Design and Development of a Mobile Medical Application for the Management of Chronic Diseases: Methods of Improved Data Input for Older People

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Abstract. The application of already widely available mobile phones would provide medical professionals with an additional possibility of outpatient care, which may reduce medical cost at the same time as providing support to elderly people suffering from chronic diseases, such as diabetes and hypertension. To facilitate this, it is essential to apply user centered development methodologies to counteract opposition due to the technological inexperience of the elderly. In this paper, we describe the design and development of a mobile medical application to help deal with chronic diseases in a home environment. The application is called *MyMobileDoc* and includes a graphical user interface for patients to enter medical data including blood pressure; blood glucose levels; etc. Although we are aware that sensor devices are being marketed to measure this data, subjective data, for example, pain intensity and contentment level must be manually input. We included 15 patients aged from 36 to 84 (mean age 65) and 4 nurses aged from 20 to 33 (mean age 26) in several of our user centered development cycles. We concentrated on three different possibilities for number input. We demonstrate the function of this interface, its applicability and the importance of patient education. Our aim is to stimulate incidental learning, enhance motivation, increase comprehension and thus acceptance.

Keywords: User centered development, Mobile usability, Patient compliance, Patient education, Mobile learning, Elderly people.

1 Introduction and Motivation

The demographical structure in many industrial countries tends towards an increasing population of elderly people. Within the next 20 years, around 25% of the population in European countries will be aged 65 and more [1]. Consequently, whatever progress in health conditions we expect, an increase in care within the next decades is required. This increasing average age of the total population inclines towards a subsequent rise

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of chronic diseases such as diabetes and hypertension, and in conjunction with today's life expectancy, a dramatic raise in medical costs.

CODE-2 Study. According to the results of the Costs Of Diabetes in Europe Type 2 study [2], which analyzed the financial expenditures for managing specific diabetes-related complications and long-term effects, the annual expense incurred due to type 2 diabetes in Germany averages 4600 Euros per patient. Only seven percent of these costs are spent on medication, and over 50 percent account for the treatment of complications. At the same time, only 26 percent of patients have an acceptable value of HbA1c, a long term indicator for diabetes control. The study concludes that diabetes control is inadequate in most patients and in order to reduce total costs, the focus should be turned to early prevention of complications and that an initial increase in treatment costs due to preventive measures can be more than compensated by savings occurring from prevention of complications [2], [3]. To date, there are no concepts for care continuity in diabetes control to be used by all patients; moreover health care providers do not even require patients to record their values using a diabetes diary. Another common example for the lack of clinical concepts in public health is hypertension, which is a common disease amongst the elderly: Untreated hypertension can lead to cardiovascular events, thus elderly have significantly higher expenditures per capita for hypertension and per hypertensive condition [4]. In Austria, for example, only 20 percent of people with hypertension are on proper medication to control this condition [5].

Older people and new technologies are currently one of the important research and development areas, where accessibility, usability and most of all life-long learning play a major role [6]. Interestingly, health education for the elderly is a still neglected area in the aging societies [7], although computer based patient education can be regarded as an effective strategy for improving healthcare knowledge [8] and the widespread use of mobile phones would enable mobile learning at any place, at any time. [9]. However, elderly patients form a very specific end user group and there is a discrepancy between the expected growth of health problems amongst the elderly and the availability of patient education possibilities for this end user group, therefore a lot of questions remain open and need to be studied [7]. However, although technology is now available (at least in Europe) at low cost, the facilitation of usage is only one aspect which must be dealt with, it is necessary to understand the uncertainties and difficulties of this particular end user group. Research is therefore also aimed at investigating ways to increase motivation and improve acceptance in order to make the technology more *elder user friendly* [10].

MyMobileDoc. In order to address some of the above mentioned issues we have developed MyMobileDoc providing a user centered and user friendly interface with no automatic electronic data exchange by sensors, since our focus is on personal awareness. The main functions include a daily medication remainder service and the provision of immediate feedback to the patient, providing educational information about relevant medical details, i.e. chronic diseases. Our main goal was to provide a personal tool designed to increase compliance and, most of all, the possibility of increasing personal responsibility and personal awareness, since we found that patient compliance, acceptance and patient education is vital. Technology should enable the patients to actively become involved in their management of chronic diseases.

2 Technical Background

Worldwide, there are a lot of various groups working on the use of mobile phones and health applications, patient monitoring, automatic data transmission and sensors [11], [12]. However, only a few are dealing with manual data entry [13], and issues of patient education and learning, motivation and acceptance of these technologies amongst elderly people are most often neglected – although elderly people are a completely different end user group. Their motivation is different, their frustration level is lower and they may have to overcome previous, negative experience [10].

2.1 Communication Concept of MyMobileDoc

The most important part in the structure of MyMobileDoc is **the patients themselves**, who regularly send their data (blood pressure; blood glucose levels, pain intensity, contentment level, etc.) via their mobile phone, or by using a standard web client on any device (Game Boy, Surf Pad etc.) to the Medical Data Centre (MDC) on the server (figure 1). The received data can then be evaluated automatically or by medical staff. On the basis of this data, appropriate feedback can be immediately forwarded to the patient. It is also possible to identify possible emergency states from the received data and on that basis, help can be called. Technologically, the patient's mobile could also be located by an Assisted Global Positioning System (AGPS). The patient data can be stored in the MDC and the patient can view his medical diary at any time. Also, the medical professionals can have access to the data, administer the patient's user information and check medical data by using the MyMobileDoc web front end for medical professionals. Patient's relatives or his nurses can gain access to the saved medical values to observe the patient's health status. However, in all these cases, data protection measures and secure data transfer must be taken into account [14]. In this paper, we concentrate on the user interface (solid lines within figure 1).

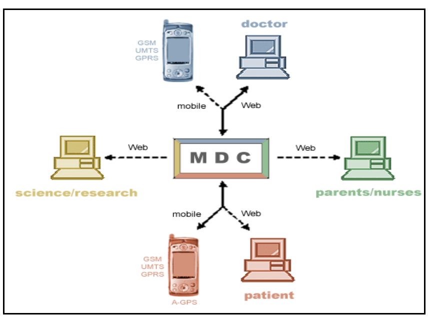

Fig. 1. The basic communication structure of the MyMobileDoc system (MDC = Medical Data Center); In this paper we concentrate only on the user interface development (solid lines)

Before creating a working prototype of MyMobileDoc, some decisions about suitable hardware for the clients and the server, as well as the programming tools to be used, had to be made.

2.2 Clients

Within the technical concept of MyMobileDoc we distinguish between two types of clients: one interface for the medical professional which is basically a standard Internet Browser; and the second type for patients, which should provide them with a maximum of flexibility. This means every terminal would be possible, however, we have chosen mobile phones due to their high availability. For our prototype, we used a Motorola A920 (figure 2) which included an integrated Flash-Player (version Flash Player 5), since we already had experience with this technology [15].

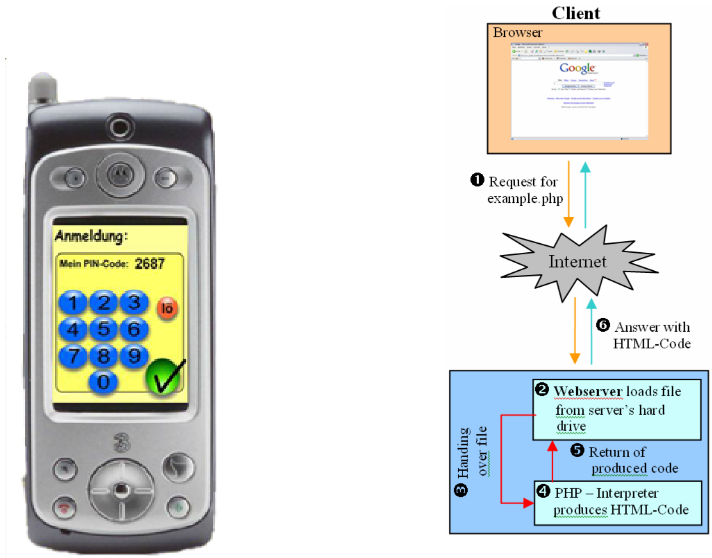

Fig. 2. A view of the user interface of MyMobileDoc: the login screen on a Motorola A920 mobile phone (left); PHP connects the client with the database server (right)

3 End User Group Analysis and Medical Indications

A suitable instrument for diagnosing and treating certain medical conditions usually has to be chosen carefully by the medical professional. If, for example, a physician decides to use the wrong tool, the treatment might not be as effective, and a patient's condition may even deteriorate. If, as in our case with MyMobileDoc, the patient is the end user and uses the tool, the situation is even more critical: It is obvious that the better the usability of the device, the more patients will be able and willing to use it. We followed the general guideline that our technological model should match the mental models of the end users [16].

Consequently, for successful everyday use of such a particular application, the following issues must be carefully considered during the design and development: the profile of the patient (compliance) and his underlying clinical condition (disease).

3.1 Patient Compliance

Identifying suitable patients is a crucial factor for successful treatment. This task is performed by medical doctors after a physical examination. Based on clinical experience, we suggest dividing patients into three groups in order to determine whether or not they will be reliable supporters in their own therapy (compliant) and benefit from MyMobileDoc.

Basically, the compliance level of a certain patient is generally hard to predict from age, gender or social factors alone. The lack of a general accepted definition of compliance makes it difficult to operationalize and consequently evaluate the psychological concept of compliance [17]. However, taken as a behavioral concept, compliance involves actions, intentions, emotions, etc. which are also known from general usability research. Therefore, indirect methods such as interviews are generally used because they have the advantage of revealing the individual's own assessment of their compliance. Assessment by nurses and physicians has usually been based on either the outcome of compliance or information obtained in interviews. Self report measures are the most commonly used to evaluate the compliance of adolescents with chronic disease. Reasons for their popularity can be seen in easy applicability and low costs [17]. During our study we identified the following three groups listed in Table 1, who reflect three commonly observed circumstances that can influence the patient's level of compliance.

Table 1. Three commonly observed groups of patients and their estimated likelihood of their compliance

	Will use MyMobileDoc	**Level of education**	**Motorical skills**	**Ability to understand risk factors**
Group 1	likely	high	sufficient	given
Group 2	unlikely	low to medium	sufficient	usually limited
Group 3	unpredictable	varying	insufficient	varying

A typical group 1 patient could be a 45 year old teacher who seeks medical advice for recently diagnosed Type 2 diabetes. He tries hard to get back to work as soon as possible. We can expect him to use MyMobileDoc for treatment, but he might not really need it as he soon knows a lot about his condition and treatment options.

A patient out of group 2 could be a 50 year old woman who has been living on a farm since the age of 20. She does not have social contacts other than her family. She is overweight and has never heard about cholesterol, nor has she ever used a mobile phone. Using MyMobileDoc will be a big challenge to her. She will have to learn about the interactions of lifestyle and diabetes, and compared to group 1 she will need much more assistance and control when using MyMobileDoc. A member of group 3, a 70 year old man who suffered a stroke that left his right arm and leg paralyzed, is physically unable to use MyMobileDoc for diabetes control, irrespective of his educational background. However, this group usually has help from relatives or (mobile) nurses available. All three groups would benefit from MyMobileDoc. Patients from group 2 need more control and education, whereas group 3 patients are in need of physical help. What we are responsible for is usability.

3.2 Clinical Conditions

Basically, there are a lot of medical conditions that can be monitored with MyMobileDoc, some are discussed here.

Blood pressure. Diagnoses of high blood pressure (hypertension) can only be established after multiple tests. Having these done by patients, avoids higher than normal values due to anxiety at the physicians office. Therapy usually lasts many years, so a mobile application can here save time and consultation costs. After introducing new medication, a patient should monitor blood pressure several times a day, also during pregnancy. Immediate feedback and information on such issues can help to raise awareness and compliance.

Blood glucose levels. Type 2 diabetes control is easy for physically fit patients. From a message generated by the database server, patients can learn about the impact of diet on their condition. If registered values are too high over a longer period, the attending physician can contact them and advise. Moreover, it is possible to include fast acting insulin into therapy, an option that only a few patients use outside the hospital. Type 1 diabetes is not an indication: MyMobileDoc depends on network connection, and hypoglycemia is, if not treated rapidly, a life threatening condition. There are diabetes diaries available on paper and on PDA's. However, compared with MyMobileDoc, none of them offer their end users spontaneous feedback and the opportunity to get educational information.

Peak-Flow. In asthmatics, acute exacerbation can be prevented by regularly measuring the peak expiratory flow, and adjusting medication accordingly. As Peak-Flow values often decrease days before the patient suffers clinical deterioration, a database server could alert the patient. Follow-up examinations are also based on evaluating Peak-Flow values written down by the patient but this is only possible retrospectively. Here a mobile application can optimize therapy and reduce the number of consultations.

Anticoagulation therapy. After cardiac valve prosthesis, heart surgery, certain forms of arrhythmia, deep vein thrombosis, pulmonary embolism and other conditions, patients might have to take medications to avoid blood clotting. Serious bleeding can be a complication if too much anticoagulant is taken, which means that therapy has to be constantly monitored. Currently, the vast majority of patients have the tests for International Normalized Ratio (INR) done by a doctor every five weeks, and the ESCAT (Early Self Controlled Anti Coagulation Trial) study showed that only 54 % of patients had acceptable INR values [18]. If patients performed these easy tests, which involve a finger prick themselves, the treatment quality would be much better, as the goal is to check the INR once a week.

Pain control. Chronic pain can be controlled ideally, if treated *before* the pain raises, thus, immediate reaction in essential. Through an electronic pain scale at the touch screen display the patient can inform the medical professional.

Subjective data. Besides the possibility of enter objectively measured data (body weight, circumference of a swollen ankle, number of steps a patient can walk, oxygen saturation, pulse rate etc.) the most interesting possibility is to record subjective parameters (depression, nervousness, contentment level etc.).

4 Some Lessons Learned During User Centered Development

4.1 Card Sorting and Paper Prototyping: Developing the Navigational Structure

We were aware of the requirement of keeping the navigation within MyMobileDoc as intuitive as possible in order to encourage, especially elderly, to use the system, even if they had no computer literacy. We applied both card sorting [19], [20] and rapid paper prototyping (paper mock-ups) [21], [22] for the design of these structures.

Card Sorting. During the Card Sorting session (see Fig. 4 left side), we prepared potential functions and menu entries on individual cards and asked people from the target end user group (N=15) to sort them in order to cluster what could belong together. At first we used Open Card Sorting, in order to exploratory analyze our application domain and afterwards we applied Closed Card Sorting, in order to comparatively test the suitability of several structures and to select the most suitable one. This helped to understand how end users categorize. With cluster analysis (dendograms) we got hierarchical structures, thus, we gained some understanding of the *mental models* of our end users. However, the limitations of this methods are well known, consequently we did not rely on any one method alone, but combined methods in order to minimize conceptual and practical errors [23]. The results reflected the logical structure for our end user group and elicited insight into semi-tacit knowledge. Unfortunately, Card Sorting did not deliver feedback whether the initial choice of options was reasonable.

Paper Prototyping. This method again proved an effective and inexpensive way to evaluate both content and navigation structure. Our test persons used their fingers to reach a specified goal, for example launching an emergency call, on a paper-simulated interface. Along with paper prototyping, we also used thinking aloud in order to gain insight into end user behavior. However, we experienced that to perform thinking aloud studies with elderly people was more difficult, possibly due to the fact that thinking aloud requires much more load on the short-term memory.

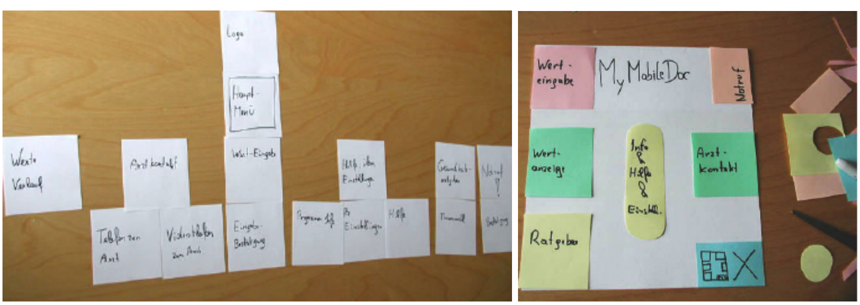

Fig. 4. A picture from the card sorting experiment (left); paper prototype (right)

4.2 The Numeric Input Interface Evaluation

Since the input interface for bio-parameters is the part of our application most often used, we evaluated three different layouts: calculator style, cursor style and slider style (see Fig. 4).

All of our 15 patients aged from 36 to 84 (mean age 65) and 4 nurses aged from 20 to 33 (mean age 26) took part in this evaluation study. None of them had any problems with the touch screen; similar to previous studies the touch screen proved again to be both usable and useful for elderly people [24], [25].

The task consisted of inputting a blood pressure value of 145 over 96, the results are as follows:

Calculator Style. 13 out of the 15 persons preferred to use the calculator-like method. This turned out to be most intuitive, although we experienced that the digit 0 has to be placed below the digit 8, which enabled visually impaired people to use the system.

Cursor Style. The second method involved using two buttons to select a digit, and another two to increase or decrease it. Contrary to our expectations, only a few patients understood this method generally, and only 2 patients under the age of 40 preferred it, in comparison to the calculator method.

Slider Style. The third layout consists of two sliders that can be moved over the display when pressed. This was very easy to understand, however, it involves a lot of practice in handling the touch screen and was definitely not suitable for the elderly, possibly due to the fact that there are far more possible blood pressure values, than pixels on the screen. However, when using a pain scale with 10 positions only, the slider method may have proved preferable.

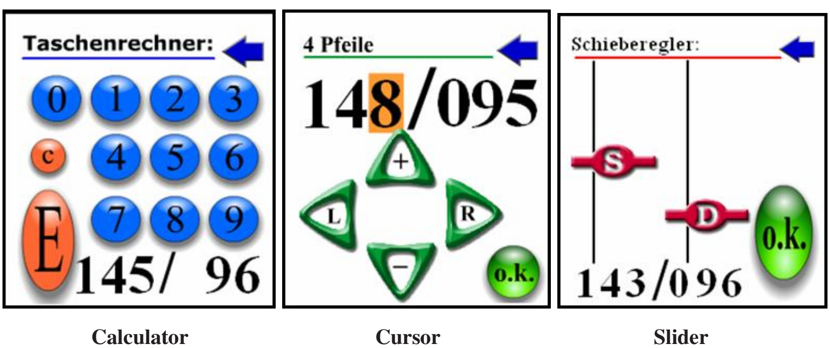

Fig. 4. Three different input possibilities were tested (from left to right): calculator style, cursor style and slider style

4.3 Reading Text from Mobile Phone Screens

During our studies we found that the older users were unable to understand certain terminology. Wording, which constitutes obvious usage amongst developers, is absolutely unclear to the elderly, e.g. user interface, front end, click, touch, etc.

We experienced that our end users preferred to *page* through the text, displayed on the mobile device, instead of scrolling through it, because the handling of elements that support scrolling are far more difficult than the handling of pagination-elements, and scrolling easily can lead to a loss of orientation between the lines [26]. Therefore on mobiles, the amount of data that can be viewed at a time should not exceed a certain number of lines. In our user studies we found that just five information blocks – call them chunks – are the maximum that patients found to be still manageable (see figure 5). The commonly known limits on human short-term memory make it impossible to remember everything given an abundance of information [27], [28]. According to Nielsen [29], humans are poor at remembering exact information, and minimizing the users' memory load has long been one of the top-ten usability heuristics. Facts should be restated when and where these are needed, rather than requiring users to remember things from one screen to the next.

Further, we saw in our study, that our end users preferred the use of sans serif fonts. It is generally known – although often neglected in mobile design – that serif fonts should be avoided, as serifs tend to impair readability at small sizes [30].

Out of this group, some fonts are recommended for use on mobile devices, for example Verdana. Embedded fonts have to be rendered as vectors on the mobile's flash player. The third group, pixel fonts, provides exceptionally crisp screen text at small sizes. Their coordinates have to be set to non fraction values und their height is specified for best results.

Similar to the study of [31], we found that *text size* did not affect our end users as much as we previously expected. Interestingly, not to scroll is more important than the text size. This is possibly, because the as awkward perceived additional scrolling caused by larger text compensates any beneficial effect of the larger text size. Also interesting was that many older users associated bullets with buttons, they just want to click on any round objects.

5 MyMobileDoc and Patient Education

Patient education has emerged as a result of health promotion and disease management programs in response to increased pressure to provide more relevant and concrete information at less cost [32], [8], [7]. Several studies reported that elderly patients having very little computer literacy had successfully learned computer based information about disease-related self care and have also reported satisfaction with computer based learning technologies [33]. In the following sections of this chapter, we describe some of the functions and our experiences during our end user studies.

5.1 Main Menu

After entering the user name and password, a logically designed start screen appears. The house symbol in the right upper corner is consistent throughout the application and designed to reload this start page (home page, see Fig. 5, left side).

This screen is the *patient's cockpit* to all the functions and displays essential information: The end user is presented with his name, and a text field for a comment, which can be changed by the attending doctor for each patient. It could for instance contain something like *"just added new medication"*. There is a second text field located below, containing the heading of medical news. It can also be changed by the doctor, but is the same for all patients. In the right upper corner of the screen, a *traffic light symbol* is displayed, which indicates how a patient is currently doing. This uses a mathematical algorithm that takes into account the last seven entries of values, with the last three being more heavily weighted. The values considered to be out of range can be set by the doctor individually for each patient. If, for example, the last blood pressure entered was 220 over 120, which is way too high, the traffic light shows red, irrespective of preceding entries. Icons along the top and left side of the text block are for launching further functions.

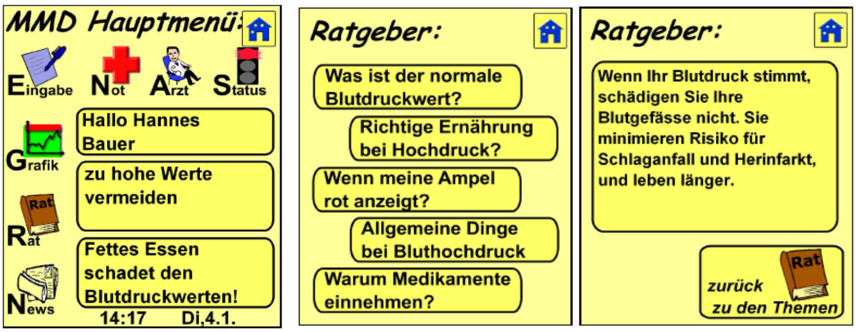

Fig. 5. Left: The main menu acts as the starting point to all functions and serves as the "point of information"; Centre and Right: The *adviser* acts as a point for unobtrusive patient education

5.2 Entering Blood Pressure

Pressing the notebook and pen icon on the top left of the main menu launches the input screen (Figure 6), which is described above, is similar to a calculator. There is no need to enter a preceding 0, as a three-digit blood pressure higher than 500 would not be compatible with life. So if the first digit is higher than four, the software

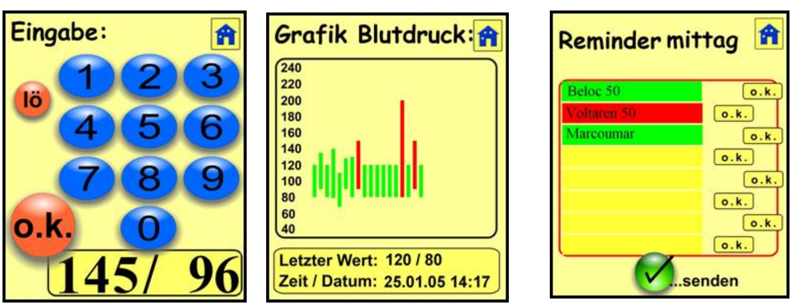

Fig. 6. The patient's input interface for entering self obtained blood pressure values (left), und the graphical representation of the last values entered (right); Pushed from the server, the reminder prevents patients from forgetting to take their medication.

concludes that the value contains two digits only. After pressing the OK-button, a confirmation display appears, followed by a feedback to the patient, whether transmission was completed. Also, a comment is generated, which depends on the value entered. For alarmingly high values, this could be *“take Nitrolingual Pumpspray immediately, consult doctor!”* Pressing OK again loads the main menu, with the updated traffic light.

Pressing the graphic-icon loads an easy to understand graphical interpretation of the last 25 entries.

High values are highlighted red and the last entry is given in detail (Figure 6). Pressing the newspaper icon loads closer information to the news heading displayed in the bottom text field of the main menu.

The book symbol, left of the main menu, loads an e-learning facility for patients. Only basic information is provided but this is what the patients often desperately need as most of them, for example, do not know the normal value for blood pressure.

Emergency Call. The Red Cross icon is to be used in emergencies only, and that’s why there is a confirmation screen after pressing it. An emergency number is being dialed by the Smartphone, and Assisted GPS (AGPS) technology can be used to localize a patient.

Medical Consultation. An icon with a seated medical doctor/medical doctor sitting down/ can be pressed in order to establish a connection to the attending doctor, either by telephone call or by video telephony, which the Motorola A920 also supports. The doctor’s number does not have to be looked up by the patient. It can be changed by the doctor over the web interface, and the patient just has to press a dial symbol. Additionally, he has his doctor’s name and number on his display.

Health Check. When pressing the traffic light icon, the patient receives more information on his status over the last couple of days. A comment is generated by the central database, stating why the traffic light has a certain color. Also, the percentage of values out of range is displayed.

Reminder Service. The reminder (Figure 6) differs from the other functions in that it is pushed by the server and loads automatically when the patient has to take his medication, which is usually four times a day. The user can mark each pill as having been taken or not. If he just presses o.k., all medications are marked as being recognized by the patient in the database. This is in order to not inconvenience compliant patients by requiring them to press all the buttons four times a day. It is clear that the reminder service can not control patient compliance, as users can mark tablets as being taken without doing so. But there are conditions, such as chronic pain or high blood pressure, where medications may be taken only when needed, which could deliver valuable information for further treatment to the doctor. But in most situations, the service simply prevents patients from forgetting to take the tablets.

6 Conclusion and Future Work

MyMobile Doc is a simple and flexible system providing *no* automatic data exchange between the measuring device (biosensor) and the mobile phone. This has, of course, the disadvantage of less comfort, since there are automatic data transmission sensors available; however, we neglected this intentionally, as we found that the patients received more motivation and a sense of responsibility when entering the data by themselves and, most of all, the patients can enter subjective personal data, for example pain intensity and contentment level – where no sensors are available. Consequently, MyMobileDoc must be seen as a mobile patient education tool, which supports patients with chronic diseases and increases patient compliance and raises acceptance. However, it must be pointed out that asking patients to enter numerical data manually is likely to lead to errors – especially with elderly patients or patients who are partially incapacitated by the effects of their chronic disease. It is also important to note that our intention was primarily to motivate cognitive involvement and the **interaction** of the patients with the device in order to stimulate awareness. Following this approach, of course, is only possible for certain patients and after a training phase. MyMobileDoc offers the end user – independent of their location – aid in the electronic documentation of the health status and supports them in the **interpretation, comprehension** and **awareness** of measured medical data.

Every design and development of mobile applications for elderly must support the end users in overcoming their fears and enable them to accept technological aids and mobile devices without reservations; i.e. the design must reflect this acceptance and not be the cause of new biases.

However, much further and deeper research is necessary in order to understand the behavior of elderly end users and in order to design and develop better usable applications.

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