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ARFood: an augmented-reality food diary app for asynchronous collaborative interaction

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Abstract: This work presents the development and evaluation of ARFood, a mobile app for cooperation between nutritionists and patients through records in a food diary, including Augmented Reality resources, Computer Vision and Artificial Intelligence for food recognition, and asynchronous collaboration. We used Unity to create the app, integrating different libraries such as LogMeal for food recognition, EDAMAM for nutritional analysis, Vuforia for augmented reality interaction, and Firebase for cloud data storage. We proceed with a pilot study with six nutritionist-patient pairs to validate the technology acceptance. Mean score results showed a medium level of acceptance by nutritionists and a satisfactory level by the group of patients (3.54 x 4.38 for perceived ease of use and 3.33 x 3.75 for perceived usefulness, Likert scale). Despite this, nutritionists and patients (83.3%) reported that they would recommend using the application as a tool for recording and monitoring a food diary. Augmented reality and computer vision proved to be outstanding resources for a Nutrition app, showing a potential usage trend as long as the insertion of more digital content and a food recognition model to recognize regional cuisine.

Keywords: Augmented Reality, Collaboration, Food Recognition, Nutrition

1 Introduction

Three-dimensional user interfaces allow the creation of applications that offer different perspectives of visualization and interaction to users, whether individual, collective, or shared [Grandi, 2018]. These solutions explore resources of immersive technologies within a context of Extended Reality (XR) [Chuah, 2018], considering representative forms such as Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR).

Some studies show that areas such as telecollaboration and data visualization have been using applications with collaborative virtual environments for a long time. As first studies, we can highlight Leigh and Johnson [1996] (VR environment for transcontinental collaboration) and Fuhrmann *et al*. [1998] (Collaborative visualization using AR). Recent approaches also continue to explore these fronts with immersive XR solutions, such as Fan *et al*. [2018] (Collaborative virtual game to support rehabilitation process for elderly) and García *et al*. [2019] (Collaborative VR platform for visualizing space data and mission planning).

However, XR technologies could present some limitations to the collaborative interaction process, such as the cost of equipment and how these applications impact a person's daily life. Rantzau and Lang [1998] describe that VR can demand a particular technology to offer good user experiences. Xu *et al*. [2023] mention that VR devices are expensive and difficult to maintain, and Vlahovic *et al*. [2024] cite that they still cause discomfort to the end-user, especially in long exposures. Tait and Billinghurst [2015] show that AR interfaces have tracking and accuracy limitations as well as usability limitations. Cordeil *et al*. [2017] point out technical obstacles such as depth of focus and resolution that still need more investment to offer a better experience. Fan *et al*. [2018] show results indicating difficulty in perception and depth control for specific groups of users (elderly).

In addition, XR devices require high computational power to render immersive virtual environments, and latency is a fundamental requirement for a good user experience [Elbamby *et al*., 2018]. This situation sometimes demotivates the user, making the use of technology secondary or hard to implement in a daily scenario. Based on Grzegorczyk *et al*. [2019], XR solutions should prioritize intuitive and easy-to-use interaction techniques that allow a multivariate and multidimensional collaborative view and that, preferably, use mobile devices.

One way to promote the regular use of immersive features and share experiences between users is through asynchronous and remote collaboration. According to Irlitti *et al*. [2016], asynchronous processes differ from their synchronous counterparts due to the cooperation occurring over some time without all parties being present simultaneously. According to Burova *et al*. [2022], this feature is beneficial to support and qualify people-to-people communication and stimulate the use of XR technology. Recently, AR mobile systems have explored asynchronous collaboration using co-annotations: a resource involving systems that inscribe annotations on an object or environment of interest to be read by others [Ens *et al*., 2019]. Among these approaches, we can highlight the creation of AR structures that persist in the physical environments [Guo *et al*., 2019] and industrial support remote apps [Reisner-Kollmann and Aschauer, 2020; Marques *et al*., 2021], showing potential for improving collaboration on visual data over distance and time.

In this context, an AR application considering Computer Vision (CV) resources to obtain information from images or any multidimensional data can offer a differentiated niche that is not explored and attractive to the end-user. Zhou *et al*. [2020] reported that CV resources are still little explored in creating immersive virtual environments or acquiring data through XR devices. Data can be analyzed and processed, creating a rich and valuable environment for knowledge and decision-making between users in an asynchronous collaborative way. It can be allowed to visualize, understand, and interact with data to draw people closer through accessible resources such as smartphones, which people use widely and are sufficient to run AR applications [Billinghurst *et al*., 2015].

One of the areas that can benefit from this kind of solution is nutrition. Professionals in this area are relevant to help individuals make educated decisions about their food choices and lifestyle and guide them in the health rehabilitation processes [Cervato-Mancuso *et al*., 2012]. They prepare nutritional diagnoses for their patients and monitor them for quality of life and change in eating behavior [Andersen *et al*., 2018]. In this contact, sometimes crucial points need a nontechnical approach to people to understand the properties of food and its benefits, selection, purchase, and preparation method. Given the complexity of eating and the change in eating behavior, investing in innovative strategies that help food choices is essential to prevent and treat obesity.

In Brazil, the prevalence of overweight in adults is over 60%, and several factors contribute to this reality [Brazilian Institute for Geography and Statistics, 2020]. The absence of food monitoring has contributed significantly to the increase in the population's weight [Freitas *et al*., 2020]. Food choices and knowledge about healthy eating stand out. Due to the COVID-19 pandemic, the Brazilian Federal Nutrition Council defined teleconsultation rules as a modality to treat patients for nutritional care [The Brazilian Federal Council of Nutritions, 2020].

Studies also show that people who keep a food diary more successfully lose or maintain their ideal weight [Fadhil, 2019]. Among the challenges of a food plan, the difficulty in understanding portion sizes can increase or reduce the total energy consumed and lead to a lower intake of micronutrients essential for health [Holmberg *et al*., 2021]. Some groups, such as athletes, follow strict diets and use scales to measure the food. However, this is not the reality for most patients, and an interactive application that brings patients and nutritionists together could contribute to this process.

With this in mind, this study presents the development and evaluation of **ARFood**, a solution that explores cooperation between nutritionists and patients through records in a food diary, including AR and CV resources, artificial intelligence (AI), and asynchronous collaboration. The proposed app can contribute to both the professional and the patient, allowing users to monitor and analyze nutritional status from different points of view using a smartphone. In addition, it is a specific solution for the Nutrition area aiming to bring actors closer to the context and usefully influence decision-making and the understanding of health based on food.

Therefore, we organized this document as follows: Section 2 highlights the material and methods applied for the conception of this study, including development libraries, ARFood presentation, test protocols, and assessment instruments; Section 3 presents the results obtained from a preliminary evaluation with users; Section 4 analyses and discusses these results, pointing trends, advantages and limitations of our approach; finally, Section 5 shows the conclusions and future work for continuing the app.

2 Materials and Methods

This section presents the resources used to build **ARFood**, a food diary app for asynchronous collaborative interaction. It has AR resources for viewing content, AI for food recognition, and asynchronous collaboration for online interaction between patients and nutritionists on Android or iOS mobile devices.

The following subsections show the app tutorial, the tools applied to implement the solution, and the methods and instruments defined to evaluate our proposal.

2.1 ARFood

The **ARFood** application is a cross-platform mobile solution for asynchronous interaction that allows recording a patient food diary, following up by your nutritionist. In addition to AR and food recognition features, it has features similar to apps in general. We designed the app under the supervision of a nutrition professional. The first version is available in the Portuguese language.

The login and registration views allow users to access their accounts hosted by the Firebase authentication system. Firebase is also responsible for creating and logging in users, saving primary data: username, email, and password.

Patients must register in the app using the mentioned data and indicate their nutritionist, previously registered in the system. Only this professional will have access to monitor and collaborate with the patient's food records. Nutritionists can also register in the app with subsequent approval of the system administrator.

After logging in, an initial menu shows four options of buttons available: 3D Suggestions (*Sugestões em 3D*), New Meal (*Nova Refeição*), Search (*Busca*) and Exit (*Sair*). The app shows a logo and a user category label (nutritionist or patient) at the top of the screen. Figure 1 presents the sequence of views for accessing the **ARFood** features.

The "3D Suggestions" option (*Sugestões em 3D*) directs the user to AR features. In this case, it is possible to point the smartphone camera at the marker cards exclusive to the application (Figure 2). These cards, once identified, can show different virtual contents to the user, such as videos, nutritional information, and 3D models, animated or not.

To demonstrate the project, we chose to use a 3D model of a breakfast meal[1], associated with the "3D View" card (*Visualização 3D*), and a video tutorial for use and demonstration of the application[2], associated with the "Videos" card (*Vídeos*).

[1] `https://shorturl.at/i3qk6`
[2] `https://youtu.be/IQJbRRf73ZA`

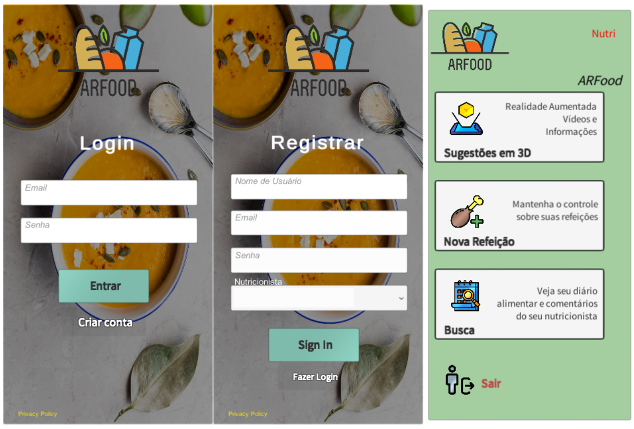

Figure 1. Login, Register (*Registrar*), and Main Menu views of ARFood.

Figure 2. AR interaction cards of ARFood.

The "New Meal" option (*Nova Refeição*), enabled only for the patient, directs the user to the food diary recording the meal. In addition, this area executes the food recognition from the registered image and displays the nutritional data of the identified ingredients using AR.

By tapping the access button, the app guides the user to capture a photo of their meal, covering all related foods, and sending the image to LogMeal's AI API servers via an HTTP request. The user visualizes results with a recognition margin greater than or equal to 55%. We defined this percentage after several empirical tests, which showed a trend towards a minimum assertive value of food recognition. After, the user must select the correct found results. You can proceed to the next registration step if the results are inaccurate. Figure 3 illustrates this procedure.

Regardless of this interaction, ARFood saves all the image processing results displayed (marked or not by the user) in the database for posterior analysis of the accuracy and error rate.

Meal registration in the food diary follows a model proposed by nutritionists [Alvarenga *et al.*, 2018] to control eating habits and the number of meals during the day. It also includes data relevant to the reason for eating, such as thoughts and feelings that can influence food amounts or eating habits.

After the food recognition step, the user can select the type of meal: Breakfast (*Café da Manhã*), Lunch (*Almoço*), Dinner (*Jantar*), Snack (*Lanche*), or Other. Your satisfaction is informed with emojis regarding the registered meal. The user enters their satiety (*Saciedade*) and hungry (*Fome*) levels using sliders (scale of 1 to 10). Two text areas are available to express who and where they were while eating (*Onde/Com quem*) and their thoughts and feelings at the time (*Pensamentos/Sentimentos*). Figure 4 shows this process.

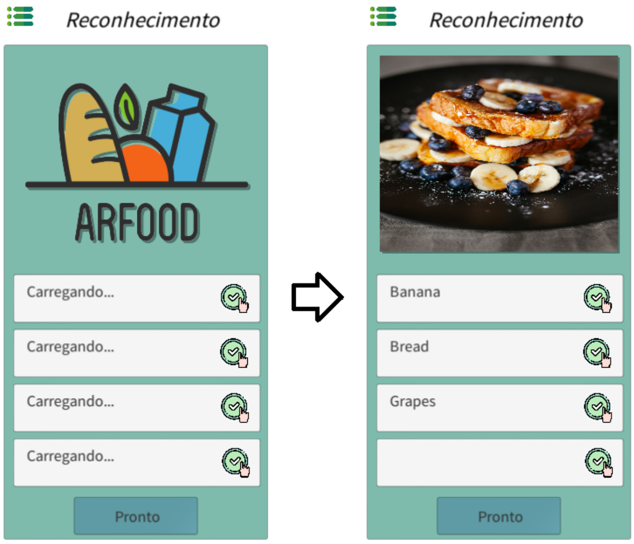

Figure 3. Food recognition (*Reconhecimento*) views of ARFood.

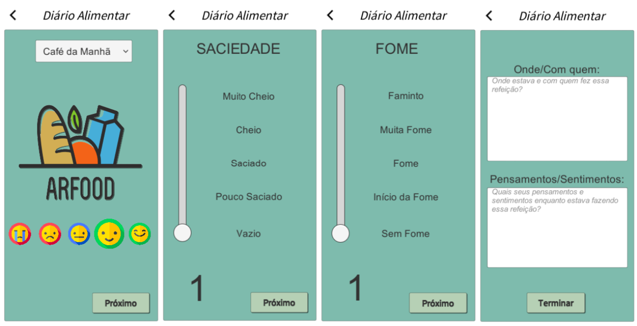

Figure 4. Food Diary of ARFood.

At the end of the registration, the user can use the "Recognition" card (*Reconhecimento*) to return to the 3D viewing area. This card is responsible for showing the nutritional data of the ingredients previously selected as correct by the user at the beginning of the new meal task. An HTTP request to the EDAMAM API returns the nutritional data, which analyzes natural language to bring up various information about the macro and micronutrients of each ingredient.

Since the app does not identify an amount of a specific ingredient within each meal, values of Protein, Carbohydrates, and Total Fat are shown in the solution considering a reference 150g portion of that ingredient. The user visualizes the return data using the AR Card through a virtual cube, ordered by recognition percentages. All data returned by the EDAMAM API is saved in the Firebase database and tied to that meal.

Figure 5 shows the virtual contents presented to the user after interacting with the AR cards supported by the application.

The "Search" option (*Busca*) allows the visualization of the food diary records by the patient and his nutritionist (Figure 6). It is possible to search by date by selecting it from the calendar, showing the meals registered on that day in ascending order of time. After selecting a meal, it is also possible to see the data saved in the food diary and the image captured.

Figure 5. Examples of AR content displayed from marker cards (from left to right: "3D View", "Videos" and "Recognition").

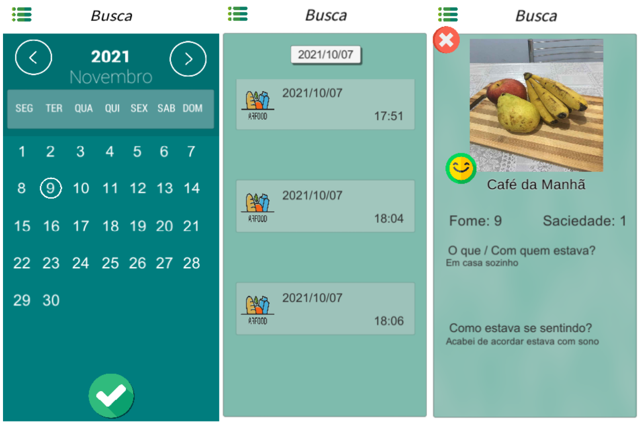

Figure 6. Food records search views by date.

In addition to personalized follow-up, the nutritionist also has the option to execute annotations over the food images using text or brush resources (Figure 7). Patients can access these annotations to maintain the collaborative aspect of the application. So, a patient shares data and images about their meals, and a nutritionist checks, analyzes and gives feedback using only the app. This space of functions tends to create a social network and a more stable approach between a patient and his nutritionist.

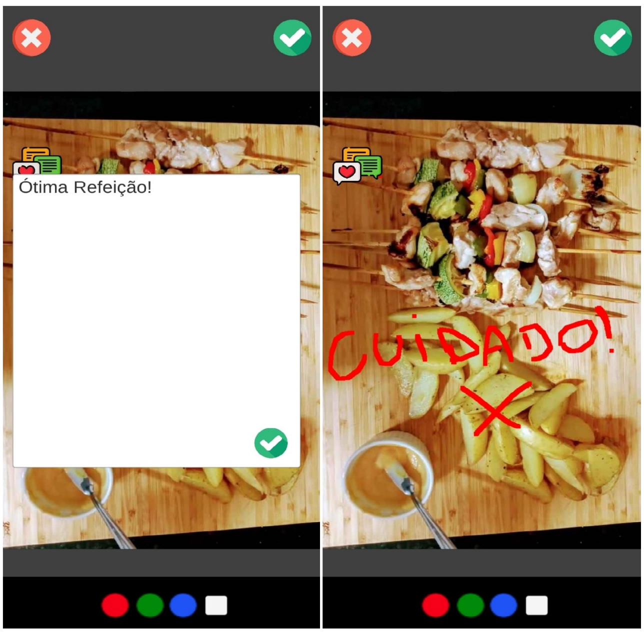

Figure 7. Editing and comments area of ARFood. Using this resource, nutritionists can provide feedback and guidance to their patients with each entry in the food diary.

The graphical user interface used components, functions, and interaction processes available in Unity, coded in C# language. In this way, we created a cross-platform version of the application, available for iOS and Android devices.

2.2 Tools

Our project considers resources to analyze images captured by the smartphone camera, send data to a cloud for image processing on a dedicated server using APIs, and generate food content to compose an AR environment. The application also stores nutritional data in the cloud and the food diary data reported by patients for further analysis and monitoring by nutritionists. With this in mind, we defined three software modules: Computer Vision, Augmented Reality, and Client-Server. Figure 8 shows the ARFood complete structuring and connections between modules.

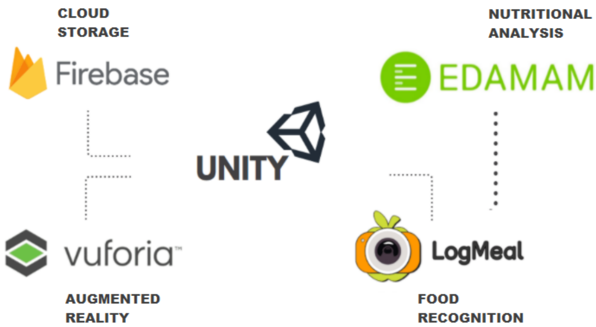

Figure 8. ARFood architecture.

For the app creation, we analyzed development platforms that use cross-platform frameworks such as Ionic [2021], Flutter [2021] and React Native [2021], as well as game engines such as Unity [2021] and Unreal [2021], and the native development for Android and iOS. As a result, we chose Unity as the base tool for the application project, considering its gamified character, for offering resources for cross-platform development, and for facilitating the integration of different libraries and additional resources in a single tool. Also, as part of the initial idealization of the project, the exploration of 3D data visualization systems encouraged the use of a game engine such as Unity, once it is free and one of the most used by the related work.

The **Computer Vision Module** considers all the processes used to obtain and generate data from images. For its development, we added resources of LogMeal [2021] API, capable of recognizing food images with AI models. Through the image sent via HTTP request, this API provides different levels of recognition, such as identifying ingredients, food types, cuisine present in the dish, and results received in the form of text supporting various languages. For this study, we chose the English language.

We selected LogMeal after analyzing different APIs with the same recognition proposal. The following were tested and analyzed: Calorie Mama [2021], Bite AI [2021], Clarifai [2021], Foodai [2021] and LogMeal. The vast majority of the analyzed APIs were paid and expensive. LogMeal is also a paid tool but offers a limited free use for 200 requests per user or 30 days open. It also presented better food recognition, stability, and more effective results than the others.

LogMeal presents the results of its recognition organized as follows: food types (divided into *food, drink, ingredient, sauce, combination dish and non-food*); food groups (divided into *meat, dessert, dairy products, seafood, rice, fruit, noodles/pasta, vegetables, fish, bread, fried food, egg, and soup*); single dishes (divided into *food, drink, ingredients and sauces*) and multiple dishes (divided into *meats, fishes, vegetables, side dishes, condiments, and other*). For the Computer Vision Module, we decided to recognize specific ingredients through the image of the meal sent by the user.

From these results, we decided to use natural language processing to show text outputs considering resources from EDAMAM [2021] through a new HTTP request. This API provides nutritional data related to the results found by image recognition, organized into macro and micronutrients, and saved in our database for later display to the user.

The **Augmented Reality Module** is responsible for building the virtual environment, with support for navigation and visualization through interaction techniques. To this end, the project chose to use the resources of the Vuforia AR [2021], integrated into the Unity Engine. In particular, we adopted the AR *templates* for cross-platform development offered by the tool, facilitating the insertion of virtual resources throughout the interaction process with the application.

The features available by the Vuforia Engine SDK have proved particularly useful within the context of the application. In this sense, we tested several of the *templates*, among them the object targets, which provide an AR visualization of data from objects. We applied VuMarks, custom AR markers that can link to data; real-time cloud recognition, providing yet another way of identifying AR markers; and geometric recognition, where the 3D content view considers the geometric shape of objects. Based on the recognition forms presented by Vuforia, the 3D content is created in a gamified way by Unity and linked to food recognition results to facilitate end-user interaction.

We created personalized markers to allow visual recognition of any camera's angle of view, considering information linked to them. The app also supports different AR markers simultaneously, providing a new form of data visualization between patients and nutritionists.

The **Client-Server Module** includes functions for collecting and retrieving data, acting as a communication bridge between the processes managed by the other modules. For its design, the technology chosen was Firebase [2021], given its character of real-time data manipulation and file storage. The Firebase functions were coupled with their SDK in the Unity project and used natively and cross-platform within the game engine.

As part of the Client-Server module's functionalities, Firebase proved to be a good option for development as it encompasses different aspects of functionality, both for persistence and storage. Firebase offered a simple, non-relational way of storing JSON files containing food registrations. In addition, it provided secure cloud storage to save different daily images registered by app users in their food diaries. Integration with Unity was confirmed simply from tutorials for the SDKs provided by Firebase.

2.3 Evaluation

After the app development, we considered a pilot study to verify the acceptance and usefulness of the tool. We also defined this stage under the supervision of a nutrition professional.

Our project was approved by the Ethics Committee of the University of Passo Fundo, Brazil, under number 48792721.4.0000.5342.

2.3.1 Sample

The evaluation process is a quasi-experiment, with non-probability sampling (convenience sampling) and adapted from the phases suggested by Wohlin *et al*. [2012].

For the study, we invited 30 nutritionist participants through social networks: Instagram, Facebook, and WhatsApp. We send initial information about the project, how to indicate a patient and a demonstration video of the application. We waited one week for a positive or negative response to the invitation.

After this period, we consolidated our sample size. The sample consisted of 12 subjects, evaluated in nutritionist-patient pairs following the models of Tait and Billinghurst [2015], totaling six nutritionists and six patients indicated by them. To calculate the sample, we considered a confidence level of 95%, a statistical power of 80%, a sampling error of 5%, and a proportion of 50%.

2.3.2 Study Design

As exploratory and technological research, the study considered evaluating the user's acceptance and usefulness of the **ARFood** application. It consisted of three stages: characterization, testing, and validation. All stages collected data through software, and we used direct contact by email and WhatsApp. As inclusion criteria, we accepted nutritionists and their indicated patients.

In the characterization stage, each participant received a link to a Google Forms form instructed to read and fill in the following instruments:

- Informed Consent;
- Sociodemographic and Characterization Questionnaire.

During the training stage, each pair of participants (nutritionist-patient) received a video demo explaining the experiment stage, passing the project purposes and instructions about how the software and devices work. We also offered a moment to help install the app, ask questions, and execute training tasks using our tool. This period took eight days.

Next, the asynchronous collaboration experiment began, where each subject interacted daily with the app for eight days.

It is important to note that the data collected during the experiment stage served only and exclusively to assess the acceptance and usefulness of the software (and not the participants' performance). During the experiment, the researcher could not answer user questions.

In the evaluation stage, participants received online instruments to evaluate the experiments through a Google Forms link. We assessed how users came to accept and use our technology. We also prepared additional questions to consider general aspects, AR resources, and food recognition features. The following subsection presents the assessment instruments mentioned.

2.3.3 Assessment instruments

To assess user acceptance, we applied TAM (*Technology Acceptance Model*) [Davis *et al*., 1989], a model designed to understand the causal relationship between external variables of user acceptance and the actual use of the information system. We used this model to create our instrument, considering 16 questions, detailed by subsection 3.2. The model suggests two primary factors influencing an individual's intention to use new technology:

- Perceived usefulness: the degree to which a person believes using a particular system would enhance their job performance.
- Perceived ease of use: the degree to which a person believes using a particular system would be free from effort.

Our study also added some specific questions. We considered open questions to collect positive and negative aspects of the solution, impressions about the asynchronous collaboration between the actors, and opinions about AR resources and food recognition. We also used closed questions to consult the use of resources and the indication of the ARFood app for other people to use. A closed-ended question asked whether the food recognition results (returned in English) made it difficult to comprehend. A final open-ended question provided space to record app improvements and other comments.

We presented all instruments written in Portuguese and were available to fill after the experiment stage for 14 days. The additional file presents the **Assessment Instruments** mentioned and used for the pilot study in the English version.

3 Results

This section presents the results obtained in the experiment with 12 volunteers, with statistical data analysis. From this, there is a discussion of the results, highlighting the advantages and limitations of the study.

3.1 Sample Characterization

The Sociodemographic and Sample Characterization Questionnaire was applied to know the groups. For each aspect of the questionnaire, we obtained the following results:

- Gender: five nutritionists and five patients selected the "Female" option. One nutritionist-participant and one patient-participant selected "Male". None chose the option "I prefer not to inform";
- Age: ranged from 22 to 54 years old (32,61$\pm$10,33). For the six nutritionists, the general age variation was the same (30,67$\pm$9,96). For the six patients, the ages ranged from 24 to 53 years old (34,56$\pm$10,34);
- Education: one participant has completed secondary education. Four participants have completed undergraduate education. The other seven participants already have completed graduate education;
- Mean regular use of apps: Seven participants indicated using up to five apps per day, four indicated using up to 10 apps, and only one marked use of 10+ apps per day;
- Most daily used apps: WhatsApp, Instagram, and Facebook were the most cited;
- Vision problem: considering a scale of 1 (mild) to 5 (severe), participants could indicate some vision difficulty. Two scored on the level 1 scale;
- Smartphone OS and model: seven participants reported using the iOS operating system, and 11 indicated using the Android. All participants indicated different models of the device.

Based on these results, we analyzed our sample considering only the nutritionist and patient groups, using descriptive statistics.

3.2 TAM - Means

Our TAM had 16 questions using a Likert scale from 1 to 5, eight for nutritionists and eight for patients. The results are shown in Table 1, Table 2, Table 3 and Table 4. The results represent the answers given by the 12 participants (six pairs).

Regarding the perceived ease of use by nutritionists, we used the following statements in the assessment instrument:

(a) It was easy to learn how to use the ARFood resources;
(b) It was easy to execute tasks relevant to me using ARFood;
(c) It was easy to become skilled using the various options in ARFood;
(d) ARFood was easy to use.

Table 1. TAM for nutritionists: "Perceived ease of use" means.

Statement	Mean	SD	VAR
(a)	3.50	0.96	1.10
(b)	3.17	0.69	0.57
(c)	3.83	1.07	1.37
(d)	3.67	0.94	1.07
Total Mean	***3.54***		

Regarding the perceived usefulness by nutritionists, we used the following statements in the assessment instrument:

(e) Using ARFood has improved my performance in treating my patients;
(f) Using ARFood has increased my productivity in my work environment;
(g) Using ARFood has improved the effectiveness of caring for my patients;

Table 2. TAM for nutritionists: "Perceived usefulness" means.

Statement	Mean	SD	VAR
(e)	3.17	0.69	0.57
(f)	2.83	0.37	0.17
(g)	3.50	0.76	0.70
(h)	3.83	0.69	0.57
Total Mean	***3.33***		

(h) Using ARFood was usefulness for the attendance of my patients.

Regarding the perceived ease of use by patients, we used the following statements in the assessment instrument:

(a) It was easy to learn how to use the ARFood resources;
(b) It was easy to execute tasks relevant to me using ARFood;
(c) It was easy to become skilled using the various options in ARFood;
(d) ARFood was easy to use.

Table 3. TAM for patients: "Perceived ease of use" means.

Statement	Mean	SD	VAR
(a)	4.50	0.50	0.30
(b)	4.17	1.07	1.37
(c)	4.17	0.69	0.57
(d)	4.67	0.47	0.27
Total Mean	***4.38***		

Regarding the perceived usefulness by patients, we used the following statements in the assessment instrument:

(e) Using ARFood improved my performance in recording my food choices;
(f) Using ARFood increased my interest in managing my food choices;
(g) Using ARFood improved the effectiveness of contacting my nutritionist;
(h) Using ARFood was usefulness for recording my food choices.

Table 4. TAM for patients: "Perceived usefulness" means.

Statement	Mean	SD	VAR
(e)	3.83	1.07	1.37
(f)	3.83	1.46	2.57
(g)	3.17	1.57	2.97
(h)	4.17	1.21	1.77
Total Mean	***3.75***		

3.3 TAM - U-test

We applied the Mann–Whitney test (U-test) to observe the data obtained by the evaluation instruments and test the heterogeneity. We chose this method due to the small sample size and non-normal distribution. The U-test is the non-parametric version of the Student's t-test.

For the Mann-Whitney U test (two-tailed, $p < 0.05$), we considered the following hypotheses:

- Alternative Hypothesis: there is a difference in user technology acceptance between the "Nutritionists" and "Patients" groups;
- Null Hypothesis: there is NO difference in user technology acceptance between the "Nutritionists" and "Patients" groups.

The results showed no significant difference between the groups considering the means in the TAM assessments, confirming the null hypothesis.

3.4 App usage frequency

Based on the patients' food records, we observed the periods of the day these participants most used the application. Figure 9 presents this data, considering the access to the application during the training and experiment periods.

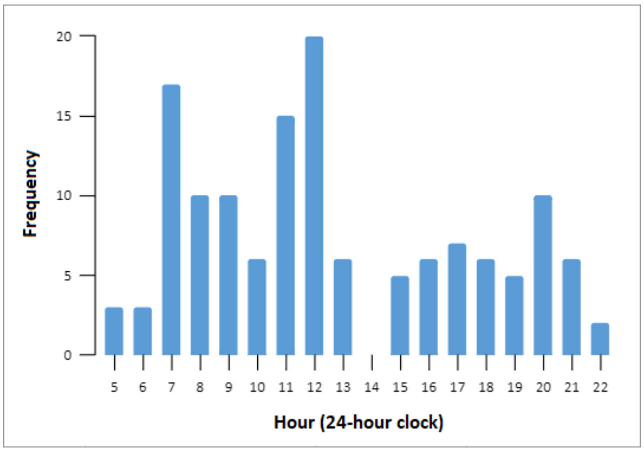

Figure 9. Histogram presenting the ARFood usage frequency per time of day by patients.

Considering the database registers, we could verify the number of daily records of each patient and the number of assessments made by nutritionists. Figure 10 and Figure 11 present the recording and feedback behavior in the food diary by patients and nutritionists, respectively. Figures represent each patient-nutritionist pair using the same color. In this way, it is possible to analyze the frequency of use of the application in detail.

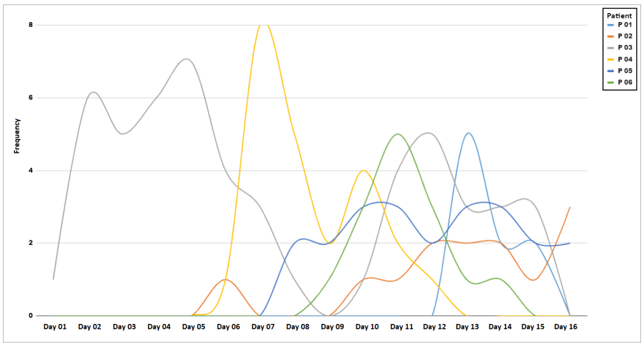

Figure 10. Daily use by patients of ARFood app (times per day), recording meals in the food diary.

3.5 Food Recognition

To evaluate the performance of the LogMeal API in identifying foods, Table 5 presents the number of significant suggestions shown by the tool and the percentage of correct answers

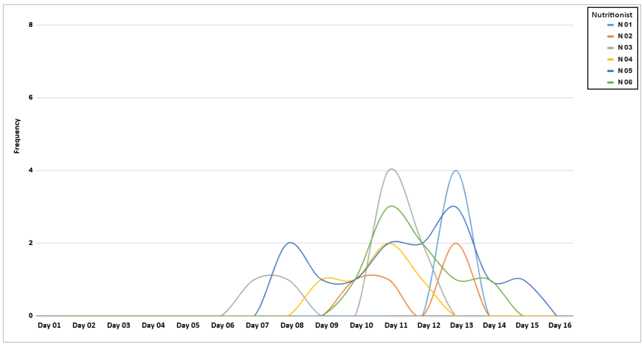

Figure 11. Daily use by nutritionists of ARFood app (times per day), returning feedback to each food diary entry.

based on the patient's confirmation of each meal recorded in the application.

Table 5. Food recognition results considering recorded meals and patient-confirmed foods.

Patient	Confirmed Suggestions	App Suggestions	Hit Rate
P1	7	15	46.67%
P2	3	24	12.50%
P3	6	19	31.58%
P4	0	25	0.00%
P5	51	92	55.43%
P6	6	13	46.15%
Total	**73**	**188**	**38.83%**

4 Discussion

We conducted the study with six Nutritionist-Patient pairs using our app, aiming to offer a differentiated environment for interaction and collaboration. We oriented each patient to enter records of their meals during the day during the training and experiment stages. Similarly, we instructed each nutritionist to proceed with the records' monitoring and evaluation of their patients, preferably daily. We motivated the participants to use food recognition and AR resources constantly.

In this context, we could infer that the participants accepted the app as a new type of nutritional process within those already used by the groups (face-to-face service and private messages through applications such as WhatsApp). According to the reports, we noted that the tool could contribute to the closer monitoring of programs made by nutritionists for their patients. We also observed that the specificity of the solution allowed a better organization in the recording and monitoring of meals and that the AR resource proved interesting in presenting food and nutritional data from the recognition.

Considering TAM results, we can highlight that nutritionists' evaluation presented lower acceptance means than the patients for perceived ease of use and perceived usefulness. These factors lead us to believe that the professionals were more resistant to using the solution. We suspected that the proposed interaction processes destined by patients and the technological resources used in the app were more difficult for nutritionists to assimilate, who may have understood that the application is of little practical use in their care routine.

One can try to explain that the medium acceptance of nutritionists is related to the app functions, which were supposed to have a better adaptable focus on patients. In the nutritionist's version, the app only allowed access to the options of "Suggestions in 3D" and "Search" to explore the AR resources and follow-up and feedback to patients, respectively. Nutritionists created an extra account to simulate use as a patient exploring the food record option in "New Meal". None of the nutritionists explored this process, although we advised about this option during the training.

As for the patients, the TAM results were higher, with the ease of use of the application becoming more evident and its perceived usefulness having a higher mean than the answers given by the nutritionists. These values lead us to believe that the application was better accepted by the patients, with the technologies used showing better acceptance in the proposed nutritional processes.

It's worth highlighting the use of the app by nutritionists had a direct impact on their patients, based on the principle that it was necessary for the nutritionist responsible for the patient to generate feedback content in the posts and food information of his patient. Evaluation instruments asked patients about their impressions of the collaboration offered by the app, and one of them mentioned: "Almost none since I had no feedback if my nutritionist viewed my meals through the app". With this in mind, many of the patients' food posts were not analyzed by their responsible nutritionist regularly, generating gaps in use and collaboration between the two. This phenomenon can be seen in the results presented in Section 3.4, generating a slightly lower mean in perceived usefulness, especially in question (g) of patients, where the effectiveness of contact with their nutritionist was low. Figure 11 and Figure 10 show this fact, showing that the number of patient records is greater than the amount of access by nutritionists. These data also corroborate the inferences about the technology acceptance.

Another detail about the app frequency use is that most participants did not use the solution during the training and concentrated use during the experiment. Considering the adherence and patients' acceptance, we believed that the features of ARFood were intuitive and easy to understand. The lack of training previously may have interfered with the nutritionists' acceptance when they needed to monitor their patients' records.

Still, concerning the frequency of use of ARFood, we observed higher usage from the morning until noon and moderate usage during the afternoon and evening (not used at night). This panorama showed that the records probably occurred at or close to meal hour. In the next app version, this data could be available to nutritionists, helping them to track profile patients' feeding routines.

We asked about the AR resources and their opinion about this functionality. Half of the participants reported having explored this resource. One of the nutritionists cited that the feature is "It is fascinating, I think it would be useful to use with children and teenagers", yet another wrote "I liked it! It would be interesting if the database were bigger to perceive more foods. But this strategy was interesting because the patient loved it and found it cool! She liked it a lot!". This positive feedback from the perspective of nutritionists may demonstrate that this type of technology has the potential for more frequent use in Nutrition. Regarding patients, those who used it commented that it was "Interesting, something new and different, fun" to view food and nutritional data from a new perspective.

On the other hand, some nutritionists and patients reported that they ended up "not being able to print the cards and when using the application, I thought that only the patient could do this"; or "I used it a few times, it took me a short time to do it, but they seem very useful in the evaluation of the results"; or "I didn't use it because I didn't quite understand this functionality". Such limitations showed difficulty or restrictions to the AR technology.

In addition, for the AR resource to be more attractive to the user, we understand that ARFood still needs to offer more digital content for users to explore. Due to time constraints and dependence on creative professionals, the project cannot make a variety of media available throughout its conception. We know that integrating more virtual elements into the app's view mixed with the real world, plus the possibility of collaboration through the simulated environment, could stimulate curiosity and encourage more frequent use of this technology. However, we still need more support from Nutrition professionals to define which 3D and AR approaches may be relevant to the context.

Another detail we could not evaluate was the joint and collaborative use of AR markers with each pair of participants in the process. The idea would be to point the camera of each user application to the cards, whether they have the same or different proposed contents. This form of cooperation cannot be verified and analyzed due to issues of difficulty in meeting between the parties during the COVID-19 pandemic restrictions.

From the API food recognition results, we calculated a hit rate of 38.83% considering suggestions marked as correct by the users. In this context, we noted one participant did not use food recognition resources biasing the final result. She received 25 recognition results but did not mark any as correct. Disregarding this fact, we would obtain a hit rate of 44.79%. We understood that, by having only English as the API recognition return and the app in Portuguese, the language made it difficult for non-fluent users to mark the recognitions that could eventually be correct.

Moreover, it is possible to identify from the food diary records that the descriptive areas such as "Thoughts and Feelings" as well as "With whom I was" were the least filled, showing a reluctance either to the questions or to the typing gesture of some people's dialog boxes.

Finally, we asked nutritionists if they would recommend ARFood to other nutritionists or new patients. Only one nutritionist answered no, claiming that there are already similar apps but not citing which ones. This nutritionist also highlighted that the differential of our app is AR. So, we can infer that adding more AR content and interaction options tends to improve technology acceptance.

4.1 Study Limitations

Some of the limitations of this study are related to the difficulty of identifying foods by the APIs found. We could not analyze the hit rate of paid APIs, thus limiting the choice of this type of technology. The food recognition results of the API in English also presented as a limitation for users once the app used Portuguese as the base language.

The low hit rate of the API tested showed that this functionality needs to consider better AI models for food recognition. A crucial factor related to this was the inadequacy of the food recognition API with Brazilian cuisine because it supported only European and North American cuisine. We confirmed this scenario by the users' feedback in the open-ended evaluation questions, where they reported that recognition was seldom accurate to hit all the ingredients on the dish.

We noted some problems in navigation features in the graphical user interface pointed out by the participants. These limitations appeared because we opted to develop the app using only game engine resources. Maybe specific mobile development frameworks could contribute to generating a more user-friendly and intuitive interface.

The small sample size may also have influenced the results obtained. Despite being a pilot study, the heterogeneity of the sample contributed to a lower statistical relevance.

Participants suggested adding photos from the gallery when they will include a new meal. This feature would allow them to complement the registrations after meals and not force them to use the app during a feed.

Some participants also pointed to the lack of application persistence as a restriction. One of the participants claimed that "it would be interesting to maintain logged in so that we don't have to log in with the account every time we need to use it". This constraint existed because we opted for the Firebase free version, allowing only this type of user persistence to login and logout options. It is an aspect that could be revised and incorporated in a future app version, considering paid packages.

Participants reported the impossibility of editing the data recorded in the food diary, for example, in the option to mark the meal satiety. The current resource could only accept an answer during the new meal registration. The best time to answer this question would be after the end of the meal. It is a change we could implement in the future version, plus the option to add photos from the gallery.

Some participants suggested using the app offline with recognition functions or an internal database to recognize previously recognized foods. We discarded it in the application design because we would need to incorporate a recognition model into the solution, potentially consuming more device resources. This processing could demand a lot of computational power, making their use hard on cheap mobile devices.

4.2 Advantages of using ARFood

First, one can highlight as an advantage of this project the offer of a specific support tool with recent technologies, which can contribute to the daily life of health professionals and their clients, digitally bringing the nutritionist and the patient closer. The ARFood development app is the main contribution of this work, showing that applying AR and CV resources can make filling out and following up a food diary app more attractive for patients and nutritionists. A pilot study around nutrition can show, preliminarily, that the application has good acceptance and is easy to use, engaging patients.

The online collaboration resources, AR, CV, and AI, available on ARFood also contribute to the information visualization and the continuous monitoring of the food program proposed by the nutritionist and the nutritional status of patients. These features could help patients make health decisions with constant guidance from their nutritionists. Furthermore, it is a cross-platform solution (Android and iOS) that facilitates its dissemination.

Nutritionists, in the practice of their profession, and their patients seeking to learn better about healthier eating habits can explore ARFood resources. Positive points highlighted in the comments and responses of the participants reflect it, especially the questions about the asynchronous collaboration that the app provides.

Nutritionists wrote some positive points that are very welcome to the application, such as "The central idea of the application is excellent as it brings the connection between professional and patient even closer". Another said that the application "Made it possible to see the patient's meals daily, allowing for greater care and better care with the same in re-appointments". Such comments evidence the contact between the parties provided by the application.

One of the patients pointed out that "it made him rethink food choices" and found "the integration between nutritionist and patient is interesting to make possible to monitor results closely". The solution also contributed to "taking stock of food choices and feelings when eating, being aware of satiety and the quantities needed in meals".

Another patient indicated that "the application was positive in bringing me closer to nutritional monitoring" and that "the application made it possible to get even closer to nutritional monitoring". It provided "ease of placing information" and "facilitated communication" with nutritionists. Other user reports highlighted that ARFood helped "improve my food choices" and "improve the relationship with my nutritionist about food doubts", showing that the application's functions proved valuable.

Other patients also reported that "it was interesting to share hunger and satiety, which the other app we used didn't allow". This statement also serves as an ARFood differential, illustrating features not present in applications previously used by participants.

Regarding the indication of ARFood by nutritionists to other people (other colleagues or patients), five participants responded positively (83.3%). Only one nutritionist claimed that he would not recommend it to other professionals, claiming that "nutritionists who use calculation software already have applications that perform the same function as the ARFood app" but not specifying which one.

We also asked patients if they had recommended ARFood to their network of contacts. Similarly, five participants answered yes to the question (83.3%). Only one patient claimed improvements in the food recognition resource and answered no: "It would have to have a database. If the photo didn't recognize it, it would have to have the option to write".

This result indicates that the application has a possible novelty differential in the market, and it may be relevant to evaluate it with a more extensive number of users.

Finally, ARFood is a computer program registered with the Brazilian Institute of Industrial Property, patent number BR512021002784-1.

5 Conclusion

Our work presented the development of ARFood, a cross-platform app for asynchronous collaborative interaction through records in a food diary. The solution enabled a new way of approaching patients and nutritionists, helping them monitor and acquire knowledge about food through CV, AI, and AR resources. A pilot study involved 12 volunteers divided into six nutritionist-patient pairs.

Our project considered the conception of an app relevant and useful for end-users as a guideline, choosing the Nutrition area as a case study and applying AR and CV resources to make a food diary manipulation more interactive and attractive. As a result of this design and development process, an outstanding product was generated for nutritionists and patients, standing out as the main contribution of this work.

Results from user technology acceptance and general resource evaluation questionnaires highlighted a medium acceptance rate of nutritionists and weak asynchronous collaboration with their patients. Nutritionists used AR features occasionally and presented difficulty using the food recognition options due to the language. Despite this, we inferred from the general assessment that nutritionists understood the method as attractive and helpful for a long time.

On the other hand, the technology acceptance by patients was satisfactory. This fact is related to engaging ARFood features, which proved to be more adaptable to the patient's point of view. We understood that the application could have an even more satisfactory result if nutritionists had given more feedback and support to the patient via the app. This situation would help strengthen the relationship between these actors. Regarding the AR, it showed potential to present virtual content.

From the pilot study, we identified some crucial points that must be improved or added to the application, namely:

- improvements in the form of login/log off session;
- post-editing of patients' food diary data (satiety and meal photos);
- design improvements (visual elements) and graphical user interface features;
- indication/notification of pending meals to the nutritionist evaluates;
- use of the Portuguese language for food recognition;
- available an app version in the English language;
- adding more AR content to the app;
- adding AR resources on food during photo capture to show nutritional information and nutritionist recommendations based on the meal plan.

In future work, we suggested an API or AI resource to recognize foods considering Brazilian or regional cuisines, improving identification accuracy. We also recommended a new evaluation considering more sample volunteers after the mentioned improvements.

Declarations

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and materials

Due to the nature of the research, due to ethical and legal restrictions, supporting data and materials are not available.

Ethics approval

This study was approved by the Ethics Committee of the University of Passo Fundo, Brazil, under number 48792721.4.0000.5342.

Consent to participate

Informed Consent Form was signed by the study participants and approved by the Ethics Committee of the University of Passo Fundo, Brazil, under number 48792721.4.0000.5342.

Authors' Contributions

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