USER CENTERED DESIGN OF PATIENT USER INTERFACES FOR REMOTE TRAINING SUPERVISION
A User Study

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Abstract: Remote training supervision is a new approach that combines medical and IT knowledge into one system. Such a system enables patients with cardiac diseases to continue a supervised training - on an ergometer bicycle and even when exercising outdoors - after rehabilitation phase in a clinic. The goal of the study presented in this paper is to develop user interfaces for an ergometer. These interfaces have to allow an intuitive interaction and to take the different capabilities, needs and preferences of potential users - often elderly people having visual impairments and different IT knowledge - into account. In order to create minimal attention user interfaces it is mandatory to apply user centered techniques, which involve potential users into the design phase of the development process. The evaluation of the study served as basis for the next iteration of the user centered design process and raised new functional requirements to the underlying system from the user's perspective.

1 INTRODUCTION

Current surveys of the IT inter-trade organization Bitkom showed that 59.8% of all Germans beyond the age of 65 would like to use tele-medicine to extend living in their familiar environment. We estimate similar values for whole Western Europe and North America. Further on 58% of the interviewed persons indicated that they would make use of alarm systems like tumble sensors, ECG or apnea measurement when they are in need of care. It is shown, that elderly people do not perceive this observation as a problem but as assistance (see Heise Online, 2008 I). Therefore there is the demand on politicians and the public health sector to enable age-based assistance systems for self-determined living at home. Since the required technology is available, assumption of costs for applications like telemonitoring and tele-homecare has to be provided by health insurances. The health care system can benefit from such systems since they help to reduce or avoid expensive hospitalizations (Stroetmann, 2007 and Heise Online, 2008 II). In the past years costs in health care exploded. Thereby cardiac diseases caused the major amount of money spent in medical care.

Rehabilitation is well established and accepted for sustaining a healthy life style after a cardiac event. Studies have shown that one year after such an event and rehabilitation phase II, not all patients reach their training goals and in some cases their cardiac risk factors even deteriorate (EUROASPIRE I and II Group et al., 2001 and EUROASPIRE II Study Group, 2001). Therefore intelligent IT solutions that provide opportunities for prevention and secondary prevention of cardiac diseases are crucial. In addition such systems must come along with clearly

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arranged and intuitively operable user interfaces, because patients with cardiac diseases are often elderly people that are not that familiar with information technology. It is a major challenge to design usable tele-medicine applications for this target group.

To face this challenges a user centered design approach is necessary. Potentially users that are interacting with tele-medicine applications often suffer under their current state of health. Therefore the system should guide them carefully. They often have age-related visual impairments and in the setup described in the next section they are quite far away from the screen. These facts have to be considered when designing user interfaces for such patients.

2 THE OSAMI-D PROJECT

The European research project OSAMI and the German sub-project OSAMI-D are funded by the German Ministry of Education and Research (BMBF) et al. In the project open services for ambient intelligence are going to be developed. OSAMI-D addresses tele-medicine and remote ergometer rehabilitation in particular as an example of use. Since ergometer training is a well-known and effective rehabilitation appliance for patients with cardiac diseases, we think that this scenario has the potential to be realized as a commercial solution one day. The idea of the scenario is that patients who successfully finished rehabilitation phase II in a hospital should be able to continue their training afterwards in order to keep up the rehabilitation process and avoid a new cardiac event. Therefore a patient after rehabilitation phase II may herself install an ergometer at home. This ergometer comes along with several sensors for measuring vital data, an internet connection and a touchscreen in front of the exercising user. During an exercise training data from the sensors is collected, automatically analyzed and transmitted to a supervisor system. Supervisors may then adapt the training plan of every patient according to abnormalities recorded in the current and/or previous session. Figure 1 shows a schema of the overall setup as far as the hardware components at the patient's home. The figure also shows the vital data sensors that are connected wireless via Bluetooth to the ergometer: An ECG sensor, a blood pressure sensor and an oxygen saturation (SpO_2) sensor. Technically, the setup consists of a tablet PC that serves as user interface, internet gateway, collector of sensor data and ergometer controller. The ergometer itself offers access to adjustable values via a network interface. E.g. it allows a changing of the current load in Watts by applying the correct pedaling resistance according to the pedaling frequency of the user.

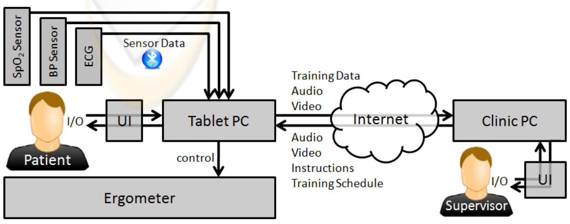

Figure 1: Scenario Schema.

In the project we differ between three training levels. In *Level 1* there's a one-to-one live supervision between the patient and a supervisor. The training data - including vital data measured by the sensors and ergometer data - as far as audio and video recordings of the patient are directly transmitted to the supervisor. The supervisor analyzes the data online and can change the training schedule immediately or issue instructions to the patient. *Level 2* training is quite similar but here a larger group of patients is observed by one supervisor simultaneously. Audio and video transmission is optional and can be manually enabled or disabled by patients or the supervisor. Finally *Level 3* enables offline training for lower-risk patients. These can exercise at any time they like. The data is recorded but not transmitted before the training is finished. A supervisor analyzes the recorded data in post processing within a given time period, e.g. 24 hours, and adapts the training schedule if necessary. The schedule is transmitted to the patient's gateway PC afterwards. The *Level 3* scenario also enables a mobile training. Patients can use simplified versions of the vital data sensors to collect data on their mobile phone or PDA via Bluetooth while exercising outdoors. This provides more flexibility to patients who can perform their preferred sport on an arbitrary place. Even though there's no live supervision the system automatically compares the vital data with threshold values predefined in the training schedule by a supervisor. If some data exceeds a limit the patient is informed about that and she's given a hint of how to react (e.g. "Walk a bit slower"). Hence the responsibility in terms of effectiveness and security lies on the patient's side solely.

3 RELATED WORK

The market of telemonitoring concepts and systems especially designed for training demands is rare.

There are some bicycle ergometer using chipcard controlled training, but there is no remote tele-monitoring yet available. Currently two research approaches exist: The SAPHIRE-Project (Busch et al., 2009) - the precursor of the OSAMI-D project - and the ongoing project HeartCycle (http://www.heartcycle.eu) that also integrate online exercise supervision into their platforms. SAPHIRE did not consider *Level 2, Level 3* or mobile training since the project solely focused on realizing Level 1 training without audio- and video-conferencing. By performing the user study we have been able to gather first knowledge about what kind of user interaction is useful and which parts of the SAPHIRE interfaces seemed to be usable, which are improvable and how. For the supervisor side we already created user interface mockups that are going to be evaluated and implemented (Klompmaker et al., 2009). Since supervisors are often familiar with complex visualizations of medical data it is expected that it is more difficult to create usable user interfaces for patients using such a system.

Gay and Leijdekkers presented an approach on how sensors for measuring vital data may be used in mobile setups (Gay and Leijdekkers, 2007). Thereby the ECG data is analyzed automatically and locally in order to provide hints to the user or to alert pre assigned caregivers whenever necessary. Anyway here the data is not transmitted during or after an exercise session but monitored permanently by algorithms. Another project focusing on mobile applications especially for elderly people is presented by Oppermann et al. (2008). Here the application that's also monitoring vital data may also only be controlled with the mobile device itself resulting in small and very simple graphical user interfaces. We can benefit from these results when designing the mobile training application but we had to do a user study for the user interface on the ergometer screen from scratch.

The concept of the company T2BEAM Technologies AG, Switzerland just emerged on the market in January 2009. The product called athlosoft (http://athlosoft.com) addresses healthy subjects, who can get online training supervision. This system is to the knowledge of the authors the most advanced IT-telemonitoring concept on the market yet but as a downside compared to OSAMI-D it does not allow the definition of medical constraints controlling a training session.

In summary we found out that there are approaches existing that address the different technical challenges of the OSAMI-D project and the different end users. However there's no system existing using the different technical approaches of live supervision on an ergometer, offline training with predefined medical constraints and mobile training altogether for patients with cardiac diseases. We think it is necessary to achieve more insights of the user's needs, preferences and habits in this specific use case. Therefore user centered design is the best possibility towards developing a successful and usable system.

4 USER STUDY

In the user study we did in a rehabilitation clinic we tried to find out what the current situation and the daily routine of patients looks like in order to use the results for the system design. We will introduce the interview lead through and the results here.

4.1 Current Setting

This section explains the current flow of the ergometer training for patients with cardiac diseases within a rehabilitation clinic. We carefully figured out what's important for patients and supervisors here and how the several training steps are executed in order to develop the OSAMI-D system according to these workflows.

The in situ training in the early rehabilitation phase is organized in groups of up to 15 patients that are all exercising simultaneously. Therefore they all start a warm-up phase simultaneously, reach the training phase simultaneously and reach and finish the cool down phase of the training simultaneously. The focus of the supervisor here lies on visual control and personal conversations. She predominantly checks the body language and body signals of the patients, e.g. skin color, sweating or pedal regularity, in order to detect critical situations. Further on she asks the patients about their wellbeing periodically. The vital data that is displayed on two large PC displays in a secondary room is not that important and only considered secondarily. Beside the proven medical effectiveness the biggest advantage of an in situ ergometer training is therefore the personal supervision through qualified medical staff. Further on many patients like the training within an exercise group because it enables social interactions with other patients. However there are some disadvantages of an in situ ergometer training. It is described as very monotonous by the patients because it provides little variety. Comparing this exercise with an outdoor bicycle training it is quite stultifying, e.g. the fresh air, the air flow and the landscape are missing. During in situ training the participants are looking towards the walls of the exercise room and just listening to quiet music. Further on patients stated that the ergometer training is not challenging but physically very easy. Since patients trust in the supervisors and the training settings they accept this issue but experience the ergometer training in a very passive way and regular feedback from supervisors is missing. Furthermore patients don't even know their personal training setting and schedule in detail. The challenge here is besides designing intuitive user interfaces also to raise new functional requirements towards the underlying system in order to implement new functionalities that motivate patients to exercise periodically and to overcome the monotony.

Therefore we collected the requirements and analyzed the context of use of the OSAMI-D system on the patient's side as a base for the user interface design. Since the training will not take place in situ anymore but at the patient's home we have to think about numerous changes in the training flow and in the interaction modalities between user and computer.

4.2 Interview Lead through

We interviewed six patients in a rehabilitation clinic, recruited by the clinic staff and in a previews session (Klompmaker et al., 2009) also four ergometer training supervisors. All patients have been described as potentially adequate for remote ergometer training supervision. Five of the six patients were around retirement age (65 years in Germany) one was a young adult (approximately 30 years old). All stayed in the rehabilitation clinic with the objective of finishing a three week rehabilitation program including in situ supervised ergometer training three to five times a week. While five patients did already reach their final rehabilitation week the last one was still in the starting week of the training. All of the interviewed persons live really active social lives and are also physically active – most of them stated that they like cycling and are undertaking cycling tours quite often. Even though some of them are beyond retirement age they all seem to be very busy and pointed out to be pinched for time. The patients all have basic computer knowledge but aren't computer experts. This seems to be one reason the clinic stuff recruited them as potentially adequate for remote ergometer training supervision. Supervisors said that patients without any computer knowledge won't ever trust in such a system. Therefore they won't ever use it and are from the clinic point of view no potential patients for remote ergometer training supervision.

We used an interview-guideline with open questions and performed semi-structured interviews (Wengraf, 2001). After asking personal questions and questions about the current in situ training (see above) we introduced the different training levels and scenarios to the patients. In doing so we recorded all answers and comments as further user input.

4.3 Results

This section introduces the main results of the semi structured interviews by abstracting the main declarations of the patients and analyzing the system requirements from the user's perspective.

Patients appreciate the possibility of performing remote ergometer training supervision as an expanded rehabilitation in general. At least those with basic computer knowledge do not have doubts regarding technology or organization. Since all of the interviewed persons have been physically active before they also do not have an issue with exercising regularly in the future. Nevertheless all patients stated that a long-term indoor ergometer training is not attractive in comparison to alternative sports especially outdoor ones. We think that therefore it is desirable to develop even mobile solutions.

Patients with cardiac diseases have the need for supervision, distraction and confirmation when exercising. Especially they would like to get their vital data visualized ("It would be nice if I knew my own values!"). Knowing these values would enable them to have food for thought and to know that everything is copacetic. Automatic feedback (current sensor values) is therefore very important.

Patients see many advantages in the planned setup: They don't need to arrange fix training dates (at least not when applying *Level 2* or *Level 3* training) and they save time in comparison to an in situ training in the clinic because they would have to travel there. Further on they can define the entertainment program on their own: Reading news, listening to music, watch TV or surf the web. Therefore an entertainment system as part of the patient user interface is desirable. However we don't think that this will overcome the monotonous training in the long term.

5 USER INTERFACE DESIGN

The results of early user questionnaires can be used as a basis to create user interface mockups. These serve afterwards as a basis for the second iteration of the user centered design process where users are asked to evaluate these mockups in a first prototype application. In this chapter we introduce the design implications we acquired from the results of the questionnaires. Then we introduce some user interface mockups as far as the conceptual ideas behind them. Further on the interviews resulted in new requirements towards the underlying software system. These are introduced in an separated chapter.

5.1 Design Implications for Remote Super-vision

One of the most definite results we figured out is that patients need to get their personal vital data visualized to overcome the monotony of the training and to compare the results concerning training success and personal threshold values. Therefore the graphical user interface of the OSAMI-D project demonstrator should present the most important data in a clearly arranged way. The interface should further on provide a mechanism to show the personal feedback from the supervisor in the form of text messages as far as a calendar showing past and future training dates.

We found out that the user interface of the precursor project had some lack in consistency especially regarding the colors of the graphical elements. Patients stated that they don't understand the applied color coding of yellow and red buttons. Further on some buttons aren't even needed – e.g. patients would never push a button when they decide to stop the training because of illness but just stop cycling and make further measures. Another inconsistency in the coding was recognized at the also implemented traffic light. Sometimes the yellow color was used to inform the patient about a high heart frequency - an alarm - sometimes it was used to inform the user to continue the training. Hence it was often unclear how dramatic the current alarm or information really is. Another issue that was evaluated as distracting was the length of the questionnaires patients have to answer before and after training in *Level 2* and *Level 3*. Many questions were unclear, others may be grouped, others are completely unnecessary (e.g. "Are you feeling good" – A patient that not feels good wouldn't have get on the ergometer to start training).

A last thing is that we had to take care of the size of graphical elements and especially fonts when designing the user interface. Patients are often elderly people with visual impairments and they are exercising when interacting with the interface. When considering a mobile training it is therefore especially important to only display the information that is really needed. Here we're also focusing on auditory and physical feedback via rumble motors.

5.2 User Interface Mockups

The implications for remote supervision were used to develop user interface mockups. Here we introduce the most important mockup figures, the overall layout and the idea behind it.

The main menu (Figure 2) appears after a patient logged in using her username and password. Even though it is not that easy for patients to remember both we are using this login mechanism due to security reasons. The main menu shows the latest supervisor feedback (top left) and offers the possibility to start a supervised training either in online mode (bottom left, only if currently available) or in offline mode (bottom center, always available for low-risk patients). All is done via simple single button clicks using a single finger. Since the user interface elements are big (screen size is 17") this is easy for nearly every patient. Everything is clearly arranged and the interface only offers the most important functions.

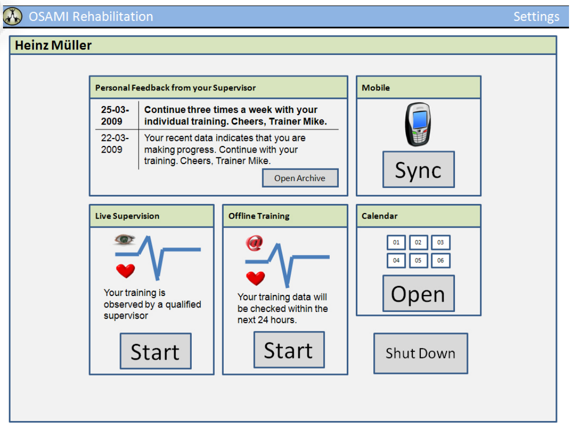

Figure 2: Main Menu.

The main menu further on offers possibilities to start a synchronization with a mobile device for performing mobile offline training, to shut down the system and to open the calendar. The calendar shows all past and future training sessions as far as information about changes in the training plan and supervised or not yet supervised sessions in the past.

Figure 3 shows how the questions of the pre- and post questionnaires of *Level 3* training should look like. In the interviews we found out, that the asked people need feedback about what exactly has been pressed on the screen. In most cases it is definite because of the following things that are displayed but not in case of questionnaires. Even so these are essential for a supervisor when analyzing the training in post processing. Therefore we decided to first highlight a selected answer and then confirm it by pressing the “Next” button. This was well accepted by all test users even if they had to click the screen twice. Figure 3 shows a multiple choice and a yes/no question. In figure 4 easy signs that differ in color and shape (therefore also operable by color-blind people) and that inform a patient about connected sensors shortly before the training starts. If a sensor sends a problem or it is not connected the corresponding help page automatically appears giving further information and instructions (see figure 4, right image).

Finally figures 5, 6 and 7 show the user interface while the patient is exercising. It can be seen that we decided to use a traffic light metaphor to display the overall situation, e.g. a green light means that everything is all right and the training should be continued. The yellow light means: Continue the training but additional hints are given (e.g. “Slow down”). When the red light appears the training will be stopped after cooling down. Traffic lights can further on also be understand by color-blind people. We’re using a unique color scheme in the user interfaces. Buttons always have the same look & feel, green, yellow and red colors are used as described.

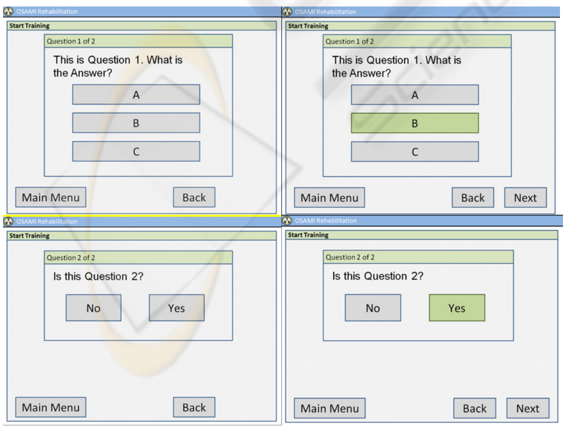

Figure 3: Questionnaires.

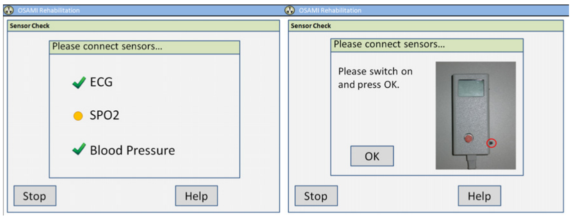

Figure 4: Sensor check.

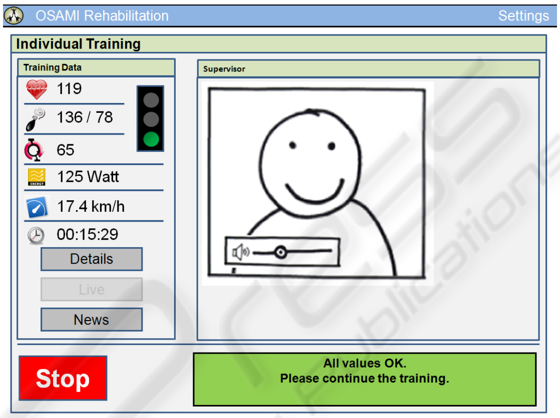

Figure 5: *Level 1* Training, live view.

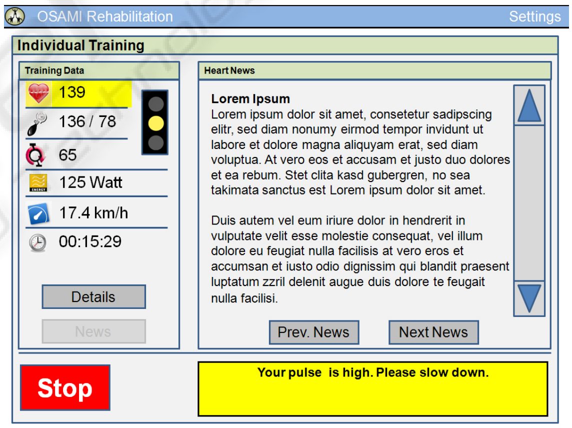

Figure 6: *Level 3* Training with yellow alarm.

We decided to use easy symbols for the vital data and the ergometer data to display the heart frequency, blood pressure value, current pedaling frequency, load, speed and time. We think that these icons are easy to understand but we have to verify this in the next iteration of the user centered design process.

For the mobile version of the offline training patients first will have to synchronize their device with the ergometer. The current training plan is downloaded to the device and the user can start the training whenever she wants. Therefore the mobile system only needs the functionality for starting a training. Alarms during the training will cause in auditory and physical feedback depending on the device capabilities.

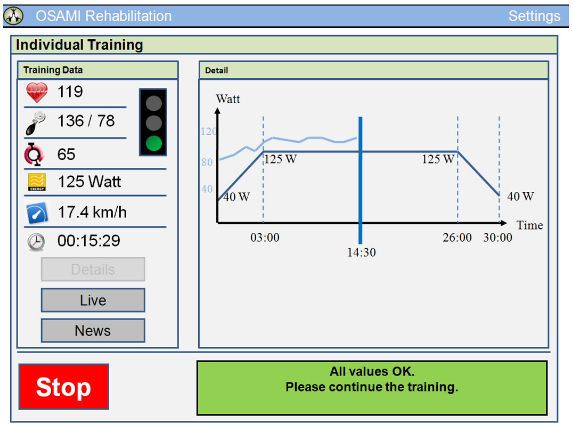

Figure 7: *Level 1* Training, detail view.

5.3 Functional Requirements towards the System

Even though the user study described above was done in order to acquire information about the user interface design for this very special use case, it also raised functional requirements towards the underlying software. First we found out that videoconferencing is essential in *Level 1* and *Level 2* training since the main information about a patients well being can be taken from his body language (skin color, position, pedaling regularity etc.). Even though in OSAMI-D it was planned to implement videoconferencing at the very beginning because of its technical feasibility we found out that it is very desirable for both user groups – patients and supervisors.

Automatic analysis of the vital data values is another requirement. Some kind of data may be analyzed quite easy (e.g. if the blood pressure value is too high), some analysis is really hard to implement (e.g. detect abnormalities in the ECG curve). Here third party solutions have to be obtained and implemented in the future.

Another functional requirement is the entertainment system. It may help to motivate the patients to exercise periodically and it may help to overcome the monotony of indoor ergometer training. Here also a mobile solution is desirable because it enables patients to exercise outdoor and she's not longer limited to cycling. Therefore the system has to offer possibilities to synchronize mobile phones with the home gateway (in our current setup this is the tablet PC on the ergometer) in order to exchange training schedules and reports.

Patients prefer to have a flexible possibility of making training appointments. Here the calendar functionality is a nice feature that enables an overview of training dates, the different training levels that are available and past training events.

Since the hardware of the ergometer itself (saddle position and material, overall weight) is not changeable (we're using an existing ergometer setup in the project) we could not consider comments regarding these values.

6 CONCLUSIONS

We found out that ergometer training competes to more attractive physical activities like outdoor sports. It is therefore extremely important to generate and keep up a high motivation of patients. Therefore the vital data of the patients should not longer be hidden but presented to them during training. This enables patients to compare values with previous sessions and allows them to keep an eye on the overall training success.

Regular feedback from supervisors further on helps to motivate patients and gives them a feeling of safety. This is a unique feature of a remote supervision system. Another issue is that patients need flexibility in organizing their free time. E-Health systems should therefore allow them to exercise whenever they want and wherever they like. Patient user interfaces should guide the users fast and intuitively. Patients don't like an overhead of time or frustrating questions that occur every time they start the training. Anyway some hints from the interviewed patients could not be considered because they would collide with the medical functionality of the system. E.g. patients would like to sail elevation profiles or change the load of the ergometer on their own.

To summarize this work: We found out interesting insights about the needs and habits of patients with cardiac diseases if they would decide to participate in a remote exercise supervision program. This helped us to design user interface mockups and a first software prototype that provide easy interaction, clarity and overall usability. We also figured out several insights about this kind of medical assistance, the problems that have to be solved and the market potential.

7 FUTURE WORK

As the next step of the user centered design process we will again present this application to patients and staff of a rehabilitation clinic and do semi-structured interviews during and after testing. Hopefully this will result in some hints for refinement that are going to be used for the final demonstrator afterwards. The focus of the user tests will lie on understandability and perceptibility of what's being presented. Further on interaction methods and menu navigations have to be evaluated. The overall goal is hence still to keep the user integrated during the whole development process.

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