Article

Stance4Health nutritional APP: A Path to Personalized Smart Nutrition

Daniel Hinojosa-Nogueira[1,2,†], Bartolomé Ortiz-Viso[3,†], Beatriz Navajas-Porras[1,2], Sergio Pérez-Burillo[1,2]; Verónica González-Vigil[4], Silvia Pastoriza de la Cueva[1], and José Ángel Rufián-Henares[1,2,*.]

[1] Centro de Investigación Biomédica, Departamento de Nutrición y Bromatología, Instituto de Nutrición y Tecnología de los Alimentos, Universidad de Granada, 18071 Granada, Spain; dhinojosa@ugr.es (D.H.-N.); beatriznavajas@ugr.es (B.N.-P.); spburillo@ugr.es (S.P.-B.); spdelacueva@ugr.es (S.P.d.l.C.)

[2] Instituto de Investigación Biosanitaria ibs.GRANADA, Universidad de Granada, 18071 Granada, Spain

[3] Departamento de Ciencias de la Computación e Inteligencia Artificial, Universidad de Granada, 18071 Granada, Spain; bortiz@ugr.es

[3] Gestión de Salud y Nutrición S.L., 33003 Oviedo, Spain; vgonzalez@gsnsoft.es

[*] Correspondence: jarufian@ugr.es; Tel.: +34 958 24 28 41

[†] These authors contributed equally to this work

Abstract: Access to good nutritional health is one of the principal objectives of current society. Several e-services offer dietary advice. However, multifactorial and more individualized nutritional recommendations should be developed to recommend healthy menus according to the specific user's needs. In this article we present and validate a personalized nutrition system based on an application (APP) for smart devices with the capacity to offer an adaptable menu to the user. The APP was developed following a structured recommendation generation scheme, where the characteristics of the menus of 20 users were evaluated. Specific menus were generated for each user based on their preferences and nutritional requirements. These menus were evaluated by comparing their nutritional content versus the nutrient composition retrieved from dietary records. The generated menus showed great similarity to those obtained from the user dietary records. Furthermore, the generated menus showed less variability in micronutrient amounts and higher concentrations than the menus from the user records. The macronutrient deviations were also corrected in the generated menus, offering a better adaptation to the users. The presented system is a good tool for the generation of menus that are adapted to the user characteristics and a starting point to nutritional interventions.

Keywords: computational nutrition; meal plan generator; nutritional app; nutritional intervention; smartphone application; diet app; diet record.

1. Introduction

Healthy eating is one of the most important health challenges in the current global context due to its role on disease prevention [1–3]. Unhealthy diet is one of the main risk factors for several diseases, being responsible for some 14 million deaths each year [4]. Adherence to a high quality diet or a prudent dietary pattern has been reported in several studies to be inversely associated with a reduced risk of mortality [1,5]. Therefore, countries are trying to promote healthy lifestyles by developing dietary and health guidelines and recommendations [5]. One of the main difficulties found is that individual responses to dietary advice and intervention are heterogeneous, which shows the need to develop precision or personalized nutrition (PN) for each individual [6]. There are different "levels" of customization, from simple questionnaires to personalized supplements [2]. PN involves many factors, such as nutritional intake, physical activity, individual characteristics specific to each person, dietary advice, dietary products and supplements, health biomarkers, gut microbiota composition and even genetic load [2,6]. All this helps to understand and create a personalized nutritional guide for each individual. Although PN is

still a relatively young phenomenon, such is the interest that the European Union (EU) has generated a regulatory framework around PN [2]. PN has great potential for disease prevention, especially when combined with the power and accessibility to mobile technology [7].

Advances in technology have led to an ever-increasing use of electronic devices such as tablets and mobile phones. More than five thousand million people around the world are estimated to own mobile devices, and more than half of them are smartphones [8]. Not only adults are using these devices, but children and teenagers are becoming the main users [9]. One of the main advantages of these devices are the mobile applications (APPs, which are used for a multitude of things (games, shopping, public services and other functions) [4]. There is currently a growing interest in mobile health applications (mHealth) for health promotion and prevention of chronic diseases. mHealth has great potential, especially in terms of cost-effectiveness and innovation [4,10,11]. Currently there are an estimated 300,000 mobile health applications available, of which around 10,000 are about nutrition and diet, and some of them are very popular in terms of user downloads [12–14]. Diet-related APPs ranked second in the 'health and fitness' category of the Google Play Store in 2020 in countries such as Italy [13]. However, it is also worth noting that, due to the overload of nutritional APP and its possible economic revenue, it is key to differentiate between those that have a scientific basis and those that do not. Not all APPs available to consumers are always reliable, useful and of high quality, nor are health professionals or researchers involved in their creation. Most of the time, a bad approach can have counterproductive effects on health or lead to poor eating habits.

In terms of how diet and nutrition-focused APPs work, their approaches are very varied: some are able to record dietary intake and physical activity, others try to score and compare foods; few APPs are able to generate a meal plan or a healthy shopping list; some are even able to set goals or receive continuous feedback on dietary behavior [1,14–16]. These APPs can not only improve diet and make it healthier, but they can also help people with nutrition-related diseases, such as obesity, food allergies or intolerances [13,17]. APPs can offer more possibilities due to artificial intelligence (AI), which is essential for understanding complex biological phenomena [14,18], and combined with the use of big data and machine learning can benefit PN [6]. APPs-based interventions have been shown to be effective in improving diet and the results are comparable to those of traditional non-digital interventions [11]. They also increase follow-up rates an user motivation [5,17].

These technologies have several advantages over conventional methods: they are not dependent on respondents' memory since they register food in real time [19], they are based on portable devices and have a better social acceptance [18,20]. In research, they also help to decrease workload, and reduce time and the risk of transcription errors [16,18]. However, there are some limitations, mostly concerning data accuracy, limited nutrient or food data, subjectivity in the scales provided or in estimating portion sizes and digitally illiteracy [20,21]. Therefore, APPs are often supported by different chemical, electrical or physical sensors [6,14,18]. Mobile and portable sensors are non-invasive and are able to monitor variations and provide real-time guidance [6,18]. Examples include sensors that measure glucose levels or sweat compounds [6], using the camera as a barcode reader to recognize food labels or algorithms for automatic recognition of food portions from pictures [18]. Wearables such as wristbands or smartwatches are the most popular health monitoring devices, whose technology has advanced quickly in recent years [14]. Due to their feasibility, cost-effectiveness and immediacy of data collection, personalized nutrition APPs combined with emerging technologies or wearables can be an effective method in nutritional interventions [8,12,18,22].

Therefore, one of the goals of the Stance4Health (Smart Technologies for personAlised Nutrition and Consumer Engagement; S4H) project [23], financed by the European Union's Horizon 2020 program, is to create and offer, with the help of new technologies and rigorous scientific support, a PN service through the use of an APP. This study shows the APP created in the framework of the project after a close collaboration between APP
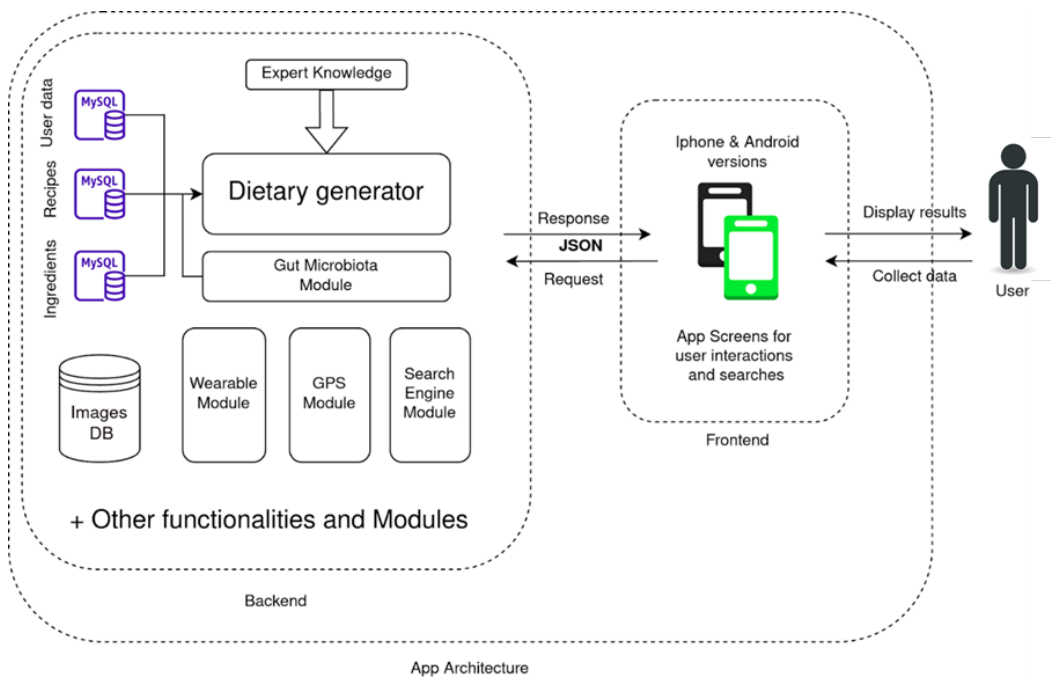
developers, nutritionists and scientists from different areas, all in order to create a rigorous and quality APP. This APP is under use in a multi-country nutrition intervention for adults and children (Trial ID: ISRCTN63745549) [24]. The APP aims to promote balanced nutrition and healthy habits by creating personalized recommendations for each individual. The APP not only takes into account personal characteristics, activity factors and dietary preferences, but it also takes into account gut microbiota nutritional requirements.

2. Materials and Methods

2.1. Development and characteristics of the S4H APP

The S4H APP was developed under the framework of the Stance4Health European project and aims to support human nutrition trials in several countries [24]. Personalized nutritional systems usually manage different sources of information that could serve for different purposes. In addition, all that information has to be stored in a proper design, as we should be able to upload, retreat or update it at any point. Those reasons lead us to build the S4H APP following a modular design, where modules can interact with different sources of information and between them. But at the same time, these modules can be changed or updated without disrupting the APP functioning (Figure 1).

Figure 1. Overview of the S4H APP design and architecture.

2.2. APP Architecture

We divided the APP framework between the frontend and the backend. An overall view of the APP architecture and main modules are depicted in Figure 1.

The frontend consists of all the services the user either sees or interacts with when they open the APP. It is responsible for the global look and feel of the APP experience and our main source of input data. In our case, Angular 8 and Bootstrap 4 were used to design and create this side of the APP.

The backend or server-side section was built by all the technology that the user does not directly see or interact with. In our case, it was built with a modular design, which lets us connect or disconnect different additional functionalities to the APP. In the backend

we have also to differentiate between the different sources of data (databases) that we need, and the modules that run different operations and algorithms.

The database management system chosen is MariaDB (MySQL), which uses Aria and XtraDB and in turn incorporates two other engines: PBXT and FederatedX. It also incorporates new system level tables, which help in database optimization tasks thanks to the storage of service statistics.

The rest of the backend was built with Java and Spring framework. Furthermore, an application programming interface (API) was enabled to interact with the modules stored on the server, mainly built with Python3.7.

2.3. Sources of data

This section contains the main sources of data that the APP needs in order to work. Moreover, several datasets were added to improve some of the functionalities and the user-APP interaction.

There are 5 main sources of information, with an additional source that incorporates useful data for the user. Other data sources could interact with the ones in this section, but they are module-dependent in the sense that they are mostly generated/used by the modules. The 5 main sources are:

1. User data: We store the main aspects of the user in a MySQL database, including information about biometrics, restrictions and behavior. This information allows us to calculate the nutrient levels we are aiming to recommend. At the same time, it also lets us filter several items in the dietary database that are not suited for the user, either due to age (as coffee or tea recipes in children) or to food allergies (not recommending milk-based products on users allergic to milk proteins). Other than hard restrictions, we also allow the users to check whether they dislike or like specific products and recipes in the dataset. The presence of preferences allows us to choose one recipe over the other when suggesting the menu.

2. Nutritional references: These data are summarized in tables that are used as rules to generate a healthy menu. They contain recommendations for a Mediterranean and sustainable diet are included [25]. The EU Dietary Reference Values (DRVs) are the reference values on which the nutritional recommendations of the APP are based [26]. This module, therefore, establishes basic rules such as portions of food groups needed per week, or micronutrient intake for a healthy diet.

3. Ingredients data: The S4H APP contains multiple nutrient information from many stakeholders. Moreover, some of these data could be updated as new analysis and reviews are made. For that reason, nutritional information for every single ingredient is stored as another set of MySQL tables. Specifically, for this APP we used the S4H food composition database (FCDB) developed within the framework of the project [27]. In summary, the S4H FCDB consists of more than 2600 foods with nutritional information on around 880 elements, including bioactive compounds. However, multiple elements can differ from one country to another. Moreover, several products are not consumed raw but they undergo some kind of thermal processing. For that reason, our dataset contains a Branded Food Products Database consisting of food from supermarkets and hypermarkets of different countries (this is likely to be a significant percentage of the food already purchased and consumed by consumers). We specifically have detailed data from three different countries: Spain (with 89,385 foods products) provided by AECOC (Spanish Association of Manufacturers and Distributors), Germany (with 211,014 foods products) provided by ATRIFY and Greece (with 3,312 foods products) provided by researchers [28]. We also included 670 different items from fast food restaurants obtained from the publications of the restaurant chains. These fast-food items could be a recipe themselves, but as it is rare to solely eat one of them, we stored them as ingredients, to give the user more flexibility when entering the different menus, they could have eaten.

4. Recipe data: S4H APP, unlike recent approaches in food recommendations, follows a recipe-centered meal planning. This means that our system recommends to the user a specific recipe for a specific time of the day. Unlike a single combination of ingredients, recipes give ingredients a context/relationship and a procedure. This allows the user to know "what to eat" and also "how to cook it". This selection has its drawback too, which is analyzed in the discussion section. The recipes were reviewed by inhabitants from each country: it started with the analysis of more than 150,000 recipes from all countries to obtain a set of some 20,000 appropriate recipes (in terms of nutritional value, cultural traditions and diversity in all the possible meal plans). This dataset of recipes was then evaluated in terms of its ingredients' names, weight, retention factors and yield factors according to the cooking technique described for each recipe. Finally, we obtain the nutritional composition of each recipe [27]. Moreover, users have the opportunity to create their own recipes, with ingredients from the ingredients database. Those user's recipes will only be available for the users that have created them.

5. Expert Knowledge: Despite recent trends in computational nutrition (that aims to provide automatic recommendations) having a source of expert knowledge has been proven as an excellent way to manage/rank all the nutritional goals and levels. Within this source the APP includes:

    - Food constraints related to health issues.
    - Food levels related to age, and biometrics.
    - Food patterns that ensure a diverse diet.
    - How several factors affect the previous items such meal distribution, physical exercise and portion size.

Both physical exercise management and size management procedures have several novelty characteristics, thus they are explained detail below.

2.4. Physical activity

Daily physical activity can deeply affect the recommended nutrient. In the S4H APP we addressed these variations asking the users to include a detailed description of their daily physical activity.

In order to calculate the metabolic expenditure related with physical activity, we established 5 groups according to the intensity of the activity. Then it is up to the user to provide the time expended along the day (in hours) in each category.
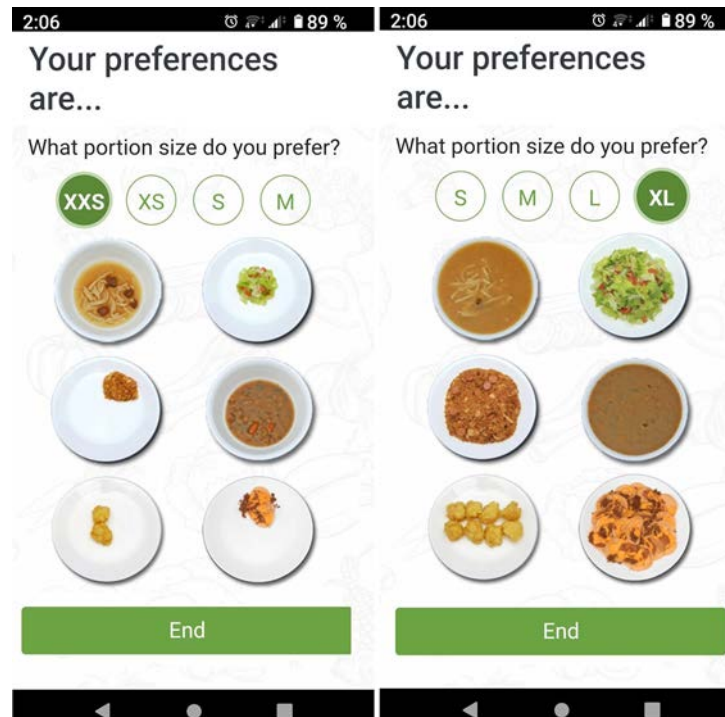
Activity values were assigned to each group of activities according to the Food and Agriculture Organization of United Nations (FAO) recommendations on physical activity level [29]. These values are weighted in the number of hours stated by the user, so that the daily physical activity is estimated. All these estimations are based on the guidelines proposed by the FAO [29]. The guide contains extensive information for children, adults and other physiological states, such as pregnancy and lactation.

2.5. Portion sizes

Different sizes of standard meals were established. Each user chooses a meal size according to their preferences. Depending on the population group, the sizes range from XXS to XL. To standardize portion sizes (that is, link the weight of the recipe with the size letter) data was collected from 200 volunteers from different countries to unravel their usual consumption and how they viewed their portion, using photographic albums and pre-established portion sizes [30–32]. After that, we created a survey with Google Forms following the research model described in [33]. Each participant indicated the usual consumption size of the different food groups and dishes (i.e. a meat-based recipe, a fish-

based recipe, a sandwich-based recipe, etc.). This was then compared with the consumption data and an average range was assigned. The results were used to classify the portion sizes in 6 different sizes (Figure 2).

Figure 2. XXS and XL portion sizes of the APP.

2.6. Additional data sources: Images, barcodes and user interaction

Finally, there are other data sources are not completely necessary but offer the user a better experience. These are the image data sources, the barcode information and the user interaction database. The image data source acts as a triple information service:
- Allows the user to see how a recipe looks when finished.
- Allows the user to identify ingredient easily.
- Allows the user to quickly check if they are using the correct product.

These three tasks that allowed us to offer a better user-experience, but could also be used in future studies assessing the impact of different imaging characteristics in food consumption/selection. It is worth noting that as we have 2 different sources of nutritional data (from recipes and ingredients) we then have two sources of imaging data: recipes and ingredients. Moreover, we also let the user upload images from their own recipes.

The barcode database allowed us to link several commercial products to their selected barcode. This information allows us to directly differentiate several products that could be really similar in terms of composition and visuals. But it specifically helps in order to add an additional way to search for products, using the camera to process the bar code, which is then searched in the database.

In addition to the images' data sources and barcodes, we also included a database for storing users' interaction with the APP. This dataset contains data on users' interactions in the APP, users' changes, users' skipped dishes, etc. This information could be used in future studies looking for, users' patterns of usage and behavior, but also for highlighting APP sections or mechanisms that should be changed to offer a better user's experience.

2.7. Generator

From those sources of data, we can run the dietary generator and add several modules that may modify how the generator works or what can be recommended. The main task of the generator is to combine the previous data sources and produce a dietary recommendation that fits nutritional levels with the other characteristics (meal size, preferences, meal behavior, health issues). The engine selected for this section follows the structure described in reference [34].

2.8. Gut microbiota module

The gut microbiota module is a side-module that allows to make recommendations aiming to optimize the user's gut microbiota. Despite the usual sources of nutritional information that can affect a meal recommendation, microbiota is rarely used despite its huge importance in the overall health, gut microbiota is rarely considered. For these reasons, we present this APP as one of the novel-state-of-the-art recommendation engines that take into account the user's microbiota to make recommendations.

Specifically, this module aims to establish guidelines based on the interaction of the gut microbiota and the diet. Studies carried out within the S4H project developed the extended reconstruction of dietary metabolism in human gut microbiota AGREDA [35], which was subsequently improved using an enzyme promiscuity approach [36]. This network establishes relevant metabolic interactions between diet and the gut microbiota. Using 16S rRNA gene sequencing data from fecal samples it is possible to establish interactions between microbiota species, evaluating the impact of different metabolites on them. We can then translate this impact into a score, which will affect the recommendation process and lead it towards a recommendation pattern that favors a set of microbial metabolite levels closer to the ones considered healthy. This score can be effectively incorporated into the recommendation engine, favoring the most beneficial ingredients and minimizing the least favorable ones.

2.9. Search engine

Giving flexibility to the user is key for them not to abandon the program. Moreover, it allows the user to describe what their daily food habits really are, which could be used to understand how they are deviating from the APP recommendation or other healthy markers. Finally, it also allows the user to make better buying decisions allowing them to see the nutritional information of commercial products in a simpler and visual way. For these reasons, two aspects are necessary: a way to search for recipes, and a way to find ingredients to create new recipes. Therefore, we incorporated several ways to accommodate these needs: text, voice and camera-based interactions:

• Camera-based interactions were primarily developed to allow users to have a quick interaction with commercial products as they may be the main source of deviation from the diet. This can be achieved through a comprehensive database linked to the commercial barcodes in the system. A user can easily scan a barcode with their smartphone and automatically find the product data in the APP database.

• Text-based interactions are based on similarity metrics of the text-chains introduced.

• Voice-based interaction runs on Google Voice recognition API.

It is also worth noting that recipes will be displayed with their information by 100 grams if they are searched without context. However, in the menu screen, these recipes will be expressed as g/portion size, which offers a more realistic view of what they are eating.

2.10. Wearable

Wearables check and store biometric data. Specifically, we were interested in wearables able to monitor body fat mass and body fat-free mass, and that could be incorporated into the system with a raw software development kit (SDK).

Through the SDK, the wearable module can connect with the APP and allows biometric data to be imported for a better adjustment of the user's profile. This wearable also gives readings of blood pressure, sleep quality, steps or energy expenditure. It also measures body fat percentage by means of bioimpedance [37]. Since wearable´s accuracy can be affected by various factors, their data are compared with data obtained through questions from APP's configuration screens. If there are no major differences, the data from the wearables will be considered valid and will be used for energy expenditure calculation. This module has room for improvement and a recent aggregator of fitness wearables as Google fit could be integrated into it.

2.11. Shopping list and GPS module

One of the key aspects of every meal plan is the shopping process. This process can be influenced by several factors such as personal preferences or market selection. Moreover, recommending a diet based on a recipe's selection can produce some confusion in the user, as some of the recipe names and photos may not reveal the ingredients needed for its consumption. Therefore, we built another module that help the user buying the necessary ingredients.

First, for every generated menu, this module compiles all the recipes and produces a unified shopping list that aggregates the necessary ingredients in a weekly planning, and gives total amount that the user will need of each ingredient. The shopping list can also be updated crossing out those that are already in stock or that have been bought.

This section integrates the Google maps service, which allows global positioning system (GPS) technology to provide the user with information about the food environment. This can facilitate food shopping by showing the nearest supermarkets and grocery shops.

2.12. APP testing and validation

There are several scales to assess the quality of health-related applications objectively and reliably. The Mobile APP Rating Scale (MARS) [38] or the Nutrition APP Quality Evaluation AQEL scale [39]. MARS is one of the most widely used scale and has a User Version (uMARS) [40]. uMARS has 4 criteria: engagement, functionality, aesthetics, and information. Each can be rated between 1 and 5, and then the average scores of the domains are obtained. Finally, an overall average score is obtained, which is indicative of the quality of the application.

To nutritionally validate the APP, different dietary records were used to study food consumption and the nutritional quality of the diet [41]. We included a food consumption frequency questionnaire (FFQ) and a 24-hour recall (which was used for two non-consecutive weekdays and one weekend day). All questionnaires (uMARS, FFQ and 24-hour recall) were used in online format by Google Forms. These forms were adapted to collect information for research purposes [33].

The APP was pre-tested for reliability to ensure that users do not experience any problems during the nutritional intervention. Throughout the test, load, recalculation and processing speed tests were performed.

In addition, 20 people from different countries (Spain, Italy, Germany and Greece) aged between 12 and 60 years old tested the APP and filled in the uMARS scale [40]. Subsequently, 20 volunteers (19-25 years old, belonging to the Nutrition's Bachelor's Degree at the University of Granada, Spain) collected their food consumption using a 24-hour dietary record and an FFQ during several days to assess whether the menus generated matched the dietary guidelines and what the users consumed.

2.13. Security and ethical aspects of APP

The legal and ethical issues of data protection and privacy in the context of personalized nutrition are extensive [2]. S4H APP guarantees that all the information collected from users is exclusively for the purpose of providing a better user experience in the use of the APP, as well as being used for research purposes. The data and results derived from the study may be published and presented anonymously in journals, conferences, etc. as indicated in the current regulation (EU) 2016/679 and the GDPR Directive 95/46/EC [42]. Furthermore, the ethical guidelines of the Declaration of Helsinki were followed.

The study was approved by different ethical committees and the nutritional intervention in which the APP is being used is registered under the number SRCTN63745549 [24]. Users must also give their consent and may request the elimination of all their data at any time. The APP guarantees, at all times, the anonymity of the user's data.

In terms of security the APP requires authentication by the user. An OAuth 2 authorization process was established. During the intervention, in order to access the APP, the user needs to enter a 10-character alphanumeric code which is provided by the researchers. This code is different for each country and user, and is the one that will load the specific data according to the needs of the study (e.g. supplementation information). All notifications, requirements and petitions that the APP requests to the users are printable. All information is encrypted and transmitted through SSL channels.

2.14. Statistical Analysis

The Python 3.7 module was used as an analysis tool, using the libraries pandas, seaborn (for calculations) and matplotlib (for final plots). We checked whether the information from the users and the FFQ was aligned to the users' biometric measures.

From these data and the FFQ data, an average of consumption across days for every user and a set of micronutrients was developed. Consequently, this also produced a biometric profile for the generator to be used. We ran a set of generations where we obtained the nutritional data (from a set of micronutrients) and analyzed their averages across different days. Both values were checked (in terms of minimal DRVs) and evaluated, selecting the average consumption for every user. FFQ data and Generated data were then compared by the average consumption across the days. As most users in the last study had the same amount of minimal DRVs, we then aggregated data by average and user in a box plot to display the 100% of their distribution, and the 75% levels; the average (numerical mean) across all users was also plotted.

3. Results

The APP is not only limited fur proposing healthy menus, but it also aims to increase the user's knowledge and awareness of their nutritional choices. The APP works as a personal dietician. If the user misses a meal or changes recipes, the APP can re-adapt the menu. This process recalculates how much the menu has changed in terms of macro- and micronutrients and offers an alternative menu that incorporates those changes to some extent (+/- 30% of difference divided in 5 or more consecutive days).

Adding recipes allows a higher level of personalization, being able to give nutritional information, which makes the user aware of the foods he/she eats and how they affect their nutritional status. The APP includes daily tips on nutrition, food or physical activity to teach the user new elements about food and nutrition. There are also alerts that show the user if his/her behavior has had an impact on a set of relevant nutrients and how to fix them in the future.
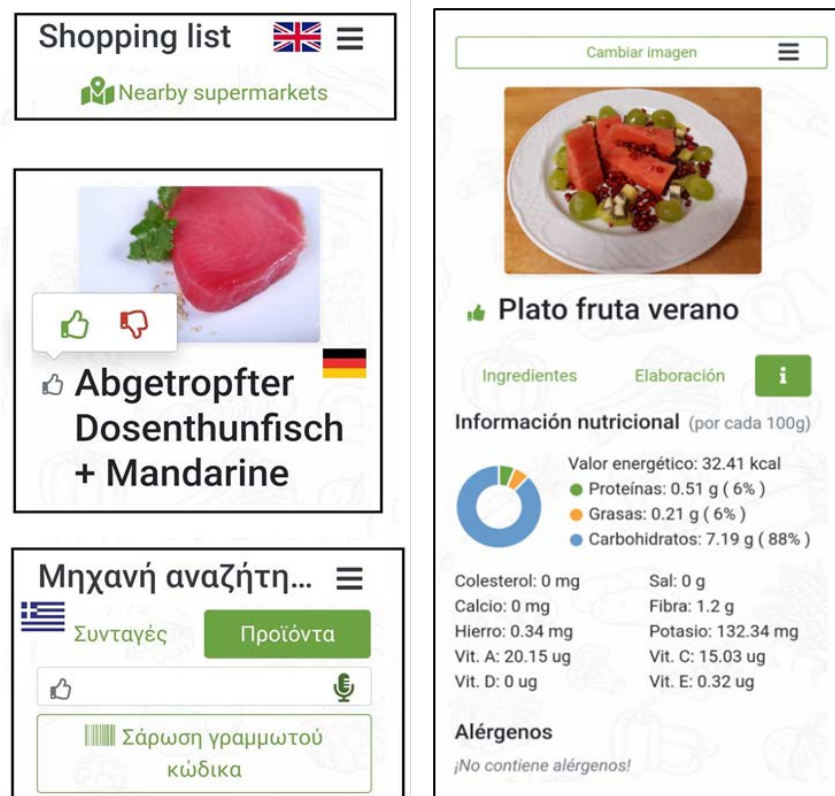
3.1. Integration between modules

All modules of the APP were correctly connected to each other. The APP was tested in all languages and showing no problems (Figure 3). Following menu changes, the recalculation allowed reaching the healthy diet targets. The wearable and microbiota modules were integrated and were able to modify the generating algorithm by modifying and upgrading the menu score of the daily diet that best achieve their secondary goal. The GPS,

preferences, and camera modules worked properly (Figure 3). It was possible to connect and create recipes that could be integrated into the menu (Figure 3).

Menus were calculated for all possible situations that could arise during the nutritional intervention. Users of all ages with food allergies and intolerances were also tested. The results were optimal, but when using commercial foods there were some challenges due to the absence of micronutrient information; in this case the absence of micronutrient levels was computed as 0 in terms of quantity.

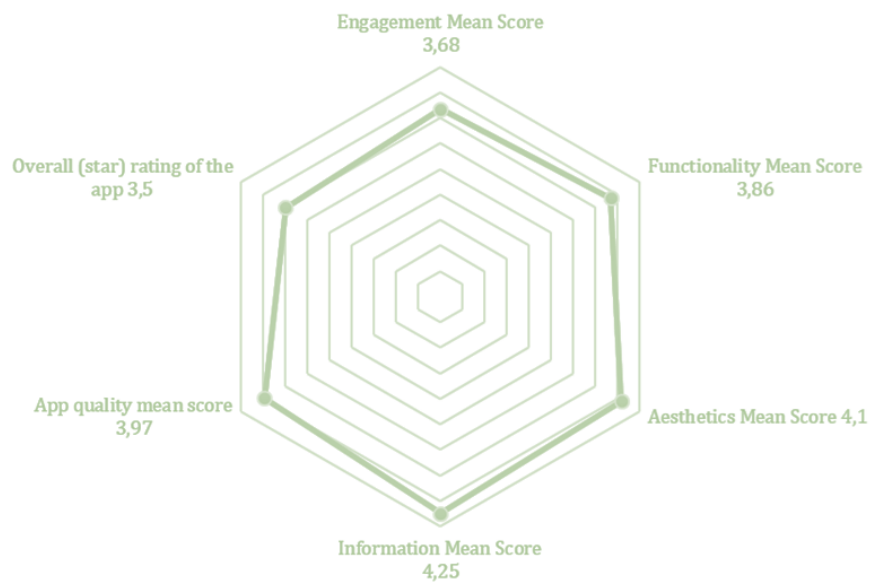**Figure 3.** APP screenshots in four languages and different use levels.

3.2. Testing the APP with real subjects

The APP was used by different team members, collaborators, and test subjects in user mode. During the continuous stress and performance testing of the server no problems were found, except for one that was due to server downtime. The APP works in an asynchronous way to reduce the loading times, which means that usually any change is stored in the server and performed independently. In these cases, the APP notifies the user that a change is going to be made, the modification is performed in the server, uploading the results as soon as they are ready. Taking all this information into account, the spent time for a whole weekly menu calculation in the server hand-side was 24s +/- 1.

The results of the uMARS questionnaires are depicted in Figure 4. The most valued by users was the information (with a score of 4.25/5), giving importance to the quality and credibility of the information included in the APP. Aesthetic appeal was the second most important and engagement was in last place (with a score of 3.68/5). Overall, the average quality score of the APP from users was 3.97/5. In addition, 88% of users would recommend the APP. In addition, 80% also reported that the use of the APP increased their nutritional literacy.

Figure 4. Average score for each section and user perception of the uMARS questionnaire.
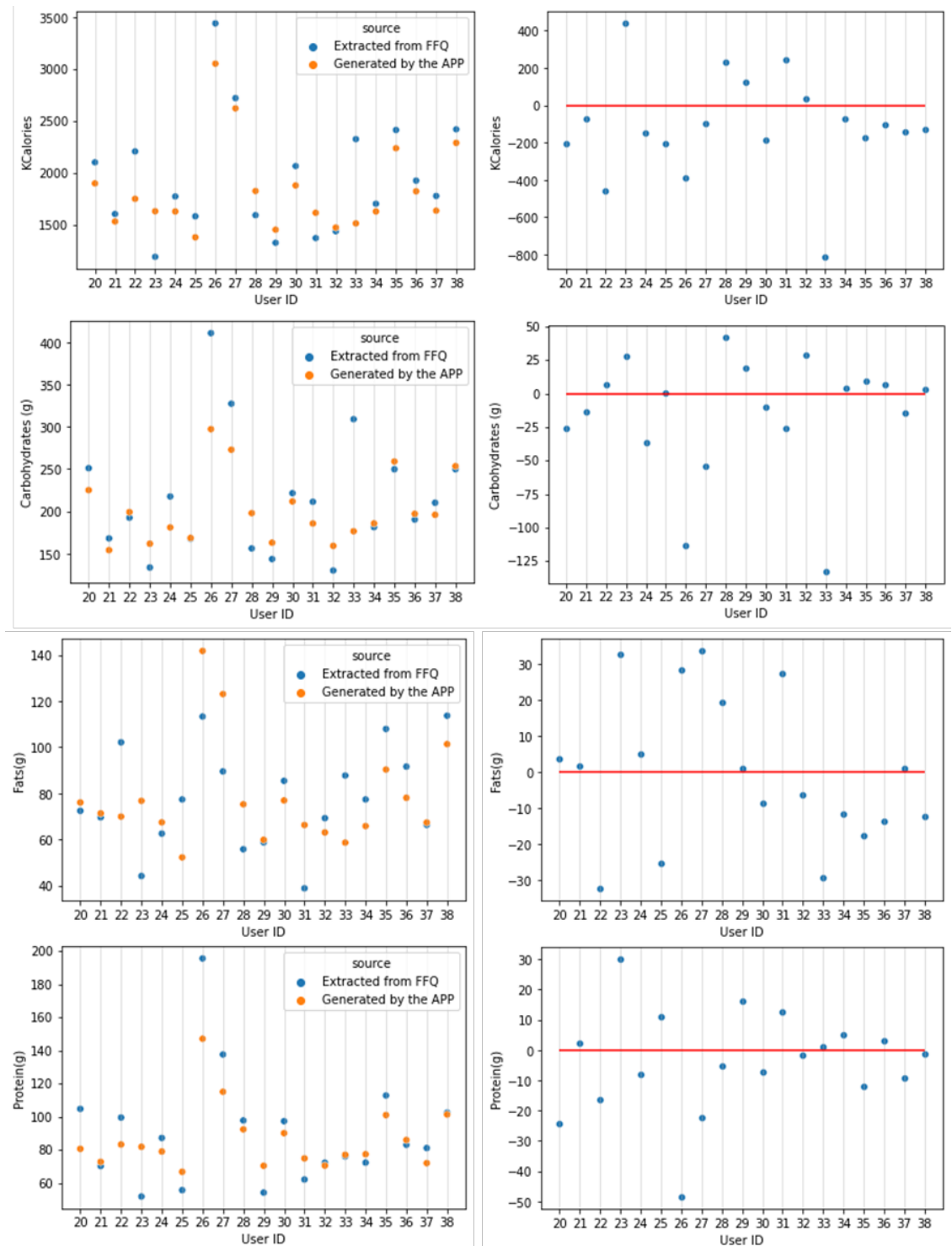
Menus were generated for 20 subjects and compared with dietary records from several days. To generate the menu, APP users' keys were created for every participant. Those 20 subjects were then analyzed and a set of goal's levels to obtain from the generator we attained. We noticed at the start of the test that all participants had different levels of micronutrient patterns, but overall, these patterns were aligned with the minimum DRVs. On the contrary, most of the macronutrient consumption was hard to align with the patterns from the APP. We divided the reasons for that into two groups: those participants that followed a hypercaloric diet with physical/fitness goals in mind, and those volunteers that have an unlikely eating pattern. Table 1 displays the differences between the data obtained by the APP and those obtained by the FFQ.

Table 1. Differences between generated APP levels and those obtained from FFQ.

	Kcal	Carbohydrates (g)	Fats (g)	Proteins (g)
Average	-111.7	-14.6	-0.1	-4.0
Standard deviation	273.2	45.1	20.5	17.1

On average, there was a global trend in the APP lowering the macronutrient intake of participants, which was mostly due to lower requirements in Kcal consumption (Figure 5). This trend varies in a large extent between users, specifically on Kcal consumption. However, most of the changes keep fairly close to what FFQ suggested, except those subjects who had a high deviation from the expected level of macronutrients.

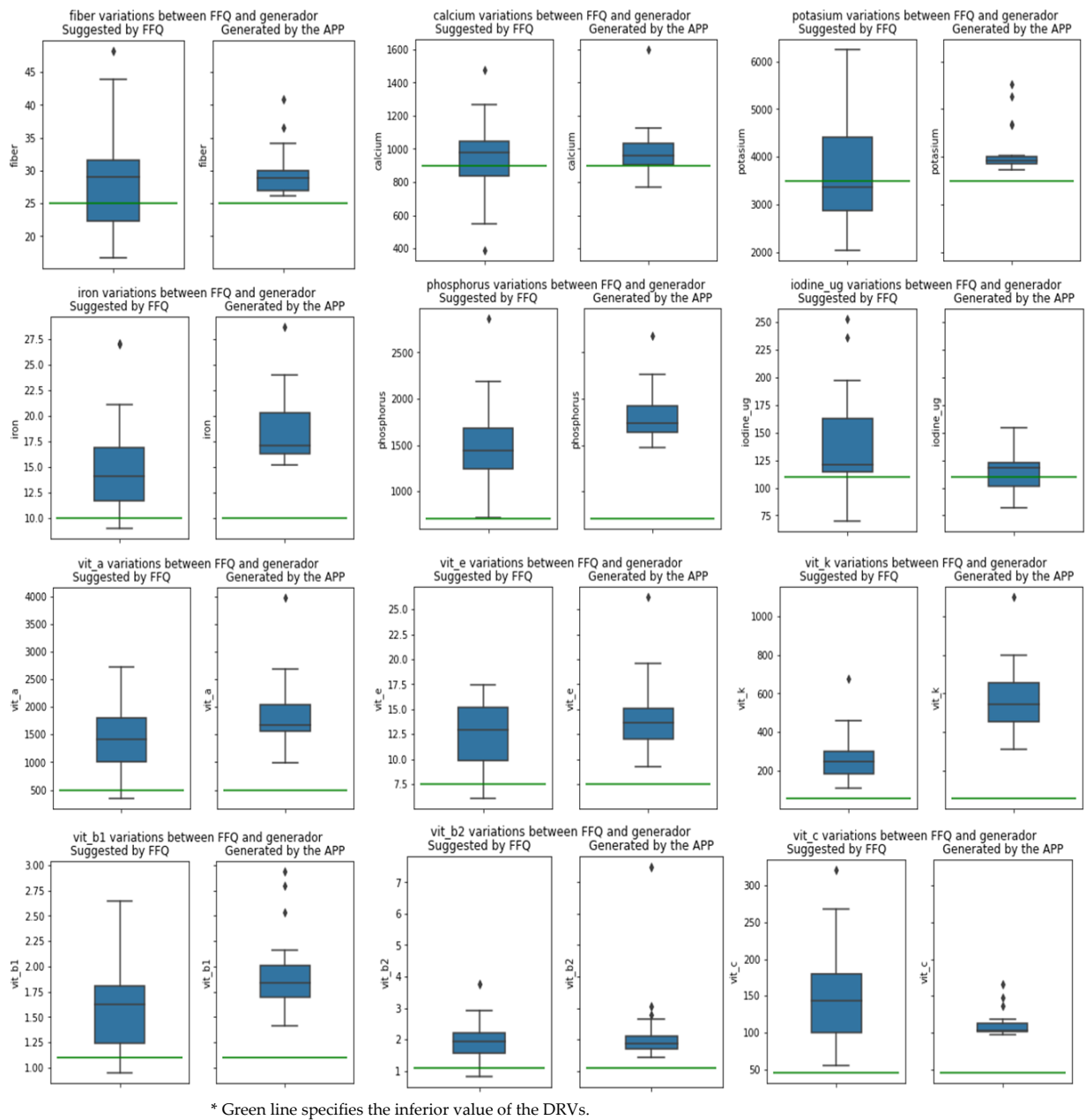**Figure 5.** Energy and macronutrient comparisons from APP vs. FFQ.

*Positive values mean APP levels were higher, Negative values imply APP levels were lower.

As expected, the rules of the generator offered a healthier macronutrient pattern consumption along with its goal of maintaining healthy habits over time. This also resulted in less variation of these quantities between days.

On the micronutrient level, the generator also followed the DRVs in micronutrients levels. The generator improved some of the micronutrient levels at the user level and remained within the DRVs in the rest. It also provided less differences between users as most of the level's goals were the same (all participants were in the range of 19-25 years old). Some levels of micronutrient (i.e. vitamin C) were higher in the FFQ data. Despite being lower, generator levels stayed within the DRVs. Iodine and calcium were the only

micronutrients that stayed below the minimum levels recommended for some users. Selected data from the micronutrient comparison is depicted in Figure 6.

Figure 6. Energy and macronutrient comparisons from APP vs. FFQ.

* Green line specifies the inferior value of the DRVs.

4. Discussion

The aim of this work was to show the development and validation of the S4H APP for a nutritional intervention. The APP was developed based on a broad scientific support and tested by users. The results confirm that S4H APP was able to take into account the habits and lifestyle parameters the users need to describe their eating habits, creating a high level of personalization. The APP information and interactions provided with nutritional education to users. This could also have a positive impact in the adherence and use time of the APP by the users.

The APP was able to generate and recalculate a healthy menu according to DVRs and reference dietary patterns. The correlation of nutrients with different dietary records

demonstrates that the APP can be a reliable tool. The only difference detected was found for some users in iodine and calcium levels. Iodine could easily be managed by the system adding some iodized salt to few recipes. In the case of calcium, low levels were associated with a specific user and was solved by swapping recipes from breakfast to include more dairy products. Another interesting outcome of the test was that the micronutrient levels of every user tended to stay above de DRVs; we didn't observe as many variations as those obtained from FFQ, implying that the APP has a regulatory effect that will diminish differences in the daily basis of the users, while recommending all of them the specific amount of macronutrients. The APP works with the constant evaluation of 12 micronutrients, but we also seek to expand this list in order to reach a nutritional evaluation process that includes a larger variety of micronutrients.

The modular development of the app allows to incorporate or to disable specific modules, and to modify the generating algorithm, as in the case or the use of the microbiota and/or wearable modules. These modules are being tested in a large human nutritional intervention (with data from fecal samples and wearables). For all these reasons, we believe that S4H APP will be a valid tool to support standalone personalized nutrition and useful in nutritional interventions, to incorporate several factors while offering a flexible healthy menu.

4.1. Comparison S4H APP with the current situation

The future of personalized nutrition involves challenging the great heterogeneity of individuals' responses to diet and customizing nutrition according to each person's needs [6]. Usually, nutritional applications focus on independent functions, such as building a food plan based on the user's objective, generating a shopping list for the target diet, or ranking foods by scores [16]. The S4H APP has a modular design which provides a higher degree of personalization, thus efficiently unifying all the services in the same APP. While health and nutrition-related APPs are increasingly used, few applications are evaluated and validated at the research level [1,10,16,43]. The popularity of nutrition-related APP among healthcare professionals is also not particularly high [8]. Even so, studies have shown that dietary recording APP's are as valid as traditional methods of dietary assessment [19,44]. Although controversial, there is evidence that mobile nutrition APPs have great potential in nutrition research, and the development of nutrition interventions [16]. In several cases, nutrition applications have improved results in terms of users' knowledge and behavior [15,45,46]. In addition, APPs reduces the time needed for researchers to prepare data compared to traditional methods [16]. Some mHealth incorporate elements of gamification or goal alerts, but expert recommendations are not provided [9].

In our case, the S4H APP provides expert-generated dietary and health guidelines aimed at increasing subjects' nutritional knowledge and adherence. In parallel, several videos were created to show how to use the APP. The videos can be accessed from the APP itself.

Adherence to the nutritional plan is key in nutritional interventions. Involving users can be a constant barrier to prove the effectiveness of interventions, particularly in child nutrition [3,22]. For this reason, and in order to validate the results, the S4H APP was tested before the nutritional intervention to make sure that it was easy to use and avoid drop-outs for that reason.

Aspects of the front-end were redesigned, adapting them to the latest trends, without losing the ease of use. Some volunteers reported that the use of the APP was time consuming, which has been already found in other studies [12]. Features were implemented to reduce usage time and give users more versatility. For example, we included quick functions to replace a proposed recipe with another one, to indicate that an intake has been skipped, or a button to go to the APP menu home instead of back. During APP testing, it was observed that breakfasts generated the highest number of recalculations. There-

fore, an option was added, where breakfast could be prefixed and excluded from recommendations and recalculations, thus speeding up the process. In addition, S4H APP has increased the number of alerts as many users forgot to change weight or modify menus. This is consistent with other studies where some participants stopped using an APP because they forgot to use it [11]. Studies have shown that mHealth have a user adherence limit of 30 days [16]. Related to this, the S4H APP aims to provide all functions in a customizable way adapted to individual needs and objectives. According to König et al. [11] a high level of customization of the APP preserves the autonomy of the users and could extend its use. Increased utilization or a particular focus of the application could also lead to better results [47,48]. In this sense, the generator system was improved by incorporating aspects such as the seasonality of fruits and vegetables, the choice of bread and beverages during meals, or the creation of new rules to take care of gastronomic aspects (such as the repetition of recipes).

Having credible, evidence-based nutritional information also improves the user experience. The S4H APP is based on the professional nutrition software i-Diet [49], which is one of the most used nutritional software in Spain for more than 9 years by nutritionists; this means that the development of the APP was based on previous nutrition experience. Some studies compare the validity of the use of nutrition APPs with diverse dietary analyses of food recordings [20,41]. Using different statistical tests, the results obtained from these applications were similar with the use of widely accepted and professionally used nutritional analysis software [20,41]. Thus, the S4H APP has a good correlation with dietary recording methods except for some micronutrients, whose reference values were not reached [26].

To strengthen the menu generation and to reach all recommendations, more recipes were introduced. In addition, branded products suffered a matching process similar to that described by other researchers [50,51]. This allowed to fill in data gaps for some nutrients in branded products, especially in fresh foods. This improved recalculation when using commercial products for recipe elaboration. A critical issue could be the use of inexact FCDB [1,11,13,19,52]. The approximate number of foods in the FCDB may be precarious or may have many missing nutrient values, and underestimate macronutrient and micronutrient values [43]. In this sense, the FCDB used by the S4H APP was built in the framework of the European project Stance4Health [27], being currently one of the most complete FCDB worldwide in terms of nutrients and bioactive compounds.

Finding the right foods or recipes can also be a preoccupation for users [11]. The S4H APP enhanced the multilingual service by creating a standardized and comprehensive food corpus, making it possible to search for food and recipes in all 4 languages more efficiently. It is important to note that most academic food related applications are usually only available in 1 or 2 languages at the most [43]. The S4H APP also offers a broad variety of recipes, which makes it attractive for discovering new dishes or food combinations. Recipes are often not taken into account for nutrient estimations [12] and are only used for meal planning or creation of shopping lists to reduce the associated time burden [44]. In the S4H APP the recipes are essential in the generation of menus. In addition, the APP shows the proposed menu and the shopping list for the whole week, so that users can organize themselves. Currently, few APPs are able to propose or filter recipes according to food allergies and intolerances [53]. In this sense, the S4H APP modified their pre-existing recipes to generate recipes with alternative allergen-free foods that still meet nutritional requirements. The serving size provided by the APPs or the possibility to choose a food from the list of uploaded foods, especially recipes, are other aspects that can lead to more estimation errors [11,13,52]. There are currently several technologies and sensors used to estimate the quantity and serving size (such as cameras) to generate 3D images for food volume estimation, or photographs and videos captured by users and translated into nutrient content estimations [18,54]. The S4H APP was based on portion size measurements obtained from user feedback, facilitating the choice of these portion sizes through images. These tools have been used in other studies for many years [51].

Higher personalization makes the APP more attractive to users, which in our case is highlighted with the gut microbiota module and wearables. The use of later, global positioning system (GPS) or cameras allows to take into account much more parameters in research, and to make APP more attractive to users [14]. The gut microbiota composition and functionality is modified by diet [6,43], so that it is one of the new targets of personalized nutrition [55]. In this sense, the PREDICT I study evaluated the contribution of dietary context, metabolic and metagenomics contribution to gut microbiota responses to predict individual responses to foods through machine learning algorithms [56]. Taking all this information into account, the Stance4Health project has focused on the relationship between diet and how it affects the gut microbiota [35,36,57]. These data have been extrapolated to the S4H APP, providing an increased personalization in the generation of menus. Moreover, the diet proposed by the S4H APP is adaptable and modulable according to the results of gut microbiota interactions. Currently, only the ZOE APP take into account the gut microbiota composition [58]. Users appreciated a high level of personalization of that APP, although it is currently only available to a small group of consumers at a high prize [2]. According to recent studies, only few users are willing to pay for personalized nutrition services [3,7,12]. Therefore, the S4H APP will be free of charge for those volunteers participating in the nutritional intervention.

4.2. S4H APP security and quality

Ensuring that data is stored securely and that privacy is respected are key factors for users of mHealth [11]. One example was the concern over a data breach at one of the world's leading diet monitoring applications [43]. The European Commission, as well as governmental agencies, have created recommendations on the design, quality and safety of these applications [59]. The S4H APP includes all the necessary security parameters to guarantee secure and anonymous use. Indeed, some APPs implement social media options [9]. In the Stance4Health study, these options were not implemented in order to guarantee the anonymity of the subjects participating in the nutritional intervention. The only incident during testing was the server downtime. Thus, the S4H APP established complementary actions to avoid future problems with the server.

According to Bzikowska-Jura et al. [1] a nutrition APP must have certain minimum parameters to be a suitable application. Although there are many tools for assessing the quality of APPs, the MARS scale is the most commonly used [3,21,38,53]. According to the different studies that evaluate the quality of nutrition APPs, the average quality of Mars scales ranges between 3.1 - 3.8 out of 5 points [3,21,38,53]. Top-rated APPs in the respective online shops received low MARS scores, reflecting poor quality. Thus, the number of reviews per APP may not always reflect quality [5]. In our study we focused on the users' opinions, so we used an adaptation of the MARS scale for users uMARS [40]. On the uMARS scale, almost 80% of the nutrition-related APPs scored above 3 out of 5, with a median score of 3.5 [4]. Our test results were higher, especially in the area of information. This indicates that users value all the scientific work and effort done during the APP development.

5. Conclusions

The global goal of Stance4Health project is to develop a complete Smart Personalized Nutrition (SPN) service based on the use of mobile technologies, as well as to optimize the gut microbiota activity and consumer engagement in the long term.

On this behalf, the S4H APP is the selected tool to achieve all the proposed objectives and will be the link between the different services to provide smart personalized nutrition. In this article we have introduced how the S4H APP was built, its different modules and some of its capabilities. Regarding the offer of an adaptable menu for the users, our results suggest that the system is able to provide a flexible personalized nutrition service, which improves the intake of nutrients. For that reason, the S4H APP is being used as the main

tool for the nutritional intervention carried out in the Stance4Health project, where the rest of the modules are under testing.

References

1. Bzikowska-Jura, A.; Sobieraj, P.; Raciborski, F. Low Comparability of Nutrition-Related Mobile Apps against the Polish Reference Method—a Validity Study. *Nutrients* **2021**, *13*, 2868.

2. RÖTTGER-WIRTZ, S.; Alie, D. Personalised Nutrition: The EU's Fragmented Legal Landscape and the Overlooked Implications of EU Food Law. *Eur. J. Risk Regul.* **2021**, *12*, 212–235.

3. Zarnowiecki, D.; Mauch, C.E.; Middleton, G.; Matwiejczyk, L.; Watson, W.L.; Dibbs, J.; Dessaix, A.; Golley, R.K. A Systematic Evaluation of Digital Nutrition Promotion Websites and Apps for Supporting Parents to Influence Children's Nutrition. *Int. J. Behav. Nutr. Phys. Act.* **2020**, *17*, 1–19.

4. Li, Y.; Ding, J.; Wang, Y.; Tang, C.; Zhang, P. Nutrition-Related Mobile Apps in the China App Store: Assessment of Functionality and Quality. *JMIR MHealth UHealth* **2019**, *7*, e13261.

5. Choi, J.; Chung, C.; Woo, H. Diet-Related Mobile Apps to Promote Healthy Eating and Proper Nutrition: A Content Analysis and Quality Assessment. *Int. J. Environ. Res. Public. Health* **2021**, *18*, 3496.

6. Sempionatto, J.R.; Montiel, V.R.-V.; Vargas, E.; Teymourian, H.; Wang, J. Wearable and Mobile Sensors for Personalized Nutrition. *ACS Sens.* **2021**, *6*, 1745–1760.

7. Pérez-Troncoso, D.; Epstein, D.M.; Castañeda-García, J.A. Consumers' Preferences and Willingness to Pay for Personalised Nutrition. *Appl. Health Econ. Health Policy.* **2021**, *19*, 757–767.

8. Vasiloglou, M.F.; Christodoulidis, S.; Reber, E.; Stathopoulou, T.; Lu, Y.; Stanga, Z.; Mougiakakou, S. What Healthcare Professionals Think of "Nutrition & Diet" Apps: An International Survey. *Nutrients* **2020**, *12*, 2214.

9. Schoeppe, S.; Alley, S.; Rebar, A.L.; Hayman, M.; Bray, N.A.; Van Lippevelde, W.; Gnam, J.-P.; Bachert, P.; Direito, A.; Vandelanotte, C. Apps to Improve Diet, Physical Activity and Sedentary Behaviour in Children and Adolescents: A Review of Quality, Features and Behaviour Change Techniques. *Int. J. Behav. Nutr. Phys. Act.* **2017**, *14*, 1–10.

10. Robles, N.; Puig, E.P.; Gómez-Calderón, C.; Saigí-Rubió, F.; Cambra, G.C.; Zamora, A.; Moharra, M.; Paluzié, G.; Balfegó, M.; Carrion, C. Evaluation Criteria for Weight Management Apps: Validation Using a Modified Delphi Process. *JMIR MHealth UHealth* **2020**, *8*, e16899.

11.   König, L.M.; Attig, C.; Franke, T.; Renner, B. Barriers to and Facilitators for Using Nutrition Apps: Systematic Review and Conceptual Framework. *JMIR MHealth UHealth* **2021**, *9*, e20037.

12.   Vasiloglou, M.F.; Christodoulidis, S.; Reber, E.; Stathopoulou, T.; Lu, Y.; Stanga, Z.; Mougiakakou, S. Perspectives and Preferences of Adult Smartphone Users Regarding Nutrition and Diet Apps: Web-Based Survey Study. *JMIR MHealth UHealth* **2021**, *9*, e27885.

13.   Mistura, L.; Comendador Azcarraga, F.J.; D'Addezio, L.; Martone, D.; Turrini, A. An Italian Case Study for Assessing Nutrient Intake through Nutrition-Related Mobile Apps. *Nutrients* **2021**, *13*, 3073.

14.   Limketkai, B.N.; Mauldin, K.; Manitius, N.; Jalilian, L.; Salonen, B.R. The Age of Artificial Intelligence: Use of Digital Technology in Clinical Nutrition. *Curr. Surg. Rep.* **2021**, *9*, 1–13.

15.   Chen, J.; Allman-Farinelli, M. Impact of Training and Integration of Apps into Dietetic Practice on Dietitians' Self-Efficacy with Using Mobile Health Apps and Patient Satisfaction. *JMIR MHealth UHealth* **2019**, *7*, e12349.

16.   Eicher-Miller, H.A.; Prapkree, L.; Palacios, C. Expanding the Capabilities of Nutrition Research and Health Promotion through Mobile-Based Applications. *Adv. Nutr.* **2021**, *12*, 1032–1041.

17.   West, J.H.; Belvedere, L.M.; Andreasen, R.; Frandsen, C.; Hall, P.C.; Crookston, B.T. Controlling Your "App" Etite: How Diet and Nutrition-Related Mobile Apps Lead to Behavior Change. *JMIR MHealth UHealth* **2017**, *5*, e7410.

18.   Vasiloglou, M.F.; van der Horst, K.; Stathopoulou, T.; Jaeggi, M.P.; Tedde, G.S.; Lu, Y.; Mougiakakou, S. The Human Factor in Automated Image-Based Nutrition Apps: Analysis of Common Mistakes Using the GoFOOD Lite App. *JMIR MHealth UHealth* **2021**, *9*, e24467.

19.   Jospe, M.R.; Fairbairn, K.A.; Green, P.; Perry, T.L. Diet App Use by Sports Dietitians: A Survey in Five Countries. *JMIR MHealth UHealth* **2015**, *3*, e3345.

20.   Fallaize, R.; Franco, R.Z.; Pasang, J.; Hwang, F.; Lovegrove, J.A. Popular Nutrition-Related Mobile Apps: An Agreement Assessment against a UK Reference Method. *JMIR MHealth UHealth* **2019**, *7*, e9838.

21.   Bardus, M.; van Beurden, S.B.; Smith, J.R.; Abraham, C. A Review and Content Analysis of Engagement, Functionality, Aesthetics, Information Quality, and Change Techniques in the Most Popular Commercial Apps for Weight Management. *Int. J. Behav. Nutr. Phys. Act.* **2016**, *13*, 1–9.

22.   Burrows, T.L.; Khambalia, A.Z.; Perry, R.; Carty, D.; Hendrie, G.A.; Allman-Farinelli, M.A.; Garnett, S.P.; McNaughton, S.A.; Rangan, A.M.; Truby, H. Great 'App-eal'but Not There yet: A Review of IPhone Nutrition Applications Relevant to Child Weight Management. *Nutr. Diet.* **2015**, *72*, 363–367.

23.   Burillo, S.P.; Nogueira, D.H.; de la Cueva, S.P.; Henares, J.A.R. Nutrición Personalizada Inteligente. *Aliment. Rev. Tecnol. E Hig. Los Aliment.* **2019**, 25–29.

24.   Dello Russo, M.; Russo, P.; Rufián-Henares, J.Á.; Hinojosa-Nogueira, D.; Pérez-Burillo, S.; de la Cueva, S.P.; Rohn, S.; Fatouros, A.; Douros, K.; González-Vigil, V. The Stance4Health Project: Evaluating a Smart Personalised Nutrition Service for Gut Microbiota Modulation in Normal-and Overweight Adults and Children with Obesity, Gluten-Related Disorders or Allergy/Intolerance to Cow's Milk. *Foods* **2022**, *11*, 1480.

25.   Serra-Majem, L.; Tomaino, L.; Dernini, S.; Berry, E.M.; Lairon, D.; Ngo de la Cruz, J.; Bach-Faig, A.; Donini, L.M.; Medina, F.-X.; Belahsen, R. Updating the Mediterranean Diet Pyramid towards Sustainability: Focus on Environmental Concerns. *Int. J. Environ. Res. Public. Health* **2020**, *17*, 8758.

26.   Dietary Reference Values | DRV Finder Available online: https://multimedia.efsa.europa.eu/drvs/index.htm (accessed on 14 September 2022).

27.   Hinojosa-Nogueira, D.; Pérez-Burillo, S.; Navajas-Porras, B.; Ortiz-Viso, B.; de la Cueva, S.P.; Lauria, F.; Fatouros, A.; Priftis, K.N.; González-Vigil, V.; Rufián-Henares, J.Á. Development of an Unified Food Composition Database for the European Project "Stance4Health." *Nutrients* **2021**, *13*, 4206.

28.   Katidi, A.; Vlassopoulos, A.; Kapsokefalou, M. Development of the Hellenic Food Thesaurus (HelTH), a Branded Food Composition Database: Aims, Design and Preliminary Findings. *Food Chem.* **2021**, *347*, 129010.

29.   United Nations University; World Health Organization *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation: Rome, 17-24 October 2001*; Food & Agriculture Org., 2004; Vol. 1; ISBN 92-5-105212-3.

30.   Al Marzooqi, H.M.; Burke, S.J.; Al Ghazali, M.R.; Duffy, E.; Al Yousuf, M.H.S. The Development of a Food Atlas of Portion Sizes for the United Arab Emirates. *J. Food Compos. Anal.* **2015**, *43*, 140–148.

31.   Marcos Suarez, V.; Rubio Mañas, J.; Sanchidrián Fernández, R.; Robledo de Dios, T. Spanish National Dietary Survey on Children and Adolescents. *EFSA Support. Publ.* **2015**, *12*, 900E.

32.   Marcos, S.V.; Rubio, M.J.; Sanchidrián, F.R.; de Robledo, D. Spanish National Dietary Survey in Adults, Elderly and Pregnant Women. *EFSA Support. Publ.* **2016**, *13*, 1053E.

33.   Hinojosa-Nogueira, Daniel Elaboración y manipulación de formularios creados con Google Forms en el ámbito de la investigación. **2022**, doi:10.5281/ZENODO.6419007.

34.   Ortiz Viso, B. Evolutionary Approach in Recommendation Systems for Complex Structured Objects.; 2020; pp. 776–781.

35.   Blasco, T.; Pérez-Burillo, S.; Balzerani, F.; Hinojosa-Nogueira, D.; Lerma-Aguilera, A.; Pastoriza, S.; Cendoya, X.; Rubio, Á.; Gosalbes, M.J.; Jiménez-Hernández, N. An Extended Reconstruction of Human Gut Microbiota Metabolism of Dietary Compounds. *Nat. Commun.* **2021**, *12*, 1–12.

36.   Balzerani, F.; Hinojosa-Nogueira, D.; Cendoya, X.; Blasco, T.; Pérez-Burillo, S.; Apaolaza, I.; Francino, M.P.; Rufián-Henares, J.Á.; Planes, F.J. Prediction of Degradation Pathways of Phenolic Compounds in the Human Gut Microbiota through Enzyme Promiscuity Methods. *NPJ Syst. Biol. Appl.* **2022**, *8*, 1–9.

37.   Bertemes-Filho, P.; Morcelles, K.F. Wearable Bioimpedance Measuring Devices. In *Medicine-Based Informatics and Engineering*; Springer, 2022; pp. 81–101.

38.   Stoyanov, S.R.; Hides, L.; Kavanagh, D.J.; Zelenko, O.; Tjondronegoro, D.; Mani, M. Mobile App Rating Scale: A New Tool for Assessing the Quality of Health Mobile Apps. *JMIR MHealth UHealth* **2015**, *3*, e3422.

39.   DiFilippo, K.N.; Huang, W.; Chapman-Novakofski, K.M. A New Tool for Nutrition App Quality Evaluation (AQEL): Development, Validation, and Reliability Testing. *JMIR MHealth UHealth* **2017**, *5*, e7441.

40.   Stoyanov, S.; Hides, L.; Kavanagh, D.; Wilson, H. Mobile Application Rating Scale: User Version (UMARS)(Appears in: Development and Validation of the User Version of the Mobile Application Rating Scale (UMARS).) Copyright: Creative Commons License. **2016**.

41.   Béjar, L.M.; García-Perea, M.D.; Reyes, Ó.A.; Vázquez-Limón, E. Relative Validity of a Method Based on a Smartphone App (Electronic 12-Hour Dietary Recall) to Estimate Habitual Dietary Intake in Adults. *JMIR MHealth UHealth* **2019**, *7*, e11531.

42.   EUR-Lex - 32016R0679 - EN - EUR-Lex Available online: https://eur-lex.europa.eu/eli/reg/2016/679/oj (accessed on 14 September 2022).

43.   Khazen, W.; Jeanne, J.-F.; Demaretz, L.; Schäfer, F.; Fagherazzi, G. Rethinking the Use of Mobile Apps for Dietary Assessment in Medical Research. *J. Med. Internet Res.* **2020**, *22*, e15619.

44.   Mauch, C.E.; Wycherley, T.P.; Laws, R.A.; Johnson, B.J.; Bell, L.K.; Golley, R.K. Mobile Apps to Support Healthy Family Food Provision: Systematic Assessment of Popular, Commercially Available Apps. *JMIR MHealth UHealth* **2018**, *6*, e11867.

45.   Villinger, K.; Wahl, D.R.; Boeing, H.; Schupp, H.T.; Renner, B. The Effectiveness of App-based Mobile Interventions on Nutrition Behaviours and Nutrition-related Health Outcomes: A Systematic Review and Meta-analysis. *Obes. Rev.* **2019**, *20*, 1465–1484.

46.   DiFilippo, K.N.; Huang, W.-H.; Andrade, J.E.; Chapman-Novakofski, K.M. The Use of Mobile Apps to Improve Nutrition Outcomes: A Systematic Literature Review. *J. Telemed. Telecare* **2015**, *21*, 243–253.

47.   El Khoury, C.F.; Karavetian, M.; Halfens, R.J.; Crutzen, R.; Khoja, L.; Schols, J.M. The Effects of Dietary Mobile Apps on Nutritional Outcomes in Adults with Chronic Diseases: A Systematic Review and Meta-Analysis. *J. Acad. Nutr. Diet.* **2019**, *119*, 626–651.

48.   Bracken, M.L.; Waite, B.M. Self-Efficacy and Nutrition-Related Goal Achievement of MyFitnessPal Users. *Health Educ. Behav.* **2020**, *47*, 677–681.

49.   Verónica, G.-V. *i-Diet un innovador y sencillo software para la elaboración y estimación de dietas personalizadas*; Zenodo, 2022;

50.   Carter, M.C.; Hancock, N.; Albar, S.A.; Brown, H.; Greenwood, D.C.; Hardie, L.J.; Frost, G.S.; Wark, P.A.; Cade, J.E. Development of a New Branded UK Food Composition Database for an Online Dietary Assessment Tool. *Nutrients* **2016**, *8*, 480.

51.   Gurinović, M.; Milešević, J.; Kadvan, A.; Nikolić, M.; Zeković, M.; Djekić-Ivanković, M.; Dupouy, E.; Finglas, P.; Glibetić, M. Development, Features and Application of DIET ASSESS & PLAN (DAP) Software in Supporting Public Health Nutrition Research in Central Eastern European Countries (CEEC). *Food Chem.* **2018**, *238*, 186–194.

52.   Braz, V.N.; de Moraes Lopes, M.H.B. Evaluation of Mobile Applications Related to Nutrition. *Public Health Nutr.* **2019**, *22*, 1209–1214.

53.   Mandracchia, F.; Llauradó, E.; Tarro, L.; Valls, R.M.; Solà, R. Mobile Phone Apps for Food Allergies or Intolerances in App Stores: Systematic Search and Quality Assessment Using the Mobile App Rating Scale (MARS). *JMIR MHealth UHealth* **2020**, *8*, e18339.

54.   Javadi, B.; Calheiros, R.N.; Matawie, K.M.; Ginige, A.; Cook, A. Smart Nutrition Monitoring System Using Heterogeneous Internet of Things Platform.; Springer, 2017; pp. 63–74.

55.   Spector, T.; Asnicar, F.; Berry, S.; Valdes, A.; Franks, P.; Wolf, J.; Hadjigeorgiou, G.; Roy, C.L.; Leeming, E.; Drew, D. Microbiome Signatures of Nutrients, Foods and Dietary Patterns: Potential for Personalized Nutrition from The PREDICT 1 Study. *Curr. Dev. Nutr.* **2020**, *4*, 1587–1587.

56.   Berry, S.; Valdes, A.; Segata, N.; Chan, A.; Davies, R.; Drew, D.; Franks, P.; Spector, T. Personal Metabolic Responses to Food Predicted Using Multi-Omics Machine Learning in 1,100 Twins and Singletons: The PREDICT I Study. *Proc. Nutr. Soc.* **2020**, *79*.

57.   Navajas-Porras, B.; Pérez-Burillo, S.; Hinojosa-Nogueira, D.; Douros, K.; Pastoriza, S.; Rufián-Henares, J.Á. The Gut Microbiota of Obese Children Releases Lower Antioxidant Capacity from Food than That of Lean Children. *Nutrients* **2022**, *14*, 2829.

58.   Asnicar, F.; Berry, S.E.; Valdes, A.M.; Nguyen, L.H.; Piccinno, G.; Drew, D.A.; Leeming, E.; Gibson, R.; Le Roy, C.; Khatib, H.A. Microbiome Connections with Host Metabolism and Habitual Diet from 1,098 Deeply Phenotyped Individuals. *Nat. Med.* **2021**, *27*, 321–332.

59.   Camblor-Álvarez, M.; Ocón-Bretón, M.-J.; Luengo-Pérez, L.-M.; Virizuela, J.-A.; Sendrós-Madroño, M.-J.; Cervera-Peris, M.; Grande, E.; Álvarez-Hernández, J.; Jiménez-Fonseca, P. Soporte Nutricional y Nutrición Parenteral En El Paciente Oncológico: Informe de Consenso de Un Grupo de Expertos. *Nutr. Hosp.* **2018**, *35*, 224–233.