HEALTH INFORMATION SYSTEM FOR OBESITY PREVENTION AND TREATMENT OF CHILDREN AND ADOLESCENTS

Prototype

Irena Pletikosa Cvijikj, ETH Zurich, Zurich, Switzerland, ipletikosa@ethz.ch

Tobias Kowatsch, University of St.Gallen, St.Gallen, Switzerland, tobias.kowatsch@unisg.ch

Dirk Büchter, Ostschweizer Kinderspital, St.Gallen, Switzerland, dirk.buechter@kispisg.ch

Björn Brogle, Ostschweizer Kinderspital, St.Gallen, Switzerland, bjoern.brogle@kispisg.ch

Anneco Dintheer, Ostschweizer Kinderspital, St.Gallen, Switzerland, anneco.dintheer-tervelde@kispisg.ch

Dunja Wiegand, Ostschweizer Kinderspital, St.Gallen, Switzerland, dunja.wiegand@kispisg.ch

Dominique Durrer Schutz, Eurobesitas, Vevey, Switzerland, dominique.durrer@bluewin.ch

Dagmar L'Allemand-Jander, Ostschweizer Kinderspital, St.Gallen, Switzerland, dagmar.lallemand@kispisg.ch

Yves Schutz, University of Fribourg, Fribourg, Switzerland, yves.schutz@unifr.ch

Wolfgang Maass, Saarland University, Saarbrücken, Germany, wolfgang.maass@iss.uni-saarland.de

Abstract

Childhood obesity is becoming an alarming issue with implications affecting the society and the healthcare sector. In response, multi-professional programs with physical activity, nutritional and psychological components have been proposed. Still, due to limited resources only small number of patients can be included in these programs. Health information systems (HIS) have the potential to tackle these challenges. Yet little is known about the design and effects of HIS in the domain of multi-professional obesity programs, in particular those tailored to children and adolescents. In order to address this problem we have built a HIS prototype with a goal to support obesity interventions for children and adolescents. The prototype provides several contributions to theory and practice. First, it fits to the concept of multi-professional obesity interventions not present in most of existing commercial and research-based applications. Second, it provides an instrument that is co-designed by patients, IS researchers, computer scientists and obesity experts, thus tailored to the specific needs of children and adolescents. Third, it provides a possibility to gain evidence-based knowledge about the potentials and the effects of HIS over obesity therapy outcomes through longitudinal field studies.

Keywords: Health information systems, childhood and adolescent obesity, multi-professional program.

1 Problem Definition

Due to the significantly increasing numbers, childhood obesity is becoming an alarming issue (Sassi, 2010). According to the World Health Organization (2014) in 2010 there were more than 40 million overweight children under the age of five with a growth that is taking epidemic proportions. For example, the rate of overweight children and adolescents in Switzerland has doubled between 1997 and 2007 (Aeberli et al., 2010) with predictions that this number will grow up to 20 percent by 2022 (Schneider et al., 2009). This situation has serious implications for the healthcare sector by increasing costs due to obesity-related comorbidities and a lack of health supply (Hänggli et al., 2008).

In order to address these issues, multi-professional programs with physical activity, nutritional and psychological components have been proposed (Sempach et al., 2007). This approach was shown to be more effective compared to mono-component interventions (Ho et al., 2012; Oude et al., 2009; USPSTF, 2010) and to have a positive effect on therapy outcomes (Savoye et al., 2007). In addition, it was found to be important for growing children, since the therapy goals are not only related to weight loss, but also to improvement of life-style habits (Epstein et al., 2007). Still, due to limited personnel, training and financial resources, only a small number of patients can be included in these programs (Kushner, 1995). Moreover, family-based interventions as an approach towards childhood obesity treatment are facing the challenges of low recruitment and retention rates due to the high demands for parents' involvement (Epstein et al., 2007; Knowlden and Sharma, 2012).

Health information systems (HIS) have potential to improve outcomes and reduce costs of health interventions by providing the possibility for self-monitoring while simultaneously supporting the patients' decision making through real-time access to relevant information (Spring et al., 2013). Yet little is known about designing such systems, as well as about their potentials and effects in the domain of multi-professional obesity programs, in particular with regard to children and adolescents. In addition, the challenges of HIS for children and adolescents are still to be addressed by monitoring the potential side-effects, such as excess use of IT systems.

In order to address these issues we have built a HIS prototype that has a goal of improving obesity therapies and preventing excess body weight of children and adolescents. The prototype complements existing interventions by serving as a coach and providing guidance to the patients in the period between the consultations, based on the prescribed therapy.

2 State-of-the-Art in IT-supported Obesity Interventions for Children

A number of studies have been conducted in order to investigate the potential of HIS over the effectiveness of obesity interventions (e.g. Arteaga et al., 2010; Knowlden and Sharma, 2012; Spring et al., 2013; Turner-McGrievy and Tate, 2011). In addition, commercial applications exist which support concepts of self-monitoring of activities and nutritional intake, such as Jawbone Up (2014), FitBit (2014), Nike+ (2014), etc. Still, majority of these interventions do not support the recommended multidisciplinary therapy approach (Kowatch et al., 2014; Spring et al., 2013). Further, most of the existing IT-supported health interventions are tailored to adults who might have different requirements and preferences compared to children and adolescents (Arteaga et al., 2010). Finally, none of these applications has been evaluated as part of an existing multi-professional obesity intervention for children and adolescents (Kowatch et al., 2014).

Moreover, reviews indicate that effects of HIS on obesity-related health outcomes remain unclear and modest (e.g. Connelly et al., 2013; Illner et al., 2012; Lieffers and Hanning, 2012; Ngo et al., 2009; Reed et al., 2012; Wieland et al., 2012; Williamson et al., 2006). Low-threshold internet based interventions were shown to be un-sustained due to reduced usage over time (Williamson et al., 2006), mostly related to low level of self-motivation and literacy, characteristics found to exist in a large group of overweight children, especially those with lower socioeconomic and/or educational background (l'Allemand et al., 2012). In addition, IS-based health interventions were shown to be more effective when they supplement the interaction with the therapists instead of completely replacing it (Mohr et al., 2011; Reed et al., 2012).

To address these issues, we designed and implemented a HIS prototype which has a goal to improve the performance of obesity expert and children teams, patients' adherence to therapy and health outcomes, by following the recommended multi-professional approach (e.g. l'Allemand and Laimbacher, 2013; Sempach et al., 2007). This approach could increase the therapy efficiency by providing detailed overview of patients' anamnesis, thus potentially revealing the cause of a particular health-related condition, e.g. obesity due to psychosocial problems (l'Allemand et al., 2006). Design principles were based on previous knowledge from obesity research (e.g. Epstein et al., 2010; Kumaharaa et al., 2010) and research on childhood obesity in particular (e.g. Durrer and Schutz, 2008; l'Allemand et al., 2006; l'Allemand et al., 2012; Lu et al., 2012) as it explains various sources of information and motivation strategies which could enhance the health behaviour (DiMatteo et al., 2012; l'Allemand and Laimbacher, 2013). In addition, practical experience with current obesity programs and special characteristics of the patients were taken in consideration. Finally, knowledge from hedonic IS (e.g. Lowry et al., 2013) and positive design theory (Zhang, 2007) was used since it was shown that hedonic characteristics significantly influence the actual system use (Gerow et al., 2013; van der Heijden, 2004). Details of the complete design process are described in continuation.

3 Design Process and Evaluation

The prototype was collaboratively developed by IS researchers, computer scientists, experts on childhood obesity, children (and their parents), and adolescents. A situation-based design science methodology (Hevner et al., 2004; Janzen et al., 2010) was applied through five steps: (1) identification of childhood obesity problems, resulting in an initial set of design principles, (2) identification of therapy-relevant situations and their validation against the identified list of problems, (3) evaluation of the HIS-supported situations with regard to the behaviour-service fit construct from situation-service fit theory (Maass et al., 2012), (4) creation of semiformal diagrammatic representations, denoted as pre-artifacts (Janzen et al., 2010; Maass and Varshney, 2012) for the top ranked situations, and (5) implementation of the HIS according to the pre-artifacts. The design process revealed several challenges including major effort required to synchronize all relevant stakeholders. To overcome this challenge, in the second phase only therapists, IS researcher and computer scientists participated in the design process, while patients were only recruited for short evaluations during the design process, thus following the Rapid Application Development principles (Beynon-Davies et al., 1999). These changes resulted in a more dynamic design and evaluation process.

The prototype will be evaluated through longitudinal field studies with children and adolescents as a part of existing obesity therapy and prevention programs. The studies will be conducted over three groups of patients: (a) control group (no HIS), (b) patients involved in HIS-based individual therapy, and (c) patients involved in a HIS-based group therapy. In addition, surveys will be conducted to evaluate subjective measures. The main constructs included in the study are: perceived usefulness, ease of use and enjoyment, since we argue that hedonic aspects of the HIS will influence the treatment adherence (Gerow et al., 2013; van der Heijden, 2004). In addition, performance of teams consisted of patients and therapists, i.e. group performance (McGrath, 1984) will be evaluated through self-reporting and usage data. Finally, the medical effect will be evaluated through established measures (e.g. BMI) and scales (e.g. EuroFIT (Adam et al., 1998)). Kowatch et al. (2014) provide detailed description of the design process and the results of the preliminary evaluation of the proposed HIS prototype. In addition, a discussion is given regarding the contribution to the HIS design theory.

4 Prototype Description

This prototype follows the recommended multi-professional approach by supporting the goal of improvement of *nutrition*, *activity*, *mood* and *relaxation* (Epstein et al., 2007; l'Allemand and Laimbacher, 2013). For each of these components a dedicated service was developed. In addition, the concept of *goal setting*, which was shown to be an important part of the behavioural treatment leading to improved therapy outcomes (Story, 1999) was added to the system. As such, the goal setting service serves as an umbrella concept and can be used in combination with all of the mentioned services.

The HIS prototype is implemented as a client-server application: the client side is a native Android application developed for tablet-PCs (by following Android design principles), while the server side is a web application (PHP, MySQL) used for synchronization with client usage data. Tablet-PC was chosen due to its portability and dimensions to provide optimal support during the consultations by showing greater level of details compared to smart phones. The users of the HIS prototype are both patients (supported by their parents, as recommended for childhood obesity treatment (l'Allemand and Laimbacher, 2013)), for self-monitoring, and therapists, acting as behavioural coaches through configuration and monitoring. These two roles will be distinguished in continuation.

4.1 The Timeline

To integrate different services and to enable the possibility to get insights into the potential correlation between individual components of intervention, a concept of *timeline* was introduced. The timeline represents a chronological visualization of all activities undertaken by the users and all events which are automatically triggered by the system, such as a reward assigned upon goal completion (see Section 4.4 for details). Each record in the timeline is represented through an *icon* which corresponds to the event or action type, a *content* part which might contain text and/or photo, and a *timestamp*. The system enables filtering of the events over two dimensions: *time period* (*1 week*, *2 weeks*, *1 month* or *custom*) and *record type* (*nutrition*, *activity*, *mood*, *relaxation* or *goal*). In the latter case, multiple-choice selection is supported. For example, the nutrition expert could filter out only those events that are relevant for him thus providing an overview into the patients' behaviour and compliance with the prescribed therapy over the period of time between the consultations. It therefore serves as a basis for discussion during the consultations. As such, the timeline plays an important role for both patients and therapists and is therefore placed on the landing screen of the application (see Figure 5).

4.2 Physical Activity Service

Physical activity therapy is more effective, when its level is increased in everyday life, compared to participation in time-limited sport programs (Epstein et al., 1985). In order to achieve this goal, the *physical activity service* is integrated with the FitBit platform. The selection of FitBit Flex as activity tracking device was based on the good acceptance by the patients due to its modern appeal and ease of use. Among other features FitBit enables tracking of the number of steps per day (spd). Synchronization with the device is done as a background process but can also be initiated by the patient. The results are presented in the timeline on a daily basis along with a motivational feedback. An overview of the obtained results is presented on a dedicated screen in a form of bar chart in order to support accurate representation of quantitative data (Mackinlay, 1986). In addition, for each day a feedback is provided by ranking the activity level on a scale from *bad* to *excellent* and which is visually distinguished through a colour scheme to support the concept of pre-attentive processing (Healey et al., 1996). The rules for different levels are initially set to predefined values by physical activity experts: *bad* - up to 5'000spd, *average* - up to 10'000spd, *good* - up to 15'000spd and *excellent* – more than 15'000spd. These values can be changed by the therapists to address differences among patients. The system also supports a concept of *achievements* with a goal of increasing the motivation of the patients by applying the gamification principles (Monu and Ralph, 2013). *Activity badges* are automatically assigned by the system if a certain threshold is reached on a daily and weekly basis. Each time a badge is assigned, a timeline record is created. Finally, in order to provide insights into the type and frequency of activities which might not be traceable through the FitBit platform, such as swimming or cycling, the system enables creation of photos of undertaken activities which will also be shown in the timeline. Illustration of the physical activity service and the settings screen which supports FitBit integration and activity level customization are shown on Figure 1.

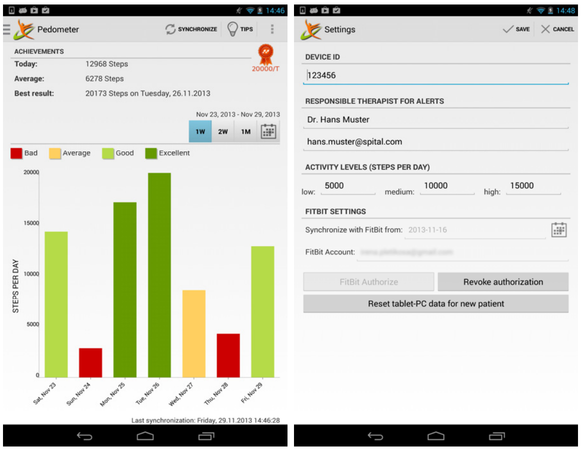

Figure 1. *Physical activity screen illustrating the level of activity over the last week and a badge for daily achievement in the top right corner (left), and the Settings screen (right).*

4.3 Nutrition-related Services

The goal of nutritional therapy is to influence the eating behaviour of the patients by providing support for dietary self-monitoring which was found to be an important component in behavioural weight loss intervention programs (Burke et al., 2011). In addition, concepts such as eating without hunger and speed of eating as factors which influence obesity should be taken in consideration (Carnell and Wardle, 2007). Based on these insights, the prototype provides two services as a part of the nutritional therapy: *food diary* and *speed of eating*. Figure 2 illustrates the mentioned services.

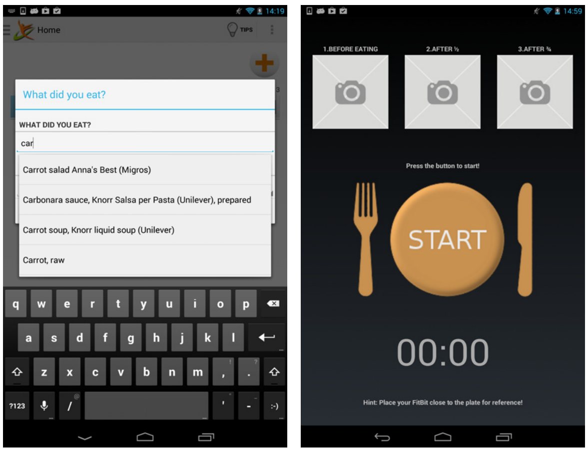

Figure 2. *Food diary service illustrating auto-complete function for ingredients entry (left) and speed of eating screen (right).*

The food diary service enables tracking of food and water intake. In order to provide nutritional information while taking in consideration cultural differences, integration with the Swiss Food Composition Database (SFCD) was made (FSVO, 2013). SFCD contains individual ingredients - such as "Carrot, raw", meals - such as "Cake with carrots" and products which can be bought in the two largest food retailers in Switzerland, where the name of the retailer is provided in parentheses, e.g. "Carrot salad Anna's Best (Migros)". In order to ensure the quality of the data, in the first version of the prototype users are only allowed to choose from the existing database records. Overcoming this limitation will be addressed in the future versions of the prototype. Once initiated, the *food diary service* guides the patients through several steps: (1) selection of the intake type (*food* or *water*), selection of the meal (*breakfast*, *morning snack*, *lunch*, *afternoon snack*, *dinner* or *anytime*) and entry of each ingredient by providing (a) the name of the ingredient – supported by the auto-complete function, and (b) quantity (in grams or millilitres, based on the measure defined in the SFCD for the chosen ingredient). Optionally, a photo of the meal can be added. Upon completion, a timeline record is created which shows the calories for each ingredient, as well as the total number of calories for the meal and the day. Similarly, in case of water intake, the entered quantity will be displayed in the timeline along with the daily water intake. An overview of the obtained results in terms of average calories and water intake is presented on a dedicated screen. In addition, a line chart illustrates fluctuations in daily food and water intake over time, with a possibility to zoom in the chart, as well as to perform pan gestures to gain better overview in the case when a larger time period is selected. Finally, to stimulate the diversity of nutritional intake, a list of ingredients is shown, sorted by (1) the frequency of intake and (2) calories. Colour coding of the overview results was deliberately avoided in order to prevent emergence or amplification of eating disorders, e.g. bulimia nervosa, which was found to be a frequent cause for childhood obesity (l'Allemand et al., 2006).

The *speed of eating service* has a goal to raise the awareness regarding the speed of eating and to address the correlation between the speed of eating and the feeling of satiety. Once the patient initiates the process, the system starts counting the time. In addition, the patient is asked to enter the current degree of hunger (from *not hungry* to *very hungry*) and make a photo of the plate before eating. The same steps are repeated when the patient has eaten half of the plate, three quarters of the plate and the full plate. In case satiety is reached before finishing the meal, the patient can indicate this by choosing the *not hungry* answer. In order to motivate the patient to stop eating at this point, an additional question is shown: "*Do you still want to eat?*" which can stop the timer if the answer was *no*. Upon completion, a timeline record will be created that shows the time needed to complete the meal ingestion, as well as the taken photos. The average degree of hunger and speed of eating (in seconds) as well as the fluctuations over time at each step of the meal are presented on a dedicated screen.

4.4 Psychological and Behavioural Services

Stress and mood disorders in childhood are found to be related to childhood and adult depression and obesity (Pine et al, 2001). To address this issue, obesity treatments include psychological treatments in a form of behavioural and cognitive behavioural therapies, such as stimulus control, goal setting, self-monitoring, rewards, etc. (Sempach et al., 2007; Spring et al., 2013). To provide support for this component the following services are added to the HIS prototype: *mood monitoring service*, *relaxation exercise service* and *goal setting* service (including *rewards* for successfully achieved goals).

The *mood monitoring service* enables tracking of the emotional state of the patients. It is based on the established, picture-based scale, known as Self-Assessment Manikin (SAM) (Bradley and Lang, 1994) which is suitable for children since it overcomes the linguistic challenges. In addition, based on the preliminary evaluation by therapists and patients, we added labels which describe each state on the scale. SAM distinguishes between three dimensions of the emotional state: *pleasure*, *arousal* and *dominance*. In addition, in order to gain insights into the potential correlation between the emotional state and the feeling of satiety, an additional measure is added which corresponds to the degree of hunger scale used in the speed of eating module (see Figure 6). After entering mood and hunger-level values, optionally the patient can also enter a reason for his mood. Upon completion, a timeline record will be created containing the entered values and the overall mood score represented through colour scheme of the icon. An overview of the mood state over time, as well as the average values over different dimensions are presented on a dedicated screen.

The *relaxation service* (see Figure 3) takes a proactive approach by providing relaxation content to the patients as a list of predefined music (classical music and sounds of nature) and photos (nature and baby animals). In addition, photos of food are added to address the concept of stimulus control since the concept of confrontation with individual food type was found to be able to reduce the consumption of this food in a stressful situation (Stephan, 2012). Patient's exposure to food images is determined by the therapist based on individual characteristics of the patient and the measured level of arousal (using skin conductance as an indicator) in an individual therapy session. Proprietary content can also be uploaded to the system including content in video format. Each time a patient initiates a relaxation service a *relaxation session* is started which can last up to three minutes. During this time, a *control button* will appear on random time intervals which should be pressed by the patient to ensure that the he is looking at the presented stimulus. Based on the number of hits, an *attention score* is measured. In addition, *movement* of the device is measured to determine the relaxation state of the patient. Mood monitoring service is triggered automatically before and after the relaxation session to estimate its effect. Results of the relaxation sessions are presented on a dedicated overview screen which shows the mood values before and after the relaxation in a form of average values for the selected time period, as well as in a form of line chart illustrating the mood difference over time. In addition, the session duration, attention score and movement are shown. For each of these measures a mean value and standard deviation are displayed above the charts to provide an aggregated result to the therapists.

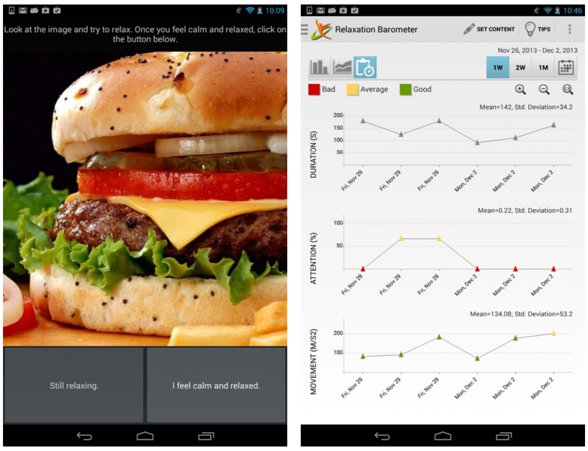

Figure 3. Relaxation session screen with the control button at bottom left (left) and relaxation overview screen showing duration, attention and movement over time (right).

The *goal setting service* is one of the key components of the system. The system supports creation of goals for each of the above mentioned services, i.e. *physical activity*, *nutrition*, *mood monitoring*, *relaxation* and a generic type, i.e. *other* (see Figure 7). Each time a goal is created it is added to the *list of active goals* where its progress can be tracked. For each goal type several possibilities for *completion* are offered: *manually*, through *photo documentation* or *automatically*. For example, for nutrition related goals, the automatic goal tracking can be achieved each time the food diary or speed of eating service is used. In case of manual tracking, the patient has to indicate the goal completion by pressing the *done button* which appears next to the goal in the list of active goals and on the daily agenda on the landing screen. Each goal is bounded by a set of rules which determine under which conditions the goal is *finished*: (1) duration of the goal - defined through *starting* and *ending date*, and (2) completion frequency - defined by *rule type* (*max* or *min* based goals), *number* of repetitions, and measurement *interval* (*per day*, *per week*, *per month*), e.g. the rule could be formulated as *min 3 times per week*. A goal is marked as finished if (1) the objective is met – for max-based goals, or (2) the end date is reached – for min-based goals. Once the goal is finished, it is moved to the *list of finished goals* where it is categorized as *successful* or *unsuccessful*. To increase the motivation of the patients and to make the system more appealing for the target group, we have introduced the concept of gamification as a form of purposeful gaming with a growing importance in the domain of IS research (Monu and Ralph, 2013). For this purpose a *reward* system was added to the goal setting service. Each time a goal is completed, points are assigned to the patient for the particular goal type. The number of points depends on the difficulty level assigned to the goal (*easy - 100*, *medium - 250* or *difficult - 500 points*). Based on the number of points, medals and trophies are assigned to the patient. Figure 4 illustrates the goal setting service and the rewards screen.

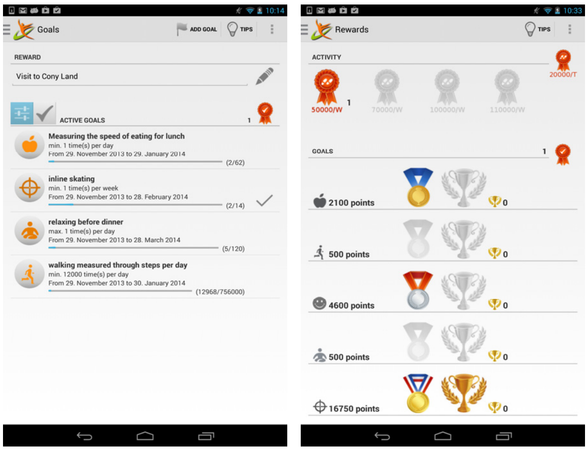

Figure 4. *List of active goals and their progress (left) and rewards screen with activity achievements, and points/medals/trophies over different goal categories (right).*

5 Contribution

The HIS prototype presented above provides several contributions to theory and practice. First, it supports the concept of a multi-professional approach not present in most of existing commercial and research-based applications. Second, it provides an instrument that is co-designed by patients, obesity experts, IS researchers, computer scientists and, thus tailored to the specific needs of children and adolescents. Third, it intends to improve therapy adherence by the incorporation of goal setting, mood monitoring and relaxation training. Moreover, to evaluate the proposed system, longitudinal studies will be conducted as a part of existing multi-professional obesity interventions for children and adolescents. This would lead to additional contributions, such as gaining evidence-based knowledge on the potentials and effects of HIS to improve outcomes of obesity therapy, and evaluating the long-term effect of the HIS-support to the therapy compliance. Finally, the system provides a possibility to gain insights into the potential side-effects of IT-supported therapy through monitoring of the overall usage of the tablet-PC. This will be achieved by installing the App Usage Tracker (Agrawal, 2014), an application which shows the usage time for all applications accessed by the user.

6 Presentation of the Prototype

The HIS prototype will be shown on a tablet-PC. In addition, for each service, a video will be available which provides a detailed explanation of the usage.

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Appendix: Screenshoots

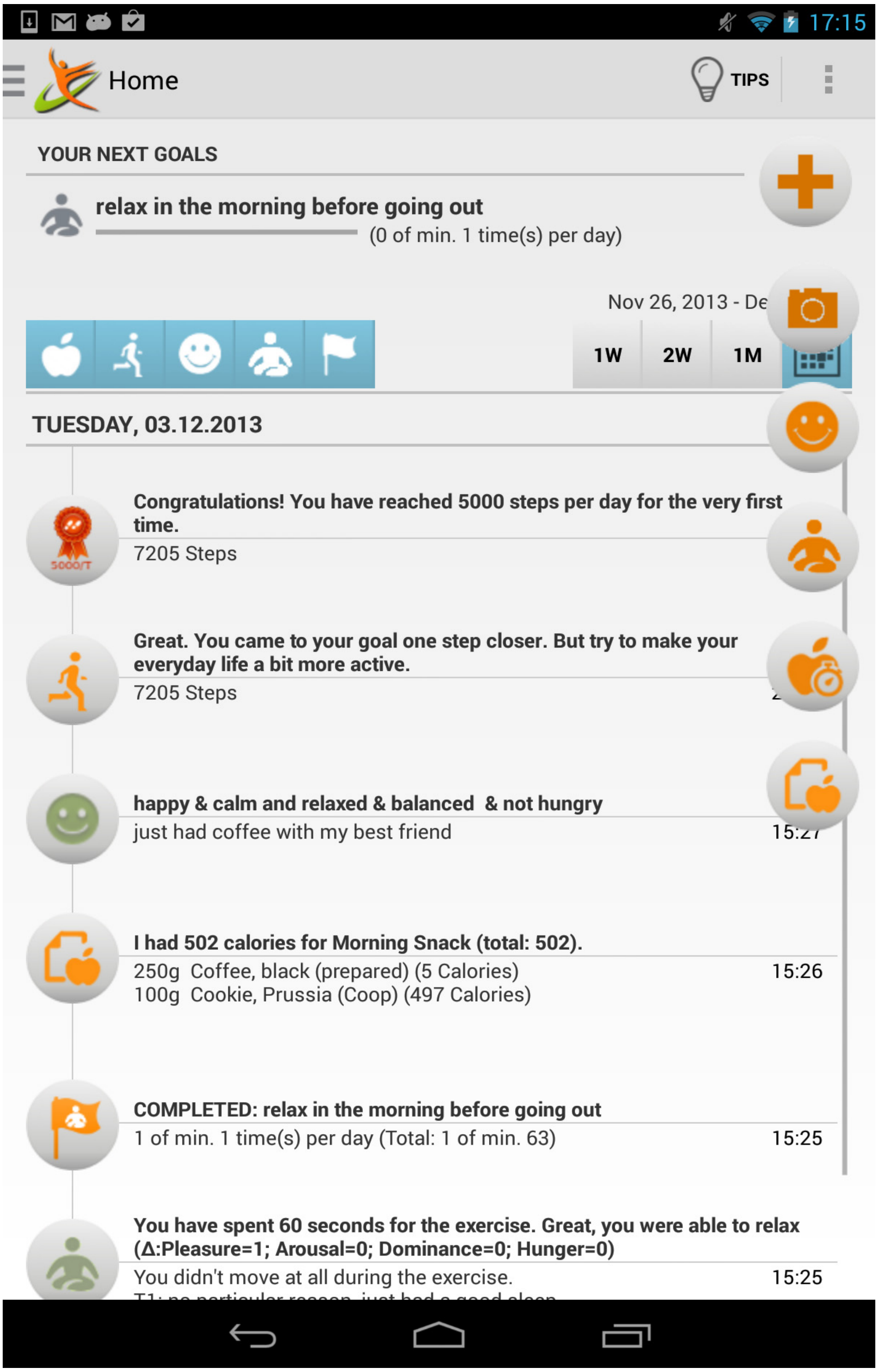

Figure 5. The landing screen containing the daily agenda with the next goals (on the top), the pop-up menu with shortcuts to main services (top right) and the timeline.

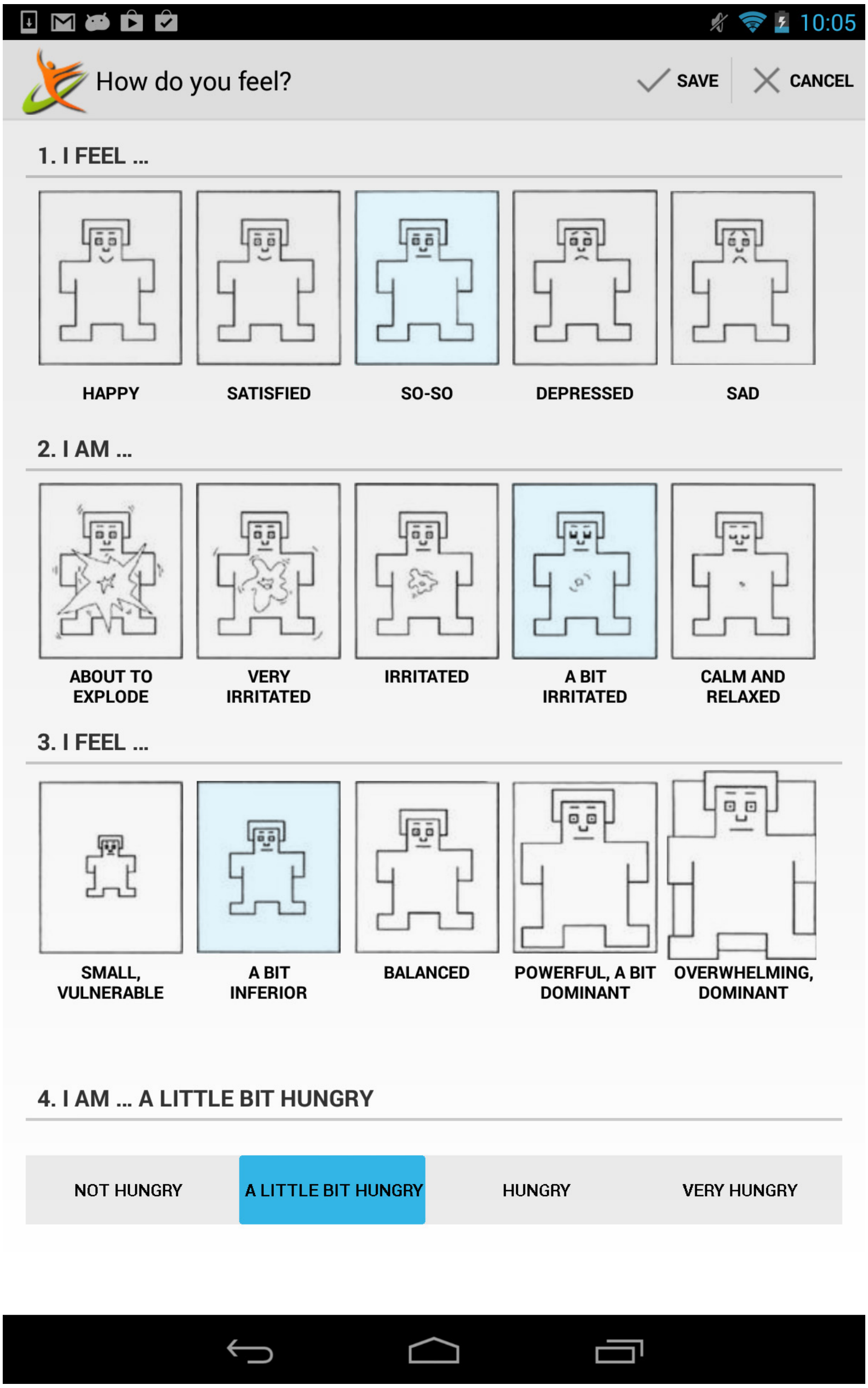

Figure 6. Mood monitoring screen enabling entry of three mood dimensions (according to SAM scale) and a degree of hunger.

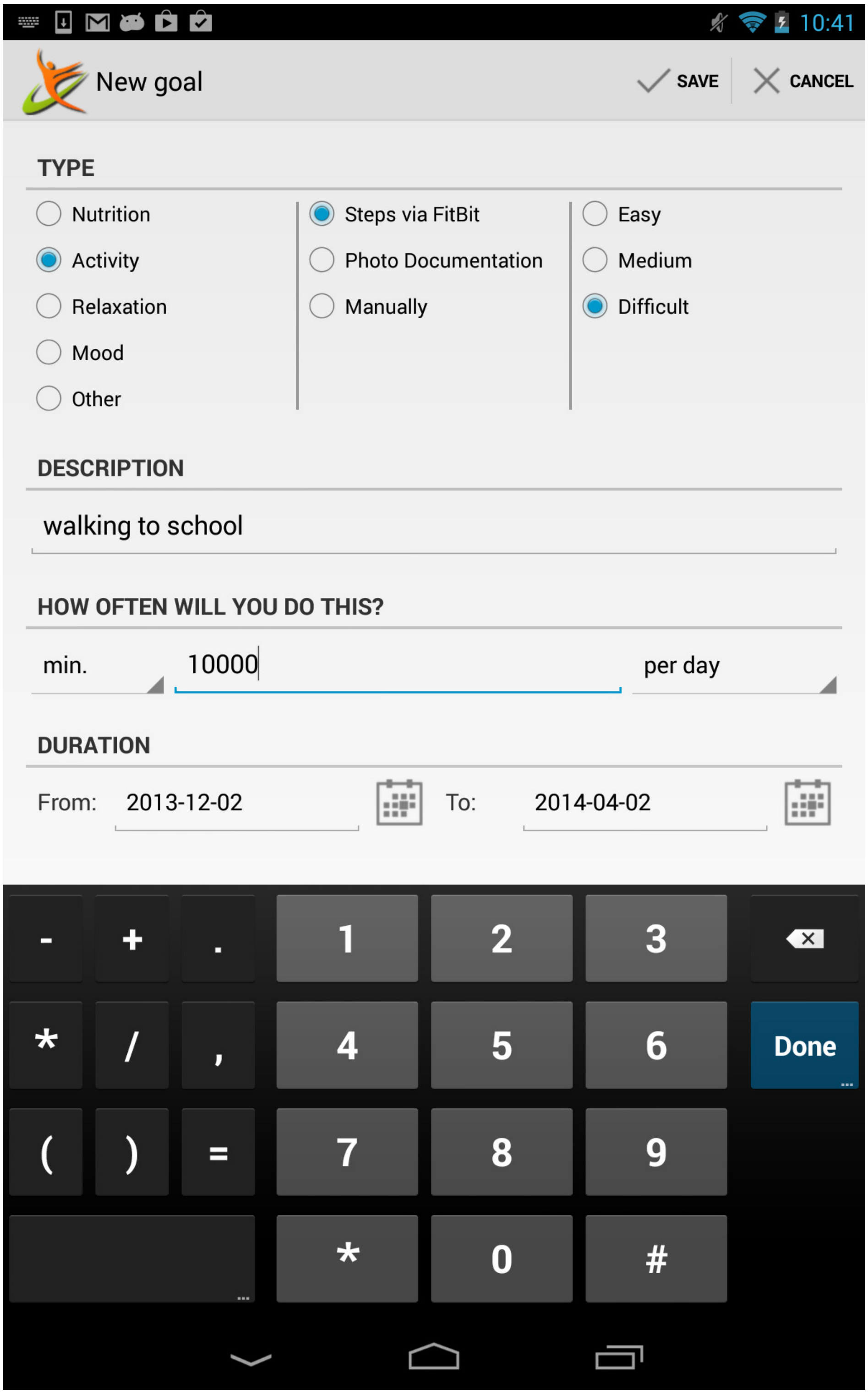

Figure 7. *Goal creation screen providing possibility to choose: a goal type, goal tracking mode, difficulty level, frequency of completion and goal duration.*