FAKULTÄT FÜR INFORMATIK
DER TECHNISCHEN UNIVERSITÄT MÜNCHEN

Bachelor’s Thesis in Computer Science

# Collection of Metadata from Mental Health Questionnaires

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# Erfassung von Metadaten aus Fragebögen zur psychischen Gesundheit

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I confirm that this bachelor's thesis is my own work, and I have documented all sources and material used.

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Garching, Munich; June 15th, 2022

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Signature

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I would like to thank the eighteen individuals who completed the System Usability Scale (SUS) questionnaire and took the time to evaluate this thesis.

## Abstract

This thesis presents a digital platform solution that enables patients to efficiently complete the PHQ-9 and GAD-7 mental health questionnaires in English and German while allowing psychiatrists to monitor the results. The digital platform operates as a web application, and the service is accessible from every Internet-connected device. The database administrator can collect a vast array of metadata from the questionnaires filled out by respondents, including scores, time, geolocation, and device information. In addition, psychiatrists are able to visualize the progress of the entire patient group, monitor each patient individually, and compare the scores of two patient groups. In addition to completing the Mental Health Questionnaires PHQ-9 and GAD-7, patients may also provide personal information to aid the mental health researchers' research progress. Subsequently, the digital platform completed a System Usability Scale (SUS) evaluation and a Lighthouse evaluation with good results. In the end, the author discusses the future enhancements, the application of this platform to real-world diagnosis as well as future research agenda.



**Keywords:** Mental Health Questionnaires, Metadata, PHQ-9, GAD-7, Digital Platform, Web Application

## Abbreviations

| | |
|---|---|
| API | Application Programming Interface |
| AWS | Amazon Web Services |
| BaaS | Back-end as a Service |
| CRUD | Create, Retrieve (or Read), Update, and Delete |
| CS | Computer Science |
| CSS | Cascade Style Sheet |
| DOM | Document-Oriented Model |
| GAD-7 | Generalized Anxiety Disorder 7 |
| NoSQL | Non Structured Query Language |
| PHQ-9 | Patient Health Questionnaire 9 |
| PWA | Progressive Web App |
| RDBMS | Relational Database Management Systems |
| RWD | Responsive Web Design |
| SPA | Single Page Application |
| SQL | Structured Query Language |
| SUS | System Usability Scale |

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# 1. Introduction

Over the past decades, the population has had a growing mental health problem. According to recent statistics, one in five of the world's children and adolescents is battling with some form of mental health condition. (*Mental Health*, n.d.) As a result, scientists and research centers around the world are working on the solution to this phenomenon. Furthermore, one needs a reliable method to detect mental health issues to perform that. One of the most commonly employed methods to detect them is through the usage of questionnaires. (Hwang & Oh, 2014) With this method, psychiatrists can consult the patients who are respondents to these questionnaires. For example, the Pfizer mental health questionnaire contains ten questions, in which the patients fill out the boxes with suitable answers about the frequency of their mental health issues, ranging from not at all to every day. (Kroenke et al., 2001) Afterward, the psychiatrists will examine the information from the filled questionnaires to diagnose and decide what kind of therapy or actions are necessary for the patients. The limitation of this approach lies in the narrowness of the obtained information: By simply aggregating the scores and assigning a category, one misses out on crucial supplemental information. As a result, one question that emerges with this method is how psychiatrists can potentially improve their ability to analyze these questionnaires. The collection of metadata and utilization of artificial intelligence are among the possible improvements that are being discussed. (Battaglia et al., 2008; Buskirk & Kirchner, 2020) Here, within the framework of the research, the thesis will investigate the collection of metadata in mental health questionnaires.

## 1.1 Motivation

While several attempts have been made to build platforms for the metadata collection of questionnaires since the beginning of this bachelor's thesis, none have been specifically designed for a mental health questionnaire, to the best of my knowledge. One of the most notable examples is Colectica, which is a suite of programs for use in documenting official statistics and specifying statistical surveys using open standards that enable researchers, archivists, and programmers to perform questionnaire design. (*Colectica*, n.d.)

In addition, the digitalization process has led to a gradual shift away from traditional psychiatry methods, such as face-to-face diagnosis, in favor of virtual counseling. (*Online Doctor Consultation Market to Grow 72% to $836 Million by March 2024*, n.d.) Patients and psychiatrists will now have the option to provide and receive diagnoses from anywhere and at any time via the Internet. This solution gives everyone considerably more flexibility in the face of life's complexities. The process is particularly reinforced and accelerated in the aftermath of the Covid-19 pandemic. (Crane et al., 2020) Seventy-five percent of respondents to a survey conducted by Boston Consulting Group (BCG) reported maintaining or increasing their productivity in a remote setting. According to respondents, this was primarily attributable to the convenience and effectiveness of virtual conference rooms and video calls. (*Survey Shows Employees Felt Surprisingly Productive During COVID-19*, n.d.)

The literature on the relationship between mental health questionnaires, such as PHQ-9 and GAD-7, and patient-related or questionnaire-related metadata is vast. Due to the fact that the data is now managed on a cloud service rather than in massive case files, psychiatrists and mental health researchers will also be able to analyze the data efficiently. Utilizing health data analytics enables improvements in patient care, including faster and more accurate diagnoses, preventative measures, more personalized treatment, and more informed decisions. (*The Role of Data Analytics in Health Care*, n.d.) It can reduce costs and simplify internal operations at the enterprise level, among other benefits. (*The Role of Data Analytics in Health Care*, n.d.) With a unified platform that collects all categories, mental health researchers will have much more freedom to investigate the statistical correlation between the variables.

## 1.2 Research Questions

The goal of this project is to create a functional digital platform where patients can fill out questionnaires quickly and psychiatrists can track their progress while collecting all of the data. Three research questionnaires are provided as a guide to achieving this goal:

**Q1 – What is the current state of the scientific literature regarding metadata usage in questionnaires?**

This research question will be approached through a scientific literature review. This literature review is supported by the summary from vom Brocke (2011). (Brocke et al., 2009)

**Q2 – What are the functionalities of a platform that improves current questionnaires in mental health by collecting metadata?**

This functionality may be done by combining the work from the first research question with a design brainstorming for the digital platform.

**Q3 – How can those functionalities be implemented?**

Evaluation of multiple technologies is the first step. Then, a concrete attempt at implementation is made. The platform will subsequently be evaluated.

## 1.3 Description of Work

This thesis addresses the abovementioned issues mentioned in the motivation section by introducing a digital platform. This digital platform's features can be implemented with a full-stack web application written in JavaScript and utilizing the Node.js and Vue.js frameworks. JavaScript is a programming language that enables complex web page features to be implemented. (*JavaScript Basics - Learn Web Development | MDN*, n.d.) Node.js enables the development of fast web servers in JavaScript. (Node.js, n.d.) With Vue.js, one has a very flexible frontend framework that can build user interfaces and single-page applications. (*Vue.Js - The Progressive JavaScript Framework | Vue.Js*, n.d.)

The backend service Supabase, which utilizes the PostgreSQL database, is complementary to the JavaScript frameworks. Supabase is a backend-as-a-service and serves as the application's backbone. It provides an Amazon Web Service-hosted PostgreSQL database with lightning-fast performance. (*Introduction | Supabase*, n.d.) The PostgreSQL database is a SQL database that supports statistical filtering and aggregation, as well as the ability to determine the relationship between columns in relational databases. (*What Is PostgreSQL?*, 2022)

This thesis also includes the design, implementation, and evaluation of the web application.

During implementation, the focus is on meeting the requirements outlined in the design section. The thesis concludes by discussing the potential implementation of this platform for patients and psychiatrists.

## 1.4 Thesis Outline

The second chapter begins with definitions and an overview of the current state of mental health questionnaire metadata. This chapter also includes a concise literature review of mental health questionnaire metadata. For the literature review, a comprehensive concept matrix is established. After that, a comparison of cutting-edge front-end and back-end technologies is presented in chapter 3.

The requirements and architecture of the web application are described in chapter 4. The front-end must be captivating and dynamic in order to capture the users' attention. Meanwhile, the back-end must be efficient and dependable to ensure that the system consistently operates at the highest level. Afterward, the design decisions for each component and the accompanying illustrations are presented to provide a comprehensive overview of what will be implemented in chapter 5. Due to the fact that this digital platform is intended to serve both patients and psychiatrists, there are sections discussing the unique challenges of each role.

The fifth chapter details the implementation of the points mentioned earlier. The fundamentals of a web application, including folder structure, routing, and local state management, are discussed first. These components are essential because they form the backbone of the entire web application. The following sections will discuss the implementation of each component of the web application. These are to be divided into three major sections, one for the common area, one for the role of patients, and one for the role of psychiatrists. Last but not least, the implementation and management of the back-end service will be discussed.

Chapter 6 then evaluates the product's implementation. Eighteen individuals, including both patients and psychiatrists, completed a System Usability Scale questionnaire to assess the web application's performance and usability. In addition, the thesis utilized Google's Lighthouse, an automated analysis tool, to evaluate the quality of the web application based on guidelines developed by industry experts.

The possibilities of integrating this digital platform into the actual use of patients and psychiatrists are discussed in chapter 7. There is additional discussion of potential difficulties that may arise due to the complexity of real-world scenarios. Another reflection on the previously discussed literature review is presented. Moreover, a list of potential future research topics is compiled based on the previous discussions. The eighth and final chapter of this thesis provides a summary and conclusion for this bachelor’s thesis.

# 2. Background and related Work

This chapter discusses the background and related work, which galvanize and give foundation to the design and implementation of the digital platform this thesis is building. Firstly, an introduction to the definition of metadata and the current state of mental health questionnaires is presented. This chapter also summarizes the current literature regarding metadata usage in mental health questionnaires.

## 2.1 Metadata in Mental Health Questionnaire

This section presents the definitions of “metadata,” “mental health,” “questionnaire,” and “mental health questionnaire.” This section is the preliminary for what to come in section 2.2, which will be a brief presentation on the literature review about the topic “metadata in mental health questionnaires.”

### 2.1.1 Metadata

Metadata is "data that provides information about other data," but not the content of the data, such as the text of a message or the image itself. There are many distinct types of metadata, including:

- Descriptive metadata — information about a resource that is descriptive. It is utilized for finding and identifying things. The title, abstract, author, and keywords are all included.
- Structural metadata — information about data containers that describes how complex objects are put together, such as how pages are organized into chapters. It explains digital materials' types, versions, relationships, and other features.
- Administrative metadata — the information to help manage a resource, like a resource type, permissions, and when and how it was created.
- Reference metadata — the information about the contents and quality of statistical data.
- Statistical metadata, also known as process data, can be used to describe statistical data collection, processing, or production processes.
- Legal metadata — provides information about the creator, copyright holder, and public licensing, if provided.

Metadata is not limited to a single category, as it can describe a data item in numerous other ways. (“Metadata,” 2022)

### 2.1.2 Mental Health Questionnaire

There are two subparagraphs that define "mental health" and "questionnaires." The following section provides an overview of the most well-established mental health questionnaires, PHQ-9 and GAD-7, which will be implemented on the digital platform. (Richardson et al., 2017)

## Mental Health

Mental health refers to cognitive, behavioral, and emotional well-being. It is all about how people think, feel, and behave. People sometimes use the term "mental health" to mean the absence of a mental disorder. (*Mental Health*, 2020)

According to the World Health Organization (WHO): "Mental health is a state of well-being in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively, and is able to make a contribution to his or her community." The WHO stress that mental health is "more than just the absence of mental disorders or disabilities." Peak mental health is about not only avoiding operational conditions but also looking after ongoing wellness and happiness. (Galderisi et al., 2015)

They also emphasize that preserving and restoring mental health is crucial on an individual basis, as well as throughout different communities and societies the world over. In the United States, the National Alliance on Mental Illness estimates that almost 1 in 5 adults experience mental health problems each year. In 2017, an estimated 11.2 million adults in the United States, or about 4.5% of adults, had a severe psychological condition, according to the National Institute of Mental Health (NIMH). (*Mental Health*, 2020)

## Questionnaire

In a survey, the researcher collects information from respondents via a questionnaire in order to answer the research questions. A questionnaire is a quick and easy way to gather information from a large number of people in a short amount of time. As a result, the questionnaire's design is critical in ensuring that accurate data is collected and that the results are interpretable and generalizable. A bad questionnaire can make the results difficult to interpret or even lead to incorrect conclusions. (Jenn, 2006)

A survey can come in many forms: postal surveys, telephone interviews, face-to-face interviews, and internet surveys. Each type of survey requires a slightly different design. A self-administered questionnaire (e.g., postal survey) should have unambiguous instructions and questions, follow a logical order and avoid complex filtering. The respondents are more likely to answer truthfully without prompting from an interviewer. On the other hand, in an interviewer-administered questionnaire (e.g., face-to-face interview or telephone interview), the questions can be more complex as they can be clarified by the interviewers. However, the presence of an interviewer may "pressurize" the respondents to give "appropriate" rather than truthful answers. (Jenn, 2006)

## Mental Health Questionnaires

The two most well-established mental health questionnaires are the Patient Health Questionnaire 9 (PHQ-9) and the Generalized Anxiety Disorder (GAD-7). (Richardson et al., 2017)

## PHQ-9

The PHQ-9 is a clinically-validated screening tool that healthcare providers use to screen for depression and also to diagnose and monitor the severity of the condition. The PHQ-9 is similar to the Edinburgh Postnatal Depression Scale (EPDS), but where the EPDS is designed to screen pregnant and postpartum women for depression, anyone can take the PHQ-9 and receive actionable results. (*Interpreting Your PHQ-9 Depression Screening Results*, n.d.)

**PHQ-9 Scoring**

The PHQ-9 consists of nine questions that ask respondents how often they have "been bothered by any of the following problems" in the past two weeks. The questions address sleep, energy, appetite, and other possible symptoms of depression. Scores are calculated based on how frequently a person experiences these feelings. (Kroenke et al., 2001) Each "not at all" response is scored as 0; each "several days" response is 1; each "more than half the days" response is 2, and each "nearly every day" response is 3. The sum value of these responses gives the patient the total score.

| Score | Diagnosis | Severity |
|---|---|---|
| **0-4** | This is considered minimal depression, which suggests that the respondent may not need depression treatment. | Minimal |
| **5-9** | This is considered mild depression. In response to this result, healthcare providers can use their clinical judgment about treatment based on the duration and severity of symptoms. | Mild |
| **10-14** | This is considered moderate depression. Similar to mild depression, healthcare providers can use their clinical judgment and knowledge of the patient to determine a course of treatment. | Moderate |
| **15-19** | This is considered moderately severe depression. This generally warrants treatment for depression using a medication, therapy, or a combination of the two. | Moderately severe |
| **20-27** | This is considered severe depression. This warrants treatment for depression using a medication, therapy, or a combination of the two. | Severe |

**Table 1: PHQ-9 score and diagnosis**
**(Source: (*PHQ-9 (Patient Health Questionnaire-9)*, n.d.))**

**GAD-7**

GAD-7 is a sensitive self-administrated test to assess generalized anxiety disorder, customarily used in outpatient and primary care settings for referral to a psychiatrist pending the outcome. The normative data enable users of the GAD-7 to discern whether an individual's anxiety score is minimally, mildly, moderately, or severely elevated. However, it cannot be used as a replacement for clinical assessment, and additional evaluation should be used to confirm a diagnosis of Generalized Anxiety Disorder. (Spitzer et al., 2006)

**GAD-7 Scoring**

The GAD-7 consists of seven questions. The questions address sleep, energy, appetite, and other possible anxiety symptoms. Scores are calculated based on how frequently a person experiences these feelings. (Spitzer et al., 2006) Each "not at all" response is scored as 0; each "several days" response is 1; each "more than half the days" response is 2, and each "nearly every day" response is 3. The sum value of these responses gives the patient the total score.

| Score | Diagnosis | Severity |
|---|---|---|
| **0-4** | This is considered minimal anxiety, which suggests that the respondent may not need anxiety treatment. | Minimal |
| **5-9** | This is considered mild depression. In response to this result, healthcare providers can use their clinical judgment about treatment based on the duration and severity of symptoms. | Mild |
| **10-14** | This is considered moderate anxiety. Similar to mild anxiety, healthcare providers can use their clinical judgment and knowledge of the patient to determine a course of treatment. | Moderate |
| **15-21** | This is considered severe anxiety. This warrants treatment for anxiety using a medication, therapy, or a combination of the two. | Severe |

**Table 2: GAD-7 score and diagnosis**
**(Source: (*GAD-7 (General Anxiety Disorder-7)*, n.d.))**

## 2.2 Literature on Metadata in Mental Health Questionnaire

This section contains a brief review of the literature on the topic of "metadata in mental health questionnaires." It is divided into two parts, preparation and concept matrix. Despite the fact that the digital platform that will be implemented will make every effort to capture as much information as possible from the following metadata, the following section can nonetheless serve as a comprehensive overview of the research. This literature review identifies which metadata is essential or has a high statistical correlation with the diagnosis process, as well as provides an explanation for why.

### 2.2.1 Literature Review Preparation

The preparation for the literature review contains three steps: Determining the research scope, gathering the foundational knowledge, and performing the database search. The research scope contains a comprehensive table establishing the taxonomy of the literature review. Foundational knowledge is primarily introduced in section 2.1. The database search establishes another table containing different metadata types

**Research Scope**

To conduct a literature review, it is necessary to start with a table defining the scope of the study. The required characteristics for the research are listed in the table below. The initial focus of the research is on the research's outcomes and their potential applications; the ultimate objective is to determine the effects of metadata on mental health questionnaires. This thesis is in the field of computer science, whereas most research papers are in the field of psychiatry. Consequently, the research methods and theories underlying these papers are of little relevance. This literature review's second objective is integrating the research findings and their applications into this dissertation. The objective is not to criticize these papers or make them the focal point of the discussion, as they are in a different domain than the one in which we are working.

This literature review is organized according to the concepts associated with each metadata. Here one can find that each piece of metadata has a unique statistical correlation with the results of the mental health questionnaires. The historical context of these papers has no significant bearing on their interpretation. In addition, the neutral nature of the perspective provided by the literature review is due to the fact that the papers are from different domains.

Because this is not the purpose of the literature review, there is no requirement to adopt a particular standpoint.

The intended audience consists of general scholars as well as those interested in learning more about metadata in general or those who are interested in learning about the roles of metadata in mental health questionnaires. It should neither be too specific for specialized scholars nor too broad for the general public. The coverage of the research papers should also be central or pivotal; because of the effects of a single metadata type, multiple research papers can be written, so it is imperative that the selection be central or pivotal.

| Characteristic | Categories | | | |
|---|---|---|---|---|
| **Focus** | Research outcomes | Research Methods | Theories | Applications |
| **Goal** | Integration | Criticism | Central Issues | |
| **Organization** | Historical | Conceptual | Methodological | |
| **Perspective** | Neutral Representation | Espousal of position | | |
| **Audience** | Specialized scholars | General scholars | Practitioners/ Politicians | General public |
| **Coverage** | Exhaustive | Exhaustive and selective | Representative | Central/pivotal |

**Table 3: Taxonomy of literature review (Shade for chosen option)**
**(Source: Own analysis)**

### Foundational Knowledge

The second step of the literature review is to provide a comprehensive overview of what is known about the topic and potential knowledge gaps. This topic is covered in detail in section 2.1 in order to provide readers with a foundational understanding of the topic. This section includes the definitions of "metadata," "mental health," "questionnaire," and the introduction of the most well-established mental health questionnaires.

### Database Search

Database searches constitute the third step of the literature review. On Google Scholar, articles are selected that contain one of the keywords PHQ-9, GAD-7, or Mental Health in addition to a metadata-related keyword. The thesis seeks to select papers with a high degree of relevance to the metadata type with a presence in prestigious journals or a high citation count. Based on the types of metadata, the following table categorizes the studies on mental health.

| Type | Classification of Mental Health Studies based on Metadata types |
|---|---|
| **Age** | (Leung et al., 2020), (Rossom et al., 2017) |
| **Gender** | (Borgogna et al., 2021) |
| **Device** | (Erbe et al., 2016), (Dosovitsky et al., 2021), (Grunauer et al., 2014) |
| **Language** | (Arthurs et al., 2012), (García-Campayo et al., 2010), (Reich et al., 2018) |
| **Score** | (Manea et al., 2012), (Plummer et al., 2016) |

**Table 4: Notable papers based on metadata types**
**(Source: Own analysis)**

## 2.2.2 Concept Matrix

From the selected papers, a concept matrix for the literature review can be derived. Relevant information includes the publication year, the institution's location, the questionnaire type, which may be either the PHQ-9 or the GAD-7, or both, the dataset description, and the metadata type and effect.

The description of the dataset includes information regarding the sample size and whether or not the dataset is internal or external. An internal dataset belongs to the same institution. An external dataset consists of data from institutions other than their own. Another example of an external dataset is when the authors perform a database search for data instead of gathering it from their own institutions. The impact of a metadata type can be little, some, or significant. For instance, if the author states that the difference is statistically insignificant, the effect can be classified as minor.

Leung (2020) aims to identify the factor structure and examine the measurement invariance of this instrument across genders and age groups in a Chinese adolescent sample. The paper shows that age has minimal effect on the results of the questionnaires and that the PHQ-9 is a reliable and valid scale that can be used to assess and compare depressive severity across ages and genders during adolescence. (Leung et al., 2020) Another similar paper is Rossom (2017), which presents research on the link between the PHQ-9 performances with suicide attempts, with a much larger sample size of 287290. This paper demonstrates that there is some effect of gender and age on the metadata's results while remaining consistent. (Rossom et al., 2017) Borgogna (2021) is another interesting paper that researches the sexuality and gender invariance of the PHQ-9 and the GAD-7, which in turn discovers that gender affects the scores. According to the research, all non-cisgender groups had significantly higher item 9 factor loadings than cisgenders. (Borgogna et al., 2021)

Erbe (2016) investigates the inter-format reliability of a computerized version of the PHQ-9, which shows high correlations to the paper format. (Erbe et al., 2016) This significant result confirms the digital platform's reliability in the thesis, which will be the main topic in chapters 4 and 5. Dosovitsky (2021) assesses the feasibility of administering the PHQ-9 in a sample of adults and older adults via chatbot, and the study shows that the PHQ-9 delivered through a chatbot is reliable. (Dosovitsky et al., 2021) Grunauer (2014) measures the efficiency of tablet-based PHQ-9 in screening depressive symptoms in primary care and concludes that tablet-based PHQ-9 is an excellent and efficient method of screening depression. (Grunauer et al., 2014)

Arthurs (2012) assesses the difference between the score of the French and English-speaking patients of Canada and finds the results between the two groups are consistent. The size of each group is 739 and 221. (Arthurs et al., 2012) García-Campayo (2010) investigates the validity of the Spanish version of the GAD-7 and confirms its relevance and adequacy of the Spanish version. (García-Campayo et al., 2010) Reich (2018) performs cross-validation of the German and the Turkish versions of the PHQ-9 and concludes that PHQ-9 scores can be compared between Turkish immigrants and Germans without a migration background without any adjustments. The size of each group is 1670 and 307. (Reich et al., 2018) Manea (2012) determines an optimal cut-off score for the PHQ-9, while Plummer (2016) determines an optimal cut-off score for the GAD-7, which is the metadata that plays the most prominent role in the questionnaire. Both papers from Manea (2012) and Plummer (2016) include a database search for the research data, so the data from these two are external. (Manea et al., 2012; Plummer et al., 2016)

The concept matrix for the literature review is displayed below:

| Year | Article | Questionnaire | | Dataset Description | | | Metadata Type | Metadata Effect | | | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PHQ-9 | GAD-7 | Sample size | Internal | External | | Little Effect | Some Effect | Major Effect | |
| **2020** | Leung (Leung et al., 2020) | x | | 10933 | x | | Age, Gender | x | | | Hong Kong |
| **2017** | Rossom (Rossom et al., 2017) | x | | 287290 | | x | Age, Gender | | x | | United States |
| **2021** | Borgogna (Borgogna et al., 2021) | x | x | 46672 | | x | Gender | | | x | United States |
| **2016** | Erbe (Erbe et al., 2016) | x | | 130 | x | | Device | x | | | Germany |
| **2021** | Dosovitsky (Dosovitsky et al., 2021) | x | | 3895 | x | | Device | x | | | United States |
| **2014** | Grunauer (Grunauer et al., 2014) | x | | 217 | x | | Device | x | | | Ecuador |
| **2012** | Arthurs (Arthurs et al., 2012) | x | | 739 and 221 | x | | Language | x | | | Canada |
| **2010** | García-Campayo (García-Campayo et al., 2010) | | x | 212 | x | | Language | x | | | Spain |
| **2018** | Reich (Reich et al., 2018) | x | | 1670 and 307 | x | | Language | x | | | Germany |
| **2012** | Manea (Manea et al., 2012) | x | | 7180 | | x | Score | | | x | Canada |
| **2015** | Plummer (Plummer et al., 2016) | | x | 5223 | | x | Score | | | x | United Kingdoms |

**Table 5: Concept matrix of the literature review**
**(Source: Own analysis)**

# 3. Technology Comparison

In this chapter, there is an evaluation of the various front-end technologies in order to build a state-of-the-art web application. Afterward, there is another evaluation of the various back-end technologies. The two should be able to complement each other and create a unified full-stack digital platform of high performance.

## 3.1 Front-end Technologies

This section describes multiple front-end technologies and assesses their advantages and disadvantages. Priority should be placed on selecting the appropriate front-end technology, as it affects the performance of the entire system and establishes the guidelines for subsequent implementation.

### 3.1.1 Web Development Technologies

Due to the rise of structural web frameworks, the successful JavaScript library jQuery has stalled in terms of popularity. (*Angular vs Jquery vs React vs Vue | Npm Trends*, n.d.) What happened is that in 2010, the first version of the web framework Angular, supported by the reputable software company Google, was released. It introduced many new concepts, such as data bindings and dependency injection, and this eases the process of writing code. This framework is a framework that is in charge of the application and controls its life cycle.

jQuery, in contrast, only offers a limited number of collections of functions that will possibly be used. Furthermore, Angular introduced the concept of directives: New functionality is added to the HTML markup, which the framework will then parse. Examples of this are the data bindings and control structures like ng-for or ng-if, which could directly be used in the markup to control the application better. (*Angular - Introduction to the Angular Docs*, n.d.)

React.js, first released in 2013 by the reputable software company Meta, or Facebook at the time, also sought to retain many benefits that Angular offered and took a similar approach. In addition, React.js introduced the usage of a Virtual DOM. (*Getting Started – React*, n.d.) The main problem solved by this is that DOM manipulations are much slower than pure JavaScript operations. For example, when a dataset of a single row of a table changes, this table is to be rerendered by most frameworks in the DOM completely. Inefficient DOM updating has become a significant problem in modern websites, especially when many DOM manipulations are made.

So to address this particular issue, a Virtual DOM was introduced. If there is an inefficient DOM update, it is done to the Virtual DOM instead. Afterward, both DOMs are compared, and only the necessary elements are transferred to the real DOM in a special process called diffing. Angular works with Watchers, so it is not as performant as a Virtual DOM. Vue.js, in addition, adapted this technology and improved it further with a lightweight implementation of a Virtual DOM. (*Vue.Js - The Progressive JavaScript Framework | Vue.Js*, n.d.)

One peculiar thing about React.js is the introduction of the JavaScript expression language JSX. JSX produces React elements which will then be injected into the DOM. The syntax of JSX looks similar to HTML, but nonetheless, JSX has elements of JavaScript. Additionally, an advantage of JSX is the ability to prevent injection attacks. Angular and Vue.js, in contrast, use plain HTML and CSS. A philosophy of Vue.js creators is the emphasis on the flat learning curve, hence the decision to use plain HTML and CSS since it makes it much easier for inexperienced developers and designers to comprehend and contribute to the codebase. A continuation is the ability to import HTML-based templates from previous codebases. (*Getting Started – React*, n.d.)

Vue.js also offers a command-line (CLI) project-generator, making it easy to start a new project with a prepared generated complex build process. The generator supports various build tools and assists the programming process. (*Vue.Js - The Progressive JavaScript Framework | Vue.Js*, n.d.)

Here is a comprehensive table comparing the technologies:

| Characteristic | jQuery | React.js | Angular | Vue.js |
|---|---|---|---|---|
| **Year released** | 2006 | 2013 | 2010 | 2014 |
| **Is a framework?** | No | Yes | Yes | Yes |
| **Virtual DOM** | No | Yes | No | Yes |
| **HTML/CSS** | Yes | No | Yes | Yes |
| **CLI for build** | No | Yes | No | Yes |
| **Leaning curve** | High | Medium | Medium | Low |
| **Complexity** | Low | Medium | High | Medium |
| **Performance** | Slow | Fast | Fast | Fast |
| **TypeScript** | No | Yes | Yes | Yes |
| **Native rendering** | No | Yes | No | No |

**Table 6: Comparison of web development technologies**
**(Source: Own analysis)**

## 3.1.2 Web Design Technologies

As stated in section 3.1.1, Vue.js permits the use of CSS. There are numerous ways to maximize this tool, with Sass, TailwindCSS, and Vuetify as the technologies that enable the smoothest design experience.

Vuetify is a framework for Vue.js 2 components. It seeks to provide clean, semantic, and reusable components that simplify application development. Vuetify uses the Material Design pattern developed by Google. (*Get Started with Vuetify*, n.d.) The downside of Vuetify is the lack of customizability since the pre-built components are limited. For more customizability, Sass and TailwindCSS are superior options.

Sass is a preprocessor scripting language interpreted or compiled into cascading style sheets (CSS). (*Sass: Documentation*, n.d.) SassScript provides the following mechanisms: variables, nesting, mixins, and selector inheritance, and as a result, provides exceptional flexibility. Meanwhile, Tailwind CSS is a utility-first CSS (Cascading Style Sheets) framework with predefined classes that you can use to construct and style web pages in your markup directly. (*Installation*, n.d.) It allows one to write CSS in HTML using predefined classes. This mechanism's drawback is that it complicates the HTML code and hinders readability.

The following table compares these technologies:

| Characteristic | Sass | TailwindCSS | Vuetify |
|---|---|---|---|
| **Type** | CSS Preprocessor | HTML Inline Classes | Prebuilt Components |
| **Flexibility** | High | Medium | Low |
| **Development Effort** | High | High | Low |
| **Readability** | Medium | Low | High |
| **Extendibility** | High | High | Low |

**Table 7: Comparison of web design technologies**
**(Source: Own analysis)**

## 3.2 Back-end Technologies

This section describes various back-end technologies and assesses their advantages and disadvantages. The back-end is the digital platform's backbone, enabling efficient database operation. The decision regarding which back-end technologies to use is also heavily influenced by the topic of the thesis, which is a domain with a heavy statistical component.

### 3.2.1 Back-end Technologies

Numerous approaches exist, but the following are the most suitable and realistically implementable approaches, given the time constraint of the thesis. The first option is constructing an entirely new back-end using the reputable cloud service Amazon Web Services. (*AWS Documentation*, n.d.) Numerous businesses and enterprises adopt this strategy because it provides the most significant degree of development flexibility. (*Increasing Flexibility*, 2020) In the scope of this thesis, however, the digital platform is intended to be less complex than that of corporations; consequently, a more straightforward approach is preferred. Firebase and Supabase are two of the best back-end as a service (BaaS) options available on the market.  (“Supabase Takes Aim at Firebase with a Scalable Postgres Service,” 2022)

Google's Firebase is a back-end as a service that is based on Google Cloud. Firebase is equipped with a NoSQL database. (*Firebase Realtime Database | Firebase Documentation*, n.d.) Supabase, on the other hand, is an open-source alternative to Firebase that utilizes the PostgreSQL database. (*Introduction | Supabase*, n.d.) The digital platform chooses Supabase in the end due to the superiority of SQL for statistical filtering and aggregation, which is a requirement for this Thesis. The discussion on the differences between SQL and NoSQL is in the next section.

Following is a table comparing all three services.

| Characteristic | Firebase | Supabase | Amazon Web Services (AWS) |
|---|---|---|---|
| **Type** | BaaS | BaaS | Cloud Service |
| **Development cost** | Low | Low | High |
| **Learning curve** | Low | Low | High |
| **Flexibility** | Medium | Medium | High |
| **Databases** | NoSQL | SQL | SQL and noSQL |

**Table 8: Comparison of back-end technologies**
**(Source: Own analysis)**

### 3.2.2 Database Technologies

SQL and NoSQL are the two principal database types. SQL, or Structured Query Language, is the query language for relational databases that is universally recognized. CRUD (Create, Retrieve (or Read), Update, and Delete) operations in SQL databases make it easier to manipulate structured data in a database. Create, retrieve (or read), update, and delete are the fundamental data manipulation operations. (*What Is SQL (Structured Query Language)?*, 2022)

Typically, SQL databases are referred to as relational database management systems (RDBMS). Traditional RDBMS employ SQL syntax, as their row-based database structures connect related data objects across tables. Backendless, Microsoft Access, MySQL, Microsoft SQL Server, SQLite, Oracle Database, IBM DB2, and others are examples of RDBMS SQL databases. (*SQL vs NoSQL Database - A Complete Comparison*, n.d.)

NoSQL databases, on the other hand, are databases that lack fixed, structured tables for data storage. All non-relational databases can technically be referred to as NoSQL databases. Since a NoSQL database is not relational, it can be set up rapidly and with little forethought. MongoDB, DynamoDB, SimpleDB, CouchDB, CouchBase, Orient DB, Infinite Graph, Neo4j, FlockDB, Cassandra, and HBase are examples of NoSQL databases. (*SQL vs NoSQL Database - A Complete Comparison*, n.d.)

SQL databases define and manipulate structured query language based on data (SQL). When viewed from an angle, this language is highly potent. SQL is one of the most versatile and widely-used options available, making it a safe option for complex queries in particular. However, it can also be restrictive. SQL requires the use of predefined schemas to determine the data structure prior to data manipulation. Additionally, all of the data must adhere to the same structure. (*What Is SQL (Structured Query Language)?*, 2022)

A common criticism of NoSQL databases is that they do not support ACID (atomicity, consistency, isolation, and durability) transactions across multiple documents. With an appropriate schema design, the atomicity of a single record is acceptable for many applications. However, many applications continue to require ACID across multiple records. (*What Is NoSQL? NoSQL Databases Explained | MongoDB*, n.d.)

| Characteristic | SQL | NoSQL |
|---|---|---|
| **Type** | Relational Databases | Non-relational Databases |
| **Structure** | Table | Key-value pair |
| **Scalability** | Vertically | Horizontally |
| **Strength** | Highly structured data | High transaction load |
| **ACID support** | Yes | No |

**Table 9: Comparison of database technologies**
**(Source: Own analysis)**

# 4. Design

This chapter discusses the web application's design. First, there is a description of the digital platform's requirements. After that, there is a second discussion regarding the architectural decisions and their impact on the users, in this case, the patients and psychiatrists. Last but not least, there is a comprehensive presentation of all the developed components and their functionalities, outlining each and every user scenario.

## 4.1 Requirements

Prior to participating in the design of any platform, it is crucial to determine the requirements, as they dictate the design process. The first step is the investigation of the validity of a mental health questionnaire on a web application. Erbe (2016) investigates the inter-format reliability of a computerized version of the PHQ-9, which shows high correlations to the paper format. (Erbe et al., 2016) This is an encouraging result that proves the validity of a mental health questionnaire on a web application.

These are broad ideas about how a digital platform can perform at a high level; the next step is to translate them into reality, which is a digital platform that can serve both patients and psychiatrists and has the capacity to collect questionnaire metadata. Nonetheless, the high-level collection of metadata from questionnaires is not a simple, isolated task. According to statistics, if it takes longer than one second for a website to become interactive, users lose interest, and their perception that the page task has been completed is broken. (*Evaluating Page Experience for a Better Web | Google Search Central Blog | Google Developers*, n.d.)

Patients desire a seamless experience and an engaging questionnaire layout. ("User Experience," n.d.) Consequently, it is of the utmost importance that the design of the questionnaires is pleasant and engaging. The digital platform will lose valuable users if the patients lose interest and no longer wish to participate in the diagnostic process.

When a platform loses valuable users, it also loses valuable metadata, indicating that it is not effectively performing its intended function, which is collecting metadata. A real-life example is the following: Walmart's revenue increased by 1 percent for each 100ms improvement in page load speed. (*Walmart Saw up to a 2% Increase in Conversions for Every 1 Second of Improvement in Load Time. Every 100ms Improvement Also Resulted in up to a 1% Increase in Revenue.*, n.d.)

In addition to serving patients, the platform also serves psychiatrists. The psychiatrist must be able to track the progress of one or multiple patients. The digital platform must make optimal use of the questionnaire-collected metadata. Consequently, this will be yet another requirement: The system must be trustworthy and reliable. In the event that the server is unavailable or stalled, neither the psychiatrists nor the patients will be able to access patient information or submit questionnaires. Similar to the requirements for the patients, the design for the psychiatrist's section must be captivating. The page requires aesthetically pleasing charts and graphs to visualize statistical data fully. The codebase and the database must both be easily maintained. The objective of the subsequent section is to translate this message into the architectural design procedure.

## 4.2 Architecture

The design of the application's architecture is another essential procedure that plays a significant role in the application's success. A robust software architecture aids in defining portability, reliability, efficiency, usability, testability, understandability, and modifiability. (Boehm, 1976)

### 4.2.1 Front-End Architecture

In light of the technology comparisons performed in chapter 3, the project has decided to build a web application using the front-end framework Vue.js. Vue.js appears to have no glaring weaknesses, while its clear code structure is an asset. This framework is especially advantageous when a new developer wants to take over and expand the project, as their learning curve will not be too steep. The web application will come with Sass, the solution providing the most flexibility and expressiveness, following the discussion in section 3.1.2.

There are two significant code paradigm alternatives for constructing a Vue.js project. Options API and Composition API are the two. The thesis has chosen the Options API due to the clarity of the component roles. Composition API provides superior code reusability, but Options API is the superior choice for a large project with an uncertain future in terms of extensibility. (Oberlehner, 2021)

The project requires a good build setup, with official VueCLI or Vites as options. Vites offers a faster build time, but it may not work with specific dependencies, so VueCLI was chosen for the thesis. (*Vue CLI*, n.d.) In addition, a page routing library and adequate local storage are required to facilitate communication between components. VueRouter and Vuex are the official options and the option chosen for this thesis, respectively.

While data is loading from the API, a spinning indicator is shown. This practice is a neat user experience trick to make the users feel the loading is faster than without. (Pencil and Paper, 2021)

### 4.2.2 Back-End Architecture

Following the discussion in section 3.2, Supabase has been selected for the project. Supabase's PostgreSQL database, which is a SQL database, is the primary reason. If one decides to add new metadata to the questionnaire's metadata database, all required is the introduction of additional columns to the SQL database. A SQL database is also excellent for statistical calculations, which will significantly facilitate the implementation of the psychiatrists' charts. When there are specific relationships between variables, SQL performs admirably. (*What Is SQL (Structured Query Language)?*, 2022)

Supabase is also built on Amazon Web Services instance. Amazon Web Services is a reputable cloud computing service with extremely high availability and scalability (*High Availability and Scalability on AWS - Real-Time Communication on AWS*, n.d.). This solution fulfills the requirement that the digital platform is highly accessible. Supabase's PostgreSQL database also supports the ACID requirement, yet another benefit. (*Introduction | Supabase*, n.d.)

## 4.3 Overview of the Components

Given that the metadata must be collected from somewhere, it has been determined that there must be a section dedicated to the patients. Since a great deal of data is available to analyze and visualize, psychiatrists need their own section. Moreover, a common neutral area for both psychiatrists and patients can be beneficial in certain circumstances, such as when a log-in action is required, since access to this information may require authorization.

### 4.3.1 Common Area

Since the role of this user is undetermined, an excellent common area is a homepage, where a user first enters the page. This user should be able to select a role on the homepage, enter credentials, and continue with the desired role, either patient or psychiatrist, if authentication is successful. Since the purpose of this page is neutral, the feedback page can also be included here. The user can also access the desired page via a navigational sidebar, which will remain expanded for convenience. In order to avoid stigma, the digital platform uses the term "user" instead of "patient."


**Figure 1: Overview page of the digital platform**
**(Source: Own analysis)**

### 4.3.2 Patient's Area

The patient's email address is displayed in the navigation sidebar, and the page links to the patient's calendar, PHQ-9 and GAD-7 questionnaires, the personal information editor, the results page, and the exit button.

The first page a patient encounters is the calendar page, where they can view the date they completed the PHQ-9 and GAD-7 questionnaires and the current date. This calendar is a valuable summary because it allows the patient to determine if this is the appropriate time to begin filling out another mental health questionnaire, the PHQ-9 and the GAD-7.

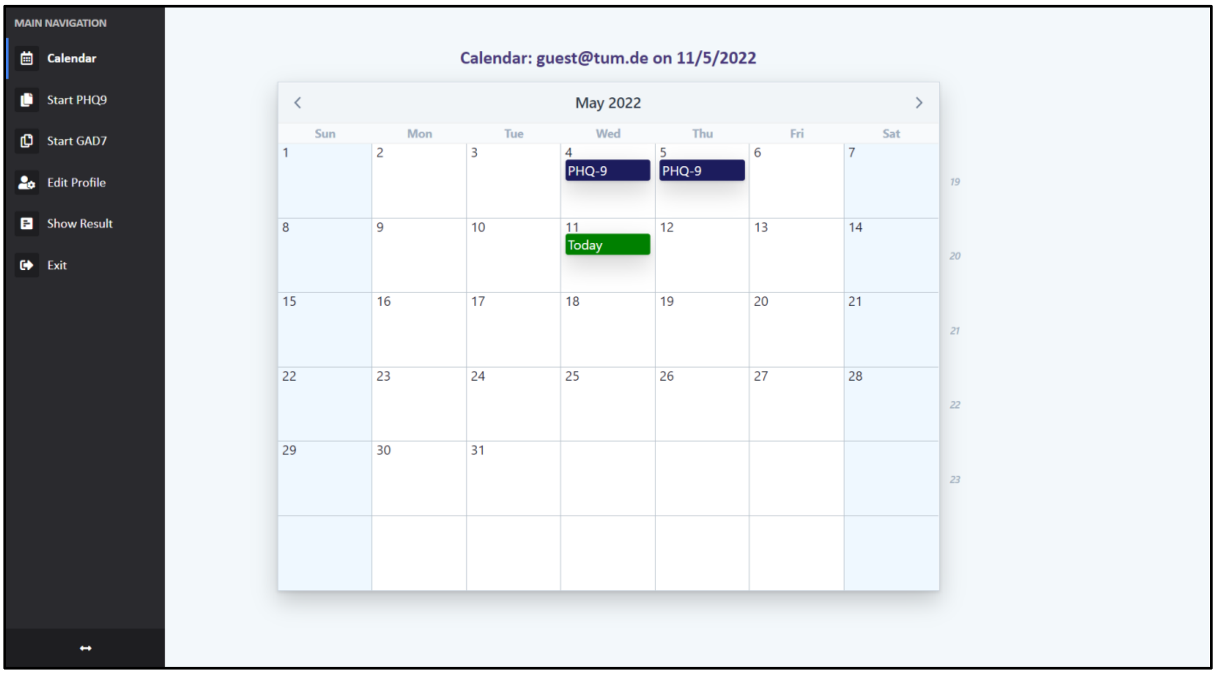



**Figure 2: Calendar page of the patient's side**
**(Source: Own analysis)**

The patient may then choose to begin completing the PHQ-9 or GAD-7 questionnaires. The patient can toggle between English and German as the questionnaire language in this section. Additionally, this information will be stored in the local storage for future use. The page will redirect to the questionnaire when the patient clicks on the card.


**Figure 3: Patient Health Questionnaire 9 (PHQ-9) page**
**(Source: Own analysis)**

The patient then begins his journey of completing the questionnaires. The patient may complete the questionnaire using either the mouse or the keyboard. The possible keys are 0, 1, 2, and 3, corresponding to the value of that answer in the questionnaire, or left and right to jump backward or forward.


**Figure 4: Questionnaire page**
**(Source: Own analysis)**

The page for the GAD-7 is very similar to the page for the PHQ-9. The GAD-7 consists of eight questions as opposed to ten on the PHQ-9. The page of the GAD-7 will be shorter, and thus, the array of metadata collected will be a little bit different.

The patient can also submit personal information voluntarily on the profile page. This information is another type of metadata that the digital platform collects, and it can have a significant impact on the mental health researchers' research progress.

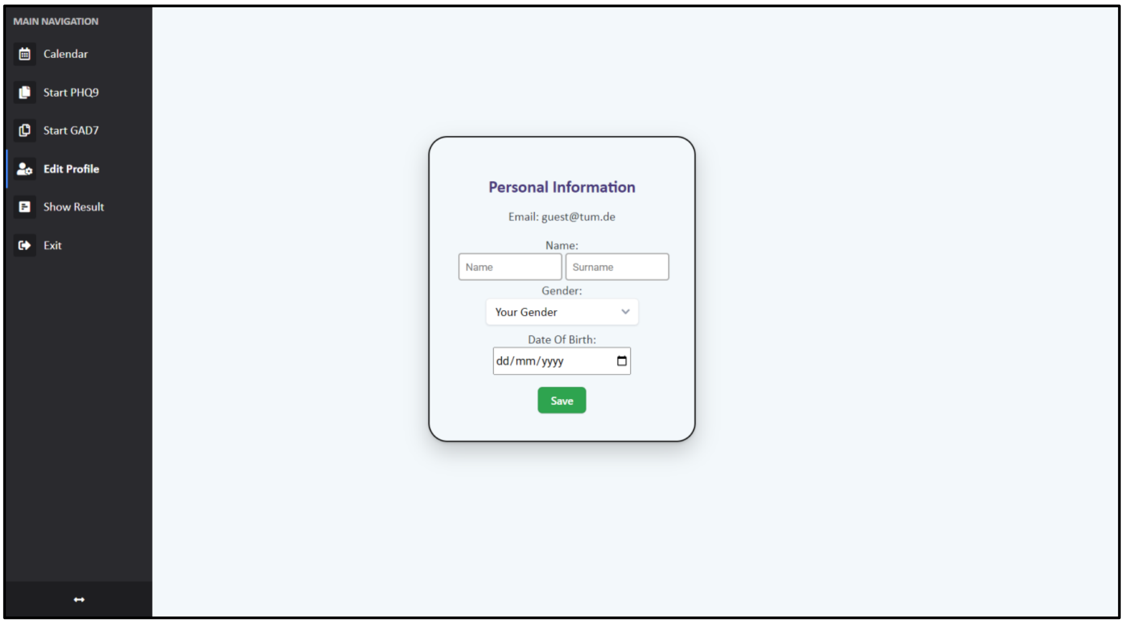



**Figure 5: Profile page of the patient**
**(Source: Own analysis)**

In addition, there is a results page. This page will store the patient's last questionnaire response and serve as a transitional page. This page will display the total score and the length of time the questionnaire took to complete. The patient may return to the homepage at the session's conclusion by clicking the “Exit” button. This button will redirect to the common area.

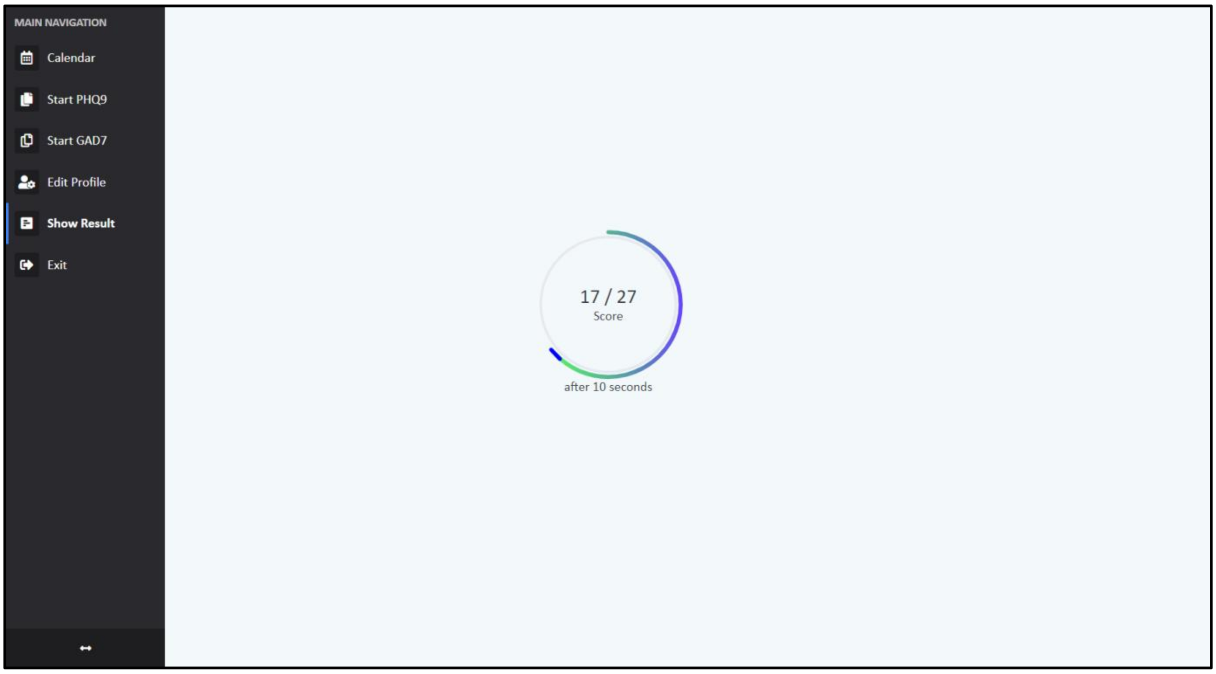



**Figure 6: Result page of the patient**
**(Source: Own analysis)**

## 4.3.3 Psychiatrist’s Area

The psychiatrist can select the statistics page, the track a patient option, or the compare multiple patients option from the navigation sidebar. So the psychiatrist has not just the ability to diagnose a patient but to have an overview of the whole group.

### Track Patient

The psychiatrist can conduct a database search on the track patient page based on the patient's email address. There are two options: Search with an email directly or show the entire patient’s list. This functionality will give the ability for the psychiatrist to find the correct patient, even in the event that they do not remember the correct email address.


**Figure 7: Search patients from the database**
**(Source: Own analysis)**

If the psychiatrist then clicks the email button, they will be able to view the charts and tables that contain all of the information regarding the previous questionnaire responses. It is then possible to view the patient's performance, consisting of a PHQ-9 database, a PHQ-9 score line chart, a GAD-7 database, and a GAD-7 line chart.

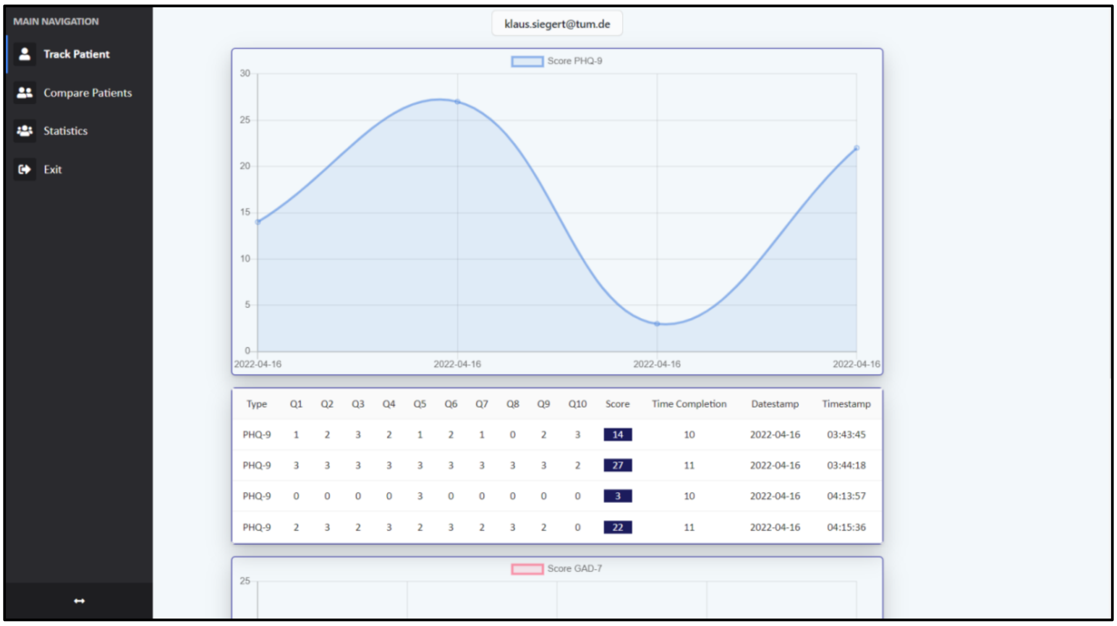



**Figure 8: Information about the patient's previous responses**
**(Source: Own analysis)**

The psychiatrist can toggle between the PHQ-9 and GAD-7 on the overview dashboard. There is a chart displaying the distribution of questionnaire responses as a heat map, the average scores for each question as a pie chart, the devices used by patients as a pie chart, and their geographic location as a map.

### Compare Patients

In the option to compare multiple patients, the psychiatrist can view a line chart comparing the score distribution of male and female patients. The information about the patient's gender is submitted of the patient's volition. Additionally, it is possible to switch between the PHQ-9 and GAD-7.

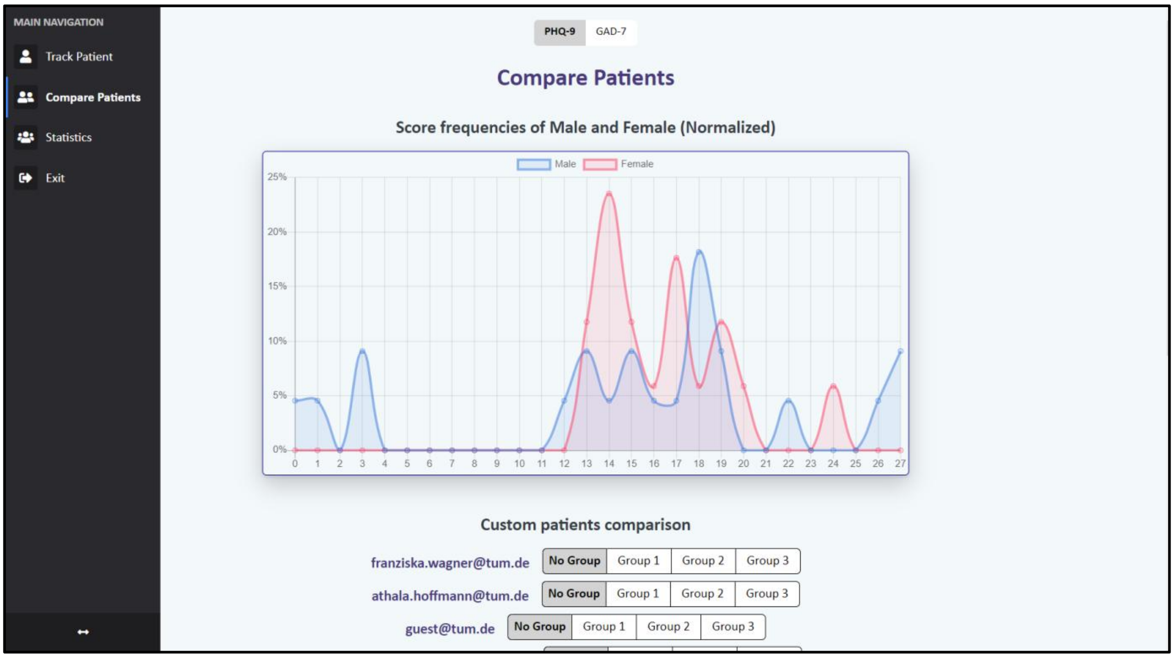



**Figure 9: Comparison of male and female patients**
**(Source: Own analysis)**

Alternatively, a custom patient group can be selected from the entire list of patients. The group color corresponds to the PHQ-9 and GAD-7 line colors. When the psychiatrist clicks on the button, the patient of that button will be moved to the corresponding list.

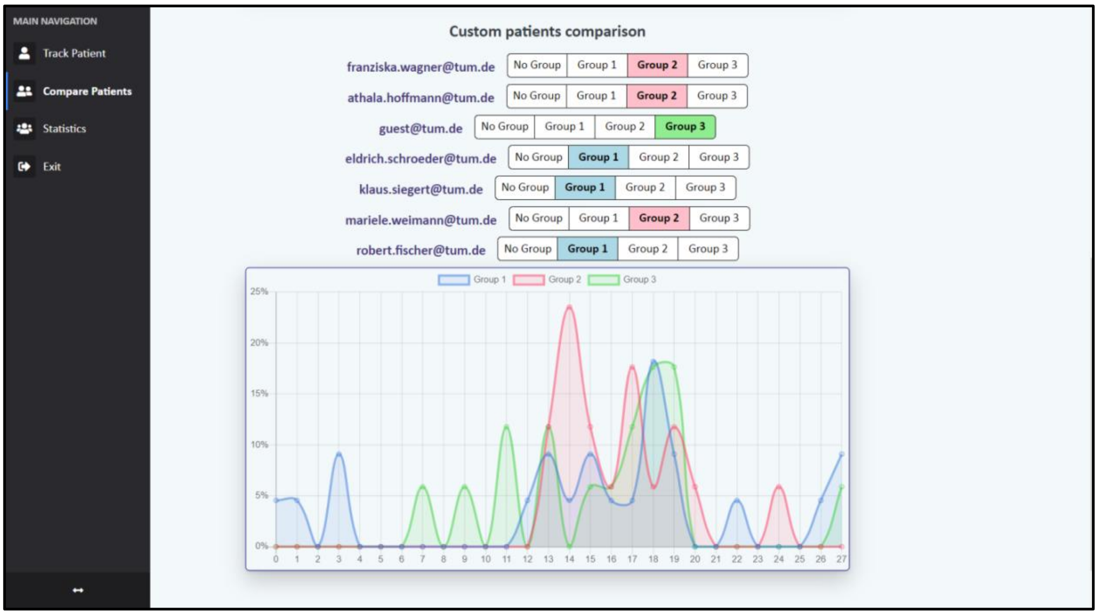



**Figure 10: Comparison of groups of patients**
**(Source: Own analysis)**

## Statistics Page

The psychiatrists can monitor the aggregated results of all patients via the Statistics page. The statistics page contains four charts: the frequency of a particular response, the average score for each question, the device used by respondents, and their geographic location. It is possible to toggle between the PHQ-9 and GAD-7, similar to the "Compare Patients" page.

"Filling frequencies of the respondents" is a heat map because it allows mental health researchers to identify the most frequently selected questionnaire response instantly. This selection is essential because some psychiatrists do not have time to delve into the detail, and with the aid of visualization from a heatmap, the psychiatrists will have an overall view effortlessly.

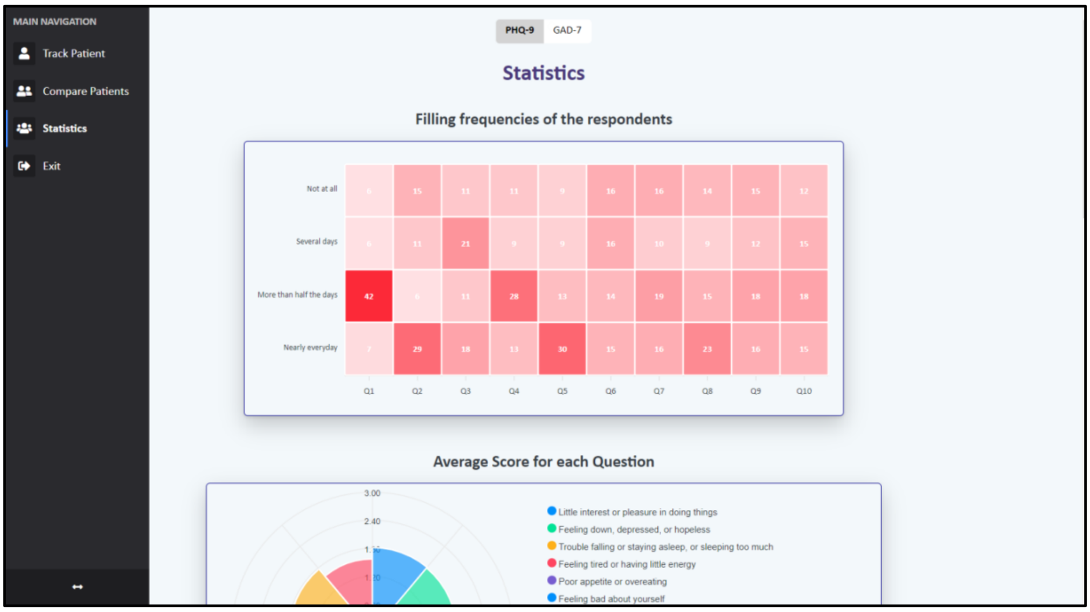



**Figure 11: "Filling frequencies of the respondents" chart**
**(Source: Own analysis)**

The "Average score for each question" is a pie chart with an area so the psychiatrists can visually compare the questions. The reason that the piechart is chosen is to enable the comparison between the questionnaire's questions effortlessly. When the psychiatrist hovers on the pie chart, they should be able to see the statistics corresponding to that color.

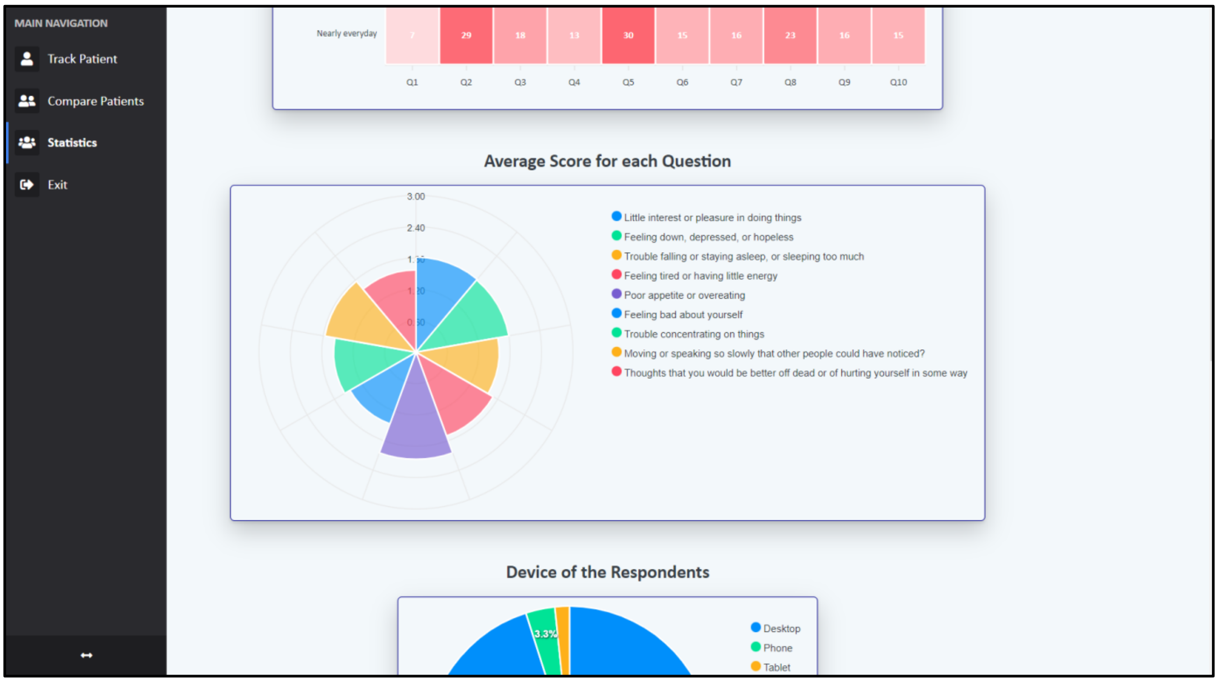



**Figure 12: "Average score for each question" chart**
**(Source: Own analysis)**

The "Device of the Respondents" is a pie chart that allows the psychiatrist to determine which device is the most prevalent. Each device corresponds to its own color. When the psychiatrist hovers on the pie chart, they should be able to see the statistics corresponding to that color.

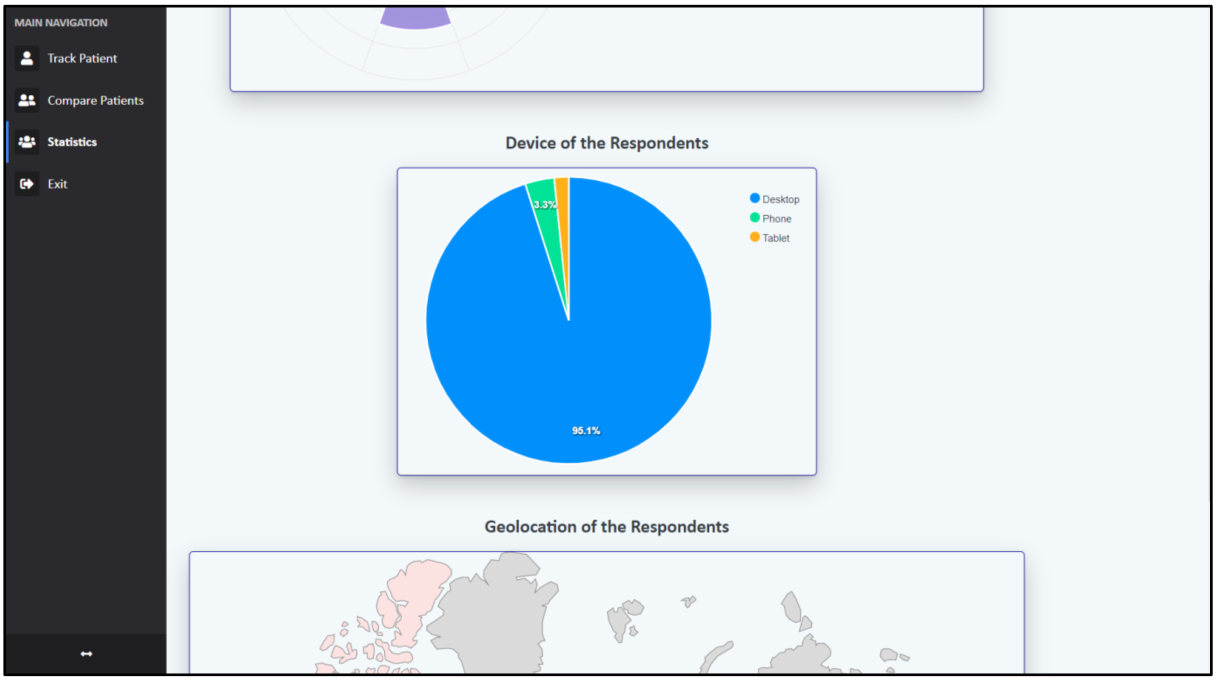



**Figure 13: "Device of the respondents" chart**
**(Source: Own analysis)**

The "Geolocation of respondents" is depicted on a map; the darker the red, the more significant the proportion of responses from that country. When the psychiatrist hovers over a particular country for more information, that country's data should be displayed.

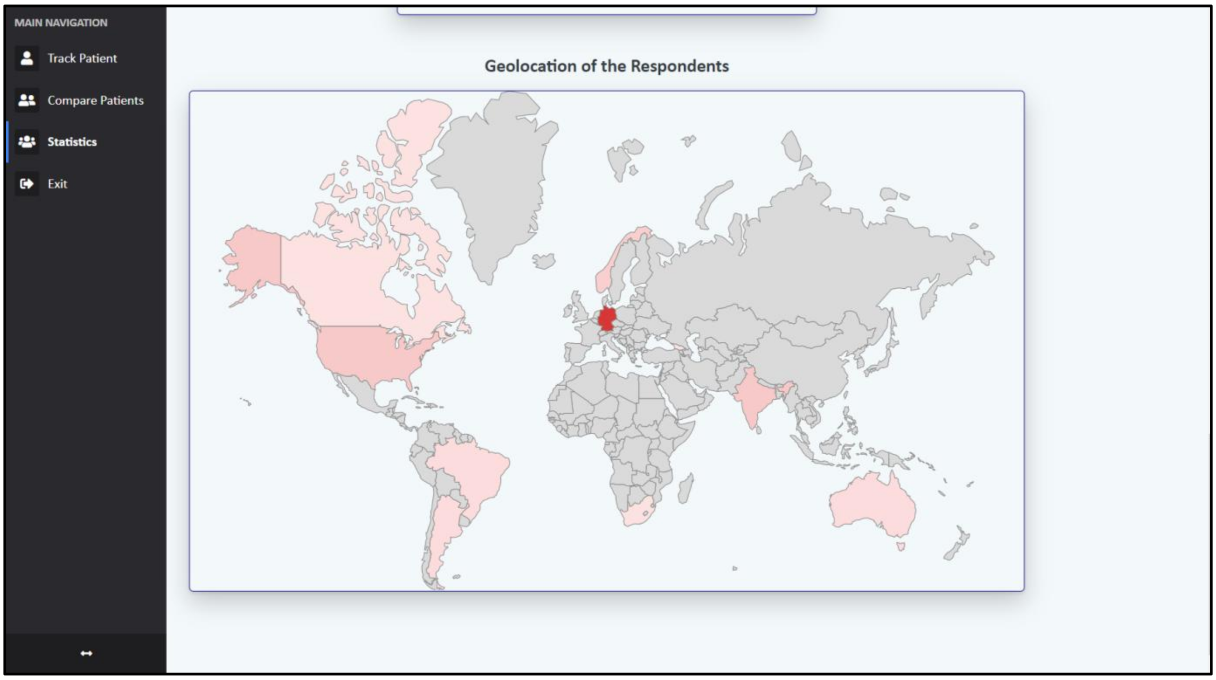



**Figure 14: "Geolocation of the Respondents" chart**
**(Source: Own analysis)**

# 5. Implementation

This chapter discusses the web application's design implementation, previously described in chapter 4. Because this web application serves two roles, patients and psychiatrists, there will be two major sections, each of which will describe the implementation of the role's components. This chapter begins with the front-end architecture and the VueCLI build process. It continues with the implementation of each component, state management, routing, and numerous other tasks. Afterward, the back-end implementation and databases will be discussed. As the databases are hosted in the cloud, the architecture of that system will also be discussed.

## 5.1 Folder Structure

The web application is based on the official Vue.js boilerplate template with Vue CLI, Vuex, and Vue Router. Vue Router is an essential component of the project that has the functionality of local memory and will be discussed in section 5.2.

The *.env* file is a hidden file that contains the project's keys. These keys must be kept confidential. The project’s keys include the API key for access to the back-end Supabase. The configuration for the *.env* is in the installation guidelines *Appendix B*. The *.babel.config.js* contains the configuration information for the Babel JavaScript transcompiler. (*What Is Babel? · Babel*, n.d.)

The /*public* folder contains multiple versions of the PHQ-9, GAD-7, and SUS questionnaires as JSON files in the */public/API* folder. Since Vue.js is a framework for developing single-page applications, the *index.html* file is in the /*public* as well. *index.html* is a template that will be processed with HTML-webpack-plugin. During the build, asset links will be injected automatically. (*HTML and Static Assets | Vue CLI*, n.d.)

The */node_modules* folder is used to save all downloaded packages from NPM on the computer for the JavaScript project that one has. *package.json* contains all essential development dependencies and dependencies. The *package-lock.json* file is an extensive expansion of the *package.json* file. It specifies the exact tree generated, allowing subsequent installations to generate identical trees regardless of dependency updates. (Package-Lock.Json | Npm Docs, n.d.)

The */src* folder contains all source codes and is the most important folder, which contains multiple subfolders. In the */src/assets* folder, there are the Sass stylesheets of the web application. The */src/router* folder contains the file of all the routes of the web application based on Vue Router. The */src/views* folder contains the essential pages of the web application. The */src/components* folder contains the components used by the */src/views* folder. The */src/store* folder contains the files for the local storage with Vuex.

The */src/views* folder contains three subfolders. The */src/views/patient* folder contains all the pages on the patient’s side, the */src/views/psychiatrist* folder contains all the pages on the psychiatrist’s side, while */src/views/category* contains all the neutral pages.

```
.
├── .env
├── .babel.config.js
├── vue.config.js
├── public
│   ├── api
│   └── index.html
├── node_modules
├── package.json
├── package_lock.json
└── src
    ├── assets
    │   └── styles
    ├── components
    │   ├── shared
    │   └── ui
    ├── router
    ├── store
    ├── supabase
    ├── views
    │   ├── patient
    │   ├── psychiatrist
    │   └── category
    └── main.js
```

**Figure 15: Folder structure of the Thesis's code**
**(Source: Own analysis)**

## 5.2 Reactivity, Router, and Local State Management

As presented in section 3.1.1, Vue.js is a progressive framework for building modern reactive user interfaces and single applications. Vue.js enables the augmented rendering of the HTML markup through a template declaration bound to a data model. Vue.js has an adaptable reactive architecture that focuses on declarative rendering of data models and component composition. Reactivity describes the situation in which changes in the application state are automatically rendered in the DOM. Reactivity in Vue.js allows Vue.js to communicate at every layer of the application and updates the view base data modification. (*Reactivity in Depth | Vue.Js*, n.d.)

One of the most significant advantages of Vue.js is the ability to build great Single Page Applications (SPAs). SPAs are effective because they do not require page loads every time the route changes. Furthermore, to build SPA, Vue Router is a critical component. Vue Router helps link the browser's URL/History and Vue's components, allowing specific paths to render whatever view is associated with it. (*Vue Router*, n.d.)

The components inside the */src/views* folder correspond to a path. For example, the component */src/view/patient/PHQ9* corresponds to the route "/PHQ9". This means that this page can be accessed with the website link plus "/PHQ9". Similarly, the component */src/view/patient/GAD7* corresponds to the route "/GAD7" and can be accessed with the website link plus "/GAD7".

The web application's state management is based on a Vuex Store. Vuex is a Vue.js "state management pattern and library." It offers a central repository for all Vue.js components. The state can then only be modified consistently via an API. When modifications are made to the Vuex Store, all components utilizing the modified attribute are notified and updated. (*What Is Vuex?*, n.d.)

In the Metadata Collector web application, Vuex temporarily stores the questionnaire respondents' metadata, including score, time, and geolocation. The temporary storage is a significant programming process simplification, and the data will be uploaded to a permanent, persistent database afterward. In addition, the questionnaires themselves, including the PHQ-9 and the GAD-7, as well as their multiple language versions, are included in the Metadata Collector Vuex store. All of these properties are accessible and modifiable via the component.

The properties are accessed and set using mutations and actions. The operational difference between these two types is: A mutation is an instantaneous and simultaneous change to a property. (*Mutations | Vuex*, n.d.) However, an action is asynchronous and returns a promise. Therefore, it is possible to make asynchronous calls within an action without resolving the promise until the asynchronous call has been completed. (*Actions | Vuex*, n.d.) In the web application, mutations were used only within the store, whereas all public methods were actions. The advantage of this concept is that the interface for modifying a property is always the same and asynchronous calls are possible.

## 5.3 Front-end Components

After the discussion of front-end architecture and the folder structure of the shared files, the concrete implementation of each component is divulged. The web application consists of three main areas: The common area, the patient's area, and the psychiatrist's area.

### 5.3.1 Common Area

Two pages comprise the common area: the login page and the System Usability Scale (SUS) feedback page. These two pages constitute two elements. The SUS feedback includes three extra components. A questionnaire card and a question view page containing a question component for dynamically loading SUS questionnaires.

The login page can also act as the website's homepage. It features a sidebar with links to the login and SUS feedback pages. The structure looks as follows: A switch and a form inside a flexbox with a border and a shadow. Inside is a greeting that reads "Patient Health Questionnaire 9" and requests your role. The user can select a role using a toggle switch. The correspondent switch displays a login form with a two-way binding variable containing the email address and a button that navigates to either the patient or psychiatrist area. In addition to the patient option, there is also a guest option.

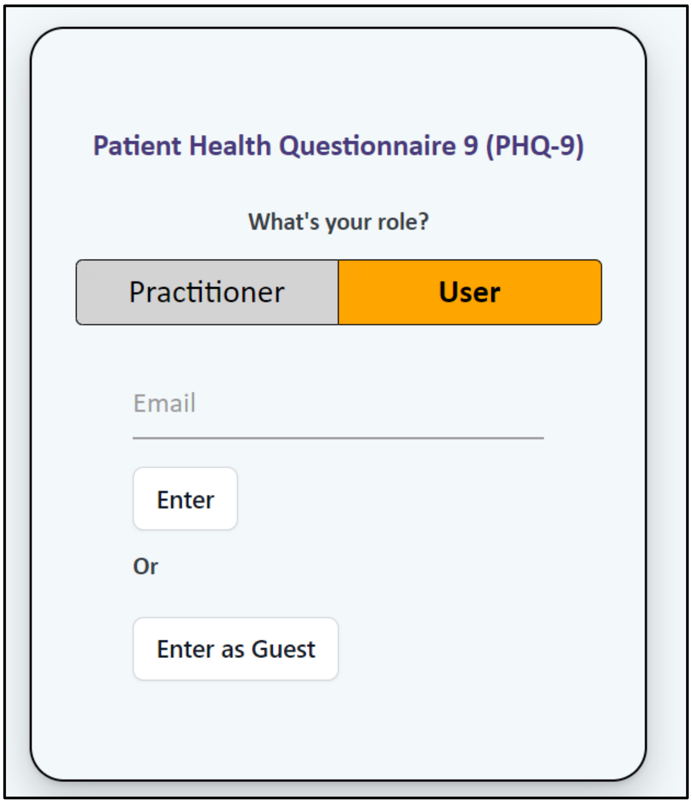



**Figure 16: Login page**
**(Source: Own analysis)**

The SUS has a questionnaire card containing the questionnaire's title, description, and the number of questions, each of which has its CSS style. When the questionnaire card component is created, Vuex is used to load the questions from the JSON file into the local storage (See section 5.2). After the user clicks the questionnaire card, the question view page will display the ten questions, each corresponding to a question already fetched from the local storage. On the top, there is a question number component that dynamically displays the question number based on the active index as passed through props. These question components from the SUS are also being reused in the PHQ-9 and GAD-7; more information on their implementation will be provided in the next section.

## 5.3.2 Patient's Role

The patient role possesses the following abilities. The first one is to be able to fill in the PHQ-9 and GAD-7 efficiently in English and German. The second one is to have the personal information stored in the database. In the navigation sidebar, the patient can go to the calendar page, the PHQ-9 page, the GAD-7 page, the profile page, and the result page and exit the patient area.

## Calendar Page

The calendar page contains the patient's previous questionnaire responses. This component is constructed with V-Calendar, a lightweight Vue.js calendar repository. This functionality is accomplished by searching the patient's previous responses; the calendar's date will be marked with the questionnaire's information. The current date will also be noted for reference on the calendar. All the meta information of the calendar is stored in an array.

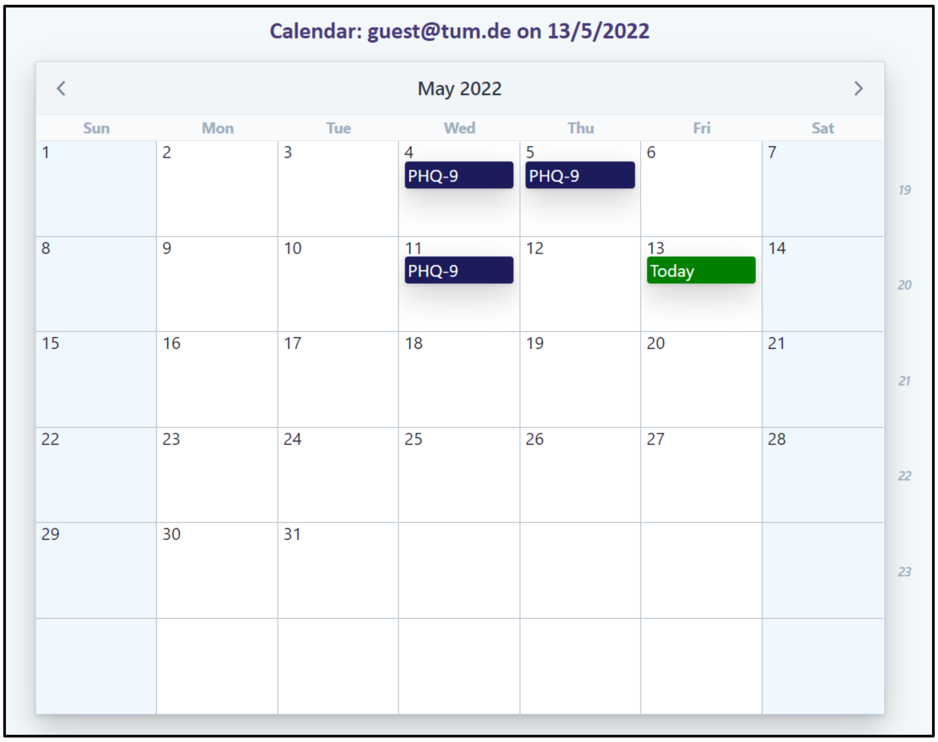



**Figure 17: Patient's calendar**
**(Source: Own analysis)**

## PHQ-9 Page

There is a questionnaire card with the questionnaire's title, description, and the number of questions on the PHQ-9 page. These questionnaire-related details are loaded into the created life cycle hook to ensure that the questionnaire card is always accurate. The page's footer has a switch for the available languages. Vuex stores the outcome of this toggle switch during the patient's login session in local storage. This information is retrieved from the local storage each time the DOM is created to ensure that the patient's preference is remembered. In addition, the data in the local storage pertaining to the previous questionnaire filling is deleted, followed by the retrieval of new data regarding the user's geolocational and device metadata.

With an Ipregistry registered account, the user can make an asynchronous call to the *ipregistry.com* server, and the web application will receive the user's metadata. Ipregistry is an internet service that provides a fast, reliable geolocation and threat data API to lookup information associated with IPv4 or IPv6 IP addresses. For each IP address processed, the API returns up to 80 unique data points, such as location data, connection data, Autonomous System Number (ASN), company name, domain, carrier data, time zone, currency, and security assessment data. (*The Trusted Source for IP Address Data (Geolocation and Threat) - Ipregistry*, n.d.)

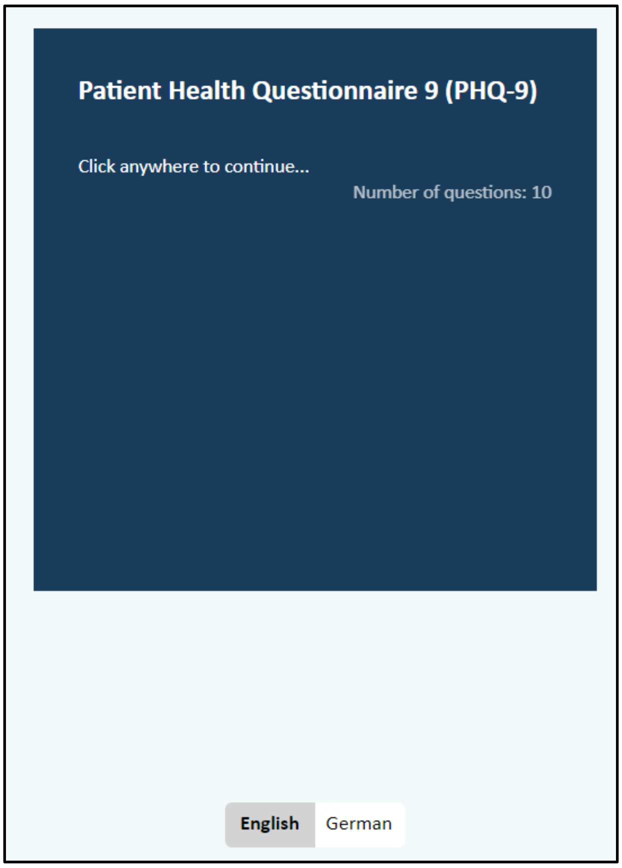



**Figure 18: Questionnaire card with language toggle (Source: Own analysis)**

The patient can now click on the questionnaire card to begin the filling process. This link will navigate the patient to the questionnaire view page. Retrieved from the system, the datestamp and timestamp are determined in the created hook of the questionnaire view page. The entire questionnaire questions (in this case, ten questions from the PHQ-9) are loaded on this page as a question component within a questionnaire feed. The purpose of this feed is to ensure that the patient can always go back and forth and alter their response on demand. In addition, there is a keyboard component responsible for keyboard clicks. This accessibility profoundly enhances the dynamic of the user experience.

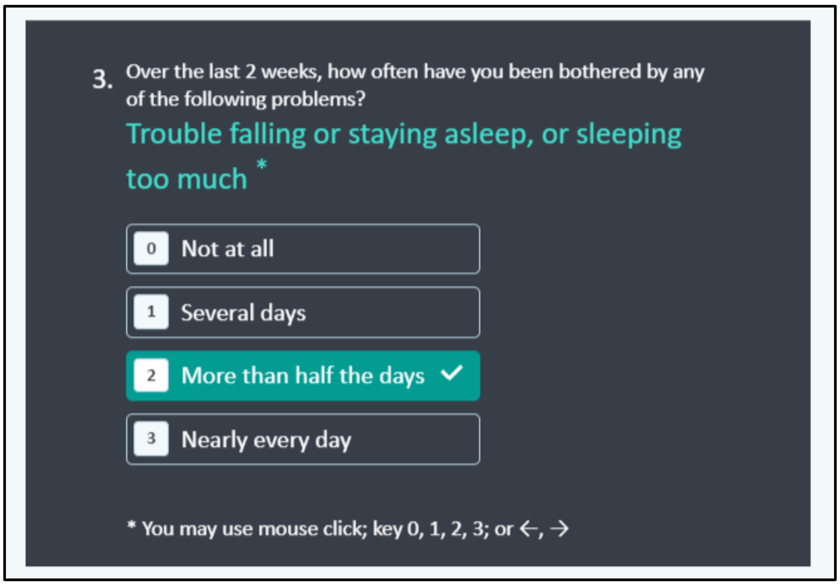



**Figure 19: The third question of the PHQ-9**
**(Source: Own analysis)**

Within a question component are the question number, the question title, the question supplementary information, the question options, and as a footer, instructions on how the patient should answer the question. The question's title is highlighted in turquoise to increase its visibility. The question options are presented using a flex display with a column as the flex direction. A keyboard icon indicates the keyboard control's availability when the patient hovers over an option.

There will be no question in the final question, and only a submit button. This event, when triggered, asynchronously uploads all data and metadata corresponding to the questionnaire database. All data and metadata are stored in the local storage prior to submission. Following submission, the web application retrieves the data from the local storage using mapGetter and uploads it to the database.

The page will then navigate to the result page, where the patient can view the previous questionnaire's results. The score is then displayed in an aesthetically constructed ellipse progress bar.

**GAD-7 Page**

With one exception, the GAD-7 page is very similar to the PHQ-9 page. The GAD-7 consists of only eight questions, whereas the PHQ-9 contains ten. This page indicates that the data and metadata are contained differently when the patient submits the data to the database in the final question. This reduction from ten to eight variables must be made manually through programming.

**Profile Page**

The profile page contains all patient-related information, including, in this case, the patient's email address, which serves as the database's primary key (More in section 5.4). In the created life cycle hook, the database is queried for all available patient information. There is a data-loaded boolean variable to ensure that the asynchronous function operates in accordance with Vue.js's reactivity.

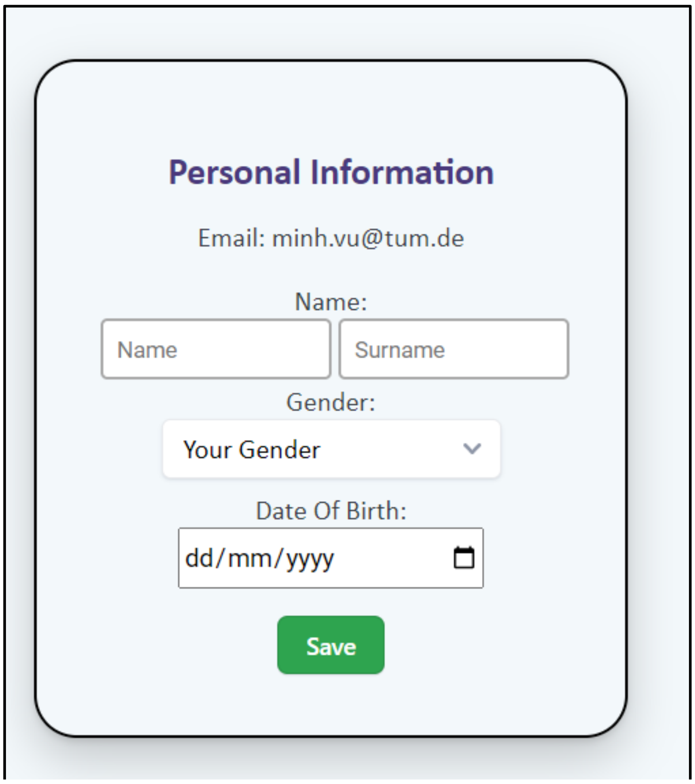



**Figure 20: Profile page**
**(Source: Own analysis)**

There is information about the email address, input forms for the name and surname, the gender in a multiple-choice input form, and a date form inside a nicely styled CSS box. After the patient completes the form and clicks the "Save" button, all their information will be sent to the server.

### Result page

The patient is directed to the results page after submitting the questionnaires. There is an ellipse-shaped progress bar for the patient to view their score. The information regarding the previous questionnaire result is saved in local storage so the patient can view it again.

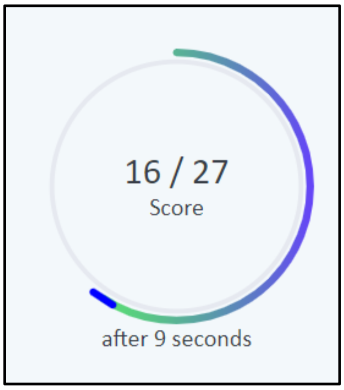



**Figure 21: Result page**
**(Source: Own analysis)**

### 5.3.3 Psychiatrist's Role

The psychiatric role consists of three primary pages. The first is a statistical dashboard, the second is patient tracking, and the third is patient comparison. All charts are styled with CSS inside a shadowed box for aesthetic purposes. Here is a breakdown of their programming.

**Statistics**

The component at the top is the switch toggle between the PHQ-9 and GAD-7. This component controls whether the charts below display PHQ-9 and GAD-7 statistics. Data is retrieved from the back-end API during the created life-cycle hook. Included are the PHQ-9 and GAD-7 databases. To comply with the reactivity of Vue.js, an additional variable is required to determine whether the data from these asynchronous functions are loaded. Once the data has finished loading, this variable's value is set to true. While the value of this variable is still false, there is a loading pattern indicating to the psychiatrists the loading procedure.

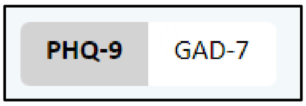



**Figure 22: Questionnaire toggle**
**(Source: Own analysis)**

The first chart is a heatmap from Apexchart that depicts the frequency with which patients select a particular questionnaire response. This heatmap contains four rows, each representing a unique response to the PHQ-9 and GAD-7. These four columns are labeled "Nearly every day," "More than half the time," "Several days," and "Not at all." The PHQ-9 heatmap contains ten columns, which correspond to ten questions. While the GAD-7 heatmap contains eight columns, they represent eight questions. After the asynchronous functions that retrieved the data have been completed, a nested-for loop is used to count the number of times patients select a particular option. This result is color-based, ranging from white to the reddest hue.

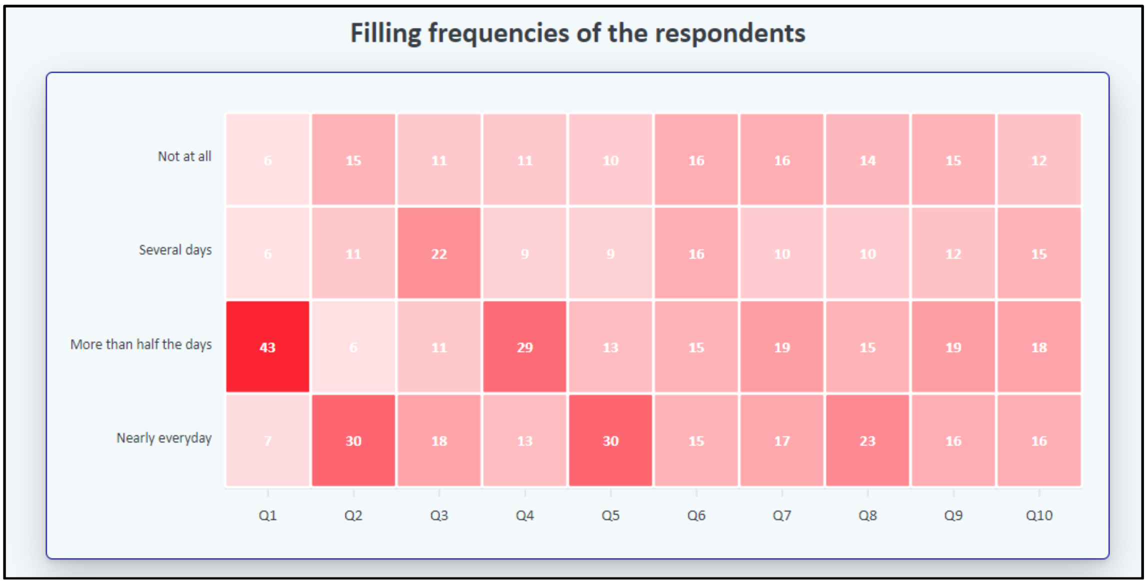



**Figure 23: Filling frequencies of the respondents**
**(Source: Own analysis)**

The second graph is a pie chart from Apexchart that illustrates the average score for each question. This PHQ-9 chart has ten labels corresponding to the ten questions, whereas the GAD-7 chart has eight labels corresponding to the eight questions. Calculating the average scores is performed concurrently with the first chart's process of determining the frequency of each answer.

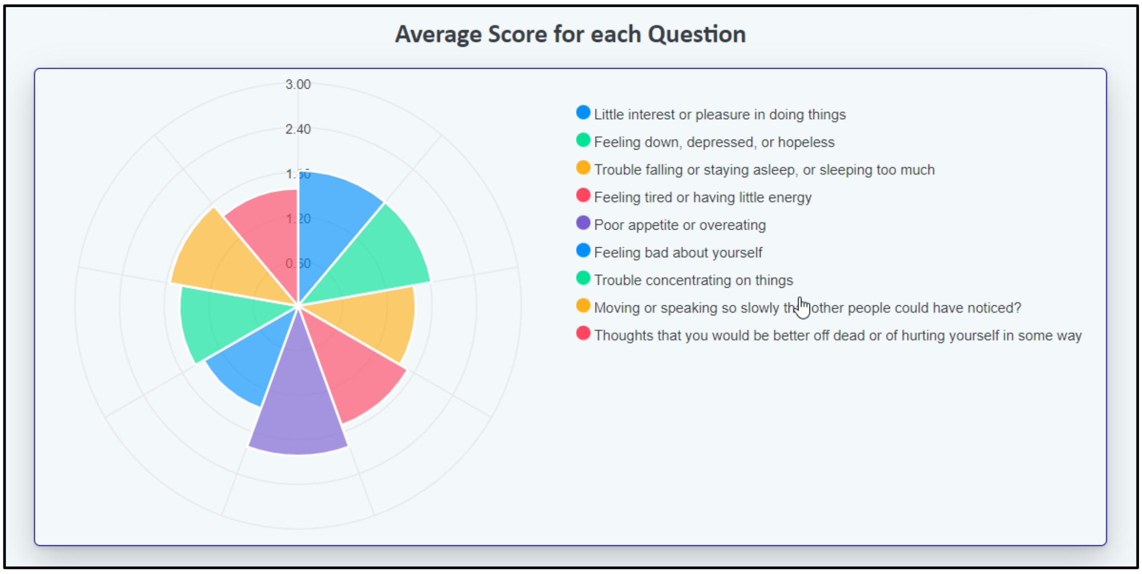



**Figure 24: Average score for each question**
**(Source: Own analysis)**

The third graph is a piechart from Apexchart that depicts the number of devices used by patients to complete the questionnaire. This statistic is calculated by counting the number of occurrences of a specific device in the "device" column of the PHQ-9 and GAD-7 databases. The main three device categories are desktop, tablet, and phone.

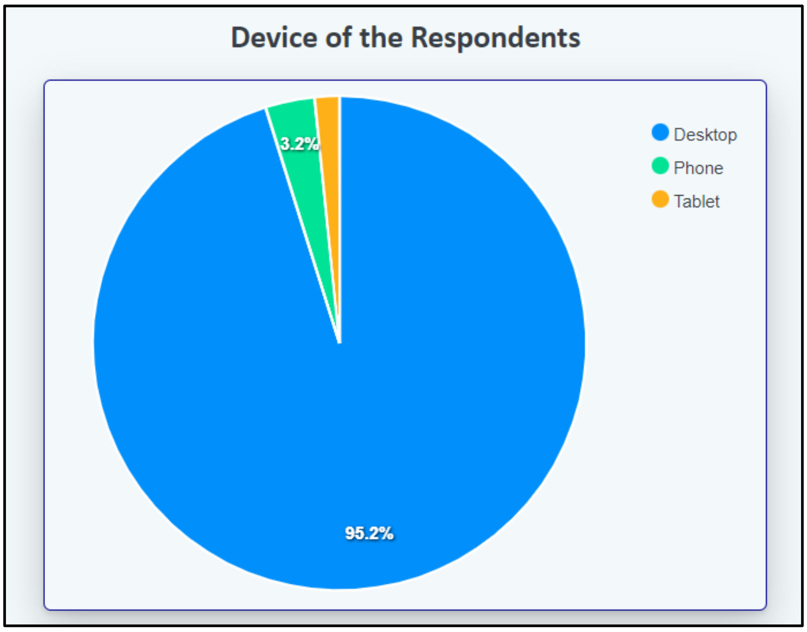



**Figure 25: Device of the respondents**
**(Source: Own analysis)**

The fourth chart is a map depicting the total number of questionnaire responses from each country. This statistic is calculated by counting the number of occurrences of a specific country in the "country" column of the PHQ-9 and GAD-7 databases. The red hue of the countries corresponds to the number of respondents.

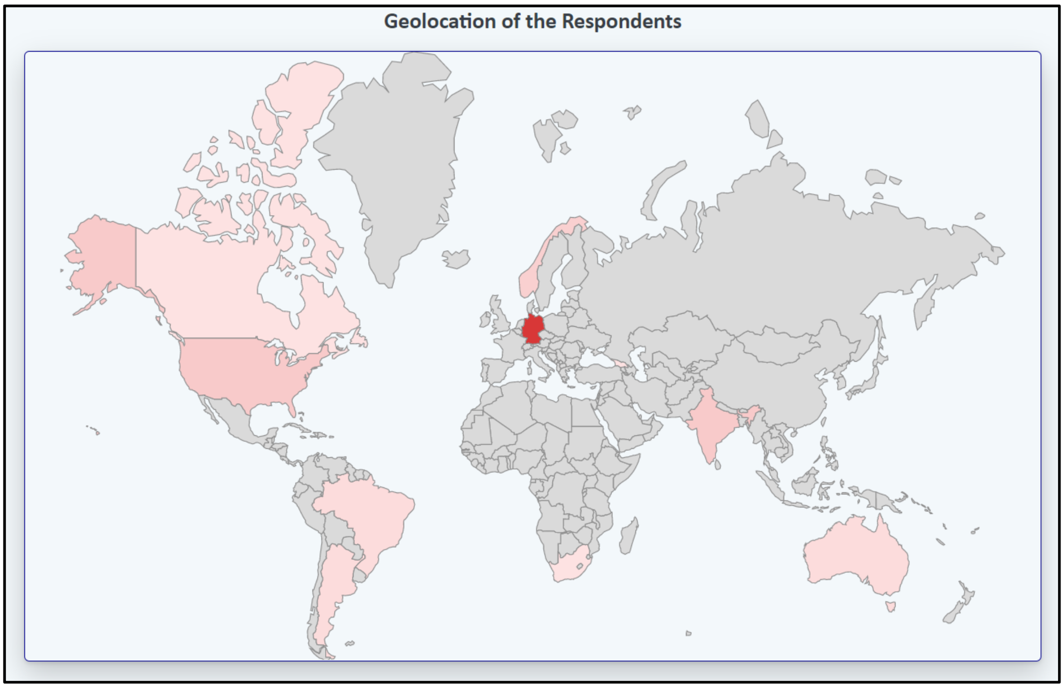



**Figure 26: Geolocation of the respondents**
**(Source: Own analysis)**

### Track Patient

The API is queried for the patient, the PHQ-9, and the GAD-7 databases prior to the creation of the life cycle hook. Similar to the Statistics page, there is a variable whose value is set to true when the asynchronous operations have been completed in order to conform to Vue.js reactivity.

On the homepage, there is an input field where the psychiatrist can search for the patient's email address. Alternatively, the psychiatrist may search the entire patient list. The emails of the patients the psychiatrist has just searched for are then displayed as buttons. If the psychiatrist wishes to locate a specific patient, the patient's information is toggled. In this section, the v-show directive of Vue.js is used to control the toggle and de-toggle processes via an array. This array ensures that when the psychiatrist clicks the button a second time, the patient's information is collapsed.

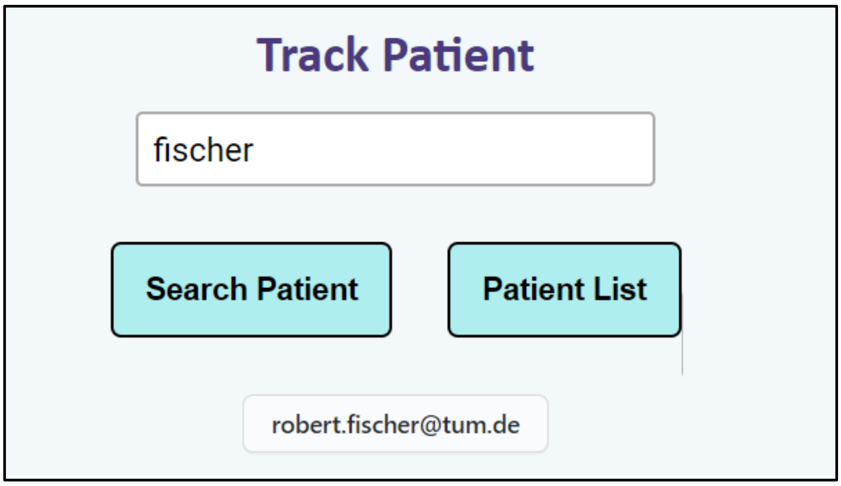
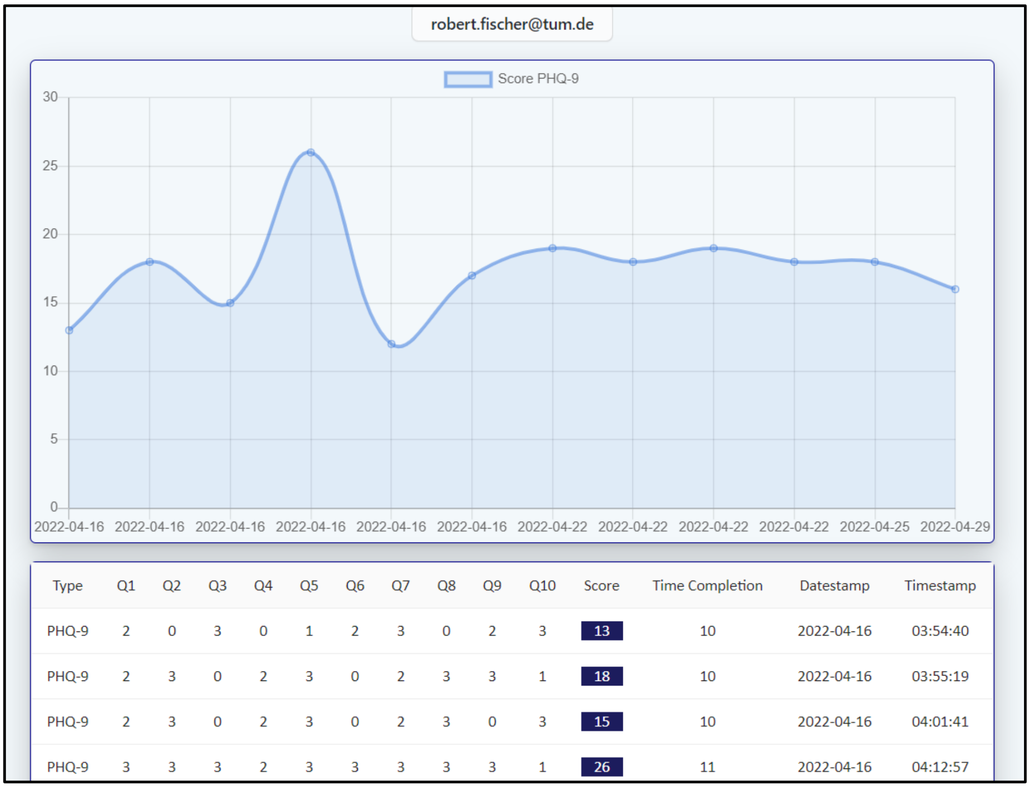



**Figure 27: Search patients or show the patient list**
**(Source: Own analysis)**

Two tables and two graphs make up the patient's information. The first is a table containing all of the PHQ-9 records filled out by this patient. The second is a Chart.js graph that displays the patient's cumulative PHQ-9 total score from beginning to end. This chart's y-axis labels are the date of the questionnaire. The third is a table listing all the GAD-7 records filled out by this patient. The fourth is a Chart.js graph that displays the patient's cumulative GAD-7 score from beginning to end. This chart's y-axis labels are also the date of the questionnaire. The PHQ-9 scores are marked in blue, while GAD-7s are in red. With this structure, the psychiatrist can retrieve complete patient information and determine whether the patient's condition improves or worsens. All charts and tables are CSS-styled within a shadowed box for aesthetic purposes.




| Type | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Score | Time Completion | Datestamp | Timestamp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHQ-9 | 2 | 0 | 3 | 0 | 1 | 2 | 3 | 0 | 2 | 3 | 13 | 10 | 2022-04-16 | 03:54:40 |
| PHQ-9 | 2 | 3 | 0 | 2 | 3 | 0 | 2 | 3 | 3 | 1 | 18 | 10 | 2022-04-16 | 03:55:19 |
| PHQ-9 | 2 | 3 | 0 | 2 | 3 | 0 | 2 | 3 | 0 | 3 | 15 | 10 | 2022-04-16 | 04:01:41 |
| PHQ-9 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 1 | 26 | 11 | 2022-04-16 | 04:12:57 |

**Figure 28: Previous questionnaire response of a patient**
**(Source: Own analysis)**

**Compare Patients**

Similar to Track Patient, the API patient, PHQ-9, and GAD-7 databases are retrieved within the created life cycle hook. Furthermore, an additional boolean "loading" variable to determine if asynchronous data is loaded.

The component at the top is the switch toggle between the PHQ-9 and GAD-7. This component controls whether the charts below display PHQ-9 and GAD-7 statistics. This component is comparable to the one on the page Statistics.

The first chart is a comparison of the frequency distribution of scores between male and female patients. A map function is created from the patient databases that map the patient's email address to their gender for computing efficiency. After that, the PHQ-9 and the GAD-7 are looped to count the instances in which a male or female patient achieves a particular score. For a more accurate statistical comparison, the data must be statistically normalized.

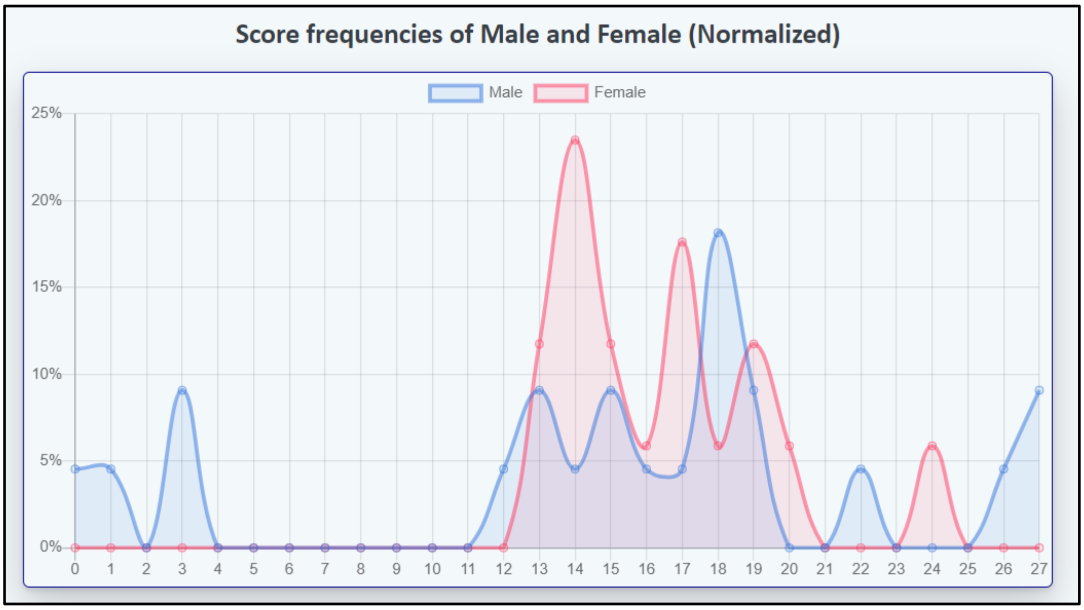



**Figure 29: Score frequencies of male and female (Normalized)**
**(Source: Own analysis)**

The second chart is an additional comparison of score frequency distribution, but this time with patient selection based on specific criteria. A multi-option toggle next to the email address of each patient indicates which group the patients belong to. By default, no patient belongs to any of the groups, but the psychiatrist has the ability to move patients individually into group 1, group 2, or group 3. A distinct color represents each group in the line chart. Again, the distribution is normalized by default to enable the comparison of groups of varying sizes. Note that the chart cannot be re-rendered automatically when the props data changes; rather, it must be re-rendered manually. This attribute is accomplished by activating the "key" property of the chart component. Each time the psychiatrist requests a data update, the "key" variable can be incremented to redraw the chart.

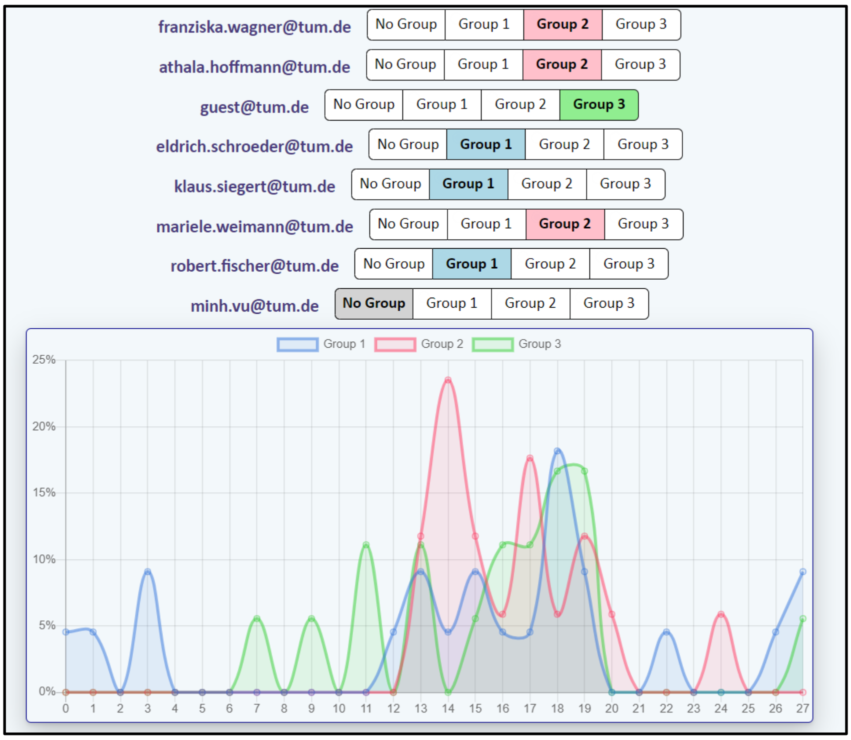



**Figure 30: Score frequencies of custom groups (Normalized)**
**(Source: Own analysis)**

## 5.4 Back-end Management

As described in the preceding section, the front-end components require dedicated storage for the stored metadata. This section will provide a comprehensive overview of the back-end management based on the architecture described in section 5.2.

### 5.4.1 Setup

The selected technology for the backend is Supabase's backend-as-a-service. Database administrators can create Supabase login accounts using either an email address or a GitHub account. For the author of the thesis, the GitHub page is associated with the Supabase account. The administrator can manually or programmatically create PostgreSQL databases. This section is covered in detail in Appendix B.

There is a comprehensive guide on how to use the database API on the main website. (*Introduction | Supabase*, n.d.) The database administrator can find the API endpoint and API key in the settings tab in order to use the back-end service. These back-end keys are located in the hidden environment file *.env*. The maximum number of rows the SQL database returns after a query, which can be set to 1,000,000 to prevent data loss, is one of the application-specific database settings that can be altered. This section is covered in detail in Appendix B.

### 5.4.2 Databases

The front-end design requires four databases: a database to store the metadata for the PHQ-9 questionnaire, a database to store the metadata for the GAD-7 questionnaire, a database to store the metadata for the SUS questionnaire, and an additional database to store the metadata related to the personal information of the patients in the profile page, as described in section 5.3.2.

**PHQ-9 database**

This column must be included in the database used to store PHQ-9 metadata. The primary key column is the most critical in a SQL database. Given that no other column is a unique identifier, the integer generator is selected as the key for this column. The second most crucial column required by this database is the email address of each respondent who completes this questionnaire, which is in the type text.

Moreover, there is data recorded from the PHQ-9 questionnaire's datestamp and timestamp. These are in the data type and time, respectively, and are stored in the database columns titled "datestamp" and "timestamp." They are recorded when the patients begin filling out the questionnaires. Whenever the patient changes their mind about the answer, there is an int variable that counts the number of such occurrences. So another column is labeled “answer _changes."

The score of each of the ten questionnaire questions is stored in a separate column, with the names q0 to q9 in the type int (integer). The total score, the sum of the ten answers, is listed in a separate column for computational flexibility. This variable's type is int (integer), and the name is "total_score."

Additionally, there are ten columns for the number of seconds it takes the patient to select each answer and an additional column for the amount of time it takes to complete the entire questionnaire. These variables are of type int (integer) and have the respective names "t0" to "t9". Time to completion is another separate column under the name "time_completion" with the type int (integer).

Following the construction of score and time metadata management, the geolocational and device data should be examined. When filling out the questionnaire, the patient is required to provide metadata about the device he or she is using, the user agent name of the device under the column “user_agent,” the operating system of the device under the column “operating_system,” the location code under the column “location,” and the city under the column “city.” These four fields of metadata necessitate four columns of the text data type.

| General metadata | | | | | | |
|---|---|---|---|---|---|---|
| **Role** | **Key (primary)** | **Email** | **Timestamp** | **Datestamp** | **Language** | **Changes of the answer** |
| **Name** | id | email | timestamp | datestamp | language | answer_changes |
| **Type** | int | text | time | date | text | int |

| Score metadata | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Role** | **Q1** | **Q2** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Q9** | **Q10** | **Total score** |
| **Name** | q0 | q1 | q2 | q3 | q4 | q5 | q6 | q7 | q8 | q9 | total_score |
| **Type** | int | int | int | int | int | int | int | int | int | int | int |

| Time metadata | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Role** | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** | **T8** | **T9** | **T10** | **Time to completion** |
| **Name** | t0 | t1 | t2 | t3 | t4 | t5 | t6 | t7 | t8 | t9 | time_completion |
| **Type** | int | int | int | int | int | int | int | int | int | int | int |

| Geolocational metadata | | | | |
|---|---|---|---|---|
| **Role** | **Country code** | **City** | **Operating system** | **User-agent** |
| **Name** | location | city | operating_system | user_agent |
| **Type** | text | text | text | text |

**Table 10: Metadata of the PHQ-9 database**
**(Source: Own analysis)**

### GAD-7 Database

The database structure used to store the metadata for the GAD-7 questionnaire is very similar to that of the PHQ-9 database. Due to the fact that the GAD-7 consists of eight questions as opposed to ten questions in the PHQ-9, this database contains only eight columns for the score of each question as opposed to ten columns in the PHQ-9 database, as well as only eight columns for the time taken in seconds for each question.

| General metadata | | | | | | |
|---|---|---|---|---|---|---|
| **Role** | **Key (primary)** | **Email** | **Timestamp** | **Datestamp** | **Language** | **Changes of the answer** |
| **Name** | id | email | timestamp | datestamp | language | answer_changes |
| **Type** | int | text | time | date | text | int |

| Score metadata | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Role** | **Q1** | **Q2** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Total score** |
| **Name** | q0 | q1 | q2 | q3 | q4 | q5 | q6 | q7 | total_score |
| **Type** | int | int | int | int | int | int | int | int | int |

| Time metadata | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Role** | **T1** | **T2** | **T3** | **T4** | **T5** | **T6** | **T7** | **T8** | **Time to completion** |
| **Name** | t0 | t1 | t2 | t3 | t4 | t5 | t6 | t7 | time_completion |
| **Type** | int | int | int | int | int | int | int | int | int |

| Geolocational metadata | | | | |
|---|---|---|---|---|
| **Role** | **Country code** | **City** | **Operating system** | **User-agent** |
| **Name** | location | city | operating_system | user_agent |
| **Type** | text | text | text | text |

**Table 11: Metadata of the GAD-7 database**
**(Source: Own analysis)**

**SUS Database**

Collecting any SUS-related metadata is unnecessary, so the SUS database is considerably less complicated. The table's primary key is an integer generator. In addition, it consists of ten columns of type int (integer) for ten questions' responses.

| SUS metadata | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Score metadata** | | | | | | | | | | |
| **Role** | **key (primary)** | **Q1** | **Q2** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Q9** | **Q10** | **Total score** |
| **Name** | id | q0 | q1 | q2 | q3 | q4 | q5 | q6 | q7 | q8 | q9 | total_score |
| **Type** | int | int | int | int | int | int | int | int | int | int | int | int |

**Table 12: Metadata of the SUS Feedback**
**(Source: Own analysis)**

**Profile Database**

This database is the database where patients’ information will be stored. The primary key column must be a unique identifier, so in this instance, patients' email addresses to log in are selected as the key. The first two columns contain the first and last names of the patients, which are of the type text. In addition, the gender of each patient must be stored in a text column. The date of birth of the patients is recorded in a column of the type date.

| Profile metadata | | | | | |
|---|---|---|---|---|---|
| **Role** | **Email (primary)** | **Name** | **Surname** | **Date of Birth** | **Gender** |
| **Name** | email | name | surname | date_of_birth | gender |
| **Type** | text | text | text | date | text |

**Table 13: Metadata of the patient's profile**
**(Source: Own analysis)**

# 6. Evaluation

This chapter discusses the digital platform's evaluation. There were two distinct approaches taken. The first approach is an evaluation of usability, which was conducted using the System Usability Scale (SUS) questionnaire and eighteen respondents. Subsequently, a second automatic analysis designed for the Lighthouse web application was performed and discussed in the next section.

## 6.1 System Usability Scale (SUS) Evaluation

The evaluation of the system must be based on the experiences of actual users. The SUS is a metric designed to assess how users feel about a system. In addition, the users may send comments on actual improvements to the platform.

### 6.1.1 Overview of the SUS

Effectiveness ("the ability of users to complete tasks using the system and the quality of the output of those tasks"), efficiency ("the level of resource consumed in performing tasks"), and satisfaction ("users' subjective reactions to using the system") should be measured in a usability evaluation.

Brooke created the System Usability Measure (SUS), a standardized usability evaluation questionnaire. SUS implemented a straightforward, ten-item scale for these measurements. It is based on a Likert scale, which provides a statement and asks the participant to indicate his level of agreement. (Brooke, 1996)

The ten-item questionnaire's statements were carefully chosen to elicit extreme expressions of the measured attitude. Brooke examined fifty possible questions. The answers to half of the selected questions indicate strong agreement, while the answers to the other half indicate strong disagreement. The items that elicited the most extreme responses were ultimately chosen for the system usability scale. (Brooke, 1996)

The ten questions are:

1. I think that I would like to use this feature frequently.
2. I found the feature unnecessarily complex.
3. I thought the feature was easy to use.
4. I think that I would need the support of a technical person to be able to use this feature.
5. I found the various functions in this feature were well integrated.
6. I thought there was too much inconsistency in this feature.
7. I would imagine that most people would learn to use this feature very quickly.
8. I found the feature very cumbersome to use.
9. I felt very confident using the feature.
10. I needed to learn a lot of things before I could get going with this feature.

Each participant receives a single SUS score number upon evaluation of their responses. According to Brooke, the SUS score is calculated as follows:

The contribution of each question to the total score varies depending on whether the question number is odd or even.

1. The score contribution for questions 1, 3, 5, 7, and 9 is the scale position minus 1. For instance, the contribution of a 4-point answer is 4 - 1 = 3.
2. The score contribution for questions 2, 4, 6, 8, and 10 is equal to 5 minus the scale position provided in response. For instance, the contribution of a score of 4 is 5 - 4 = 1.

The total score is then multiplied by a factor of 2.50. This score results in the participant's SUS score.

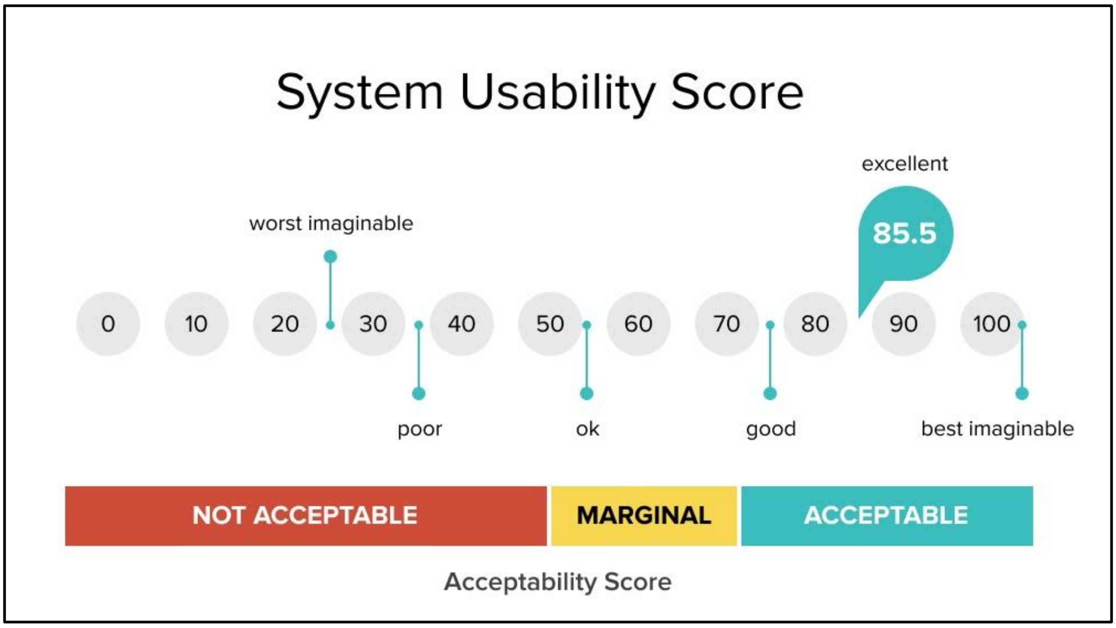



**Figure 31: Visualization of System Usability Scale (Source: Adobe XD ("The System Usability Scale & How It's Used in UX | Adobe XD Ideas," n.d.))**

## 6.1.2 Evaluation

Among the eighteen respondents, seven respondents are either final-year computer science students or a holder of computer science degrees. These respondents have sufficient expertise to judge the technicality of the digital platform. Six respondents are medical experts and have a degree related to medicine. These respondents have sufficient expertise to judge the role of the psychiatrist. None of whom in these two groups actually was at the time suffering from mental health illnesses. Additionally, five respondents were, unfortunately at the time, suffering from some kind of mental health illness and filled in the role of patients. These respondents are more suitable to judge the usability of the patient's role.

The digital platform obtains a good evaluation with an overall score of 80. A total of three users give an excellent score, and fifteen users give a good score. The respondents with the expertise in computer science give an average score of 85, the respondents with the expertise in medicine give an average score of 81, and the respondents with one of the mental health issues give an average score of 75. The complete SUS scoring table is located in Appendix C. Underneath is the line chart of the respondents' evaluation, rounded up or down to the nearest value.

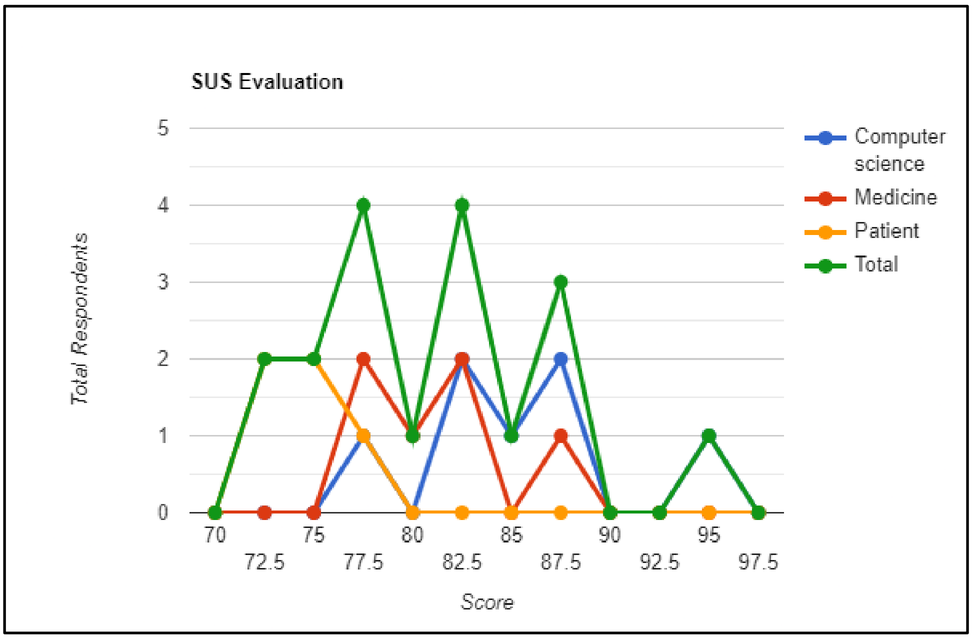



**Figure 32: Line chart of respondents' SUS evaluation (Source: Own analysis)**

### 6.1.3 Discussion

The evaluation can be even better since some questions in the SUS might be interpreted as ambiguous in the context of mental health. For instance, the response to the first question, "I would like to use this feature frequently," could be interpreted as the respondent's desire to remain mentally ill; and, thus, has an adverse effect on the evaluation. Among the odd questions, the third question, "I thought the feature was easy to use," achieves the best score, indicating the digital platform's ease of usage. On the other hand, the first question, "I think that I would like to use this feature frequently," achieves the worse score for the reason stated above.

| | | | | | |
|---|---|---|---|---|---|
| Computer science respondents | Q1 | Q3 | Q5 | Q7 | Q9 |
| | 2,43 | 5 | 4,71 | 4,86 | 4,71 |
| Medicine respondents | Q1 | Q3 | Q5 | Q7 | Q9 |
| | 3,5 | 4,83 | 4,5 | 3,67 | 4,33 |
| Mental health respondents | Q1 | Q3 | Q5 | Q7 | Q9 |
| | 3 | 4,4 | 4,2 | 3,8 | 4 |

**Table 14: Respondents on the odd questions (Blue denotes the lowest score in that row, orange denotes the highest) (Source: Own analysis)**

The author decided to perform an adjusted version of the SUS without the first question, which was deemed ambiguous. The adjusted version of the SUS now contains only nine questions, without the presence of the first question, and is scaled up to the maximum score of 100 and the scoring mechanism stays intact. The adjusted version of the SUS yields a score of 84, which is nearly excellent. On the other hand, by no means does the author claim that the adjusted version is superior, but it is constructed to give a glimpse of the impact an ambiguous question can have on the evaluation.

Among the three categories of the respondents, the best scoring group is the one that possesses the expertise in computer science with an excellent score of 85, while the worst scoring group is the one consisting of the mental health patients with a score of 75. This data shows that there have to be improvements in terms of accessibility with respect to marginalized groups, who possess much fewer computer skills. Some of which are discussed in section 7.2.3, where accessibility of disabled patients is discussed, or section 7.3.1, where the ease of use of the digital platform is the topic.

There are three notable improvements from the comments from the respondents. The first one is: The questionnaire card required the usage instructions, which were amended subsequently. Otherwise, some users might have gotten confused about how the questionnaire card worked.


**Figure 33: Questionnaire card before and after the caption (Source: Own analysis)**

The navigation was initially collapsed in the previous version of the web application but then was switched to uncollapsed by default in the final version; otherwise, the users would not know the navigation bar existed in the first place. Therefore, it was suggested by one user in the comment that this navigation bar needed to stay uncollapsed the whole time.


**Figure 34: Navigation bar before and after uncollapsing**
**(Source: Own analysis)**

On the patient's side, one user suggested that there needed to be a calendar to help the patient keep track of the progress. Otherwise, the patient would not know when they last filled in the questionnaire. This information is valuable information to track one's progress in mental health. Therefore, a calendar page was finally introduced as one of the main features.

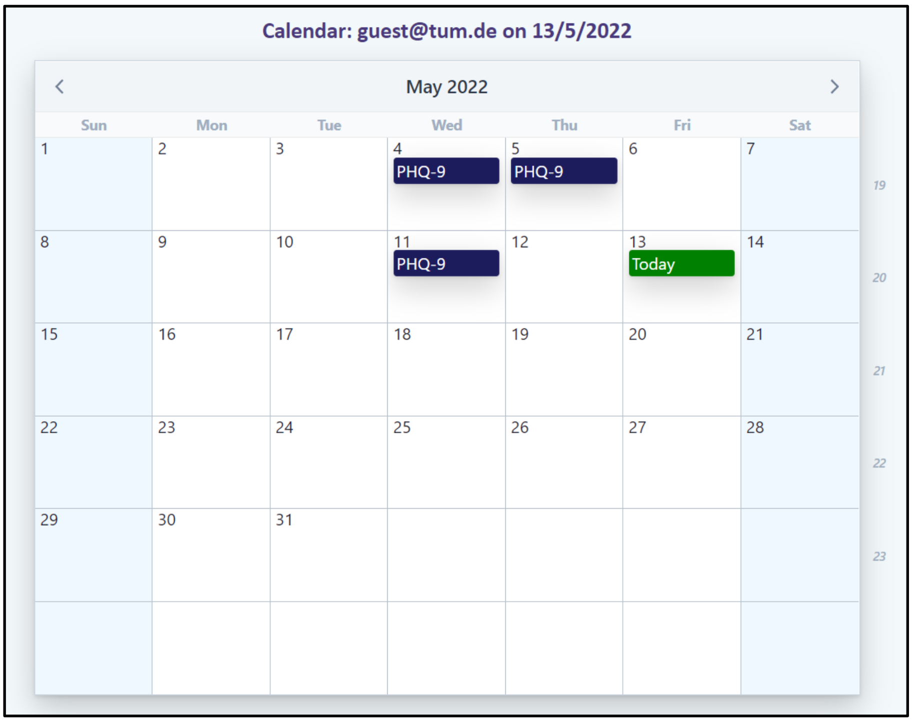



**Figure 35: Patient's calendar, which denotes the events**
**(Source: Own analysis)**

## 6.2. Lighthouse Evaluation

The previous section discusses an evaluation approach based on real-life respondents. Furthermore, for this section, the digital platform will undergo an alternative approach based on automation, where the analysis is from the tool Lighthouse, a standard set by the reputable software company Google. (*Lighthouse | Tools for Web Developers | Google Developers*, n.d.)

### 6.2.1 Overview of Lighthouse

Lighthouse is a tool developed by Google for evaluating web apps concerning their quality which collects performance metrics and insights. It can be run as an extension within Google Chrome or directly installed into the Google Chrome Dev-Tools. In an analysis of a web page, several audits are run. The quality is then measured in five categories: Progressive Web App, Performance, Accessibility, Search Engine Optimization (SEO), and Best Practices. Lighthouse calculates a single score between 0 and 100 for each of those four categories. It can be used as a verification tool for the Progressive Web App requirements. (*Lighthouse | Tools for Web Developers | Google Developers*, n.d.)

### 6.2.2 Evaluation

Every webpage that is crawled by a search engine is evaluated with a score from 5 categories: Performance, Accessibility, Best Practices, SEO, and PWA. These categories are given a score between 0 – 100. A better lighthouse score will affect how high up the webpage will appear on a search engine. ("Lighthouse Scores - What Are They and Why Are They Important?," 2021)

Each of these categories is judged on the following:

- Performance is judged on how quickly it takes the webpage to load.
- Accessibility is judged by how accessible the website is, especially for users who might require technology such as a screen reader or have difficulty with colors.
- Best Practices are judged by factors that are usually only apparent to developers. This category will be on code health, for example, using deprecated Libraries/APIs, asking for permission if one wants the user's locations, and ensuring that it is a secure HTTPS connection.
- SEO (Search Engine Optimization) is judged by ensuring the page is optimized for search engine results. This category is a large area of website design, but some simple examples could be header names and using keywords, making sure images have descriptive names so a search engine can label them.
- PWA (Progressive Web Apps) does not receive a score; it is either there or not.

The website achieves a good score. The Performance score is 97; the Accessibility score is 92; the Best Practices score is 92; the Search Engine Optimization (SEO) score is 89, slightly lower than the other three.

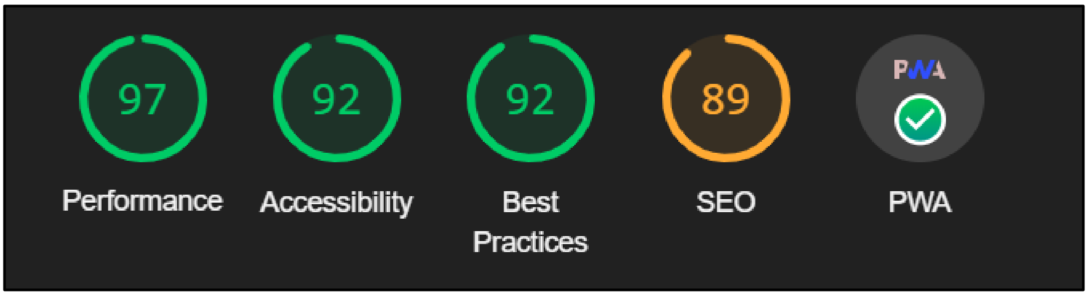



**Figure 36: Lighthouse evaluation of the digital platform**
**(Source: Own analysis, generated with Lighthouse)**

## 6.2.3 Discussion

The web application does not currently support Progressive Web App (PWA), so it does not receive a Lighthouse score in this category. This utility will instead be discussed in section 7.2.2, in which PWA can be introduced as a possible way to improve the application.

As a comparison, the 100 leading e-Commerce retailers average a Lighthouse score of 25. (*100 Leading ECommerce Retailers Average a Lower Performance Score Than You'd Expect | Layer0 Blog*, n.d.) So this means that the web application performs significantly better than many large corporations based on Lighthouse metrics. One beneficial aspect of having a higher Lighthouse score is that Google takes into the score for website ranking. ("Lighthouse Scores - What Are They and Why Are They Important?," 2021) The website with a higher Lighthouse score can get into the top pages of search engines, become more prevalent, and receive more traffic. Therefore, should the web application have its own domain name and wish to be available for search engines, it is beneficial to achieve a higher Lighthouse score.

The website achieves an excellent Performance score. A performance score is a measurement of how quickly it takes the webpage to load. From the platform requirements set out in section 4.1, the web application has performed fulfilled the target set out.

Possible improvements to the Performance and Best Practices score suggested by Lighthouse are to reduce unused JavaScript files, most of which, in this case, are not in the author's control. To improve the Search Engine Optimization (SEO) score further, one possible solution is to use a meta-framework for universal applications based on Vue.js, such as Nuxt.js. (Nuxt - Meta Tags and SEO, n.d.)

# 7. Discussion

Since the number of real-world possibilities is infinite, the digital platform may encounter complications and constraints that were not anticipated following implementation. Here, a sincere effort is made to reconcile these complexities. In the end, the chapter concludes with a list of future research agendas.

## 7.1 Reflection on Metadata Literature

The digital platform collects the age and gender of the patients based on volition, and this can helps meatal health researchers who are interested in these metadata. Moreover, the digital platform collects the platform of the metadata so that researchers can compare these platforms. Research papers such as Leung (2020) and Rossom (2017) can be replicated and validated. (Leung et al., 2020; Rossom et al., 2017) These two papers research the effect of age and gender on the questionnaire’s scores. These papers provide a valid reason why these two metadata are stored in the patient’s database.

Currently, due to the constraints of the thesis, the digital platform is only available in English and German. As far as I am aware, no research paper systematically compares the effect of these two languages. Hence, the current digital platform can help the research of such a topic. Moreover, the digital platform can be extended to multiple languages. For example, if this platform obtains a Turkish version for the questionnaire, then the studies from Reich (2018) can be replicated and validated using the digital platform. (Reich et al., 2018)

Moreover, this digital platform records the metadata of the user's device. The paper from Grunauer (2014) attempts to measure the validity of a tablet-based PHQ-9, and this information is also recorded by the digital platform, which means a replication of the research can be done. (Grunauer et al., 2014) Moreover, mobile devices are also recorded, so this can help research another paper should there be further research on the effects of mobile devices.

Another piece of information that has research potential is datestamp and timestamp. The time the questionnaires take place might have a particular effect on the results. Additionally, geolocational data can be utilized in a similar manner, where mental health researchers can determine whether the location of the patients might actually have an effect on the results.

## 7.2 Further Enhancements

There are many ways to enhance the digital platform's usability that fall outside this thesis's scope. The first two being discussed are responsive web design and the development of progressive web applications, both of which are intended to target a wide variety of devices. The original design of the web application is only targeted at desktop devices, while web traffic on mobile devices is growing at an incredible pace. (*Mobile Percentage of Website Traffic 2021*, n.d.) The second objective is to improve accessibility for the disabled and impaired, as they are one of the marginalized groups at risk for mental health issues. (*The Mental Health of People with Disabilities | CDC*, n.d.)

### 7.2.1 Responsive Web Design

Responsive web design (RWD) or responsive design is an approach to web design that aims to make web pages render well on various devices and window or screen sizes from minimum to maximum display size to ensure usability and satisfaction. (*Responsive Design - Learn Web Development | MDN*, n.d.)

A responsive design adapts the web-page layout to the viewing environment by using techniques such as fluid proportion-based grids, flexible images, and CSS3 media queries, an extension of the @media rule, in the following ways: ("Responsive Web Design," 2022)

- The fluid grid concept calls for page element sizing to be relative units like percentages rather than absolute units like pixels or points.
- Flexible images are also sized in relative units to prevent them from displaying outside their containing element.
- Media queries allow the page to use different CSS style rules based on the characteristics of the device the site is being displayed on, e.g., the width of the rendering surface (browser window width or physical display size).
- Responsive layouts automatically adjust and adapt to any device screen size, whether a desktop, a laptop, a tablet, or a mobile phone.

The components of the patient role respond reasonably well to the demand of the responsive design. This characteristic is due to the fact that most components of the patient role have relatively small widths. Meanwhile, the psychiatrist's role in dealing with real-time charts and graphs is unfortunately inelastic in this regard. The charts and graphs are programmed to have a fixed size. To achieve the requirement of responsive web design, a possible solution going forward is to have a screen width watcher and produce the charts and graphs dynamically with a script and use media queries.

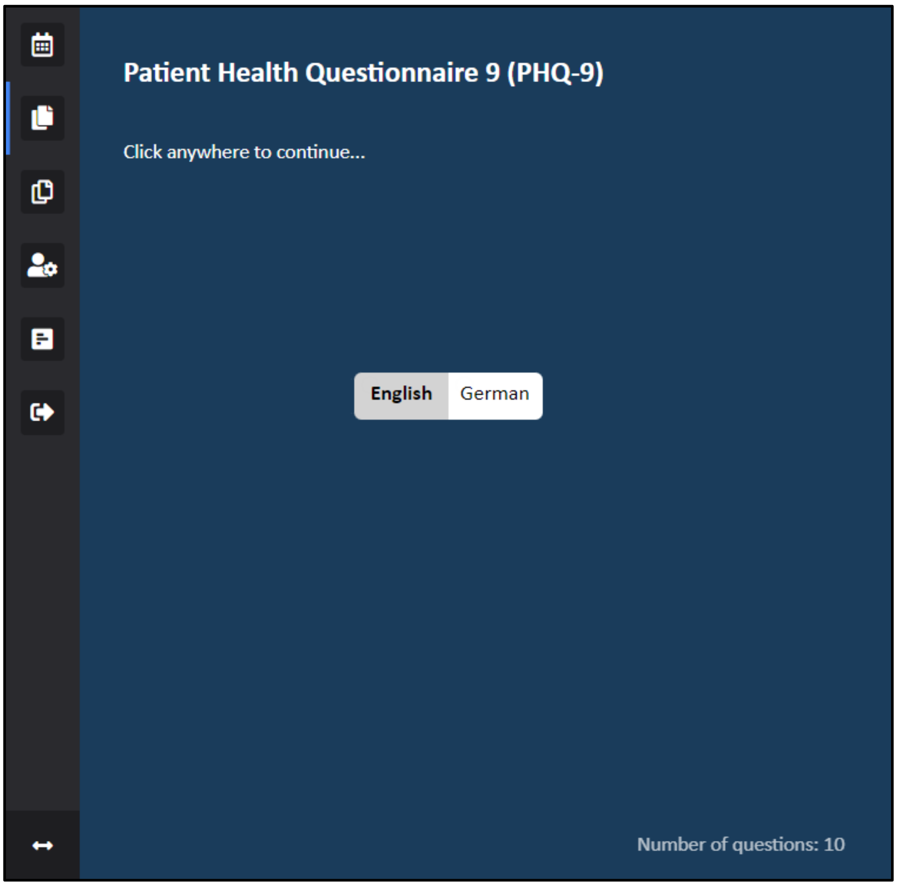



**Figure 37: A page from the patient's side that supports RWD on a tablet (Source: Own analysis)**

### 7.2.2 Mobile Integration with Progressive Web Application (PWA)

A progressive web application (PWA), commonly known as a progressive web app, is a type of application software delivered through the web, built using standard web technologies including HTML, CSS, JavaScript, and WebAssembly. It is intended to work on any platform using a standards-compliant browser, including desktop and mobile devices. (*Progressive Web Apps (PWAs) | MDN*, n.d.) Statistics from the transport-sharing service Lyft shows that users book 11% more on PWA than native applications. (*Lyft*, n.d.)

Since a PWA is a type of webpage or website known as a web application, they do not require separate bundling or distribution. Developers can just publish the web application online, ensure that it meets baseline "installability requirements," and users will be able to add the application to their home screen. Publishing the app to digital distribution systems like Apple App Store or Google Play is optional. (*Progressive Web Apps (PWAs) | MDN*, n.d.)

There is also an adapted solution for this web application to work on mobile, which is setting up a PWA. A responsive front-end web design is an essential pre-requisites for a successful PWA, which has already been discussed in section 7.2.1.

### 7.2.3 Accessibility to the Disabled

There are many scenarios concerning the condition of the users. Statistics show that people who suffer from visual impairments or blindness by age 50 are four times more likely to report mental health problems, including anxiety and depression than those with better eyesight. (*The Mental Health of People with Disabilities | CDC*, n.d.) Another recent study found that adults with disabilities report experiencing more mental distress than those without disabilities. In 2018, an estimated 17.4 million (32.9%) adults with disabilities experienced frequent mental distress, defined as 14 or more reported mentally unhealthy days in the past 30 days. (*The Mental Health of People with Disabilities | CDC*, n.d.) For the visually impaired or movement disabled, support for voice control or keyboard control is imperative. This section is a straightforward analysis of how these functionalities can be implemented.

**Voice Control**

Integrating the digital platform with a voice-to-text service and another text-to-voice service would be an excellent addition for those with a visual impairment or mobility disability. Users can use a voice command such as "Where am I?" to determine which screen they are on and receive a voice response. As a result of this integration, users are also able to issue voice commands. To enter the PHQ-9 page, for instance, users can simply say, "I need to fill out the PHQ-9."

The integration of Microsoft Azure Text-to-Speech and Speech-to-Text is one solution for implementing voice control. Audio to text can be transcribed quickly and accurately in over 100 languages and dialects. (*Speech to Text – Audio to Text Translation | Microsoft Azure*, n.d.) The models can be improved for domain-specific terminology accuracy, which in this case is healthcare. (*Speech to Text – Audio to Text Translation | Microsoft Azure*, n.d.)

**Keyboard Control**

Incorporating keyboard control across the digital platform is an additional solution for people with vision impairment, in addition to voice control. (Rajendran et al., 2016) The current version of the digital platform supports keyboard control in some capacity. Only the keyboard may be used to navigate the questionnaire filling interface. However, many pages of the digital platform have not yet supported the integration of keyboard control, and complete integration of keyboard control would be an excellent addition to the existing set of capabilities.

## 7.3 Integration into real-life Diagnosis

It is essential to measure the performance of this digital platform based on real-world standards and scenarios, which can be highly unpredictable because the primary purpose of this digital platform is to assist in daily diagnosis.

### 7.3.1 Ease of Use

Ease of use is a central concept in usability. Usability encompasses all user experience (UX) factors about how users can learn, discover content, and perform additional tasks with a design/product. Usability is a prerequisite for any successful product in UX design. (*What Is*

*Ease of Use? | Interaction Design Foundation (IxDF)*, n.d.)

Patients and psychiatrists are the primary demographics of this digital platform's users; for some, technology may still present a legitimate barrier. (Triana et al., 2020) New users visiting the page might not know which functions the digital platform offers, so the solution is to provide a navigation sidebar, and its existence is absolutely crucial. This sidebar can be collapsed by default, but users will be unaware that it exists in this instance.

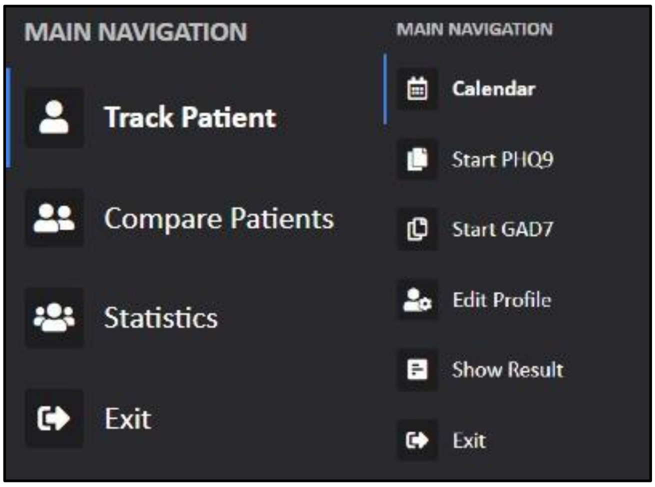



**Figure 38: Navigation sidebars of the psychiatrist and the patient, respectively (Source: Own analysis)**

Under the questionnaire, there should be instructions on how to use it; otherwise, users may become confused. Without the instruction, it is likely that the users will not be aware of the presence of keyboard control.

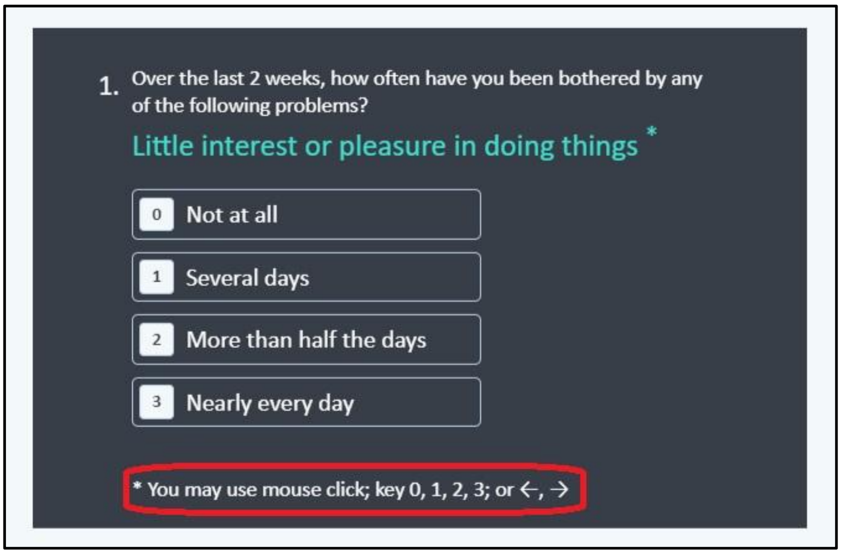



**Figure 39: Instruction underneath a questionnaire card (Circled in red) (Source: Own analysis)**

## 7.3.2 Scalability

Since this digital platform has the potential to serve clinics, it is crucial to estimate when the database will contain a certain number of patients and questionnaire responses. In the case of extensive databases, an algorithmic evaluation will be conducted.

The algorithmic complexity from the patient's side is currently neglectable. Meanwhile, the cost for a call to build up statistical tables from the psychiatrist's side is roughly $O(NM)$, where $N$ is the number of patients and $M$ is the number of responses in the databases. Hence, the current digital platform works with a magnitude of 4 for the number of patients and a magnitude of 4 for the total number of questionnaire responses. ("Instructions per Second," 2022)

In addition, the database's backend, Supabase, is constructed within an Amazon Web Services (AWS) instance. AWS is the leading cloud service platform with exceptional availability and scalability; hence this is beneficial to the digital platform's requirements. (*High Availability and Scalability on AWS - Real-Time Communication on AWS*, n.d.)


**Figure 40: The back-end service inside an AWS container**
**(Source: Own analysis)**

Despite theoretical calculations, scalability issues arising from real-world scenarios are highly unpredictable. (*20 Obstacles to Scalability - ACM Queue*, n.d.) Insufficient caching and the use of a single database copy are some of the obstacles.

### 7.3.3 Comparison of similar Solutions

Numerous internet websites allow the patient to fill in the PHQ-9 and the GAD-7 quickly. The most unique website is mdcalc.com, in collaboration with the creators of the PHQ-9 and GAD-7. (*PHQ-9 (Patient Health Questionnaire-9)*, n.d.) Unfortunately, as far as I am aware, the functionalities of these websites are limited to aggregating the score; the patients and psychiatrists will miss out on crucial supplementary information. There is also no way for the patients to view their history or for psychiatrists to view a patient's progress.

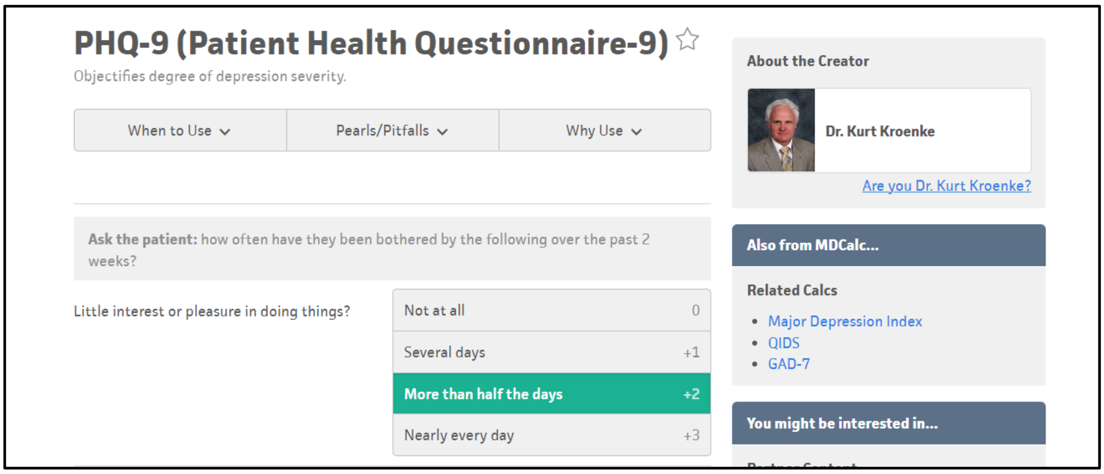



**Figure 41: A screenshot from mdcalc.com**
**(Source: mdcalc.com (*PHQ-9 (Patient Health Questionnaire-9)*, n.d.))**

Additionally, a mobile application for the PHQ-9 is called "Depression Screening Tool: PHQ-9 Test" from Psycnet Software. (*Depression Screening Tool*, n.d.) This application is freely available and offers the functionality to perform a PHQ-9. In this regard, this application is relatively similar to the above solution of mdcalc.com in that the ability for more profound analysis is somewhat limited. Moreover, this application offers a page where all the questions about depression are answered.

Another solution on the market is the software "Penelope" from Athena Software. (*Standard Assessments | PHQ9, K10, ACE & More | Athena Software*, n.d.) It offers access to not just the PHQ-9 and the GAD-7 but also to multiple medical assessments, such as the Edinburgh Post-Natal Depression Scale or the Rosenberg Self-Esteem Scale. Unfortunately, this is commercial software, and due to the scope of the thesis, the author has decided against scheduling a demo and purchasing the full version of the software.

Therefore, the digital platform of the thesis can serve as an alternative solution, taking into account the dearth of solutions on the market. The patients have the ability to fill in the questionnaires swiftly while having a complete history of past submissions in the form of a calendar; the psychiatrists have the ability to diagnose a single patient and have an overview of the patients. Compared to the software "Depression Screening Tool: PHQ-9 Test" from Psycnet Software or the web application from mdcalc.com, the digital platform offers a much more comprehensive solution. The underneath table compares the functionalities of the three solutions.

| Characteristic | MDCalc | Depression Screening Tool: PHQ-9 Test | Thesis' platform |
|---|---|---|---|
| **Type** | Web application | Mobile application | Web application |
| **Filling in PHQ-9** | Yes | Yes | Yes |
| **Mental health information** | Yes | Yes | No |
| **History collection** | No | No | Yes |
| **Metadata collection** | No | No | Yes |

**Table 15: Comparison of mental health questionnaire's solutions**
**(Source: Own analysis)**

## 7.4 Future Research Agenda

As stated in section 7.1, the future research agenda for the domain of psychology is the determination of the effect of a patient's location and patient's device on the result of the mental health questionnaires. Moreover, should there be another version of the questionnaire in additional languages available, there can be future research on the discrepancy between the two different languages. The datestamp's and timestamp's effect on the questionnaire scores can be further researched and elucidated.

In addition, as stated in sections 7.2.1 and 7.2.2, extending the current web application with Responsive Web Design (RWD) and Progressive Web Application (PWA) is a possible future research agenda. These are another future research agenda in the domain of computer science. In section 7.3.2, there is a brief discussion of the platform's scalability, and additional research can be performed on this topic.

Furthermore, several research topics will require special knowledge across two domains: medicine and computer science. Extra functionalities to make the web application accessible to patients with disabilities are another focal research agenda following the discussion in section 7.2.3. Different types of disabilities, such as visual impairment or movement disability, will require different approaches. Last but not least, a recent paper determines which PHQ-9 items can be chosen to screen for suicide with machine learning, and there is much more potential with the metadata collected for further medical research with a machine learning approach. (Kim et al., 2021)

| Psychology | Computer Science | Medicine and Computer Science |
|---|---|---|
| The effects of location on mental health | Mental health platform with RWD | Mental health platform for visually impaired patients |
| The effects of devices on mental health | Mental health platform with PWA | Mental health platform for movement disabled patients |
| The effects of languages on mental health | Scalable mental health platform | Machine learning on mental health questionnaires' metadata |
| The effects of time on mental health | | |

**Table 16: Future research agenda across domains**
**(Source: Own analysis)**

# 8. Conclusion

The primary outcome of this thesis is a digital platform that collects metadata from the PHQ-9 and GAD-7 mental health questionnaires. The digital platform is a web application that provides a simple interface for patients to fill out questionnaires and a transparent method for psychiatrists to manage patients.

The PHQ-9 and GAD-7 questionnaires can be filled out in either English or German. Multiple metadata associated with the score, time, geolocation, or devices are stored in local storage before being submitted to a SQL database. Patients are also able to submit their personal information to the server, which is an additional metadata category collected by the digital platform. This information can be utilized for further mental health research. The digital platform aims to provide patients with a pleasant questionnaire-filling experience to enjoy the diagnosis process.

Psychologists are able to review the results of questionnaires, monitor an individual patient, and compare two patient groups. The digital platform optimizes the collected metadata and facilitates a meaningful diagnosis by effectively allowing psychiatrists to visualize the data through colorful charts and graphs.

The application was evaluated using the System Usability Scale (SUS) and the Lighthouse evaluation, and the results indicate that both the SUS and Lighthouse scores are good and excellent. Numerous proposals for future work were discussed to increase these values even further.

Moreover, there is a discussion regarding future expansions for the digital platform, including a mobile-integrated Progressive Web App (PWA) version with a responsive design, and another discussion regarding the likelihood of integrating into real-world diagnosis with possible impaired patients. Last but not least, a comprehensive list of future research agendas is compiled.

For the first research question, the paper has performed a comprehensive literature review in section 2.2 based on the literature review method from van Brocke (2009). This literature review includes a concept matrix and the relevant preparation for said concept matrix. The literature review dissects the influence of different types of metadata on the results of mental health questionnaires.

For the second research question, the current digital platform collects a wide range of metadata, including the score, time, geolocation, and device; it provides the patients with a seamless questionnaire experience and allows the psychiatrists to diagnose the patients effectively. Moreover, patients have a calendar to track their diagnosis progress, while psychiatrists can track a patient, compare two groups, and have a broad overview of the statistics.

For the third research question, the digital platform is a web application that utilizes the front-end technologies Vue.js and Sass, and the back-end technology Supabase and the database PostgreSQL. Vue.js is a high-performance front-end framework, Sass is a fully customizable design solution, Supabase is a reliable backend-as-a-Service, and PostgreSQL allows efficient statistical operations. This solution is a highly harmonious and efficient full-stack solution.

## Bibliography

*20 Obstacles to Scalability—ACM Queue*. (n.d.). Retrieved May 13, 2022, from https://queue.acm.org/detail.cfm?id=2512489

*100 Leading eCommerce Retailers Average a Lower Performance Score Than You'd Expect | Layer0 Blog*. (n.d.). Retrieved June 12, 2022, from https://layer0.co/post/top-100-retailer-lighthouse-performance-score

*Actions | Vuex*. (n.d.). Retrieved June 15, 2022, from https://vuex.vuejs.org/guide/mutations.html

*Angular vs jquery vs react vs vue | npm trends*. (n.d.). Retrieved May 13, 2022, from https://www.npmtrends.com/angular-vs-jquery-vs-react-vs-vue

*Angular—Introduction to the Angular Docs*. (n.d.). Retrieved May 11, 2022, from https://angular.io/docs

Arthurs, E., Steele, R. J., Hudson, M., Baron, M., Thombs, B. D., & Group, (CSRG) Canadian Scleroderma Research. (2012). Are scores on English and French versions of the PHQ-9 comparable? An assessment of differential item functioning. *PloS One*, *7*(12), e52028.

*AWS Documentation*. (n.d.). Retrieved May 11, 2022, from https://docs.aws.amazon.com/

Battaglia, M., Sampling, N., & Lavrakas, P. J. (2008). Encyclopedia of survey research methods. *Publication Date*.

Boehm, B. W. (1976). Software engineering. *IEEE Trans. Computers*, *25*(12), 1226–1241.

Borgogna, N. C., Brenner, R. E., & McDermott, R. C. (2021). Sexuality and gender invariance of the PHQ-9 and GAD-7: Implications for 16 identity groups. *Journal of Affective Disorders*, *278*, 122–130.

Brocke, J. vom, Simons, A., Niehaves, B., Niehaves, B., Reimer, K., Plattfaut, R., & Cleven, A. (2009). *Reconstructing the giant: On the importance of rigour in documenting the literature search process*.

Brooke, J. (1996). Sus: A "quick and dirty'usability. *Usability Evaluation in Industry*, *189*(3).

Buskirk, T. D., & Kirchner, A. (2020). Why machines matter for survey and social science researchers: Exploring applications of machine learning methods for design, data collection, and analysis. *Big Data Meets Survey Science: A Collection of Innovative Methods*, 9–62.

*Colectica*. (n.d.). Retrieved May 11, 2022, from https://www.colectica.com/

Crane, S. J., Ganesh, R., Post, J. A., & Jacobson, N. A. (2020). Telemedicine Consultations and Follow-up of Patients With COVID-19. *Mayo Clinic Proceedings*, *95*(9), S33–S34. https://doi.org/10.1016/j.mayocp.2020.06.051

*Depression Screening Tool: PHQ-9 Test - Apps on Google Play*. (n.d.). Retrieved June 10, 2022, from https://play.google.com/store/apps/details?id=com.newandromo.dev7998.app636500&hl=en&gl=US

Dosovitsky, G., Kim, E., & Bunge, E. L. (2021). Psychometric properties of a chatbot version of the PHQ-9 with adults and older adults. *Frontiers in Digital Health*, *3*, 41.

Erbe, D., Eichert, H.-C., Rietz, C., & Ebert, D. (2016). Interformat reliability of the patient health questionnaire: Validation of the computerized version of the PHQ-9. *Internet Interventions*, *5*, 1–4.

*Evaluating page experience for a better web | Google Search Central Blog | Google Developers*. (n.d.). Retrieved May 11, 2022, from https://developers.google.com/search/blog/2020/05/evaluating-page-experience

*Firebase Realtime Database | Firebase Documentation*. (n.d.). Retrieved June 15, 2022, from https://firebase.google.com/docs/database

*GAD-7 (General Anxiety Disorder-7)*. (n.d.). MDCalc. Retrieved June 14, 2022, from https://www.mdcalc.com/gad-7-general-anxiety-disorder-7

Galderisi, S., Heinz, A., Kastrup, M., Beezhold, J., & Sartorius, N. (2015). Toward a new definition of mental health. *World Psychiatry*, *14*(2), 231–233. https://doi.org/10.1002/wps.20231

García-Campayo, J., Zamorano, E., Ruiz, M. A., Pardo, A., Pérez-Páramo, M., López-Gómez, V., Freire, O., & Rejas, J. (2010). Cultural adaptation into Spanish of the generalized anxiety disorder-7 (GAD-7) scale as a screening tool. *Health and Quality of Life Outcomes*, *8*(1), 1–11.

*Get started with Vuetify*. (n.d.). Vuetify. Retrieved May 11, 2022, from https://vuetifyjs.com/en/getting-started/installation/#vue-ui-install

*Getting Started – React*. (n.d.). Retrieved May 11, 2022, from https://reactjs.org/docs/getting-started.html

Grunauer, M., Schrock, D., Fabara, E., Jimenez, G., Miller, A., Lai, Z., Kilbourne, A., & McInnis, M. G. (2014). Tablet-based screening of depressive symptoms in quito, Ecuador: Efficiency in primary care. *International Journal of Family Medicine*, *2014*.

*High availability and scalability on AWS - Real-Time Communication on AWS*. (n.d.). Retrieved May 11, 2022, from https://docs.aws.amazon.com/whitepapers/latest/real-time-communication-on-aws/high-availability-and-scalability-on-aws.html

*HTML and Static Assets | Vue CLI*. (n.d.). Retrieved June 13, 2022, from https://cli.vuejs.org/guide/html-and-static-assets.html

Hwang, I. H., & Oh, D. H. (2014). Questionnaires for Assessing Stress and Mental Health. *Hanyang Medical Reviews*, *34*(2), 91. https://doi.org/10.7599/hmr.2014.34.2.91

*Increasing flexibility: Capital Markets firms in the cloud adapt more quickly*. (2020, May 29). Amazon Web Services. https://aws.amazon.com/blogs/industries/increasing-flexibility-capital-markets-firms-in-the-cloud-adapt-more-quickly/

Instructions per second. (2022). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Instructions_per_second&oldid=1084579428

*Interpreting your PHQ-9 depression screening results*. (n.d.). Retrieved June 14, 2022, from https://www.oviahealth.com/guide/107365/fertility-pep-understanding-phq9

*Introduction | Supabase*. (n.d.). Retrieved May 11, 2022, from https://supabase.com/docs/

*JavaScript basics—Learn web development | MDN*. (n.d.). Retrieved May 11, 2022, from https://developer.mozilla.org/en-US/docs/Learn/Getting_started_with_the_web/JavaScript_basics

Jenn, N. C. (2006). Designing A Questionnaire. *Malaysian Family Physician : The Official Journal of the Academy of Family Physicians of Malaysia*, *1*(1), 32–35.

Kim, S., Lee, H.-K., & Lee, K. (2021). Which PHQ-9 Items Can Effectively Screen for Suicide? Machine Learning Approaches. *International Journal of Environmental Research and Public Health*, *18*(7), 3339. https://doi.org/10.3390/ijerph18073339

Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*(9), 606–613.

Leung, D. Y., Mak, Y. W., Leung, S. F., Chiang, V. C., & Loke, A. Y. (2020). Measurement invariances of the PHQ-9 across gender and age groups in Chinese adolescents. *Asia-Pacific Psychiatry*, *12*(3), e12381.

*Lighthouse | Tools for Web Developers | Google Developers*. (n.d.). Retrieved May 11, 2022, from https://developers.google.com/web/tools/lighthouse

Lighthouse Scores—What are they and why are they important? (2021, July 7). *MCD Helps Customers Transform Their Businesses by Harnessing the Power of Digital Technology. We Design and Build Digital Products across Mobile and Web.* https://mcdsystems.co.uk/lighthouse-scores-what-are-they-and-why-are-they-important/

*Lyft*. (n.d.). PWA Stats. Retrieved June 13, 2022, from https://www.pwastats.com

Manea, L., Gilbody, S., & McMillan, D. (2012). Optimal cut-off score for diagnosing depression with the Patient Health Questionnaire (PHQ-9): A meta-analysis. *Cmaj*, *184*(3), E191–E196.

*Mental health*. (n.d.). Retrieved May 11, 2022, from https://www.who.int/health-topics/mental-health

*Mental health: Definition, common disorders, early signs, and more*. (2020, April 14). https://www.medicalnewstoday.com/articles/154543

Metadata. (2022). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Metadata&oldid=1084575692

*Mobile percentage of website traffic 2021*. (n.d.). Statista. Retrieved June 13, 2022, from https://www.statista.com/statistics/277125/share-of-website-traffic-coming-from-mobile-devices/

*Mutations | Vuex*. (n.d.). Retrieved June 15, 2022, from https://vuex.vuejs.org/guide/mutations.html

Node.js. (n.d.). *About*. Node.Js. Retrieved May 11, 2022, from https://nodejs.org/en/about/

Oberlehner, M. (2021, July 3). *Vue 3 Composition API vs. Options API*. https://markus.oberlehner.net/blog/vue-3-composition-api-vs-options-api/

*Online doctor consultation market to grow 72% to $836 million by March 2024: Study*. (n.d.). Business Today. Retrieved May 13, 2022, from https://www.businesstoday.in/lifestyle/health/story/online-doctor-consultation-market-to-grow-72-to-836-million-by-march-2024-study-304689-2021-08-19

Pencil and Paper. (2021, February 24). UX Design Patterns for Loading. *Pencil & Paper Design Company*. https://pencilandpaper.io/articles//ux-pattern-analysis-loading-feedback/

*PHQ-9 (Patient Health Questionnaire-9)*. (n.d.). MDCalc. Retrieved June 10, 2022, from https://www.mdcalc.com/phq-9-patient-health-questionnaire-9

Plummer, F., Manea, L., Trepel, D., & McMillan, D. (2016). Screening for anxiety disorders with the GAD-7 and GAD-2: A systematic review and diagnostic metaanalysis. *General Hospital Psychiatry*, *39*, 24–31.

*Progressive web apps (PWAs) | MDN*. (n.d.). Retrieved May 11, 2022, from https://developer.mozilla.org/en-US/docs/Web/Progressive_web_apps

Rajendran, C., Parab, C., & Gupta, S. (2016). EGDE, a soft keyboard for fast typing for the visually challenged. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, 50–55.

*Reactivity in Depth | Vue.js*. (n.d.). Retrieved June 15, 2022, from https://vuejs.org/guide/extras/reactivity-in-depth.html#how-reactivity-works-in-vue

Reich, H., Rief, W., Brähler, E., & Mewes, R. (2018). Cross-cultural validation of the German and Turkish versions of the PHQ-9: An IRT approach. *BMC Psychology*, *6*(1), 1–13.

*Responsive design—Learn web development | MDN*. (n.d.). Retrieved May 11, 2022, from https://developer.mozilla.org/en-US/docs/Learn/CSS/CSS_layout/Responsive_Design

Responsive web design. (2022). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Responsive_web_design&oldid=1091954126

Richardson, T., Wrightman, M., Yeebo, M., & Lisicka, A. (2017). Reliability and Score Ranges of the PHQ-9 and GAD-7 in a Primary and Secondary Care Mental Health Service. *Journal of Psychosocial Rehabilitation and Mental Health*, *4*(2), 237–240. https://doi.org/10.1007/s40737-017-0090-0

Rossom, R. C., Coleman, K. J., Ahmedani, B. K., Beck, A., Johnson, E., Oliver, M., & Simon, G. E. (2017). Suicidal ideation reported on the PHQ9 and risk of suicidal behavior across age groups. *Journal of Affective Disorders, 215*, 77–84.

*Sass: Documentation*. (n.d.). Retrieved May 11, 2022, from https://sass-lang.com/documentation

*Speech to Text – Audio to Text Translation | Microsoft Azure*. (n.d.). Retrieved May 11, 2022, from https://azure.microsoft.com/en-us/services/cognitive-services/speech-to-text/

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine, 166*(10), 1092–1097.

*SQL vs NoSQL Database—A Complete Comparison*. (n.d.). Retrieved June 15, 2022, from https://backendless.com/sql-vs-nosql-database-a-complete-comparison/

*Standard Assessments | PHQ9, K10, ACE & more | Athena Software*. (n.d.). Social Solutions. Retrieved June 10, 2022, from https://athenasoftware.net/features/operational-tools/standard-assessments/

*Survey Shows Employees Felt Surprisingly Productive During COVID-19*. (n.d.). BCG Global. Retrieved May 11, 2022, from https://www.bcg.com/press/11august2020-survey-shows-employees-felt-surprisingly-productive-during-covid-19

*The Mental Health of People with Disabilities | CDC*. (n.d.). Retrieved May 11, 2022, from https://www.cdc.gov/ncbddd/disabilityandhealth/features/mental-health-for-all.html

*The Role of Data Analytics in Health Care*. (n.d.). Retrieved May 11, 2022, from https://online.shrs.pitt.edu/blog/data-analytics-in-health-care/

The System Usability Scale & How it's Used in UX | Adobe XD Ideas. (n.d.). *Ideas*. Retrieved May 13, 2022, from https://xd.adobe.com/ideas/process/user-testing/sus-system-usability-scale-ux/

*The Trusted Source for IP Address Data (geolocation and threat)—Ipregistry*. (n.d.). Retrieved June 15, 2022, from https://ipregistry.co/

Triana, A. J., Gusdorf, R. E., Shah, K. P., & Horst, S. N. (2020). Technology literacy as a barrier to telehealth during COVID-19. *Telemedicine and E-Health, 26*(9), 1118–1119.

User Experience: Reimagining Productivity and Business Value. (n.d.). *Knowledge at Wharton*. Retrieved May 13, 2022, from https://knowledge.wharton.upenn.edu/article/user-experience-reimagining-productivity-and-business-value/

*Vue CLI*. (n.d.). Retrieved May 11, 2022, from https://cli.vuejs.org/guide/

*Vue Router*. (n.d.). Retrieved June 15, 2022, from https://router.vuejs.org/guide/

*Vue.js—The Progressive JavaScript Framework | Vue.js*. (n.d.). Retrieved May 11, 2022, from https://vuejs.org/guide/introduction.html#what-is-vue

*Walmart saw up to a 2% increase in conversions for every 1 second of improvement in load time. Every 100ms improvement also resulted in up to a 1% increase in revenue.* (n.d.). Retrieved May 11, 2022, from https://wpostats.com/2015/11/04/walmart-revenue.html

*What is Babel? · Babel*. (n.d.). Retrieved May 11, 2022, from https://babeljs.io/docs/en/

*What is Ease of Use? | Interaction Design Foundation (IxDF)*. (n.d.). Retrieved May 11, 2022, from https://www.interaction-design.org/literature/topics/ease-of-use

*What Is NoSQL? NoSQL Databases Explained | MongoDB*. (n.d.). Retrieved May 11, 2022, from https://www.mongodb.com/nosql-explained

*What Is PostgreSQL?* (2022, February 10). PostgreSQL Documentation. https://www.postgresql.org/docs/14/intro-whatis.html

*What is SQL (Structured Query Language)? - SQLCourse*. (2022, January 9). SQL Course. https://www.sqlcourse.com/beginner-course/what-is-sql/

*What is Vuex? | Vuex*. (n.d.). Retrieved May 11, 2022, from https://vuex.vuejs.org/

# Appendix A

### Contents of the Thesis Directory

- The DOCX and PDF documents of the thesis.
- The source code for implementation of the web application.

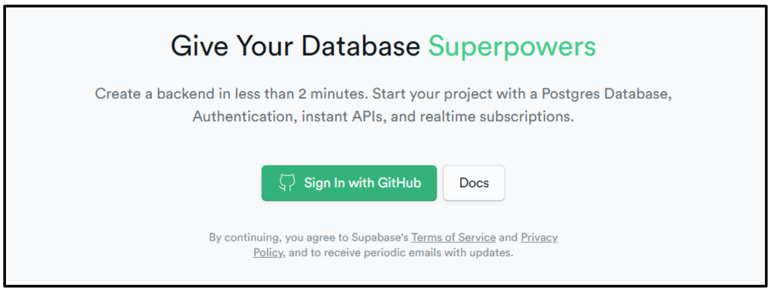
# Appendix B

## Installation Guidelines

To run the digital platform, the web application needs to be started. To do this, one should follow the subsequent steps:

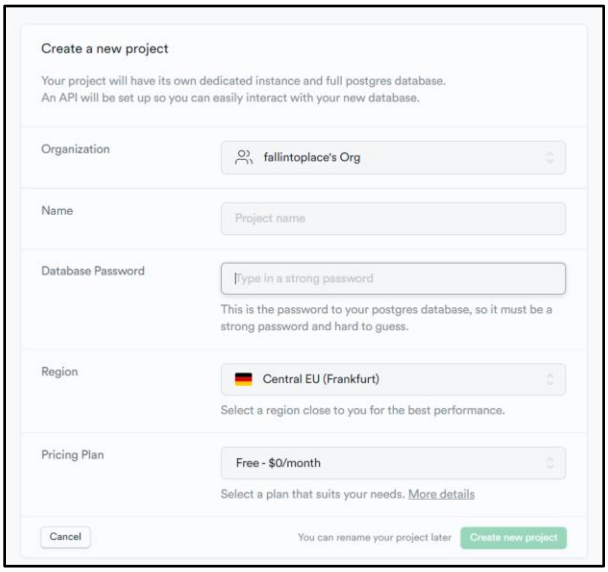
### Setup the back-end

1. Create and sign in to the Supabase account at:
   [https://app.supabase.com/](https://app.supabase.com/)

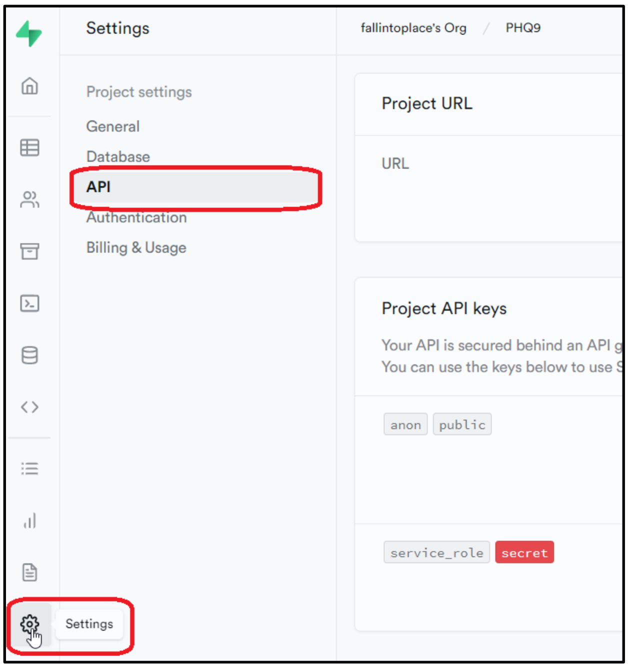



2. Create a new Supabase project by clicking the "New project" button.

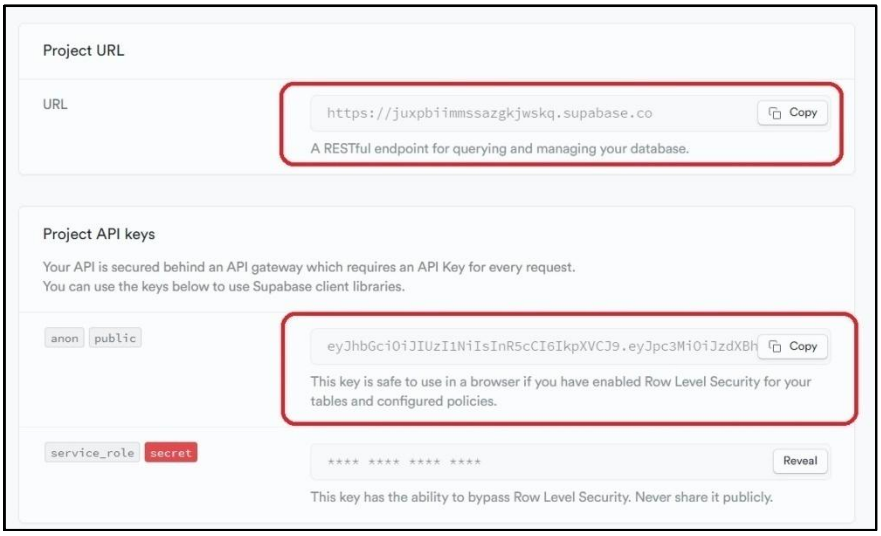

3. Fill in all the information for new project creation, which takes some time to set up.

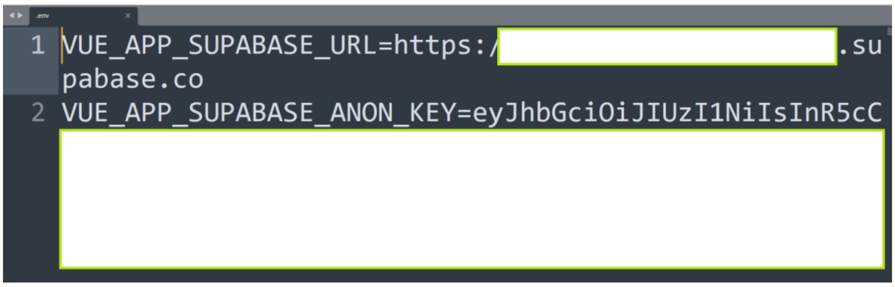


4. On the left-hand side, locate the “Settings” tab and find “API.”

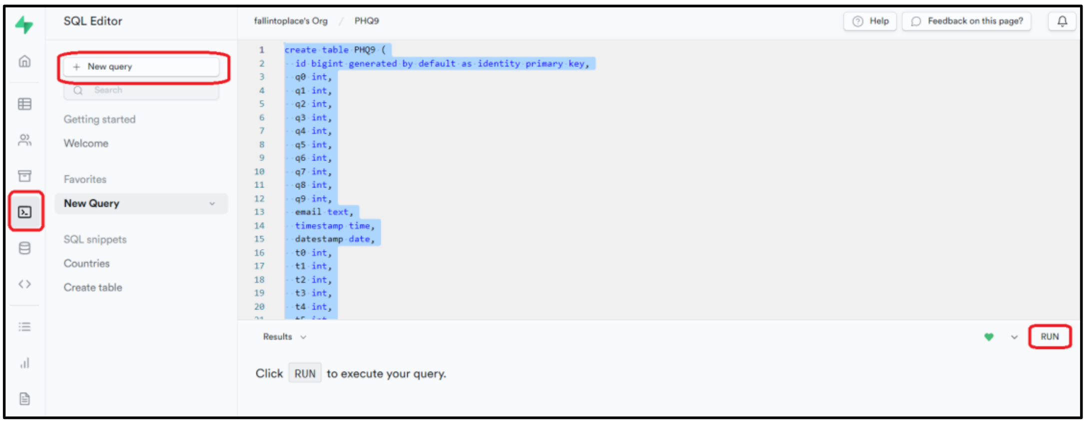



5. Copy the “Project URL” and anonymous “Project API key” to the “.env” file of the source code of the thesis directory. “VUE_APP_SUPABASE_URL” is the “Project URL,” and “VUE_APP_SUPABASE_ANON_KEY” is the anonymous “Project API key.”



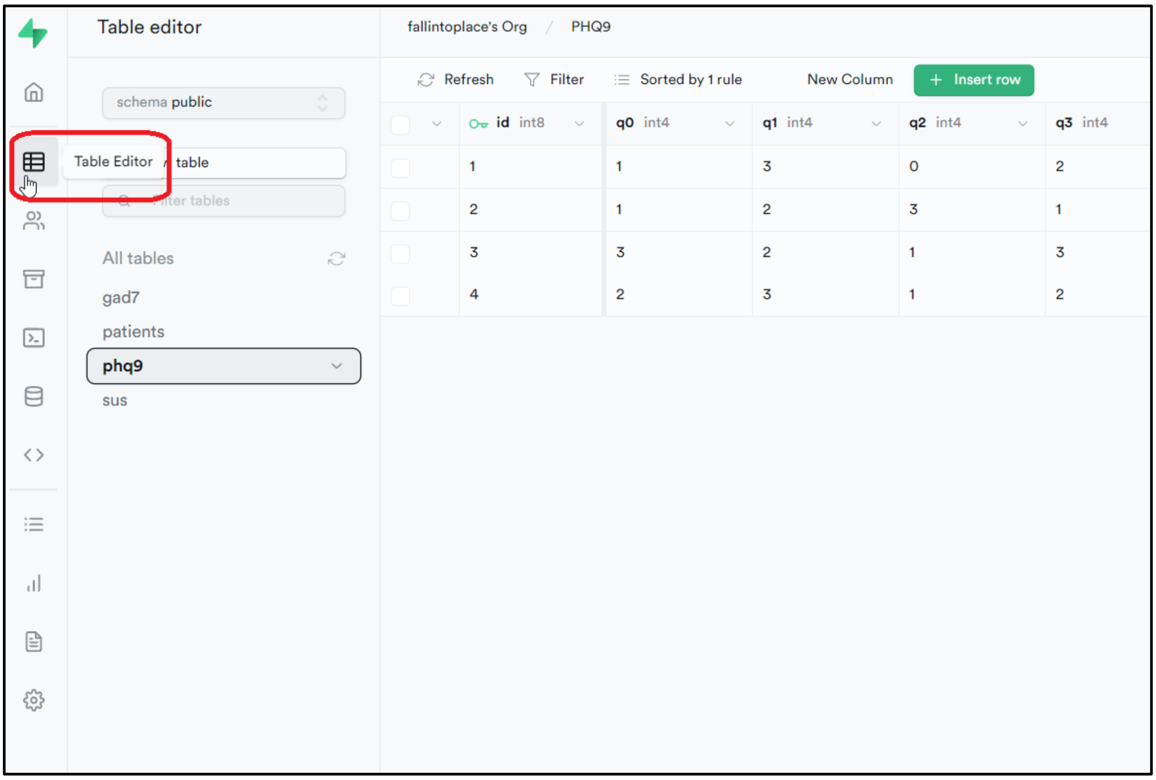
6. Create four tables in the PostgreSQL database: the PHQ-9 metadata, GAD-7 metadata, patients' metadata, and the SUS metadata. Find SQL editor on the left-hand side, and click on "New query." Copy the following script into the terminal and click on "Run." (The SQL script is also in the thesis directory in the file */installation_guidelines/create_table.txt*)



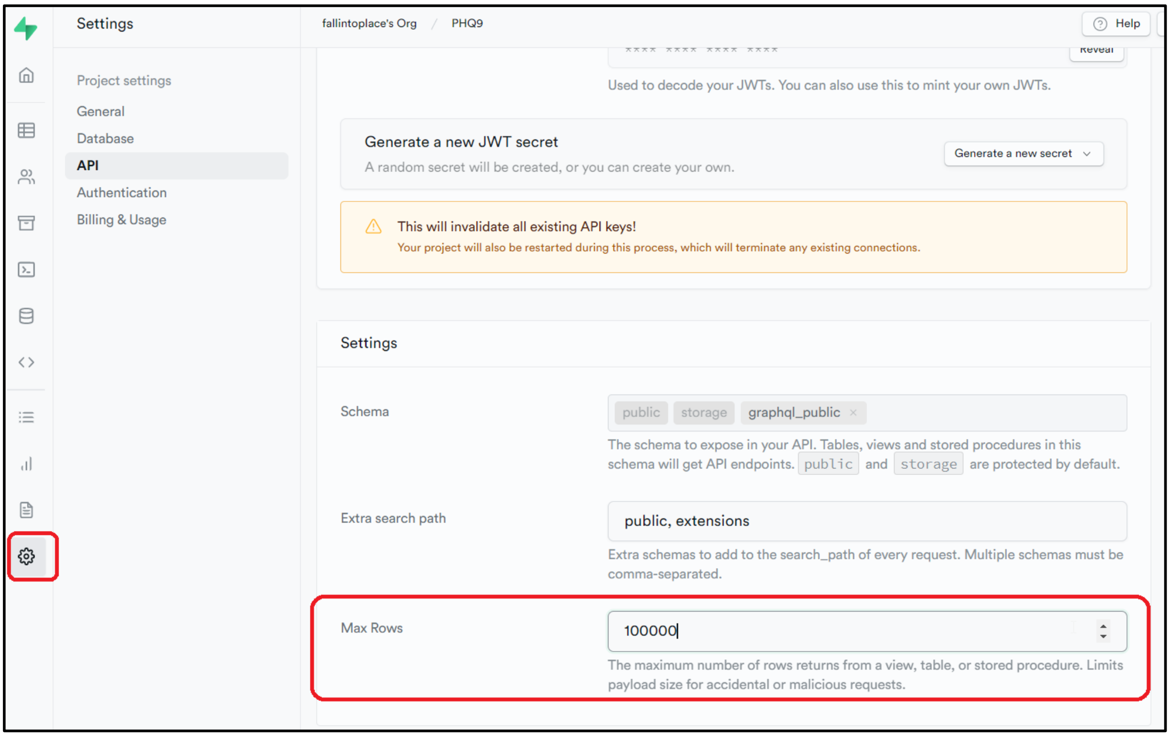

```sql
create table phq9 (
  id bigint generated by default as identity primary key,
  q0 int,
  q1 int,
  q2 int,
  q3 int,
  q4 int,
  q5 int,
  q6 int,
  q7 int,
  q8 int,
  q9 int,
  total_score int,
  email text,
  timestamp time,
  datestamp date,
  t0 int,
  t1 int,
  t2 int,
  t3 int,
  t4 int,
  t5 int,
  t6 int,
  t7 int,
  t8 int,
  t9 int,
  time_completion int,
  language text,
  answer_changes int,
  location text,
  city text,
  device text,
  operating_system text,
  user_agent text
```

```
);
create table gad7 (
  id bigint generated by default as identity primary key,
  q0 int,
  q1 int,
  q2 int,
  q3 int,
  q4 int,
  q5 int,
  q6 int,
  q7 int,
  total_score int,
  email text,
  timestamp time,
  datestamp date,
  t0 int,
  t1 int,
  t2 int,
  t3 int,
  t4 int,
  t5 int,
  t6 int,
  t7 int,
  time_completion int,
  language text,
  answer_changes int,
  location text,
  city text,
  device text,
  operating_system text,
  user_agent text
);
create table patients (
  email text primary key,
  name text,
  surname text,
  date_of_birth text,
  gender text
);
create table sus (
  id bigint generated by default as identity primary key,
  q0 int,
  q1 int,
  q2 int,
  q3 int,
  q4 int,
  q5 int,
  q6 int,
  q7 int,
  q8 int,
  q9 int,
  total_score int
);
```

7. Should everything work correctly, all four tables are visible in the table editor on the left-hand side, and a database administrator can visually monitor all the changes here with a dedicated user interface.

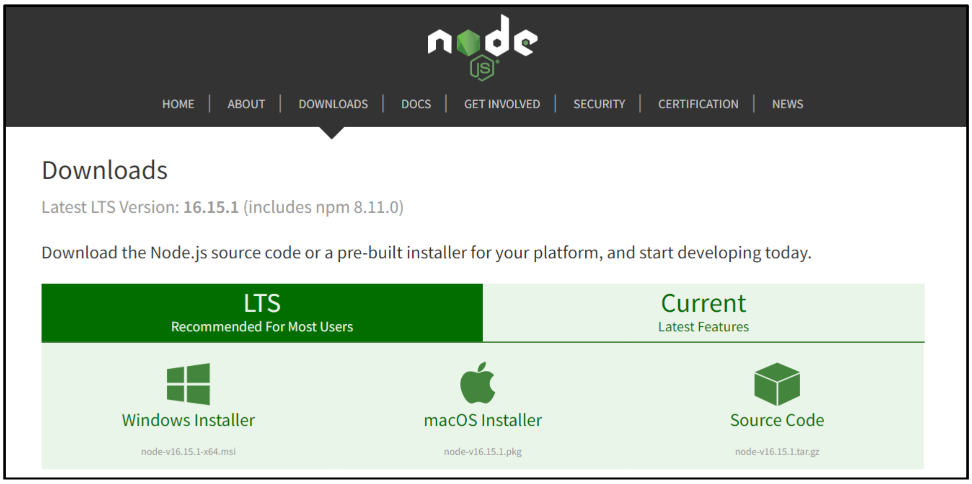



8. A database administrator can set the maximum number of rows returned in the settings.



### Setup the front-end

1. Install the latest Node.js version from the official website. https://nodejs.org/en/download/




2. Install all the dependencies in the *package.json* file with:

```
npm install
```

3. Build with hot reload at localhost:8080 with:

```
npm run serve
```

# Appendix C

### System Usability Scale: Evaluation of the Respondents

Each respondent belongs to one of the three categories: Computer science (CS), medicine, or patient. The first seven respondents are either last-year computer science students or holders of computer science degrees. The subsequent six respondents have a medical degree. The last five respondents were mental health patients while performing the questionnaire.

| Respondent | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Score | Expertise |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **R1** | 1 | 1 | 5 | 2 | 5 | 2 | 5 | 1 | 4 | 1 | 82,5 | CS |
| **R2** | 3 | 1 | 5 | 1 | 3 | 2 | 4 | 2 | 4 | 2 | 77,5 | CS |
| **R3** | 2 | 1 | 5 | 1 | 5 | 2 | 5 | 2 | 5 | 1 | 87,5 | CS |
| **R4** | 3 | 1 | 5 | 3 | 5 | 2 | 5 | 3 | 5 | 1 | 82,5 | CS |
| **R5** | 3 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 5 | 1 | 95 | CS |
| **R6** | 4 | 1 | 5 | 1 | 5 | 3 | 5 | 3 | 5 | 1 | 87,5 | CS |
| **R7** | 1 | 1 | 5 | 1 | 5 | 2 | 5 | 2 | 5 | 1 | 85 | CS |
| **Average** | 2,43 | 1 | 5 | 1,43 | 4,71 | 2 | 4,86 | 2 | 4,71 | 1,14 | 85,36 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **R8** | 4 | 2 | 5 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 77,5 | Medicine |
| **R9** | 4 | 1 | 4 | 1 | 4 | 1 | 5 | 2 | 4 | 1 | 87,5 | Medicine |
| **R10** | 2 | 1 | 5 | 1 | 4 | 1 | 3 | 2 | 3 | 1 | 77,5 | Medicine |
| **R11** | 3 | 3 | 5 | 1 | 5 | 1 | 3 | 3 | 5 | 1 | 80 | Medicine |
| **R12** | 5 | 3 | 5 | 1 | 5 | 2 | 2 | 2 | 5 | 1 | 82,5 | Medicine |
| **R13** | 3 | 1 | 5 | 3 | 5 | 2 | 5 | 3 | 5 | 1 | 82,5 | Medicine |
| **Average** | 3,5 | 1,83 | 4,83 | 1,5 | 4,5 | 1,5 | 3,67 | 2,33 | 4,33 | 1,17 | 81,25 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **R14** | 5 | 1 | 5 | 4 | 5 | 3 | 2 | 2 | 3 | 1 | 72,5 | Patient |
| **R15** | 3 | 2 | 4 | 3 | 5 | 3 | 5 | 2 | 5 | 1 | 77,5 | Patient |
| **R16** | 3 | 1 | 5 | 1 | 3 | 2 | 4 | 2 | 4 | 3 | 75 | Patient |
| **R17** | 1 | 1 | 4 | 1 | 5 | 1 | 3 | 2 | 3 | 1 | 75 | Patient |
| **R18** | 3 | 2 | 4 | 3 | 3 | 3 | 5 | 2 | 5 | 1 | 72,5 | Patient |
| **Average** | 3 | 1,4 | 4,4 | 2,4 | 4,2 | 2,4 | 3,8 | 2 | 4 | 1,4 | 74,5 | |

**Table 17: Evaluation of the respondents for the SUS feedback**
**(Source: Own analysis)**