Objective and Subjective Meal Registration via a Smartphone Application

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Abstract. SPLENDID is a research programme that develops a novel preventive intervention for young people at risk for obesity and eating disorders. The SPLENDID app, a novel smartphone application that mediates the monitoring and modification of the participants' eating and activity behaviors, resides in the intervention's core. The app receives and manages eating and physical activity related signals from three communicating sensors as well as subjective user input. In this paper, we present two discrete meal registration mechanisms – subjective and objective – that have been implemented and incorporated in the SPLENDID app, along with the relevant user feedback. In objective meal registration, the app records meal information with the help of a portable food weight scale, while an electronic meal report is employed for the subjective registration. Certain components of the proposed registration mechanisms and the relevant feedback have been evaluated with respect to usability on forty young adolescents, yielding promising results.

Keywords: Sensory meal recording · Subjective meal reporting · Smartphone application · Obesity · Eating disorders

1 Introduction

Obesity and eating disorders (ED), such as boulimia nervosa, have emerged as major concern for public health, affecting – among other age categories – young adults and adolescents at a worrisome increasing pace. As a result, several treatment interventions (surgical, pharmacological, and lifestyle) have been proposed and, in most cases, rejected as ineffective. Contemporary approaches attempt to *prevent* obesity and eating disorders with the help of modern technology, such as sensors and mobile phones. In this scope, the ongoing EU-funded research programme SPLENDID develops an ICT system for delivering a novel lifestyle intervention for the prevention of obesity

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and ED on young populations [1]. The SPLENDID system is going to monitor the eating and physical activity behavior of its users (adolescents and young adults) by integrating objective recordings from 3 wearable sensors and – subjective – user input. Its goal is to evaluate a list of eating and physical activity indicators defined by the SPLENDID intervention in order to assess the risk of a user for obesity or ED. For those at risk, the SPLENDID system – using the same sensors – will attempt to permanently modify their hazardous eating and physical activity habits with the help of personalized behavioral goals and performance feedback mechanisms.

In the heart of the SPLENDID system, one can find the SPLENDID app [2], a modern smartphone application that is responsible for (1) collecting the recordings from the communicating sensors, (2) providing a bidirectional interface to the end-users for collecting subjective input and presenting the feedback of the system, and (3) communicating with the Decision Support System of SPLENDID, which calculates the behavioral indicators and evaluates the obesity and ED risk for the end-user. The various components of the SPLENDID system are outlined in Fig. 1.

The objective of this work is to present the novel meal ICT-enabled approach of SPLENDID for meal registration via the SPLENDID app. This offers an alternative to standard objective meal registration methods (e.g., meal image acquisition). Two novel mechanisms have been developed for registering meals into the SPLENDID app: Objective meal recording with the help of the Mandometer, i.e., a food weight scale with Bluetooth communication capabilities, and subjective self-reporting of meals via an electronic questionnaire. The mechanism that provides user feedback concerning the registered meals is also in scope of this work. The design and implementation (by means of the resulting screens of the app) of all three developed mechanisms are presented along with their partial evaluation with respect to usability in two experiments.

2 Related Work

Several smartphone applications for dietary management employ multimedia for meal registration. Most of them make use of wearable sensors (e.g., smartphone cameras, barcode scanners, RFID readers and IR sensors) to objectively capture characteristics of the user meals. However, monitoring and feedback features can be found to apps such as SapoFitness [3], an application that keeps a daily record of one's food intake and daily exercise, motivating the user to use the system. MANUP [4] is a mobile application that targets health literacy improvement, promoting physical activity and eating.

Relevant applications target weight management are mentioned; SmartLossSM [5] a smartphone-based weight loss intervention using additional wireless sensors such as scale and activity monitor. My Meal Mate [6] is a smartphone application, designed to support weight loss. The app helps the users to record food and drink intake, allowing them to take photos of foods while applying goal-setting information to automatically generate a specific daily energy target for them.

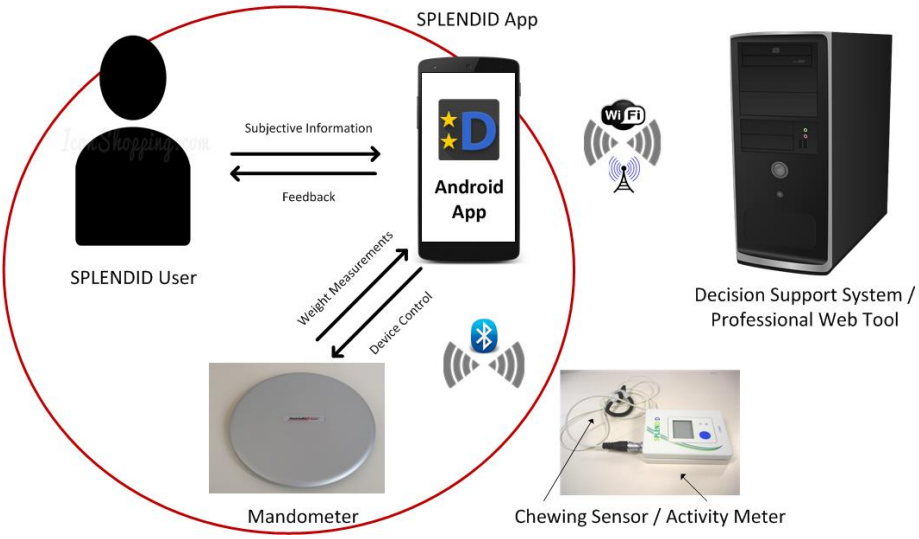

Fig. 1. Overview of the SPLENDID System indicating the main components and actors along with their interactions and means of communication. The part of the system that is of interest for the present paper has been included in a red circle.

3 Methods

The ability to monitor the eating activity of the end-users, i.e., meal occurrences and characteristics, is critical for the SPLENDID intervention, since this is the primary input for the behavioral indicators extraction and risk assessment algorithms of the system. Therefore, functionalities for registering the meals of the end-users into the SPLENDID system in as much detail as possible had to be designed. Evidently, the preferred means of registration requires the recording of the meal with one of the available sensors (objective information). However, in a real-world system like SPLENDID, a backup solution for subjectively reporting a past meal is also needed to ensure that at least some information about the non-recorded meals is registered into the system. At the same time, the provision of feedback to the end-users concerning (1) their eating and physical activity, and (2) the proximity to the set behavioral goals is of major importance for the SPLENDID intervention, as this feedback can help their recollection and motivate the modification of their eating and physical activity behavior. Specifically for meal registration, the most straightforward user feedback concerns an aggregated presentation of past registered meals.

The functionalities presented in the remainder of this section have been integrated into the SPLENDID app, which has been developed as an Android application. The flows of screens that carry out the aforementioned functionalities are displayed on Fig. 2 as actual screen captures from an Android Smartphone.

3.1 Objective Meal Registration

The primary sensor that is employed for meal recording is the Mandometer, a portable weight scale that periodically takes food weight measurements and sends them via Bluetooth to the SPLENDID app, which stores the resulting food weight time-series into its database. The SPLENDID app is able to drive the Mandometer (establish connection send start/stop recording signals, etc.). The meal recording functionality is delivered through a useable user interface (UI) that requests also the input of subjective meal information by the user. The Chewing Sensor, a currently developed ear plugged device incorporating an open air microphone and a photophethysmography (PPG) sensor, is SPLENDID's alternative for meal recording. When available, the Chewing Sensor will be able to generate and send to the SPLENDID app audio and visual signals respectively conveying chewing information. From the UI standpoint, this recording mechanism will be almost identical similar to the already developed functionality for recording meal with Mandometer.

A modern, clean and informative UI has been designed for recording a meal with the help of the Mandometer in the SPLENDID app (see Fig. 2): After selecting the meal registration option in the main screen of the app, the users specify the recording device and fill in the type of the meal (breakfast, lunch, dinner and snack). Then, they follow the illustrative instructions on how to put the food on the plate and initiate the recording process by pressing the "Start" button. The Mandometer starts sending via Bluetooth food weight measurements at 1Hz frequency, until the users press the "Finish" button to complete the recording. While the meal is in progress, a dialogue asking the users for their satiety level pops up every 2 minutes; the users specify their satiety with the help of vertical slider.

The recorded data combined with the subjective input of the users (e.g., satiety) comprise the primary input for the advanced computational algorithms of SPLENDID that extract the behavioral indicators and subsequently assess the risk of the users for obesity or ED.

3.2 Subjective Meal Registration

The – subjective – self-reporting mechanism enhances the overall meal registration functionalities of the SPLENDID app by complementing the sensor-based recording approach. This is considered as an alternative to objective recording for the cases where the latter is not possible. In this context, the main information about a meal is subjectively completed by the user.

This functionality reuses some of the meal recording screens and also introduces some resembling screens (see Fig. 2): After initiating the meal registration process in the main screen of the app, the users select the self-report option. Then, they specify the type/kind and estimated quantity of food and drink that they consumed, along with the time the meal took place. The reporting process concludes by asking the users to rate their satiety level at the specific time of meal reporting.

This feature manages to fill in the gaps at times when the sensor recording is unavailable by collecting some basic information about the meal in a subjective fashion. As above, this information is also fed to indicator extraction and risk assessment algorithms of the SPLENDID system.

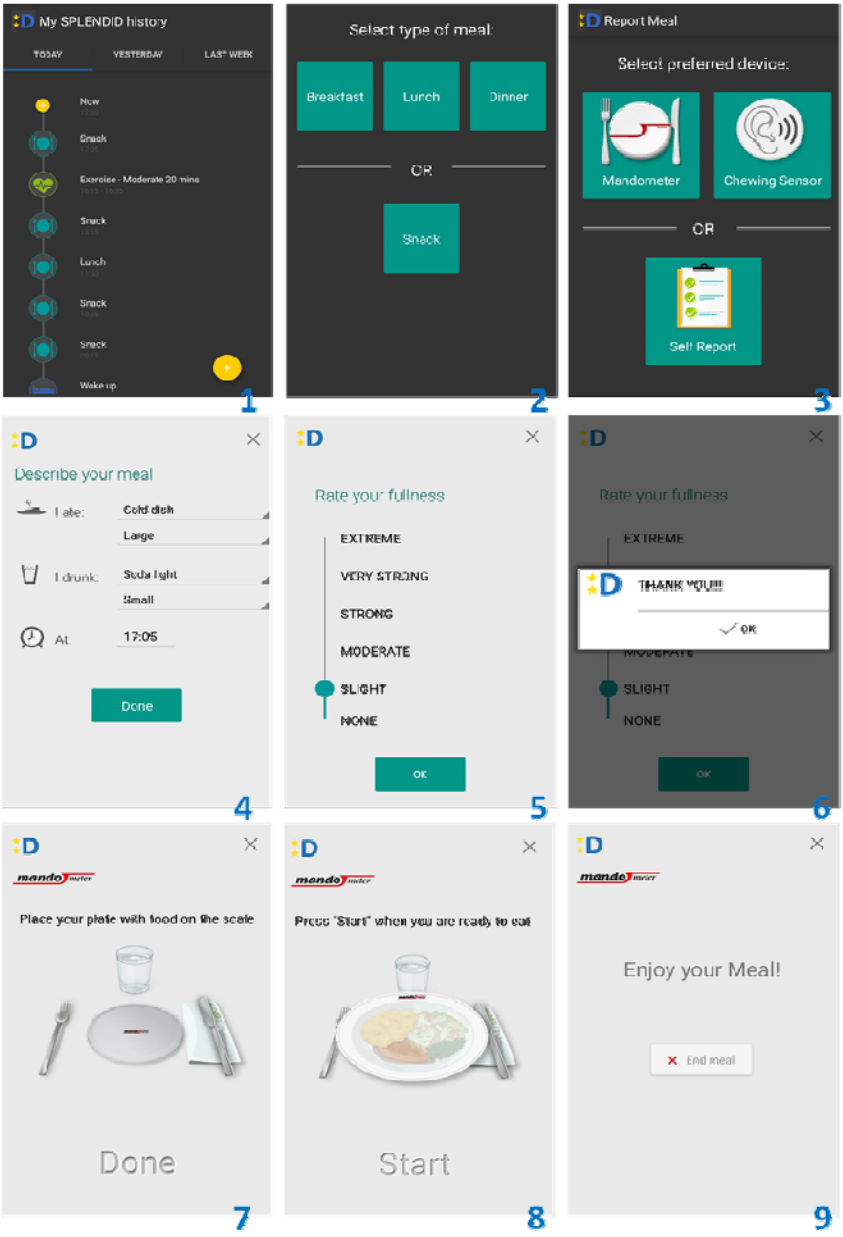

Fig. 2. Screens developed for the discussed functionalities. To complete meal reporting, the user navigates through screens 1, 2, 3, 4, 5, 6 and back to 1, while for meal recording, the screen flow is 1, 2, 3, 5 (recurs every 2 min), 7, 8, 9 and back to 1. Feedback is provided via screen 1.

3.3 User Feedback

The provision of up-to-date feedback through the app has been considered to be a critical factor for the success of the entire intervention, helping users' recollection and encouraging them to go on. The meal related feedback mechanism presented here serves mainly user recollection. The provided feedback concerns both user provided and sensor acquired information and it is delivered in an ambient manner via a modern, visual modality, i.e., the SPLENDID timeline.

The SPLENDID timeline (see Screen 1 in Fig. 2) is part of the main screen of the app. The timeline is an easily understandable visual log of the past events of interest for the SPLENDID intervention. Piece of information presented in the timeline include the occurrence and the type of the meals the users had during the day, as well as, the duration and intensity of their physical activity. The timeline is automatically updated to display the events of interest as they occur, using distinct icons per event type. In this context, the users are able at any time to recap every day habits and monitor their eating/activity history.

4 Usability Evaluation

Among the implemented functionalities, the *meal registration* and the *meal-related feedback* have already gone through a preliminary evaluation with respect to *usability* but also *aesthetics and design*. The evaluation was conducted in the context of two pilot studies that took place at the Internationalla Engelska Gymnasiet Södermalm in Stockholm (Sweden) on March and April 2015. Forty normal-weight students of both genders (19 males and 21 females with mean BMI 21.59 and 20.92 respectively) between 15-17 years of age participated in the evaluation experiment.

4.1 Usability Evaluation Protocol and Questionnaire

The evaluation protocol that was employed for meal registration and feedback functionalities is summarized as follows: The main concepts of the SPLENDID intervention, system, and app were introduced to the students. Then, groups of four students were formed and each group received a smartphone with the SPLENDID app installed. A fictional character associated with a paradigmatic dieting profile (overweight, under-weight, and normal-weight) was assigned to each group; a log of the eating and physical activity related actions of the corresponding character was provided to the group. Next, *each group* was asked to report on the SPLENDID app a specific meal of their character according the provided log and then observe the updated timeline. After that, *each student* was asked to fill in a questionnaire.

The objective of the developed questionnaire is to evaluate the usability of the demonstrated functionalities of the SPLENDID app as well as their *ease of completion* with the help of an enhanced version of the widely used System Usability Scale (SUS) [7]. An enhanced version of SUS was designed including 13 statements, i.e., the original 10 statements of SUS followed by three statements proposed by the authors (see Table 1). Same as in the original SUS, generally positive statements are

alternating with generally negative ones and the users have to specify their extent of agreement/disagreement with each statement using a Likert scale of 5 categories (spanning from "Strongly agree" to "Strongly disagree").

4.2 Analysis of Usability Evaluation Results

The SUS scoring function was employed for the original SUS, resulting in scores in the range [0,100]. The same rationale was applied to the enhanced SUS which was then normalized in the aforementioned range to allow direct comparison with the original SUS. The summarized scores that were achieved are presented in Table 2.

Table 1. Proposed statements extending the System Usability Scale (SUS)

Order	Statement
11	I had to do more things than needed while using the app
12	It was easy to enter information in the app
13	The app had too many screens for what it does

Table 2. Mean and standard deviation (STD) of achieved scores for original and enhanced SUS

		Males	Females	All
SUS	Mean	73.62	68.21	70.78
	STD	8.77	14.14	12.06
Enhanced SUS	Mean	74.58	69.42	72.29
	STD	9.20	11.94	11.31

According to the scientific literature on usability testing, a SUS score above 68 is considered to be above average [8]. Table 2 makes clear that SPLENDID app passes this threshold (for both genders when considered separately and the ensemble of the participants). Moreover, the mean scores become even higher when the *ease of task completion* qualities are taken into account (enhanced SUS).

5 Conclusions

In this paper, we have presented the design, implementation and partial usability evaluation of the mechanisms that have been developed for meal registration and relevant user feedback in the SPLENDID app. The developed functionalities of the app allow its end-users to record each meal as a time series of food weight measurements acquired by a wirelessly connected weight scale and also either complement or replace – when there is no other way – this objective information with self-reported subjective information about the consumed food and beverage. The meal registration is accompanied with a functionality of aggregated feedback on past meals, to help users' recollection.

The next step of this work would be the exploitation of the second available sensor for meal recording, i.e., the Chewing Sensor that generates audio and optical time-series – air acoustic signal and photophethysmogram, respectively. Another feature that is planned to be included in the meal registration process is the acquisition of a digital photograph of the meal by means of the smartphone camera to be used for the visual annotation of the meal in the SPLENDID system. Once the development of the app is over, the main evaluation goal is to conduct well-sized pilot studies for assessing the efficiency of the app – and the proposed mechanisms – in monitoring and, subsequently, facilitating the modification of the eating habits of the users.

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