimmons and guava are excellent snack options during meal intervals and you can take them with you anywhere. Make natural foods the basis of your diet.

Translation
Food log analysis
Character name’s Days – Food amount
Health (long-term indicator’s results) Unprocessed and minimally processed foods Homemade culinary preparations Processed foods Ultra-processed foods
### 3.3 Step 3

The first version of the app was tested by a small group of adolescents (convenience sample, n=6, mean age: 15.8 ± 0.9 years) for 30 days. The participants owned different brands of Android and iOS smartphones.

No problems due to technical aspects of the app and the game interface were reported. Overall, the adolescents were positive about the game and the avatar design (Table 4A).

Participants gave two recommendations. About the food menu, the participants suggested increasing the options because they would like to feed the avatar with the same foods.

### Table 4. Example user’s perspective quotes derived from the qualitative analysis of ‘participants’ interviews.

<table>
<thead>
<tr>
<th>Dimensions evaluated</th>
<th>Example user’s perspective quote</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. User testing: usability</strong></td>
<td>(A1) [...] the interface is very intuitive. I think everything is well planned, I understood a lot. I thought it is very simple to understand. I thought it was cute [about the avatar].</td>
</tr>
<tr>
<td></td>
<td>(A5) I thought it is super interactive, it explains everything, (…) it was super cool, I liked it. I think it's very easy to understand. When you go to feed the avatar, you click on the food and the information appears. I thought it was normal [about avatar].</td>
</tr>
<tr>
<td><strong>B. User testing: feasibility</strong></td>
<td>(A3) I would put more food options in the game. [...] I had doubts about classifying the food, for example, sometimes it wasn't there, then I had to take a look, to compare what came closer, you know? Sometimes I drink coffee too, but then I put it as juice. Apart from that, I thought it is very good, and very intuitive to use.</td>
</tr>
</tbody>
</table>
| Completeness       | (A5) I think it could have a message, such as “your avatar is going to pass out”.
| **C. Engagement (User testing)** | (A1) Yes. [...] Home-made popcorn, for example, I thought it was super fatty food, you know? But, if prepared with a little oil and a little salt, it is healthy. Some foods I had no such idea. |
| **D. Formative evaluation** | (A1) The more you add ultra-processed [...] the more they [indicators] decrease, and as for vegetables, fruits, things that are made at home, [...] they increase. [...] |
| About food choice impact on the food indicator | (A4) The processed food lowered it a little and the ultra-processed lowered it more. When I chose the soda, it went down a lot because ultra-processed [food] is more harmful to health. |
| **D. Formative evaluation** | (A1) [...] because in the beginning, health did not come out of the red. With the first day it would not change that much, right? But then, over the days, I kept choosing healthier foods, her [avatar] health was increasing, then it would turn green, it was like the food indicator, you know? I think it is over time that it gets better if she is consuming healthier things. Because in association with our normal life, if you have high cholesterol, and if you eat healthy for a day, it will not improve overnight. |
| About the difference between the food and health indicators | (A4) The health [indicator] took longer to rise than the other. I think it’s not only one food that will affect health. It is a set of several ones. It increased little by little. |
| **D. Formative evaluation** | (A2) Yes. It makes you appreciate the food more, also because it is a time for socializing, [...], as it said [the game] it would be good if you didn't have a cell phone or television around, so [you're] not distracted and eat so quickly. |
| About the choice of the meal location, and the decision whether or not it would be held in company | (A6) I think this makes a lot of difference in the meal, for example, when you go to eat alone, you eat faster. When you're with someone you eat less, and talk more, then it's different. [...] when the television is on, it may be that he eats and looks at the television and ends up eating more than he should, or he doesn't pay attention to what he's eating. |
| **D. Formative evaluation** | (A1, A4) He fainted. I think it was because he didn't eat for a long time. |
| About the avatar outcomes | (A1) At the end of the week, I noticed that she changed, right? I think she got a little thinner. Because health increased as I gave her more natural foods and culinary preparations. |
| (A3) I've noticed it around the last few days. I remember that at the beginning, she was quite chubby, and at the end when the health bar was higher, she was thinner, I had this impression. |
| **E. Story immersion** | (A1) [...] because sometimes I wanted to do it according to what I ate that day, you know? I wanted to give the avatar the same thing I ate. |
| | (A3) I eat a lot of bread, so I gave it [at the avatar]. But I think I had a good diet. |
| | (A5) [...] I ate 0% of ultra-processed. That's good, I think. Processed 10%, culinary preparations, which I'm very used to, was 35%, and in natura and minimally processed 35%. |
| | (A6) [...] most of the time I ate in the kitchen because it's not very good to eat with the television on, but probably one day or two I must have eaten in the living room.
they ate in their routine during the test period. About the notifications, they suggested the inclusion of a smartphone notification to remind them to take care of the avatar. Despite the suggestions, all adolescents would recommend the app to others (Table 4B).

The adolescents liked the game a lot (median of 8.75, range, 8 - 10) and considered it with a low level of difficulty (median of 2.5, range, 1 – 4). According to the comments, the scores the adolescents attributed to the game were due to its missing aspects (Table 4C).

In the formative evaluation, the adolescents showed the expected associations between food processing and its respective impact on the short-term indicator. They were able to perceive the difference between the feed and health indicators as short and long-term indicators. The answers about the circumstances - time and focus, location, and company, showed that adolescents thoughted about the behaviours that influence eating. Thus, the adolescents showed associative learning between eating with someone and in the appropriate location with a protective, health practice. They also made the expected associations between regularity of meals, type of food, change in physical shape, and health (Table 4D).

The mean story immersion score was 30.3 ± 1.9, a value superior to the median (26, range, 13 – 39), therefore, demonstrating the participant's involvement with the game's narrative. The story immersion was also seen in the player mirroring the avatar. During the interviews, some answers showed that the players were referring to the avatar in the first person and they would like to feed the avatar the same foods they were eating at that time (Table 4E).

3.4 Final version of mHealth nutrition education app

The final version of the game was adapted to meet one of the two suggestions presented by the adolescents. As part of the reinforcement dimension, a push notification was included in the game to remind the adolescents to take care of the avatar. The inclusion of more food options in the menu was not carried out because, initially, the goal was to teach about the classification of foods according to the NOVA classification, based on a list of the most common foods in the Brazilian diet. The mHealth app is free and compatible with Android and iOS devices, and it is copyrighted by the Brazilian National Institute of Industrial Property (#BR512020000765-1).

4 Discussion

This study described the development steps and the assessment of a new mHealth nutrition education app for adolescents: the Nutrigame - your food guide. To our knowledge, this is the first study documenting the development of a new mHealth app focused on improving adolescents' knowledge of the NOVA food classification system.

The app was tested by a small group of adolescents, for 30 days. Nielsen et al. (1993) showed that usability testing with only 5 participants will reveal 85% of usability problems. In our study, the user test demonstrated that the chosen dimensions and gamification elements lead to the comprehension of the main concepts about the extension of food processing and healthy commensality attitudes. In the story immersion, the adolescents mirrored the avatar, demonstrating the involvement with the game's narrative - a critical determinant of its immersive quality that is essential to the learning goal (Green et al. 2000).

The game uses several dimensions and gamification elements (Schmidt-Kraepelin et al. 2018). The menu was designed to simulate real-world dietary choices, which may increase confidence in making real-life healthy eating decisions (IBGE 2010; Vidgen et al. 2014). For example: as the gamer plays, it is possible to make choices that lead to different endings; the performance is evaluated by several indicators; the player is repeatedly exposed to information and instructions via text.

Players' recommendations about the game – to increase the menu options, were not followed. The game's persuasive intention is to teach food classification basic concepts and the circumstances (time and focus, space and companion) that affect eating. After learning the concepts, the player should be able to classify and choose food in daily life, independent of its presence on the game list. Moreover, with this knowledge, adolescents can increase their autonomy in future food choices and can positively change attitudes regarding choosing healthy foods. Our initial data indicates that this goal can be achieved with the game, in accordance with studies that demonstrated results this nature using serious games and food knowledge (Wang et al. 2015; Wang et al. 2017; Brown et al. 2020; Chagas et al. 2020). Thus, the Nutrigame – your food guide, an mHealth nutrition education app, is a nutritional education tool, attractive to its audience, accessible and easy to use. It has the potential to improve knowledge and encourage autonomy and the intrinsic motivation to make healthy choices in real life as much as possible.

These are currently been investigated in a clinical trial. According to the ORBIT model, phase 1 is shown in this paper (Czajkowski et al. 2015). Currently, as a part of phase 2 (preliminary evaluation), the effectiveness of the game as a public nutrition education tool is being evaluated in a randomized clinical trial study with a control group. The clinical trial is registered in The Brazilian Registry of Clinical Trials (ReBEC) (#RBR-2h29zc).

This study includes some crucial strengths. An interdisciplinary team of experts was engaged in the app development process, which is a feature of high-quality digital interventions, as it ensures that all the dimensions are represented (Whittaker et al. 2012; Michie et al. 2017). The game was developed based on theory and evidence, which is a determinant of effectiveness (Czajkowski et al. 2015; Yardley et al. 2015). During user testing, several interviews were employed, associated with the use of mixed qualitative and quantitative research methods (think-aloud interviews, semi-structured interviews, and questionnaires), as recommended (Alwashmi et al. 2019). The use of multiple methods in this study provided a set of data about the user experience, and, consequently, it ensured that the game met the needs of the
target audience. Thus, this research supports the recommendations from research and OMS which strongly emphasise the importance of a gradual and iterative approach before conducting a randomized clinical trial, as they ensure the best chance of developing new and effective tools to improve health (WHO 2016; 2019).

This work and app have implications for public health. This work provides useful insights to public health researchers and nutrition educators planning to develop a mHealth nutrition education app from a practical perspective. Another one is the development of a new tool that can support educators in public health interventions, especially those related to adolescents’ food literacy. Nutrigame - Your Food Guide is attractive to its audience, accessible, and easy to use. This app can also be used in research that aims to investigate alternative strategies for nutrition education. The Nutrigame - Your Food Guide was awarded the Best Game for popular vote in the SBGames 2021, the greatest Latin American academic event in the field of games and digital entertainment.

5 Conclusion

The manuscript describes the development and assessment of a mHealth nutrition education app to improve the food knowledge of adolescents. It was constructed in accordance with a person-based approach and evidence-based behavior change techniques. The app content was based on the Brazilian Dietary Guidelines that gained notoriety in the international media and scientific community. The Brazilian Dietary Guidelines are innovative as propose that healthy food choices should be qualitative, based on food processing extension, rather than quantitative, based on calories and nutrient content. It follows the NOVA food classification system. The gamification elements chosen led to the comprehension of the main learning contents. The mean story immersion score demonstrates the participant’s involvement with the game's narrative.

This paper brings implications for practice and research. It describes all steps used for the app development, highlighting the theoretical benchmark of the stepwise approach method. Therefore, it can provide useful insights to public health researchers and nutrition educators that are planning to develop a mHealth nutrition education app from a practical perspective. In addition, it is a nutritional education tool that is attractive to its audience, accessible, and easy to use. Therefore, it can contribute to the quality of services provided by dieticians and nutritional educators.

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Notes

This manuscript is an extended version of the short paper “Efeitos do serious game Nutrigame - seu guia alimentar no conhecimento alimentar de adolescentes: um estudo piloto qualitativo de avaliação formativa”, (Santos et al. 2021), presented in the XX Brazilian Symposium of Digital Games and Entertainment - SBGames 2021.

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