Tell Me What to Eat – Design and Evaluation of a Mobile Companion Helping Children and Their Parents to Plan Nutrition Intake

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Abstract. Obesity is a global issue and has a direct impact on the public and private healthcare system. In this paper we describe the design and evaluation of a novel mobile health application that supports obese children and their parents to improve their nutrition intake. First results from quantitative app usage logs, questionnaires and interviews indicate that the mobile health app provides relevant information to attain a balanced nutrition. A discussion of the results and an outline of future work conclude this paper.

Keywords: Children, Parents, Overweight, Obesity, Mobile App, Healthcare.

1 Introduction

Obesity is a global issue and has a direct impact on public and private healthcare system [1]. In Switzerland, prevalence of overweight and obesity in childhood has stabilized over the last ten years but 20% of children remain overweight and urgent efforts are needed to control the epidemic [2]. Implications of these observations are not only psychological and physiological drawbacks for those being affected but it has also serious effects on the public and private healthcare sector by increasing costs due to overweight- and obesity-related comorbidities and a lack of health supply [3]. In Switzerland, for example, obesity-linked disease costs have more than doubled from 2.600 Mio USD in 2001 to 5.800 Mio USD in 2006 [4], which equals to almost 10% of all health expenses in Switzerland (according to the Swiss Statistical Office).

In order to address these issues, multi-professional programs with physical activity, nutritional and behavioral interventions have been proposed [5]. Such programs were

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shown to have positive effects on therapy outcomes [6]. However, due to limited personal and financial resources, only a small percentage of children affected can participate in such programs. In Switzerland, for example, this is less than one percent of overweight children [3].

Information technology has the potential to improve outcomes of health interventions and to significantly reduce costs [7, 8]. Therefore, we propose to address the problem by a novel mobile app that accompanies obese children and their parents during everyday situations, namely planning of their nutrition intake.

The contributions of this paper are as follows: In the next section, we provide some examples from related work that leverages IT to improve people's health condition. Based on major shortcomings of these research endeavors, we then describe the design process of the mobile health app. This process included not only computer scientists and information systems researcher but also several physicians, nutrition experts, obese children and their parents. We proceed with the description of a pilot study, in which the mobile health app was assessed, and present the results. Finally, the discussion and future work shed light on how to further validate, revise and improve the proposed mobile health app.

2 Related Work

2.1 Health Applications

In this section we present various examples of health applications that have the potential to support health-promoting behavior in teenagers (for a comprehensive list of prototypes and preliminary studies on IT-supported obesity interventions see [9]). For instance, Huston [10] is a mobile app that fetches users' physical activity data from a pedometer and demonstrates it on a mobile phone. UbiFit Gardens [11] links a user's daily step count to the emotional state of a garden shown on the screen of her/his mobile phone. Fish'n'Steps [12], a social computer game that translates a player's daily foot step count to the growth and facial expression of a fish, reveals the effectiveness of using games and emotional design to improve users' attitudes towards physical activities.

In addition to encouraging people to do more physical exercises, other apps aim at helping people to optimize their nutrition intake. For example, HyperFit [13] is an Internet service for personal management of nutrition and exercise. It monitors users' diet and exercise behavior through logging and barcode scanning tools. PmEB [14] is another app that enables people to log their food intake and physical activity everyday. Calorie consumption and expenditure is calculated so that users can self-monitor their calorie balance in real time. Regarding the design of recipe recommendation apps, Harvey et al. [15] revealed that healthiness, preference on specific ingredients, and preparing time have been found to be relevant to users. Wu [16] shows that compatibility, perceived usefulness and perceived ease of use have strong influence on people's acceptance on mobile applications in the healthcare domain. According to

design styles, Khan [17] shows that parents prefer straightforward design while children and teenagers prefer gamification and social interaction.

2.2 Shortcomings of IT Interventions for Childhood Obesity

Although there are already many applications available to help people form a healthier lifestyle, at least four shortcomings can be observed. First, Kowatsch et al. [9] conducted a systematic review of 17 research papers and 13 commercial applications and found out that the majority of these applications did not consider a multi-professional approach as recommended and, in most cases, they did not evaluate evidence-based effects on health outcomes. Furthermore, applications reviewed [ibid.] had not been co-designed and evaluated by therapists, children, their parents and IT experts together. In addition, only few IT-supported health interventions are tailored to children and adolescents with their individual needs and requirements (e.g. weightdog.me or kurbo.com). Moreover and with a particular focus on diet behavior the following can be observed: Although people's preference on specific ingredients is one of the most important factors in recipe recommendation, current applications have not taken it into account. Finally and most important, the applicability of a mobile app in the day to day life of the patient and his family together with side effects regarding dieting or excessive IT use were not documented for most applications.

Consequently, our research aims to address these shortcomings and thus, we decided to develop a novel mobile health app. As a first step, we focused on diet-related services as described in the remainder of this paper (complementary services are developed and described in [9] and [18]).

3 Design Process

3.1 Research Setting

Teenagers with overweight or obesity, defined as body mass index above percentile 90 of reference data [2], were recruited from patients in an outpatient pediatric department to co-design the mobile health app in workshops, by questionnaires, interviews and practical everyday use as mentioned below. The patients were participating in a multiprofessional obesity program. The local ethics committee approved the design process and pilot test of the mobile health app. Informed consent was obtained both from patients and parents.

3.2 Concept of the Mobile Health App

To determine the app's services, a situation-based design approach was adopted [19, 20]. Through interviews and workshops with obese children, their parents and physicians, several requirements with a focus on diet behavior were identified: First, the app should recommend recipes based on ingredients available at home, prioritize desired ingredients of the patients, and foster a diverse meal plan based on the consumption history of previously chosen ingredients. Second, as the users navigate

through the recommendations and make their choices, they should receive direct feedback on recipes and ingredients with regard to healthiness. Finally, the app should also help physicians trace and evaluate children's therapy compliance.

To avoid dieting and to ensure an adequate balanced composition of the proposed recipes, 50 recipes were selected by a nutrition expert from a cooking book [21] that is not only widely used in the national primary education but also a standard book in almost every household of the targeted patients and their families. Quality of recipes and quantity of nutrients are in accordance with recommendations of the Swiss Society for Nutrition (www.sge-ssn.ch). The most important messages include a diversified choice out of each main nutrient group with an adequate portion size. These recipes and their corresponding ingredients were saved locally in the app. Detailed information about how to cook the recipes was described in a cookbook with which the patients and their parents were supplied together with a mobile device running the app.

3.3 Services of the Mobile Health App

The mobile health app was realized on an Android-based tablet PC and is used together with a cooking book [21] as shown in Fig. 1.

Fig. 1. Overview of the mobile health app with five diet-related services

The app consists of five diet-related services as shown on the main screen of the mobile health app in Fig. 1. These servicers are:

1. Available Ingredients service ("At home, we have …") designed for parents
2. Desired Ingredients service ("I would like …") designed for patients
3. Recipe List service ("Recipe recommendations?") designed for patients
4. Shopping List service ("Our shopping list") designed for parents
5. Photo Documentation service ("My photo diary") designed for patients

The Available Ingredients service helps parents log the available ingredients at home. By entering the name and quantity of ingredients, a list of available ingredients can be created and stored in a local database on a mobile device. In addition, ingredients can also be modified and deleted with the help of the same service.

Similarly, children can add and modify their desired ingredients with the help of the Desired Ingredients service. The only difference to the Available Ingredients service lies in the fact that a direct feedback is provided, which was perceived as an important design choice by the design team to direct and correct diet-related behavior. That is, direct feedback for a diversified and balanced food composition is provided in a form of a smiley as shown in Fig. 2a together with a brief textual description similar to the screenshot depicted in Fig. 2c in case the smiley was tapped with the finger. This smiley reflects the "balanced nutrition", namely the adequate frequency of intake with respect to nutrient content of this ingredient (refer to algorithm in detail below). Red, yellow and green smileys stand for the number of times ingredients were selected (too often, often and adequate, respectively) during a one-week period. By touching the smileys, the rationale for the color is provided by a brief textual description from an "anonymous" nutrition expert as shown in Fig. 2c.

Furthermore, Fig. 2b illustrates the Recipe List service used by children to select three out of five recommended recipes. Similar to the Desired Ingredients service with regard to the choice of a direct feedback rationale, each recipe also has a smiley with color green, yellow or red that serves as a feedback, again based on the frequency of prior selected recipes in the past week. The picture and ingredients of a recipe will be demonstrated when a "Details" button is pressed. In case a child selects a recipe with a yellow or a red smiley, a notification will be pop up to encourage the child to take another recipe or update her list of desired ingredients to get new recommendations, as shown in Fig. 2c.

Once three recipes are selected in the Recipe List service, a shopping list is generated for the parents by the Shopping List service (see Fig. 2d). Ingredients' names and quantities are ordered alphabetically and categorized into different groups like meat, vegetables and drinks to ease the shopping process in supermarkets.

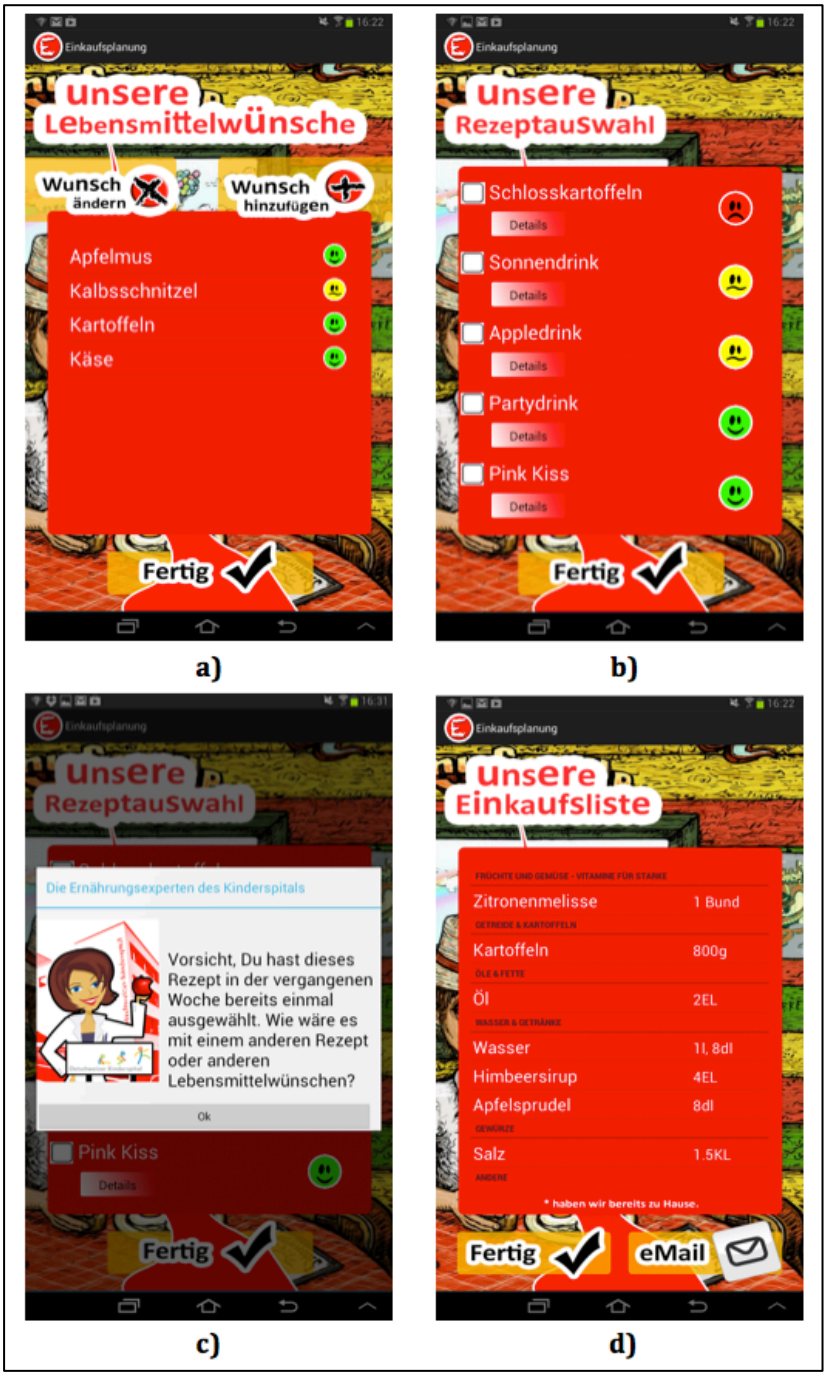

Fig. 2. Screenshots of the diet-related services of the mobile health app

An optional asterisk nearby ingredients indicates that the corresponding ingredient is already available at home, i.e. it was added to the list of available ingredients in a prior step. Due to the fact that parents requested a paper-based shopping list in the design phase, an email function was integrated to send out the generated shopping list to a pre-defined email address for printing.

Finally, it was crucial that a feedback to patients exists and that the use of the mobile health app is supervised by a health professional, e.g. a nutritionist, online or personally. In order to monitor patients' compliance to the recommended recipes and shopping list in their everyday life, the actual behavior is documented with the Photo Documentation service. For example, patients were asked to take photos of the purchased ingredients, the cooking process and the resulting meals as pieces of evidence. This behavioral data was shared and discussed with a supervising health professional. Pictures taken by the children in the field test are shown in Fig. 3.

Fig. 3. Pictures as pieces of evidence taken by children in the field test

3.4 Feedback and Recommendation Algorithm

Two feedback algorithms, one for ingredients and another for recipes, were used to generate the smileys. An ingredient in the 50 selected recipes was defined as unhealthy when it has been consumed too many times in a short period of time. A nutrition expert set the actual threshold for the recommended upper limit of an ingredient per week. For example, according to current recommendations on healthy nutrition

(www.sge-ssn.ch), the threshold value for beef was set to four, which means it was better not to eat beef more than four times per week.

Whenever a recipe was selected with the help of the Recipe List service, the current timestamp would be compared with the *start_time* of all of the ingredients in that recipe. If the time difference was smaller than seven days, the *current_consumption* value of that ingredient would be increased by one. Then the feedback point of each ingredient was calculated from dividing its *current_consumption* value by the corresponding threshold value. This point was represented by a smiley as an intuitive feedback for the teenagers. High (> 0.7) and low (< 0.3) feedback points were represented by red and green smileys, respectively. Feedback points in between were represented by yellow smileys. Contrasting with that, if the time difference was larger than seven days, *start_time* of the ingredient would be replaced by the current timestamp and its *current_consumption* value would be set to one. Meanwhile, its feedback point was calculated based on the same strategy as described above.

Similarly, the feedback algorithm for recipes was also based on the consumption history of each recipe in the past week. A green or yellow smiley feedback was set to a recipe if it was consumed for up to once per week. In contrast, if a recipe was selected more than twice per week, it would be assigned a high feedback score.

The recommendation algorithm includes three factors: (1) current available ingredients at home, (2) current desired ingredients of the patients, and (3) current consumption history of all the ingredients. As parents stated that they needed healthy recipes that could reuse the available ingredients to the greatest extent, the healthiness of each recipe was calculated by using Eq.1:

$$\text{Healthiness} = \rho1 \cdot |\text{REP} \cap \text{AVB}| + \rho2 \cdot |\text{REP} \cap \text{DSR}| + \rho3 \cdot (\text{fb} - 10) \quad (1)$$

The set REP represents all the ingredients in a recipe. The sets AVB and DSR reflect all the available and desired ingredients. The term $|\text{REP} \cap \text{AVB}|$ represents the number of elements in the intersection of REP and AVB. The weights $\rho1$, $\rho2$ and $\rho3$ were set to 3, 1, and 0.5 respectively in the mobile health app. These weights were selected empirically to make sure that factor (1) and (3) have a stronger influence than factor (2) on ordering all the 50 recipes. The parameter fb in the equation is set to 10, 5 or 0 for green, yellow and red smileys. Thus, the last polynomial serves as a punishment if an ingredient has been consumed more than 30% of its threshold value.

Before entering the Recipe List service, the value of "balanced nutrition" of each recipe is calculated first. All the recipes would then be ordered from the highest value of "balanced nutrition" to the lowest. Finally, the top five ranked recipes are shown in the recipe selection view (see Fig. 2b).

3.5 Data Collection

A logging mechanism was implemented for quantitative analysis of the screen time consumed: when a button of the mobile health app was pressed, a log entry in JSON format would be sent to the backend database by an HTTP Request. Such an entry includes user id, button name, current timestamp, and action related information such as editing an available ingredient or selecting three recipes. Color of smileys for reci-

pes and desired ingredients would also be transferred to the backend when their corresponding services were used.

In addition to the log data, questionnaires were designed to get children and their parents' direct feedback on the design and functionalities of the mobile health app. Here, patients evaluated different aspects of the app on six-point Likert-scales ranging from strongly disagree (1) to strongly agree (6). An even number of the Likert-scale anchors was used to address common answer patterns (in particular, with regard to the neutral "neither" anchor if five or seven-point Likert scales would have been used) that were already observed by our health professionals in prior studies with the target group of this mobile health app.

4 Evaluation

4.1 Design of the Pilot Field Study

In order to test the mobile health app in a pilot study, the physician responsible invited several patients between age 11 and 14 who already participated in an individual obesity therapy in the outpatient department of the children's hospital. Second, a consultation with patients and parents was conducted to inform them about the objective of the study and the usage of the mobile health app. Then, a tablet PC with the app pre-installed, the cooking book and a monetary compensation were provided so that the family was able to buy the ingredients of the selected recipes. Patients and their parents were then asked to use the app at least once for meal planning, preparation and documentation purposes at home. For this task, they were given three weeks on average. Finally, patients, parents and physicians discussed the results during the second consultation in which the app-related questionnaires were filled out, too.

The primary research questions regarding the current work were:

1. Which sort of content provided by the mobile health app is perceived as useful information for selecting recipes?
2. Which sort of content provided by the mobile health app actually influences the decision on selecting recipes?

Whereas the first question is formulated from a more general third-person point of view, the second question addresses rather the individual perspective of the patients with regard to the actual decision-making situation. Answers to these questions would not only reveal first evidence on the utility of the mobile health app but they would also help the design team to further improve it.

4.2 Participants of the Study

Overall, six male children each with one parent participated during the first consultation and four male children with one parent during the second consultation between April and June 2013. The dropout of two families was not related to the study but

rather to limited time resources of the patients and their parents. The average age of the four resulting patients was 12.8 (SD = 2.6).

4.3 Results of the Study

On average, 3.75 (SD=2.22) usage sessions with a length of 13 minutes (SD=4) were identified through the backend data log. Furthermore, the patients took 12.3 photos (SD=6.95) on average. Examples of these photos are depicted in Fig. 3. The descriptive statistics and details with regard to the two primary research questions are shown in Table 1.

Further empirical results of this study with a focus on other theoretical constructs such as perceived usefulness, perceived ease of use, perceived enjoyment (of the overall mobile health app to improve health behavior) or the potential of the mobile health app to improve shared understanding and cross-understanding among patient and therapist with regard to obesity therapy are published in [9] and [22].

Table 1. Descriptive statistics of the pilot study (N=4). Note: answers were anchored on six-point Likert scales ranging from strongly disagree (1) to strongly agree (6).

What content provides useful information for selecting recipes:		
Content	***Mean***	***Std. Dev.***
Order of recipe recommendations	3.50	1.30
Color of the smiley feedbacks	5.75	0.50
Image of a recipe	4.00	0.00
Ingredients of a recipe	4.50	1.00
What content has influenced my decision on selecting recipes:		
Content	***Mean***	***Std. Dev.***
Order of recipe recommendations	3.00	1.41
Color of the smiley feedbacks	4.50	1.29
Image of a recipe	4.00	1.41
Ingredients of a recipe	4.50	1.00
Estimated cooking time	4.25	0.50

Four patients selected 27 recipes during the field test. Recipes located in the first place, however, were selected only twice. Recipes located in other places were selected almost evenly, with seven times for the second and fifth place, six times for the third place and five times for the fourth place. Regarding the direct feedback via smileys and a brief textual description by the "anonymous" nutrition expert, patients found that the color of smileys was helpful in providing them with useful information for recipe selection, followed by the ingredients of recipes and the image of recipes.

When asked what influenced their decisions on choosing a particular recipe, children selected the color of smileys and ingredients of a recipe as the most influential aspects. From all the sessions except those identified as testing, only one recipe with

yellow smiley was presented to a user, and it was not selected. All the other recipes were presented with green smileys.

The limited number of presented yellow and red smileys could be explained by the limited app usage per week, as well as the effectiveness of the recommendation algorithm.

With regard to the recipe recommendations, the algorithm performed in accordance with the recommendations of a nutrition expert. However, based on the qualitative feedback, almost all patients and their parents disliked the limited number of recipes for selection and the restriction that exactly three recipes should be selected each time, which was actually intended by the design team to reduce not only the complexity of the mobile health app but also of the tasks and homework of patients (and their parents) within obesity interventions in general.

5 Discussion and Conclusions

We presented the design and evaluation of a mobile health app that aims to help obese children and their parents to plan their daily nutrition intake. The smiley feedback was regarded important for providing valuable information and helping children to make decisions on recipe selection. The prototype's feedback and recommendation algorithm helped obese children to eat more diversified and healthier food due to the fact that none of the participants had selected a single recipe twice in a week. This is important in so far as overweight people tend to have a very limited choice of food [23]. It can also be concluded that those children were highly motivated because they used the prototype several times although they were requested to use it only once in the field test period.

Furthermore, an excessive use of the mobile health app was not observed. Together with the flexible advice on balanced meals and the supervision by a nutritionist or a physician this mobile health app may contribute to avoid potential side effects as media abuse or eating disorders.

From a therapist's point of view, the feedback loops on nutrition behavior and the photo documentation were important not only for the patient and his family to increase awareness on their lifestyle but also for the therapist to recognize, how recommendations were implemented at home.

Having more flexibility to select from all available recipes (in addition to the preselected three) was given the highest importance during the final qualitative feedback round. This must be taken into account when designing a mobile companion for high user involvement.

Based on the original design, recipes were ranked based on how well their ingredients match the current available and desired ingredients and how frequently their ingredients were consumed in the past week. Therefore, recipes with higher rank not only mean that they are healthier and cater better to the personal desire but also mean they bring financial advantages since they can reuse the available ingredients to the largest extent. Rationally, among all the five recommended recipes, the first one should be selected most frequently whilst the fifth one should be the least preferred.

Thus, reordering all the recommended recipes might help people make more "nutritional balanced" decisions. This strategy could be applied to other mobile apps that provide users with several options to select from (e.g. with regard to physical activities).

Overall, we could learn from this research that mobile health apps (1) enrich therapist-patient communication and relationship by incorporating advice through feedbacks, (2) help families to jointly engage not only in the decision process of selecting food and recipes but also in meal preparation and enhancing eating habits, and (3) have the potential to give more patients access to therapy programs through their scalability.

6 Future Work

As next steps, we plan to improve the mobile health app by removing current restrictions on recipe selection. In addition to nutrition intake planning, also patients' physical activities, relaxation and emotional self-regulation capabilities will be measured and integrated into IT-supported obesity interventions [9, 18]. An evaluation of these services, including their effects on therapy outcomes such as the body mass index is in progress [24-26]. Finally, the app should be also released in the app-store allowing an even broader evaluation with a larger population of users in the wild [27].

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