Prototyping a Diet Self-management System for People with Diabetes with Cultural Adaptable User Interface Design

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Abstract

Diet management is a critical part of diabetes self-management. This project developed a working prototype application on Android-based mobile phone called SMART CARB that assists people with diabetes to self-manage their diet. The system particularly focused on monitoring carbohydrate intake in order to control their blood glucose levels. The project was positioned as a research extension to the development of the Few Touch mobile phone-application for diabetes self-management system that has been already in use. Food and meal are deeply embedded in local cultures. The project goal was to develop a prototype application that provides diet-self-management tools that reflect users' behavioral patterns and nature of food in their cultures. For the comparative case studies two cultural settings, Norway and Korea, were selected in order to understand differences in requirements from different food cultures that are critical for developing cultural adaptation mechanisms for the diet self-management system. Two versions of the application, one for Norwegian users and the other for Korean users, were developed with different interfaces reflecting the different natures of these two food cultures and user feedback was obtained through interviews with people with diabetes in these countries.

Keywords:

Cultural factors, Interaction design, Diabetes, Diet management, Mobile applications

Introduction

Recently many mobile applications have been developed to assist people to enhance their health and healthy life behavior such as dietary monitoring and fitness assistance. People with chronic medical conditions such as diabetes require more rigorous control over their health conditions. Some mobile phone applications have been developed for monitoring glucose level and diet patterns in order to enhance self-management capability for people with diabetes. The application we have developed and implemented is one of such systems developed over the last several years on different device platforms and features for both diabetes mellitus Type 1 (T1DM or commonly called Type 1 diabetes) and diabetes mellitus Type 2 (T2DM or commonly called Type 2 diabetes) [2, 3]. It has been tested and used by several hundred people in Norway.

Feedback from users of our application suggested that some improvements were needed in the nutrition management module. With the rough categorization scheme of Few Touch (six different categories: low carbohydrate snack, high carbohydrate snack, low carbohydrate meal, high carbohydrate meal, low carbohydrate drink, and high carbohydrate drink) by low and high carbohydrate, users could not make a judgment where the food they consumed should be placed. In addition they wanted to have more detailed food information than just categories. Moreover the users wanted to know how different food types influenced on their blood glucose level.

Medical recommendations for both Type 1 and Type 2 diabetes include the areas of nutrition, physical activity, and medications. These are the main factors that affect the blood glucose level. Of these three factors, patients regard following nutrition recommendations as especially challenging due to their lack of knowledge, understanding or skills concerning diet management. Ahlgren et al. [4] said that in diabetes management, adjusting dietary lifestyle is often very hard for people with diabetes. According to the findings by Nagelkerk et al. [5], 'Lack of knowledge and understanding of a specific diet plan' was ranked top as the perceived barrier by twenty-four people with Type 2 diabetes. They need to have a good understanding of the diet regimen for their successful diet management [6].

Successful implementation of dietary management systems therefore requires consideration on factors such as user acceptance, motivation, usability, learning as well as basic functionality of the system. Dietary patterns are deeply embedded in people's lifestyle and underlying food culture. People have different ways of living, understanding their environments, managing daily activities, motivating themselves, etc. Particularly people living in different culture have different living environments, history, social settings, value systems and different ways of viewing and thinking. Such cultural difference influences every stages of human action cycle that is modeled as "the seven stages of interaction" by Norman [7]. In order to enhance people's acceptance of a new technological solution and its sustainable usage, design of interactive systems such as dietary management applications needs to adapt to and accommodate cultural differences.

The goal of the project was to develop a prototype mobile phone application that provides a platform for studying different cultural needs for dietary management as a part of the diabetes self-management. This paper presents the results of the project.

Materials and Methods

An android-based smart phone prototype application, SMART CARB, was developed as a potential extension of Few Touch mobile diabetes management system in order to help people with diabetes make better choices in selecting food items and improve their nutrition management. This prototype can also be used as a platform to further explore culturally adaptable solutions for diabetes self-management systems.

For the comparative case studies two cultural settings, Norway and Korea, were selected in order to understand different requirements of the two cultural groups, particularly on food and food related activities that are critical for developing cultural adaptation mechanisms for the diet self-management system. Each version was tested with people with Type 2 diabetes in the corresponding country and the study produced important information for future research and design of a mobile diet self-management application in different cultures.

In the initial phase after setting the general goal of this project, in order to figure out the current status of the related research fields and to obtain future prospects, academic literatures about mobile terminal-based tools for diabetes diet management, food in different cultures, general cultural issue in UI design were reviewed. In parallel to the literature research, a series of interviews were conducted to elicit expert opinion about self-diet management for people with diabetes. Unstructured interviews were held with nutritionists in Norway and South Korea. Few persons with diabetes who participated the previous Few Touch development project were also interviewed. In the second phase, requirements and specifications for the system development were generated based on the findings from the first phase. Then the following phase, prototype models with different media, first paper much with sketches, then Excel prototype models with more details were developed. Informal evaluation by a person with diabetes who is familiar with diet and glucose level management applications made a final adjustment of ideas before the real system prototyping. Two versions, one for Korea and the other for Norway were developed. The two versions were then used for interview sessions with people with diabetes in respective countries for acquiring feedback regarding cultural adaptation of each version.

Existing Research

Applications (apps) developed for use on mobile phone platforms offer potential to address the challenges that are associated with the chronic disease, diabetes – both Type 1 and Type 2 [8]. There are a growing number of research publications and applications around diabetes self-management support, and advances in information and communication technology (ICT) provide a variety of options for developing efficient hardware and software platforms. Mobile phones provide a promising foundation for developing cost-effective diabetes systems that can be incorporated into diabetes patients' routines. However, research on usability and suitability in different cultures with a focus on this domain is difficult to find.

Mobile phones have proven to be a helpful tool for the self-treatment of diabetes [9, 10]. Our research have been focused around the Few Touch Application concept, a mobile phone system that has been developed and tested as a tool for research and assistance in self-management for people with Type 1 and Type 2 diabetes (T1DM and T2DM) [2, 3]. The system emphasizes ease of use through the application Diabetes Diary, where automatic wireless transfer of blood glucose values from the blood glucose meter using Bluetooth, and physical activity-, nutrition- and medication data captured through a simple user interface. Trials have shown a high degree of user adherence, with many users expressing their wish to use the tool after the trial. Many users also reported health benefits from using the system. However, feedback has also revealed the need for general food information that is useful for managing their health conditions as part of a mobile phone-based tool.

In their recent review of mobile-phone-based apps for diabetes management, Goyal and Cafazzo [11] concludes that "fully harnessing the capabilities of smartphones to deliver real-time feedback, diabetes education and secure data sharing remains largely underexplored" – which also is true for the nutritional functionalities part of such apps. Suggestions such as mobile systems including digital image recognition technology described by Hu et al. [12], nutritional behavior change interventions for young adults described by Hebden et al. [13], mobile phone messaging interventions where healthy nutritional reminders were part of a type 2 diabetes prevention programme described by Ramachandran et al. [14], and a PDA-based nutrition monitoring intervention using barcode scanning combined with voice recording described by Connelly et al. [15]. All these are good examples on innovative mobile nutritional systems and illustrates the variety of possibilities.

A mobile phone based system for supporting lifestyle changes among people with type 2 diabetes, the application has been designed and tested on a cohort of 12 patients [2, 3]. This application comprises a blood glucose monitor connected to a Bluetooth adapter, a tailor-made step counter, a nutrition habit registration system, and a system for practical tips. Feedback received from participants after a 6-month trial of the Application, indicated that there is a need for information related to calorie-rich food in order to enhance practicality of the system use.

Cultural Issues in the design of mobile phone-based systems

Food is an important factor of culture. In different cultures, people attach different meanings to events and objects in their daily lives and develop their unique patterns of behavior, significance, interpretation and rituals. In Norway, cold food for breakfast and lunch and hot food for dinner is a common pattern. Some also include a cold supper if they have an early dinner. In Korea every meal usually includes some hot food although Korean meal traditionally includes many cold side dishes.

Culture may be defined as 'Cultivation of individuals through the agency of external forms which have been objectified in the course of history' [16]. There have been many academic arguments and definitions made around the term "culture" from different perspectives including anthropology, sociology, philosophy and psychology [17]. The term culture can be used in a simple pragmatic way to indicate ways of living, including food, customs, language, etc. An interesting exhibition 'East Meets West – Differences of German & Chinese,' by Yang Liu [18], illustrated some different viewpoints from people in Germany and China, with simple diagrams for example, contrasting social relations, behavioural patterns, and characteristics of meals between the two countries.

Theoretical Frameworks of Cultures

In design, in order to better understand people's needs in different culture and create a better way to make technology accessible, acceptable and effective in the cultural context, frameworks of cultures have been often referred and used by designers. Some frameworks are more suitable for certain types of design problems and more practical implications. Examples of such frameworks are Hall's framework [19] with four dimensions, time, context, message speed and space and Hofstede's framework "five dimensions of culture" [1] that explain how the dynamics of culture influences individual and organizational behavior.

Hofstede's framework is composed of five dimensions: 1) Power Distance Index (PDI), 2) Individualism versus collectivism (IDV), 3) Masculinity versus femininity (MAS), 4) Uncertainty avoidance (UAI), 5) Long-term versus short-term orientation (LTO), 6) Indulgence versus Restraint (IVR). This framework has been applied in many areas such as marketing, organization, services and policies. With a focus on organizational culture, the framework has been further developed to a framework with eight dimensions. Table 1 shows a comparison of behavioral patterns possibly exhibited by weak and strong UAI groups.

Table 1 - Comparison of example behavioral patterns based on the difference on uncertainty avoidance (adopted from [1])

Week UA	**Strong UA**
People feel happy	People feel less happy
There are more nurses but fewer doctors	There are more doctors but fewer nurses
Teachers may say "I don't know"	Teachers are supposed to have all the answers
In shopping, the research is for convenience	In shopping, the research is for purity and cleanliness
Risky investment	Conservative investment

Nisbett [20] revealed the difference in the pattern of viewing information between Asian and American through his eye tracking pattern experiments. He interpreted the resulting differences between the two groups as a representation of difference between holistic versus analytic ways of viewing the world.

These theoretical frameworks offer system designers conceptual foundations and tools for understanding cultural difference and for further investigating specific design issues and designing specifications for interactive systems design, For example, cultural frameworks could be effectively applied for answering design questions such as how information should be presented and how navigation should be structured. But such information should be used in combination with rigorous user studies looking into more specific use issues in the overall system operation context. There have been many studies done in UI design areas to produce general design guidelines for cultural UI design (for example, [21-23]). Marcus, for example, thoroughly interpreted Hofstede's framework for practical UI design [21].

Cultural Background of Diet Management

In this research, the focus was on the issue of how the mobile application for diet management can make an easy access to its food database and effective assistance for entering meal data. Within this scope of the interest, types of ingredients, food items, categorization schemes of food items, and the way of assessing the amount of food in different cultures are primary elements that provide a basis for cultural differentiation of the user interface. Types of food regularly served in particular regions or countries are often available on databases provided by government agencies or private organizations. Regardless of how databases categorize food items, people develop their own categorization schemes and associations between food items based on various cultural aspects including daily meal patterns, distribution, associated events, and preparation methods.

Norwegians eat a mix of cold and warm meals. Contemporary Norwegian breakfast typically serves cold food with possibly hot drink; lunch most commonly consists of cold sandwiches; and dinner includes at least a primary warm dish although sometime it is simplified to a cold supper. South Koreans often have three warm meals. Food categorization methods in Norway and Korean are also different. Norwegian food items are more often categorized by food type. However Korean food items were categorized both by cooking types and by food types. Measuring methods of food amount are also different in the two countries. Different reference units for displaying the amount of carbohydrates were used for Norwegian food and Korean food due to different characteristics of food items and serving.

Culture changes over time by its internal evolutional forces and external forces from other cultures. Food types and meals have been changed fast in recent years by social changes such as urbanization, industrialization, globalization, information accessibility etc. Therefore the difference of food cultures is caused by many other factors besides regional and ethnic traditions. As a result even within a country many cultural groups can be identified with different differentiation factors such as life styles, food preference, and meanings of meals.

Requirements and System Specifications

Source of requirement

Previous work [2, 3] provided the main source of requirements regarding food registration. People with diabetes were recruited for this previous research and the group has been working on diabetes self-help tools. From the participants' feedbacks, it was found that they wanted to have more advanced tool for nutrition management. This project was initiated in response to this user need.

More detailed information about the food they eat, and a function that enables them to know the influence on their blood glucose level by changing their dietary habits are the main focuses for improvement.

A paper prototype was made first. Then an Excel prototype was built based on the initial idea informed by literature research. Since most of the functions of the system are based on simple calculation, Excel was used as a tool for making rapid prototypes. To get Experts' feedback and opinions about the Excel prototype, a meeting with a nutritionist was held. Requirements and points to improve were discussed at the meeting. Based on the feedbacks from the nutritionist, second version of the excel prototype was developed. A person with diabetes was also invited in testing excel prototypes to evaluate prototype concepts, then four versions of the next round excel prototype were sent to the same person for evaluation. The areas for improvement were discussed through phone and Skype. Some requirements that he indicated were adopted. Regarding other requirements such as how to categorize the food items and select food items included in the app, e-mail advices from the nutritionists both in Norway and South Korea were also adopted.

Then a simple Android mobile application was developed with the improved design specification. This prototype includes 24 Norwegian food items based on the fifth excel prototype to check the application's usability. The design was done by the app inventor designer and tested using the android emulator.

Information and Navigation Structure for Selecting Food Types

Different food cultures use different ingredients, combinations of use, processing methods, and serving methods. Therefore people's association patterns between even same ingredients are different. Different categorization methods of food types were used for quick search and access in the Norwegian version and the Korean version. Norwegian food items were categorized primarily by food type and Korean food items were categorized by the way to cook.

The following categories were used in the Norwegian version: Bread, Meat and fish cold cuts, Cheese, Breakfast corn and porridge, Milk and Yogurt, Drinks, Sugar, honey and jam, Fruits, Vegetables. These categories were selected and organized based on discussions with a Norwegian nutritionist. Oil, butter, margarine, mayonnaise was excluded in the categories because only small amount of oil is used compared to other types of food items. However some food items such as salami, cooked ham and white cheese, which do not have any carbohydrates, were included in categories as well. Because the SMART CARB application also addresses the need of self-learning, these foods items with no or negligible amount of carbohydrate were included. Although overall diet pattern is important for all of us particularly people with diabetes, SMART CARB as a prototype only implemented carbohydrate-monitoring functions for simplicity.

The following categories were used in the South Korean version based on Korean nutritionist's consultation: Rice/Porridge, Soup/Stew, Kimchi/Pickles, Herbs/Seasoned food, Steamed food/Boiled food, Fried food/Grilled food, Fried food, Noodles/Dumplings, Drinks, Fruits/Vegetables, Rice cake/Bread. The categorization of food item was discussed with a Korean nutritionist through e-mail.

Figure 1 - Opening screen for the Norwegian version (left) and the Korean version (right).

Selecting food items

Due to the different food culture and dishes that normally are served in Norway and in Korea, different food items were included into each application. For the Norwegian version, the Norwegian table of food "Matvaretabellen" was used to select food items and to provide the amount of carbohydrates in the food items. Since only bread-based meal type was regarded in the Norwegian version, 118 related bread meal food items were selected. (As mentioned above, most Norwegians have a cold, mostly bread-based, 1st and 2nd meal.) The 150 most common and popular food items were selected for the South Korean version. These items and the information about the amount of contained carbohydrates from a smart phone application 'Calorie Codi' developed by the Korean food and drug administration were used.

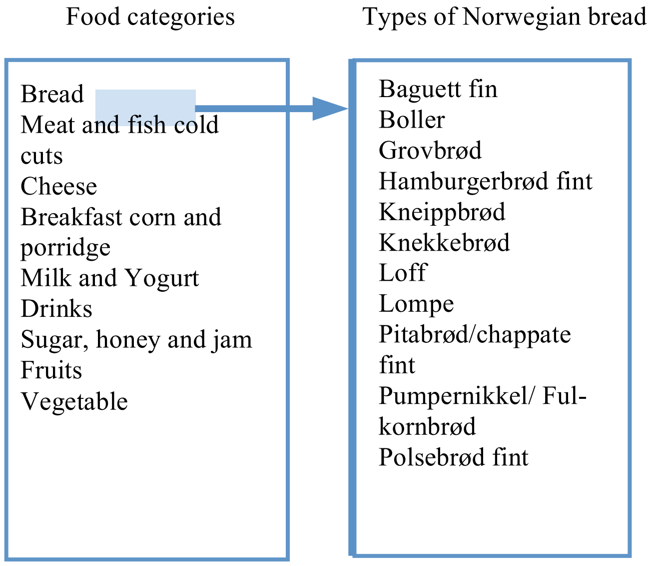

Figure 2 - Categorization of food items in the Norwegian version. When "Brød" (Eng., bread) is selected, the list with types of bread (to the right) appears.

Figure 3 - Categorizing of food items in Korean version.

Measuring amount of food items

The SMART CARB application also had to take into account the differences in measuring methods for the food portion. In the Norwegian version estimations are based on weight. In the South Korean version the estimations are based on portions. It is easier to measure the weights of Norwegian food items with scale since the form of food items for bread meal type is easy to weigh. However it's difficult to weigh Korean food items because there are many liquid food items such as soup, stew, etc. Due to the characteristic of food items, different portion sizes were used for Korean food. Therefore standard portion sizes were used in the Korean version and 100 gram portions was used in the Norwegian version as the reference unit for displaying the amount of carbohydrates.

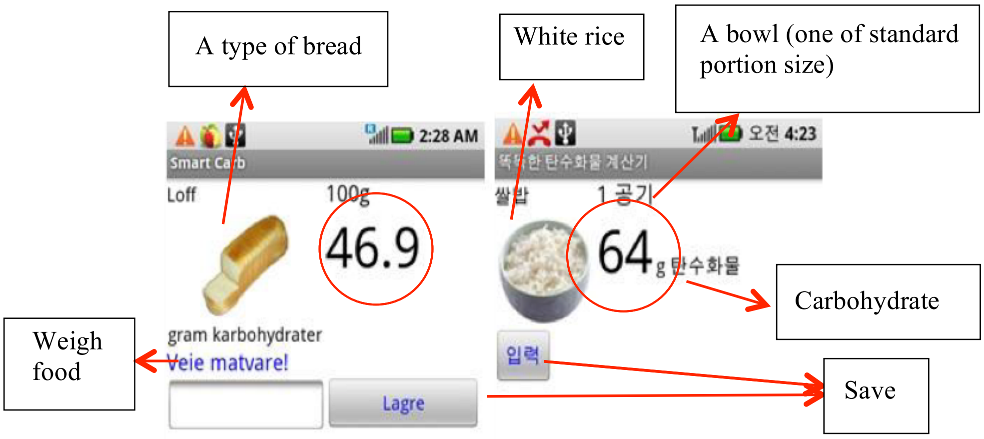

Figure 4 - The Norwegian version with weight (in 100 g) (left) and the Korean version with standard portion size (right).

Design and Prototype Development of SMART CARB

Basic Functions and Use case

After the information to be displayed on the graphical user interface was identified, paper prototypes and Excel prototypes were developed based on the accumulated information. A meeting with nutritionist was held to get feedback about the developed prototypes and to discuss the points that should be improved. The prototype was then further improved based on the advices from the nutritionist. A UML use case diagram was built to outline the scope of the prototype.

Opening screen

Different food pictures were used for the opening screens. The displayed food items represent the differenct characteristic of food in Norway and South Korea.

Categorizing Food Items

Different categorizing methods were used for easy follow-up and quick finding in the Norwegian version and the Korean version respectively. Norwegian food items were categorized by food type and Korean food items were categorized by the way of cooking.

Task Flow

Figure 6, left, shows the flow chart for the use of the Norwegian version of Smart Carb. For the food items in 'Drink' and 'Milk and Yogurt' categories, empty glass should be weighed first, before the food item with glass are weighed for the first time users and occasional calibrations.

Even for Norwegian version, it is too demanding and troublesome to carry around a scale and weigh food at a table. Weight can be still used for entering food amount but by using conversion table or some references for accurate estimates. It is ok for sandwiches but Norwegian each other types of food too.

The South Korean version of Smart Carb is presented in Figure 6, right. The difference is that there is no process of weighing food items in the South Korean version. Thus there is no process of weighing empty glass, either. Due to the characteristic of the South Korean dishes, it is difficult to weigh the food items. Instead of weight, standard portion sizes are displayed with the amount of contained carbohydrates of the selected food items.

Case Study and User Feedback

To compare the perception of this application from a comparative point of view, interviews and usability tests were conducted in Norway and South Korea. Interviews were held with this android mobile phone application by showing how to use the application first and then letting them try the application. Seven and 20 participants with Type 2 diabetes were involved in individual interviews in Norway and in South Korea, respectively. The age range of the subject group was between 40 and 80 years old. The participants were also requested to fill out a questionnaire at the same place before interviews to see the condition of their nutrition management and their level of satisfaction.

'Smart carb' was introduced with a PowerPoint file. This presentation included the purpose of 'Smart Carb' application, the procedure of using the application, examples of screen shots by following step by step, required amount of carbohydrate per day or per meal and practice with some typical diet. To give participants a better impression they practiced 'Smart Car' application with supervision and to enhance the reality, real food items were used. Below are the food items, which were displayed:

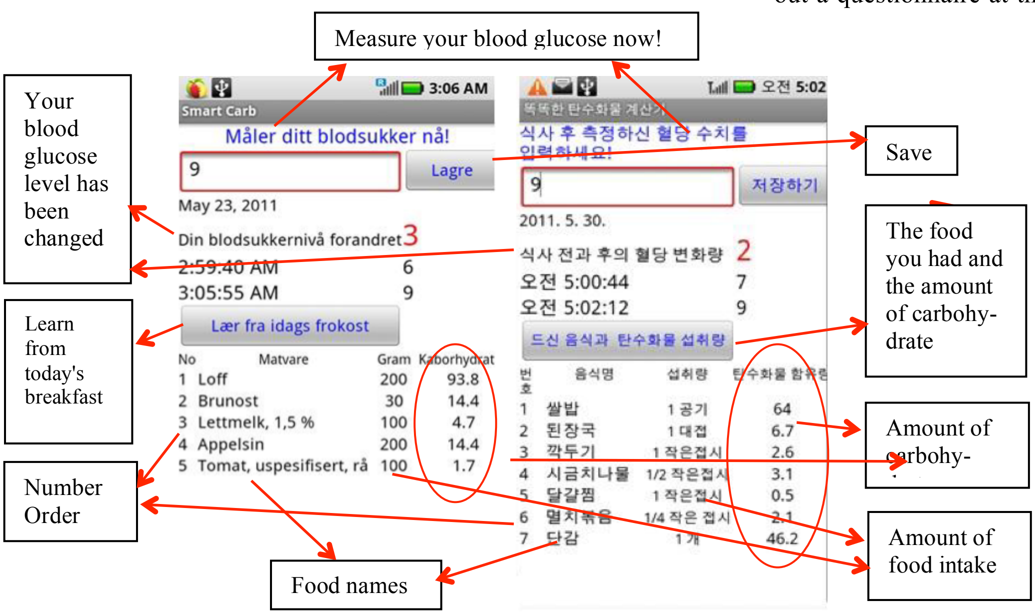

Figure 5 - The amount of food intake by gram (Norwegian, left) and the amount of food intake by portion (South Korean, right)

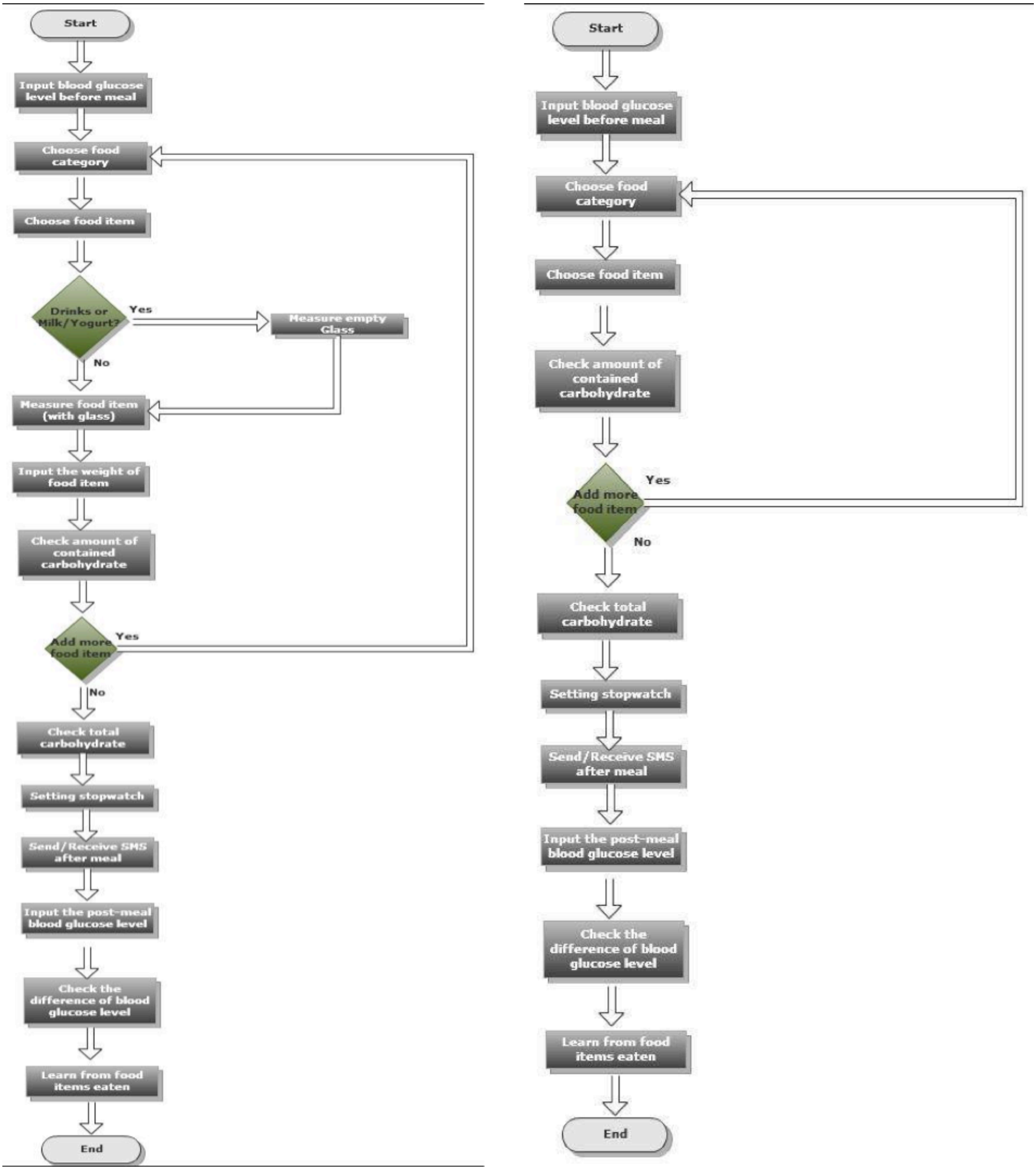

Figure 6 - Flow chart for Norwegian version (left) and. South Korean version (right)

- Bread: 2 boller, 3 slices of bread
- Topping: 3 slices of boiled eggs, 3 slices of white cheese, 2 slices of salami, 2 slice of ham (2 types)
- Vegetable: cucumber, tomatoes
- Fruits: 1 mandarin, 1 apple, 4 slices of orange, half kiwi, green grape, strawberry
- Drinks: milk, orange juice, 2 bottles of soda
- Equipment: 1 empty glass, scale

When the participants tried Smart Carb application, they were allowed choose the food items they would like to eat for their meal. They weighed each items with scale and registered the weights of the food items into the application.

However no real food item was used for the Korean participants' practice because Korean food items are difficult to weigh. Serving portion was displayed for users' reference instead of weigh the food items. The Korean participants found the food items which they wished to eat in the application and checked the carbohydrate amounts in default portion size. Then they registered the food items.

User feedback was collected through usability test sheets and verbal interviews.

The Norwegian participants who had experience with the 'Few Touch application' [2, 3] expressed a strong willing to use this application. However the Korean participants who did not have experience with such kind of application and the smart phone itself, were skeptical or afraid of using this application. Most of the participants agreed on the importance of tracking the amount of carbohydrate intake, and expressed difficulty in estimating the amount of carbohydrate in food items. Therefore they wanted to have a tool to help them to estimate carbohydrate amounts.

Lessons learned through the interviews are as follows:

- Difficulties in behavior change are reported in terms of nutrition habit
- Concerning tool features, customization or modification based on personal data or users' skills is considered important and beneficial
- Timely, automatic and personalized feedback should be incorporated in a motivating and easily interpretable manner
- A system showing nutrient and calorie content is considered powerful if it contains enough variety and numbers of food and drink items that are familiar to users
- Simple categorization for recording nutrition habits was well accepted and appreciated for routine use, but some participants consider such categorization too coarse).
- Photographs of food and drink items are considered useful, especially if they include a scale or familiar cutlery as a reference of size, for adjusting portion sizes.

Conclusion

This paper described the process of developing a mobile application for diet self-management, SMART CARB, with a focus on users' cultural difference. The way cultural factors were incorporated in the solution to enhance accessibility to information and data entry for people from two cultures, Norway and Korea. Because of the very different food cultures, two versions of user-interface were built with the same platform with the same concept to enhance user's awareness about calorie intake and nutrition in general. Several versions of prototypes including the final working prototype application were developed and used to get feedbacks from potential users and experts. Each patient's nutrition management and the level of satisfaction with the application presented to him or her through the process were recorded.

This application enables the user to learn effects of diet patterns on blood glucose level by providing carbohydrate Smart Carb represents a self-help tool for people with diabetes which can provide rich information regarding nutrition management. The paper presents an attempt to test a nutrition self-management mobile phone based application for people with diabetes in different cultures.

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