A customizable dashboard platform for caregivers to aid telemonitoring of chronic diseases

Master thesis Computer Science

Dennis Cardinaels

Promotor: Professor Mieke Haesen
Assistant: Jens Brulmans

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Preface

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Abstract

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Contents

1 Introduction

With the continuous growth of ubiquitous computing, the possibility of continuing rehabilitation at home rises. The caregiver monitors the patient at a distance and if needed, the patient is contacted. As a result, resources on both the caregiver and patient side can be saved. This process is called telemonitoring. Research investigated telemonitoring for chronic disease management. Due to the length of these conditions, patients report the status of their condition using a device such as a smartphone or digital blood pressure monitor.

New platforms are created by telemonitoring literature, instead of reusing one or extending an existing health system. Using different applications to monitor for example diabetes and cardiovascular diseases would result in redundancy, as parameters such as blood pressure are important for both disease groups. These values need to be updated at two locations, which leads to higher chance of human error. The ability to monitor all parameters in one singular location, would prove to be beneficial.

Most health care institutions have transitioned to electronic patient records. Software solutions interact with these records to automatically generate statistics, decision support, and many types of alerts. Monolithic software applications are often used for more general care, while specific software applies to specific types of care. There are benefits and drawbacks to both, but no literature was found which reported on integrating the specific applications with a monolithic system. In a perfect world, one singular system provides all the required functionality.

Another gap in health software literature, is the effect of customization. Each patient is different and a customized rehabilitation trajectory is preferred. Current health systems provide a general view for all patients, where relevant information is buried behind many different screens and menus. Should the software allow the clinicians to indicate what is of importance, this information can be reached much faster. In other words, a customized dashboard gathers all important data as indicated by the caregiver in a singular location. This dashboard can generate summaries, while details are one click away.

The issues mentioned in the last few paragraphs signify the need to quickly see relevant information at a glance. Not only for telemonitoring, but also for general care given in a hospital setting, this can be beneficial. Together with customization, care is delivered with greater efficiency. This thesis proposes a dashboard design that allows the caregiver to personalize its functionality according to the patient's needs in terms of treatment. It will mainly focus on chronic disease management for use in telemonitoring.

First, to get a thorough understanding of related subjects, a background information is given in section 2. The topics include electronic health record systems, chronic disease management, a literature review on telemonitoring, dashboard design, and health data privacy and standards. Based on this background information a dashboard design is proposed (section 3). This section highlights the design process and the made choices. Also, personas, scenarios and paper mockups give a first indication of how the system is used. Implementation of the dashboard started after the design process. In section 4 the used frameworks and changes compared to the low fidelity prototypes are described.

As soon as the implementation was finished, a usability test was conducted. Section 5 describes the test setup, the created documents, and information concerning the testers. The results of the test are discussed in the following section. Finally, the thesis concludes with a summary of its findings.

2 Background

A literature study has been conducted to situate the thesis topic. Multiple subjects lay at the base of the design described in section 3. First, the switch to, the components, and types of electronic health record systems are described. Next three key subjects are explained in the following order: chronic diseases, telemonitoring, and dashboard design. The last section mentions the issues surrounding medical data privacy and standards.

2.1 Electronic health record systems

Health information systems are becoming an important part of health care. They support patient care as well as administrative and financial tools. At the heart of these systems lies the electronic health record. An electronic health record (EHR) is a repository of electronically maintained information about an individual's health status and health care, stored such that it can serve multiple legitimate uses and users of the record [1]. An electronic health record system (EHRS) provides tools to manage and interact with these records. These tools include reminder generation, data analysis, and decision support. It helps the clinician to organize, interpret and react to medical data.

The first section describes the transition from paper-based records to digital and its implications for the medical world. A summary of the main components present in an EHRS is described in the next section. The functionality of an EHRS can be categorized into two types: a monolithic system tries to provide more general care, while smaller and more specialized systems cater to more specific types of care. The last section compares the two types and highlights the benefits and drawbacks of both.

No existing EHRS were reviewed. Access to these systems is limited to open-source solutions as most are purchased under a license. Consequently, reviews of these systems are difficult to find as institutions only purchase software after thorough review of its features. Only one article was found which compared three open-source health systems [2]. However, no literature was found for proprietary systems.

2.1.1 Moving away from paper

For modern medicine, the traditional paper-based medical records are not suited in today's world filled with technology. The drawbacks of information on paper are obvious when compared to digitally stored information.

Functionality Digital records allow systems to aggregate, process and create statistics of the data it contains. For example, a system can generate heart rate graphs with statistics, summarizing many values. If the user hovers over a data point in the graph, the exact value is shown. Printed tables and graphs showing the same data lack this interaction. Also, more effort is required from the clinicians, as data is scattered across multiple paper-records.

A paper-based medical dossier can store for example medical images, such as x-rays. Compared to a digital image, paper loses a lot of detail. As such, other multimedia types cannot be stored on paper, while a digital record can. An EHRS can provide tools to interact with all these types of file formats.

In terms of data input, an EHRS can detect and prevent false data input. The system can make sure all necessary data fields filled in and in the correct format. This results in more complete and accurate data gathering with fewer errors.

Information quality A summarizing paper noted that the use of EHRS leads to more complete, accurate, comprehensive, and reliable data compared to paper-based records [3]. As mentioned in the previous paragraph, a digital system can impose rules on data fields to avoid missing or entering the wrong data. In terms of comprehensibility, poor handwriting leads to wrong or loss of information, which digital systems avoid.

Accessibility Paper records are difficult to access because most of the time only one copy exists. Therefore, transferring these records to other branches or institutions is difficult: the record has to be found in the often large medical dossier, has to be copied and then manually sent. Also, misfiling, flooding or fires lead to irrecoverable loss of the data. Creating backups of the digital records avoids the last issue, but difficulties surrounding data transfer are still present. Most institutions have their own database structures which hinders the transfer of raw data. To remedy this, IT staff has to create an interface to read the data. Sending for example PDF-reports via email is a convenient alternative, although limited in functionality compared to paper records.

Moving data from paper to a digital format requires a lot of manual work. While automation is possible, such as scanning and processing the paper forms with software, verification is still necessary. All the data fields from the documents need to find a place in the EHR, which frequently is not possible. Extra diagnostic information scribbled all over the the document, will be lost for example. Also, what do we do with unreadable data due to poor handwriting? What happens with two forms which contain partly the same information? Do we save the information twice or do we add extra checks? Because of these reasons, adopting an EHRS is a significant undertaking for an institution. As such, the benefits are not immediately apparent.

Because digital storage increases accessibility significantly, security measurements have to be taken. If not, data can be stolen, deleted or even altered, which means a breach of privacy (see section 2.5.1. This also adds to the complexity of developing EHRS.

Efficiency An important task of an EHRS is to facilitate effective care. An early study saw a 6% increase in productivity when EHRS were deployed in health care institutions [4]. However, other factors are at play, such as the adoption rate. The transition from paper-based documenting to digital is accompanied by a learning curve, which can be steep. After the switch, the productivity will most likely be lower at the start. As the users become more experienced with the software, it will increase. Today most institutions have already made the transition to an EHRS, so this has become less of an issue.

2.1.2 Components of an EHRS

As mentioned before, EHRS do not simply store patient records. They consist of many components which ultimately defines how well they perform in health care. Literature defines many lists of components which should be essential. However, we list the following five components as key [1]:

Integrated view of patient data An EHR must allow storage of a wide range of data types. This can be text, numbers, images, video, and others. Some data can still be on paper due to lacking support of the EHRS, as mentioned in section 2.1.1. To display more complex data types, such as x-ray images, standards are used. A brief overview of medical standards is described in section 2.5.2.

Clinician order entry The point at which the clinician enters treatment instructions is called order entry. An order entry system assists the clinician during the decision-making process to ensure the instructions are correct. It also reduces errors and costs compared to paper order entry for the same reasons already mentioned in section 2.1.1.

Clinical decision support A decision support system embed into an EHRS aids the clinician by suggesting certain actions when certain situations occur. If for example, a patient is due for vaccination, the system notifies the clinician by presenting a constructed order which needs to be confirmed or denied. The system can do this for a bulk of patients, so manual checkups are not required, thus saving time.

Access to knowledge resources During the writing of notes or orders for a patient, clinical questions often arise. Instead of asking colleagues or searching through multiple manuals, the EHRS can search for relevant literature to address the question. Due to the internet, a very large source of information is readily available.

Integrated communication and reporting support Communication is an important part of health care. Often clinicians spread across multiple institutions provide care for the same patient. Communication, therefore, directly affects the effectiveness of patient care. Tools that easen and simplify this process are essential for a health system.

Most institutions are bound by their own EHRS. If data resides in another institution's health system, then access has to be requested. Health Information Exchange removes the need to manually ask for data access as institutions are able to reach beyond their own system. This, however, needs to be supported by the institution.

Throughout the years, many EHRS have been developed which may or may not integrate all of the above components. Should an essential component be missing, an institution may add another software system. This has its own benefits and drawbacks.

2.1.3 Monolithic vs. multiple EHRS

Health care institutions can opt for a monolithic EHRS or combine multiple EHRS to achieve all required functionality. There advantages and drawbacks to both [5]. Elements that influence this choice include IT infrastructure, safety risks, the volume of care and frequency with which patients move facilities. It is possible that a single EHRS does not satisfy the requirements of an institution. A reason for this is that certain branches require specially tailored software for their clinical practice, which the current EHRS in use lacks.

Functionality wise, a monolithic EHRS tends to appeal to more general types of care, whereas it lacks in very specific ones. Also, vendors that offer these all-in-one solutions have less experience with these special types of care which reduces the chance it will be added to the system. Vendors of specific EHRS do have this expertise and can tailor the system to the needs of the customer. In this case, combining a system that supports general care with special care systems seems like the best choice. However, other factors have to be considered.

The advantage of a monolithic system is that the data it uses is centralized. This ensures that all data is accessible anywhere throughout the system and is easier to maintain. When multiple systems are in place, data has to be exchanged between them. As a result, searching for data is more difficult. As mentioned in section 2.1.1, due to different data structures, data exchange is difficult. To solve this issue, an intermediate EHRS can be developed. This system serves solely for the purpose of data collection and transformation. All other systems search for data in this intermediate system. However, this leads to another system, requiring additional costs, development effort, and maintenance.

2.2 Chronic diseases

A chronic disease can be defined as a long-lasting human health condition. If the length of the condition is at least three months, the term chronic is used. The World Health Organization defines four major categories of chronic diseases: cardiovascular diseases, cancer, diabetes and chronic obstructive pulmonary disease [6]. Cardiovascular disease is the leading cause of death worldwide [7].

Combined with cancer, they accounted for 46% of all deaths in the United States in 2015 [8]. Also, 86% of all health care spending of 2014 was for patients with one or more chronic conditions [9].

We now briefly define each disease category. All diseases that involve the heart or blood vessels belong to the cardiovascular disease group. Typical examples of such diseases are stroke and coronary artery disease. Cancer has many different variants, but all of them share the same behavior. This is when some cells of the human body start to divide without stopping and that it spreads to surrounding tissues [10]. Diabetes is a disease group in which there are high blood sugar levels for a long period. There are three types of diabetes: type 1, type 2, and gestational diabetes. Lastly, chronic obstructive pulmonary disease (COPD) is a chronic lung disease that is characterized by persistent respiratory symptoms and airflow problems [11]. Examples of these symptoms are shortness of breath and coughing. The worsening of these symptoms for a period of time is called an acute exacerbation.

The following sections give more information on the prevention and management of these diseases.

2.2.1 Prevention

2.2.2 Management

2.3 Telemonitoring

Monitoring patients at a distance through the use of information technology is called telemonitoring [12]. Here, the patient uses special monitoring devices to gather data which in turn is sent to the health care provider. While many health conditions can be monitored, telemonitoring is most prevalent in chronic diseases discussed in the previous section. A study showed that not only the complications of chronic diseases and costs can be reduced by the use of telemonitoring, but also care can be provided without the use of hospital beds and the time spent managing the disease is lower [13].

To get a better understanding of telemonitoring, an overview of the its application to chronic disease management is given. Second, the difficulties surrounding telemonitoring are mentioned.

2.3.1 Chronic disease management

A lot of studies have been conducted to test the effect of telemonitoring on chronic disease management. For all but one of the four disease categories mentioned in section 2.2 general literature was found: the literature found on cancer focussed on very specific types of the disease and not in the general sense. Consequently, only the application of telemonitoring on the other categories will be discussed.

Cardiovascular diseases One study recruited 390 patients to test the effect of telemonitoring to reduce hospital days and total costs [14]. 193 individuals in the intervention group were to take daily measurements using special hardware. The hardware recorded the weight, blood pressure, heart rate and blood oxygen levels. Diabetes patients received an additional blood glucose meter. Patients were also required to fill in a predetermined set of questions every week. On the clinician's end, nurses were shown a summarizing table indicating if the sent results were good, bad or missing. Based on these results, the nurses decided to contact the patient if extra care was required.

The study concluded that telemonitoring appears to facilitate more efficient outpatient care and potentially reduce costs. The total numbers of hospital days for the patients in the intervention group showed a tendency to be lower and fewer emergency department visits. However, there were more urgent care and primary care visits.

Another research paper reviewed 30 studies and noted that most patients had a positive experience and little difficulty with telemonitoring technology [15]. In total there were more than 9500 patients in the studies. The summary concluded that there were fewer deaths, fewer hospital admissions and improved quality of life. There were also hints of reduced cost, but some studies did not report on this topic. None of the studies reported on the optimal duration of for telemonitoring.

The effect of telemonitoring treatment on cardiovascular patients is still unclear. A paper criticized the aforementioned one, stating that the conclusions made were only valid for small studies. For large trail studies, there was no significant effect [16].

Diabetes Due to the majority of research reporting on telemonitoring for diabetes type 2, type 1 will not be considered in the scope of this thesis. Due to it being a long-term disorder, combining the management of diabetes with telemonitoring is well documented in literature.

One study required 32 patients to take blood glucose measurements for nine months using a Bluetooth capable glucose meter. The meter sent the measurements to a mobile phone which in turn forwarded them to a hospital server. Based on the measurements clinicians would review them and send recommendations to the patient and their general practitioner. The results showed a decrease in HbA_{1C} from 8.40% to 7.76%. Due to the low amount of patients, the final conclusion said that the benefit of telemonitoring would likely be small [17].

Diabetes also has an effect on blood pressure, as approximately 50 to 80% of diabetes type 2 patients suffer from hypertension which can lead to cardiovascular disease. A target blood pressure for diabetes patients would be 130/80 [18]. One study kept this goal in mind and developed a home telemonitoring program [19]. It is labeled as 'home' due to the fact that a smartphone generates self-care messages for the patient, based on multiple previous readings. The results, however, would still be sent towards the clinician. Careful reviewing and responding to the patient would not be necessary, ultimately saving the clinician time. There were 55 patients in the telemonitoring group and as well in the control group. Both groups were required to measure their blood pressure using a device, but only the telemonitoring group had the device connected to a smartphone, generating the self-care messages. The results showed that the blood pressure only decreased significantly in the telemonitoring group. Also, the percentage that reached the 130/80 target blood pressure was 51% for the telemonitoring group and only 31% for the control group. Lastly, the self-caring nature of the program resulted in worsened depression compared to the control group.

Weight loss also influences blood sugar. The Active Body Control Program reported the effects of telemonitoring in combination with a dietary program [20]. The subjects were obese with diabetes type 2. They were a weighing scale, an accelerometer and a device which would gather the measurements and send them to the hospital server. After six months significant improvements in blood sugar and weight loss were observed. No relevant changes were observed in the control group.

Lastly, medication management is also linked to telemonitoring and diabetes. A study asked 64 patients (the telemonitoring group) to measure their blood glucose, blood pressure and weight on a daily basis [21]. A nurse would receive these measurements and adjust the medication intake five times a week. The control group consisted of 73 patients who took measurements of the same parameters, but they only received a phone call once a month to have their medication schedule adjusted. The results noted a significant decrease in $\mathrm{HbA_{1C}}$ for the telemonitoring group after three and six months, compared to the control group.

Chronic obstructive pulmonary disease A 2003 study investigated the feasibility of telemonitoring for patients with COPD [22]. In the first phase of the study 23 patients were observed for 12 months during their medical visits. For the second phase, patients were given a device which uses a finger clip to measure the oxygen saturation and heart rate. This device sends the data towards the caregivers. The caregivers analyzed the measurements and communicated comments on the symptoms and prescription changes to the patients. Results noted decreases in the numbers of hospital admissions (50%) and acute home exacerbations (55%). The hospitalization costs were 17% lower compared to the first phase and 96% of the patients were satisfied with the telemonitoring equipment.

Another study observed the quality of life of telemonitoring compared to usual care [23]. The control group received standard care for 52 weeks. The telemonitoring group received devices asking them questions about their symptoms twice a day. Also, the temperature and oxygen saturation were recorded by the device. If two of these measurements crossed a threshold, the respiratory nurses received an alert and called the patient. Between the two groups there were no significant differences seen in the quality of life, meaning that telemonitoring had no effect on this outcome.
Test

2.3.2 Difficulties

Many of the aforementioned studies described problems which they faced during their trail.

2.3.3 Summary

2.4 Dashboards

The primary goal of a dashboard is clear communication, which is achieved with an effective design. A formal definition is as follows: "A dashboard is a visual display of the most important information need to achieve one or more objectives; consolidated and arranged on a single screen so information can be monitored at a glance." [24]. This definition mentions four key characteristics:

Dashboards are visual displays. It is important that data is represented visually. Displaying charts and other graphics allows more efficient communication compared to textual information. For example, trends and outliers are easier to spot in a line chart compared to a table with the same values.

Dashboards display information needed to achieve specific objectives. The data that is shown, must be of use for the job that needs to be done. It is possible that the data needs to be gathered from multiple sources and tailored to the specific context so an efficient visualization can be created.

A dashboard fits on a single computer screen. In order to see all information at a glance, scrolling must be prevented. If multiple screens are present, then it is no longer a single dashboard. This leads to another question: what type of display is the information shown on? Due to the wide variety of screen sizes and aspect ratios, a responsive dashboard would be most beneficial.

Dashboards are used to monitor information at a glance. Important data should be immediately noticed, whereas very specific details should be hidden. This means data must be summarized or aggregated in order to be effectively shown. However, if the user wishes to view the detailed data, the dashboard should provide a way to do so.

To create an effective dashboard, the user-base must be known and well understood. What type of users are we dealing with? What are their characteristics? This is an important question to ask, as one user may not comprehend one visualization while another one can. This means that the focus should be put on the user [25].

2.5 Data privacy & standards

2.5.1 Privacy

2.5.2 Standards

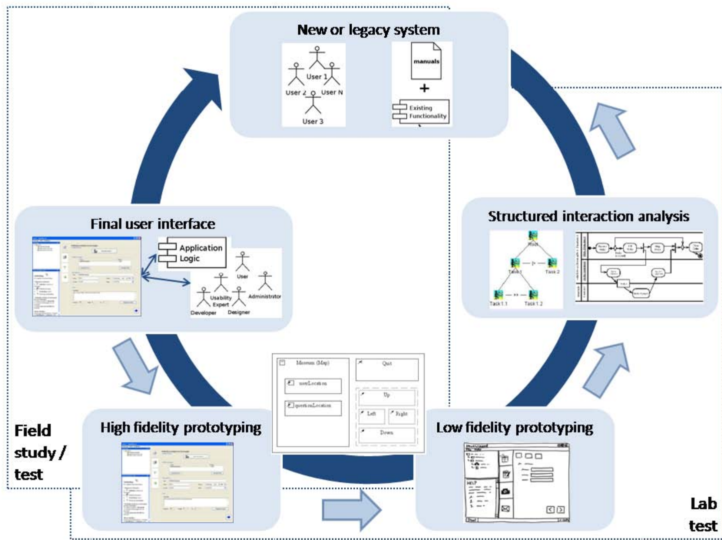

Figure 1: MuiCSer process

3 Design

After the literature study, a design for the dashboard solution was made. What follows is a short explanation of the design process that was used. Based on the topics mentioned in section 2, a proposal was made to tackle some of the highlighted problems.

3.1 MuiCSer

This section describes the MuiCSer framework, made for user-centered software engineering processes in a multidisciplinary context [26], which will be used to create the prototype. This framework focuses on optimizing the user experience during the entire software engineering cycle to ensure that the end-user's needs are fulfilled. By combining user-centered design and software engineering principles the user experience of the final product can be improved substantially of the final product.

3.1.1 Process

The MuiCSer process is summarized in figure 1. After each phase, the result is evaluated, verified and validated to ensure that the required functionality is present. The received feedback can, in turn, be used to reiterate over the previous phase. On the figure, this is denoted with the light arrows, while the dark one represents the overall process direction.

New or legacy system At the start of the process an existing system in need of improvement is either evaluated or a new one has to be designed. This requires an analysis of the tasks and needs of the user, as well as the objects and resources required to perform these tasks. Personas and scenarios are the resulting artifacts of this phase. First, personas describe the personalities of the potential end users including hobbies, skills and the environment they surround themselves in [27]. Its goal is to uncover behavior patterns which can be of use when designing a user interface. Second, a scenario is a story describing the use of a fictitious system from the persona's point of view [27]. It tries to sketch the usage of the system for which a design must be made.

Structured interaction analysis During this phase, the results of the analysis are used to create task models. These models specify concrete tasks and goals which can be dissected into specific actions or steps the user has to take. These artifacts lay the foundation for designing a user interface which supports these tasks and goals.

Low fidelity prototyping When the actions have been specified using the task models, low fidelity prototypes can be designed. Paper sketches and mock-ups are such examples and are ideal for visualizing the layout of the software its user interface. Without spending too much time and resources, presenting such prototypes can yield valuable feedback from the end-user or customer. However, there is no interaction present. Typically multiple versions of these prototypes will be created until the customer is satisfied after which high fidelity prototypes can be developed.

High fidelity prototyping Creating high fidelity prototypes requires a lot more effort compared to low fidelity prototypes, as they offer functionality closely resembling the final product. However, the feedback will be much more valuable as not only design, but also functionality is tested.

Final user interface When the latest iteration of the high fidelity prototype satisfies all user requirements, the final user interface can be created. It would be beneficial to reuse the code from the prototype in order to save time and resources. As a final step, the task models are checked against the interface to check if all required functionality is present.

3.2 Proposal

3.3 Personas & scenarios

Based on the proposal mentioned in the previous section, personas and scenarios have been created to get a better understanding of its users and how the system will work. Each of these tries to highlight the problems the users face and how the new system tries to solve them.

3.3.1 Jake

Persona Jake is a 25-year-old male who currently works as a nurse at the hospital in his city. He has been working for 4 years for the hospital and lives alone in his apartment. Still being a young adult, Jake grew up with technology. As such he experiences no difficulties when using new software on his computer or smartphone. His hobbies include music, playing the guitar and video gaming.

Currently, the workflow at the hospital is dated. A new health information system was introduced to summarize and gather all medical data in a singular space. Because this is a monolithic system, a lot of features that Jake does not need still clutter the screen. Navigating the system is a pain and customization is not present. Jake wishes to only see the features he uses most while hiding the features he does not need.

Scenario Jake starts his first day using the new system by reading the manual that is accompanied with it. He starts the application and for each patient he is presented with a few standard layouts to choose from, based on illnesses: cardiovascular diseases, respiratory diseases, diabetes and a few others.

After selecting a standard layout, Jake is given the opportunity to customize the dashboard. The dashboard contains all the wanted functionality of the system, where each “block” represents a module that can be added or deleted. Jake enters the edit mode enabling him to move the blocks around and arrange the order. He deletes a few modules and now he wants to add other modules. Jake opens the modules window where he is presented with all the available modules. A module is added to the dashboard when Jake selects it.

By examining the new module Jake quickly notices that on the dashboard a summary is given. But when Jake clicks on the module, the block expands to fill the whole screen where detailed information is given. Jake feels he is in control of the system and that it will improve his productivity.

This scenario highlights the benefits of customization. Hiding unwanted components, while adding the useful ones allow for a clear dashboard to be displayed. The user is in control and is able to quickly view data of importance. It is also possible to view detailed data.

3.3.2 Dan

Persona Dan is a general practitioner since he graduated from university. He is on the job for 21 years and he is the preferred doctor in his town. Throughout the years Dan has used a multitude of systems and he always tries new ones to improve his workflow. Because he has been a general practitioner for such a long time, he has 500 patients that visit him at least twice a year. Some patients, especially the elderly, visit as much as once a month.

Most of Dan’s patients visit for illnesses such as fever and a cold. To diagnose these illnesses no data is necessarily needed, just a description of what the patient feels will suffice most of the time. If Dan performs such a diagnosis, he promptly adds it to the information system and to the electronic health record of the patient.

However, if a patient visits that has a lot of problems regarding his blood pressure, then Dan has to perform a more complex diagnosis using historical data. In the current system that Dan uses, it is very difficult to search for this data. But what bugs Dan the most is that he has to do it every time this patient visits.

Scenario Because of Dan's ongoing curiosity, he tries a new health information system which allows customization for each specific patient. Because the diagnoses of most patients can be very different from time to time, Dan creates a default module group which is displayed for each patient, unless that patient has a specific module configuration. The default module group includes past diagnoses, known allergies, patient information (blood type, last weight, height...) and medication list.

The first patient of the day describes what sounds like a fever. Dan confirms this and prescribes the patient some medicine. The diagnosis is added to the 'past diagnoses' module and the prescribed medication to the 'medication list' module. Dan did not need other health data to perform the diagnosis. Therefore, Dan does not change the configuration of this patient.

The next patient, an elderly woman, came for her second visit of this month. Dan knows from the past that it will probably be a heart problem. Dan searches for other modules labeled as 'heart problems' and adds them to the configuration of the elderly woman. Now both the default module group and the heart rate modules are present, which is unnecessary according to Dan. He removes some modules of the default module group. Now, the next time the elderly woman visits, that configuration will be loaded.

One specific patient had broken his arm three times in less than a year. When the patient came for a routine visit, Dan immediately added a module to easily view x-ray photos and view them in a timeline.

Again, the benefits of system customization for each patient are obvious. Initially, it will take some time to configure each dashboard for all of the patients, but the system will try to provide default layouts useful for certain types of care. Once the configuration is done, the time spent during a consultation will decrease.

3.3.3 Emily

Persona Just like Dan, Emily has been a successful general practitioner for quite some time. However, she has different needs of an EHRS. Between each patient visit, there is a period of time in which Emily does not know what happens to patients regarding certain parameters. For example, if a person has to regularly measure his heart rate and blood pressure because of cardiac disease, it is imperative that the doctor is made aware of these values. If Emily sees that these values are not looking well, she can contact the patient to come in for a checkup.

If a patient has sleep issues, Emily wishes to not see detailed measurement values, but regular descriptions of the nights sleep. This includes the hours of sleep, amount of wake-ups, subjective feeling of tiredness. Currently, Emily has no way of regularly receiving this information without having the patient visit, because it needs to be documented at the practice.

Scenario Emily has recently received notice of a new platform that includes telemonitoring support. Several mobile applications are developed that can send data using an API to the platform, which in turn processes the values and can notify Emily of any anomalies. It includes customization for certain parameters in which Emily can individually assign thresholds for each patient.

A patient which has recently had a cardiac arrest is continuing rehabilitation at home. However, the patient has chest pains and pays Emily a visit. She tells the patient to regularly measure his blood pressure and heart rate and take note of these values in a mobile application. This application also allows taking general notes, such as feeling pain or having caught a cold. After they have scheduled the next visit, the patient is sent home.

As the next few weeks pass by, Emily is notified that this patient has crossed a threshold regarding his blood pressure. Immediately Emily checks the measured data and sees a graph of all measured values. This dataset delivers insight into the history of the patient and Emily sees that there is currently no need to panic. She decides to not take action and configures a weekly reminder to keep monitoring the blood pressure.

The next week, Emily receives a notification that the patient has made a note. It reads that he experienced chest pains. Again, Emily takes a look at the blood pressure data and sees a worsening trend leading to hypertension. Emily decides to call the patient to schedule an early visit. The system helped Emily to intervene as soon as the situation seemed to worsen while avoiding having the patient visit too early which in turn saves Emily time.

Another patient has sleep issues. Emily encourages the patient to use a sleep monitor, which is a wristband. This device is connected to a smartphone which communicates the quantitative data to the new platform. The application on the smartphone allows the patient to take note of qualitative data such as a general description of the night or what food he/she ate. One night the patient has slept only three hours and took note that he went out and drank a lot of alcohol. This could explain for example the bad sleeping rhythm for the next few days. Emily wishes to keep track of this patient on a weekly basis and configures the platform to notify her.

3.4 Modules

As mentioned in the proposal, the dashboard will feature a module-based design. This section will describe the modules that will be built in the prototype. For each module, the reasons behind the design choices are given, as well as a low-fidelity paper mockup. Keep in mind that all modules are primarily chosen to aid with chronic disease management.

3.5 Other components

4 Implementation

high fidelity

4.1 Overview

4.2 Backend

4.3 Frontend

5 Usability test

A usability test has been conducted to test the effectiveness of the high-fidelity prototype. The test involves users filling in questionnaires before and after using the prototype. The tester was required to follow a predefined list of steps while using the prototype. Only once the final step was completed, the test was finished.

The following section will first describe in detail the setup of the whole usability test, such as the followed process, the documents (questionnaires, list of steps), the testing environment and information concerning the testers. Thereafter, the results of the test are shared and analyzed.

5.1 Process

5.2 Result

6 Discussion

TODO

7 Conclusion

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A Appendix

A.1 RESTful API reference

A.2 Usability test documents

References

[1] Edward H Shortliffe and James J Cimino. *Biomedical informatics*. Springer, 2006.

[2] Beatriz Sainz de Abajo and Agustín Llamas Ballestero. Overview of the most important open source software: analysis of the benefits of openmrs, openemr, and vista. In *Telemedicine and E-Health Services, Policies, and Applications: Advancements and Developments*, pages 315–346. IGI Global, 2012.

[3] Kristiina Häyrinen, Kaija Saranto, and Pirkko Nykänen. Definition, structure, content, use and impacts of electronic health records: a review of the research literature. *International journal of medical informatics*, 77(5):291–304, 2008.

[4] Dwight C Evans, W Paul Nichol, and Jonathan B Perlin. Effect of the implementation of an enterprise-wide electronic health record on productivity in the veterans health administration. *Health Economics, Policy and Law*, 1(2):163–169, 2006.

[5] T Payne, J Fellner, C Dugowson, D Liebovitz, and G Fletcher. Use of more than one electronic medical record system within a single health care organization. *Applied clinical informatics*, 3(04):462–474, 2012.

[6] World Health Organization et al. Noncommunicable diseases: progress monitor 2017. 2017.

[7] Shanthi Mendis, Pekka Puska, Bo Norrving, et al. *Global atlas on cardiovascular disease prevention and control.* World Health Organization, 2011.

[8] National Center for Health Statistics (US et al. Health, united states, 2015: with special feature on racial and ethnic health disparities. 2016.

[9] Jessie Gerteis, David Izrael, Deborah Deitz, Lisa LeRoy, Richard Ricciardi, Therese Miller, and Jayasree Basu. Multiple chronic conditions chartbook. *Rockville, MD: Agency for Healthcare Research and Quality*, 2014.

[10] National Cancer Institute. What is cancer? 2018.

[11] Claus F Vogelmeier, Gerard J Criner, Fernando J Martinez, Antonio Anzueto, Peter J Barnes, Jean Bourbeau, Bartolome R Celli, Rongchang Chen, Marc Decramer, Leonardo M Fabbri, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease 2017 report. gold executive summary. *American journal of respiratory and critical care medicine*, 195(5):557–582, 2017.

[12] Guy Paré, Mirou Jaana, and Claude Sicotte. Systematic review of home telemonitoring for chronic diseases: the evidence base. *Journal of the American Medical Informatics Association*, 14(3):269–277, 2007.

[13] Stephane Meystre. The current state of telemonitoring: a comment on the literature. *Telemedicine Journal & e-Health*, 11(1):63–69, 2005.

[14] Christopher Tompkins and John Orwat. A randomized trial of telemonitoring heart failure patients. *Journal of Healthcare Management*, 55(5), 2010.

[15] Sally Inglis. Structured telephone support or telemonitoring programmes for patients with chronic heart failure. *Journal of Evidence-Based Medicine*, 3(4):228–228, 2010.

[16] Sarwat I Chaudhry, Jennifer A Mattera, Jeptha P Curtis, John A Spertus, Jeph Herrin, Zhenqiu Lin, Christopher O Phillips, Beth V Hodshon, Lawton S Cooper, and Harlan M Krumholz. Telemonitoring in patients with heart failure. *New England Journal of Medicine*, 363(24):2301–2309, 2010.

[17] Robert SH Istepanian, Karima Zitouni, Diane Harry, Niva Moutosammy, Ala Sungoor, Bee Tang, and Kenneth A Earle. Evaluation of a mobile phone telemonitoring system for glycaemic control in patients with diabetes. 2009.

[18] Lewis Landsberg and Mark Molitch. Diabetes and hypertension: pathogenesis, prevention and treatment. *Clinical and Experimental Hypertension*, 26(7-8):621–628, 2004.

[19] Alexander G Logan, M Jane Irvine, Warren J McIsaac, Andras Tisler, Peter G Rossos, Anthony Easty, Denice S Feig, and Joseph A Cafazzo. Effect of home blood pressure telemonitoring with self-care support on uncontrolled systolic hypertension in diabetics. *Hypertension*, pages HYPERTENSIONAHA–111, 2012.

[20] Claus Luley, Alexandra Blaik, Kirsten Reschke, Silke Klose, and Sabine Westphal. Weight loss in obese patients with type 2 diabetes: Effects of telemonitoring plus a diet combination–the active body control (abc) program. *Diabetes research and clinical practice*, 91(3):286–292, 2011.

[21] Roslyn A Stone, R Harsha Rao, Mary Ann Sevick, Chunrong Cheng, Linda J Hough, David S Macpherson, Carol M Franko, Rebecca A Anglin, D Scott Obrosky, and Frederick R DeRubertis. Active care management supported by home telemonitoring in veterans with type 2 diabetes:(the diatel randomized controlled trial). *Diabetes care*, 2009.

[22] Carmela Maiolo, Ehab I Mohamed, Cesare M Fiorani, and Antonino De Lorenzo. Home telemonitoring for patients with severe respiratory illness: the italian experience. *Journal of Telemedicine and Telecare*, 9(2):67–71, 2003.

[23] Keir E Lewis, Joseph A Annandale, Daniel L Warm, Claire Hurlin, Michael J Lewis, and Leo Lewis. Home telemonitoring and quality of life in stable, optimised chronic obstructive pulmonary disease. *Journal of telemedicine and telecare*, 16(5):253–259, 2010.

[24] Stephen Few. Information dashboard design. 2006.

[25] Richard Brath and Michael Peters. Dashboard design: Why design is important. *DM Direct*, pages 1011285–1, 2004.

[26] Mieke Haesen, Karin Coninx, Jan Van den Bergh, and Kris Luyten. Muicser: A process framework for multi-disciplinary user-centred software engineering processes. In *Engineering Interactive Systems*, pages 150–165. Springer, 2008.

[27] Sabine Madsen and Lene Nielsen. Exploring persona-scenarios-using storytelling to create design ideas. In *Human work interaction design: Usability in social, cultural and organizational contexts*, pages 57–66. Springer, 2010.