HOW TO USE A WEARABLE LIKE A SMARTWATCH AS A TOOL TO HELP GUIDE STUDENTS INTO A BETTER MENTAL WELL-BEING

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Abstract

In 2019, 12,7% of the Dutch student population suffered from a bad mental well-being. This number had almost doubled two years later, when the amount reached a percentage of 22,4% [33]. This increasing decline in mental well-being among students necessitates the development of a solution that addresses the various factors – stress, sleep and physical activity - contributing to this phenomenon. In the domain of wearable technology, multiple solutions have already been introduced to counter these factors separately, while a comprehensive approach still remains missing. This research therefore aims to combine stress, sleep, and physical activity as focal points to improve students' mental well-being.

It will do so by answering the following research question: *How to use a wearable like a smartwatch as a tool to help guide students into better mental well-being?* This bachelor thesis will present an answer to this research question by both amplifying the existing literature on the topic and creating and user testing a web-application in combination with automated data collection and self-reporting on data. The prototype of this thesis shows effectiveness in reducing stress levels and enhancing mental well-being on the aspect of stress. However, it falls short in adequately addressing sleep and physical activity and lacks a clear depiction of the interrelatedness between these factors, therefore also failing to fill this gap in research. Further refinement and alternative approaches that are required to improve the prototype's functionality and comprehensiveness are finally depicted.

Keywords: wearables, smartwatch, mental well-being, data visualization, students, improving

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1. Introduction

Smart devices that measure user data are becoming increasingly widespread [1]. From cars that measure when you get tired or use face recognition to install the proper, user-based sitting position, to watches that measure sleep time and heart rate; active devices are increasingly used as an addition to lifestyle and as an improvement of life quality. In this domain of improving lifestyle through collecting data, technological wearables are especially gaining popularity [2].

Smartwatches are the prime example of a wearable that shows a continuous growth in popularity. With technology constantly being improved from a technical perspective, an extended number of new possibilities arise in the domain of smartwatches [3]. Among these possibilities are an easy-to-use heartbeat sensor or an advanced step-tracking system, which are both provided to help the user in a specific task by obtaining data about the user's life.

Since the focus within the domain of wearables and smartwatches specifically increasingly shifts towards improving the user's lifestyle or quality of life, it can open opportunities for dealing with multiple social issues. An important social issue that could possibly benefit from a solution associated with smartwatches is the declining mental wellbeing throughout the Dutch student community. In 2019 and 2020, 11% of the Dutch students were reported to be mentally unhealthy. The numbers in 2021 draw an even worse picture, with a percentage of 18% of the Dutch students between 12 and 25 years old having a bad mental health [33]. In this study, multiple factors were found to influence these students' mental wellbeing under which were stress, sleep and a lack of physical activity. Especially stress has been proven to be of huge significance in the Dutch student's population, with 25% of the Dutch students encountering stress on a daily basis [4]. However, when considering the students that experience stress 'often', the percentages rise up to 50% [4]. Finding solutions for this problem can be considered difficult though, as an individual is often not aware of the root of the problem [51].

As stated before, smartwatches are increasingly used as a tool for improving life quality and could therefore be considered as having an unseen and unused potential to be a tool to find a personal solution to counter a decline in mental well-being. The ultimate goal of wearable technology would be to be able to use a smartwatch as a tool to improve mental well-being. To contribute to this goal, the aim of this research is to discover how to create an application that is easy to use and follow and reaches students that are in need of such an application. Therefore, this thesis' main research question will be formulated as follows:

'How to use a wearable like a smartwatch as a tool to help guide students into better mental well-being?'

This research question also constitutes two sub questions, being:

1. *Can a wearable read and predict accurate data about the mental well-being of a user?*
2. *How can the gathered data be visualized in an uncomplicated way that triggers change?*

2. Background Research

In order to conduct a comprehensive and effective research study, it is crucial to follow a systematic approach. The initial step involves examining existing knowledge (literature research) and understanding the current state of the subject matter (state-of-the-art). This chapter will focus on this step and is therefore divided into two main parts: a literature review and an exploration of the state-of-the-art.

2.1 Literature research

2.1.1 Introduction

The World Health Organisation (WHO) defines mental well-being as “a state of wellbeing in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community” [16]. Following this definition, one could argue that everything that opposes this state of mental well-being can be considered to be a mental well-being issue. The RIVM categorizes stress and sleeping problems as mental well-being issues and states that more than half of the Dutch students suffer from these issues [23]. Research has indicated that mental well-being is influenced not only by factors such as stress and sleep but also by physical activity [30]. Enhancing physical activity levels has been found to positively impact the experienced mental well-being of individuals [30]. Considering that a large number of students do suffer from mental well-being problems, it is essential to have a good view of what indicators of well-being contribute to this and how this can be influenced to improve the well-being of a user. Based on the issues offered by the RIVM research, the focus of this chapter will be on existing literature about the three important pillars of mental well-being: sleep, physical activity and stress and their connection to the technology of the current smartwatches.

2.1.2 Sleep

A good sleeping pattern could lead to a wide variety of improvements regarding mental well-being, such as a large decline in depression and anxiety and an increase in the overall mental well-being [27]. Furthermore, an improved quality of sleep also leads to a medium-sized improvement in stress, which is also an important pillar in decreasing an individuals' stress level [27].

Within the domain of smartwatches, sleep-tracking has become involved in almost every generation over the years. The technology behind this feature has changed over the years. Older smartwatches like the Fitbit flex 2 and Samsung gear fit 2 use wrist movement to track sleep [19]. Smartwatches nowadays use heart rate monitoring and heart rate variability in combination with beats per minute (bpm)to make assumptions on sleep duration and sleep stages [19]. Smartwatches cannot actually measure sleep time or sleep stages but make an

assumption or estimation based on monitored data [22].

2.1.3 Physical activity

Exercise is widely known to be a major factor in reducing the risk of all-cause mortality, cardiovascular disease, stroke, and diabetes [29]. Nevertheless, the significance of exercise extends beyond its physical benefits for an individual. While participating in a physical activity may decline chances of diseases and physical problems, it also has a key influence on mental well-being. As an example, people who regularly participate in physical activity had a 62% decline in symptoms of depression [30].

A smartwatch can use an accelerometer to measure the amount of activity within a day. The data that is being collected through this sensor is put within an algorithm that will calculate various parameters such as steps taken and burned calories [32]. This is, however, only an estimation based on calculations. The outcomes derived from the smartwatch's calculations may vary depending on the specific algorithm employed by each individual smartwatch. In order to optimize calculations and assumptions about the steps taken and calories burned, data like height and weight can be used to optimize accuracy within this data.

2.1.4 Stress

Frequency stress amongst students

The amount of stress and its effects varies widely among students. According to CBS [4], 25,4% of the Dutch students between 12- and 25-years old experience stress on a daily basis. Additionally, 25,2% of the students did not experience stress on a daily basis but did experience it often.

Physical health and stress

There are a multitude of reasons for stress, physical stress can also be one that leads to mental stress. According to Sathyapalan [5], “those that work or live in stressful environments, have a higher likelihood of many disorders. Stress can be either a triggering or aggravating factor for many diseases and pathological conditions”. Stress as a health factor on a person’s body may include an increase in blood pressure, headaches, fatigue, increased muscle tension, and rapid heartbeat, among other physical indicators [7].

Mental health and stress

Furthermore, stress also has a great impact on the mind. The brain can create an imbalance as a result of stress [6]. This imbalance could lead to problems with anxiety, decision-making, or mood. This mood may increase or decrease the expressions of the person that is stressed. In addition to this, the imbalance in the neural circuitry affects the systemic physiology through “neuroendocrine, autonomic, immune and metabolic mediators“ [6].

The type, timing, and severity of the stress in combination with the above-mentioned bodily and mind influences of stress may eventually lead to life-threatening effects and/or death [5]. This

stress-health relationship has also been modelized: “Stressful event (X) leads to a biological change (Y) that then leads to the disease state or related outcome (Z)” [10]. Especially an extended time period of stress can in this case lead to possible life-threatening situations.

Measuring and recognizing stress

As has been discussed, stress manifests itself in various aspects of life, in both the mind and the body. Therefore, stress can be hard to measure [5,6,7].

Stress has been defined as follows: “Any intrinsic or extrinsic stimulus that evokes a biological response is known as stress. The compensatory responses to these stresses are known as stress responses” [5]. However, this implies that there is no single biological indicator that someone is enduring stress. This probably is a result of the fact that stress does not only invoke an objectively measurable biological effect like increased blood pressure or heart rate. Stress also creates non-objectively measurable outcomes like feelings of anxiety or excitement [10]. Both of these stress results may also be invoked through non-stress-related activities. Next to this hard-to-measure stress outcome, the commonly known stress hormone “cortisol” ‘suffers’ from the same problem. “Not all cortisol increases are triggered by increases in psychological stress responses, nor does every experience that people perceive as stressful cause cortisol to rise“ [11].

Even though it is difficult to measure and recognize stress, the newest smartwatches have obtained a new sensor that contributes to finding and measuring stress. These new sensors are able to use EDA (Electrodermal Activity Sensing) sensing as a tool to measure calmness or distress in someone [28]. Although this new sensor is fairly accurate, it still has the downside of not being able to distinguish between physical and mental distress. This technical gap in research is something that still needs to be filled.

Personal solutions to stress

Creating and finding a personal solution to stress is often time-consuming and exhausting. In order to mitigate stress, there are a few factors that directly influence the perceived stress of a person. The main points are sleep quality and quantity, a healthy diet, moderate physical activity, and having a positive outlook on life [6].

When finding a solution to stress, it is often believed that a person needs to revert to what they have done. However, a person could also “change in trajectory” [6]. Somebody who endures stress is believed to benefit from trying and finding ways to adapt to what they already have in life and move it towards something that is available and viable to them. For example, it is often not possible for someone to become an extreme athlete overnight. Nonetheless, it may be possible to train twice a week. In addition to the mentioned example of physical activity, research has demonstrated the significance of creating and maintaining a proper sleep schedule for overall mental well-being [13]. Where sleep and physical activity are two of the main factors that influence stress, and therefore should be focused on when trying to mitigate stress [13]. However, this is not the only way to mitigate stress. There are plenty of exercises to do to help reduce stress experience. According to Can [13,14], yoga and traditional mindfulness are two of the best ways to mitigate stress. Both of these techniques use breathing as a tool to find ease within yourself [15].

So, when trying to find a personal stress mitigation technique a person should try to change their trajectory instead of reversibility. This is most efficient in sleep and physical activity and be supplemented with various stress mitigation techniques.

2.2 State-of-the-art

According to recent market trends and research [43], the best-selling smartwatches in the year 2022 offer features, including the ability to measure physical activity, heart rate, and stress levels. Furthermore, some of these devices may also incorporate a sleep-tracking tool. However, not all these smartwatches use the same method to get to their measurements. The following chapter will investigate what is already out there regarding mental well-being and wearables.

2.2.1 Physical wearables

The Fitbit Versa 3 is a versatile smartwatch compatible with both Android and iOS operating systems. While it may not be the most advanced smartwatch in terms of its features and apps, it offers a well-rounded set of functionalities with a strong emphasis on health-related features.

One of the notable health features of the Fitbit Versa 3 is its ability to track sleep using the SpO2 sensor and body temperature statistics. By leveraging these data points, the device can provide users with estimates of sleep duration and quality. This information can be valuable in understanding and improving one's sleep patterns and overall well-being.

Furthermore, the Fitbit Versa 3 excels in measuring physical activity and monitoring various aspects related to it. Through a combination of different sensors, including EDA sensors, heart rate monitoring, heart rate variability analysis, and skin temperature tracking, the smartwatch offers an extensive assessment of physical outcomes.

While the Fitbit Versa 3 may not have the most advanced features in the market, its focus on health-related functionalities, including sleep tracking, physical activity monitoring, and stress estimation, it as a well-rounded smartwatch for individuals seeking to prioritize their overall well-being [44].

Figure 1: Fitbit versa 3[1]

The Oura ring is a unique wearable device designed in the form of a ring that offers a range of health monitoring features. While it may differ in design from traditional smartwatches, it provides insights into various aspects of health, including sleep and heart rate.

The Oura ring utilizes LEDs, specifically green, red, and infrared LEDs, to measure heart rate. By analyzing the differences in heart rate detected by these LEDs, the device can provide users with accurate heart rate measurements during different activities throughout the day.

When it comes to sleep tracking, the Oura ring incorporates multiple sensors to make assumptions about sleep duration and quality. These sensors include:

- Time spent in light, deep, and REM sleep
- Resting heart rate and heart rate variability
- Number of breaths per minute (respiratory rate)
- Body temperature
- Nighttime movement

By combining data from these sensors, the Oura ring provides users with an extensive overview of their sleep patterns and quality.

[1] https://www.fitbit.com/global/nl/products/smartwatches/versa3

Figure 2: Oura ring gen 3[2]

2.2.2 Applications and interpretations

The field of mental well-being consists of both physical and non-physical matters. In addition to physical changes, the understanding of mental well-being includes non-physical shifts in thoughts, emotions, and behaviors. This area also witnesses ongoing developments in applications and research focused on data interpretation and feedback mechanisms. The wide array of available applications offers diverse approaches to supporting individuals in their mental health journeys. Each application has unique goals and employs distinct strategies to achieve them. This paper aims to dive into two specific applications dedicated to enhancing mental well-being, providing an analysis of their features and functionalities.

Sanvello [3] is a data-driven application designed to promote mental well-being. Available for download on both the Play Store and the App Store, it enables users to track their thoughts and feelings on a daily basis [38]. The application provides a user-friendly interface where individuals can record their emotional state each day using a color-coded circle. The circle ranges from green, representing a positive mood, to red, indicating a negative or distressing mood. By consistently inputting their emotions over an extended period, users can visualize their mood patterns through a graph, providing a comprehensive overview of their emotional well-being (see figure 3). This feature enables users to identify trends, fluctuations, and potential

[2] https://ouraring.com/product/heritage-silver
[3] https://www.sanvello.com/

triggers in their emotional states, empowering them to better understand and manage their mental well-being.

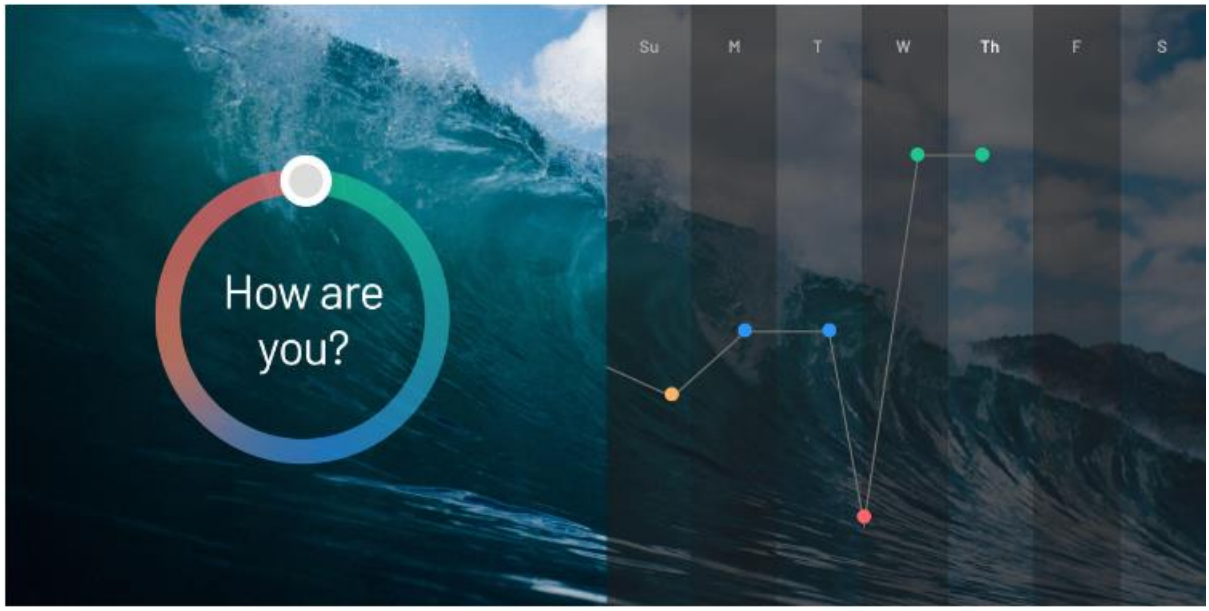


Figure 3: Interface Sanvello, measuring how you feel

The Sanvello application offers additional features to support users in their mental well-being journey. It provides daily reminders, either randomly or based on a specific schedule determined by the user's preference, to prompt them to record their emotions [38]. This feature ensures regular self-assessment and helps individuals stay engaged with monitoring their feelings.

Moreover, the application allows users to manually track various factors such as exercise, sleep, and caffeine intake. By inputting this information, users can gain insights into how these factors relate to their mood and overall well-being. This self-reported data contributes to a clear understanding of the interplay between lifestyle choices and emotional states.

In addition to data tracking, Sanvello offers modules that provide valuable information and techniques for managing specific mental health challenges such as depression, anxiety, and stress. These modules serve as guided learning experiences, empowering users with practical skills to better cope with and regulate their moods and emotions. Figure 4 illustrates the presence of multiple modules tailored to different goals, ensuring a personalized approach to mental well-being.

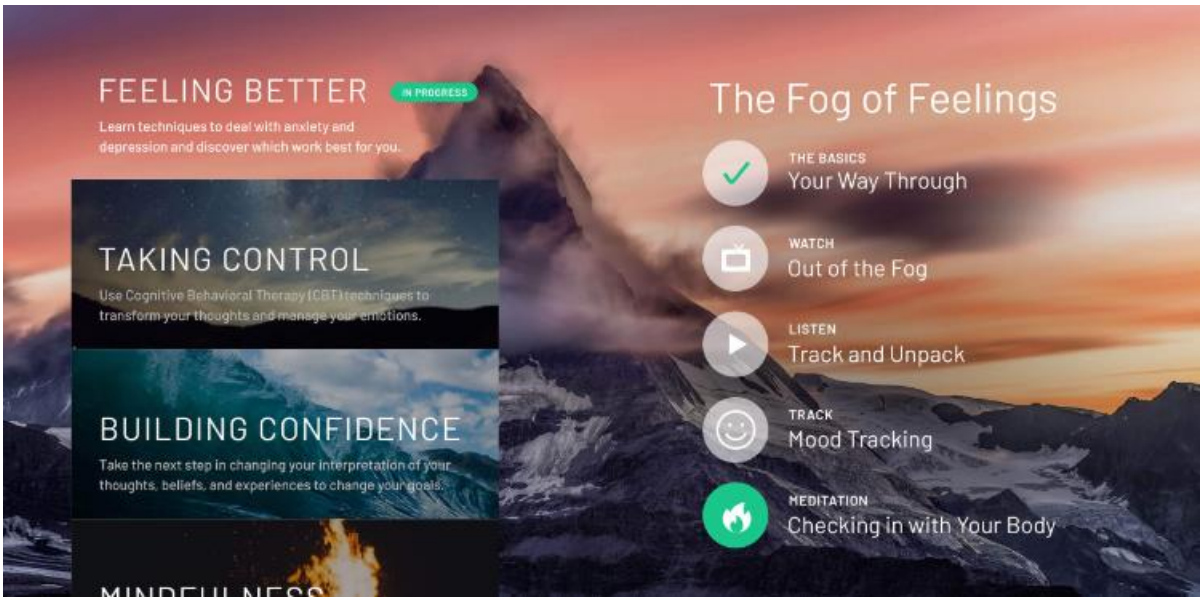


Figure 4: Sanvello, modules a user can follow

Calm[4] is an alternative downloadable application that places its focus on enhancing sleep quality while also providing additional features beyond sleep improvement (see figure 4).

[4] https://www.calm.com/

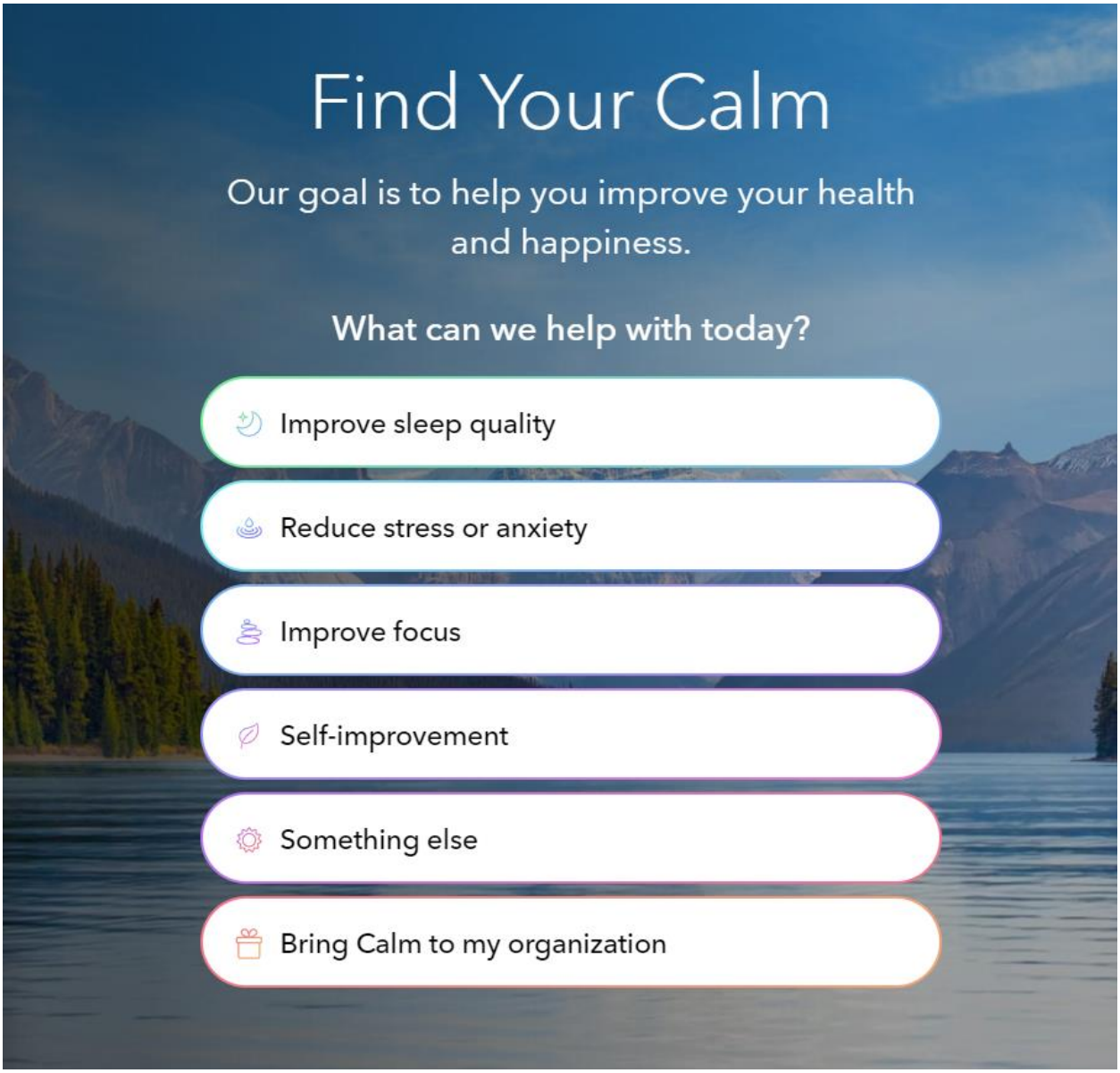


Figure 5: Calm interface and options

When downloaded and set to focus on ‘improve sleep quality’ the application will ask a list of questions to personalize the experience. These questions consist of:

- How often do you have trouble sleeping?
- What do you have trouble with when sleeping?
- What type of content are you interested in?

This application focusses more on auditorial experiences to enhance sleeping. With the final goal of improving mental well-being.

An additional noteworthy application to mention in the context of state-of-the-art technology is Sense-it [45]. Specifically designed for individuals who struggle with recognizing their own emotions, Sense-it helps those with borderline personality disorder. This application utilizes a combination of a smartwatch and a smartphone to aid users in managing their emotions.

Sense-it [5]uses the heart rate monitoring capability of the smartwatch. By establishing a baseline heart rate measurement, the smartwatch can detect deviations in heart rate patterns. When such differences are detected, either the smartwatch or smartphone promptly notifies the user through a personalized message. These messages, composed by the user themselves, may include phrases like "Relax," "Control your breathing," or "Take a step back from the situation."

Figure 6: Sense-it application interface

Individuals with borderline personality disorder often struggle with emotional regulation, which can lead to increased impulsivity, self-perception difficulties, and strained relationships with others [46]. In this context, an application like Sense-it plays a crucial role in providing support.

Sense-it generates notifications for users when they might not have consciously recognized their own emotions. This awareness allows individuals to adapt and respond to their emotions more effectively. A notable feature of the application is its capability to prompt users to manually input potential causes or triggers when a change in heart rate is detected. By actively engaging users in understanding the underlying factors contributing to their emotional responses, Sense-it encourages reflection.

[5] https://senseitapp.nl/

The application also functions as a data log, storing the recorded information for future reference. This enables users to review and analyze their emotional patterns over time. They can then discuss these insights with their caregivers or psychologists.

2.3 Conclusion about background subject

The research conducted on the effects of sleep, physical activity, and stress confirms that these factors significantly influence an individual's mental well-being. Therefore, the sub-research questions can be largely addressed and answered. The findings consistently show that sleep, physical activity, and stress directly impact various aspects of mental health.

Can a wearable read and predict accurate data about the mental well-being of a user?

Mental well-being encompasses three primary pillars: sleep, physical activity, and stress. To gain a comprehensive understanding of an individual's mental well-being, it is crucial to carefully examine these three aspects. With the technological advancements of newer wearables, built-in sensors enable the measurement of physical activity and provide reasonably accurate approximations of a user's sleep, including different sleep stages. However, accurately measuring stress remains challenging. While most wearables employ heart rate and heart rate variability as indicators of stress, this approach lacks precision due to numerous factors that can influence these metrics. Physical activities, such as exercise, can impact heart rate and heart rate variability, further complicating stress measurement.

To address this issue, newer smartwatches incorporate Electrodermal Activity (EDA) detection, which offers a more accurate representation of stress levels. Nonetheless, it is important to note that even this method is not flawless. Therefore, a potential solution is to combine the measured data from sensors with user-reported subjective experiences of stress. By obtaining self-assessments from users regarding their perceived stress levels and merging this information with sensor data, a more complete understanding of their stress levels can be achieved.

How can the gathered data be visualized in a way that triggers change?

In order to effectively support a user's mental well-being, it is crucial for this research to establish a system that can provide meaningful feedback based on the collected data. This feedback should serve as a motivator for users to take specific actions that can potentially improve their mental well-being. Insights gained from the background research can guide the development of such a feedback system.

The first step towards providing feedback involves implementing a daily reminder for users to reflect on and input details about their mental well-being. This simple reminder prompts users to consider their well-being and encourages them to actively engage in the process. This serves as an initial step towards raising awareness through self-reflection.

The second step focuses on delivering personalized feedback based on the individual data points collected. Each aspect, such as sleeping schedules, physical activity levels, and stress

levels, can be assessed individually. By analyzing these data points, tailored feedback can be provided to users. For example, specific recommendations can be given regarding adjustments to their sleep patterns, suggestions for increasing physical activity, or techniques for managing stress.

The final step is to provide feedback on the overall progression and correlations within the collected data, both automatically and manually. This feedback can highlight trends and relationships between different variables. For instance, it can illustrate how an irregular sleeping schedule negatively affected mental well-being in a particular week. The overarching goal of this feedback system is to encourage users to make meaningful changes in their lives, based on their own data and observations.

Results

Wearable or application	Wearable/application name	Heart rate/Heart rate variability	Physical activity	Sleep quality	Stress	Manual input about well-being	Feedback
Wearable	Fitbit versa 3	yes	yes	yes	yes	no	Feedback through graphs
Wearable	Oura ring (gen 3)	yes	yes	yes	yes	no	Feedback through Oura account on other applicationyes
Application	Sanvello	no	no	No (but manual input possible)	No (but manual input possible)	yes	General feedback for improved mental well-being. Feedback through graphs on manually inputted data
Application	Calm	no	no	No (but manual input possible)	No (but manual input possible)	yes	General feedback for improved mental well-being. Focused on sleep and calmness
Application (with wearable connection)	Sense-it	Yes (in combination with wearable	no	no	yes	yes	Feedback through buzzing of smartwatch and graph in the application

Table 1: Overview of the State-of-the-art findings

The conclusion of background research and state-of-the-art findings reveals substantial progress and numerous attempts to enhance mental well-being. Promising advancements have been made in sensor technologies and methods of gathering user input to assess mental well-being. This combined knowledge will be used in the current project, utilizing sensors like those found in the Fossil 5E smartwatch to track sleep, physical activity, and certain levels of stress. However, it is acknowledged that the accuracy of these measurements may vary.

To address this issue, the state-of-the-art research proposes utilizing user input through targeted questioning. By asking users about their feelings and perceptions regarding specific aspects such as sleep and stress, more accurate and personalized data can be obtained. The

combination of sensor-derived data and user-reported information can provide a clear understanding of an individual's mental well-being.

There are still opportunities to improve the existing applications identified in the state-of-the-art research is the limited integration of sensor data and manually inputted data as can be seen in Table 1. While some applications focused on collecting self-reported information, they lacked the capability to measure objective data such as physical activity and sleep quality/quantity, which provide valuable insights. Accurate measurement of sleep, in particular, is challenging for individuals themselves, emphasizing the need for sensor-based solutions [40]. Additionally, there was a lack of focus on specific populations, such as students, whose data could contribute to more precise understanding and tailored interventions.

By addressing these gaps, the current project aims to leverage both sensor data and user-reported information to provide a more complete and accurate assessment of mental well-being. This approach, combined with a focus on student populations, has the potential to yield valuable insights and contribute to the development of an effective prototype to improve mental well-being.

3. Ideation

3.1 Introduction

In the ideation chapter, the evaluation and elaboration of the process from brainstorming to the final idea will be conducted. The focus of ideation will be to approach the problem with the user in mind, aiming to create a solution that best suits the target group consisting of students.

The ideation process will incorporate multiple techniques to generate and refine ideas, using creativity and innovation. The main ideation technique employed is based on the Creative Technology Design Process [34], which has been adapted with iterations to improve the overall design process.

The chapter will be structured into 4 different categories, serving as a guide throughout the ideation process. These categories will provide a systematic approach to ideation.

3.2 Stakeholder analysis

To obtain a comprehensive understanding of the various stakeholders involved in this project, a stakeholder analysis has been conducted. This analysis aims to provide insights into the stakeholders' influence, needs, and working methods, thereby minimizing conflicts and avoiding unnecessary work throughout the project. The stakeholder analysis consists of four key components: identification, prioritization, understanding, and results.

3.2.1 Identifying the stakeholders

The first step into stakeholder analysis is the identification of the stakeholders. To give an overview of all the possible stakeholders a list will be created with everyone who might be a stakeholder. This can be a person or an organization [37].

In the first step of stakeholder analysis, the identification of stakeholders is essential. To ensure a comprehensive overview of all possible stakeholders, a list will be created that includes individuals and organizations who may have an interest or involvement in the project [37]. This includes both end-users and individuals/organizations actively involved in the research's development, either through direct participation or providing assistance and collaboration.

The stakeholders are:

- research participants (students and adults)
- students

3.2.2 Prioritizing

When conducting a stakeholder analysis, assessing the level of influence of each stakeholder within the project is important. This can be effectively visualized using a stakeholder grid [37]. The stakeholder grid consists of a horizontal axis representing the stakeholders' level of interest in the project, ranging from low interest on the left to high interest on the right. The vertical axis represents the stakeholders' power and influence within the project, with higher levels of power/influence positioned higher on the grid.

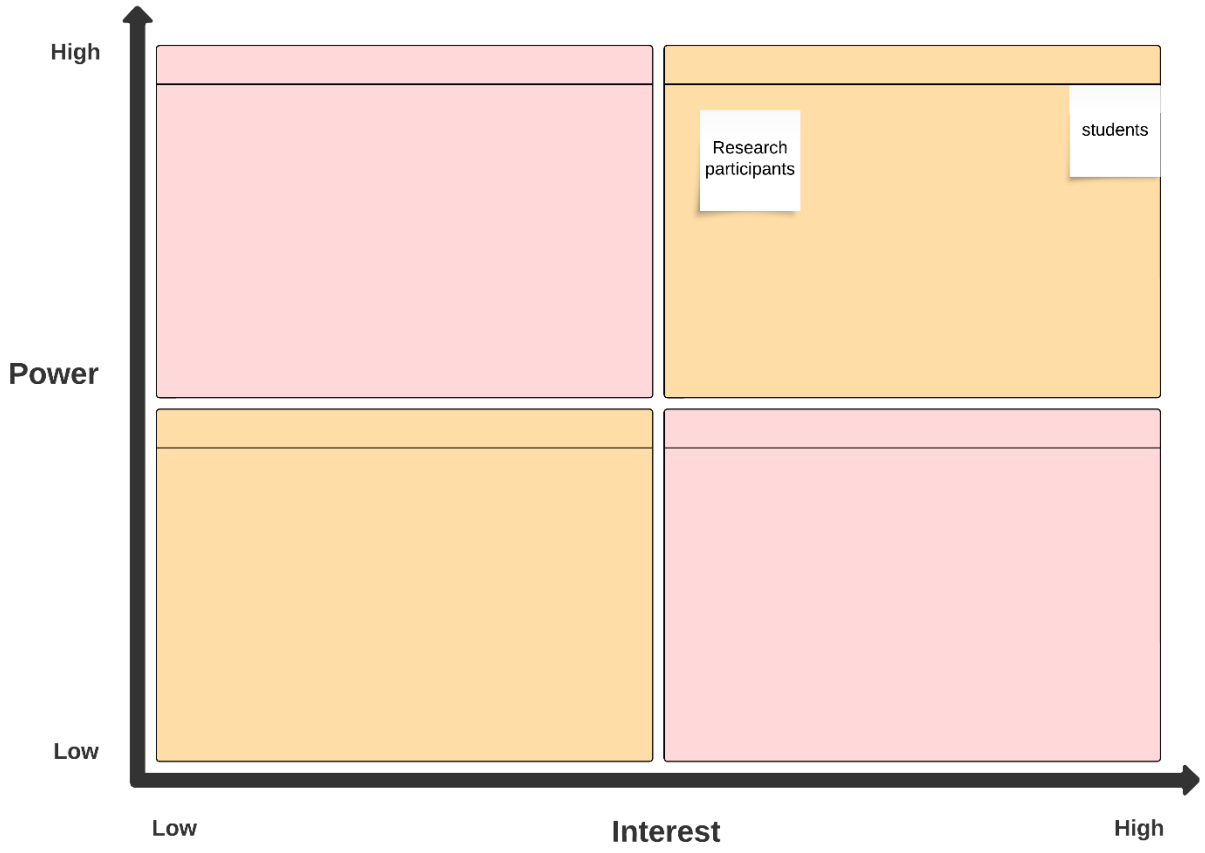


Figure 7: Stakeholder grid made with Lucid chart

3.2.3 Understanding

To understand the stakeholders that are involved, it is essential to adopt a stakeholder perspective and analyze their interests and motivations within the project. Within this specific project, the stakeholders have a non-financial interest primarily centered around the emotional impact of the research on student mental well-being. They are driven by the belief that the research outcomes will yield positive effects for students experiencing poor mental well-being.

The stakeholders' interests primarily revolve around enhancing the mental well-being of future students who are most likely to benefit from the research. Their objective is to address the challenges and difficulties associated with bad mental well-being among students. By actively supporting and engaging with the research, they aim to contribute to the development of effective solutions that positively impact the well-being of students.

3.3 Brainstorming

3.3.1 Introduction

Brainstorming is a solution-finding technique utilized by individuals or groups to generate a multitude of ideas to address a problem. Typically conducted in an open group discussion, participants freely express their thoughts and suggestions, aiming to generate as many ideas as possible. The focus of brainstorming is on quantity rather than feasibility or realism [35].

Throughout the project, brainstorming has been employed at various stages of the ideation process. It serves as a valuable tool to foster creativity, encourage diverse perspectives, and explore a wide range of potential solutions. The brainstorming process initially consisted of two brainstorming sessions. Due to a change in directory for this research, the amount expanded to three brainstorming sessions.

3.3.2 Procedure

First brainstorm

Goal first brainstorm
The initial brainstorming session employed the gap-filling brainstorming technique, which was conducted individually. This technique involves the participant identifying the current state and the desired end goal. The participant then explores potential ideas and solutions to bridge the gap between the starting point and the desired outcome [36].

In this particular brainstorming session, the current state was characterized by the difficulty in effectively tracking and measuring stress levels and providing personalized stress mitigation techniques. The end goal was to develop an application that could offer personalized stress mitigation strategies, tailored to the user's specific needs. The current state and the end-goal were written down on a whiteboard. Following this, the results would be written down on this whiteboard. It is important to note that this brainstorming session took place before the stakeholder analysis with a total of 7 participants who are studying at the University of Twente.

Results first brainstorm
The results of 45 minutes of this first brainstorming session were:

- Identify a relationship between personal stress experience and possible solution

- Design an application for a wearable that tracks bodily stress indicators and gives immediate feedback so that a user knows what actions cause stress
- Design an application that will guide a user to find a personal stress mitigation technique
- Identify a relationship between new and upcoming sensors that can measure physical stress indicators
- Design a new wearable (hardware and software) focused on stress throughout the day
- Identify what type of person experiences more stress than others and how this is possible through sensor and technology

Analysis first brainstorm
After conducting extensive background research about the target group of students, apart from this brainstorming session, it became evident that stress experienced by students was just one component of a larger issue: mental well-being. It became apparent that addressing stress alone would not sufficiently tackle the broader problem. As a result, the research trajectory shifted towards focusing on mental well-being as a whole, with stress being one aspect among others. Mental well-being was identified as comprising three key categories: sleep, physical activity, and stress.

Considering this new understanding of the problem, a new brainstorming session was deemed necessary to explore potential solutions within this expanded scope. The first brainstorming session would be disregarded as the second brainstorming session would be aimed to generate ideas and strategies that encompassed the interconnectedness of sleep, physical activity, and stress in promoting and maintaining overall good mental well-being.

Second brainstorm

The second brainstorming session took the form of a group session conducted with 4 students from the University of Twente, who are all stakeholders in the project. The brainwriting brainstorming technique was utilized for this session, focusing on active participation and idea generation from all participants.

Goal second brainstorm, first round
In the first round of this group session brainstorming session, the participants anonymously generated their ideas by writing them down on a piece of paper. This approach ensures that everyone has an equal opportunity to contribute their ideas, including individuals who may be more introverted or hesitant to speak up in a group setting. The participants shared ideas on how to improve mental well-being among students with the mentioned factors of stress, sleep, and physical activity. It was up to this brainstorming session to find a multitude of solutions to one aspect of this problem like, sleep, stress or physical activity, or a larger aspect of mental well-being in general. It was mentioned that the overall theme consisted of a wearable, but it was not obligatory to use this wearable in the ideation or the final prototyping.

Results second brainstorm, first round
The results of first 30 minutes of this brainstorming session were:

- How to understand and improve sleep to therefore improve mental well-being
- How to understand and mitigate stress to therefore improve mental well-being
- How to understand and improve physical activity to therefore improve mental well-being
- Find the relation between sleep, physical activity, and stress. How do they influence mental well-being
- Design a smartwatch that can measure mental well-being status based on the three aspects of mental well-being
- Design an application that can measure mental well-being status based on the three aspects of mental well-being
- Design a website that can measure mental well-being status based on the three aspects of mental well-being
- Create a new type of wearable, maybe with an Arduino to actively reflect on the mental well-being of a user
- Use Arduino sensors to measure different type of activities to gain more insight into the physical activity of a user and maybe improve on this
- Create an overview of stress, sleep, and physical activity to help the user gain insight in all of them and help the user improve on this (machine learning)
- Create something that can detect a bad mental well-being, if it detects this help the user with personalized feedback on that specific problem to boost mental well-being
- Create a plushie that can talk to a user or give general advise about mental well-being
- Create an application on the wearable that is something like a plant, it grows when a user is experiencing a good mental well-being and is dying if the user experiences a bad mental well-being

Goal second brainstorm, second round

The second round of the brainstorming session involved discussing the ideas in a random order. Participants provided feedback on each other's ideas, collaboration and the exploration of different viewpoints. This open exchange allows for further idea refinement, building upon the initial concepts put forward during the anonymous phase.

The goal of the second brainstorming session centered around exploring the mentioned solutions to the problem of mental well-being among students. Participants were encouraged to think about the written down ideas that address mental well-being.

The definition of mental well-being was established as "The state of being comfortable, healthy, or happy" [16]. However, it was communicated to the participants in advance that the aspect of "healthy" within mental well-being would be somewhat disregarded due to ethical considerations. It was not feasible to request future participants to disclose their health statuses. Instead, the brainstorming session concentrated on the subjective aspects of happiness and comfort.

One of the challenges addressed during the session was the subjectivity of happiness and comfort. Different individuals may have varied interpretations of what constitutes comfort or

happiness. To overcome this issue, the participants were tasked with finding a solution to mitigate the subjectivity and ensure the prototype's effectiveness for a diverse range of users, focused on students.

The brainstorming session emphasized the direct influences on mental well-being, which were identified as sleep, physical activity, and stress. These variables were recognized during the background research as significant factors that contribute to an individual's overall mental well-being.

Lastly, the participants would select the best solutions that they thought would be most viable and most effective.

Results second brainstorm, second round

The results of second 20 minutes of this brainstorming session were:

After the completion of the first round of idea generation and the subsequent feedback session in the second round, the papers with the participant's written ideas were discussed. After merging some of the ideas together, participants came up with a rating of the ideas. The following four ideas were rated as the best:

*Note: some ideas have been named or phrased somewhat differently based on the discussion during the second brainstorming phase of this session

- Identify a relationship between different factors of mental well-being and how they influence this.
- Design a smartwatch or application that can measure mental well-being status accurately according to the user.
- Design an application that can link with wearables to help the user gain insights into their own daily patterns of mental well-being
- Designing a clear way for students (users) to know what is wrong with their mental well-being and how to overcome problems

Analysis second brainstorm, first and second rounds

The brainstorming sessions have generated four promising ideas for this research. However, in order to proceed effectively, it is necessary to clarify what the ideas entailed. The ideas as of now could be interpreted in a lot of ways leading to a wide variety of possible ideas. To specify the wide range of ideas, it was deemed necessary to conduct another brainstorming session.

Third brainstorm session

Goal third brainstorm session

In the third and final brainstorming session involving stakeholders, the focus was on specifying the concepts of the previous brainstorming session, with the same goal of improving mental well-being and the variables associated with it.

The 4 participants were given the following goals to ensure the final idea would be a useful one including the results of the previous brainstorming sessions.

Goal given to the participant for the final brainstorm session:

- Find a solution to improve mental well-being through technology
- Find a rather short time solution, a user should be able to make sense out of data from smaller time periods of using (think of a week or two)
- What will this solution look like?

Results third brainstorm session

The results of the 90 minutes of this brainstorming session were:

Brainstorm findings from last/third brainstorm session (the list is not ranked):

- Tamagotchi that tracks sleep and physical activity and stress through talking to user
- Tamagotchi in a smartwatch that can measure data and uses this to talk to a user
- Tamagotchi that dies or gets happy when it is getting good manual feedback from a user
- Having a physical robot pet that follows you and will try to motivate you to relieve stress and improve physical activity of a user
- Having a robot with different choices to improve mental well-being (robot could give feedback)
- Having a digital diary in which a user explains to themselves how they feel and where this might come from
- Having an external person with mental problems as well talk to each other and see how they can help one another
- Using the mirror on different locations around the house to give advice to a user to motivate them to for instance have a good physical activity and therefore improve mental well-being
- Using a mirror to give advice while doing make-up or toothbrushing to relieve stress (maybe through a video)
- Using a smartphone to sense data in combination with different applications that a user is already using to gain insight in what factors on mental well-being to improve on
- Using a smartwatch to collect data through sensors and give feedback to a user on this
- Using a smartwatch to collect data through sensors and give feedback to a user on this and combine this with a possible application on a smartphone to have manual input on mental well-being factors
- Using a smart fridge to gather data from the user through questions
- Set up a smart clock system that will ask you questions about the day of the user before it is able to be used
- Create a hotline for phoning a friend or psychologist to ask questions when needed about mental well-being
- Creating an application in which a user can map how they feel at a given day through games

- Creating an application that will notify a user to do a small survey on their mental well-being. (Multiple times a day)
- Creating a game which will collect data and therefore create a picture about the mental well-being of a user (2nd time with same idea)
- Set up a camera in the room of a user to track sleep and physical activity

Analysis third brainstorm session

This study will primarily focus on the ideas that have been deemed relevant. The selection criteria for these ideas were twofold: firstly, they were verified by scientific literature, indicating their validity and theoretical basis; secondly, they demonstrated a realistic technological solution, implying the possibility of practical implementation. Therefore, the ideas that have been listed above will be divided into two categories: Feasible, and not feasible.

After the division of the group of ideas the ideas will be ranked on a scale from 1 to 10, in which case 1 is the best idea. This ranking has been done by the researcher based on what is most feasible and would be most helpful based on the background research.

Feasible

- Tamagotchi in a smartwatch that can measure data and uses this to talk to a user
- Tamagotchi that dies or gets happy when it is getting good manual feedback from a user
- Having a digital diary in which a user explains to themselves how they feel and where this might come from
- Using a mirror to give advice while doing make-up or toothbrushing to relieve stress (maybe through a video)
- Using a smartphone to sense data in combination with different applications that a user is already using to gain insight in what factors on mental well-being to improve on
- Using a smartwatch to collect data through sensors and give feedback to a user on this
- Using a smartwatch to collect data through sensors and give feedback to a user on this and combine this with a possible application on a smartphone to have manual input on mental well-being factors
- Using a smart fridge to gather data from the user through questions
- Creating an application in which a user can map how they feel at a given day through games
- Creating an application that will notify a user to do a small survey on their mental well-being. (Multiple times a day)

Not feasible

- Tamagotchi that tracks sleep and physical activity and stress through talking to user
- Having a physical robot pet that follows you and will try to motivate you to relieve stress and improve physical activity of a user

- Having a robot with different choices to improve mental well-being (robot could give feedback)
- Having an external person with mental problems as well talk to each other and see how they can help one another
- Using the mirror on different locations around the house to give advice to a user to motivate them to for instance have a good physical activity and therefore improve mental well-being
- Set up a smart clock system that will ask you questions about the day of the user before it is able to be used
- Create a hotline for phoning a friend or psychologist to ask questions when needed about mental well-being
- Set up a camera in the room of a user to track sleep and physical activity

Ranking of feasible ideas + reasoning

1. Using a smartwatch to collect data through sensors and give feedback to a user on this and combine this with a possible application on a smartphone to have manual input on mental well-being factors

   Using a smartwatch as tool to collect data is very useful, the smartwatch is designed with features and sensors to sense a lot of data. To ensure that the data is being processed and used to give feedback a combination with a possible application would ensure that the application could be used everywhere to obtain feedback. Moreover, having an option for manual input would fil in data gaps that could not be measured trough the smartwatch.

2. Using a smartphone to sense data in combination with different applications that a user is already using to gain insight in what factors on mental well-being to improve on

   This idea is mostly similar to the higher ranked variant. This idea is rated less because it consists of a smartphone to collect data rather than the smartwatch. The smartwatch is better equipped with biometric sensor which could be used to measure aspects of mental well-being.

3. Using a smartwatch to collect data through sensors and give feedback to a user on this

   This idea also looks like the previous two with the support of sensing capabilities and giving feedback on the collected data. However, this idea failed to specify a good way of doing so. The possible application of both previous ideas could lead to a way of self-reflecting trough manual input which this idea lacked.

4. Creating an application in which a user can map how they feel at a given day through games

   Gamifying as a tool to collect data is a very plausible way of collecting data, however it fails to automatically collect data as the smartwatch and or smartphone could. This idea is focused on manual, self-reflecting input.

5. Tamagotchi in a smartwatch that can measure data and uses this to talk to a user

   Using the smartwatch as a tool to measure data is very important, however this idea lacks manual input. This idea is focused on automated data collection, which fails to measure stress properly as seen in the literature review.

6. Having a digital diary in which a user explains to themselves how they feel and where this might come from

   This idea is useful for a specific group of the overall target group who can clearly write about their feelings and explain where they are coming from. On the other hand, the students who are not capable of sensing where it came from or writing their feelings down would be at a disadvantage and this would not be as useful.

7. Creating an application that will notify a user to do a small survey on their mental well-being (multiple times a day)

   Having reminder multiple times, a day to think about mental well-being is very important and positive. However, only the survey is not enough. This idea fails to create a way of giving feedback to the user.

8. Using a mirror to give advice while doing make-up or toothbrushing to relieve stress (maybe through a video)

   The mirror as a tool to give advice to relieve stress could be used as a proper tool to distribute information, due to the task that are performed are often physical tasks rather than mental tasks. However, the mirror is only stationary which is difficult when needing feedback at specific times during the day.

9. Using a smart fridge to gather data from the user through questions

   The smart fridge could be viable however it stationary which forces the user to use it at specific times or when at home. On top of this the target group of students often don't own smart fridges.

10. Tamagotchi that dies or gets happy when it is getting good manual feedback from a user

    A Tamagotchi that gets happy with positive feedback is good and supportive, however when feedback is less positive reinforcing this feeling with a dying Tamagotchi would not be the way to go about mental well-being.

3.4 Results/Concept formation

In the ideation phase, specifically in Sections 3.2 to 3.4, a multitude of ideas were identified, based on the goal of the brainstorming sessions to improve mental well-being among students. It was observed that certain ideas showed better potential compared to others. However, considering the limitations set by time constraints and the feasibility of certain ideas, it is

acknowledged that not all of the ideas and requirements mentioned will be pursued for development and testing within the scope of this research.

This study will primarily focus on the ideas that have been deemed relevant. The selection criteria for these ideas were twofold: firstly, they were verified by scientific literature, indicating their validity and theoretical basis; secondly, they demonstrated a realistic technological solution, implying the possibility of practical implementation. The final idea that has been concluded from the ideation phase based on these criteria is the following:

Using a smartwatch to collect data through sensors and give feedback to a user on this and combine this with a possible application on a smartphone to have manual input on mental well-being factors.

The idea that emerged as feasible during the concluding ideation brainstorming session was distinguished by its technological feasibility. It entailed leveraging a combination of sensing data and manual input to obtain a comprehensive understanding of the components contributing to mental well-being, namely sleep, physical activity, and stress. Additionally, this proposed solution aligns seamlessly with the wearables and lifestyle.

4 Specification

The specification of the research is a crucial aspect that ensures the concept aligns with the vision and goals of the study while meeting the participants' needs. By clearly defining the specifications, potential misunderstandings can be prevented, and the final concept can be developed to meet all the stakeholders' expectations.

4.1 Requirements

4.1.1 Introduction

A requirement analysis is a valuable process to identify the specific needs and expectations of the concept. It helps in understanding the key requirements and priorities, which can be further refined and categorized using the MoSCoW method. The MoSCoW method, of which the letters represent Must have, Should have, Could have, and Won't have, provides a framework for prioritizing requirements [42].

During the requirement analysis, a comprehensive list of requirements is compiled, ensuring each requirement is accompanied by a clear explanation. This list encompasses all the necessary features and functionalities that stakeholders deem important for the concept's success.

Afterward, the prioritization process takes place, where each requirement is categorized into one of the MoSCoW categories.

- Must-have requirements: These are critical and non-negotiable features that are essential for the concept's core functionality and meeting the research objectives.
- Should-have requirements: These are important features that significantly enhance the concept's usability and user experience, although they may have some flexibility in terms of their implementation or timing.
- Could-have requirements: These are desirable features that are not crucial for the core functionality but can provide additional value or enhance the concept's performance, if resources and time permit.
- Won't-have requirements: These are features that are explicitly excluded from the current scope or are deemed unnecessary or unfeasible at the present moment.

4.1.2 Identified requirements

To successfully incorporate the MoSCoW method, a list of requirements needs to be set up. The following section provides a complete list of the identified requirements, accompanied by concise explanations for each:

- **Concept will be easy to understand with various types of background knowledge in technology**

The concept should be easy to use for a variety of students. For example, people with a technical background might have more knowledge of applications, however, this concept is aimed at all students. It should have a user-friendly and intuitive design.

- **Concept has a clear overview of what data is collected and what it is used for**
  The user should be informed in an easy way about what data is being collected and how this data is used for the concept. This helps to prevent possible miscommunication between the user and the concept.

- **Concept is easy to use, users should be able to use the application without too much hesitation or questions**
  The system should have a user-friendly interface, ensuring that users can navigate it confidently and without substantial uncertainty or the need for excessive assistance.

- **Concept visualizes data and feedback of the user in a clear and understandable way**
  As not every student has the same background in technology or data understanding, it should be easy to navigate and understand what the reflected data means. Users should be able to understand what the feedback means and how to implement this.

- **Concept has multiple language features**
  Not all users might speak English or Dutch. It would therefore be beneficial if the concept has a feature to translate into multiple languages that can be adapted to the preferred language of the user.

- **User can interact with different parts of concept to gain more insight into the causes of bad mental well-being, and how to improve this**
  This requirement for the concept is aimed at more background knowledge for the user. The user might have the option to dive deeper into the reasons and causes of stress, a bad sleeping habit, or physical activity.

- **User can leave feedback about the prototype within the prototype itself**
  The prototype will have an option to give feedback. This feedback can then again be used to improve design or be used to give insight for future researchers.

- **Concept gives insight into mental well-being and a user knows what could be improved**
  The concept will give insight into the mental well-being of a user through visualizations. This in combination with feedback on the collected data will hopefully result in greater insight into the mental well-being of the user.
- **Concept gives recommendations for mental well-being improvement points based on collected data**
  The concept should be able to give personalized feedback on how to improve mental well-being based on the data collected. This should be based on scientifically proven baselines.

- **Concept has a decent accuracy for measurements**
  The concept should measure data accurately. There is little point in measuring data if it is not accurate. Users have to agree with the data that has been sampled.

- **Concept allows for external tracking systems to be implemented**
  The concept may have the option for external tracking systems to be implemented, such as communication between different devices.

- **Concept allows to have preferences for usage**
  The concept may have preference options for the user, such as a dark mode and a possible time for reminders.

4.1.3 Must have requirements

The must-have requirements are critical and non-negotiable elements that must be implemented in the final concept to ensure a successful outcome. These requirements can be further categorized as follows:

- Essential functionality: These requirements are fundamental to the core functionality of the concept. Without their implementation, the concept would not serve its intended purpose effectively.

- Legal compliance: These requirements ensure that the solution adheres to all applicable laws, regulations, and ethical considerations. Failure to implement these requirements may result in legal issues.

- Safety considerations: These requirements focus on the safety aspects of the solution. They ensure that the concept is designed and implemented in a way that minimizes risks to users, stakeholders, and the environment [42].

The must have requirements are:

  - Concept should have an overview of what data is collected and what it is used for

  - Concept visualizes in a clear and understandable way. Users should know what the concept envisions

  - Concept gives insight into mental well-being and a user knows what could be improved

  - Concept gives recommendations based on collected data

  - Concept has a decent accuracy for measurements. Users should not feel that the data is inaccurate.

4.1.4 Should have requirements

The should-have requirements are important elements that are not critical for the basic functionality and delivery of the concept. These requirements can be further described as following:

- Secondary functionality: These requirements enhance the usability and user experience of the concept but are not essential for its core functionality. They add value and improve the overall effectiveness of the solution, but their absence would not prevent the concept from being delivered or functioning as intended.

- Time-constrained workarounds: These requirements represent temporary solutions or alternative approaches to address certain aspects of the concept that cannot be fully implemented due to time constraints or limitations [42].

The should have requirements are:

  - Concept is easy to use, users should be able to use the application without hesitation or questions

  - Concept is easy to install

  - User can leave feedback for the concept within the concept

4.1.5 Could have requirements

The could-have requirements are optional elements that are desirable but not essential for the core functionality or delivery of the concept. These requirements can be described as follows:

- Additional features or enhancements: these requirements represent additional functionalities or improvements that can enhance the concept's capabilities or user experience. While they are desirable and may add value, their absence would not significantly impact the basic functionality of the prototype.

The could have requirements are

  - Concept has multiple language features

  - User can interact with different parts of concept to gain more insight

  - Concept allows to have preferences for usage

4.1.6 Won't have requirements

The won't-have requirements are elements that were not implemented in the current concept due to time constraints or limitations, but they could be considered for future implementations or further research. The won't-have requirements serve as suggestions for future iterations or versions of the concept.

The won’t have requirements is

- Concept allows for external tracking systems to be implemented

4.1.7 Functional vs Non-functional

After mapping all the requirements using the MoSCoW method, it is necessary to categorize them into two distinct sub-groups: functional requirements and non-functional requirements. The separation of requirements into these groups is crucial for a clear and comprehensive understanding of the project's specifications.

Functional requirements can be defined as the specific actions and capabilities that the system must possess in order to achieve success. These requirements focus on the system's functionality and describe what tasks it should be able to perform, how it should behave, and what features it should provide to fulfill the needs and expectations of the stakeholders and users [52].

On the other hand, non-functional requirements pertain to aspects that do not directly impact the system's functionality, but rather influence its performance, behavior, and other qualities. These requirements encompass characteristics such as performance, reliability, security, usability, and maintainability. They address the system's operational attributes and describe how it should perform in various contexts and scenarios [52].

To ensure the viability and usefulness of the final product or service, it is vital to validate both the functional and non-functional requirements with the stakeholders and users. This validation process, as detailed in section 4.3 Survey, involves collecting feedback and insights through surveys.

This research draws upon a comprehensive range of sources, including literature reviews, state-of-the-art analysis, and brainstorming sessions. The selection and integration of these diverse sources have contributed to the formulation of both functional and non-functional requirements for the study. The sources will be denoted with the requirements itself.

The following are the formal descriptions of the functional requirements that are expected to be implemented:

- FR1: Concept has an overview of what data is collected and what it is used for (literature review)

- FR2: User can interact with different parts of concept to gain more insight into the causes of bad mental well-being, and how to improve on this (brainstorming)

- FR3: User can leave feedback about the prototype within the prototype itself (state-of-the-art)

- FR4: Concept gives recommendations for mental well-being improvement points based on collected data (literature review)

- FR5: Concept has a decent accuracy for measurements about stress, sleep, and physical activity (literature review + state-of-the-art)

The following are the formal descriptions of the non-functional requirements that are expected to be implemented:

- NFR1: Concept will be easy to understand with various types of background knowledge in technology (literature review)

- NFR2: Concept is easy to use, users should be able to use the application without questions (state-of-the-art + brainstorming)

- NFR3: Concept visualizes data and feedback of the user in a clear and understandable way (state-of-the-art)

- NFR4: Concept gives insight into the three aspects of mental well-being and a user knows what could be improved based on the three aspects (literature review + state-of-the-art + brainstorming)

4.2 Survey

With the ideation process summarized in combination with the functional and non-functional requirements, it is crucial to get user input from the target group of students, conduct a survey among the target group to gain insights into their needs, preferences, and technological preferences would be beneficial. By understanding their requirements and work processes, the research can be tailored to meet their specific needs. Additionally, it is important to assess how the target group currently manages their mental well-being and their awareness and knowledge regarding the research solution. This information will help in designing the project to provide relevant support to the users.

Moreover, actively involving participants in the research study while testing the prototype is essential. To encourage active participation, it is necessary to understand the factors that motivate participants to engage in the research. By gathering their input on what would motivate them to actively participate, the research can be structured in a way that aligns with their interests and encourages their active participation.

The survey was conducted using an online survey platform known as Microsoft Forms. It consisted of a total of nine questions, with the first question pertaining to the participants'

agreement for data collection. Prior to answering the survey, the participants were provided with an information form outlining the details of the survey and the goal of the research.

The survey was distributed to friends and roommates of the researcher and focused targeting individuals who were actively engaged in studying at the time of survey distribution. The objective of the survey was to obtain a response range of ten to fifteen answers. Ultimately, a total of 19 surveys were sent out, and 15 of them were completed and returned. Consequently, the response rate amounted to 78.95%.

4.2.1 Results

Below the survey results are displayed, which have been reviewed prior to analysis. Responses that did not answer the question have been excluded to ensure the accuracy of the analysis. No outliers have been removed for questions involving personal relevance, as individual differences are expected and valuable. It should be noted that some participants provided answers in Dutch rather than English. To maintain the integrity of the data, the Dutch responses will be analyzed without translation, as translating them may introduce inaccuracies. Based on the analysis of the survey results a suggested improvement for the prototype will be given.

2. What are indicators to you, that explain the state of your mental well-being (Regardless of a good mental well-being or bad mental well-being.)

15 Responses

ID ↑	Name	Responses
2	anonymous	In my energy and willingness to go and do things (instead of playing video games and watching Youtube all day)
3	anonymous	I experience it as really impactfull on your life, because it can really influence your mood.
4	anonymous	I experience mental well-being quite sensitive and well.
5	anonymous	Sleeping well, being happy
7	anonymous	(Social) battery, how much I feel like laughing
8	anonymous	Can find joy in aspects of everyday life
9	anonymous	Energie overdag, eetlust, sociale batterij
10	anonymous	Level of happiness, quality of sleep, energy during the day
11	anonymous	sleep, life-work balance, stress, me-time, working out
12	anonymous	Amount of humour used, amount of alcohol consumption
14	anonymous	My emotions, Stress and pressure
15	anonymous	My social battery

Figure 8: Survey 1 result on how participants indicate levels of mental well-being

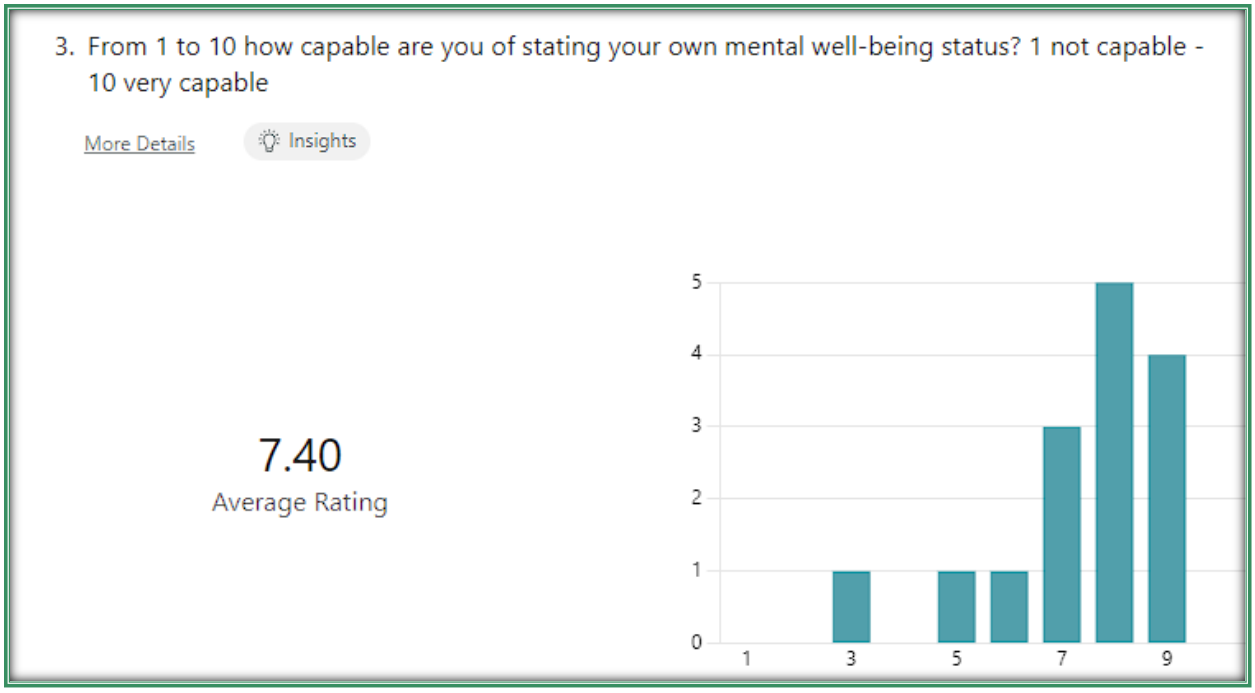


Figure 9: Survey 1 result on capability of stating own mental well-being status

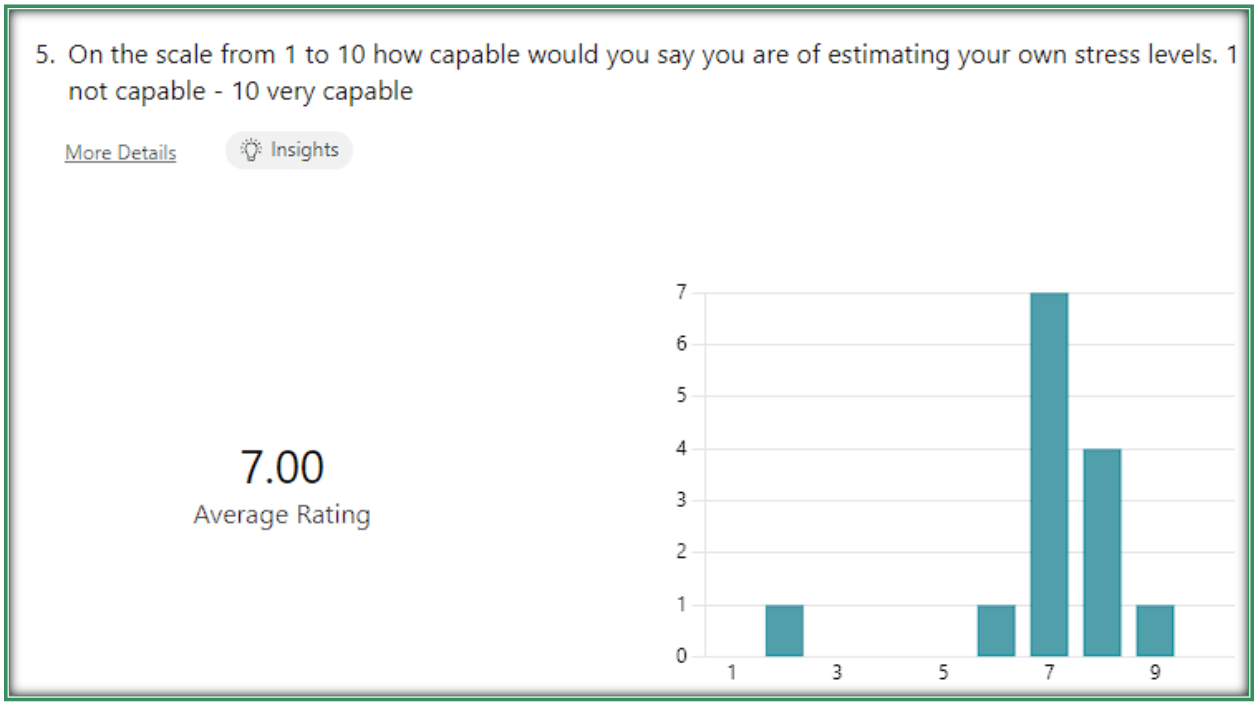


Figure 10: Survey 1 result on capability of stating own stress levels

Figure 11: Survey 1 question on intuitive ways to represent stress levels

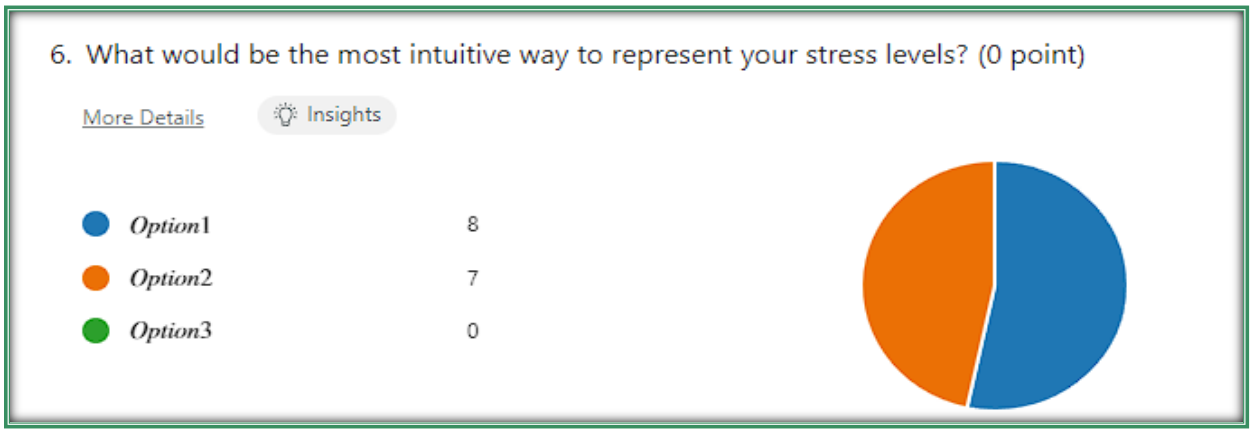


Figure 12: Survey 1 answers on intuitive ways to represent stress levels

7. To help you remind to do a certain action, what would be a convenient way to receive a notification? Think of e-mail, pop-up, letter, alarm, etc.

15 Responses

ID ↑	Name	Responses
1	anonymous	Mail
2	anonymous	As a pop up on my phone, where I can schedule what time it pops up.
3	anonymous	Whilst you are on your phone, then the notification pops up.
4	anonymous	Via smartphone since I will be on there probably most of the day
5	anonymous	Pop up
6	anonymous	Pop up
7	anonymous	Pop-up
8	anonymous	Pop-up
9	anonymous	Alarm
10	anonymous	Pop-up
11	anonymous	a pop-up but a repetitive one, I like to have a 'stok achter de deur'
12	anonymous	alarm or pop up
13	anonymous	Alarm, pop-up
14	anonymous	A pop-up or notification
15	anonymous	An alarm

Figure 13: Survey 1 answers on reminding participants to undertake certain actions

8. How often should you rate your stress level to have a clear view of average stress over the day?

15 Responses

ID ↑	Name	Responses
1	anonymous	4 times, morning/wake (8:00/9/00) up, midday (12:00/13/00) afternoon (16:00/17:00) evening (21:00/22:00
2	anonymous	5 to 6 times
3	anonymous	Once every half an hour
4	anonymous	once every hour ?
5	anonymous	Daily
6	anonymous	Every 20 minutes
7	anonymous	4 times: wake-up, end of morning, end of afternoon, when going to bed
8	anonymous	Three times
9	anonymous	Om de 3 uur denk ik
10	anonymous	5 times a day
11	anonymous	6 times: beginning of the morning, end of the morning, beginning of the afternoon (after lunch), end of afternoon, beginning of evening (after dinner), end of evening (when going to bed)
12	anonymous	5 times
13	anonymous	5
14	anonymous	Every hour I believe, because your stress can change by every minute
15	anonymous	6 times

Figure 14: Survey 1 answers on how often stress levels should be reported

9. What theme's and colors represent a relaxing surrounding?

15 Responses

ID ↑	Name	Responses
1	anonymous	Grey/light green (light green maybe affect the results)
2	anonymous	Turquoise, yellow and pinks. Sun, sea, palmtrea 😎
3	anonymous	Blue, green and yellow
4	anonymous	Pastel colors
5	anonymous	Pastel colors, light colors
6	anonymous	That the colors match and warm white colors
7	anonymous	Bright colours (mostly green, yellow). Round shapes
8	anonymous	Natural Green and blue
9	anonymous	Aarde tinten, groen
10	anonymous	Blue colors
11	anonymous	light blue, light green : nature colours
12	anonymous	warm colors
13	anonymous	Pastels, soft colours
14	anonymous	The nature theme,
15	anonymous	Blue or green

Figure 15: Survey 1 answers on theme's that represent a relaxing surrounding

4.2.2 Analysis + improvements

Analysis Q1 + 2

Question one pertains to the voluntary participation in this survey, in conjunction with all the obtained ethical approvals, as explicitly stated herein. It is essential to note that all participants possessed awareness of their rights and willingly consented to participate in the study.

Question two, on the other hand, was deemed unnecessary for analysis, as the outcomes derived from it did not contribute to further improvements. The prototype under consideration would not incorporate these parameters as data entry points.

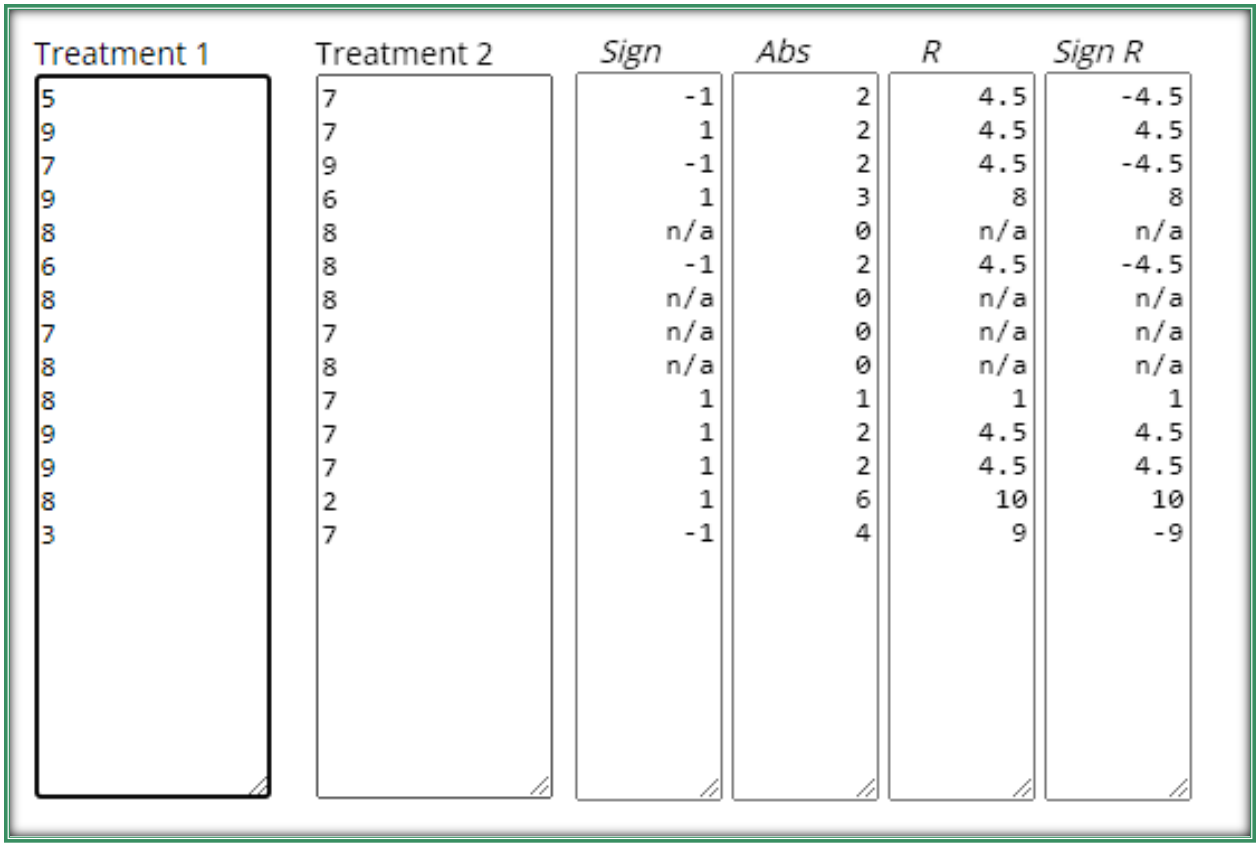
Analysis Q3 + Q5

Questions three and five from the survey were combined for the analysis to assess the participants' ability to report their mental well-being status and stress levels. Figure 9 and Figure 10 present the findings regarding this capability.

To accurately analyze both questions, it is important to examine the data using appropriate statistical methods. The distribution of responses does not follow a normal distribution, necessitating the use of a Wilcoxon test instead of a regular t-test. This is particularly applicable since the question contains two paired groups involving the same individuals. The conducted test will be a two-tailed test, considering a significance level of 5%.

The Wilcoxon test, also known as the Wilcoxon, signed-rank test, is a non-parametric statistical test used to assess the difference between paired samples. It does not assume normality in the data and is well-suited for situations where the distribution is not symmetric, or the sample size is relatively small.

By employing the Wilcoxon test in this scenario, we aim to determine whether there is a significant difference in the scores between the two questions. The null hypothesis (H0) assumes no difference in the scores, while the alternative hypothesis (H1) suggests a significant difference exists.



Treatment 1	Treatment 2	*Sign*	*Abs*	*R*	*Sign R*
5	7	-1	2	4.5	-4.5
9	7	1	2	4.5	4.5
7	9	-1	2	4.5	-4.5
9	6	1	3	8	8
8	8	n/a	0	n/a	n/a
6	8	-1	2	4.5	-4.5
8	8	n/a	0	n/a	n/a
7	7	n/a	0	n/a	n/a
8	8	n/a	0	n/a	n/a
8	7	1	1	1	1
9	7	1	2	4.5	4.5
9	7	1	2	4.5	4.5
8	2	1	6	10	10
3	7	-1	4	9	-9

Figure 16: Wilcoxon test calculation

Result Details

W-value: 22.5
Mean Difference: 0.6
Sum of pos. ranks: 32.5
Sum of neg. ranks: 22.5

Z-value: -0.5096
Mean (*W*): 27.5
Standard Deviation (*W*): 9.81

Figure 17: Wilcoxon test results

Based on the Wilcoxon signed-rank test, the calculated W value for the paired datasets is 22.5. With a sample size of N = 15 and a significance level of $p < .05$, the critical value for W is 8.

Comparing the obtained W value to the critical value, we find that W (22.5) exceeds the critical value (8). Therefore, we fail to reject the null hypothesis. This implies that there is no significant

difference in the capability of rating stress levels versus the capability of rating mental well-being status.

However, it would still be beneficial to improve the participants' ability to accurately report their stress levels, it is therefore recommended to provide them with insights into the factors that may contribute to their individual stress levels [48]. By understanding the triggers and causes of stress, users can make more informed assessments and contribute to a more accurate representation of their stress levels within the system.

Improvement Q3 + Q5

In order to enhance the users' capability to state their stress levels accurately, the application will include a feature where users can provide a reasoning behind their reported stress level. For instance, if a user rates their stress level as 5 out of 5, they will be prompted to explain the reasons behind this stress level. This reasoning will be collected and displayed in the data section of the application, allowing users to review and analyze their stress-related experiences over an extended period of time.

By gaining insight into the factors contributing to their stress levels, users can become more self-aware and better equipped to assess and manage their own stress. This, in turn, can contribute to their improvement of mental well-being.

Furthermore, to further support the capability of stating mental well-being levels, the information section of the application will have to include a dedicated segment on mental well-being. This section will provide information about the symptoms of good or poor mental well-being and offer strategies for improving one's mental well-being. By providing users with educational resources and guidance, the prototype aims to help them to actively manage and improve their mental well-being.

Analysis Q6

Question six of the survey focused on the design aspect of the application, aiming to ensure that users feel understood and have a user-friendly method to express their emotions and convert them into analyzable data for personalized feedback. The questionnaire presented three options, as illustrated in Figure 15.

Upon analyzing the survey results, it was evident that there was a closely contested competition between option 1 and option 2, as illustrated in Figure 16. Notably, both options shared the characteristic of utilizing colors to represent stress levels.

Given the close competition and the lack of a clear winner between the two options, it was important to delve deeper into the scientific background of the potential outcomes. As a result, research was undertaken to explore the validity and suitability of each option.

During this research, it became apparent that the smiley scale, specifically the Ottawa mood scale, emerged as a utilized phenomenon for measuring and indicating various moods, including stress, arousal, anger, and worry [53]. Through a comprehensive evaluation of this

scale, it was concluded that the smiley scale, represented by a range of facial expressions, was a valid and reliable tool to assess stress levels among students.

Improvement Q6

Based on the analyses conducted, it is concluded that the smiley scale, as a visual representation of stress levels, will be selected due to its scientific foundation. This approach is intended to offer users a more intuitive and relatable method of expressing their emotions.

Analysis Q7

Based on the results of the survey, it was found that a majority of the participants expressed a preference for receiving notifications in the form of pop-ups. This indicates that pop-up notifications were deemed preferable and user-friendly compared to other notification methods. Due to the lack of a follow-up question on what pop-up would be preferable the researcher had to pick one himself.

Improvement Q7

Considering the participants' preferences of a pop-up as a call to action, a proper and effective solution must be found. Considering widespread use of smartphones with WhatsApp among the target audience (students), it has been determined that utilizing WhatsApp notifications for the prototype would be an effective and efficient approach.

Analysis Q8

Question eight sought to highlight participants' perspectives on the frequency at which they believe stress levels should be measured to obtain meaningful insights into their stress patterns over a specific period. The responses to this question found substantial variability, with participants expressing a wide range of preferences. These preferences spanned from measuring stress levels daily to as frequently as every 20 minutes. Nonetheless, a notable concentration of responses was observed within the range of measuring stress levels 4 to 8 times a day, as indicated by the clustering of data points in Figure 19.

Amount of times rating stress a day	Grouping them in segments of 4 hours				
4					
5.5	0 till 4	4 till 8	8 till 12	12 till 16	16+
32	2	9	0	2	2
16					
1					
48					
4					
3					
6					
5					
6					
5					
5					
16					
6					

Figure 18: Data points about number of times measuring stress in a day

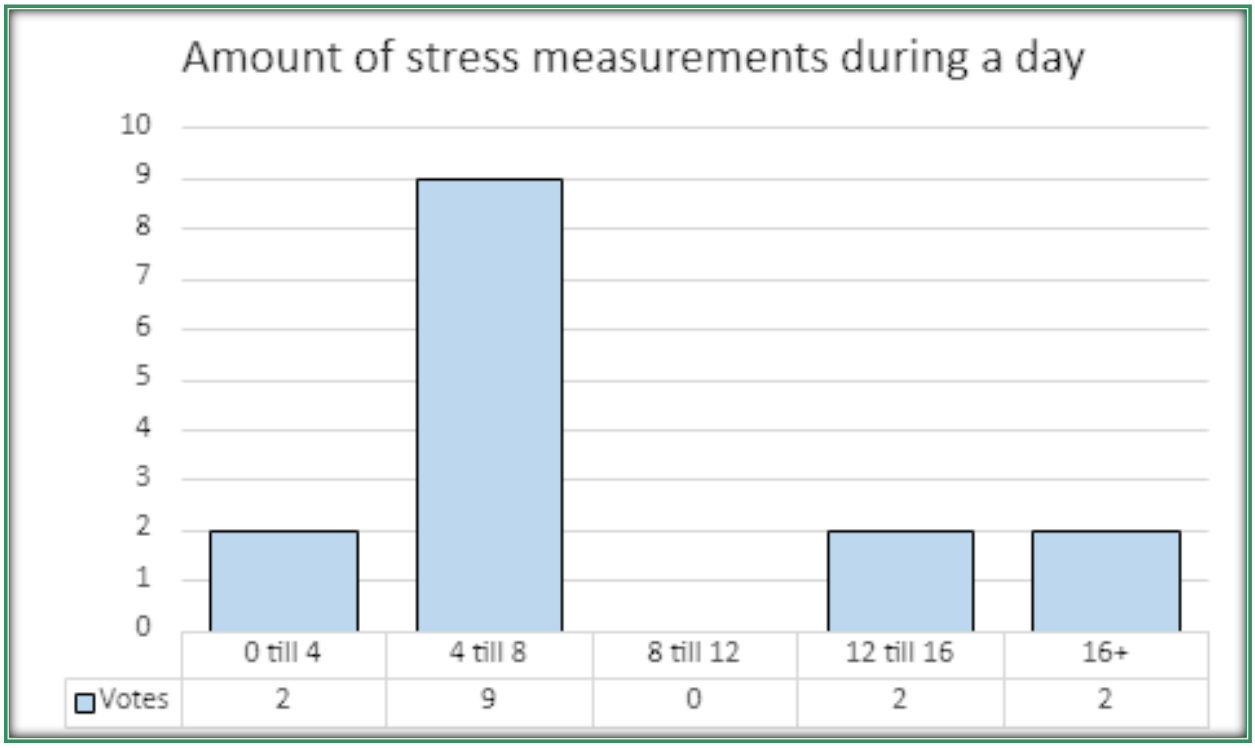


Figure 19: Distribution of the stress measurement times during a day in a graph

Improvement Q8

To ensure a sufficient number of data points and capture stress levels in line with the desired frequency of 4 to 8 times a day, a calculation was performed based on the average waking

hours of a Dutch person. It was found that the average wake time is approximately 15 hours and 48 minutes, considering an average sleep duration of 8 hours and 12 minutes [47].

To achieve the desired frequency of 4 to 8 measurements per day, the wake time was divided by the average of 6, resulting in an interval of approximately 2.63 hours between notifications. However, considering that most participants expressed their preference for 4 to 8 times a day, the number of notifications will be rounded up to every 3 hours.

Analysis Q9

Through the analysis of user feedback and preferences, it was observed that light, natural, and pastel colors emerged as the most prevalent choices. These colors were found to be particularly effective in promoting a relaxing environment. As a result, a combination of these color palettes was deemed suitable for achieving the desired outcome.

Improvement Q9

The decision has been made to incorporate a light pastel color scheme into the prototype as part of the improvement.

4.3 Final definition and envision of prototype

This section aims to provide a description of the envisioned features of the prototype for user testing. Drawing upon the previously stated requirements and the data collected from the initial survey completed by participants, an envisioning of the prototype can be formulated.

In the initial envisioning of the prototype, a smartwatch is envisioned to be connected to a web application. The following paragraphs will elaborate on the envisioned features of the prototype. Afterwards, the envisioned prototype will be translated into an actual working prototype, which will then undergo evaluation through a user testing session. During this session, participants will be asked to complete a questionnaire that assesses their experience with the prototype. Finally, based on the findings from the user testing session, a conclusion will be drawn, highlighting the aspects that should be incorporated into future prototyping or considered for further research.

4.3.1 Environment

The prototype consists of three primary components, namely the Fossil 5E smartwatch, a smartphone, and a web application.

The hardware and software components involved in the data collection and communication process operate in co-existence with each other through the utilization of the Google Fit API. The Google Fit application installed on both the Fossil 5E smartwatch, and the smartphone serves as the primary means of data collection and storage.

Once the data is stored within the Google Fit application on the smartwatch and smartphone, the web application is designed to retrieve this data. The web application sends requests to the Google Fit API, which acts as an mediator, fetching the requested data from the storage in the smartwatch and smartphone. The retrieved data is then transmitted to the web application for further processing, analysis, and display.

The Google Fit API provides a diverse array of parameters related to physical activity. Among these parameters, the "Activity" parameter proves to be the most valuable in assessing overall physical activity. This parameter records various activities encompassing for instance walking, as well as a wide range of sports. Each activity is assigned a start time and an end time, enabling the aggregation of active minutes over a specified time interval. The proposed prototype intends to gather all recorded activities and convert them into active minutes per day for the best overview of physical activity.

The central element of the prototype is the web application, which is designed as a HTML-based website complemented by JavaScript functionalities. To ensure efficient data management and meet the specified requirements, the web application is supported by a database system. This allows users to store and retrieve data as needed. Together with the use of the previously mentioned Google Fit API, sleep and physical activity data can be sent and requested.

4.3.2 Layout

The prototype vision is that there is a specific layout that is easy to grasp for all participants and future users. The layout should consist of 4 separate pages. The first and initial page should give answers to the repeating questions about stress and about sleep time. There should be an easy way to navigate through the different pages. This is most likely a button, which a user can click.

The vision for the prototype is to develop a user-friendly layout that can be easily understood by both current participants and future users. With the help of the User Interface Design Basics, a few basic rules can be followed to create a user-friendly layout [54]. The layout is designed to consist of four distinct pages, each serving a specific purpose.

The initial page of the prototype aims to provide answers to recurring questions related to stress levels. From here on out, the user can reach every page.

To facilitate good navigation between the different pages, a user-friendly mechanism will be implemented, most likely in the form of a clickable button. This intuitive button will enable users to effortlessly move between the various sections/pages of the prototype.

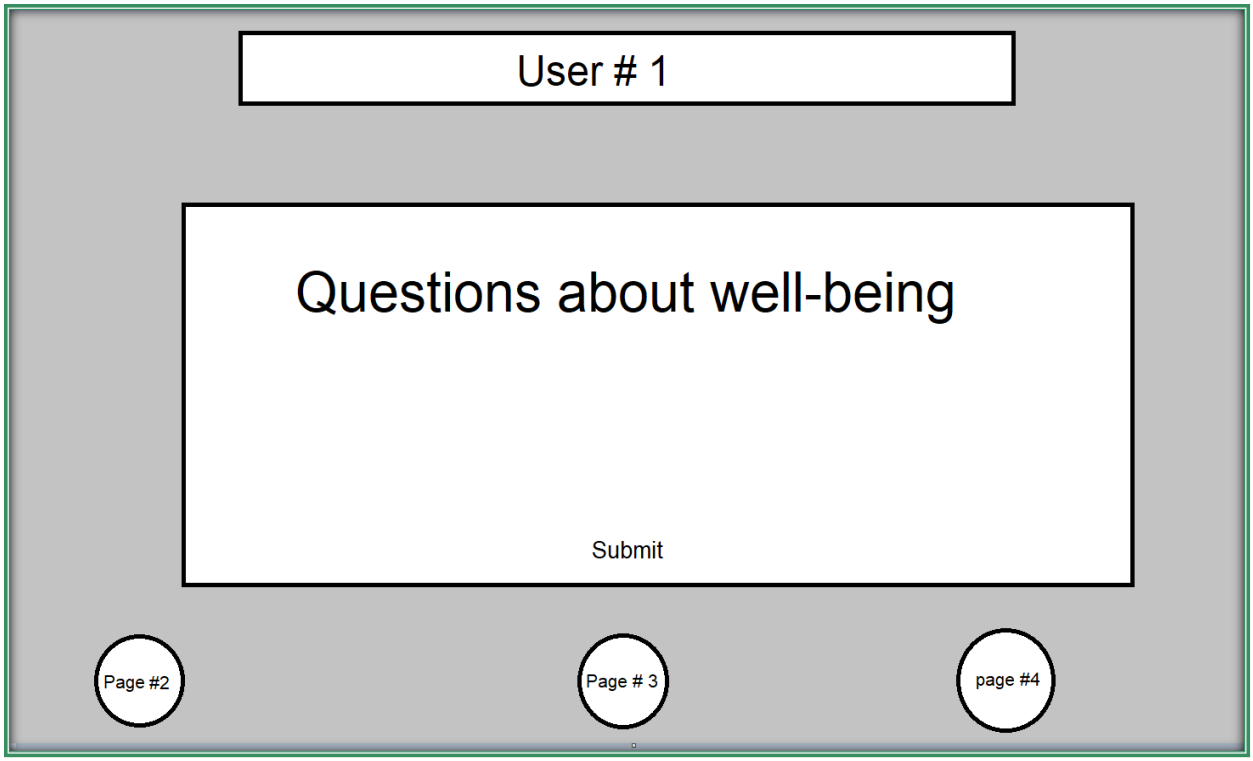


Figure 20: Envisioning of layout of initial page

The prototype incorporates a dedicated data reflection section, allowing users to visualize and comprehend their collected data. The reflected data encompasses stress levels and its corresponding reasons, sleep time and active minutes. The presentation of this data aims to be easily understandable and insightful for users.

For stress levels, a graphical representation over time is envisioned, enabling users to observe fluctuations and patterns in their stress levels. This graph provides a clear visual depiction of stress variations and aids in identifying potential triggers or patterns in combination with the users stated reason.

To enhance the understanding and comparison of sleep time, a straightforward format consisting of day, hours, and minutes will be employed. This presentation allows users to easily compare the duration of sleep across different days.

Similarly, for tracking active minutes, the same approach will be used. By utilizing a clear statement that includes the day, hours, and minutes spent being active, users can easily identify patterns and assess their level of physical activity over time.

Throughout the data reflection section, the user interface will maintain its user-friendly design, ensuring that the buttons for website navigation remain easily visible and intuitive to use.

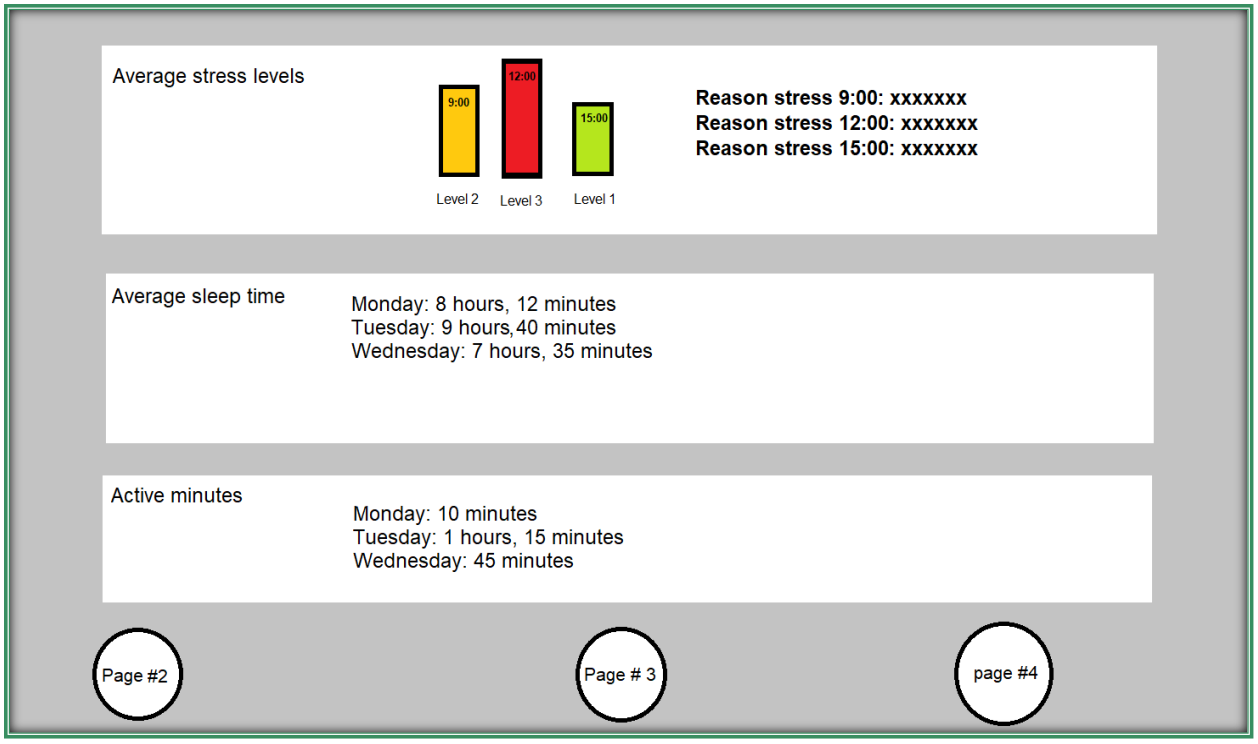


Figure 21: Envisioning of layout of data page

In addition to the existing pages, the prototype will incorporate an informative section dedicated to mental well-being, sleep, stress, and physical activity. This page will provide general information about these subjects. The information provided will encompass various aspects, including the detection of problems related to mental well-being, sleep, stress, and physical activity. It will offer insights into common issues that individuals may encounter and provide potential solutions or strategies to address these problems effectively.

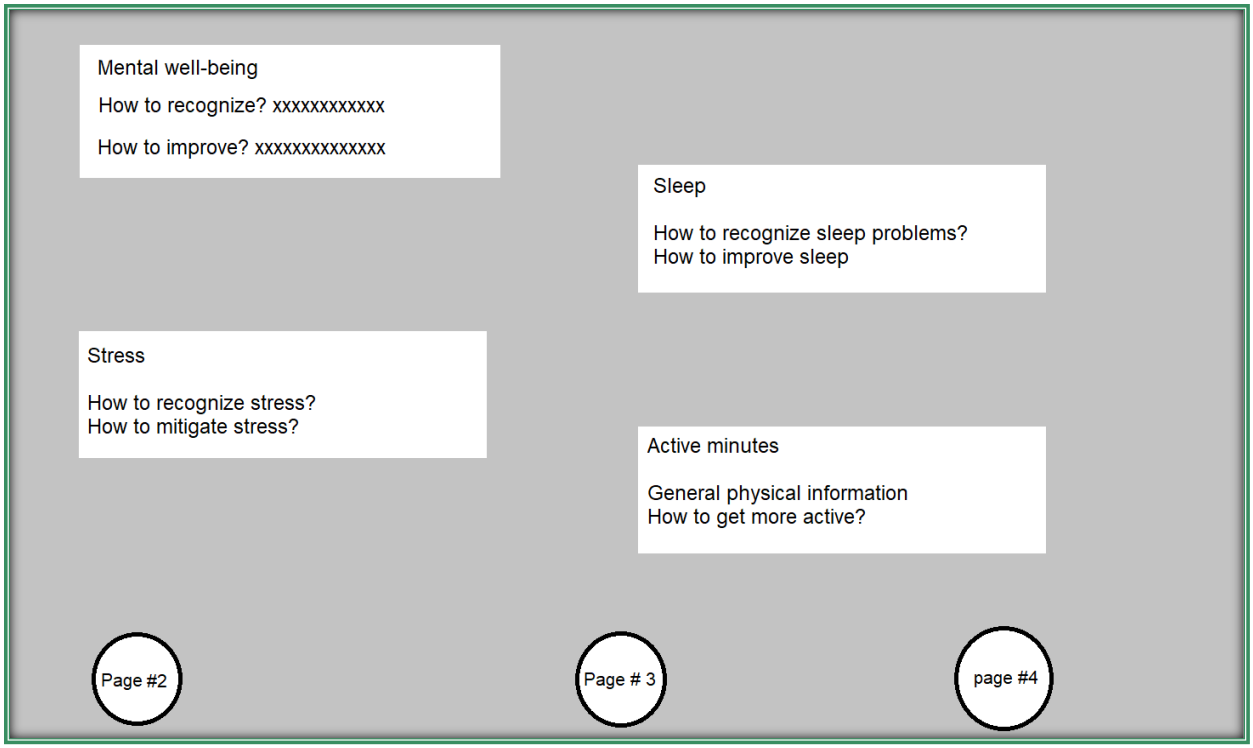


Figure 22: Envisioning of layout of information page

The fourth and final page of the prototype is dedicated to a contact page, providing participants with access to the researcher's details and offering a means to report feedback or address any issues encountered with the web application, smartwatch, or smartphone.

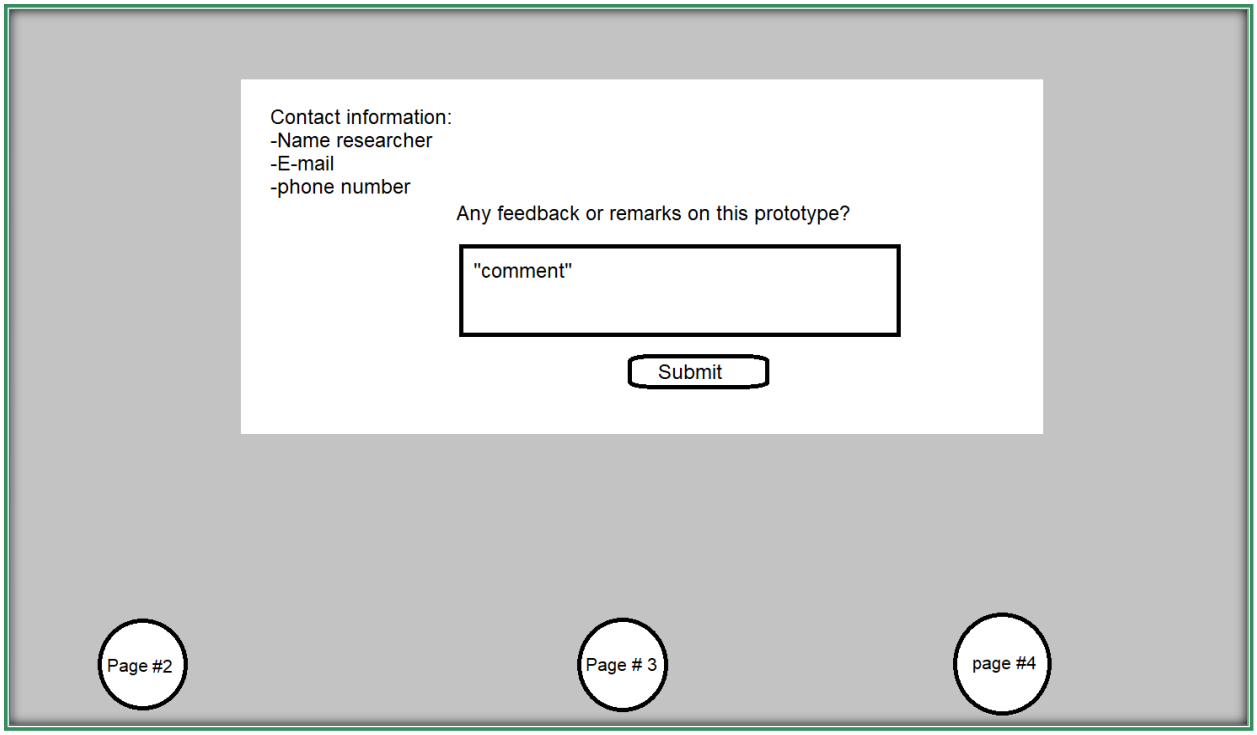


Figure 23: Envisioning of layout of contact page

To ensure transparency and maintain an overview of the collected data, the prototype will incorporate a dedicated data overview page. This overview will align with the MoSCoW method prioritization, clearly indicating the elements of data being collected.

The data overview page will be designed to look like figure 21, effectively highlighting the specific data components being gathered. Sleep, stress, and physical activity will be presented in a clear and easily understandable format, allowing users to quickly grasp the data being collected and monitored.

Additionally, within the information tab (referenced as Figure 22), all these elements will be returned, providing further assistance and guidance to the user. This ensures that users not only understand what data is being gathered but also comprehend its purpose and relevance.

4.3.3 Features

In order to implement most of the MoSCoW requirements based on the feedback collected from the survey and background research, it is important to incorporate several crucial features into the prototype. These features will be distributed across four distinct web application pages. Underneath all features will be discussed, assigned by their place within the prototype.

- **Stress log page**
  On the initial web application page, users will have the ability to log their experienced stress level over the past 3 hours. It is crucial that upon reaching this page, the tasks are immediately clear to the user. Clear instructions and intuitive interface elements will guide users throughout the process.

  Once users have submitted their average stress level over the last 3 hours, immediate feedback will be provided in the form of a text overview. This feedback will be tailored to the information just provided by the user, as well as the average stress levels of all the previously recorded data. The feedback will consist of a new page that opens with the just submitted stress level that will be compared to the all the averages of stress levels over the time that the user had used the application. The feedback will automatically detect if the just submitted stress level is higher or lower than the average and notify the user of this.

  Following the feedback, users will be prompted to explain the reasoning behind their reported stress level. This explanation, along with the stress level, will be submitted to a dedicated database responsible for collecting and storing user data.

- **Data page**
  The data page plays a crucial role in visualizing the user's data, aiming to present it efficiently and comprehensibly. To achieve this, stress data will be displayed in the form of a graph, which has proven to be an effective visualization tool [55]. Bar charts, for example, can be utilized to enhance the visual representation of the data, as demonstrated in Figure 21. Sleep time and physical activity will be visualized as discussed before by, stating the time duration of the activity in combination with the day associated with it.

  In addition to visualization of sleep, stress, and physical activity, it is important for the prototype to be responsive to the user's inputs. This ensures that the user receives immediate feedback and confirmation that their data has been successfully uploaded. This responsiveness is particularly relevant for the initial page where the user logs their stress levels. By providing a visual indication of successful data input, the user gains assurance that their input has been registered accurately.

- **Information page**
  On the information page, it is essential to provide users with easy navigation options to access and explore the relevant information on improving the three main pillars of mental well-being: stress, sleep, and physical activity.

  To enhance visual understanding and prevent overwhelming users with excessive information, the prototype will implement a drop-down menu system. This approach allows users to selectively access the specific sections or subsections of information they are interested in.

  By incorporating a drop-down menu, users can easily navigate through the different sections of the information page. Each section can be listed in the menu as a clickable

item, and upon selection, the corresponding content will be revealed and displayed for the user.

- **Contact page**
  The final page of the prototype, the contact page, is a way for users to access the contact details of the researcher and provide immediate feedback in case of any issues or problems encountered.

  The contact page will display the contact details of the researcher, including name, email address, and phone number. This allows users to easily find the necessary information to communicate with the researcher directly.

  To enable instant feedback without the need to contact the researcher personally, the prototype will include a text box where users can type and submit their feedback or report any problems they have encountered with specific features or aspects of the prototype. Upon submission, this feedback data will be securely stored in the database, allowing the researcher to review, analyze, and take necessary actions to address any reported issues or implement updates and improvements to the prototype.

- **General features**
  In addition to the specific features assigned to each page, there are also general features that apply across all pages of the prototype. One such feature is the notification system, which prompts users to perform certain actions. To notify users, a pop-up notification will be delivered to the user's smartphone, through a platform like WhatsApp. This notification will contain a direct link to the corresponding page where the user can log their experienced stress levels over the last three hours or input their sleep time. Furthermore, efficient navigation is needed for the user to access all the necessary pages within the prototype. To accomplish this, the envisioned prototype employs a bottom navigation approach, featuring buttons positioned at the bottom of the screen. This consistent placement ensures the buttons remain consistently visible to users without being overly prominent or obstructive. To enhance user-friendliness and facilitate quick recognition, each button consists of relevant pictures or icons that visually represent the destination of the page. These pictures assist users in identifying and selecting the appropriate button that leads to their desired page.

  Lastly, the envisioned prototype incorporates the utilization of a database as the prefer

  ed method for storing user data. Among various options available, a database proves to be the most efficient and optimal choice, as it requires minimal user effort and presents a low probability of failure. The database serves the purpose of storing user data and forwarding user data to the prototype.

4.3.4 Theme

As part of our overarching goal to enhance mental well-being, the theme of the web application will play a significant role. Based on the survey results, it is shown that utilizing light natural colors with a preference for pastel palettes is the most suitable approach. These color choices aim to create a visually relaxing environment for users.

The web application will consistently incorporate these light natural and pastel colors throughout its design. These colors will be carefully selected and applied to various elements such as backgrounds, buttons, text, and other interface components.

Figure 24: Light pastel colors that will be implemented in prototype

Flow diagram

Combining all the elements/requirements that have been mentioned, the following user flow diagram is created. This user flow diagram serves as a tool for finding the proper navigation in combination with the functional and non-functional requirements in the prototype.

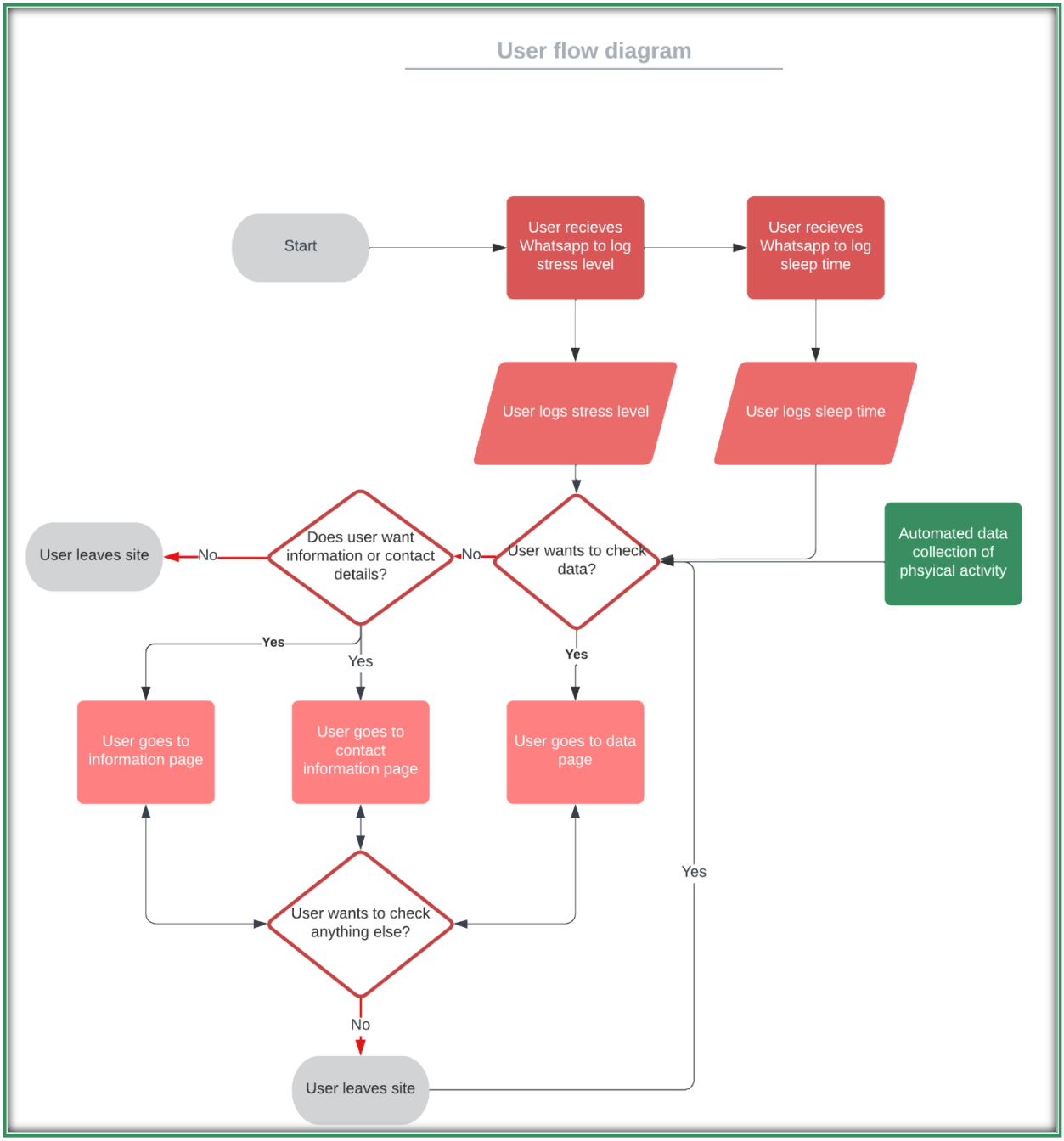


Figure 25: User flow diagram

5. Realization

As described in Chapter 4.3, the final prototype was developed based on the envisioned features and layout. However, during the realization process, certain adjustments and modifications were made due to feasibility constraints or the identification of better approaches to address specific challenges. These adjustments ensured that the final prototype was practical and effective in achieving its intended goals.

This chapter will focus on the adjustments made in the realization process. It will do so including both the hardware and software side of the prototype.

5.1 Hardware

The hardware requirements for the prototype consists of three essential elements, each playing an important role in the development and testing process. The first two elements consisted of specific devices, namely the Fossil 5E smartwatch and the provided Samsung Galaxy A13 smartphone. These devices were essential components used during the prototype user testing phase. To facilitate the testing process, participants received both the smartwatch and smartphone directly from the researcher.

The third and final hardware requirement involved a physical location to securely store the collected data from the web application. To prioritize data privacy and ensure its protection, the researcher took measures to set up a dedicated database at their own residence through the Django [6] framework. This database served as a secure place for storing the gathered information, complying with privacy regulations and keeping the participants' data throughout the prototype development and testing stages safe.

5.2 Software

The prototype consists of a multitude of software applications combined. The software that is used can be defined as pre-existing and research made software. This chapter will further explain these types of software and will explore how they have been used within the prototype.

5.2.1 Pre-existing

The pre-existing software utilized in this research project is Google Fit. This software was already pre-installed on the smartwatch, being the Fossil 5E. Additionally, the Google Fit software was installed on the provided smartphone. Both the smartwatch and smartphone were linked together through a Google account, enabling synchronization of data between the

[6] https://www.djangoproject.com/

devices. Furthermore, the framework of the database was already existing, this has been utilized to create a personal database.

5.2.2 Research made

The research made software can be divided into two sections. The backbone of the website, and the user experience including the functionality.

5.2.2.1 Website backbone

The research-made software is built as a web application, utilizing HTML, CSS, and JavaScript. The web application serves as the main platform for users to interact with the prototype and access its features.

HTML is used to structure the content and layout of the web pages, defining the elements and their organization. CSS is responsible for the visual presentation of the web application, providing styling and aesthetics to enhance the user interface experience.

JavaScript, on the other hand, plays a crucial role in providing the necessary functions and features of the web application, allowing users to engage with different elements, submit data, and receive real-time feedback.

The web application relies on a database to store and manage the collected data. This database ensures that the website is always accessible for users, providing a reliable and consistent user experience. The researcher has set up the database to create a secure and useful environment for data storage and retrieval.

Starting here on out all features will be explained with pictures.

5.2.2.2 The websites user experience and functionality

This section can be divided into the layout, followed up by the four pages of the prototype.

*Note: Some of the figures may be hard to read in this document. The figures are not altered in favor of readability to 100% resemble what to prototype looked like. The displaying of the pictures was at all times readable to the users during the prototype evaluation.

Layout

The web application follows a consistent layout across its pages as described in 4.3.2 “Layout”, see figure 20. The central area of each page contains the relevant information or content specific to that page. This central placement helps users focus on the primary content without distractions.

The header section of each page provides users with a clear indication of their current location within the web application. It serves as a navigation, allowing users to understand where they are in the applications.

At the bottom of each page, there is a footer that serves as a navigation menu. This footer includes buttons that allow users to navigate to different pages within the web application. The buttons are labeled with pictures, providing a visual representation that helps intuitive navigation.

If a web page extends beyond the visible screen height, the footer moves along with the scrolling action, the scrolling action is dependent on the hardware that the user is using, this would mean either to the bottom or to the right. This behavior keeps the footer consistently positioned at the bottom of the page, regardless of the page's length. This allows users to access the navigation buttons conveniently, even when scrolling through lengthy content.

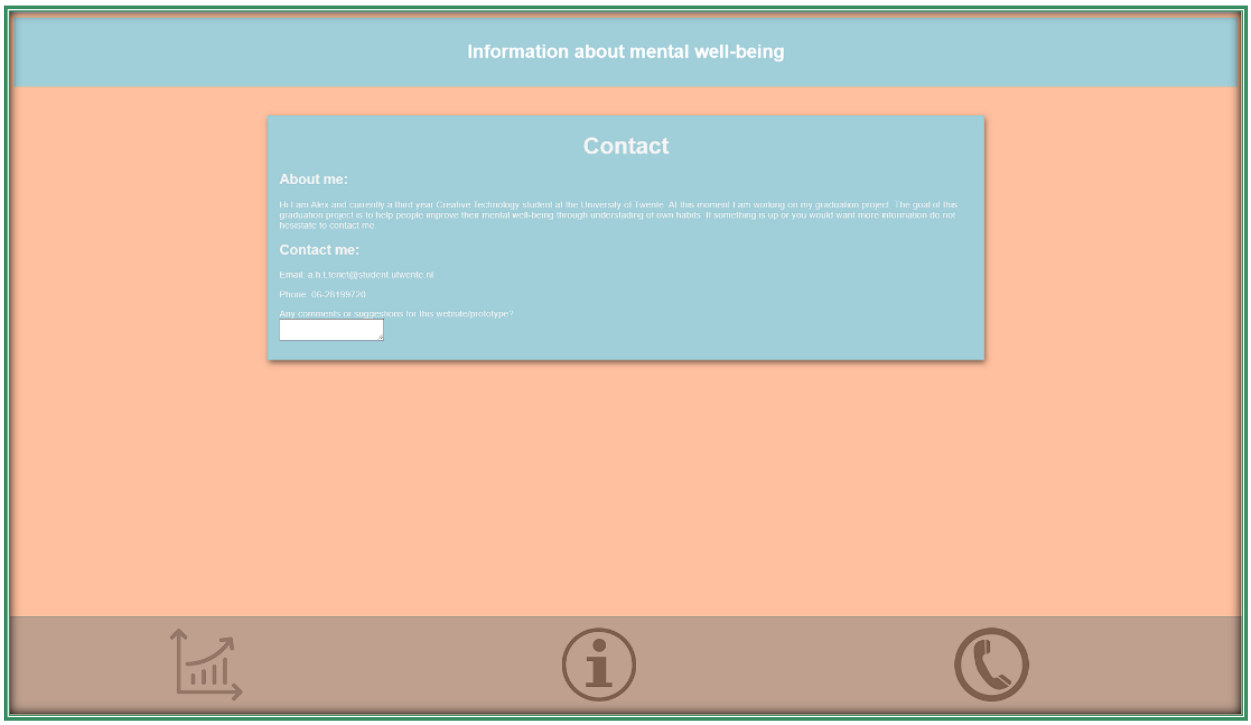


Figure 26: Layout of the web application

Figure 27: Stress reflection of a user

Initial stress page

Upon receiving a WhatsApp message, the user is prompted with the following instruction: "Please log your average stress level over the last 3 hours". The message also contains a hyperlink directing the user to the stress evaluation page. By clicking the link, the user is automatically redirected to the screen, where they can assess their stress level experienced during the past 3 hours, see Figure 27.

To facilitate stress evaluation, a combination of smileys and numerical values has been implemented as part of the initial survey. The selected set of smileys serves as visual representations to denote levels of stress, and the corresponding numerical values provide a quantifiable measure for the user to express their stress level accurately.

This number can then be selected through a drop-down menu that can be seen in figure 28:

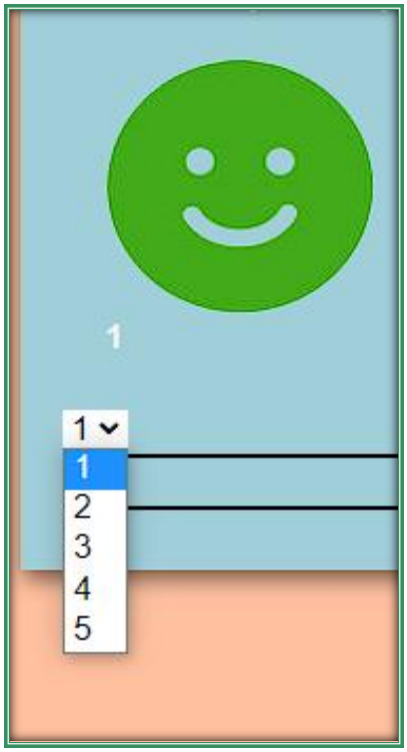


Figure 28: drop-down menu stress evaluation.

After selecting and submitting an option on the initial form, the form itself will disappear from the screen. In its place, a new form will appear, which will compare the previously submitted stress level to the average stress level derived from all the data collected thus far. This new form allows for the assessment of how the user's recent stress level compares to their overall stress level trend.

This is visualized as follows (figure 29):

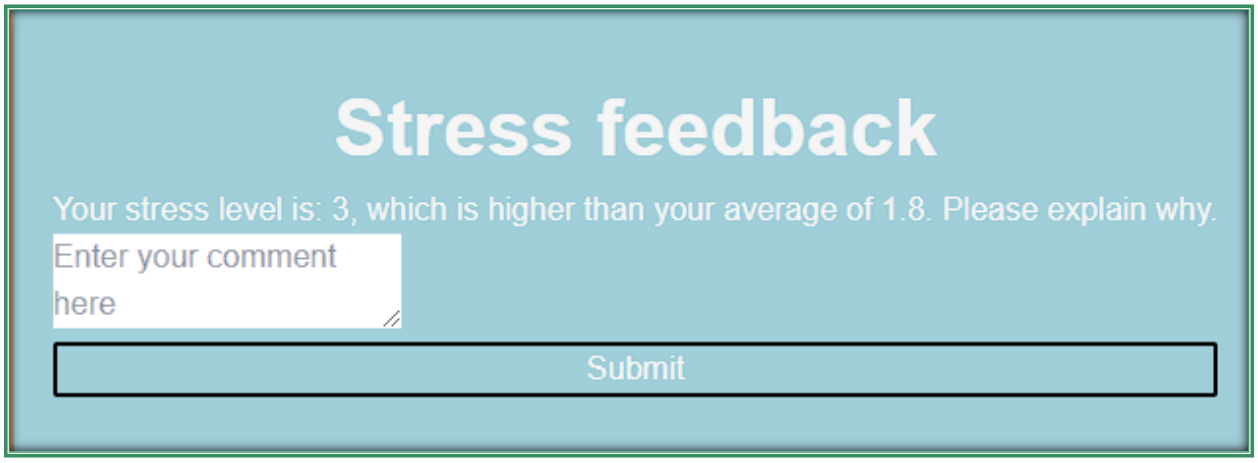


Figure 29: Stress feedback form

The user is provided with information indicating whether their current stress level over the last three hours is higher or lower than their average stress level. Based on this comparison, the user is given the opportunity to provide an explanation regarding their current stress level. This allows participants to offer self-reported individual insights into their stress levels and potential reasons behind fluctuations.

Upon submitting their reasoning, the web application displays a message confirming the successful collection of the data. This feedback assures the user that their input has been recorded and stored.

To prevent accidental or intentional multiple form submissions, the web application includes a built-in timer. This timer ensures that the stress level form is displayed only at the appropriate time interval of every three hours. This functionality promotes accurate and controlled data collection by aligning with the intended frequency of stress level logging. Finally, the data collected from the stress level forms is sent to the designated stress graph on the data information page of the web application.

Data page

The second page of the web application is the data page, which is represented by the graph symbol. On this page, users can access and view all the collected data. The data page provides an overview of information gathered throughout the user testing phase. Users can explore and self-analyze various data points, trends, and patterns through visual representations. The data page is portrayed below in figure 30 and 31:

Figure 30: overall layout of the data page

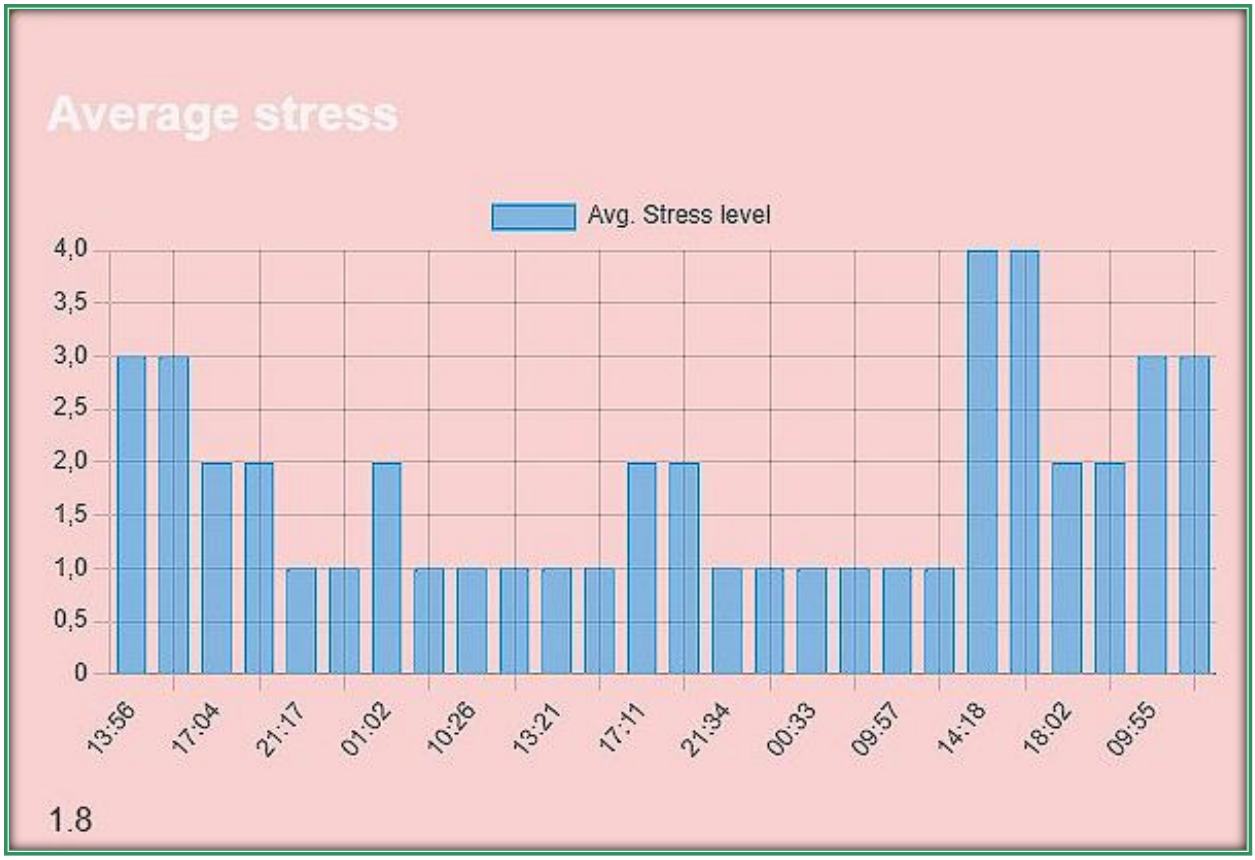


Figure 31: Average stress of the user

Average stress

The bar graphs of average stress and physical activity on the data page are dynamically updated every time a user submits their stress level and corresponding reasoning on the previous page or a new entry point for active minutes is detected. The graph represents stress levels on a scale of one to five, where one signifies minimal stress and five represents enormous stress levels.

In the bottom left corner of the graph, there is a numerical value of 1.8, which represents the calculated average of all the collected stress level data. This average value is continuously updated and sent back to the reflection section when a user reflects on a new stress level experienced in the previous three hours.

The bar graph is sorted based on the ID of the implemented stress level, which can be seen as a timestamp. In the implemented system, an ID number is assigned to each reflected stress level. The ID number serves as a unique identifier for each entry and helps differentiate between different instances of stress reflection over the last three hours. The ID starts with 1, and each time a user reflects on their stress level, a new graph is created with an incremented ID. This arrangement provides a continuous overview of when the stress levels occurred over time. Additionally, to provide insights

into the specific timing of stress level occurrences, the timestamp of implementation is recorded alongside each stress level data point.

Underneath the calculated average value on the graph, users can find the reasoning behind specific stress levels. This information offers an overview of the causes and triggers associated with stress levels at different moments, enabling users to identify patterns and gain a deeper understanding of their stress experiences.

Figure 32: Reasoning visualization for stress level

Figure 33: Sleep time

Sleep time

Unfortunately, the sleep time is logged manually by the user as the API for sleep time did not correctly forward the data, resulting in inaccurate information. To address this issue, each morning, the user also received a WhatsApp notification requesting them to manually input their sleep time. The user responds with their sleep time, and once they press the 'Submit' button, the submitted sleep time becomes immediately visible on the web application.

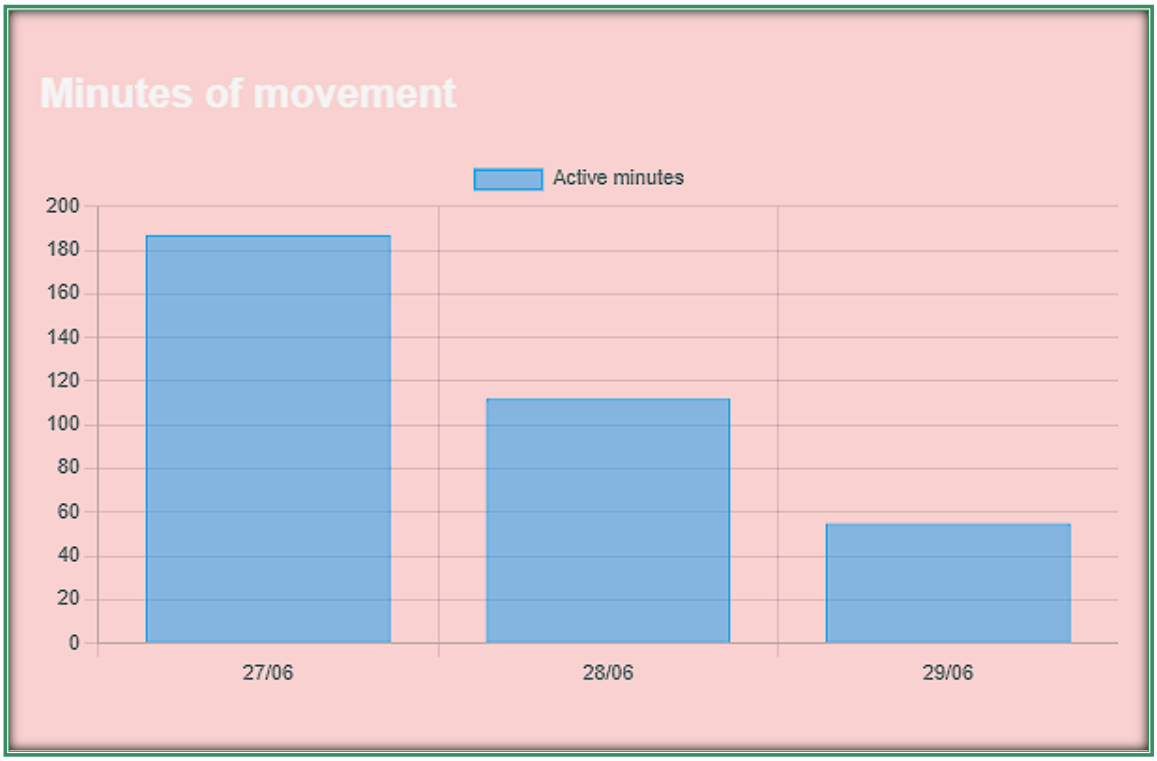


Figure 34: Minutes of movement

Minutes of movement

The active minutes as a mean of displaying physical activity are retrieved from the smartwatch using the Google Fit API[7]. The Google Fit API is a tool provided by Google to collect data from google applications for own purposes. In this research the “Activity read” function is used to read the active minutes from the Google Fit application. The user was automatically logged in to a Google account that was created for this research. This Google account could be used to retrieve the data from the smartwatch and the smartphone and forward this data to the web application.
The active minutes data is displayed in a bar graph, providing an easy overview of the user's active minutes throughout the week. The bar graph automatically extends as new data inputs are recognized this creates unlimited scaling possibilities. This holds also true for the bar chart of stress levels.

[7] https://developers.google.com/fit

Information page

On the third page, the information, as usual the page begins with a header indicating that the user is on the information page. On this page, the user is presented with four options to choose from, mental well-being, physical activity, sleep, and stress, each represented by a foldable drop-down menu. When a user clicks on a specific option, the corresponding tab expands, revealing the information related to that particular topic. As an example, if the user navigates to the stress aspect section within the information page, they would be presented with information regarding the recognition and mitigation of stress, see figure 35 and figure 36.

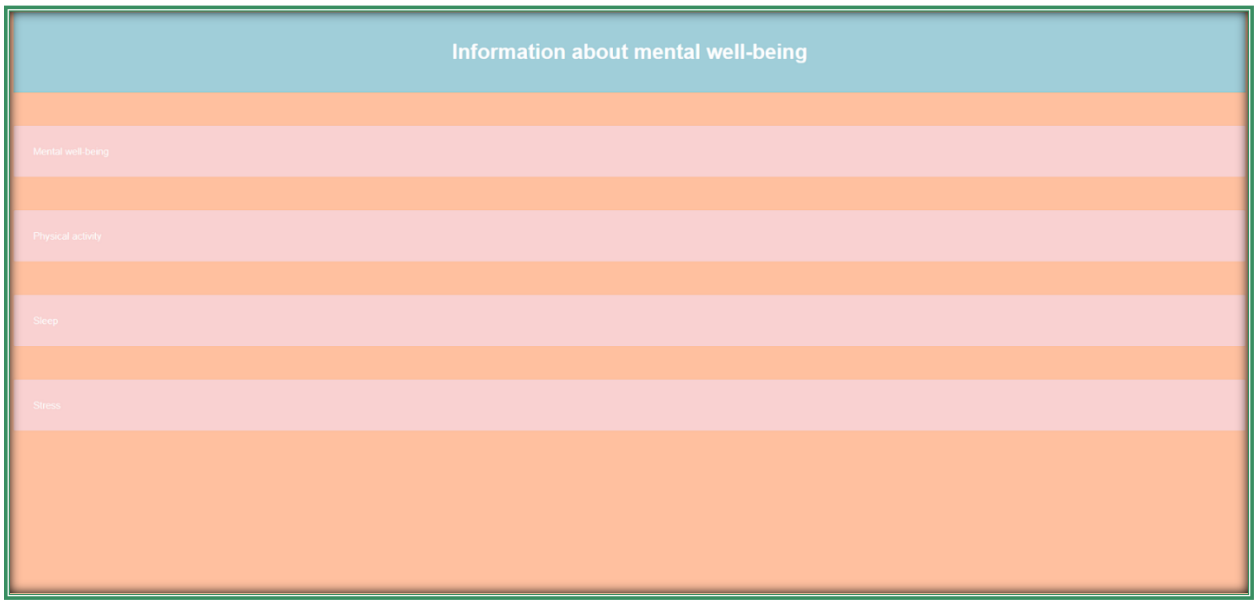


Figure 35: Layout of the information page

Figure 36: Opened tab about stress

Contact page

The final page of the web application is the contact page. This page serves as a resource for users who may encounter difficulties or have questions related to the application. It provides a contact form where users can see the researcher and reach out for assistance. The contact details of the researcher are provided, enabling users to contact them through the provided means of communication. Additionally, there is a comment box at the bottom of the page where users can leave their feedback or comments to engage in further communication with the researcher or other participants.

Figure 37: Contact information page

Visual design

The visual aspect of the web application incorporates a pastel color palette to create a soothing and relaxing environment for the users. This choice of colors was determined based on feedback received during the initial survey, which indicated that light pastel colors contribute to a calming atmosphere. Each page of the web application maintains a consistent background color and layout to enhance navigation and ensure a seamless user experience. This approach aims to improve the efficiency and ease of use for the participants.

6. User evaluation

This chapter presents a clear overview of the preparatory work conducted for the upcoming user prototype testing. It begins with a discussion of the recruitment process of participants, followed by a clarification of the evaluation procedure employed for the testing phase.

6.1 Recruitment

6.1.1 Participant Recruitment Criteria

The recruitment of participants for this study was based on specific requirements. The outlined criteria aimed to ensure the inclusion of active students studying at a university in the Netherlands. The following criteria were employed for participant recruitment:

- Active Student Status: Participants needed to be currently enrolled as students at a university in the Netherlands during the time of the study.

- Age Range: The age of participants was limited to individuals between 18 and 25 years old. This age range was chosen to focus on the young adult demographic students), which aligns with the target population for this study.

- Language Proficiency: Participants were required to be proficient in English. This language proficiency ensured effective communication during the participation in the prototype testing phase.

- Voluntary Participation: Participants volunteered to take part in the research study without receiving any compensation. Their participation was driven solely by their willingness to contribute to the advancement of this research.

- Participant Withdrawal: Participants had the right to discontinue their participation in the research study at any time without providing a reason. Furthermore, participants had the option to request the withdrawal of any information collected from them during the study, ensuring their data privacy and protection.

- No Exclusion Criteria: The recruitment process did not impose any specific exclusion criteria. This approach allowed for the inclusion of a diverse range of participants, enabling a better understanding and overview of the testing of the prototype.

6.1.2 Participant Selection

The participant selection process for this study involved a non-random approach, wherein participants were personally approached by the researcher to gauge their interest in participating. This method allowed for a more targeted selection based on specific criteria relevant to the study objectives. Ultimately, three participants were chosen to participate in the research.

To ensure a diverse range of technical and non-technical backgrounds, the researcher deliberately selected participants with varying studies, leading to a wider range of technological backgrounds.

It is worth noting that the selection process did not solely focus on participants from the University of Twente, which is considered a technical university. This decision was made to avoid limiting the generalizability of the study's findings solely to the student community of a single institution. By including participants from different universities, a more representative sample of the Dutch student community was obtained, contributing to a broader understanding of user perspectives.

6.2 Evaluation procedure

For detailed information regarding the full procedures of the user testing prototype, please refer to Appendix D: Prototype Procedures. The following section provides extensive details on the specific steps and activities involved in conducting the user research on the prototype.

To ensure ethical and informed participation, participants were required to read the 'information form' and provide their agreement by signing the 'consent form'. These forms outlined the purpose of the research, the procedures involved, and the rights and responsibilities of the participants. By signing the consent form, participants indicated their understanding of the study and their willingness to participate. The procedure that followed encompassed two distinct phases: the user testing phase and the evaluation phase.

6.2.1 User testing phase

During the user testing phase of the prototype, the location for the testing was not specifically indicated. Participants were free to wear the smartwatch (see figure 38) and engage with the prototype in their normal living environment. This approach aimed to capture authentic data and provide insights into participants' daily living patterns to improve mental well-being.

The user testing phase of each participant lasted three days. Starting for each participant in the morning. There would be no distinguish made for weekdays or weekend days as the goal of this research would not be influenced by what day of the week it was. Data would maybe differ between weekdays and weekend days but this would not influence the goals of the prototype.

As part of the user testing, participants were instructed to perform certain tasks to ensure data collection and engagement with the prototype. These tasks included:

- Wear the wearable
- Self-report sleep time (once a day, preferably in morning)
- Open the Google Fit application on the smartphone (once a day)
- Log stress levels (every 3 hours starting from 8 am)

The "Wear the Wearable" task was included to facilitate data collection through the smartwatch. Participants were encouraged to wear the smartwatch as frequently as possible throughout the day without a specific timeframe. There was no need to wear the smartwatch during the night so the participant could use this time to recharge the smartwatch. This task aimed to ensure consistent and continuous data collection for analysis and insights related to activity minutes.

To ensure proper connection and data synchronization, participants were instructed to open the Google Fit application on their provided smartphones at least once a day. This step was crucial to enable the transfer of data from the smartwatch to the smartphone and subsequently to the web application. Opening the Google Fit application helped prevent any potential issues or delays in data transmission, ensuring the visibility of collected data on the web application. The user had to have an internet connection at least once a day to send this data to the web application.

For the self-report of sleep time, participants were asked to provide their sleep duration on a daily basis. Ideally, this self-report was expected to be completed in the morning, allowing participants to recall their sleep time accurately. Participants were requested to give the input of the sleep duration in hours and minutes.

Regarding the "Log Stress Level" task, participants received WhatsApp notifications every three hours as a reminder to log their current stress levels. Participants were expected to respond to the notification by providing their stress level and reasoning on the web application. This periodic logging of stress levels combined with the reasoning aimed to capture patterns throughout the day, contributing to the analysis of stress and potential triggers. To ensure participants had a clear understanding of this task and to address any potential concerns, *the following information was provided*:

Participants would receive a WhatsApp message from the researcher as a reminder to report their stress levels over the past three hours. Importantly, participants had the flexibility to fill in this information at their convenience, without needing to interrupt or immediately stop ongoing activities or tasks. They could choose a suitable time within the upcoming three-hour window to report their stress levels.

It was emphasized that there would be no consequences if a participant forgot to respond to the notification or missed logging their stress levels altogether. Participants were not penalized for missing a specific data entry. The aim was to create a stress-free environment, in which participants felt comfortable engaging with the task, without feeling pressured or burdened.

In addition to the aforementioned information on the usage of the product, participants were reminded that the user testing of the prototype would span a duration of three days. It was made clear to participants that their involvement in the study would be limited to this specific timeframe to create equality between all the participants.

Figure 38: Hardware given to the participan

6.2.2 Evaluation phase

Upon the completion of the three-day user testing period, the researcher would contact each participant to arrange the collection of the hardware used during the study (see Figure 38). This step aimed to ensure a smooth and organized conclusion to the user testing phase. During the collection of the hardware, the researcher would also take the opportunity to discuss with the participant their overall experience and address any questions or concerns that may have arisen during the user testing period. In addition to this, an online survey was distributed to the participants, which can be found in Appendix B: Survey Phase 3.

The survey aimed to gather feedback from the participants regarding their experience with the prototype. It included questions about their overall experience, their identified shortcomings, and their suggestions for improvement. Participants were encouraged to provide their insights and suggestions to enhance a future prototype.

One of the evaluation methods employed was the System Usability Scale (SUS) analysis. The System Usability Scale evaluation, also known as SUS evaluation, is a measuring tool to review if the prototype that was built had a decent usability level. The “quick and dirty” measuring device as the organization explains it themselves [49] provides a numerical value rated between 0 to 100 to check how high or low the usability of the prototype is. It is noteworthy to emphasize that the SUS analysis can maintain score reliability even when conducted with a limited number of participants. Therefore, the result can easily differentiate between usable and unusable systems. However, the SUS analysis is not a diagnostic or a percentage rated from 0 to a 100%. The SUS analysis is a tool to classify the ease and use of the prototype in the environment tested.

In addition to the SUS analysis, the survey also contained open-ended questions. These questions were analyzed individually to gain a deeper understanding of participants' perspectives. The analysis of the open-ended questions was particularly relevant for assessing whether the functional and non-functional requirements of the prototype were met, and ultimately, to be able to answer the main research question.

7. Evaluation of results

After the completion and finalization of the prototype, a user evaluation was conducted to assess its performance and gather feedback from users. The evaluation of results aims to gain insights into the aspects that worked well for users and those that did not meet their expectations. By analyzing user feedback, the evaluation helps identify the strengths and weaknesses of the prototype, creating opportunities for improvement

7.1 Technical System Usability Scale evaluation

The SUS analysis consists of ten questions that are all answered on a five-point scale. This five-point scale on the far-left side is denominated with a one that means strongly disagree. On the far right the strongly agree can be found, denominated with a five. The ten questions are preceded by an important ethical question being:

Q1: I understand that this questionnaire is voluntary and that there are no risks. You can withdraw at any time.

The ten questions succeeding the ethical question are:

Q2: I think that I would like to use this system frequently.
Q3: I found the system unnecessarily complex.
Q4: I thought the system was easy to use.
Q5: I think that I would need the support of a technical person to be able to use this system.
Q6: I found the various functions in this system were well integrated.
Q7: I thought there was too much inconsistency in this system.
Q8: I would imagine that most people would learn to use this system very quickly.
Q9: I found the system very cumbersome to use.
Q10: I felt very confident using the system.
Q11: I needed to learn a lot of things before I could get going with this system.

It is essential to acknowledge a notable condition regarding the participant selection process employed in this research study. The methodology entails the intentional inclusion of participants known personally to the researcher, thus deviating from a random selection procedure. This deliberate non-random selection method introduces a potential bias that may display in participants providing more positive responses to the study questions than would be represented of the wider population.

7.2 Technical Requirements evaluation

In the following section, an evaluation will be conducted to assess the compliance of the prototype based on the functional requirements outlined in section 4.1.7: "Functional vs Non-functional". The evaluation will involve testing the prototype and comparing its performance against the specified requirements. The functional requirements stated in section 4.1.7 are as follows:

- FR1: Concept has an overview of what data is collected and what it is used for
- FR2: User can interact with different parts of concept to gain more insight into the causes of bad mental well-being, and how to improve on this
- FR3: User can leave feedback about the prototype within the prototype itself
- FR4: Concept gives recommendations for mental well-being improvement points based on collected data
- FR5: Concept has a decent accuracy for measurements about stress, sleep, and physical activity

The objective of this evaluation chapter is to determine whether the prototype successfully fulfills these functional requirements as initially stated in section 4.1.7. The functional requirements will be tested by the researcher himself to see if all of these requirements are met.

7.3 User Testing evaluation

After finalizing the user testing of the prototype, the user was presented with a questionnaire. As mentioned before, the first part of the questionnaire was planned for the SUS analysis, but the second part of the questionnaire was implemented for open questions to give insights into certain aspects of the prototype, and check if the non-functional requirements are met that could not be answered with the results of the SUS analysis. Through analyzing the results of the open question, the non-functional requirements could be assessed.

Questionnaire questions:

To get a good understanding of the results and findings of the questionnaire the questions asked in the questionnaire will be further explained.

- Q12: How would you describe your overall experience with the prototype? Focused on the dashboard.
  The initial question was to gain insight into the general experience of the prototype. This was focused on the dashboard, as there was no research made software or hardware outside of the web application/dashboard. This question is broad on purpose so a participant would be stimulated to talk about what was important to them.
- Q13: What have you learned from using the application?
  The second question was aimed at understanding what the prototype had done for the participants. This could be in every aspect they deemed important to mention.
- Q14: What have you learned about yourself using this prototype?

This question looks like the previous one but is only focused on what a student had learned about themselves.

- Q15: I like that the prototype had? (features)
  This question helped to gain insights into the strengths of the prototype. The answers can be used to re-implement these features in a possible second iteration.

- Q16: I wish the prototype had? (features)
  The answers to these questions are important for the limitations of the prototype. The user missed some possible features that were essential to the goal or to the user friendliness of the prototype.

- Q17: If you could change anything about your experience, what would you change?
  This question was aimed to clear the gap between the two previous questions. How could the researcher re-do these features in a future prototype/study.

- Q18: Did you feel like there was a clear connection between stress, sleep, and physical activity? (explain)
  This question aimed if the application succeeded in combining the elements that make up mental well-being. Having an open question could lead to a more in-depth answer.

- Q19: Any other final questions, remarks or feedback?
  The final question was implemented so the user could speak about anything they still wanted to, without the limitation of a guiding question.

Non-functional requirements

As part of the survey, the questions will not only gather feedback on the prototype's functionality but also serve to assess the fulfillment of non-functional requirements and evaluate its overall performance. The analyzed answers to the survey will also result in an answer for the non-functional requirements. The non-functional requirements stated in section 4.1.7 are as follows:

- NFR1: Concept will be easy to understand with various types of background knowledge in technology

- NFR2: Concept is easy to install or setup, users should be able to use the application after reading manual

- NFR3: Concept visualizes data and feedback of the user in a clear and understandable way

- NFR4: Concept gives insight into mental well-being and a user knows what could be improved

7.4 Results

This section will explain the results of the System Usability Scale, the functional requirement evaluation, and the open questions results from the survey.

7.4.1 System Usability Scale results

The SUS analysis has no ordinary calculation for the points awarded for each question. Each question has a score contribution with a range from 0 to 4, where zero is the least and four is the highest possible score. To calculate the SUS score for each question, the questions are divided into two groups. In the first group, which includes questions 1, 3, 5, 7, and 9, the score for each question is determined by subtracting 1 from the scale position. For the second group, which comprises questions 2, 4, 6, 8, and 10, the score for each question is calculated as 5 minus the scale position.

The scores of each question are based on the average of the n=3 participants focused on each independent question:

Q2: I think that I would like to use this system frequently. = 3

Q3: I found the system unnecessarily complex. = 4

Q4: I thought the system was easy to use. = 3,67

Q5: I think that I would need the support of a technical person to be able to use this system. = 3,67

Q6: I found the various functions in this system were well integrated. = 2,67

Q7: I thought there was too much inconsistency in this system. = 3

Q8: I would imagine that most people would learn to use this system very quickly. = 3,67

Q9: I found the system very cumbersome to use. = 3,67

Q10: I felt very confident using the system. = 2,67

Q11: I needed to learn a lot of things before I could get going with this system. = 4

By combining the individual average scores of the questions, the overall score of the System Usability Scale (SUS) analysis, ranging from 0 to 40, can be calculated as follows: 3 + 4 + 3,67 + 3,67 + 2,67 + 3 + 3,67 + 3,67 + 2,67 + 4 = 34,02.

To convert this score to the standardized scale of 0 to 100, the value of 34,02 is multiplied by 2,5. Therefore, 34,02 * 2,5 = 85,05 with a standard deviation of 12,33

To conduct a comprehensive analysis of the SUS score of 85,05 as a result of n=3 participants, it is important to refer to the table provided by the creators of the SUS analysis.

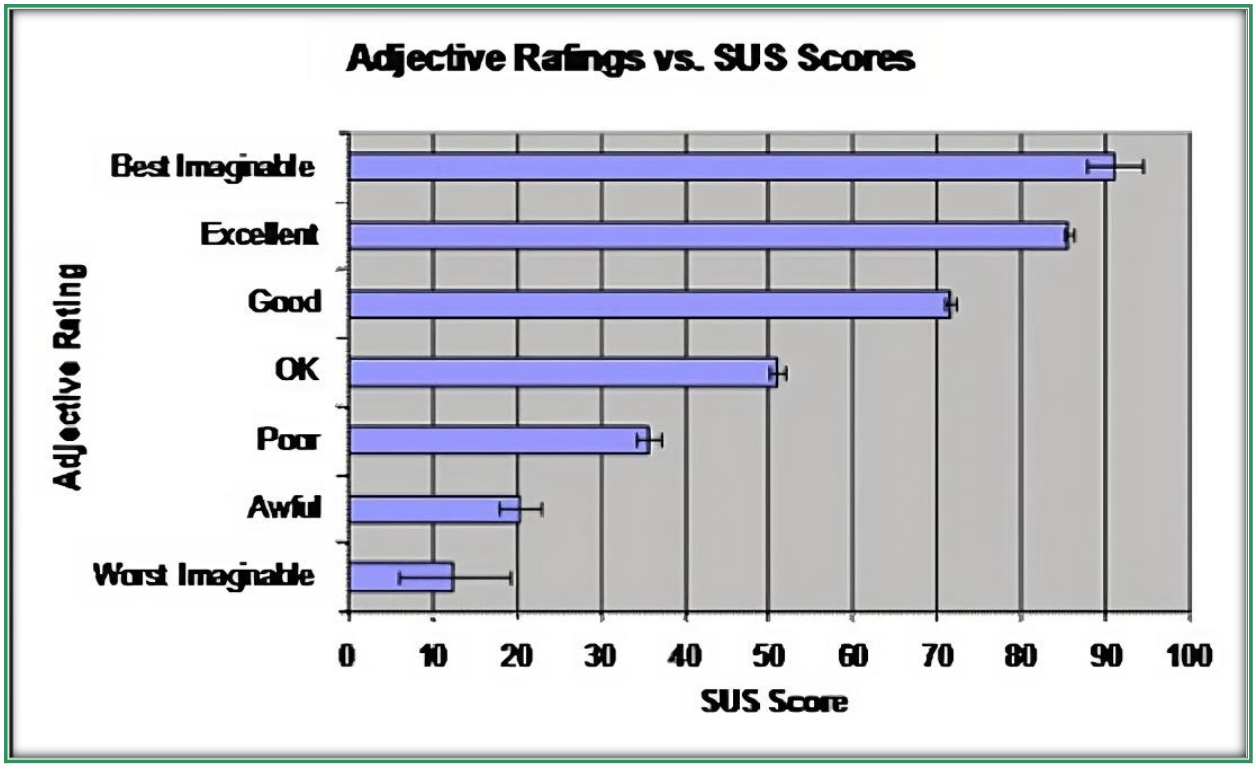


Figure 39: Mean SUS score ratings corresponding to the seven adjective ratings [50]

Upon comparing the prototype's SUS score of 85,05 with the reference table above provided by the creators of the System Usability Scale (SUS) analysis, it can be inferred that the score indicates a near-excellent usability rating, although it has a slight inclination towards the lower boundary of the excellent range. Therefore, the prototype, evaluated using the System Usability Scale, can be characterized as excellent usability, as reported by the three user testers.

The score in the excellent range suggests that users found the prototype to be highly usable, with a positive overall user experience. The small skew towards the lower bound of excellent indicates that there is still some room for improvement, but overall, the prototype's usability can be considered highly usable based on the answers of the prototype users.

*Note: within the context of the "Technical Requirements evaluation" conducted in this study, it is important to acknowledge a particular limitation associated with the participant selection process. As previously mentioned, the non-random selection of participants, which includes individuals known to the researcher, introduces a potential bias into the evaluation results. Consequently, the trustworthiness of the "excellent" range observed in the usability testing outcomes can be called into question. It is plausible that if a random selection of all students were employed, the actual number of participants rating the prototype in the "excellent" range might be lower than what was observed.

7.4.2 Technical requirements evaluation

After testing the final prototype, the researcher himself checked if the final functional requirements were met, the following could be concluded:

Funtional Requirements:		Yes/No
FR1:	Concept has an overview of what data is collected and what it is used for	Yes
FR2:	User can interact with different parts of concept to gain more insight into the causes of bad mental well-being, and how to improve on this	Yes
FR3:	User can leave feedback about the prototype within the prototype itself	No
FR4:	Concept gives recommendations for mental well-being improvement points based on collected data	Yes
FR5:	Concept has a decent accuracy for measurements	Yes
	Functional requirement implemented	
	Functional requirement partly implemented	
	Funtional requirement not implemented	

Figure 40: Table of results on the final functional requirements

The evaluation of the functional requirements mentioned in section 4.1.7, titled "Functional vs Non-functional", reveals that some of the expected requirements have been successfully implemented in the final prototype.

Functional requirement 1:

Functional requirement 1 is partly implemented as there is no message for the user to know what is being collected, however the reoccurring theme of stress, sleep, and physical activity in combination with the information brochure provides insight into the overview of collected data.

Functional requirement 2:

Functional requirement 2 is fully implemented in the prototype. The user can interact with the porotype in various ways and navigate through different parts. The prototype has dedicated sections like the data page and the information page to give the participants more insights, this backed up by the results of the survey that will be discussed underneath.

Functional requirement 3:

Functional requirement 3 is unfortunately not implemented due to technical difficulties encountered in sending a proper text request to the server.

Functional requirement 4:

Functional requirement 4 is implemented successfully the user will receive feedback and recommendations based on the collection of data.

Functional requirement 5:

Functional requirement 5 is also implemented successfully. The researcher had tested all of the accuracy for the concept previous to the actual user testing, he did a pilot run. The accuracy of the stress, and sleep would be decent as it was manually implemented. This would not mean that is was 100% accurate as it is not possible to be certain about exact sleep times, but it would be decent in accuracy. For the stress the manual input would be considered the most accurate way of doing it as concluded from the background research, therefore this answer would be considered decent. For physical activity the researcher pilot tested the collection of active minutes for the smartwatch. The researcher wore it for one day and measured all the active minutes himself and later compared it to the smartwatch. The smartwatch was 6 minutes off by measuring 114 active minutes compared to the 108 active minutes measured by the researcher. This meant an accuracy of 94,73% which is deemed decent.

7.4.3 Open questions results

With the results of the survey conducted after user testing, the data was structured in Microsoft Forms, there all the answers were manually analyzed to gain insights into the user experience and identify any issues encountered with the prototype. This analysis will also address the completion of the non-functional requirements.

- Q12: How would you describe your overall experience with the prototype? Focused on the dashboard.
  The overall experience of the prototype was positive, primarily because it was well-organized and had a structured design, which made it easy to comprehend even for participants with limited technical background knowledge compared to that of the researcher. However, the experience on smartphones was somewhat lacking, as the web application was not properly adapted or optimized for mobile devices.

- Q13: What have you learned from using the application?
  The overall experience of using the application centered around the users' ability to learn about their own stress levels and the underlying reasons behind them. The way of displaying the data in a clear overview of numerical stress levels in combination with the reasoning provided valuable insights into the causes of stress. Users found the information page particularly useful as it enabled them to gather knowledge that could be utilized to effectively manage and reduce stress levels.
  By emphasizing stress and rating and explaining it every three hours in combination with the information, the application facilitated a deeper understanding of stress triggers and equipped users with techniques to mitigate stress.

It is important to highlight that all the answers provided in the survey pertained specifically to stress-related questions and did not have the other aspects related to mental well-being, physical activity or sleep time.

- Q14: What have you learned about yourself using this prototype?
  It is noteworthy once again that all responses to the question exclusively revolved around stress-related experiences. Participants frequently provided insights into their understanding of the causes of stress during specific moments.

- Q15: I like that the prototype had? (features)
  The responses to these questions revealed a wide range of perspectives. Notably, one of the well-received aspects of the prototype was its engaging and relaxing nature. Participants found the prototype to have a relaxing and pleasant ambiance. Additionally, two out of the three participants mentioned their appreciation for the extensive information page. Furthermore, the visualization of stress levels throughout the day was praised and deemed effective, indicating that participants found it valuable and informative.

- Q16: I wish the prototype had? (features)
  Participants wished there was a more convenient method to log their sleep time, suggesting a preference for a direct logging feature on the smartwatch itself rather than relying on notifications on WhatsApp. They also expressed appreciation for the possibility of automatic data collection, as opposed to the manual inputting of sleep time. These suggestions indicate a desire for automated processes that would enhance the user experience by reducing the effort required to log sleep time or reducing the number of visits to the web application through WhatsApp by logging stress levels on the smartwatch.

- Q17: If you could change anything about your experience, what would you change?
  Participants mentioned diverse preferences regarding changes they would have liked to see in the prototype. Building upon the previous question, participants specifically mentioned a desire for automatic logging of sleep time, eliminating the need for manual input.

  Additionally, one participant suggested extending the study duration to gain a deeper understanding of the factors influencing stress levels at specific moments. A longer study period would provide more insights into stress patterns and facilitate a more nuanced analysis of stress levels.

  Furthermore, another participant recommended adapting the feedback system to provide positive reinforcement when their experienced stress levels were lower than the average logged stress level.

- Q18: Did you feel like there was a clear connection between stress, sleep, and physical activity? (explain)

The participants mentioned that the prototype lacked a clear connection between stress, sleep, and physical activity. It was not initially evident how these three elements were interrelated within the application. Furthermore, the prototype fell short in providing feedback on the combined influence of these factors. Participants expressed a desire to receive feedback on multiple factors and, ideally, on the interaction between stress, sleep, and physical activity.

The absence of a cohesive integration and feedback system for these three components hindered participants' ability to understand the impact of stress, sleep, and physical activity on their overall mental well-being.

- Q19: Any other final questions, remarks or feedback?
  One participant made a final remark regarding a technical bug encountered in the application. The participant described an issue where, after logging their stress level and providing reasoning, they were automatically redirected back to the smiley grading phase of the logging process.

Non-functional requirements result

Upon analyzing all the answers and drawing conclusions for each question, valuable insights can be obtained. These insights provide answers on the non-functional requirements.

- NFR1: Concept will be easy to understand with various types of background knowledge in technology
  Based on the answers gathered from question 12, a conclusion can be drawn: the concept of the prototype was easy to understand, even for participants with limited knowledge of technology. The feedback and remarks provided by participants indicated that the prototype's organization and structure were well-designed, enabling individuals with varying levels of technical background to grasp and comprehend the concept without difficulty.

- NFR2: Concept is easy to use, users should be able to use the application without too much hesitation or questions
  Based on the results obtained from the System Usability Scale (SUS), it is deemed that the system is highly usable and easy to understand. Specifically, when analyzing the question "Q4: I thought the system was easy to use", it received a score of 3.67. By converting this score to a 1 to 10 grade scale, it equates to a rating of 9.3, indicating a high level of ease of use.
  *Note: once again note the non-random selection bias which may influence the accuracy of the answering of this non-functional requirement.

- NFR3: Concept visualizes data and feedback of the user in a clear and understandable way

The participants' feedback reveals that the prototype successfully visualized stress and was easily understandable to them. The feedback system in relation to stress was deemed helpful, providing valuable insights and guidance. On top of this, the visualization of active minutes was clear and understandable but provided less insight than the stress. However, participants expressed a lack of clarity regarding the visualization and understanding of the sleep tab. Furthermore, the participants mentioned the failed interconnection between sleep, stress, and physical activity.

- NFR4: Concept gives insight into mental well-being and a user knows what could be improved
  The evaluation of the prototype revealed that it effectively provided insights into stress and offered guidance on improving mental well-being in that specific aspect. Participants reported positive experiences and acknowledged the value of the stress-related information provided by the prototype, which served as a trigger for change.

  However, the evaluation also uncovered a significant limitation: the prototype failed to adequately address the comprehensive integration of sleep, stress, and physical activity to enhance overall mental well-being. Participants expressed the desire for a more cohesive integration of these three elements, accompanied by a clearer explanation of their interconnections. Despite the researcher's attempt to address these concerns based on requirements derived from the literature review, state-of-the-art analysis, and brainstorming, the prototype fell short of creating a comprehensive overview of the interrelatedness of sleep, stress, and physical activity. The thought process of the researcher to put the three elements next to each other as a way to indicate that these were related and would create a clear overview of how these were interrelated through data visualization failed. It is evident that an alternative approach should have been pursued to effectively communicate the interdependencies among these elements and provide a comprehensive understanding of their impact on mental well-being.

8. Discussion and Conclusion

8.1 Conclusion

Various design processes have been used in the pursuit of an effective approach for using a wearable device, such as a smartwatch as a guiding tool to enhance students' mental well-being. The design process starts off with a comprehensive literature review aimed at understanding the existing research and technological advancements that have been undertaken thus far to address this issue. After identifying what was already out there, a brainstorming session helped to find a possible solution. To realize this idea, a prototype has been developed. Eventually, this prototype has been tested with three possible future users to determine its usability and test if the prototype reached its goal of improving mental well-being among students.

Can a wearable read and predict accurate data about the mental well-being of a user?

In order to obtain precise data on the mental well-being of students, it is crucial to ascertain the factors that influence it. Mental well-being, as a construct, is connected through three distinct components: sleep, stress, and physical activity. In order to develop a thorough comprehension of an individual's mental well-being, it is crucial to analyze and evaluate each of these components, thereby obtaining a clear and extensive overview.

According to the findings of existing literature, it has been indicated that measuring stress levels accurately using a smartwatch presents challenges. Smartwatches have demonstrated limitations in effectively distinguishing between physical stress and emotional stress. Therefore, for a more precise assessment of stress levels, it is recommended to request students to manually log their stress levels. This approach would yield more accurate and reliable data regarding the students' subjective experience of stress.

Furthermore, based on the outcomes derived from the literature review, it can be reasoned that the smartwatch shows a reasonable capability in estimating the sleep duration of a user. However, it is important to note that this estimation is not without limitations and achieving a 100% accurate measurement of sleep time remains challenging.

Lastly, the research has demonstrated that the smartwatch has proven to be highly efficient in accurately measuring physical activity. It possesses the capability to track and record various aspects of physical activity, providing detailed information regarding the timing, location, type, and duration of specific activities. This clear overview of data allows for a comprehensive overview of an individual's physical activity patterns.

How can the gathered data be visualized in an uncomplicated way that triggers change?

The collected data, whether obtained through the smartwatch or manually logged, should be presented in an easily accessible format to facilitate understanding. Additionally, an effective system for triggering change based on the data should be established. Given that sleep, stress, and physical activity are distinct data points, it is advisable to represent them in different ways to enhance clarity and facilitate a trigger for change.

According to the pre-user testing survey findings and literature review, stress evaluation can be simplified through the utilization of a smiley rating system, which allows individuals to easily assess and express their stress levels. Once the collected data has been processed, stress levels can be effectively reflected through a bar graph. This visual representation provides a clear and concise overview of stress levels, enabling individuals to visualize the magnitude and fluctuations of their stress over time. By combining the bar graph with the reasoning behind the stress levels, individuals can gain a deeper understanding of the factors contributing to their stress. This is also an automated trigger for change.

In addition to stress, physical activity can also be effectively represented through a bar graph. By utilizing a bar graph to represent physical activity, users can easily grasp the information and gain a clear overview of their activity patterns over the days.
Contrarily, the analysis indicated that representing sleep data in a clear and informative manner posed challenges. Feedback obtained from a post-user testing survey revealed that simply stating the sleep time of the user had minimal impact and failed to provide meaningful insights into sleep patterns. It is therefore important to explore alternative approaches for presenting sleep data to enhance its usefulness.

Based on the findings, it can be deduced that a well-designed representation of the data itself acts as a trigger for change. The visual depiction of data, such as through bar graphs or other suitable visualizations, enhances individuals' understanding and awareness of their mental well-being factors, namely stress, physical activity, and sleep. This raised awareness for the individuals to recognize the need for change and motivates them to undertake action. In addition to this, extensive and detailed information about each subject area (stress, physical activity, and sleep) is crucial in helping individuals to trigger effective changes. By offering extensive insights into the specific factors influencing their mental well-being, individuals were better equipped to counter possible problems and implement scientifically proven strategies for positive change.

How to use a wearable like a smartwatch as a tool to help guide students into better mental well-being?

The integration of the key components of mental well-being, namely sleep, stress, and physical activity, has demonstrated the potential to enhance the mental well-being of students. By accurately collecting data on physical activity through the use of a smartwatch, and incorporating manual reflection on stress and sleep, a visualization of this data could be created. This data visualization would serve as a trigger for change when combined with an extensive information page.

The prototype developed in this study has been proven by survey (see question 13) to successfully display stress levels and effectively create a trigger for change, ultimately leading to improvements in the mental well-being of students in this particular aspect. However, the

other two aspects, sleep and physical activity, did not have the same impact. Participants struggled to draw meaningful conclusions from the data related to sleep and physical activity.

One of the key findings from this research underscores that contrary to the researchers initial believe, the prototype failed to effectively integrate the three elements—sleep, stress, and physical activity. Participants did not grasp the relation between these elements from the beginning, and this understanding did not improve during the testing phase of the prototype. The elements were perceived as separate aspects, hindering the realization of their full potential for achieving impactful positive change in the mental well-being of students.

The application showed the elements in distinct categories, rather than as a cohesive unit. This separation was also reflected in the information page, where participants encountered the elements as separate pieces of information. Consequently, the lack of a clear connection between sleep, stress, and physical activity hindered the prototype's effectiveness in promoting significant improvements in the mental well-being of students.

8.2 Strengths, limitations and future work

In the upcoming sections, an in-depth analysis of the research's strengths and limitations, and some future work recommendations will be presented. This comprehensive examination aims to provide a balanced assessment of the research, highlighting both its successes and areas for improvement.

8.2.1 Strength

A significant strength of this research lies in its state-of-the-art result. The study concluded that there is limited existing work focusing on the combination of the three pillars: stress, sleep, and physical activity. By combining these elements within a clear dashboard an overview of this could be created, this was different to other designs trying to solve a similar problem. While each of these elements has been individually explored, the overall integration of these factors remains largely unexplored. By identifying this research gap, the study highlights the potential for combining these three categories to improve mental well-being. This insight underscores the originality and novelty of the research, as it contributes to filling a significant knowledge gap in the field.

8.2.2 Limitations

The limitations encountered in this research can be categorized into two groups: limitations surrounding the research itself and limitations associated with the prototype.

8.2.2.1 Limitations of research

One significant limitation of this research stems from the researcher's lack of prior experience in conducting such a research. As a result, various mistakes were made throughout the research process, including inadequate follow-up questions in the survey and a need for clearer and more effective data analysis methods for both the surveys and user testing.

The absence of prior experience in research design and execution have obstructed the researcher's ability to anticipate and address potential methodological pitfalls. Inadequate follow-up questions in the survey may have limited the depth of the data collected, potentially missing crucial insights or nuances that could have enhanced the research findings. Similarly, the data analysis methods employed may not have been optimal for extracting meaningful and actionable conclusions from the collected data, leading to potential oversights or misinterpretations.

A different limitation that should be acknowledged is the relatively small sample size of participants involved in the user evaluation of the prototype (N=3). The number of participants in any study is an important factor in determining the reliability and generalizability of the findings. In this case, the sample size of the user evaluation falls on the lower end, indicating that the conclusions drawn from the study are based on a limited amount of data.

With a smaller sample size, there is a reduced ability to capture the full range of perspectives and experiences. The findings derived from a smaller sample may not fully represent the broader population. As a result, the generalizability of the conclusions may be limited, and caution should be exercised when applying the findings to a larger context.

Another noteworthy limitation of the research lies in the similarity of the participant group in terms of age. While the participants were students from various disciplines and universities, they still fell within the same age group. This lack of age diversity among the participants restricts the generalizability of the findings to a broader population, particularly individuals from different age brackets.

In addition to the before mentioned findings, it is crucial to acknowledge a potential limitation associated with the participant selection process, which involved non-random selection of individuals known personally to the researcher. This aspect introduces the possibility of bias, as the familiarity between the researcher and participants may have influenced their perspectives and potentially skewed the results towards a more positive view of the research and prototype. It is important to consider this factor when interpreting the evaluation outcomes, as the presence of bias may have impacted the participants' feedback and overall assessment of the prototype.

An additional limitation of the research lies in the rapid advancement of wearable technology. The field of wearables is evolving at a fast pace, with new devices and technologies being developed and released regularly. This poses a challenge in terms of the potential obsolescence of the prototype and its relevance in the face of newer, more advanced wearables that may offer improved accuracy and functionality in measuring sleep, stress, and physical activity for the greater aim of mental well-being.

8.2.2.2 Limitations of prototype

The prototype lacked extensive features. Not all the envisioned features were implemented due to time constraints or lack of technical skill. Implementation of these features could be essential in a better and more well-rounded evaluation of the concept. Additionally, certain features of the prototype were not fully supported with Google Fit API or were not accurately reported and updated, leading to the deletion of important functionalities.

One other significant limitation of the prototype testing was the constrained timeframe in which participants were able to evaluate the prototype. The participants expressed that the limited time frame made it challenging to effectively recognize and understand patterns within the data collected. As a result, the prototype's maximum efficiency and usefulness was potentially unused by the insufficient duration of testing. Extending the testing period to provide participants with a longer timeframe would be beneficial in enabling a more thorough exploration and understanding of patterns related to stress, sleep, and physical activity.

The primary limitation of the prototype was its inability to effectively illustrate the relatedness and significance of stress, sleep, and physical activity for mental well-being. The prototype maintained a segmented approach, treating these elements as separate entities rather than emphasizing their relatedness. As a result, participants were unable to gain a comprehensive understanding of how these aspects influenced one another and their overall mental well-being. This limitation hindered the prototype's ability to provide a good perspective on the relationship between stress, sleep, and physical activity.

8.2.3 Future work

During this research, a prototype aimed at improving the mental well-being of students was developed, despite its inherent limitations. However, in order to fully realize the potential of this tool, further research would be necessary.

Firstly, future research should involve a larger sample size to enhance the reliability and generalizability of the findings. By including a larger range of participants, the results can better reflect the experiences and perspectives of a broader population. In combination a larger sample size a random selection of students should be used to prevent possible biases in using the prototype.

Secondly, conducting a user study with a longer duration is essential to capture more comprehensive data and assess the long-term effectiveness of the prototype. Three days was deemed insufficient to fully understand the impact and potential benefits of the tool. Extending the study duration would provide a more accurate assessment of its effectiveness over time.

Thirdly, it is crucial to highlight the existence of a research gap pertaining to the correlation between mental well-being among students and the integration of wearables. While this research has shed some light on this information void, there remains a necessity to delve deeper and provide further insights into this area. The subject of mental well-being among students in combination with wearables is of significant importance, emphasizing the need for continued scientific investigation within this domain.

Lastly, addressing the failed integration of the stress, sleep, and physical activity segments is crucial for future research. The prototype's inability to effectively demonstrate the connectedness and influence of these factors limited participants' understanding. Future iterations should focus on developing a more integrated approach that highlights the interaction between these elements, providing a clear view of their impact on mental well-being. A possible solution to address this limitation of integrating the sleep, stress, and physical activity segments could be to overlap the corresponding graphs or create an average line that allows for easy comparison between the segments. By visually presenting the relationship between physical activity levels and stress levels, it would become more apparent how lower physical activity may contribute to increased stress.

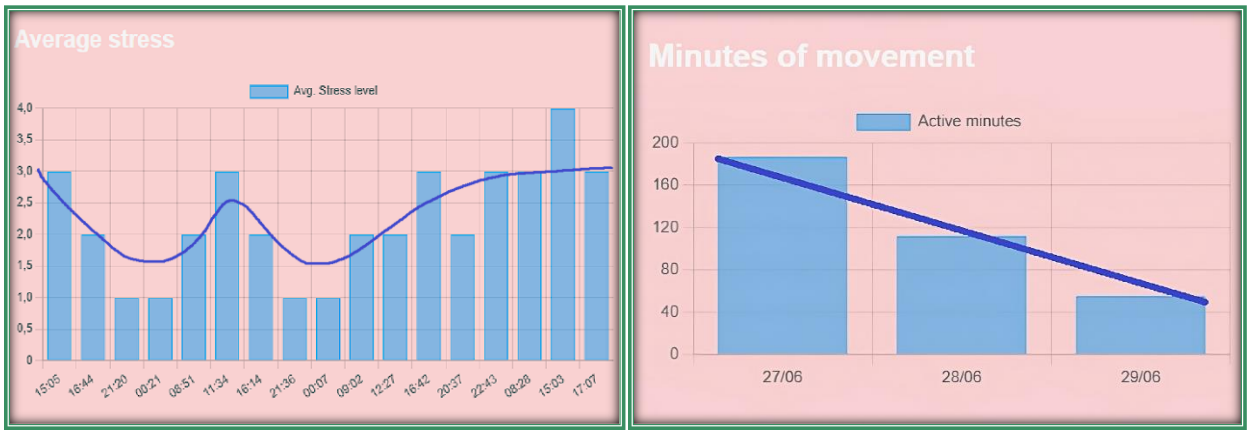


Figure 41: an updated visualization method that displays trend lines of average stress and physical activity levels over an extended time period

In conclusion, while this research has yielded valuable information through the prototype for improving mental well-being among students, it is important to acknowledge its limitations. Future research should try to aim to overcome these limitations. By doing so, a more complete understanding of the effects of stress, sleep, and physical activity in combination with a smartwatch on the mental well-being of students can be achieved.

9. Appendix

A. Literature

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B Questions asked during user testing

Survey phase 1

1. I understand that this questionaire is voluntary and that there are no risk. You can withdraw at any time.

- ◯ Yes
- ◯ No

2. What are indicators to you, that explain the state of your mental well-being (Regardless of a good mental well-being or bad mental well-being.)

Enter your answer

3. From 1 to 10 how capable are you of stating your own mental well-being status? 1 not capable - 10 very capable

1	2	3	4	5	6	7	8	9	10

4. How do you experience stress? What symptoms arise?

Enter your answer

5. On the scale from 1 to 10 how capable would you say you are of estimating your own stress levels. 1 not capable - 10 very capable

1	2	3	4	5	6	7	8	9	10

6. What would be the most intuitive way to represent your stress levels?

Option1

Option2

Option3

7. To help you remind to do a certain action, what would be a convenient way to receive a notification? Think of e-mail, pop-up, letter, alarm, etc.

Enter your answer

8. How often should you rate your stress level to have a clear view of average stress over the day?

Enter your answer

9. What theme's and colors represent a relaxing surrounding?

Enter your answer

Survey phase 3

1. I understand that this questionaire is voluntary and that there are no risk. You can withdraw at any time.

- Yes
- No

2. I think that I would like to use this system frequently. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

3. I found the system unnecessarily complex. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

4. I thought the system was easy to use. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

5. I think that I would need the support of a technical person to be able to use this system. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

6. I found the various functions in this system were well integrated. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

7. I thought there was too much inconsistency in this system. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

8. I would imagine that most people would learn to use this system very quickly. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

9. I found the system very cumbersome (hard to handle) to use. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

10. I felt very confident using the system. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

11. I needed to learn a lot of things before I could get going with this system. 1 - Strongly disagree, 5- Strongly agree

1	2	3	4	5

12. How would you describe your overall experience with the prototype? Focussed on the dashboard

Enter your answer

13. What have you learned from using the application?

Enter your answer

14. What have you learned about yourself using this prototype?

Enter your answer

15. I like that the prototype had? (features)

Enter your answer

16. I wish the prototype had? (features)

Enter your answer

17. If you could change anything about your experience, what would you change?

Enter your answer

18. Did you feel like there was a clear connection between stress, sleep, and physical activity? (explain)

Enter your answer

19. Any other final questions, remarks, or feedback?

Enter your answer

C Consent form and information brochure

Consent Form for wearables and mental well-being
YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	□	□
I understand that taking part in the study involves answering questions through a questionnaire and if willing participate in a prototype testing where data about sleep, physical activity and mental well-being will be collected	□	□
Use of the information in the study		
I understand that information I provide will be used for my bachelor graduation project	□	□
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	□	□
I agree that my information can be quoted in research outputs	□	□
I agree to joint copyright of the collected data to Alex te Riet (Researcher)	□	□
Future use and reuse of the information by others		

I give permission for the collected data through surveys and prototyping that I provide to be archived in my hard drive so it can be used for future research and learning.	□	□
Signatures		
_____ _____ _____ Name of participant Signature Date		
I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting. _____ _____ _____ Researcher name [printed] Signature Date		
Study contact details for further information: [*Name, email address*] Alex te Riet (Researcher) a.h.t.teriet@student.utwente.nl		

Information brochure

User study information brochure

Title of research project: How to use a wearable like a smartwatch as a tool to help guide students into better mental well-being?

Student researchers:

Dear participant,

I would like to invite you to take part in a user research study on wearables in combination with mental well-being and how to support students in a better mental well-being. Before you make a decision on whether to participate, you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully. Ask questions if anything you read is not clear or if you would like more information. Take your time to decide whether or not to take part.

1. Study Duration

The study will take place on a day yet to be specified and the survey will last at most 30 minutes.

2. Study Nature

The overall aim of this study is to gain insights on how to improve mental well-being among students through the help of a wearable. This research will use a survey as a testing tool. There are 2 different surveys:

First survey: The first survey will be aimed towards knowledge into measuring mental well-being of different users. The questionnaire will ask questions about how a certain user experiences different emotions and how to compare this to other feelings. Furthermore, the user will be asked on how the participant can explain this feeling. This will be done with approximately 15 people.

Final survey: For the final survey, the user that has tested the prototype and will be asked to give feedback on the prototype through a survey. This will be tested with the 3 to 5 people that have participated in the prototype testing.

The study is conducted as a part of a Bachelor graduation project at the University of Twente that aims to design a wearable that helps students with metal well-being problem to be guided into the right direction with the help of their own data. The results of the user study will be included in the final report.

3. Voluntary participation

Participation in this study is completely voluntary. You do not have to give any reason if you do not want to participate. Even if you give your permission now, you can withdraw this permission at any time without having to give a reason.

4. Possible Advantages and Disadvantages

Participating in this study will not provide you with any direct disadvantage. The participant in the survey will not have a possible advantage or disadvantage. However, the user may get to know him or herself a little bit better, this can be seen as an advantage.

5. Confidentiality of personal details and access by third parties

The information collected in this study will be treated confidentially. All data will be handled abiding by the regulations of secure storage and processing as outlined in the European Union's General Data Protection Regulation (GDPR). All personal details collected during this study will be anonymized via participant numbers. Only these numbers will be used for study documentation and in the final report of the project. The person corresponding to a code number can only be identified by the main researchers and the project supervisors.

6. Who should you contact for further information?

For any further information you can contact the researchers:

a.h.t.teriet@student.utwente.nl

If you have questions about your rights as a research participant or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the project supervisor

Additionally, you can contact the Secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente through ethicscommittee-cis@utwente.nl.

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1. Study Duration

The study will take place on a day yet to be specified. The participant will be asked to use the prototype. This will take approximately 3 days.

2. Study Nature

The overall aim of this study is to gain insights on how to improve mental well-being among students through the help of a wearable. This research will use a prototype testing scenario.

Prototype testing scenario: The aim of the prototype testing is to gather data on sleep, physical activity, and self-reported stress levels as part of mental well-being. You will be asked to wear a smartwatch for 3 days. You will continue to live your life as you normally do. Meanwhile, you will be asked through the watch to fill in certain questions that are given through the smartwatch. Questions can consist of explaining certain data that the watch has measured for example a spike in heart rate or difference in sleeping quality. On top of this, you will be asked to explain the mental well-being of you at that given time. The smartwatch will provide feedback on collected data to improve your mental well-being.

The study is conducted as a part of a Bachelor graduation project at the University of Twente that aims to design a wearable that helps students with metal well-being

problem to be guided into the right direction with the help of their own data. The results of the user study will be included in the final report.

3. Voluntary participation

Participation in this study is completely voluntary. You do not have to give any reason if you do not want to participate. Even if you give your permission now, you can withdraw this permission at any time without having to give a reason.

4. Possible Advantages and Disadvantages

Participating in this study will not provide you with any direct disadvantage. The possible and hopeful advantage would that a user would find a way to improve mental well-being, through sleep, physical activity or stress management.

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D Prototype procedure

Goal of the user study

This user study will hopefully lead to a finding that a user creates insights into their own sleep, physical activity, and stress pattern. This pattern can then be understood and adapted by the user with information in the prototype to improve overall mental well-being.

Planning

- User receives smartwatch and smartphone from researcher which has the necessities to test
- Do an explanation of the prototype
- Explain the tasks to user
- User tests 3 days
- User hands back all equipment
- User fills in survey about user experience
- Repeat process with new participant
- After 3 users have tested, collect all data
- Analyse all data into results

Tasklist

Before starting the real user testing the user needs some information about what the application does and how to interact with it. The face-to-face explanation should not spoil too much about the accessibility as this is also part of the experience.

Explanation of prototype

Together with the user we will do a quick round through the application. I will explain what will happen in the upcoming days. The user will need to perform certain tasks which will be described in the explain the tasks section. To successfully complete these tasks the user needs to know where to find this and how to answer. This explanation will look at how to evaluate stress, where to find this data and how to evaluate sleep. The user will also be guided towards the information page but will not read anything. The last thing the user will be notified of is the feedback tab, where a user can find contact information about me to ask questions or stop the user testing entirely.

Explain the task that user must perform

The user needs to perform 4 tasks (answers to these tasks may be in Dutch if users prefer this):

- Wear the wearable
- Open the Google Fit application on the smartphone (once a day)
- Self-report sleep time (once a day, preferably in morning)
- Log stress levels (every 3 hours starting from 8 am)

Furthermore, the application has a multitude of features that can be discovered. It is up to them to use this to gain insights in themselves and eventually reach the goal.

E Software code prototype

All software code for this prototype can be found here:

https://github.com/Student-Alex/Gp_project