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Developing a medical software to enhance patient participation

Master's thesis at Ulm University

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Abstract

Mental health disorder is a frequent issue among cancer patients. It is estimated that in about 30% of cancer patients, psychological issues are undetected. Psychooncology is a subdomain of psychology, which studies cancer related psychological issues and, hence, develop appropriate treatments. With the help of screening instruments like the *Distress Thermometer*, patients are rated according to their mental state. The result of the screening indicates, whether a patient needs psychological treatment or not. However, in most medical facilities this screening is processed using paper-based questionnaires, which complicates the treatment. This thesis aims for enhancing the screening process as well as the overall psychological treatment with a newly developed mobile application *Feelback*.

The mentioned application uses patient participation principles by applying the latter. Patients shall feel more involved in the psychological treatment process. This results in patients that take a more active role in making decisions related to their treatment. Moreover, sophisticated gamification concepts guarantee long-term motivated users. From the medical facility's point of view, screened patients are evaluated in an automated manner, which, in term, saves time and money. In addition, *Feelback* makes it easier to document psychological treatments. At the current state of development, further steps should focus on user acceptance testing, in order to verify, whether the mentioned concepts work as intended.

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1

Introduction

Patients suffering from cancer often also suffer from mental distress and other psychological issues. In many cases, this is often not properly detected [1] [2] [3]. In most medical facilities, the process for screening mental distress is often performed in a paper-based fashion, which involves several drawbacks for patients and practitioners. From patients' point of view, this means, that they cannot immediately see the results nor the answers of screenings. Because of this, patients get their screening result at a much later point in time, which makes the process for both, patient and practitioners, time-consuming. Furthermore, filling out paper-based questionnaires is often error-prone and time consuming and is perceived as inconvenient [4]. From practitioners' point of view, the evaluation of screenings is a resource consuming process, as there are technical hurdles. In terms of archiving health data, there are certain law regulations e.g. the legal retention period. The legal text §630f *Bürgerliches Gesetzbuch [German Civil Code]* requires that, for certain health data, a retention period of 10 years must be complied¹. Archiving those paper-based health data takes up large space and is costly. Only with high expense, for the medical facility it is possible to view and analyze these archived data. Furthermore, the medical facility as a whole is hardly able to make assertions about cancer patients which are treated from psychological issues. To put in detail: Medical facilities try to guarantee, that they screen patients with a subsequent psychological treatment by a rate of 100%. With the use of paper-based screenings, these intentions are difficult to prove by externals.

From a more technical point of view, paper-based questionnaires can only be evaluated with high expense, in order to treat patients according to the results of the screening. In

¹https://www.gesetze-im-internet.de/bgb/___630f.html last accessed: 2020-03-03

1 Introduction

most medical facilities, the filled out questionnaire is scanned so it can be processed by the HIS. Additionally, practitioners manually add metadata to the questionnaire so it can be evaluated by different parties. With this approach, more problems arise when other medical facilities want to access this data, because of the inconsistent way in handling data. Furthermore, making statistical statements (e.g. how many patients have been treated psychologically) is difficult, because there is no metadata from paper-based documents. Also, the communication with the Hospital Information System (HIS) and the paper-based screenings is impaired. This may be crucial when the treatment process involves more than one party, since such processes require more consultation and hence data exchange which is requested from the HIS.

With the easy access to smartphones, it is with a low amount of resources possible to perform such screening processes in a digital manner. Patients fill out the *Distress Thermometer* on their own smartphones or use a provided one from the medical facility and can subsequently see their screening result on the device. The filled out questionnaire can be analyzed with a clear and easy to use polar chart. Line charts show how often patients fill out questionnaires, since this mobile application can also be used as a way of tracking the psychological course. But not only patients profit from this. From the medical facility's point of view, such digital process with smartphones and the corresponding infrastructure within the HIS leads to better internal communication. On the one hand, the infrastructure which consists of the HIS and the presented *Feelback* system can communicate in an automated manner and on the other hand, practitioners who want to operate with the system can easier access the data. Also, with this new process, the medical facility is capable of documenting the treatment of patients in a digital manner. This means that the previously mentioned law regulations can be met with lower costs which saves space, time and money. Furthermore, patients feel more involved in the psychological treatment process, because they see their screenings and can evaluate themselves at any time, which enhances the treatment. In addition, with this newly developed application *Feelback*, patients are motivated in using the application in the long run, because various gamification concepts are utilized. The concept of levels and a reward system are part of it.

1.1 Structure

The further structure of this thesis is as follows. Chapter 2 describes basic concepts like patient participation, eHealth, gamification and the field of psychooncology are explained, in order to provide profound background. In Chapter 3, the current As-Is and the future To-Be process of the overall system is illustrated. Furthermore, this chapter also contains the most important user stories of *Feelback*, which means that the most common actions of users are listed. The overall technical architecture as well as sequence diagrams describe the system in a more technical manner. Finally, mockups which are made in *Figma* are presented with screenshots. Chapter 4 explains the use of gamification frameworks as well as the gamification concepts within *Feelback*. In Chapter 5, important implementation aspects are discussed in details. These include, for example, native plugins or routing structure. Also, the concept of reactive forms in *Angular* are presented. Finally, the mobile application is presented via screenshots. Chapter 6 discusses related work in the context of this thesis. In Chapter 7, limitations of the presented thesis are stated, while Chapter 8 summarizes the thesis and discusses further work.

2

Fundamentals

In this chapter important terms like patient participation as well as other terms are defined in order to provide a profound background. Furthermore, basic concepts of related topics in patient participation are described. Finally, there are several terms like *patient* or *participant* used in a specific manner. In order to provide clarification, these terms are also defined.

2.1 Patient Participation

The term patient participation is widely used, however there exists no unique definition in literature [5]. Also, there are several synonyms for it like *patient empowerment*, *patient engagement*, *patient and public involvement* or *patient involvement*. In the medical context, these terms are used interchangeable. This thesis uses the term patient participation, because it is most commonly used.

Speaking of patient participation, the European Patients' Forum (EPF) provides a widespread definition in [6]. It is described as a process of helping people get control of their situation or issue by increasing their knowledge. This newly gathered knowledge helps the patient taking a more active role in meaningful decision making. The EPF states that this kind of knowledge is experiential knowledge that comes from a frequent contact with the healthcare system. Depending on how much experience the patient has, he/she can influence the medical treatment.

In Figure 2.1 a patient with little experience starts from complaining and goes through giving information, listening and responding, consulting and advising to full participation.

2 Fundamentals

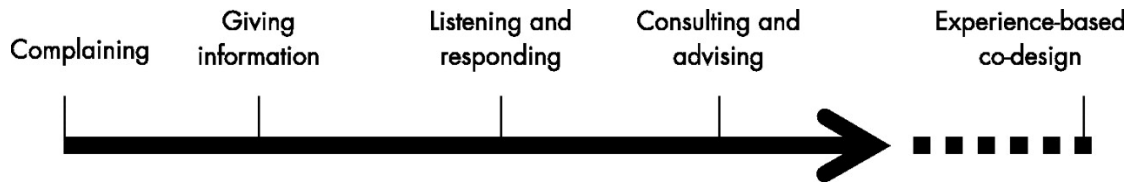


Figure 2.1: Continuum of Patient Influence [7]

Experience-based co-design is a design process of accessing the users experience to improve patient participation and so the medical treatment [7].

2.2 eHealth

The described concept of patient participation can be enhanced in different ways. In a simple scenario where a physician treats a patient, the physician could inform the patient about his/her disease and the related treatment in an understandable way. This scenario is normally applied in most clinics. It improves patient participation, because the patient is in a better situation when deciding about his/her treatment if the decision process is distributed. In a distributed decision process, the practitioner as well as the patient can decide which treatment is the best suitable for both sides [6].

In a more technical scenario, electronic devices like smartphones, tablets or computers can also improve patient participation. For example, the patient increases his/her knowledge due to the usage of an electronic application or searching related databases. The utilization of such devices in the field of medicine is called *electronic health* or short *eHealth*.

Eysenbach defines eHealth as a way to improve healthcare by providing information with the usage of the Internet and other related technologies. He also states that the term is used in the interdisciplinary fields of medical informatics, public health and business [8].

2.3 Gamification

Gamification is an important concept in the context of eHealth to improve patient participation. One purpose of applying such techniques is long-term motivation of users of an electronic application.

Deterding, Khaled, Nacke and Dixon established a widespread definition that is most commonly accepted. According to Deterding et al. (2011), "Gamification is the use of game design elements in non-game contexts." (p. 12-15). Moreover, the authors distinguish between *serious games* and *gamification*. A serious game is a complete game that has a different purpose than entertaining. Deterding et al. state that this purpose is perceived subjective, because the purpose of a game can be for each individual a different one [9]. From a game designer's perspective, e.g. a puzzle game could be designed for enjoying the creativity, whereas a certain player could perceive the game objective as training for memorization.

Gamification not only helps motivating the users. Depending on how the gamification aspects are designed, one can achieve different purposes. When, for example an application designer wants to achieve that a questionnaire is filled out on a regular basis, then the gamification aspect of the application should reward the players when they do so. With this in mind, every use case can be represented in gamification aspects.

Gamification concepts have various domains in eHealth. Sardi, Idri and Fernandez-Aleman made a systematic review where they reviewed the domain of gamification in eHealth by investigating 46 papers. Most often, gamification is applied in treating chronic diseases like cancer, Alzheimer's disease, stroke, obesity and diabetes. The second most often domain is physical activity. Next, mental health and hygiene are the least common domains for gamification [10].

Also, the authors of [10] investigated the advantage of gamification in eHealth. Most papers state, that gamification sustains users' engagement with the application. Also, gamification fosters a positive emotional state and self-esteem. In 14 papers, users feel motivated in changing health behaviors. Making the application more entertaining and easy to use led in most papers to a better user experience, especially for children

and the elderly. 20 of the examined papers state, that gamification enhances intrinsic and extrinsic motivation. Lastly, physical activities are perceived as less exhausting and social game mechanics were perceived to be appealing [10].

2.4 Psychooncology

The application of concepts like patient participation, eHealth or gamification are manifold. One scenario, which is also the running example of this work, is in the field of psychooncology.

Psychooncology, as the name indicates, is a subdomain of oncology. Oncology is the discipline of treating cancer. Speaking of psychooncology, it came up in the 1970's. In 1975, a working group called *The Psychosocial Collaborative Oncology Group* found out, that 47% of investigated cancer patients suffer from psychological illnesses like depression, anxiety, and delirium. Most often it was adjustment disorder [11].

In the 21st century, research took several steps forward and so psychooncology was established in different fields: research to lower the cancer risk, research for early detection of cancer, treating sequelae of cancer, controlling psychological symptoms like anxiety, depression or pain in a cancer treatment and handle palliative or end-of-life care [11].

A key component for quantifying psychological symptoms are *screening instruments*. This is a special kind of questionnaire, which is used to screen a patient by questioning him/her [12]. There are different instruments for screening a patient like *Distress Thermometer* [13], *Hospital Anxiety And Depression Scale* [14], *Hornheider Screening Instrument* [15], *Fragebogen Zur Belastung Von Krebskranken* [16], *Psychoonkologische Basisdokumentation* [17] and numerous others [18].

The first of the listed questionnaire is used in this work.

2.4.1 Distress Thermometer

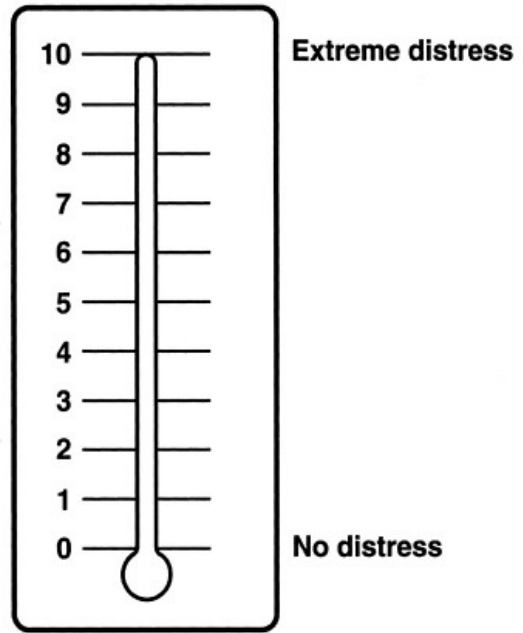
Figure 2.2 depicts the *Distress Thermometer*. The questionnaire comprises two parts. The upper part is a 11-point range *Distress Thermometer* scale, whereas the lower part comprises a problem list of 34 questions. The National Comprehensive Cancer Network states, that a score of five and higher of the thermometer indicate a distressed cancer patient. According to the National Comprehensive Cancer Network, the problem list says, which service should be applied to the patient. Practical and psychosocial problems should be tackled by social workers, emotional and psychological by mental health services and spiritual problems by pastoral counselors [13].

Several studies validated the cutoff score of *Distress Thermometer* like [19]. Jacobsen et al. found out, that a cutoff score of four is the optimal trade off between sensitivity and specificity, in order to screen a patient. For this, Jacobsen et al. investigated 380 patients in five different medical facilities. This finding is in line with the National Comprehensive Cancer Network [19].

The methodology of screening patients with a screening instrument, in order to decide if a patient is mentally distressed leads in some studies to controversy like in [20]. The question, whether an untreated psychological disease can be found with screening instruments in an oncological setting [20].

2 Fundamentals

FIRST: Please circle the number (0-10) that best describes how much distress you have been experiencing in the past week including today.



SECOND: Please indicate if any of the following has been a problem for you in the past week including today. Be sure to fill in YES or NO for each.

| YES | NO | <u>Practical Problems</u> | YES | NO | <u>Physical Problems</u> |
|-----------------------|-----------------------|-------------------------------------|-----------------------|-----------------------|--------------------------|
| <input type="radio"/> | <input type="radio"/> | Child care | <input type="radio"/> | <input type="radio"/> | Appearance |
| <input type="radio"/> | <input type="radio"/> | Housing | <input type="radio"/> | <input type="radio"/> | Bathing/dressing |
| <input type="radio"/> | <input type="radio"/> | Insurance | <input type="radio"/> | <input type="radio"/> | Breathing |
| <input type="radio"/> | <input type="radio"/> | Transportation | <input type="radio"/> | <input type="radio"/> | Changes in urination |
| <input type="radio"/> | <input type="radio"/> | Work/school | <input type="radio"/> | <input type="radio"/> | Constipation |
| | | | <input type="radio"/> | <input type="radio"/> | Diarrhea |
| | | | <input type="radio"/> | <input type="radio"/> | Eating |
| | | | <input type="radio"/> | <input type="radio"/> | Fatigue |
| <input type="radio"/> | <input type="radio"/> | <u>Family Problems</u> | <input type="radio"/> | <input type="radio"/> | Feeling swollen |
| <input type="radio"/> | <input type="radio"/> | Dealing with children | <input type="radio"/> | <input type="radio"/> | Fevers |
| <input type="radio"/> | <input type="radio"/> | Dealing with partner | <input type="radio"/> | <input type="radio"/> | Getting around |
| | | | <input type="radio"/> | <input type="radio"/> | Indigestion |
| | | | <input type="radio"/> | <input type="radio"/> | Mouth sores |
| | | | <input type="radio"/> | <input type="radio"/> | Nausea |
| <input type="radio"/> | <input type="radio"/> | <u>Emotional Problems</u> | <input type="radio"/> | <input type="radio"/> | Nose dry/congested |
| <input type="radio"/> | <input type="radio"/> | Depression | <input type="radio"/> | <input type="radio"/> | Pain |
| <input type="radio"/> | <input type="radio"/> | Fears | <input type="radio"/> | <input type="radio"/> | Sexual |
| <input type="radio"/> | <input type="radio"/> | Nervousness | <input type="radio"/> | <input type="radio"/> | Skin dry/itchy |
| <input type="radio"/> | <input type="radio"/> | Sadness | <input type="radio"/> | <input type="radio"/> | Sleep |
| <input type="radio"/> | <input type="radio"/> | Worry | <input type="radio"/> | <input type="radio"/> | Tingling in hands/feet |
| | | | | | |
| | | | | | |
| <input type="radio"/> | <input type="radio"/> | <u>Spiritual/Religious Concerns</u> | | | |
| <input type="radio"/> | <input type="radio"/> | Loss of faith | | | |
| <input type="radio"/> | <input type="radio"/> | Relating to God | | | |

Other Problems: _____

Figure 2.2: Distress Thermometer [13]

2.5 Basic Terms in Context of Feedback

In the following Table 2.1, all relevant terms in the context of this work are described. This ensures clarity in using the corresponding terms.

| Term | Description |
|---------------|---|
| Patient | A patient is a participant in the <i>Feelback</i> study, whereas not only a patient in the strict sense is meant. Also, relatives or acquaintances of the patient can participate in the <i>Feelback</i> study. |
| Practitioner | A Practitioner is a member of the clinical staff, where member can be the practicing physician or the creator of the medical study. |
| User | A User is the person who interacts with the application. This could either be a patient or a practitioner. |
| Screening | A method for detecting psychological conspicuousness, utilizing self assessment questionnaires. |
| Questionnaire | In the psychooncological context, a questionnaire (or survey) is a screening instrument, which is used to quantify psychological symptoms. |
| Application | An electronic application (or short <i>app</i>) is software that runs on electronic devices like smartphones, tables or computers, in order to meet a certain purpose. |
| Feelback | The name of the project, which has its application in the field of psychooncology. Screening instruments are utilized in order to quantify psychological symptoms. |

Table 2.1: Basic Terms

3

Concept

In the following section, an application scenario is provided. It explains the technical system and the integration into a clinical environment. Furthermore, user stories explain, what a user shall accomplish by using the newly developed application. Afterwards, the overall system architecture is depicted, described and essential user stories of the overall system are visualized in sequence diagrams. Lastly, mockups show how the application could look like.

3.1 Application Scenario

In this section, clinical as well as technical aspects of an overall application are investigated. Furthermore, special focus is put on the integration of the technical part into the clinic's everyday life. For this purpose, the As-Is as well as the To-Be processes are investigated. Finally, the advantages of the new process is presented.

3.1.1 As-Is Process

Figure 3.1 depicts the current process in medical facilities. Starting at number (1), the patient is at his/her cancer treatment in a clinic, hospital or other medical facilities. Because cancer disease and its treatment often lead to psychological and mental issues (cf. Chapter 2.4) at number (2) medical staff hands out various screening instruments like the *Distress Thermometer*.

Screening a patient helps to identify if the person suffers from a psychological illness. The *Distress Thermometer* is heterogeneous in this As-Is process, which means, that

3 Concept

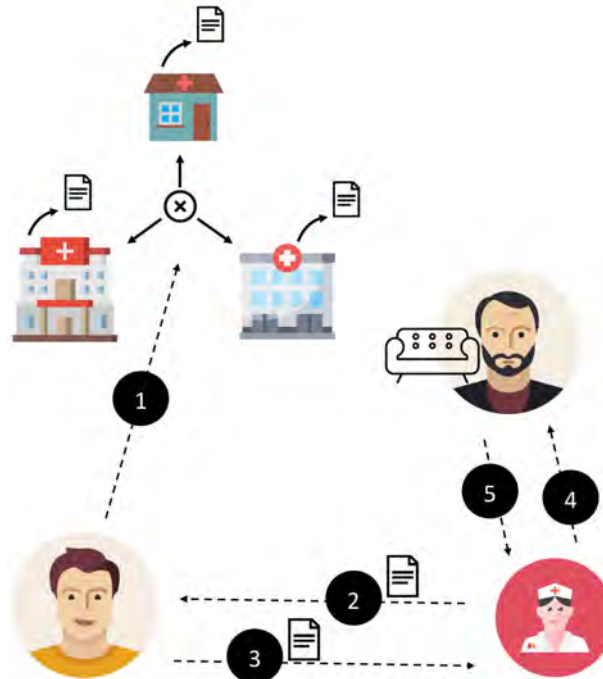


Figure 3.1: As-Is Application Scenario

a medical facility can adapt the screening instrument if required. For example, some clinics use a modified questionnaire containing an extra checkbox to find out, whether the patient explicitly requests a psychological treatment whereas other clinics adapt the screening instrument otherwise. For instance, the field for religious concerns is sometimes combined into a single question. This makes comparing screenings and their results from different medical facilities impossible. Furthermore, the screening instrument is paper-based, which implies several other disadvantages in regards to automated evaluation and accessibility for other parties.

When the patient fills out the questionnaire (3), the document is scanned and saved in the Hospital Information System (HIS) of the medical facility. Because the document is now just a digital picture, additional information for automated evaluation is required. This is often manually handled by medical staff. In terms of evaluation, this process is also heterogeneous, which means that *clinic A*, for example, can rate a patient to be physically distressed when the distress value is greater than five, whereas *clinic B* can

classify a patient to be physically distressed, if a patient checks more than six optional stress factors.

If the result of evaluation is positive (indicating that the patient is probably distressed), the psychologist gets notified (4). In case the psychologist is located in the same medical facility and uses the same HIS, he/she receives the scanned screening. This may also be a manual process. In case the psychologist is located in another medical facility, he/she must manually consult the other facility, in order to receive the required screening. The same problem arises, when the psychologist finishes the treatment. The generated reports of the psychological treatment are important for the patient's record, but only with high expense, these reports (5) appear in the patient's record.

Finally, communication between different facilities is also problematic. For this, there are several use cases, for instance, when a patient receives a treatment in *clinic A* and thereafter one in *clinic B*. *Clinic B* needs for this the patient record including psychological screenings. For this use case, the exchange of data is with a high probability just manually possible. The situation becomes worse when for example *clinic A* archives their screenings only in conventional folders.

3.1.2 To-Be Process

The process is described in Figure 3.2 (1), namely when the patient is treated at the medical facility. There, the patient is asked if he/she wants to participate in the study *Feelback*, in order to do a digital *Distress Thermometer* screening.

If the patient agrees, the practitioner hands over a card as indicated at number (2). The card has a Quick Response (QR) Code printed on it for authenticating the patient. Also, the medical staff notes on an e.g. sheet of paper, which patient received which card. More information on this approach is provided in Figure 3.4.

At number (3) of Figure 3.2 there are two possible branches. The first branch, indicated with an orange color, uses the smartphone of the study for filling out the *Distress Thermometer* questionnaire.

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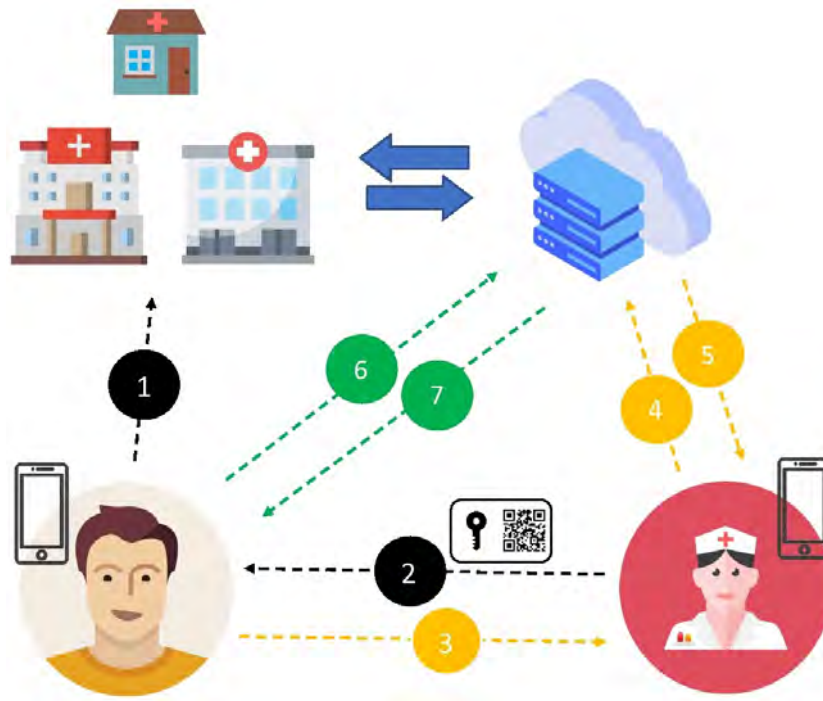


Figure 3.2: To-Be Application Scenario

At number (4) the practitioner scans the QR Code of the patient, so the practitioner is allowed to collect his/her data. In the following situation, the practitioner interviews the patient, guided by the questionnaire. The orange path is chosen, if, for example, the patient feels uncomfortable in using smartphones or if he/she is incapable of properly using such devices.

The second branch, indicated with a green color, uses the smartphone of the patient. At number (6) to (7) the patient scans his/her QR Code in order to authenticate himself/herself to the system. Now the patient fills out a questionnaire on his/her own. This branch is typically chosen, if the patient has an affinity for technology and owns a smartphone. An advantage of it is, that the practitioner could proceed to his/her work. Also, the smartphones of the clinic are not blocked for other patients.

Comparing the As-Is process with the To-Be process with respect to the automated processing and evaluation of the *Distress Thermometer*, it can be seen that this process can be fully automated. The required data exchange is possible, because in medical

facilities psychologists and physicians can communicate with a consistent and persistent data storage in a server. Furthermore, rules for evaluation can now be managed in a single location, which increases consistency. Also, clinic-to-clinic communication is easier to achieve, because each participant of *Feedback* can communicate with other participants with a central server infrastructure.

In this To-Be process, it is also important that the questionnaires are filled out on a regular basis. Note that a simple notification, which serves as a reminder, is not enough, because this concept does not motivate users. Here, gamification concepts may help to motivate users filling out questionnaires on a regular basis (e.g. weekly). Furthermore, these concepts help to achieve different purposes, like collecting meaningful data (data that has a significance in psychooncology).

3.2 User Stories

This section lists important user stories of the *Feedback* project. In agile software development, user stories are general software requirements expressed in everyday language. Use-cases are also a way expressing these requirements, but they are more detailed [21].

User Stories as a practitioner:

1. As a practitioner I want to follow an invitation, so I can use the *Feedback* system.
2. As a practitioner I want to login with my email address and password in order to use the functionality of the system.
3. As a practitioner I might forget my password.
4. As a practitioner I want to personalize my application by choosing a color theme.
5. As a practitioner I want to change my personal data: name, email address, profile picture and password.
6. As a practitioner I want to have an overview of patients I'm currently treating.
7. As a practitioner I want to select a patient, in order to see his/her screening data.

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8. As a practitioner I want to see a single screening of a patient.
9. As a practitioner I want to be able to alter a screening's date, in order to correct the date.
10. As a practitioner I want to start a new screening for a patient.
11. As a practitioner I want to add new patients I'm currently treating.
12. As a practitioner I want to request a screening which was not previously assigned to me.

User Stories as a system administrator:

1. As an admin I want to create n (e.g. n = 1000) users. For each user a card with a printed QR Code on it shall be generated.
2. As an admin I want to invite practitioners to the system.
3. As an admin I do not want to save medical data, in order to comply to the data protection regulations.
4. As an admin I want to save only a pseudonym for the patient, so I do not share any personal data.
5. As an admin I want to separately manage the login database from the regular database, in order to comply to the data protection regulations.

User Stories of a patient

1. As a patient I want to get access to the system with either a QR Code on a card or manually via pseudonym and password.
2. As a patient I might forget my password.
3. As a patient I want to change my password.
4. As a patient I want to accept or reject requests for my screening data.
5. As a patient I want to assign a new practitioner to my account.

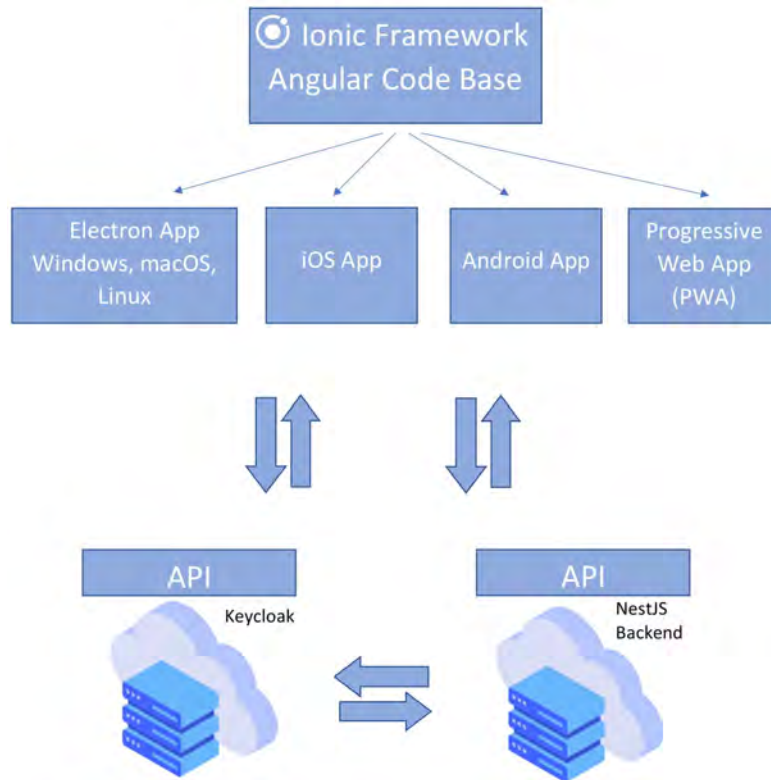


Figure 3.3: Technical Architecture

3.3 Architecture

From a more technical point of view, Figure 3.3 depicts the architecture of the new process. Starting from bottom-up, there are two main services. First, Keycloak¹ is an identity provider as well as an access management tool. An identity provider authenticates users to access the overall system. Other parties of the architecture can consult Keycloak via the Application Programming Interface (API) whether the user is the user that he/she pretends to be. Keycloak also handles access management, which means, that Keycloak checks, whether a specific user is allowed to call a specific action.

Second, on the bottom right there is a NestJS² service, handling requests for the general database via its own API. In NestJS, one can write typescript code for running all kinds

¹<https://www.keycloak.org/> last accessed: 2020-01-22

²<https://nestjs.com/> last accessed: 2020-01-22

3 Concept

of server software. In this architecture, the NestJS service also communicates with the Keycloak service, in order to authenticate users backend-wise.

Next, the software that runs on a user's device is presented. For this, a framework called *Ionic*³ was used. Ionic is a platform independent framework, build with Stencil.js⁴ web components. A web component is encapsulated web code that is compiled to reusable components. This generic approach of Ionic has several advantages. For example, programmers can choose, whether they want to use Angular⁵, React⁶ or Vue⁷ as code base. An additional step is required to run the web code on a device. If iOS or Android is the desired platform, Apache Cordova⁸ or capacitor⁹ is required, in order to generate native code, but this process is automated. Also, Electron Apps¹⁰ for Windows, macOS and Linux as well as Progressive Web App (PWA) are supported.

3.3.1 Sequence Diagrams

In this section, the most important user stories of the system as a whole, are presented.

Figure 3.4 shows the registration process of *Feelback*. A patient is at the medical facility for his/her cancer treatment. There, the patient is asked if he/she wants to proceed with a digital psychooncological screening. For this, patients need a card with an QR Code on it, so the patients can login. These cards are usually prepared prior to the registration, so there is a specific contingent cards for patients that are participating in this process. When the patient has his/her card, he/she can log in by scanning the QR Code. Now the patient is able to perform a psychooncological screening.

Figure 3.5 depicts the evaluation process. A patient performs a screening using the mobile app on their own. After that, the data is transferred back to the *Feelback* backend, where it is saved in the database. When later in the process a practitioner wants to know,

³<https://ionicframework.com/> last accessed: 2020-01-22

⁴<https://stenciljs.com/> last accessed: 2020-01-22

⁵<https://angular.io/> last accessed: 2020-01-22

⁶<https://reactjs.org/> last accessed: 2020-01-22

⁷<https://vuejs.org/> last accessed: 2020-01-22

⁸<https://cordova.apache.org/> last accessed: 2020-01-22

⁹<https://capacitor.ionicframework.com/> last accessed: 2020-01-22

¹⁰<https://www.electronjs.org/> last accessed: 2020-01-22

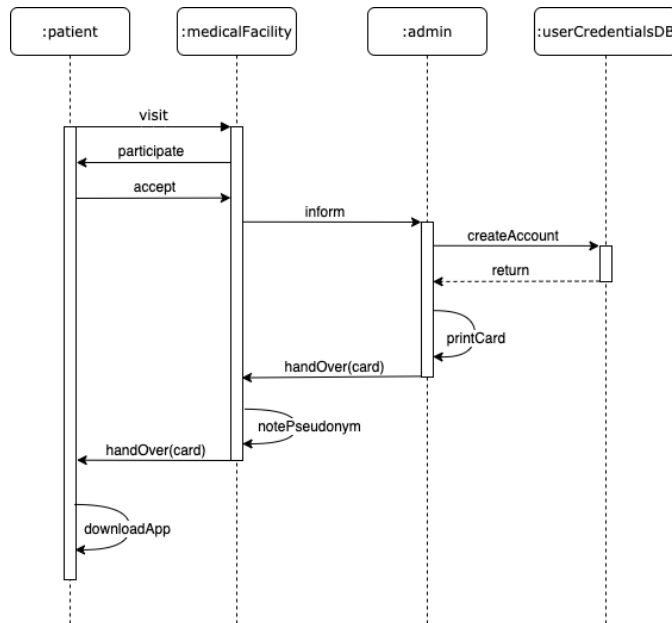


Figure 3.4: Registration for Feedback

whether a patient has symptoms for distress, he/she can request the patient's data. The patient is notified, asking him/her to accept or reject the request. If the patient accepts the request, the practitioner receives the data and can evaluate it in an automatic way. Furthermore, the evaluation process is standardized, because the rules for evaluation are defined in the backend. This guarantees the same evaluation results for all parties. In case of a positive outcome, indicating that the patient shows symptoms for a distress, he/she is transferred to a psychological for a consultation.

As one can see, Figure 3.6 builds upon Figure 3.5. It depicts how different parties (like practitioner and psychologist) can access a patient's screenings. It is also important to note, that the parties are not necessary located in the same medical facility for accessing data. Especially in scenarios, where patients visit different facilities like hospitals, general practitioners or cancer counselling services, this approach offers huge benefits.

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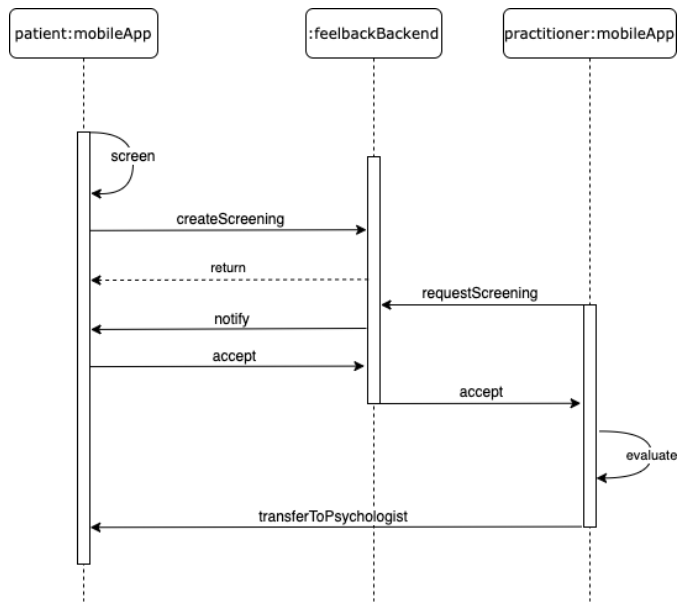


Figure 3.5: Evaluation of a Screening

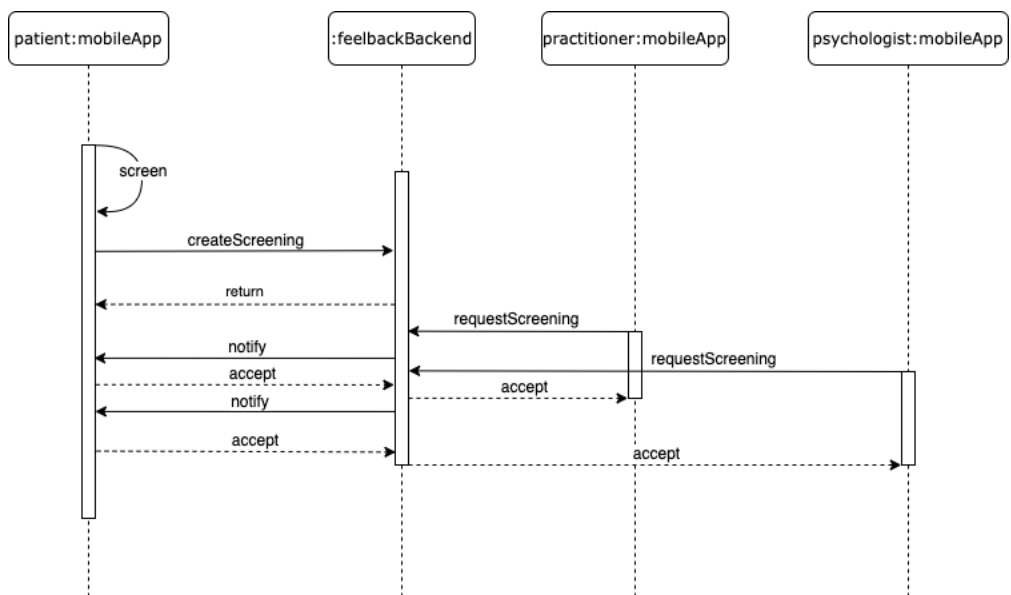


Figure 3.6: Different Parties Request Screenings

3.4 Mockups

The following mockups demonstrate how the application might look like. The software which was used to create the mockups is called *Figma*¹¹. For this thesis it was chosen, because in Figma it is possible to design not only mockups, but also prototypes.

On the upper left side of Figure 3.7 the welcome screen of the application can be seen. From here it is possible to login with either the QR Code card or manually with pseudonym and password. The upper right side shows the screen, when a user wants to log in via card and so with the QR Code. The screen on the lower left side shows how the manual login with pseudonym and password could look like. When a user clicks on *Forgot password?*, he/she gets redirected to the lower right side of Figure 3.7 where he/she can request a new password.

Figure 3.8 shows the mockup for the screenings of a patient. As soon as the patient logs in, this screen is shown. On top of the screen there is a tab bar showing the most important functions for a patient, namely *My Screenings*, *Permissions* and *Profile*. For each screening there is a title, describing the name of the screening, a subtitle describing the name of the filled out questionnaire and a date which describes the date when the questionnaire was filled out, is shown. Also, there is a green Floating Action Button (FAB).

When the user clicks on the FAB he/she will be redirected to Figure 3.9 where he/she can choose which questionnaire to fill out. On the bottom of each questionnaire a progress bar is shown, indicating the current progress of the respecting questionnaire. When a user fills out a questionnaire, the progress bar increases until it is filled. Reaching the end, a collectable item is assigned to the user. This gamification concept supplements the general level system of a patient. In the last questionnaire in Figure 3.9 an alternative gamification concept is shown where a multiplier is depicted. By filling out questionnaires continuously, the multiplier is increased. Both concepts have their reason for existence and can be used to motivate users over a longer period of time.

¹¹<https://www.figma.com/> last accessed: 2020-01-22

3 Concept



Figure 3.7: Mockups for Welcome, QR Code Scan, Manual Login and Forgot Password

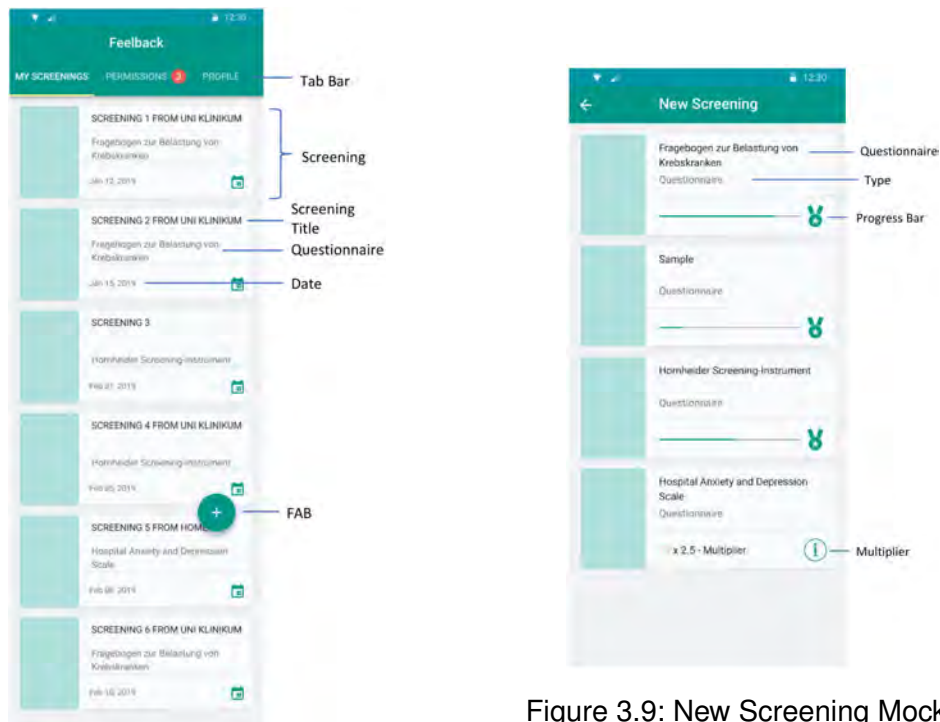


Figure 3.9: New Screening Mockup

Figure 3.8: My Screenings Mockup

In Figure 3.10 the user has an overview of pending permissions. If a practitioner requests a screening of a patient, these requests are shown here. For each request the title of the screening, the name of the questionnaire, which practitioner wants to access the screening and the date of the request is shown. The patient can decide if he/she wants to allow the request or reject it. Furthermore, the patient can view the answers of the requested questionnaire.

Figure 3.11 shows the last tab for the patient. Here, the patient can see his/her pseudonym, current level, collected badges and radio buttons for theme selection.

Figure 3.12 shows a sample questionnaire with different kinds of question types. The question types are a slider, radio buttons for single selection, check boxes for multiple choice, a yes no switch and a free text input. In Figure 3.13 a filled out questionnaire is depicted.

As one can see in Figure 3.14, this is the start screen for a practitioner. In this mockup, all for the current logged in practitioner, patients are listed. In addition, all important

3 Concept

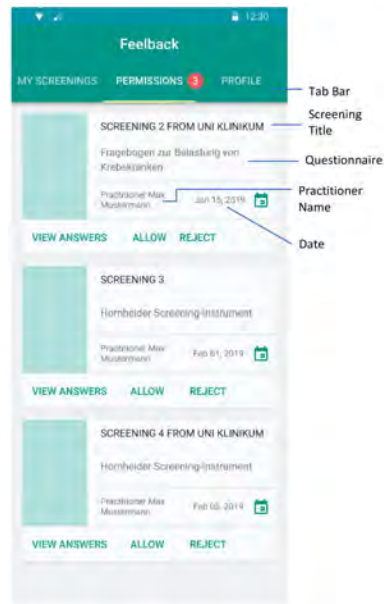


Figure 3.10: Permissions Mockup

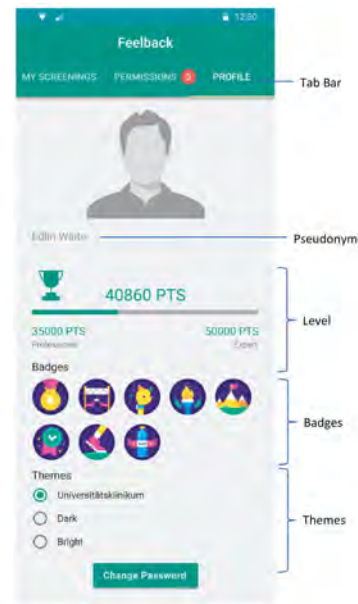


Figure 3.11: Profile Mockup

areas for a practitioner are presented in three tabs, namely *My Patients*, *All Patients* and *Profile*.

Mockup 3.15 depicts the second tab for a practitioner, where all available patients are listed. In this mockup, grey buttons indicate already assigned patients, whereas green buttons indicate patients that can be assigned to a practitioner.

In Figure 3.16 one can see screenings of a specific patient. Each screening has a screening title, a questionnaire name, a date when the questionnaire was filled out, and a status describing whether a practitioner can access the screening. The green check icon indicates, that the practitioner can access this screening. A green plus button indicates, that a practitioner can request access to a patient's screening. The last screening has a grey button, indicating that the patient rejected the request. With the green FAB button, the practitioner can create a new screening for the patient, if he/she is allowed by the patient. This is done by scanning the QR Code.

Figure 3.17 shows the mockup dialog when a practitioner clicks on a green button, trying to add a patient to their list of patients.

3.4 Mockups



Figure 3.12: Questionnaire Mockup

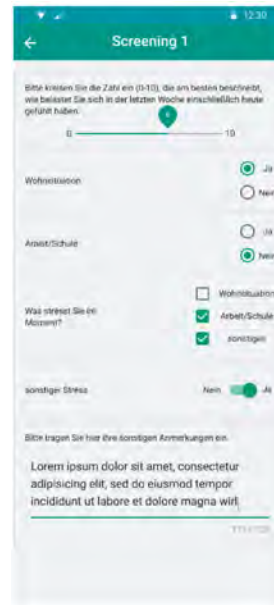


Figure 3.13: Answers Mockup

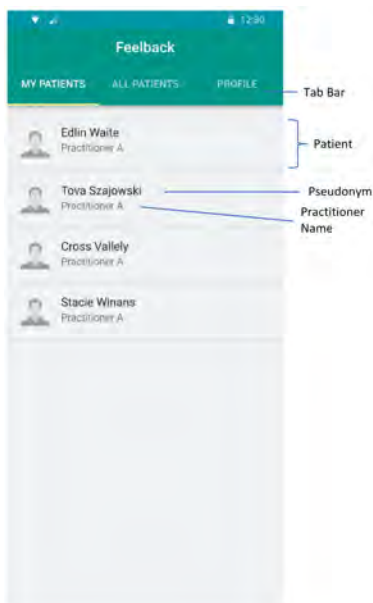


Figure 3.14: My Patients Mockup

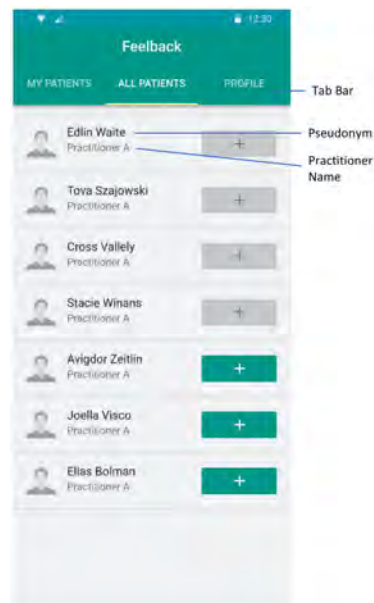


Figure 3.15: All Patients Mockup

3 Concept

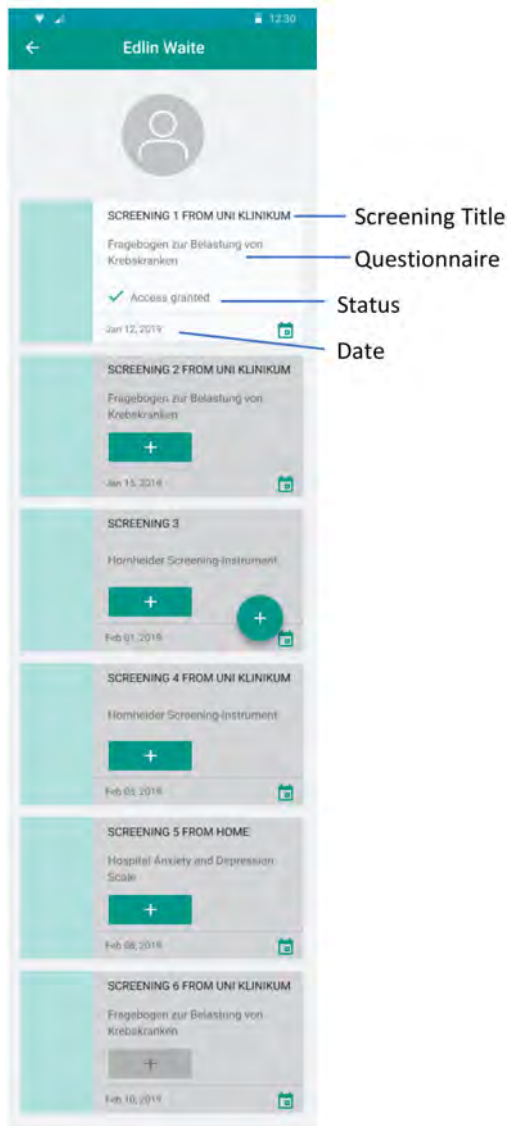


Figure 3.16: Screenings Of a Patient

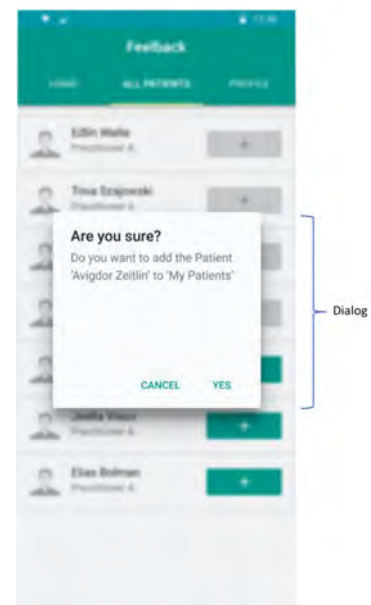


Figure 3.17: Add Patient Mockup

4

Gamification

This chapter describes basic gamification concepts and how they may be applied in the context of the *Feelback* application. Furthermore, common challenges illustrate what should be circumvented when designing gamification concepts for an application. Next, special focus is put on gamification for elderly people and if it is necessary to adjust common game mechanics to them. Finally, the gamification concept developed for *Feelback* is presented.

4.1 Conception of Gamification

When designing gamification aspects for an application, it is vital to have an overview of the existing game mechanics.

Sardi, Idri and Fernandez-Aleman made a systematic review [10] where they investigated game mechanics described in 46 papers. They found out, that in 93% of the investigated applications, an automated feedback system with collectible rewards like badges and points was applied. Furthermore, social interaction was observed in most approaches. Leaderboards for competing with other users and instant messaging within the application are two common examples for social interaction. Also, the integration of social networks like Twitter or Facebook was applied for socializing between users [10].

Another game mechanic described are progress bars, which help visualizing the progress of current activities or tasks and keep track about it. Challenges and quests were applied for various purposes. Trophies, ribbons, medals and badges were used to reward completing tasks or users for leveling-up. Finally, sound effects for notifications,

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congratulatory messages and videos were also applied as common game mechanics [10].

What is also important are the challenges of previous approaches. Avoiding these pitfalls results in better gamification experience.

The authors of [10] also investigated these effects. Various investigated papers of [10] state, that it is difficult to motivate users in the long term. Some application designers bypass this effect by constantly adding new gamification content to the application. For example, designers could extend existing game mechanics e.g. adding new badges to existing ones or add complete new concepts to the application. Furthermore, diverse papers state, that a lack of customization of gamification concepts often leads to an effect, where users do not see the purpose of gamification.

The next problem which is mentioned in [10] is, that not every gamification concept is suitable for all ages. Also, cheating, the usage of only one game mechanic and irrelevant rewards are also pitfalls. Two papers state, that when health professionals are not involved in the process of designing gamification, the concept is rated with a lower credibility [10].

4.2 Gamification for Elderly People

Most cancer diseases have a linear relationship between incidence and age [22]. With this in mind, special focus is put on gamification concepts specially designed for elderly people. In the following it is examined, whether elderly people need adjusted game mechanics.

De Vette, Tabak, Dekker-van Weering and Vollenbroek-Hutten found out, that no gamification framework has a special focus on elderly people [23]. An investigated paper of [23] states, that the most challenging issue is the unfamiliarity of seniors with game elements like points, levels and badges. However, other sources of [23] state, that gamification for elderly people has huge potential, because it decreases the fear and frustration of using modern technology, if gamification aspects are carefully designed [23].



Figure 4.1: Marczewski's Player Type Model [24]

In order to answer the question, whether elderly people need adjusted game mechanics, a player taxonomy is presented. In this theory, players are classified into groups. This is a common approach in game industry, since it gives insights into players' behavior. There are various models, however, this thesis uses Marczewski's player type model, as it is commonly used and can be applied in gamification settings [24].

Figure 4.1 describes each player type in an edge. Players that want to disrupt the system in order to achieve positive or negative changes are *Disruptors*. *Free Spirits* are players that are motivated by autonomy, in order to explore and create content. *Achievers* are motivated by mastery, so they can train skills and overcome challenges. *Players* do what the system wants them to do, in order to gain rewards. A *Socialiser* is motivated by relatedness. This means that they want to connect to other players. A *Philanthropist* is motivated by purpose, meaning that this player wants to do something good to others or help them. They do not expect that they will ever be rewarded [24].

In the examined player taxonomy of De Vette et al. [23] as well as Marczewski's taxonomy [24], they both describe an individual personality regardless of their age. Nevertheless, this field requires more research, because firstly a literature search for *elderly people* and *gamification framework* does not return any results [23] and secondly there are contradictory statements, e.g. elderly people need adjusted game mechanics [23], whereas others state, that this is regardless of age [25].

4.3 Gamification Concept for Feedback

In the following, the gamification concept for *Feedback* is presented. The concept comprises general levels for a patient or a practitioner, collectable stars, a multiplier and collectable badges.

Starting with levels, an easy to follow mathematical function was chosen, because this enables the usage of infinite levels.

$$f(x) = 0.001 * x^2 \tag{4.1}$$

The Function 4.1 describes, how much experience a user needs for a corresponding level. X represents Experience Points (XP) and $f(x)$ the corresponding level. A quadratic function with a coefficient of 0.001 was chosen, because the increase of the function is moderate. When for example a questionnaire rewards the user with ten XP, approximately three questionnaires are needed for the first level. Four for level two, five for level three and so on.

Table 4.1 illustrates, how much experience a user needs for the first few levels.

| Level | Experience Range | Required Experience for next level |
|-------|------------------|------------------------------------|
| 1 | [0-30] | 31 XP |
| 2 | [31-74] | 44 XP |
| 3 | [75-128] | 54 XP |
| 4 | [129-191] | 63 XP |
| 5 | [192-262] | 70 XP |

Table 4.1: Required Experience For The First Few Levels

Next, the collectable stars are presented. The stars are utilized to reward users when they fill out a certain questionnaire (cf. Figure 3.9). Stars (or other arbitrary collectable items) complement the general level approach and motivate users in different ways.

The following mathematical equation 4.2 describes the process of gaining stars.

$$g(x) = 40 \tag{4.2}$$

4.3 Gamification Concept for Feedback

This Function 4.2 describes, how much XP a user needs for gaining a star per questionnaire. A linear function with zero slope was chosen, as this collectable item should be easy to gain. It is a kind of a *gap filler* when the user does not level up. A constant of 40 was chosen, so normally the user gains levels and stars alternatingly.

Table 4.2 illustrates the first few numbers of stars. Especially at the experience range fields, one can see the alternating effect.

| Level | Experience Range | Required Experience for next level |
|--------------|-------------------------|---|
| 1 | [0-39] | 40 XP |
| 2 | [40-79] | 40 XP |
| 3 | [80-119] | 40 XP |
| 4 | [120-159] | 40 XP |
| 5 | [160-199] | 40 XP |

Table 4.2: Required Experience For The First Few Stars

In terms of experience, a patient gains ten XP per filled out questionnaire for the level and the star counter. If the questionnaire takes longer than usual, he/she may get an increased number of experience points (e.g. 20 XP). Also, a practitioner receives ten XP for level and star when he/she fills out a questionnaire for a patient. Additionally, practitioners are rewarded with 20 XP when they treat a patient.

The concept of the multiplier works as follows: It starts by 1.0 per patient and practitioner and increases by 0.1 when an action resulting in experience was achieved. The multiplier decreases to 1.0, if the patient or the practitioner did not gain any experience within one week.

Badges also represent some kind of collectable item. Patients and practitioners are able to collect six different badges. There are additional five level per badge, resulting in a total of 60 different rewards. This helps to keep the number of total badges low, which results in a better user experience. Users see their badges in their profile like one can see in Figure 3.11.

The first badge *Total Experience Points* is illustrated by the second column of Table 4.3, showing the reward for total experience points. This badge is collectable by patients and practitioners. The second badge *Reaching a Level* is illustrated by the third column of

4 Gamification

| | | Required | | | | | |
|-------|------------|----------|-----------------------|------------|-------------------------------|--------------|------------------|
| Level | Experience | Level | Amount questionnaires | Multiplier | Amount questionnaires on time | Amount Stars | Treated patients |
| 1 | 100 | 5 | 7 | 2.0 | 3 | 5 | 3 |
| 2 | 250 | 10 | 20 | 3.0 | 7 | 15 | 7 |
| 3 | 500 | 20 | 45 | 4.0 | 13 | 30 | 13 |
| 4 | 1000 | 40 | 85 | 5.0 | 21 | 50 | 21 |
| 5 | 2000 | 80 | 175 | 6.0 | 32 | 100 | 32 |

Table 4.3: The Badge System of Feedback

Table 4.3. It is collectable by patients and practitioners. The third badge *Amount of Filled Out Questionnaires* is shown in Table 4.3 fourth column. It is also collectable by patients and practitioners. The fourth badge *High Multiplier* is shown in Table 4.3 fifth column and it is collectable by patients and practitioners. The fifth badge *Amount of Filled Out Questionnaires on Time* is only collectable by the patient. For this, the patient must start to fill out a questionnaire within five minutes. This approach helps to collect significant psychological data. Table 4.3 column 6 illustrates the badge. The sixth badge *Total Amount of Stars* is again collectable by patients and practitioners. Table 4.3 column 7 shows this badge. Last badge *Amount of Treated Patients* is a badge for practitioners. In the *Feedback* application, there will be a checkbox where a practitioner can note, that a patient is treated, shown in Table 4.3 column 8.

As one can see in the different badge level tables, when a user gains a specific badge at a certain time, other badges do not overlap. Next badges are typically gained during the next user interaction. With this technique, almost every action of a user triggers some kind of reward.

It is also possible to integrate hidden badges. This is a special kind of badge that is only shown to users, when the user already fulfilled its objective. This concept triggers users to seek for hidden achievements within the application, resulting in long term motivation.

5

Implementation

This section presents a small overview of some important concepts introduced by Ionic, including the grid system, CSS and routing. After that, two utilized JavaScript frameworks (SurveyJS and Chart.js) used within the *Feelback* project are demonstrated. Also, the native plugin (PhoneGap Plugin BarcodeScanner) that communicates with the hardware API is presented. During development, there was a need for a functioning backend system. In order to be able to develop the mobile application independently, a mockup backend was developed and will be declared (Chapter 5.4). Next, the overall tabs and routing structure of patients and practitioners in *Feelback* is presented. In the *Feelback* Ionic project, a concept of generic components was used for specific parts of the app. This is presented in Chapter 5.6. Furthermore, reactive forms instead of template-driven forms were used. This approach is stated in Chapter 5.7. Last, the mobile application itself is shown in Chapter 5.8.

5.1 Ionic Framework

For this thesis as mentioned in Chapter 3.3, Angular was chosen as the code base within the Ionic framework. In Angular, developers can write web code in Hypertext Markup Language (HTML) and Typescript¹. As usual, CSS is used for styling. The widespread concepts of Angular e.g. modules, components, services, service injection, templates, directives, data bindings and others are also applicable in Ionic.

Ionic itself is a collection of web components, that are build by StencilJS. Programming in Ionic basically means to access these bundled web components using Angular. The

¹<https://www.typescriptlang.org/> last accessed: 2020-02-19

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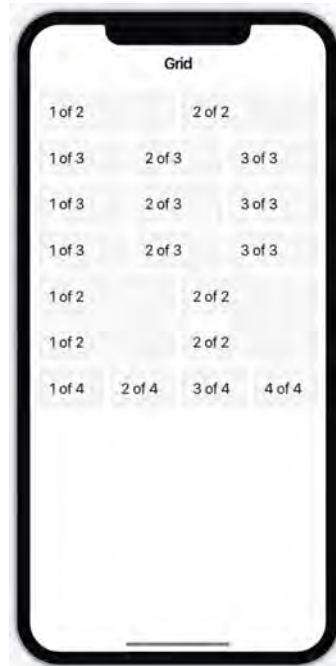


Figure 5.1: Example Responsive Grid of Ionic

mentioned web components of Ionic are a powerful tool in developing web code, because these components adapt themselves according to the operating platform. This means that these web components look different for each platform, imitating a native application. Furthermore, there are other convenience functions e.g. the color adaptation of the component. This means, that when developers decide to take e.g. a dark background for the component, the text color automatically changes to white, providing a look and feel for the application.

Also, Ionic's web components are highly scalable with regard to display sizes. By utilizing Ionic's grid, developers can constrain the components in relation to size, without constraining the scalability of the component. Figure 5.1 depicts such a grid of Ionic.

As one can see, there are seven rows and two to four columns per row. In general, the default grid system of Ionic has a size of twelve, which means a total width of 100%. The mentioned grid system is similar to other frameworks like Bootstrap², where developers also build their user-interfaces upon grid systems. Looking at the first row of Figure 5.1,

²<https://getbootstrap.com/> last accessed: 2020-02-20

this means that the two columns have a size of six, achieving that each column takes up 50% of the total row width. In addition, it is possible to constrain the size of a column by the size of a display. This can be achieved by writing *Size-md="8"*, meaning that this column takes up a size of eight, for displays of medium size and larger. Reasons why one should use such constraints are manifold. Some components, for example, do not look appropriate when they are stretched too wide, especially on large displays. The resolution of the display required to be categorized as e.g. *medium* or *large* is provided in the Ionic documentation. This concept is called *Breakpoints* and can also be customized by using CSS variables.

Ionic uses a special extension for CSS which is called *Sass*³. *Sass* has several advantages compared to plain CSS. For example, *Sass* has concepts of variables and developers can write cleaner code, by utilizing the cascading structure of CSS as well as several other advantages.

What's more special about Ionic is the usage of Angular's routing module in terms of transitions. Mobile applications typically have a kind of transition, indicating that the current view was changed to a new one. For these transitions, most often a slide effect is used, indicating that a view is either pushed to the graphical view stack or popped from the latter. Websites do not have such transitions, and so Angular does not have transitions in the router module either. This is where Ionic's *NavController* is applied by calling *push()*, *pop()* or *navigateRoot()*. This *NavController* utilizes Angular's router module internally, in order to perform a view change. Additionally, the *NavController* builds up this mentioned view stack and automatically manages back buttons for users, if they want to navigate backwards. An important aspect of the *navigateRoot()* method is, that previous views on the view stack will be deleted, meaning that no back button on top of a view is presented to users.

³<https://sass-lang.com/> last accessed: 2020-02-19

5.2 Additional JavaScript Frameworks

In the Ionic *Feedback* project, several additional JavaScript frameworks were used. This section presents two of them, namely SurveyJS⁴ and Chart.js⁵.

SurveyJS is a framework for dealing with digital questionnaires. There is a module for creating a questionnaire, a model for displaying highly responsive questionnaires in someones own application and several services for analyzing the results of the questionnaire. In terms of the *Creator* module, this is an application where the questionnaire can be configured and finally graphically represented. The *Creator* can either run in someones own application or can be used by the online application on the website of the project.

Configuring the questionnaire is possible by drag & drop, which can be done by non-developers. Third party JavaScript frameworks like noUiSlider⁶ can also be used by dragging & dropping the element into the questionnaire. The website contains a list of all supported third party frameworks. As a result of configuring the questionnaire in the *Creator* module, a JSON file is outputted, where the structure of a questionnaire is described.

Listing 5.1 depicts an example questionnaire structure of a single radio group with two radio buttons.

```
1 {
2   "pages": [{
3     "name": "page1",
4     "elements": [{
5       "type": "radiogroup",
6       "name": "question1",
7       "title": "Please indicate if Depression has been a problem for
8         you in the past week including today.",
9       "choices": [{
10        "value": "item1",
11        "text": "YES"
```

⁴<https://surveyjs.io/> last accessed: 2020-02-19

⁵<https://www.chartjs.org/> last accessed: 2020-02-19

⁶<https://refreshless.com/nouislider/> last accessed: 2020-02-19

```

11         },
12         {
13             "value": "item2",
14             "text": "NO"
15         }
16     ]
17 }
18 }
19 }

```

Listing 5.1: JSON Radio Button Example from the Distress Thermometer

Figure 5.2 shows the result of the radio button example, which can directly be inspected in the *Creator*.

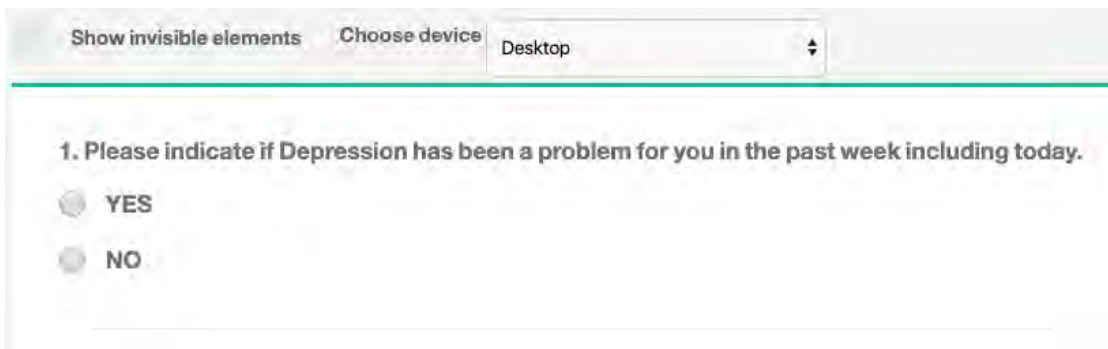


Figure 5.2: Graphical Result of the Radio Button Example from the Distress Thermometer

In the *Feelback* project, the *NestJS* service sends the JSON file of the questionnaire directly to the Ionic mobile application, without using the infrastructure provided by SurveyJS. This has multiple advantages, e.g. that the filled out questionnaire is directly sent back to the *NestJS* service, where it can be evaluated in a custom manner. Moreover, there is no dependency of a third party server infrastructure, increasing the reliability of *Feelback*.

Next, the integration of Chart.js into the Ionic *Feelback* project is presented. Chart.js is a JavaScript framework for displaying highly responsive charts. Although there are many supported types of charts, the realized mobile application currently only makes use of

5 Implementation

line and polar charts. A line chart is used for visualizing a chronological sequence of filled out questionnaires. This is a gamification concept for user motivation.

Polar charts are used for analyzing results of a questionnaire. In the *Distress Thermometer*, there are five groups within the problem list, namely practical problems, family problems, emotional problems, spiritual concerns and physical problems. For each group, a part of the circle is drawn with respect to the total checked problems in the questionnaire. Moreover, the scoring is normalized, because the number of problems differ for each group. Figure 5.3 is an example evaluation, using a polar chart of Chart.js.

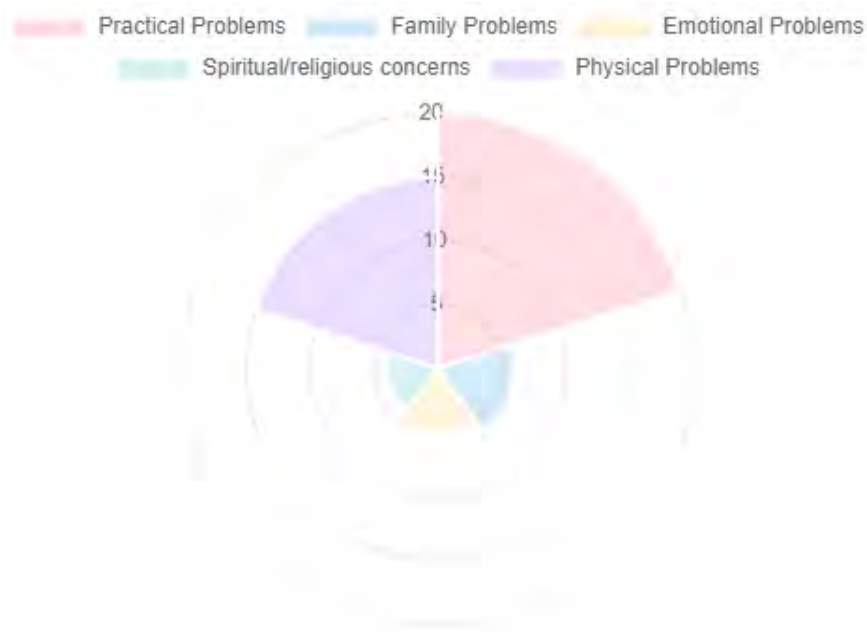


Figure 5.3: Questionnaire evaluation by means of a polar chart

The integration of Chart.js into Ionic is achieved with HTML Canvas elements. Canvas elements are multimedia elements for all kinds of graphics and drawings. In the TypeScript controller, developers can access these canvas elements by using Angular's *ViewChild* decorator.

5.3 Native Plugins

Ionic supports feature-rich native plugins which can be integrated in applications by developers. There is a distinction between *Community* and *Premier* plugins. *Premier* plugins are developed by the Ionic team and are charged, whereas *Community* plugins are a collection of open source software for Cordova. Native plugin means that the software is dedicated to a specific platform, however a plugin can support multiple platforms like Android, iOS and Windows. These plugins often communicate with dedicated hardware of the device, like the camera, microphone or location sensors like GPS.

For this thesis, a plugin for scanning QR Codes was used. It is called *PhoneGap Plugin BarcodeScanner* and can scan several code types like QR Code, bar code and 14 others. Supported platforms are Android, iOS, Windows and diverse browsers. Because this plugin is integrated with Cordova, only Android and iOS are supported in *Feedback*.

Integrating native plugins into an Ionic project works as follows: First, developers must add the plugin to cordova by calling `ionic cordova plugin add phonegap-plugin-barcodescanner`. Next, a package manager of developers choice like `npm` needs to add the source code to the project by calling `npm install @ionic-native-/barcode-scanner`. Last, *BarCodeScanner* must be imported into the providers array of the root app module.

```
1 this.barcodeScanner.scan().then(barcodeData => {
2   console.log('Barcode data', barcodeData);
3 }).catch(err => {
4   console.log('Error', err);
5 });
```

Listing 5.2: BarcodeScanner Example

Listing 5.2 shows how to use the bar code scanner. By calling `barcodeScanner.scan()`, the camera of the device is activated and ready to scan QR Codes. Within the asynchronous callback at Line 2, the data of the QR Code can be used for further steps. In the Ionic project, user credentials for patients are decoded for the authentication

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process, which are then sent to Keycloak afterwards. If something goes wrong, errors can be caught within the asynchronous error callback (Lines 3 to 5).

5.4 Mockup Backend System

During development, there was a need for a functioning backend system, however at this time the NestJS service did not exist. Therefore, a mock backend system was developed by using a Node.js⁷ server.

Within the Node.js server, a Typescript framework called *faker.js*⁸ was used for generating realistic data. Faker.js has functions for generating all kinds of fake data grouped by addresses, commerce, company, databases, dates, finance and others. Additionally, a location can be set for generating location specific data, which increases the realism of the data. Also, randomness can be added by calling e.g. `random.number()` to receive a random number. For *Feelback*, *faker.js* was used for generating fake users, patients, practitioners, screenings and pending permissions.

```
1 {  
2   "users": [  
3     {...}, {...}, {...}  
4   ], "screenings": [  
5     {...}, {...}, {...}  
6   ]  
7 }
```

Listing 5.3: JSON Server database

The fake data was utilized by another TypeScript framework called *JSON Server*⁹. This framework automatically generates a Representational State Transfer (REST) API, depending on a file database. This database is represented by a JSON file called `db.json`, where routes and the corresponding objects are stored. Listing 5.3 is an example `db.json` file, where *users* and *screenings* have three example objects. JSON Server automatically

⁷<https://nodejs.org/en/> last accessed: 2020-02-19

⁸<https://github.com/marak/Faker.js/> last accessed: 2020-02-19

⁹<https://github.com/typicode/json-server> last accessed: 2020-02-19

generates two routes (/users and /screenings), addressed by auto generated GET, POST, PUT, PATH and DELETE methods.

For full flexibility, an ordinary *Node.js* server was utilized, in order to provide custom API routes that extend the autogenerated routes of *JSON Server*. The automatically generated routes by *JSON Server* can be integrated into Node.js by calling `server.use(jsonServer.bodyParser)`. An example of such a custom route is the mockup authentication process. During development, the *Feelback* frontend needed an authentication service, which returned fake tokens for patients and practitioners.

```
1 server.post('/auth/login', (req, res) => {
2   let pseudonymOrEmail = req.body['pseudonymOrEmail'];
3
4   if (pseudonymOrEmail==='patient') {
5     res.status(200).jsonp({
6       token: "token",
7       role: "patient"
8     });
9   } else if (pseudonymOrEmail==='practitioner') {
10    res.status(200).jsonp({
11      token: "token",
12      role: "practitioner"
13    });
14  } ...
15 });
```

Listing 5.4: Node.js Mockup authentication

Listing 5.4 shows a very simple mockup authentication for the POST route /auth/login. Depending on the field `pseudonymOrEmail` which is in the POST body, the Node.js service authenticates a user as a patient or a practitioner by sending the status code 200. With this technique, the frontend can show patient views for the patients and practitioner views for the practitioners.

5.5 Tabs and Routing Structure

In mobile applications, there are typically two basic approaches how a user navigates within the application, in order to reach the functionality of the app. First, there is a menu (or side menu), which can typically be activated by clicking a hamburger button. After clicking, the menu slides from left or right into the view, containing all navigation items that are available for the user. Second, there is the concept of tabs, which shows all its content to the user. These tabs can also be divided into special tabs that show similar content within a specific domain of the app and also hide themselves when users leave the domain. The other variant shows the overall structure of the app constantly. Both, side menus and tabs, have their advantages, however in *Feelback constant tabs* were chosen, because constantly showing all available content of the app enhances user's orientation, especially when most users are elderly people.

Side menus are represented by Ionic's ion-menu and tabs by ion-tabs and the corresponding routing on it. In the *Feelback* project, patients and practitioners have their own ion-tab, showing *My Screenings*, *Permissions* and *Profile* for patients and *My Patients* and *Profile* for practitioners.

```
1 {
2   path: 'tabs2',
3   component: TabsPractitionerPage,
4   canActivate: [AuthGuardService],
5   data: { roles: Role.Practitioner},
6   children: [
7     {
8       path: 'my-patient',
9       children: [
10        {
11          path: '',
12          loadChildren: './../my-patient/my-patient.module#
13            ↪ MyPatientPageModule'
14        },
15        ...
16      ]
17     }
18   ]
19 }
```

Listing 5.5: Routing for practitioners tabs

Listing 5.5 shows exemplary the routing of practitioners for such tab. When loading the tab *My Patients* (Line 8 to 13), the module *MyPatientPageModule* is lazy loaded (Line 12) into the tab module. Lazy loading means, that the required module is only loaded if it needs to. This technique dramatically improves performance in terms of load time and application response. Additionally, the tabs for practitioners are protected with an authentication guard (Line 4). This service checks, whether a user is authorized as a practitioner and can, therefore, access the tab.

5.6 Generic Components

By default, Ionic generates its components (or pages) in separate modules, containing the routing, controller, view, styling and unit testing, providing their functionality only for the module itself. However, it is also possible to write custom Angular modules that can provide functionality to other pages. With this approach, developers can generate generic modules.

Listing 5.6 shows, that components which provide functionality to other components are listed in the exports section. Also, it is vital to import the *IonicModule* (Line 8) when the components within the generic module want to use Ionic's components.

```

1 @NgModule({
2   declarations: [
3     PermissionPatientComponent,
4     ...
5   ],
6   imports: [
7     CommonModule,
8     IonicModule
9   ],
10  exports: [
11    PermissionPatientComponent,
12    ...
13  ]
14 })

```

Listing 5.6: Generic Angular Module

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When developers want to access e.g. `PermissionPatientComponent`, they can do so by importing the whole generic module. This approach of generic components has several advantages like great flexibility in the way of coding, which means that developers are able to program just one generic component which can then be utilized in the whole application.

Figure 5.4 shows the graphical representation of the `PermissionPatientComponent` component. Ionic's `ion-card` component was used, which represents a card¹⁰. Input parameters like titles and names can be set by utilizing the Angular decorator `@Input()`. Setting these input parameters is done by standard input binding.

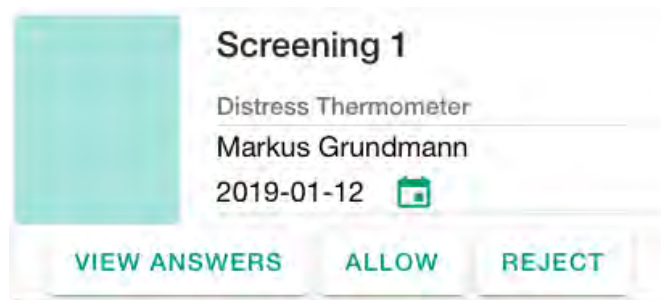


Figure 5.4: Generic Component Example

5.7 Reactive Forms

In Angular and therefore in the *Feelback* Ionic project, there are two basic types of forms, namely reactive forms and template-driven forms. With both techniques, developers can achieve the same result, whereas both have their advantages. In the *Feelback* project, reactive forms were chosen, because of the following advantages compared to template-driven forms.

Reactive forms are easier to unit test, because in an automated test, developers can query and set its values by simply calling `form.value`. With template-driven forms, this can only be achieved indirectly using the `@ViewChild()` decorator. Also, building

¹⁰<https://material.io/components/cards/> last accessed: 2020-02-19

a reactive form mainly takes place in the controller of a component, whereas template-driven forms are built in the view. Shifting the logic of a form to its controller is a clear way of coding, since it enhances the idea of encapsulating logic of a component into its controller. Finally, form validation can be programmed within the controller, because this is the place where the form was built, increasing the clarity of code. Drawbacks of reactive forms, as stated by developers, are that building and managing such forms feel less intuitive, compared to template-driven forms. For this, Angular offers the *FormBuilder* class for an easier building process, which can be seen in Listing 5.7.

Listing 5.7 demonstrates a reactive form, containing two *FormControls*. `Fb` is the previous mentioned *FormBuilder*, which makes it easier to build *FormGroups*, *FormControls* and *FormArrays*. `Fb.group` creates a *FormGroup* which is a container for *FormControls* like `pseudonymOrEmail`. A *FormControl* is a container for saving the value and state of an input. The first argument in Listing 5.7 Line 2 of the square bracket is the default value of the input, whereas the second argument defines validators for the input. Developers can also define custom validators or asynchronous validators, for example, a validator in the registration process, when at first a database lookup is processed, checking if the entered username is already in use.

```

1 loginForm = this.fb.group({
2   pseudonymOrEmail: ['', Validators.required],
3   password: ['', Validators.required]
4 });

```

Listing 5.7: Reactive Login Form

Connecting the reactive form `loginForm` with the view is possible by the input binding `formGroup`, which is demonstrated in Listing 5.8. *FormControls* can be connected (see Line 2) with the usage of `formControlName` binding.

```

1 <form [formGroup]="loginForm" (ngSubmit)="login()">
2   <ion-input formControlName="pseudonymOrEmail" type="text">
3   </ion-input>
4 </form>

```

Listing 5.8: Reactive Login Form View

5.8 Presentation of the Mobile Application

This section presents the user-interface of the developed application by showing screenshots of it. First, the patient's domain is presented followed by the practitioner's domain.

Figure 5.5a shows the welcome screen for a patient and a practitioner. Using the upper button *SCAN CARD* users can login via QR Code, whereas with the lower button *LOGIN* the login is performed manually via pseudonym and password.

Figure 5.5b depicts the manual login screen. In the screenshot a pseudonym was already entered, but the password is missing. This is annotated with red color. By clicking on *LOGIN*, the patient or the practitioner is redirected to the corresponding start screen. *FORGOT PASSWORD?* redirects to a form, where users can enter their pseudonym or email address.

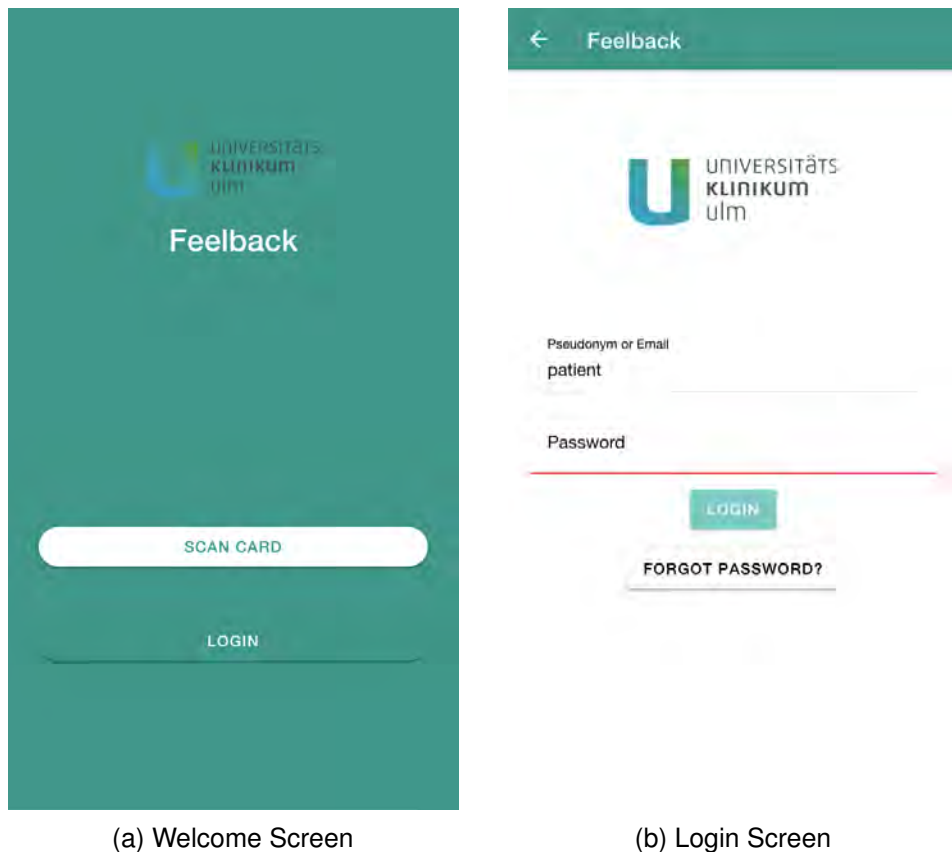


Figure 5.5: Welcome and Login Screen

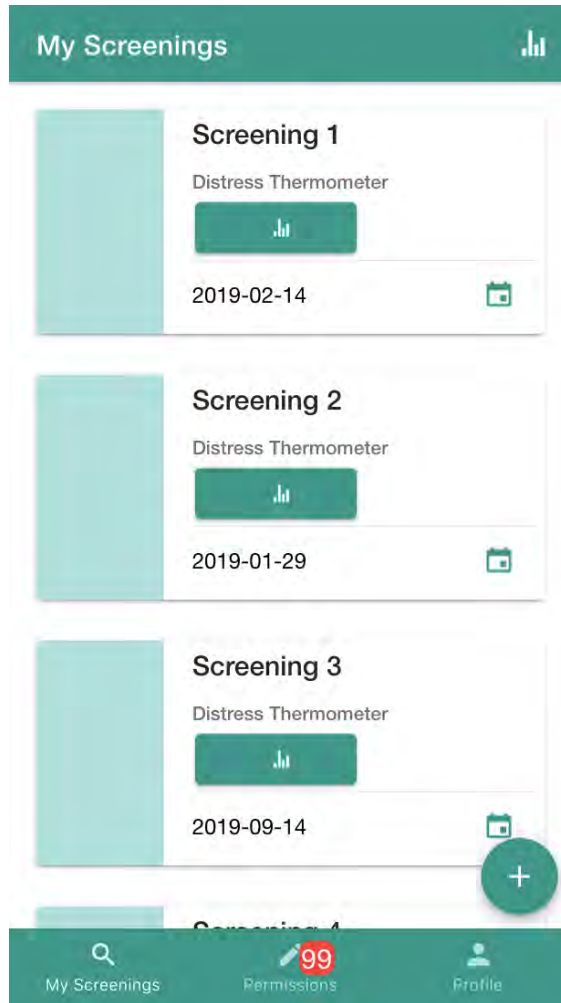
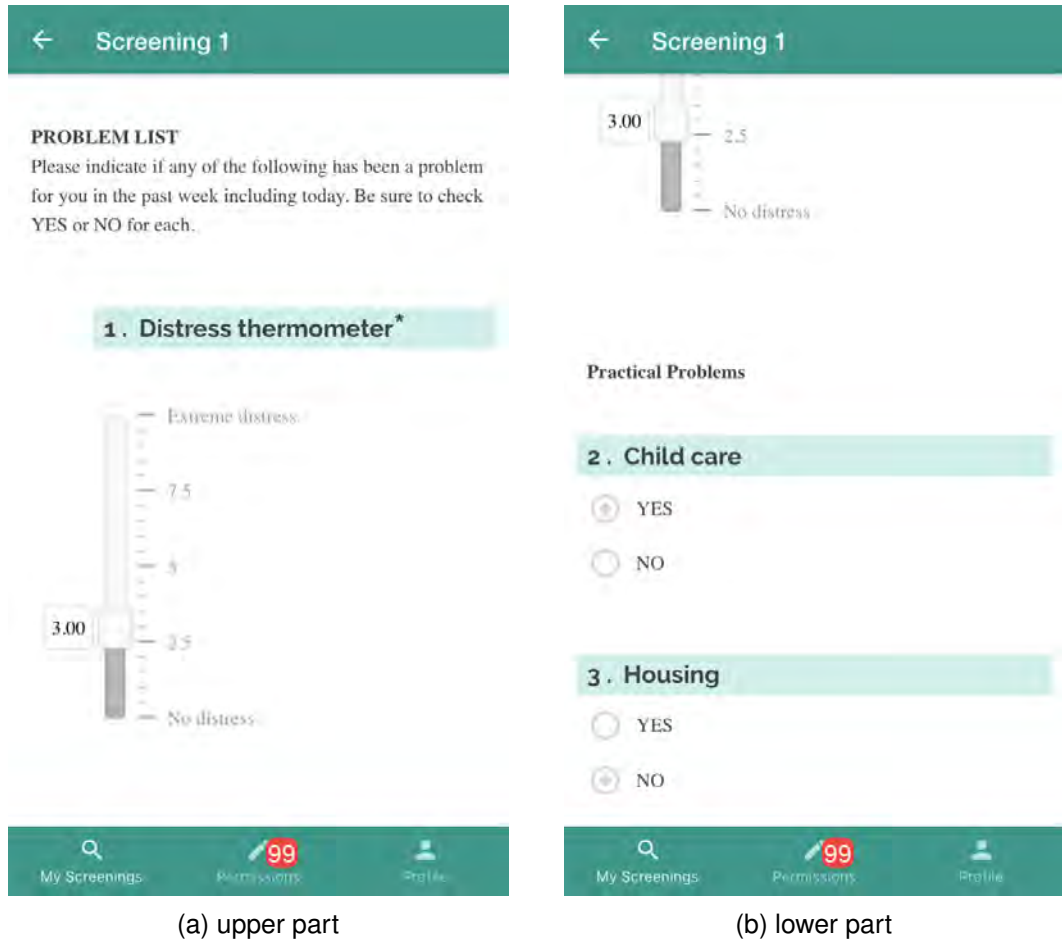


Figure 5.6: My Screenings View

Figure 5.6 shows the start screen of a patient. In tab *My Screenings*, the patient sees previous screenings (Screening 1 to 4 in Figure 5.6). He/she can access them by clicking the corresponding card. Furthermore, one particular screening can be analyzed by clicking the green analyze button. An overall analysis is also possible, by clicking on the white analyze icon on the top right corner. With the FAB button, a user can fill out new screenings. The tabs *Permissions* and *Profile* are shown in Figure 5.13 and 5.14.

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(a) upper part

(b) lower part

Figure 5.7: Screening 1

When users click on a single screening, Figure 5.7 is shown to the patient. In this Figure, the *Distress Thermometer* questionnaire is used for visualization, showing that the user entered 3.00 in the thermometer and several other values at the problem list. The thermometer is visualized via a vertical slider that goes from bottom to top and is also extended via the labels *Extreme distress* and *No distress*.

5.8 Presentation of the Mobile Application

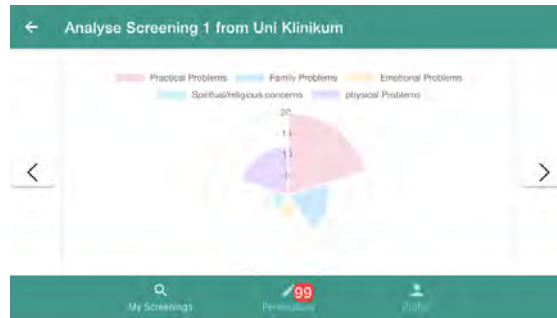


Figure 5.8: Single Screening Analysis

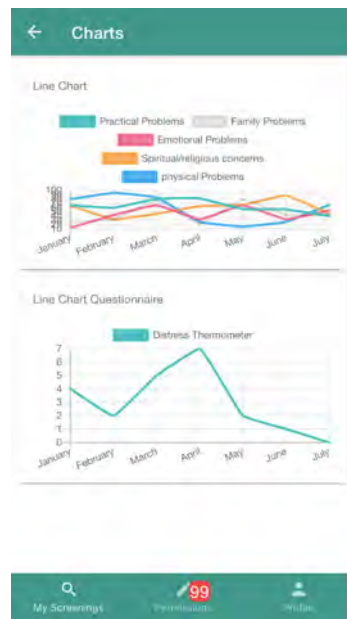


Figure 5.9: Multiple Screening Analysis

Figure 5.8 depicts the screen, when a user clicks on the green analyse button within the card on his/her start screen. Either by swiping or by clicking the arrow buttons, users can analyse different screenings. Figure 5.9 shows overall analysis over every screening using two different line charts. The upper line chart analyses the screening regarding the group of the problem list, whereas the lower line chart shows the total amount of filled out questionnaires.

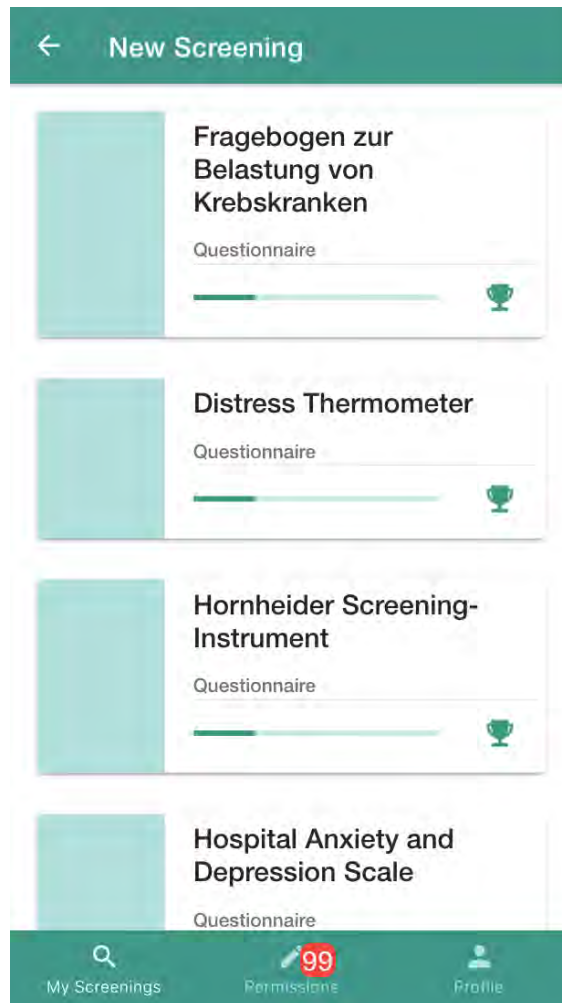
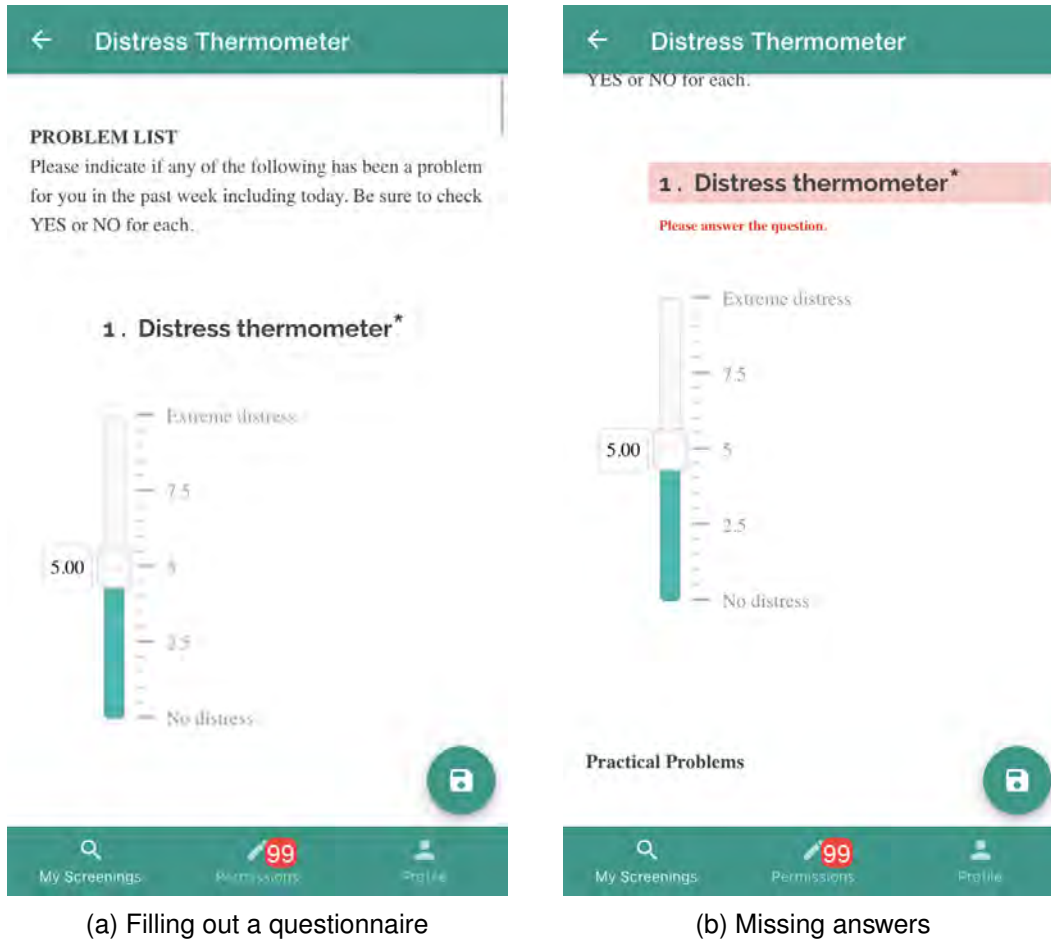


Figure 5.10: All Questionnaires

Figure 5.10 shows an overview of all available questionnaires of the system. This view is shown, when users click on the FAB of Figure 5.6. For each questionnaire, a progress bar is shown to users, where the current progress is depicted. This is a gamification concept, where users can collect stars. By clicking on a questionnaire, users are redirected to Figure 5.11a, where they can fill out the questionnaire.

5.8 Presentation of the Mobile Application



(a) Filling out a questionnaire

(b) Missing answers

Figure 5.11: New Screening of Feelback

Figure 5.11 shows the user-interface for filling out a questionnaire. On Figure 5.11a users can fill out the questionnaire and can save it with a save FAB button. Figure 5.11b shows what happens when a user forgets to fill out a required field.

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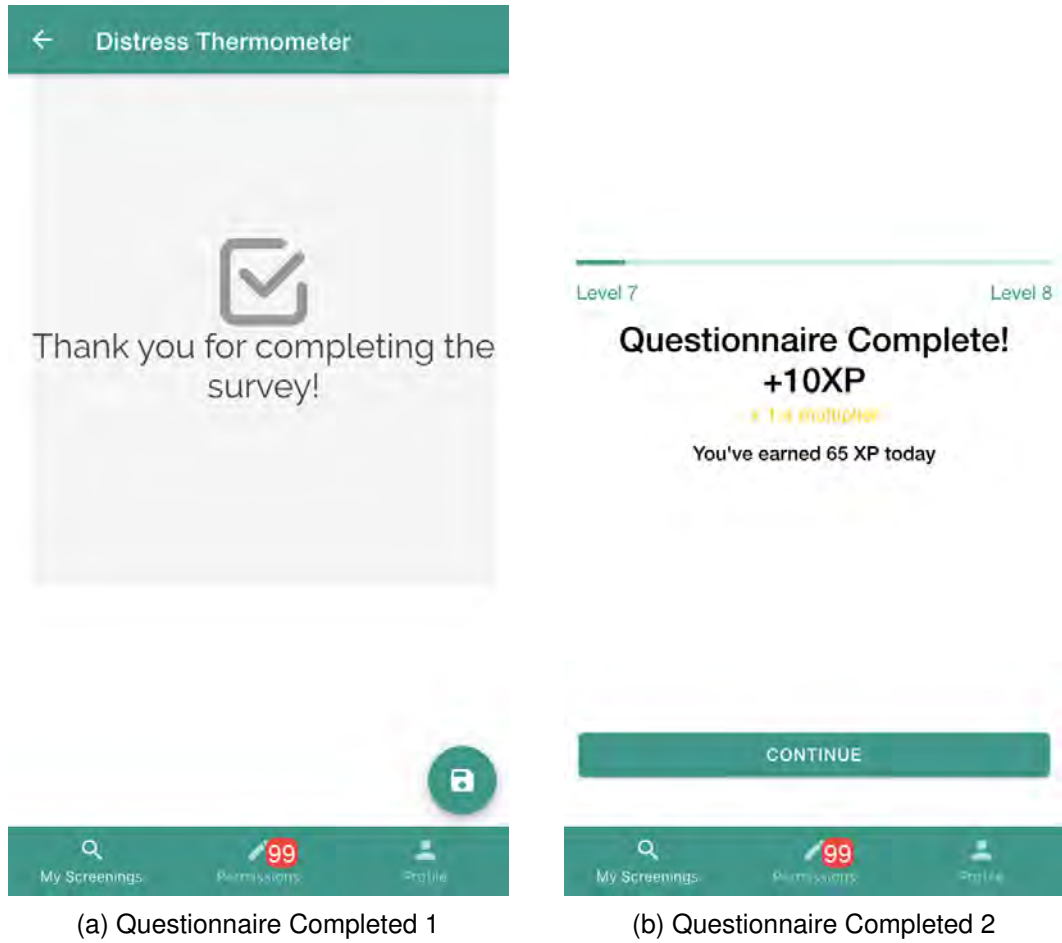


Figure 5.12: Questionnaire Completed

Figure 5.12a shows the user-interface after a screening was completed. After five seconds, the patient is redirected to Figure 5.12b where he/she is rewarded with XP. By clicking on *CONTINUE*, patients and practitioners are redirected to the start screen.

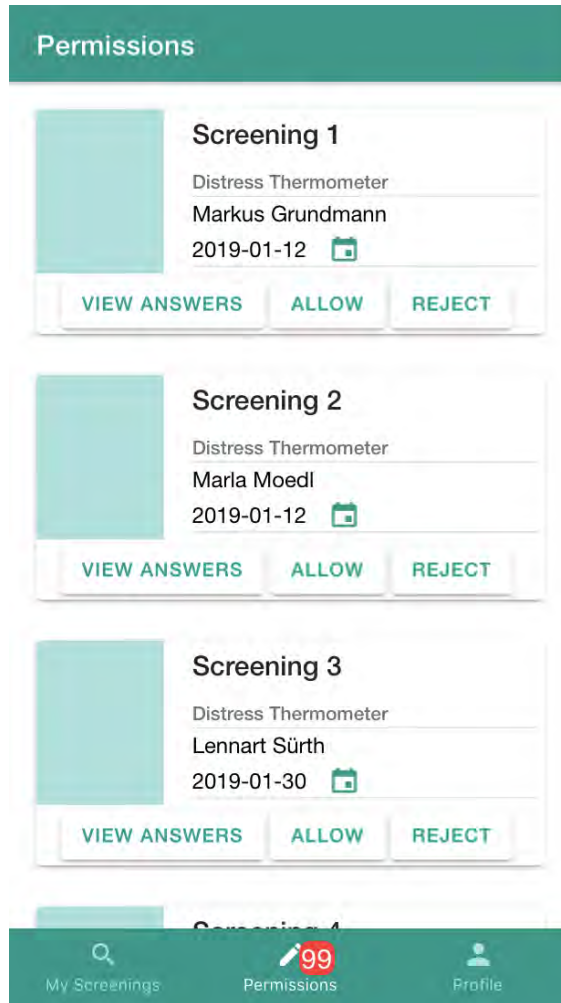


Figure 5.13: Permissions View

Figure 5.13 shows the second tab for patients, where pending permissions are shown to the patient, when a practitioner requests access to a screening. The patient can either allow or reject the request. Also, he/she can click on *VIEW ANSWERS*, in order to see his/her answers, so the patient makes sure, that this is the right screening. The red number next to the icon (99) indicates, that there are requests pending.

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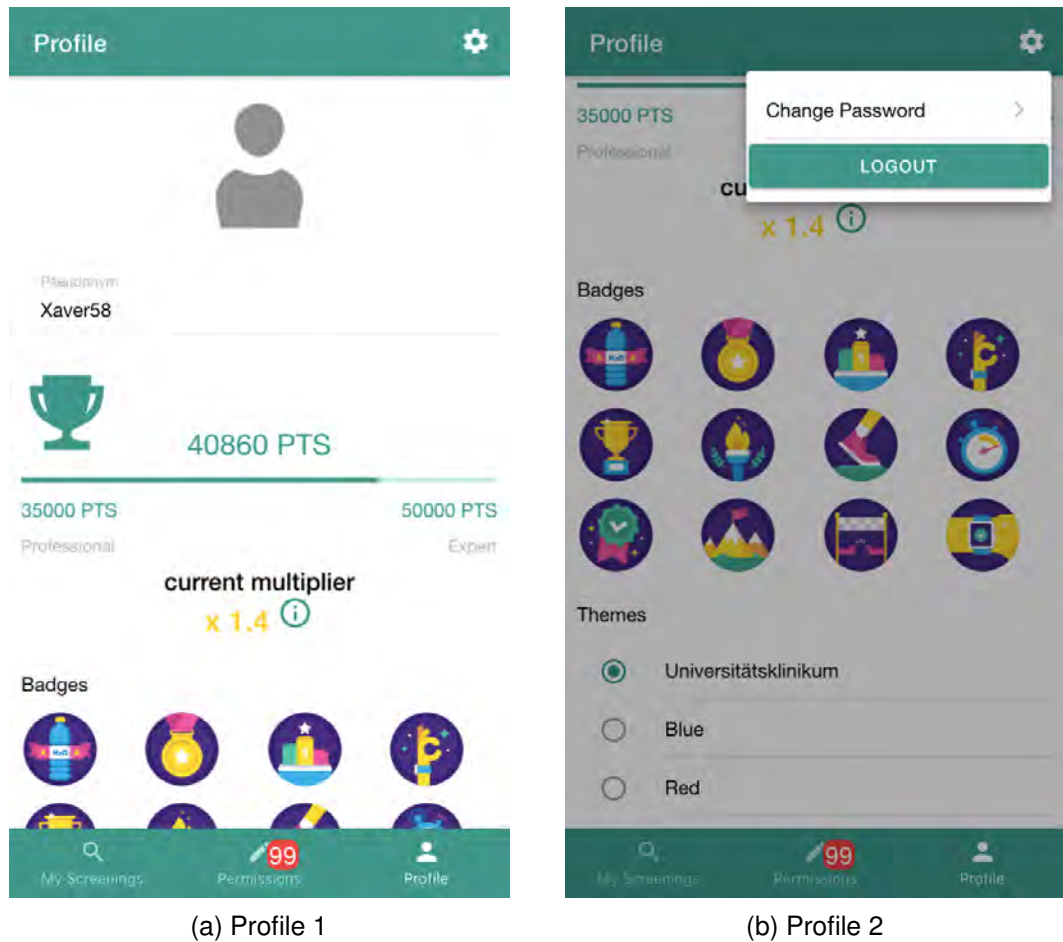
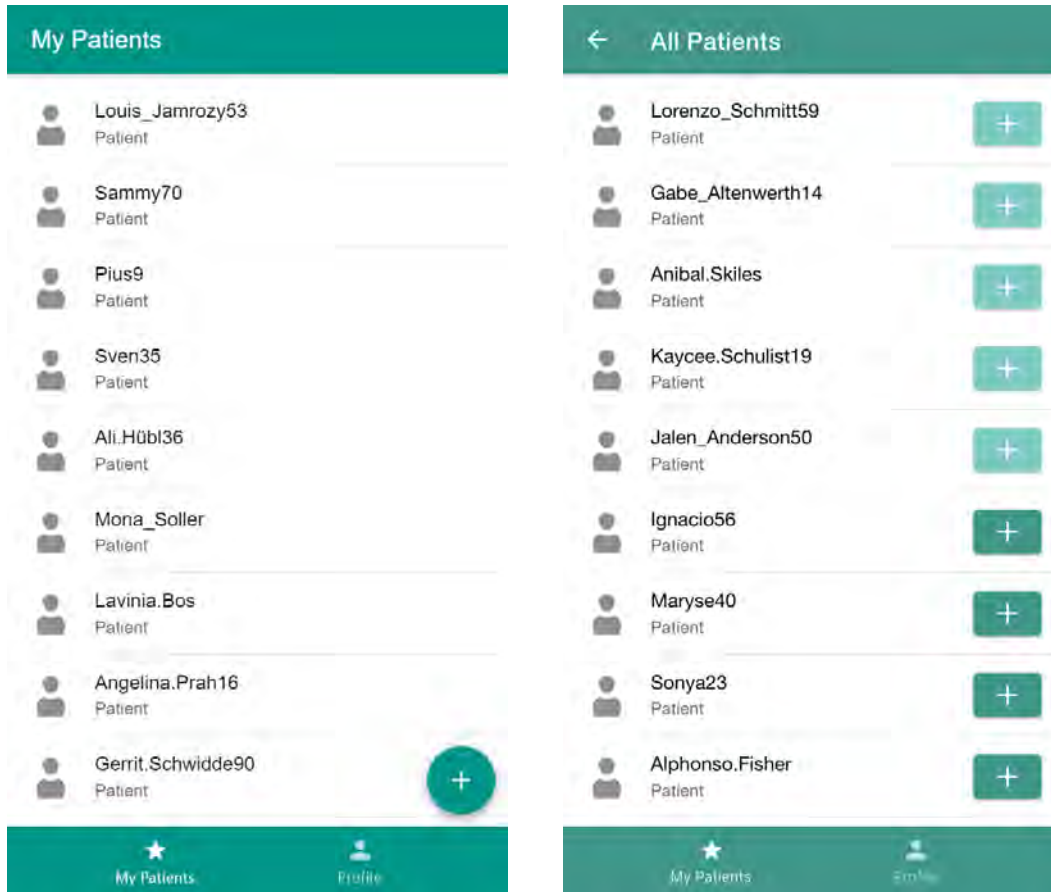


Figure 5.14: Profile View

Figure 5.14 depicts the third and last tab for patients. Practitioners have the same profile view, but on the second tab. In this profile section, users see their pseudonym, current level, current points, multiplier and collected badges. Also, users can change the theme of the app by clicking the corresponding color. Figure 5.14b shows the popover view for changing the password and logout functionality when a user clicks on the gear icon.

5.8 Presentation of the Mobile Application



(a) My Patients tab

(b) All Patients

Figure 5.15: Patients View

Figure 5.15 shows the start screen for practitioners, which lists all patients that are currently assigned to the logged in practitioner. By clicking on the white *add* icon, the practitioner is redirected to Figure 5.15b where all patients of the system are listed. Patients who are already assigned to the practitioner are depicted with a greyed out plus button and patients who can be assigned are depicted with a green plus button.

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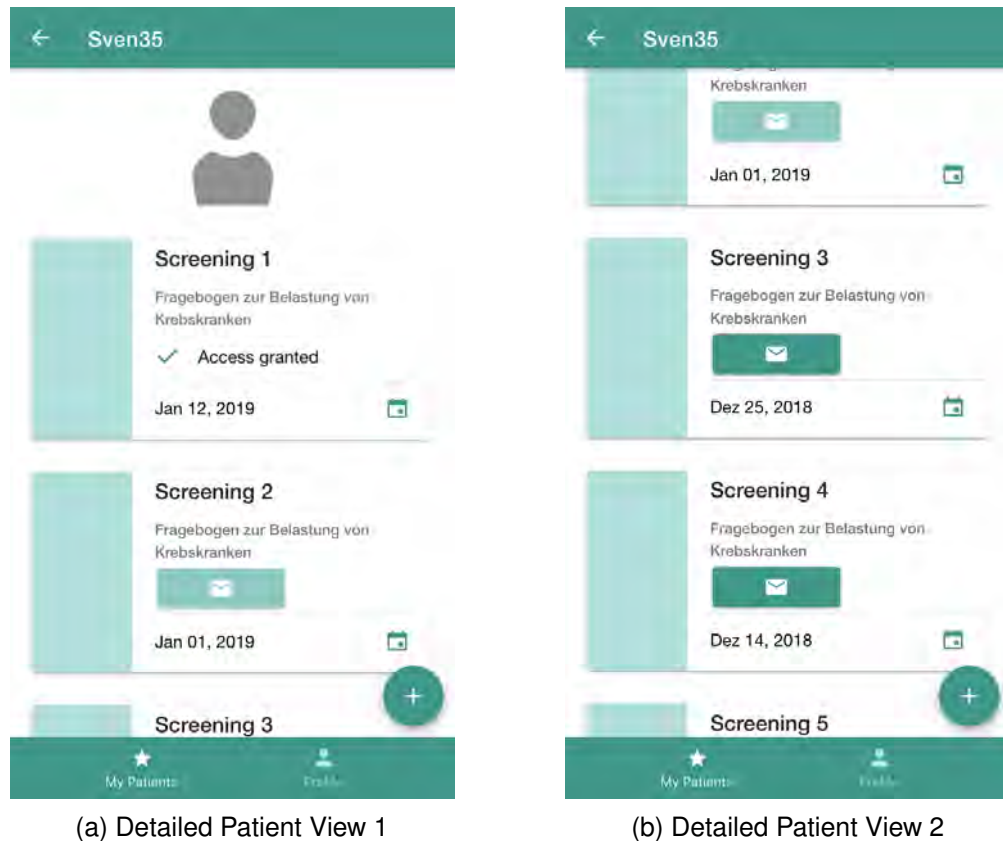


Figure 5.16: Detailed Patient View

Figure 5.16 depicts the detail view of a patient when practitioners click on the corresponding patient. Each screening is listed as a card, showing its title, questionnaire name, access status and date of creation. The access status can either be *Access granted* indicated with a green check icon, *rejected* indicated with a greyed out mail button and *ready for request*, indicated with a green mail button. If a practitioner clicks on this green mail button, a request is sent to the patient, containing a message, that this practitioner wants to access this screening. A screening that can be accessed (first card in Figure 5.16a, namely Screening 1) is depicted in Figure 5.16a. By clicking the green *add FAB* button, the practitioner makes a new screening for the patient by scanning the QR Code.

6

Related Work

In context of the *Feelback* project, related work is manifold. However, in this chapter related topics are restricted to work containing self assessment questionnaires in various scientific fields. Furthermore, related work that deals with mobile application in the context of cancer and psychological illnesses is also considered.

6.1 Narrow Related Work

In the following, related work is divided into narrow and wider related work. Work that utilizes similar approaches and is thematically related to this work is classified as narrow, whereas wider related work is thematically related.

6.1.1 Pain Squad

Pain Squad is a mobile application developed by Stinson et al. to assess the pain level of patients during cancer treatment. According to the authors, assessing pain is the first vital step for managing pain. If pain is badly managed, it may result in anxiety and distress and may develop psychological issues [26] in the long-term.

Most commonly, pain assessment is done by paper-based questionnaires. This has several drawbacks like this technique often leads to inaccuracies, because questionnaires are possibly not filled out during painful episodes. Reconstructing such events is biased. Furthermore, patients tend to hoarding (back filling) questionnaires, which also lead to inaccuracies [26]. In order to provide a way in which patients can digitally manage

6 Related Work

their pain level, *Pain Squad* enables patients to keep a diary for pain. In this application, users play a fictitious law enforcement officer, in order to hunt down pain. With every diary entry, users get closer to this goal [26].

One gamification concept in *Pain Squad* is the whole *law enforcement* theme of the app, imitating a video game. Furthermore, the authors developed a ranking system in which users can level up by filling out three reports (i.e., diary entries). The users are notified, reminding them to keep the diary. The timing of the notifications can also be configured in the options of the application. Another gamification concept that was implemented are the video clips of law enforcement officers, acting as members of the squad. This is sometimes used as promotion for the next rank or just as a reward. Also, users can collect badges and medals, which are shown at a specific domain of the app (see Figure 6.1), where users also can play again the video clips [26].



Figure 6.1: Pain Squad [26]

Figure 6.1 shows the reward system in which ranks, badges, medals and videos are presented. In the right part of Figure 6.1 a video is shown for rewarding the patient.

In order to provide a good user acceptance, it is vital that users can relate the gamification aspect of the application to assessing pain. Stinson et al. had a theme *Gum Shoe* at

first, but this could not be related to pain assessment, because it was unclear to users. This negative user experience led to a new development, which resulted in the officer theme, leading to an overall higher user acceptance [26].

Feelback and *Pain Squad* have several concepts in common. For example, several gamification concepts like the reward system are used for motivating users. Also, self assessment questionnaires enhance the medical treatment because of the higher patient participation. In addition, the medical context of both applications is very similar, which probably indicates, that concepts like self assessment questionnaires and gamification can be applied in the field of cancer treatment. Several other studies like [27] indicate, that this assertion is most probably true.

As previously mentioned, *Pain Squad* uses a theme, which is present in the entire user interface, whereas *Feelback* uses its gamification concepts in a more subtle way. This design principle is due to the fact, that the targeted average patient's age of *Pain Squad* is younger than in *Feelback*. Also, user acceptance of these gamification in *Feelback* must be evaluated in further studies.

6.1.2 Pit-a-Pat

Among cancer patients, depression is a widespread accompanying illness which is only detected by approximately 30% of the patients. This has several reasons like the lack of time of clinical staff or patients feel not comfortable and reluctant with their mental state [4].

In order to enhance the detection rate for depression among cancer patients, doctors recommend to keep a daily diary, however this paper-based approach is error-prone, because patients often reconstruct entries. Furthermore, for patients it is inconvenient to keep a paper-based diary. For this purpose, Kim et al. developed an iOS and Android application called *Pit-a-Pat*, in which patients can assess their mental health rating on a daily basis. In the beginning of the study, patients fill out a demographic questionnaire which questions age, educational attainment, marital status and occupation. After that, patients can fill out the daily questionnaire on a self assessment basis [4].

6 Related Work

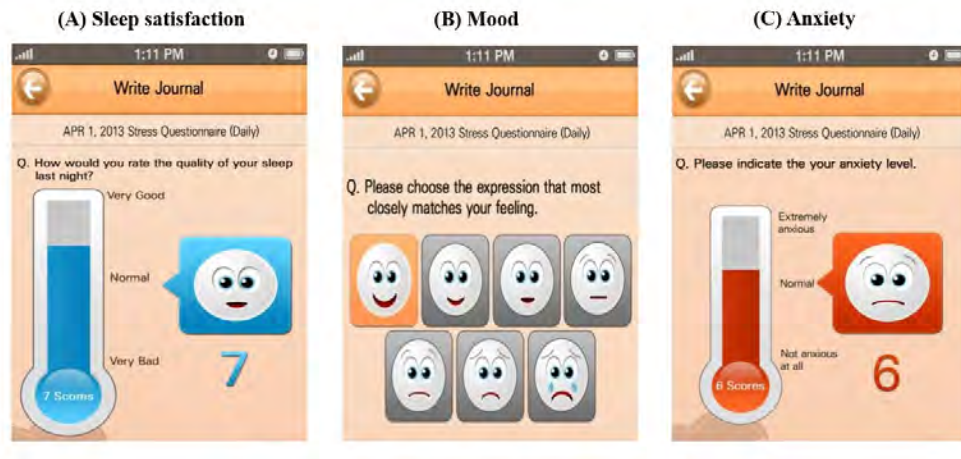


Figure 6.2: Pit-a-Pat: daily diary assessment [4]

Figure 6.2 shows the daily questionnaire which consist of sleep satisfaction, mood and anxiety. This questionnaire checks whether the patient suffers from sleep disturbance which is an indicator for mild depression. Quality of sleep and anxiety level were displayed as a distress thermometer with face emoticons. Everyday at nine am and six pm, users receive notifications, which serve as a reminder to fill out the daily questionnaire. For result validation of the study, users were notified to fill out the Patient Health Questionnaire-9 (PHQ-9) every two weeks.

In total, 78 patients participated in the study over a period of 48 weeks. The main purpose was to investigate, whether it is possible to screen patients for depression, using a digital application, which is completely based on self assessments. The authors of [4] found out, that the self assessment approach is validated with a high accuracy of depression screening. This validation was achieved by a calculation in which it is assumed that PHQ-9 reported the correct screening.

In early 2013, Min et al. did a feasibility study for the Pit-a-Pat application and found out that the overall compliance rate is 45%, which is higher compared to studies that do not use such mobile applications [28].

Figure 6.3 depicts the compliance rate over 91 days, showing that there is a constant decrease. The authors of [28] state, that this effect may results from patients that simply

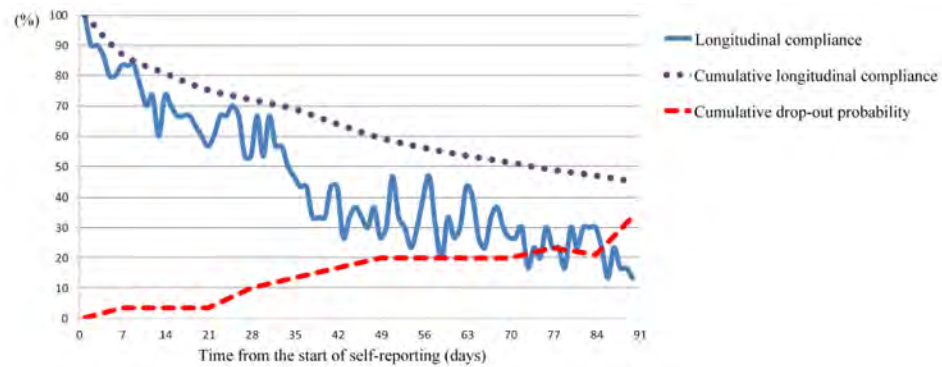


Figure 6.3: Changes in compliance over time [28]

forget the notification. Additionally, it is noted that there are no gamification concepts in *Pit-a-Pat*, compared to *Feelback*.

However, it is noteworthy that user interface elements, like the distress thermometer, are used in a more playful way compared to *Feelback*. This difference is possibly justified with cultural differences between Europe and Asia, because *Pit-a-Pat* is mainly applied in South Korea.

6.2 Wider Related Work

Other related work that use questionnaires for self assessment in mobile applications are [27] [29] [30] [31] [32]. However, the objectives of the mentioned publications are manifold. The authors of [27] answer the question, whether it is possible to assess the psychological state of patients by utilizing the application *Mindful Moods*. Again, the application uses a subset of the PHQ-9 questionnaire. The objective of [29] is to determine, whether users of the mobile application *Health Monitor*, are willing to go to health care professionals when the application detects high depression symptoms. The authors of [30] use self assessment mechanics to find out, whether it is possible to use self-monitoring applications for enhancing the well-being of the users. In *TrackYour-Tinnitus* they developed a mobile application for assessing the fluctuations of tinnitus during daily routines. In addition, the microphone of a smartphone detects a loudness value when filling out questionnaires [32]. In [31] they try to detect emotional changes

6 Related Work

during the day, by using self assessment techniques. In *Feelback*, such techniques are utilized, in order to screen for psychological distress among patients suffering from cancer. Several studies like [29] show, that mobile applications are a valid approach for this.

Findings of the mentioned articles that are worth mentioning are, for example, that a digital subset of the PHQ-9 questionnaire is as accurate as the paper-based. Furthermore, patients with suicidal ideation can be better detected compared to the traditional paper-based approach [27]. BinDhim et al. showed, that approximately 38% patients with high depressive symptoms consult a health care professional, if the mobile application detects high depressive symptoms [29]. The authors of [30] found out, that it is possible to decrease patients' depressive and anxious emotional state and increase their well-being by using self assessment questionnaires. However, this effect was just detected among patients that are rated as clinically depressed at time of the baseline assessment [30]. Pryss et al. showed exemplary for a patient, that the assessed tinnitus loudness fluctuated the most in quiet environments, whereas the tinnitus was perceived in a lower level when the environment was louder. Also, the perceived tinnitus loudness was depicted over time and it showed, that for this individual patient the loudness value increased over the day reaching its maximum at night [32].

Several publications like [27] indicate, that self assessment using questionnaires is a valid way of screening, diagnosing and monitoring patients. Also, such mobile applications are used for a method which is called *Experience sampling method*. In this method, users keep a diary for assessing symptoms on a daily basis.

7

Discussion

In this chapter, general limitations as well as alternative approaches are presented. Moreover, fundamental concepts like gamification for elderly people are discussed.

As already mentioned in Chapter 5.3, Ionic provides Community and Premier plugins. Community plugins are a collection of open source software for Cordova, maintained by the community, whereas Premier plugins are maintained by the Ionic core team. During development, the mobile application required functionality for scanning QR Codes. The first search within the ionic homepage for an appropriate plugin resulted in the open source project *QR Scanner*¹. However, with the introduction of Swift 5² in March 2019, there were severe changes, which broke the native compilation process of *QR Scanner*. This example demonstrates the underlying problem of poor maintained third party software. Developers should always keep in mind that with the release of breaking major releases, the third party software must be updated to this release as well. What is also often a problem of these third party software is the missing or incomplete documentation, which leads to ambiguities in using the API resulting in bugs.

Another limitation which should be mentioned, are the short development cycles of Ionic. Frontend frameworks, especially in web technology, tend to change very frequently. Since Ionic is a framework in this domain, there are new major releases roughly every six months which lead to breaking changes. This means, in order to maintain an Ionic project, high development costs are to be expected. During writing this thesis, the new Ionic version 5.0.0 was released, which should be considered as the next development

¹<https://ionicframework.com/docs/native/qr-scanner> last accessed: 2020-02-20

²<https://swift.org/blog/swift-5-released/> last accessed: 2020-02-20

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step, since the current used version is 4.11.10. The migration process³ from major version 4.X to 5.0 could probably take some time, because there are breaking changes in APIs for various components. Since the underlying major version of Angular also changes (from 8 to 9), this also comes with changes for someone's own project as well as in third party software. Used third party software could be build with major version 8, which would probably break the software as a whole.

In Chapter 5.2, the usage of the JavaScript framework *SurveyJS* was introduced. This usage involves several limitations to the *Feelback* project. *SurveyJS* supports all types of questions like single choice questions or multiple choice questions, but only supports about 15 custom widgets like the previously mentioned *noUiSlider*. Additionally, the integration of these widget's API is in some cases poorly managed like it was here the case. In case of the *noUiSlider*, special features like sliding from right to left could not be integrated into *SurveyJS*. Since *SurveyJS/widgets*⁴ is an open source project, developers can overcome this problem by extending the source code. This was done in *Feelback*⁵, so the *noUiSlider* can be used as a Distress Thermometer in the corresponding questionnaire, in order to map the paper-based Distress Thermometer (see Figure 2.2). Note that developers which use *SurveyJS* are always restricted to the supported widgets. Moreover, when extending the source code of *SurveyJS/widgets*, developers are always dependent on staff of *SurveyJS* that accept the pull requests on GitHub. Of course, this hurdle can be overcome by writing a custom questionnaire framework, but this approach consumes many resources, in order to provide as many features as *SurveyJS* has. Furthermore, the integration of third party JavaScript frameworks into someone's own project increases the dependency to other software, which involves limitations to the project. For example, the project, which uses the third party software is dependent on the maintenance of the third party software. As one can see in the previous paragraph dealing with the *QR Scanner*, this is often a pitfall for software projects. If the maintenance of a third party software has stopped, developers should consider to use another framework. This process is always resource consuming and probably could

³<https://github.com/ionic-team/ionic/blob/master/BREAKING.md> last accessed: 2020-02-21

⁴<https://github.com/surveyjs/widgets> last accessed: 2020-02-20

⁵<https://github.com/surveyjs/widgets/pull/156> last accessed: 2020-02-28

lower the quality of the software project, since the new third party framework has e.g. different functionality or even a different user interface.

Another limitation of this work was that there was no backend available during development. In order to develop the frontend independently, the backend was simulated using a mockup component (Chapter 5.4). This approach has limitations, for example, when the real backend is deployed, the mobile application must possibly be adapted to the new backend. Also, it is required that the entire functionality of the mobile application is tested when such critical software part changes. For this, the existing unit tests should indicate, whether the real backend acts in an expected or unexpected manner.

As described in Chapter 4.2, several gamification frameworks do not consider elder people in their conception [23]. Most probably, this is due to fact, that the target group for gaming in mobile applications are younger persons. However, when developing concepts for long term motivating patients in mobile eHealth applications, elderly people are the largest target group. Because of this fact, special focus should be put on those people. In several gamification frameworks like in [24], players are classified into specific player types. This classification describes players with their personality, regardless of their age. Furthermore, it can be expected that all humans have a certain play instinct, which is also independent of age. For certain video games like *Counter Strike*, there are groups of elderly people playing together in clans. They call themselves *Silver Gamers*, playing on several tournaments all over the world⁶. However, in this field further research is required, to examining gaming techniques for elderly people.

Finally, the change of the current process in a medical facility should also be considered. As described in Chapter 3.1, the current process of screening patients with subsequent psychological consultation is mostly paper-based. In order to digitalize this process, several steps are necessary to restructure the hospital's internal work-flow. For example, the HIS current used must be extended, in order to communicate with *Feelback*. Furthermore, medical staff like practitioners or people who are directors of studies must be able to operate with smartphones, in order to explain critical features of the application, if the patient requests this help.

⁶<https://www.arte.tv/de/videos/086138-021-A/re-silver-gamers/> last accessed: 2020-02-21

8

Conclusion

The objective of this thesis was to develop a medical, mobile application with principles of patient participation, gamification and self assessment questionnaires. Such concepts will enhance the screening process and, therefore, result in a better overall psychological treatment of patients. The application field of this software is in a medical setting, where a) cancer patients are screened for psychological issues and b) practitioners of different parties access these screenings, in order to treat the patient.

This goal was reached with the help of the mentioned techniques. Patient participation enhances the medical treatment process, because patients take a more active role in decision making processes. This leads to a better overall treatment. Moreover, the developed application enhances the medical screening process by digitalizing the latter. With this approach, results can be evaluated in an automated manner. Furthermore, the communication between patients, practitioners and other participating parties, like psychologists is enhanced.

This medical application fulfills a patient centralized approach. Whenever practitioners want to access data from patients, the patient has to permit access to this person. This technique increases trust in the system, which most likely result in proper data of the self assessment questionnaires.

Furthermore, this thesis describes the current As-Is process and what is needed for the To-Be process. Within this thesis, the integration of the mobile application into the To-Be process is described. This enhances the communication of the participating parties by using a dedicated application.

8 Conclusion

Concepts for long term motivation like gamification enhance user experience on the one side and the generated data from the self assessment questionnaires on the other side, because the study dropout rate is low.

Finally, this thesis describes the user interface of *Feelback*, which contains all the previously mentioned principles.

8.1 Further Research

In order to run this application in a productive environment, several tests are necessary. First, *End to End* testing frameworks like Cypress¹ should be utilized for writing such automated tests. For this, Cypress seems to be a profound framework, because it is an All-in-One solution and furthermore provides constant results of tests [33].

In a next step, the technical aspects of the mobile application should be tested by humans (e.g. beta testers). Special focus should be put on different environments like iOS, Android and various browsers. Furthermore, several display sizes should be evaluated by using different devices like smartphones or tables.

The next step is to evaluate the overall user acceptance of the application. The design of the user interface and clarity of routing should be evaluated. Additionally, it is vital to evaluate, whether the gamification concepts of *Feelback* work as expected. This can be checked with large scale acceptance testing. Here, special focus should be put on elderly people and whether these gamification concepts motivate them.

It is also important to test the mobile application again when the development of the final backend system is completed. This is due to the fact, that migrating from the mockup backend to the real backend will require certain adaptations.

Finally, the entire system which is integrated in a medical facility should also be evaluated in a further work. Within this test, special focus should be put on the seamless communication between *Feelback* and existing HIS.

¹<https://www.cypress.io/> last accessed: 2020-03-03

Bibliography

- [1] Maguire, P.: Improving the detection of psychiatric problems in cancer patients. *Social science & medicine* (1985)
- [2] Zabora, J., BrintzenhofeSzoc, K., Curbow, B., Hooker, C., Piantadosi, S.: The prevalence of psychological distress by cancer site. *Psycho-Oncology: Journal of the Psychological, Social and Behavioral Dimensions of Cancer* **10** (2001) 19–28
- [3] Stark, D., Kiely, M., Smith, A., Velikova, G., House, A., Selby, P.: Anxiety disorders in cancer patients: their nature, associations, and relation to quality of life. *Journal of clinical oncology* **20** (2002) 3137–3148
- [4] Kim, J., Lim, S., Min, Y.H., Shin, Y.W., Lee, B., Sohn, G., Jung, K.H., Lee, J.H., Son, B.H., Ahn, S.H., et al.: Depression screening using daily mental-health ratings from a smartphone application for breast cancer patients. *Journal of medical Internet research* **18** (2016) e216
- [5] Moser, A., Steckelberg, A., et al.: Patient participation-what is it? *Zeitschrift für Evidenz, Fortbildung und Qualität im Gesundheitswesen* **110** (2016) 12–15
- [6] EPF: Epf background brief: Patient empowerment. https://www.eu-patient.eu/globalassets/campaign-patient-empowerment/epf_briefing_patientempowerment_2015.pdf (2015) last accessed: 2020-01-17.
- [7] Bate, P., Robert, G.: Experience-based design: from redesigning the system around the patient to co-designing services with the patient. *BMJ quality & safety* **15** (2006) 307–310
- [8] Eysenbach, G.: What is e-health? *Journal of medical Internet research* **3** (2001) e20
- [9] Deterding, S., Khaled, R., Nacke, L.E., Dixon, D.: Gamification: Toward a definition. In: CHI 2011 gamification workshop proceedings. Volume 12., Vancouver BC, Canada (2011)

Bibliography

- [10] Sardi, L., Idri, A., Fernández-Alemán, J.L.: A systematic review of gamification in e-health. *Journal of biomedical informatics* **71** (2017) 31–48
- [11] Holland, J.C.: History of psycho-oncology: overcoming attitudinal and conceptual barriers. *Psychosomatic medicine* **64** (2002) 206–221
- [12] Gundlach, H.: What is a psychological instrument. *Psychology's territories: Historical and contemporary perspectives from different disciplines* (2007) 195–224
- [13] Network, N.C.C., et al.: Distress management. clinical practice guidelines. *Journal of the National Comprehensive Cancer Network: JNCCN* **1** (2003) 344
- [14] Zigmond, A.S., Snaith, R.P.: The hospital anxiety and depression scale. *Acta psychiatrica scandinavica* **67** (1983) 361–370
- [15] Rumpold, G., Augustin, M., Zschocke, I., Strittmatter, G., Söllner, W.: Die Validität des Hornheider Fragebogens zur psychosozialen Unterstützung bei Tumorpatienten. *PPmP-Psychotherapie· Psychosomatik· Medizinische Psychologie* **51** (2001) 25–33
- [16] Herschbach, P., Marten-Mittag, B., Henrich, G.: Revision und psychometrische Prüfung des Fragebogen zur Belastung von Krebskranken (FBK-R23). *Zeitschrift für Medizinische Psychologie* **12** (2003) 69–76
- [17] Herschbach, P.: Behandlungsbedarf in der Psychoonkologie. *Der Onkologe* **12** (2006) 41–47
- [18] Herschbach, P., Weis, J.: Screeningverfahren in der Psychoonkologie. Testinstrumente zur Identifikation betreuungsbedürftiger Krebspatienten. Berlin: Deutsche Krebsgesellschaft (2008)
- [19] Jacobsen, P.B., Donovan, K.A., Trask, P.C., Fleishman, S.B., Zabora, J., Baker, F., Holland, J.C.: Screening for psychologic distress in ambulatory cancer patients: a multicenter evaluation of the distress thermometer. *Cancer* **103** (2005) 1494–1502
- [20] Coyne, J.C., Palmer, S.C., Shapiro, P.J., Thompson, R., DeMichele, A.: Distress, psychiatric morbidity, and prescriptions for psychotropic medication in a breast cancer waiting room sample. *General hospital psychiatry* **26** (2004) 121–128

- [21] Cockburn, A.: Structuring use cases with goals. *Journal of Object-Oriented Programming* **10** (1997) 56–62
- [22] Pike, M.C., Krailo, M., Henderson, B., Casagrande, J., Hoel, D.: ‘Hormonal’ risk factors, ‘breast tissue age’ and the age-incidence of breast cancer. *Nature* **303** (1983) 767–770
- [23] de Vette, F., Tabak, M., Dekker-van Weering, M., Vollenbroek-Hutten, M.: Engaging elderly people in telemedicine through gamification. *JMIR serious games* **3** (2015) e9
- [24] Marczewski, A.: User types. Even Ninja Monkeys Like to Play: Gamification, Game Thinking and Motivational Design **1** (2015) 65–80
- [25] Primack, B.A., Carroll, M.V., McNamara, M., Klem, M.L., King, B., Rich, M., Chan, C.W., Nayak, S.: Role of video games in improving health-related outcomes: a systematic review. *American journal of preventive medicine* **42** (2012) 630–638
- [26] Stinson, J.N., Jibb, L.A., Nguyen, C., Nathan, P.C., Maloney, A.M., Dupuis, L.L., Gerstle, J.T., Alman, B., Hopyan, S., Strahlendorf, C., et al.: Development and testing of a multidimensional iphone pain assessment application for adolescents with cancer. *Journal of medical Internet research* **15** (2013) e51
- [27] Torous, J., Staples, P., Shanahan, M., Lin, C., Peck, P., Keshavan, M., Onnela, J.P.: Utilizing a personal smartphone custom app to assess the patient health questionnaire-9 (phq-9) depressive symptoms in patients with major depressive disorder. *Journal of medical Internet research mental health* **2** (2015) e8
- [28] Min, Y.H., Lee, J.W., Shin, Y.W., Jo, M.W., Sohn, G., Lee, J.H., Lee, G., Jung, K.H., Sung, J., Ko, B.S., et al.: Daily collection of self-reporting sleep disturbance data via a smartphone app in breast cancer patients receiving chemotherapy: a feasibility study. *Journal of medical Internet research* **16** (2014) e135
- [29] BinDhim, N.F., Alanazi, E.M., Aljadhey, H., Basyouni, M.H., Kowalski, S.R., Pont, L.G., Shaman, A.M., Trevena, L., Alhawassi, T.M.: Does a mobile phone depression-screening app motivate mobile phone users with high depressive symptoms to seek

Bibliography

- a health care professional's help? *Journal of medical Internet research* **18** (2016) e156
- [30] Bakker, D., Rickard, N.: Engagement in mobile phone app for self-monitoring of emotional wellbeing predicts changes in mental health: Moodprism. *Journal of affective disorders* **227** (2018) 432–442
- [31] Rickard, N., Arjmand, H.A., Bakker, D., Seabrook, E.: Development of a mobile phone app to support self-monitoring of emotional well-being: a mental health digital innovation. *Journal of medical Internet research mental health* **3** (2016) e49
- [32] Pryss, R., Reichert, M., Langguth, B., Schlee, W.: Mobile crowd sensing services for tinnitus assessment, therapy, and research. In: 2015 IEEE International Conference on Mobile Services, IEEE (2015) 352–359
- [33] Wohlwend, V.: Comparative Analysis of UI Testing Frameworks for Web Applications. Bachelor's thesis, Ulm University, Ulm (2019)

A

QR Code Card

Figure A.1 depicts an example QR card as it could look like. The QR Code contains the patient's credentials encoded into a JSON object.



Figure A.1: Example Design for a QR Code Card

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Acronyms

API Application Programming Interface. 19, 35, 42, 43, 65, 66

CSS Cascading Style Sheets. 35, 37

EPF European Patients' Forum. 5

FAB Floating Action Button. 23, 49, 52, 53, 58

GPS Global Positioning System. 41

HIS Hospital Information System. 2, 14, 15, 67, 70

HTML Hypertext Markup Language. 35, 40

JSON JavaScript Object Notation. 38, 39, 42, 75

PWA Progressive Web App. 20

QR Quick Response. 15, 16, 18, 20, 23, 24, 26, 41, 48, 58, 65, 75, 77

REST Representational State Transfer. 42

XP Experience Points. 32, 33, 54

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Honesty disclaimer

I hereby affirm that I wrote this thesis independently and that I did not use any other sources or tools than the ones specified.

Ulm, 07.04.2020



Michael Schrepp