SousChef: Mobile Meal Recommender System for Older Adults

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Abstract: Nowadays, following a healthy diet is a challenge, either due to the large variety of food and ingredient combination possibilities or due to the lack of knowledge required to make healthy choices. This problem is even more patent amongst older adults. Although some recommender systems and applications have been proposed with aim to monitor calorie consumption and/or to suggest healthy recipes to general consumers, no similar solution was yet presented focused on older adults' needs. In this work, a mobile meal recommender system, SousChef, for this target group is presented. This system is capable of creating a personalized meal plan based on the information provided by the user, including the anthropometric measures, personal preferences and activity level. The nutritional recommendations and the application was thought and designed for older adults, presenting friendly user interfaces and following the guidelines of a nutritionist. Tests with users were conducted in order to ascertain recipe and nutritional plan suitability as well as usability of the mobile application. Results showed that more than 70% of the older adult participants were satisfied with the meal plan suggestions and with the simplicity of the SousChef application.

1 INTRODUCTION

According to the literature improved nutrition is a major cause of increased lifespan in the last two centuries (Le Couteur et al., 2016; Bunker, 2001). Poor diet, in contrast, is the main risk factor for death and disabilities in developed nations (Murray et al., 2013). Although the exact definition of elderly age group is controversial, for high-resourced countries the World Health Organization have accepted the chronological age of 65 years as a definition of 'elderly' or older person (World Health Organization, 2010). An ageing population tends to have a higher prevalence of chronic diseases, physical disabilities, mental illnesses and other co-morbidities (Saka et al., 2010). Thus, in order to promote long-term biological effects, continuing efforts to increase the relevance and effectiveness of nutritional recommendations have been made (World Health Organization, 2002). When looking at older demographics, several studies refer that older adults often struggle with making the right decisions regarding meal preparation, healthy diets or groceries shopping. Studies also suggest that many older adults neglect nutrition and are more inclined to do so if they happen to live alone (Ramic et al., 2011). Furthermore, under financial restrictions, which older adults often find themselves in, balancing healthy eating habits with money saving can become a complicated task (World Health Organization, 2002; Ministry of Health, 2013).

Taking into account the previous facts and acknowledging that nowadays technologies are always present and may be used to assist people, in this work we present SousChef, a mobile meal recommender system to assist older adults by providing a nutrition companion to guide them into making wise decisions regarding food management and healthy eating habits.

The meal recommender system was developed to create personalized nutritional plans according to the

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information provided by the user, namely, the personal preferences, activity level and the anthropometric measurements (weight and height). The system intelligence was built with the professional knowledge and participation of a nutritionist, who formulated the diet plans and healthy meals suggestions, and took part in the final system validation.

The present paper is organized as follows: section 2 presents the related work; in section 3 the system is described while in section 4 the mobile application is presented; in section 5, the user testing results are shown; finally, conclusions and future work are drawn in section 6.

2 RELATED WORK

Regarding mobile technologies related to food and nutrition, several studies may be found in the literature addressing issues such as: recommender systems (Aberg, 2006; Mika, 2011; Sezgin and Ozkan, 2013; Hazman and Idrees, 2015; Espín et al., 2015), social interaction (Terrenghi et al., 2007), menu generation (Kuo et al., 2012) or cooking assistance for users with specific impairments, such as in memory (Tran et al., 2005) or language (Tee, et al., 2005). As this work presents a recommender system, we will briefly detail the related work in this topic.

In (Adomavicius and Tuzhilin, 2005), the authors performed a survey of the State-of-the-Art on recommender systems and identified three main types of systems based on the employed methodologies: content-based, collaborative and hybrid recommender systems. The challenges related to the design and implementation of nutritional recommender systems are discussed in (Mika, 2011). This author identifies the uncertainty of nutritional information of recipes or foods, or the missing or incorrect data from food recording measurements as the main challenges and suggests ways to tackle them. In (Sezgin and Ozkan, 2013) a literature review on Health Recommender Systems (HRS) is presented: studies have demonstrated that HRS have branched out in different fields of health industry and HRS applications have been increasingly embedded in the health service systems. Challenges and opportunities in HRS are also addressed in this paper.

In (Åberg, 2006) the author has focused specifically on older adults and their nutritional needs, designing a recommender system with user interfaces designed to consider the specific needs of the user group. The recommendations generated by this system are based on parameters that go beyond nutritional needs, such as taste or available food items at the person's home. However, the description of the system says nothing about recipes prepared specifically by dieticians, it did not allow multiple users and it was not designed to accommodate specific medical conditions. Moreover, the user interface, given the time of that work, does not consider current mobile contexts of use.

In (Hazman and Idrees, 2015), a prototype for a healthy nutrition expert system for children is proposed that considers all stages of the child, their growth stage, gender and health status. A case study is presented and a web application was developed however, the validation of the knowledge for the proposed system is still needed.

Recently, (Espín et al., 2015) presented NutElcare, a semantic recommender system that provides healthy diet plans for the older adults. It claims to retrieve reliable and complete information from expert sources as nutritionists, gerontologists as well as knowledge from information systems and nutritional databases and with that information aim to assist older people to take advantage of these tips and make their own diet plans.

Regarding commercially available ICT applications designed for non-professionals, there are different options, such as EatThisMuch[1], MyFitnessPall[2], Lose It![3], Lifesum[4], or Nutrino[5]. Among other features, in general all of these applications offer the ability to monitor calories consumption based on the manual input of food from a database. Other features can be provided, such as step-by-step guidance to prepare meals, a shopping list or the use of social interactions through social networks and gamification. Among these applications, only Nutrino and EatThisMuch are capable of creating personalized meals plan.

The mobile meal recommender system that we are presenting could be a good solution for older people, providing them healthy and personalized dietary plans, which are suitable to their individual requirements (based on age, sex, activity level, weight and height) and dietary preferences. SousChef system is specifically addressed to this

[1] https://www.eatthismuch.com/
[2] https://www.myfitnesspal.com/
[3] https://www.loseit.com/
[4] https://lifesum.com/
[5] https://nutrino.co/

target group because consider the nutrient intake recommendations for older persons (age > 65) regarding (1) Energy: 1.4-1.8 multiples of the basal metabolic rate to maintain body weight at different levels of physical activity; (2) Protein intake of 0.9-1.1 g/kg per day, the equivalent of 15-20% of the daily energy; (3) Lipids intake of 30% of the daily energy in sedentary older persons and 35% for active older persons; consumption of saturated fats should be minimized and not exceed 8% of energy, and (4) Carbohydrates intake of 55 to 60% of the daily energy (World Health Organization, 2002). Moreover, dietary recommendations using the "food-based dietary guideline approach" (Wahlqvist, 2002) were also taken into account. SousChef system can be a remarkable advantageous system compared to other applications available in the market.

3 SYSTEM OVERVIEW

The SousChef system is composed of a central cloud server and a mobile application which is the user interface for the system. The cloud server is responsible for centrally storing the information of the system and making it accessible through web service application programming interfaces (APIs). Its easy accessibility also facilitates the integration of information from other sources, which is demonstrated through the integration with Fitbit cloud services to retrieve users' activity measurements measured by Fitbit[6] devices.

Given the computational demands for the creation of meal recommendation, the superior processing capability of the server when compared to mobile devices also makes it a more suitable option. The generation of recommendations can be triggered by the mobile devices through web service APIs.

The recommendations are created considering information from different sources: personal information provided using the user interface, activity data through Fitbit devices and nutritional information from the food composition database. Work performed on top of the database will be described in the following subsection.

[6] http://www.fitbit.com/eu/home

3.1 Food and Recipe Database

The development of the SousChef system was based on the Portuguese Food Composition database elaborated by INSA (Ministério da Saúde, 2006). This database contains the nutritional composition of over a thousand products.

For the purpose of the system, the ingredients that are not suitable for direct consumption (e.g. raw chicken meat) and the specific ingredients (e.g. salty chips) which are not considered healthy for the target group were selectively removed by the nutritionist. Moreover, combinations of recipes and ingredients were also created by the nutritionist to ensure that SousChef's recommendations are not only suitable for every meal of the day and for the target population, but also culturally acceptable. In this system context, a recipe does not refer to the instructions to prepare the meal, but rather to a combination of ingredients and respective quantities. Multiple combinations were created for each meal of the day: 40 combinations for breakfast, mid-morning and mid- afternoon snacks; 20 combinations for supper and 340 combinations for main dishes. Each combination for a meal comprises the list of ingredients and respective quantities based on a daily intake of 2000 kcal.

3.2 Recommender System

The implemented recommender system is a content-based recommender system and mainly employs information retrieval techniques (Adomavicius and Tuzhilin, 2005). In order to create a personalized weekly meal plan, there are three main steps: calculation of nutritional requirements, selection of food items for each meal and scaling the meals to match the user's caloric needs (Figure 1). The algorithm was designed in collaboration with a nutritionist.

The Estimated Energy Requirement (EER) is calculated from the predictive Harris-Benedict equations (Long et al., 1979) equations used to estimate the Basal Metabolic Rate (BMR) by multiplying with the physical activity level (PAL) (National Research Council, 1989). BMR is calculated based on a user's energy expenditure, age, sex, weight, height and PAL is calculated based on the Total Energy Expenditure measured using Fitbit devices. The daily caloric need is then distributed across meals as follows: 15% for each breakfast, middle morning and middle afternoon snack meals; 25% for each lunch and dinner and 5% for supper (Candeias et al., 2005).

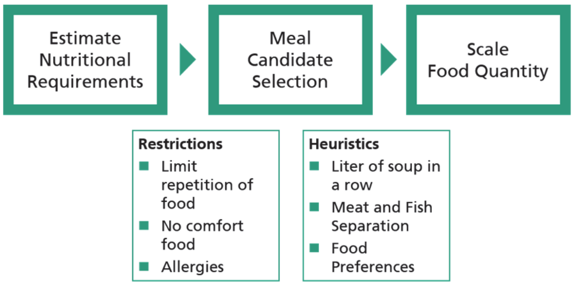

Figure 1: Overview of Meal Plan Recommender System.

After estimating the user's caloric needs, the next step consists in selecting the most appropriate ingredient combinations for each meal considering a given context. The meal planning context consists of the user's personal information, including nutritional needs and food preferences, as well as meal planning history (in order to enable dietary diversity in the resulting plan). Considering the previously created combinations as candidates, for each meal of the week being planned, a two phase selection process will determine the most suitable candidate for that meal. The first phase consists of applying restriction rules, which filters candidates that are not suitable for a given meal and context. Multiple rules have been implemented for removing candidates: limiting repeated recipes in the same week by removing candidates which have been used in planning more than twice; removing any candidates that include comfort food; filtering candidates that include ingredients users are allergic to.

The next phase consists in selecting the most suitable candidate from the ones that were not filtered. This is performed by calculating a score S for each candidate c according to different criteria measured by different heuristic functions H_n. Each heuristic function evaluates the meal planning context, which meal is being planned and a single candidate and assigns a suitability score between 0.0 and 1.0 to each candidate. Different heuristic functions have been implemented to reflect the criteria identified by the nutritionist. One of them consists in favouring main dish combinations with the same soup in four consecutive meals (about one litre). The idea behind this criteria is allowing users to cook soup for several days. The heuristic function checks if the series of one litre was met. If so the same value (0.5) is assigned to every candidate. Otherwise, 0 is assigned to candidates with a different soup and 1 to the others. Another criteria is to favour meat dishes for lunch and fish for dinner in order to have lighter dinners. For main dishes, the candidates meeting the criteria are assigned the score 1 and 0 to the others. All candidates for other meals are assigned 0.5. Finally, another heuristic takes the food preferences of users into consideration. Using the application, users are able to provide ratings to ingredients from 0 to 4, which are normalized into a value between 0 and 1. The preference for a candidate is calculated by combining the preference for each of its composing ingredients whenever available or the value 0.5 instead. The final score, *S*, for a candidate is also calculated as the average of the values calculated by each heuristic function.

The chosen candidate for each meal being planned is the one with highest suitability score S. The approach followed by this algorithm benefits the scalability of the system, since it facilitates the inclusion of new restrictions and heuristics to consider new criteria and data to provide users with better recommendations. It also enables in the future to use different weights to each heuristic function for each user, personalizing the recommendations even further.

Once the ingredient combination has been chosen for each meal, the final step of the planning process consists in scaling the ingredient quantities in order to match the energy requirements of that particular individual. The previously calculated caloric requirements for a given meal are compared with the total energy of the ingredients in the chosen candidate's plan. If the difference is higher than an acceptable deviation, the quantity of the ingredients will be scaled to suit the requirements. To ensure that daily nutrient requirements are maintained, only ingredients from specific categories will be scaled: cereals, fruit and legumes, dairy products, meat, fish, eggs and oil. The new quantity for each scalable ingredient is then calculated using a weighted average so the quantity of more caloric ingredients change more than others, therefore reducing the changed amount in grams of the overall combination.

4 MOBILE APPLICATION

To make the interaction between the food recommender system and the end-user possible, a mobile application was designed. The current version of the mobile application is organized in three different components: the meal plan, the grocery list, and the activity monitoring.

Supporting these different components, there is a profile that aggregates the various settings and preferences used to tune the system. The profile contains anthropometric data, food-related preferences, and activity profile. Regarding the food-related preferences, two levels of control are provided: food restrictions, and dietary considerations. Food restrictions are hard constraints that remove food from the recommendation engine. That is, some food added to the food restrictions list will not be returned in the meal recommendation. Dietary considerations work with a similar principle, but on a group level, therefore, restricting an entire set of products, and consist of a predefined list of diets that can be followed by the user (e.g. vegetarian, lactose free). For instance, if the lactose free diet is selected all the products with lactose will be removed.

4.1 Meal Plan

The Meal Plan section is the centre of the entire system from a technical perspective but also from the point of view of the user. The Meal Plan fulfils two main goals: to generate new meal plans, and to track the user's food intake. In the application, the Meal Plan section is responsible for presenting all the information related to nutrition.

The Meal Plan (Figure 2) is the place to record everything that the user eats throughout the day. There are two different ways to log information into the food diary: 1) Automatic food recommendations; 2) Manual input.

Automatic food recommendation: The fundamental feature of this system is the ability to generate personalized meals plan according to the needs of the user.

Manual input: Although the system is in theory capable of generating an entire meal plan, in practice, the recommendations generated by the system might not be enough to cover all the different scenarios involved in a typical diet. To address this issue, it is possible to manually record additional information in the diary. New entries can be added based on a search query on the food database that also powers the food recommender engine.

To complement the food diary, which provides a quick overview of the user's diet, each recipe or ingredient has a dedicated view to display additional information and actions (Figure 3). The nutritional information of a product is one of the aspects that are provided in this user interface. Besides the energy value in calories, there is also the macro and micro nutrients information. Basic mechanisms for editing the product and the diary (for example, removing products form the diary) are also provided. The user is able to control the recommender engine by removing ingredients from the list of approved products. In this case, products added to that list are entirely ignored by the system. However, the control level is rather limited since users are only able to make binary decisions. In order to provide the user with additional control of the system, another feature particularly important in terms of personalization is the ability to personally rate the products both recipes and ingredients. Whereas in the former case the system works with hard constraints that remove products from the recommender engine entirely, in the latter case the user input is used to influence the weight of a product in the engine. The rating system used in this evaluation contains three different values, which are used to adjust the weight of the product when a new plan is generated. From the perspective of the user, this translates to (Figure 3, right): 1) "I don't like it that much", 2) "I like it",

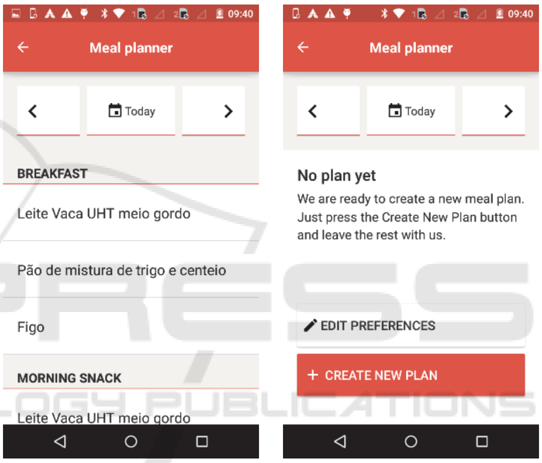

Figure 2: Meal Plan.

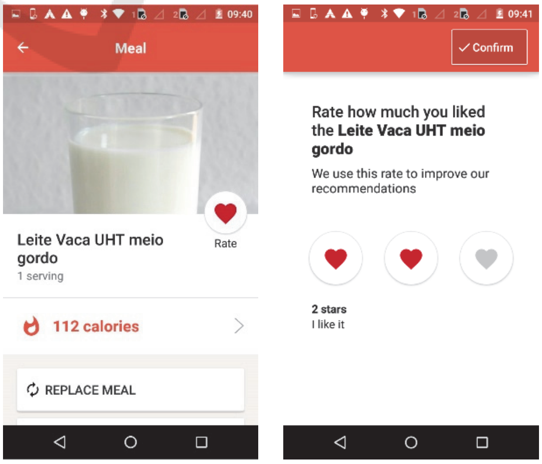

Figure 3: Ingredient view.

and 3) "I love it". For instance, a product rated with the first score will not stop being recommended to the user, but since it has a lower weight, it will be recommended less often.

4.2 Grocery List

Although the Grocery List is not the focus of the SousChef system, it can nevertheless be a valuable tool in the above mentioned goal to assist food management. The goal of the Grocery List component is to help the user with shopping related activities. This component takes on a physical grocery list, but augments it with new capabilities (Figure 4). One of the main features is the integration with the Meal Plan component and the ability to automatically add products to the list based on the ingredients of a recipe. There is also the option to manually add new products to the list based on a database search.

Since the goal of the Grocery List is to assist users in their shopping activities, there was the concern to design a user interface that would be easy to use in the wild, e.g. in the supermarket. Therefore, one characteristic of the system is the ability to work offline, so that the user does not need an Internet connection to access his or her grocery list while in the supermarket. Users are also able to mark products as bought as they go, and that information will be synchronized the next time there is an Internet connection. Moreover, products are organized by aisles to make the shopping process in the store more efficient.

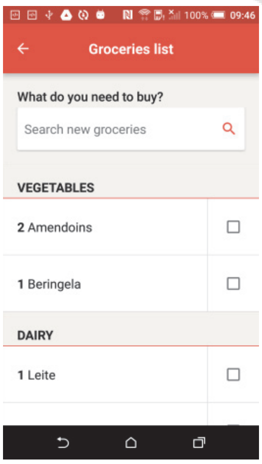

Figure 4: Grocery List.

4.3 Activity Monitoring

Along with nutrition, an important part of a healthy lifestyle is a person's activity level. The Activity Monitoring used in the SousChef system presents the users with metrics related to their activity (Figure 5). The system is able to collect and display calories burned, steps and active time. For each of these metrics, daily objectives can be set in order to raise awareness to their healthy physical activity habits.

Given that one of the inputs required by the system in order to generate new meals is the level of activity of the user, the Activity Monitoring component is responsible for collecting user activity data and feeding those data to the recommender engine. In order to do that the system can be connected to an activity monitoring device such as a Fitbit bracelet. The information gathered from such devices is then converted to a scale that classifies the level of activity as belonging to one of five levels, ranging from "sedentary" to "extremely active". The advantage of using a wearable device such as Fitbit is that the user activity information can be collected seamlessly, without direct input, with a reasonable level of accuracy, and updated automatically to our system. However, in order to free the system from dependence on external devices or systems, it is also possible to manually insert this information in the user profile. In such scenario, the charts with the user activity information would not be used.

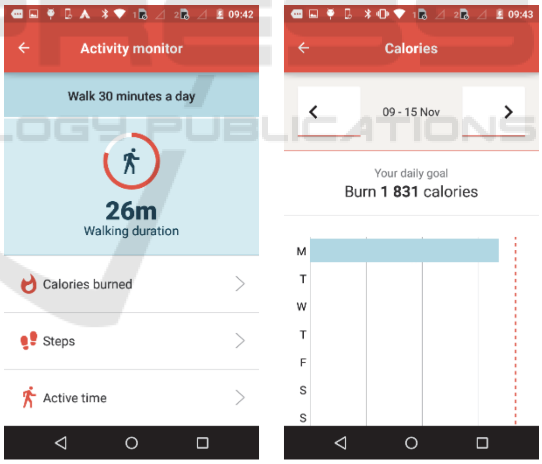

Figure 5: Activity monitoring.

5 USER TESTING

5.1 Algorithm Validation

In this section the results of the tests performed with older adults regarding the recommender system and the mobile application itself are presented and discussed. For both tests, the project was explained to the subjects and informed consents were obtained.

The questionnaires and protocols were designed to be applied to older people.

In order to ascertain user's quality perception of the meal recommender system, a first set of tests were performed with 16 subjects, 8 men and 8 women, with a mean age of 70 ± 4.2 years, mean height of 1.64 ± 0.07 m and a mean weight of 76 ± 12 Kg. Besides the anthropometric measures to insert in the system, participants were also asked about their preferences concerning ingredients and their activity level. This information was then submitted to the system in order to generate a personalized weekly plan composed of six meals per day. Afterwards, participants were asked questions regarding the recommended meals, daily plans and the weekly plan itself, which they were asked to evaluate on a 4 point Likert scale, ranging from 1 (Strongly disagree) to 4 (Strongly agree).

For each meal, participants were asked whether they could eat the suggested recipe and if they considered the recipe to be adequate for that meal. Regarding the daily plans, participants were asked if they felt the daily plan was adequate for them. Finally, for the weekly plan, participants were asked: if they would follow the generated weekly plan; if they would use the application to create a meal plan, should this application be available to them; to rate the sentence "I do not like the system, therefore I would not use it". It should be noted that the last two questions are actually the inverse of each other. This was done in order to minimize biases in the subjects' personal perception of the questions. In addition to these questions, the subjects were asked, by answering yes/no, if the generated weekly plan was good for them. Furthermore, throughout the questionnaire, the subjects' comments and suggestions were also annotated.

Regarding the results for meals, the subjects were, in general, agreeable with the recommended meals. Concerning the case if they could eat the suggested meal 60.86% of the subjects strongly agreed, 26.04% agreed, 8.48% disagreed and 4.62% strongly disagreed. To the question about recipe adequacy to the meal 52.98% of the subjects strongly agreed, 22.02% agreed, 20.69% disagreed and 4.31% strongly disagreed. In Figures 6 and 7, the answers are grouped by meal type.

Considering Figure 6, it can be seen that participants felt that the recipes for mid-afternoon and mid-morning meals were not as conforming to their dietary restriction as were the recipes allocated to the remaining meals (in this case, it was due to the recommendation of too many recipes with pork sausage). When it comes to Figure 7, it can be seen that the participants overwhelmingly felt that the recipes allocated to the mid-morning meal were not a good fit. Through the observation of the participants' comments on the suggested recipes for the mid-morning meal, the cause for this misfit is due to the fact that they either felt that the recipes consisted of too much food or that this meal was not necessary. It should also be noted that some subjects felt that the recipes for dinner consisted of too much food.

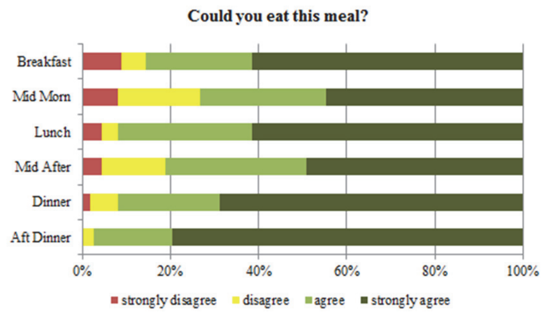

Figure 6: Scores for per meal regarding if the subject could eat the suggested meal.

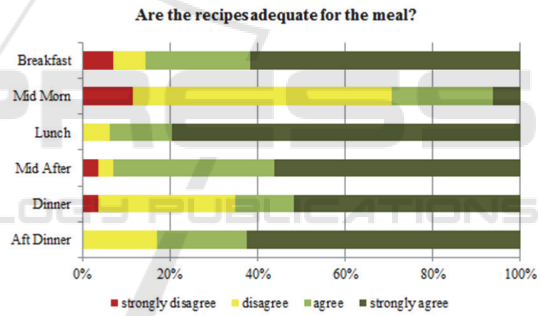

Figure 7: Scores regarding recipes adequacy for the meal.

Considering the results about the adequacy of the daily plans, Figure 8 shows that the most disliked daily plans where those for Sundays. Taking into account the participants' comments throughout the tests, the cause of this was due to the fact that in this day the participants usually eat recipes that are not eaten in other days of the week or that they do not have as many as meals in this day as they do in the other days of the week. Regarding all evaluations of the judged adequacy of each daily plan, 6.25% were graded with 2 (disagree), 41.07% with 3 (agree) and 52.68% with 4 (strongly agree).

Concerning the weekly personalized plan, as depicted in Figure 9, it is possible to conclude that the majority of the participants would follow such a plan (more than 70%) and also use an application like this one, with 20% of the subjects disagreeing. Furthermore, 50% of the participants felt that the weekly plan was good for them. Figure 8 shows that, in general, the participants had a positive experience with the system.

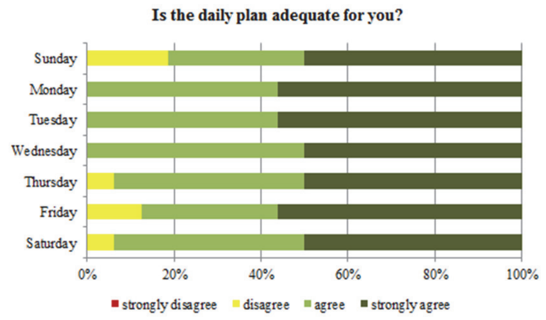

Figure 8: Scores for daily plan adequacy.

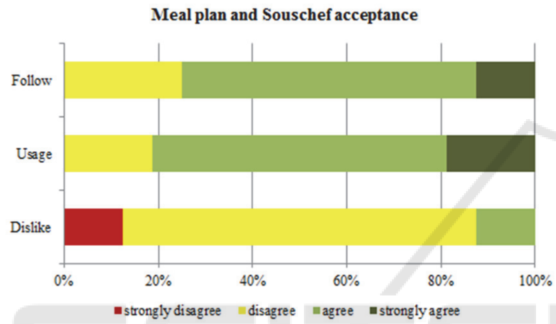

Figure 9: Meal plan and SousChef acceptance scores.

5.2 User Interface Validation

In parallel to the validation of the outputs of the recommender engine, we were also evaluating the user interface. The evaluation of the SousChef application was executed through the assistance of usability tests with a low-fidelity prototype of the user interface. The primary objectives of these tests were to: 1) identify navigation and flow issues; 2) evaluate the rating system used for the recipes; 3) explore different data visualization methods with elderly users.

Usability test sessions took place at a local day-care centre, and five participants over 65 years were recruited to participate. All of the participants had taken part in previous usability tests with smartphones or tablets. For the testing material, a Motorola Moto G with a 5-inch screen and running Android was used. An interactive prototype developed with InVision was used in order to simulate behaviours and flows.

Participants were required to complete a total of seven small tasks. Task success, errors, deviations and assistances were collected in order to evaluate the performance of the users. Standard usability tests were not used at this point because, rather than general levels of usability and satisfaction, the authors were seeking to identify specific problems with the user interface, information architecture and the mechanics of interaction, which could be improved in future iterations. Task analysis was a better fit for the purpose. On a user level, three participants completed six out of the seven tasks successfully; one performed five tasks successfully; and the other participants only completed four tasks. The main problems were identified in Task 3, which required participants go back to the previous page by using the back button. And on Task 6, which required participants to view the meal plan for the entire week. This was a critical navigation issue that resulted from the lack of affordances of the button to change the week.

In terms of data visualization, there were a few issues with the charts used. First, the measurement unit was not clear; the labels were also not readable enough; and the daily objective plotted on the chart was not self-explanatory.

All of these issues will be addressed in the next iteration of the application.

6 CONCLUSIONS AND FUTURE WORK

In this work a mobile meal recommender system, named SousChef, was presented having as target audience older adults. SousChef is intended to act as a nutrition companion that guides older adult users into making wise decisions regarding food management and healthy eating.

Although in the literature, recommender systems were presented and different ICT applications are available, we have found no similar mobile-based solution designed with a focus on older adults' needs.

Tests to the recommender system and mobile application were made with older adults, to infer, on the one hand, the adequacy and quality of the meal plans suggested and, on the other hand, to test the usability of the mobile application itself for this specific audience. The user testing results were very satisfactory with more that 70% of the participants considering following the meal plan suggestions and use an application like the one presented. On the usability side, results were also satisfactory for the first prototype and we will keep iterating the current solution and testing new features.

As future work, new features are to be implemented, such as choosing the number of meals to be planned per day and setting recurrent meals. Another interesting feature to implement in the system would be to take into consideration the profile of more than one person. Also, a study with more participants will allow a more detailed analysis of the quality of the recommendations in terms of the nutritional requirements of the participants.

This paper reports the first version of the system and respective user mobile application, which brings some limitations. Due to its stage of development, it has not yet been possible to conduct a full-fledged evaluation of the system. Because people have many deeply rooted habits and beliefs related to food, we are aware that a thorough evaluation on the usability, usefulness and acceptance of the system may only be done in a longitudinal study in users' real context. The authors are aware of this current limitation. However, in this regard, the strength of the work relies on it having involved older adult users from onset, which allows to identify and eliminate potential barriers to acceptance and use of SousChef.

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REFERENCES

Aberg, J. (2006). Dealing with Malnutrition: A Meal Planning System for Elderly. In *AAAI Spring Symposium: Argumentation for Consumers of Healthcare*, pages. 1-7.

Adomavicius, G., and Tuzhilin, A. (2005). Toward the next generation of recommender systems: A survey of the state-of-the-art and possible extensions. *IEEE transactions on knowledge and data engineering* 17(6), 734-749.

Bunker, J. P. (2001). The role of medical care in contributing to health improvements within societies. *International Journal of Epidemiology*, 30(6), 1260-1263.

Candeias, V., Nunes, E., Morais, C., Cabral, M. and Silva, P. R. (2005). Princípios para uma Alimentação Saudável. *Lisbon: Direcção Geral de Saúde*, page 255.

Espín, V., Hurtado, M. V., and Noguera, M. (2015). Nutrition for Elder Care: a nutritional semantic recommender system for the elderly. *Expert Systems*.

Hazman, M. and Idrees, A. M. (2015). A healthy nutrition expert system for children. In *E-Health and Bioengineering Conference (EHB)*, 2015, pages 1-4. IEEE.

Kuo, F. F., Li, C. T., Shan, M. K., and Lee, S. Y. (2012). Intelligent menu planning: Recommending set of recipes by ingredients. In *Proceedings of the ACM multimedia 2012 workshop on Multimedia for cooking and eating activities*, pages 1-6. ACM.

Le Couteur, D. G., Solon-Biet, S., Wahl, D., Cogger, V. C., Willcox, B. J., Willcox, D. C., Raubenheimer, D., and Simpson, S. J. (2016). New Horizons: Dietary protein, ageing and the Okinawan ratio. *Age and ageing*, page afw069.

Long C. L., Schaffel N., Geiger J..W., Schiller W. R. and Blakemore W. S. (1979). Metabolic response to injury and illness: estimation of energy and protein needs from indirect calorimetry and nitrogen balance. *Journal of Parenteral and Enteral Nutrition*, 3(6):452-456.

Mika, S. (2011). Challenges for Nutrition Recommender Systems. In *Proceedings of the 2nd Workshop on Context Aware Intel. Assistance, Berlin, Germany*, pages 25-33. Citeseer.

Ministério da Saúde (2006). Tabela da composição de alimentos. *Instituto Nacional de Saúde Dr Ricardo Jorge. Centro de Segurança Alimentar e Nutrição*. 1a Edição. Compil. Ilda Martins; concep., elab. e coord. da edição Andreia Porto e Luísa Oliveira. INSA: Lisboa, p 355. ISBN: 978-972-8643-19-5.

Ministry of Health. (2013). Food and Nutrition Guidelines for Healthy Older People: A background paper. *Wellington: Ministry of Health*. Report, ISBN: 978-0-478-39399-6.

Murray, C. J., Abraham, J., Ali, M. K., Alvarado, M., Atkinson, C., Baddour, L. M., Bartels, D. H., Benjamin, E. J., Bhalla, K., Birbeck, G., et al. (2013). The state of us health, 1990-2010: burden of diseases, injuries, and risk factors. *Jama*, 310(6):591–606.

National Research Council (1989). Recommended Dietary Allowances. 10 ed. Washington, D.C., National Academy Press.

Ramic, E., Pranjic, N., Batic-Mujanovic, O., Karic, E., Alibasic, E., and Alic, A. (2011). The effect of loneliness on malnutrition in elderly population. *Medical Archives*, 65(2), 92.

Saka, B., Kaya, O., Ozturk, G. B., Erten, N., and Karan, M. A. (2010). Malnutrition in the elderly and its relationship with other geriatric syndromes. *Clinical Nutrition*, 29, 745-748.

Sezgin, E., and Özkan, S. (2013). A systematic literature review on Health Recommender Systems. In *E-Health and Bioengineering Conference (EHB),* 2013, pages 1-4. IEEE.

Tee, K., Moffatt, K., Findlater, L., MacGregor, E., McGrenere, J., Purves, B., and Fels, S. S. (2005). A visual recipe book for persons with language impairments. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 501-510. ACM.
Terrenghi, L., Hilliges, O., and Butz, A. (2007). Kitchen stories: sharing recipes with the Living Cookbook. *Personal and Ubiquitous Computing*, 11(5), 409-414.
Tran, Q. T., Calcaterra, G., and Mynatt, E. D. (2005). Cook's collage. In *Home-Oriented Informatics and Telematics*, pages 15-32. Springer.
Wahlqvist, M. L., Kouris-Blazos, A. and Savige, S. (2002). Food-based dietary guidelines for older adults: healthy ageing and prevention of chronic noncommunicable diseases. In *Keep fit for life: Meeting the nutritional needs of older persons*, pages 81-111. Geneva Switzerland: World Health Organisation 2002. ISBN 92 4 156210 2.
World Health Organization (2002). Keep fit for life: meeting the nutritional needs of older persons. In *Keep fit for life: Meeting the nutritional needs of older persons*. World Health Organisation 2002. ISBN 92 4 156210 2.
World Health Organization (2010). Definition of an older or elderly person. Geneva, Switzerland: WHO; 2010. http://www.who.int/healthinfo/survey/ageingdefnolder/en/index.html [acessed 20/03/2017].