Lightweight Visual Data Analysis on Mobile Devices - Providing Self-Monitoring Feedback

Simon Butscher, Yunlong Wang, Jens Mueller, Katrin Ziesemer, Karoline Villinger, Deborah Wahl, Laura Koenig, Gudrun Sproesser, Britta Renner, Harald T. Schupp, and Harald Reiterer

University of Konstanz, Germany
{[firstname].[lastname]}@uni-konstanz.de
http://hci.inf.uni-konstanz.de

Abstract. Self-monitoring is an important part of behavior intervention technologies. In order to increase the effectiveness of self-monitoring, we do not only have to track data but also give feedback to the user. In the interdisciplinary project SmartAct, we aim at developing and empirically testing the effectiveness of an open access toolbox for mobile, real-time interventions targeting healthy eating and physical activity. The SmartAct toolbox for behavior change is a set of tools for personal mobile technology which decreases the implementation barrier for mobile interventions. It consists of tools for physical activity tracking, food journaling, questionnaires, notifications, feedback and interventions, workflow management, data storage, and client-server synchronization. The toolbox is still under development, but a first reference implementation for a food diary application has already been tested in a pilot study. For the intervention tools an interactive visualization was designed which places special emphasis on context and imprecision aspects.

Keywords: mobile behavior intervention, behaviour change, toolbox, interactive visualization, food diary, physical activity

1 Introduction

Self-monitoring of diet and physical activity is an important part of behavior intervention technologies. In order to increase the effectiveness of self-monitoring we do not only have to track data, but also to give feedback to the users [1]. In the context of behavior change technologies ongoing research focuses on food database reliability, missing log values [2], and meaningful intervention moments [3]. Also, novel ways of manual and automatic data collection [4] and the visual presentation of the collected information [5] are investigated. However, there is still a lack of research on interventions in terms of feedback visualizations, and their effectiveness [6]. Most commercial applications only provide feedback in terms of simple one-dimensional visualizations which convey that more (physical activity) or less (food intake) is better. Whereas this can be true for low-intensity physical activity (e.g., walking), for vigorous activities, our body needs time for regeneration. For food intake it is even more complex, as calories alone do not tell us much about how healthy our eating behavior is; a balanced diet seems to be more important. Therefore, there is a need for more powerful feedback visualizations which allow for a lightweight visual analysis of the collected data. Based on data about the nutrients of meals, tracked activities, and additional information like eating motives or times and locations where meals took place, visualizations can provide a convenient way to analyze the self-monitored behaviour on mobile devices. This allows users to better understand their behavior and how they can change it towards a healthier lifestyle.

2 Project SmartAct

In the interdisciplinary project SmartAct[1], we aim at developing and empirically testing the effectiveness of a toolbox for mobile, real-time interventions targeting healthy eating and physical activity using personal mobile technology (smartphones, body monitoring). The SmartAct toolbox for behavior change is a set of tools which decreases the implementation barrier for mobile interventions. Interventions are based on *what people do* (behavioral pattern), *why people do what they do* (psychosocial and & contextual triggers of behavior), and *when people do what they do* (timing of behavior and & triggers). The toolbox consists of tools to design client applications for Android devices as well as tools to store and manage the collected data on a remote server.

- **Physical activity tracking tools:** The physical activity tracking tools track the users activity level (low, moderate and vigourous). To ensure high-quality data we use a very exact mobile sensor for the acquisition of physical activity[2] which is connected to the smartphone and therefore allows for a almost real time intervention based on the activity level.
- **Food journaling tools:** The food journaling tools consist of two modules: a picture taking module to save a visual representation of the meal and a food item selector to classify the meal. A detailed food item database contains additional information, like food groups ("fruits", "vegetables", "grain", "meat", "milk", "oil & sugar") and the detailed nutritional values.
- **Questionnaire tools:** The questionnaire tools allows for a very flexible and quick definition of questionnaires, e.g., collecting additional information about users' motives or emotions. The questionnaires as well as the questions they are build of are defined on a server database and are automatically transferred to the mobile applications. Different question types are supported (e.g., open questions, single-choice, Likert scales, or groups of Likert scales).
- **Notification tools:** The notification tools allows for sending messages to the users at a certain time (e.g, a reminder in the morning that the users should track their food intake) or when a timer elapsed (e.g., a user started to track a meal but did not finish entering all necessary data within a certain period of time).

[1] https://www.uni-konstanz.de/smartact/

[2] Activity Sensor Move 3 from movisens (http://www.movisens.com/)

- **Feedback and intervention tools:** The feedback tools are planned to provide rich and interactive feedback to the user. Different (multidimensional) visualizations with drill down functionalities provide different perspectives on the collected data. Notifications can be send to the user in order to higher the chance that users use the feedback functionalities.
- **Workflow tools:** Workflow tools are used to tie all the previously described tools together. With the workflow tools the sequence in which the other tools appear can be defined (e.g., the user first has to answer a questionnaire, then take a picture of the meal, then classify the meal and finally get feedback about the healthiness of the meal). The workflow tools also allow for a definition of times when notifications should be send as well as the definition of usage data logging.
- **Data storage tools:** On the database server side, we enable secure data storing, as well as user group management and user group dependent bidirectional data synchronisation. This allows for group dependent feedback (e.g., feedback about the food intake of a family).

Using this toolbox we developed a food diary application which was evaluated in a pilot study in order to test the concepts and improve the toolbox. Taking the data collected during the pilot study as example we designed a first draft of an intervention in terms of an interactive visualization.

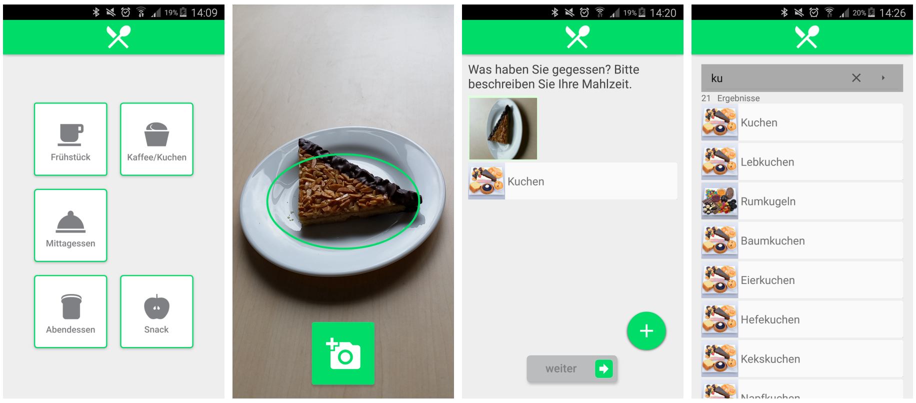
3 Reference Implementation: Food diary

With the SmartAct toolbox we designed an application (See Fig. 1) to answer two main questions: *what do people eat?* and *why do people eat what they eat?* To track *what people eat,* the application contains a picture taking tool and a manual food classification tool. To track *why people eat what they eat,* a questionnaire about eating motives [7] has to be filled out during each meal.

The application was tested in a pilot study with 35 participants who used the application for 8 days. The aim of the pilot study was twofold. First, we evaluated the user experience with the help of the *User Experience Questionnaire* [8]. Second, we collected a data set with approximately 1,000 tracked meals. This data is intended to inform the design of interventions, in terms of interactive visualizations (e.g., it gives insights about the average number of meals a day or the number of tracked food items per meal).

An analysis of the user experience revealed that participants perceived the application as being attractive (M=1.1/*above average*[3]). Furthermore the pragmatic quality of the application was rated high (perspicuity: M=2.3/*excellent*; efficiency: M=1.6/*excellent*; dependability M=1.8/*excellent*). Thus, the users perceived the application as easy to learn and understand, as well as efficient and practical to use. These aspects are very important to support long-time usage

[3] Interpretation of values in comparison with benchmark provided by the *User Experience Questionnaire Data Analysis Tool* (http://www.ueq-online.org/)



(a) (b) (c) (d)

Fig. 1: The food diary workflow: (a) selection of meal type, (b) picture taking, (c/d) food classification.

of the behavior intervention technology. The scores for hedonic quality (stimulation: M=0.3/*bad*; novelty: M=1.0/*good*), are not as high as for the pragmatic quality. However, this is not surprising since no feedback or intervention was provided during the pilot study.

4 Intervention: Interactive Visualizations

Based on the collected data and the users' feedback we will design interventions on participants' food intake, targeting a balanced diet as such a "nutritious dietary pattern is an indispensable component of a healthy lifestyle, essential for promoting health and reducing the risk of major chronic diseases" [9]. For the design of the interventions we have to deal with two important aspects: the *context* of the visualized data and the *imprecision* of the data.

Context: Values are evaluated in relation to our expectations and goals. We can distinguish between two kinds of contexts which can help to interpret the collected data:

- *Normative context*: The normative context describes general values to which the collected values can be compared and which help to interpret the collected values (e.g., the widespread recommendation to take 10,000 steps a day).
- *Individual context*: The individual context describes individual values which help to set the collected values in relation to previously collected (e.g., values collected during a baseline phase) or individually defined goals.

Imprecision: Imprecision in the data occurs because of two reasons:

– *Imprecision of tracked data*: The sensor input and the transformation and interpretation (e.g., steps taken or time spent in a specific activity level) as well as the manually entered date my be imprecise (e.g., the manually entered amount of food).
– *Imprecision of contextual data*: The context to which we compare the values (normative or individual) is not precise. For the individual context we have to face the problem of imprecision in the automatically collected or manually entered data (e.g., when collecting the baseline values). For the normative context the values to compare to are not well-defined (e.g., how many vegetables should we eat a day) and the consequences of deviations from the normative context for various measures are different [9] (e.g., it is more harmful to eat one more unit of the "oil & sugar" food group than one more unit of the "vegetables" food group).

In the following we present a design draft of an intervention targeting a healthy diet in terms of a balanced diet (See Fig. 2). In this example we use the normative context for a balanced diet, as defined by Asghari et al. [9] Instead of using exact values for each food group, Asghari et al. developed a guideline that defines a fuzzy range for the recommended intake of each food group. This avoids tasking the users to meet very specific goals, and allows for interventions based on rough recommendations.

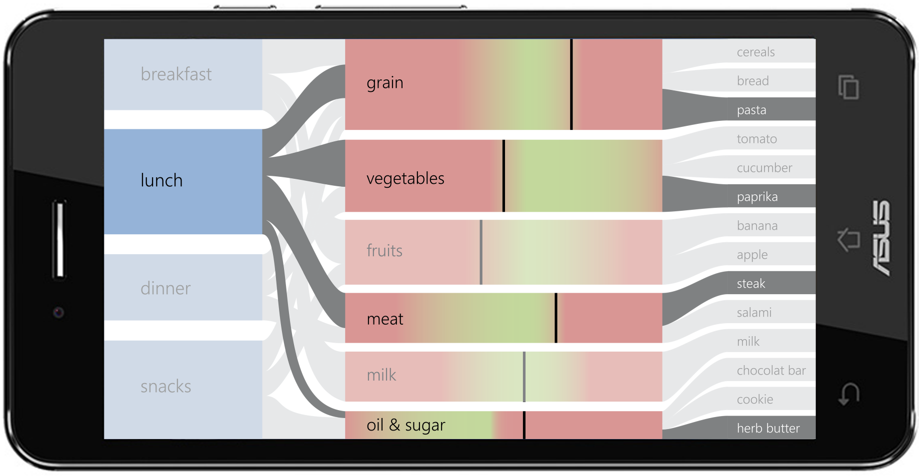


Fig. 2: Intervention: Feedback on balanced diet. Lunch is selected and related values are highlighted in the other two dimensions.

The proposed visualization shows the types of meals ("breakfast", "lunch", "dinner" and "snacks") on the left side. The height of the items correspond to the percentage of calories consumed during meals of a certain type. In the center of the visualization the six food groups ("grain", "vegetables", "fruits", "meat", "milk", "oil & sugar") are visualized. The height of the boxes roughly indicate how the food should be spread over the six groups (e.g., that one should eat more vegetables than milk products). The black vertical bars indicate the current values of the tracked food intake. The goal is to reach the green area of each food group. The color gradients represent the fuzzy range for the recommended food intake which should be reached. For vegetables the color gradient shows that it is totally fine to eat more vegetables (gradient is also greenish on the left side of the box), but that one should eat at least a certain amount of vegetables (abrupt color change to red on the left side). On the right side the individual food items tracked by the user are listed. Each item (meal types, food groups or individual food items) can be selected by the user which highlights the related values in the other two dimensions. This visualization deals with the imprecision of the normative context and allows for the simple analysis of relations between different dimensions.

5 Conclusion and Future Work

In a pilot study of our reference implementation for a food diary application built with the help of the SmartAct toolbox we received promising feedback for the user experience of the application. In the next step, the presented intervention in terms of a feedback visualization will be implemented and evaluated. The aim of the evaluation is to find out if the mobile intervention will allow users to analyse their eating behaviour and therefore change their behaviour towards a healthier lifestyle. Furthermore, applications for physical activity tracking and interventions targeting physical activity will be implemented and their effectiveness will be evaluated. The SmartAct toolbox for behavior change aims at decreasing the implementation barrier for mobile interventions and lowering the burden for testing novel mobile interventions. Although mobile interventions designed with the help of the SmartAct toolbox are planned to provide automatic feedback to the end users, the toolbox can also be utilized for clinical interventions as the real-time client-server synchronisation allows clinicians to provide almost real-time expert feedback to the end users (e.g., to target dystrophy).

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