

July 12, 2020

Professor William Craig Scratchley
School of Engineering Science
Simon Fraser University
British Columbia, V5A 1S6



RE: ENSC 405W/ 440 Design Specification

Dear Professor Scratchley,

As part of Sleep Glory Technologies Inc., I am writing to present the design specification. Medeor is designed to track each individual's brain activity, heart pulse, snoring, and movements. The data collected is used to improve their lifestyle by providing the user with live feedback. We intend to build a fully functional smart headband and Android application, that is targeted as a health tracker, towards the general public.

The purpose of this document is to provide the technical details for the proof of concept model of our product. This document includes an in-depth review of the entire system by analyzing the circuitry, theoretical calculations and background, and relevant design specifics. The specifications outlined in this document are of strict importance for the implementation and development of the project.

Sleep Glory is comprised of five talented and hardworking senior engineering students in the concentration of Electronics Engineering, Systems Engineering, and Computer Engineering: Andriy Romaniv, Gurjinder Singh, Yury Zykov, Negar Bagheri Hariri, and Prithivi Kogulanathan.

On behalf of the team, we would like to appreciate your time to review our design specification. Please feel free to contact us at aromaniv@sfu.ca with any questions or concerns you may have.

Yours sincerely,

A handwritten signature in black ink, appearing to read "Andriy", written in a cursive style.

Andriy Romaniv
CEO
Sleep Glory Technologies Inc.



PoC Prototype Design Specifications: Medeor

Partners:

Andriy Romaniv, CEO, aromaniv@sfu.ca

Gurjinder Singh, CTO, gsa76@sfu.ca

Yury Zykov, COO, zykov@sfu.ca

Negar Bagheri Hariri, CFO, nbagheri@sfu.ca

Prithivi Kogulanathan, CIO, pkogulan@sfu.ca

Contact:

Andriy Romaniv

aromaniv@sfu.ca

Submitted To:

Dr. Craig Scratchley, P.Eng, ENSC 405W

Dr. Andrew Rawicz, ENSC 440

School of Engineering Science

Simon Fraser University

Date of Submission:

July 12th 2020

Table of Contents

Table of Contents	1
List of Figures	4
List of Tables	6
Abstract	7
1. Introduction	8
1.1 Background	8
1.2 Scope	9
1.3 Intended Audience	9
1.4 Design Classification	10
2. Product Overview	11
3. Design Specifications:	13
3.1 System specifications	13
3.2 Physical Specifications	13
3.3 Hardware Specifications	14
3.3.1 Sensor specifications	15
3.3.1.1 EEG	15
3.3.1.2 Heart Pulse sensor	21
3.3.1.3 Snoring detection sensor	24
3.3.1.4 Accelerometer	25
3.3.2 Microcontroller Specifications:	27
3.3.3 Power Supply Specifications	29
3.3.4 Speaker Specifications	30
3.3.5 Wireless Connectivity Specifications	31
3.4 Software Specifications	33
3.4.1 Microcontroller Software Specifications	33
3.4.2 Mobile Application Software Specifications	34
4. Conclusion	37
Appendix A	39
Acceptance Test Plan	39
1. User Testing	39
2. Hardware Testing	40
3. Software Testing	42
4. Mechanical Testing	45

Appendix B	47
User Interface Design	47
1. Introduction	47
1.1. Purpose	47
1.2. Scope	47
2. User Analysis	48
2.1. Headband User Analysis	48
2.2. Application User Analysis	49
2.2.1. Proposed User Experience	50
2.2.1 Proposed Design	56
3 Technical Analysis	62
3.1 Discoverability	62
3.1.1 Headband	62
3.1.1 Software Interface	62
3.2 Feedback	62
3.2.1 Headband	62
3.2.2 Software Interface	62
3.3 Conceptual Models	63
3.3.1 Headband	63
3.3.2 Software Interface	63
3.4 Affordances	63
3.4.1 Headband	63
3.4.2 Software Interface	63
3.5 Signifiers	63
3.5.1 Headband	64
3.5.2 Software Interface	64
3.6 Mapping	64
3.6.1 Headband	64
3.6.2 Software Interface	64
3.7 Constraints	64
3.7.1 Headband	65
3.7.2 Software Interface	65
4 Engineering Standards	65
5 Usability Testing	66
5.1 Analytical Usability Testing	66
5.2.1 Headband	66
5.1.2 Mobile Application	66
5.2 Empirical Usability Testing	66

5.2.1 Headband	67
5.2.2 Mobile application	67
6 Conclusion	67
References	69

List of Figures

Figure 1 - Medeor System Block Diagram	9
Figure 2 - Model of Medeor	10
Figure 3 - Different stages of sleep cycle	14
Figure 4 - Layout of Amplification Circuit	14
Figure 5 - Stage 1(Instrumentation Amplifier) of Circuit in Detail	15
Figure 6 - Figure 6: Stage 2(High Pass Filter) of Circuit in Detail	16
Figure 7 - Feedback as Reference Ground Circuit in Detail	16
Figure 8 - Stage 3(2 stages Low Pass Filter) of Circuit in Detail	17
Figure 9 - Overview of the pulse sensor	19
Figure 10 - Pulse sensor connection circuit	20
Figure 11 - Image of possible pulse detection areas on the face	20
Figure 12 - SPW2430 Microphone chip	22
Figure 13 - SPW2430 connection circuit	23
Figure 14 - ADXL335 Accelerometer	24
Figure 15 - ADXL335 connection circuit	24
Figure 16 - Arduino Pro Mini	26
Figure 17 - BLE HM-10	29
Figure 18 - Bluetooth connection circuit	30
Figure 19 - Data Flow in a Microcontroller System	32
Figure 20 - Layout for Mobile Software	34
Figure 21 - Model of Medeor (headband)	47
Figure 22 - The Loading Page of application	49
Figure 23 - navigation toolbar	49
Figure 24 - The Home Page Layout	50
Figure 25 - The Home Page Layout with error message	51
Figure 26 - The Statistics Layout	52
Figure 27 - The Dashboard Layout	53
Figure 28 - The Setting Layout	54
Figure 29 - Homepage Design of the Software Application	55
Figure 30 - Error message displayed on Home Page	56
Figure 31 - Sleep Cycle Graph on Statistics Page	57

Figure 32 - Dashboard Design	58
Figure 33 - Settings Page	59
Figure 34 - Edit Profile page(left) and Prompted Message(right)	60

List of Tables

Table 1 - List of stages of development	9
Table 2 - POC Design Specifications for the System	12
Table 3 - PT Design Specifications for the System	12
Table 4 - PT Design Specifications for the Headband	13
Table 5 - FP Design Specifications for the Headband	13
Table 6 - POC Design Specifications for Amplification Circuit	19
Table 7 - FP Design Specifications for Amplification Circuit	18
Table 8 - POC Design Specifications for EEG Electrodes	20
Table 9 - POC Design Specifications for Pulse sensor	22
Table 10 - FP Design Specifications for Pulse sensor	23
Table 11 - PT Design Specifications for Microphone sensor	24
Table 12 - POC Design Specifications for Accelerometer sensor	26
Table 13 - POC Design Specifications for Microcontroller System	27
Table 14 - PT Design Specifications for Microcontroller System	27
Table 15- POC Design Specifications for Power Supply	28
Table 16 - Prototype Design Specifications for Power Supply	28
Table 17 - Prototype Design Specifications for Speaker	29
Table 18 - POC Design Specifications for Wireless Connectivity	31
Table 19 - POC Design Specifications for Microcontroller Software	32
Table 20 - PT Design Specifications for Microcontroller Software	33
Table 21 - FP Design Specifications for Microcontroller Software	33
Table 22 - POC requirements for Mobile Application Software	35
Table 23 - PT Design Specifications for Mobile Application	35
Table 24 - FP Design Specifications for Mobile Application	35
Table 25: List of Engineering Standards	64

Abstract

Medeor is a lightweight and comfortable smart headband that acts as a health tracker by monitoring an individual's sleep cycle, pulse, and snoring. Medeor will be placed on the head where the EEG electrodes and sensors will be in direct contact with the skin. Unlike other smart headbands, such as the Philips SmartSleep and Deep Sleep Headband, that focus on improving one's sleep, our product is aimed to also act as a health monitor, where if the sensors and EEG monitoring system pick up an irregular activity and notify a user. Furthermore, our product is coupled with an application that is aimed to provide the end user information regarding their sleep and health, as well as providing some recommendations.

The document outlines the design specifics for each of the components and is intended to meet the requirements from the Requirement Specification document. The design specification document outlines the design elements of the current Proof-of-Concept (POC) prototype and targets the three main areas as follows:

1. The sensors and EEG monitoring system circuitry
2. The headband design & functionality
3. The software application that accompanies the product

Along with the design specification, this document contains the User Interface and Appearance, and Supporting Test Plans Appendices. The UI and Appearance Appendix will outline the design specifics in the user interface of both the headband and software application. The Supporting Test Plans will allow the team to test the design elements of the system and components to ensure the prototype is fully functional.

1. Introduction

Medeor is a cost-effective tool that can be used as a daily health monitor by tracking an individual's sleep cycle via electroencephalogram (EEG), pulse and breathing. The system will be able to collect the user's sleep patterns, analyze them, and recommend the solution. The input data are compared against pre-set values to determine the sleeping behavior of the user. If an irregularity has been detected the user or any caretaker will receive a notification to inform them of any possible abnormalities.

Medeor is targeted towards people suffering from insomnia due to anxiety, stress, etc. However, with the additional built-in features such as the pulse sensor and snoring detector, Medeor is made for the general public interested in maintaining their health through a cost-effective and robust system.

1.1 Background

The market for sleep-associated technology is expected to cross \$27 Billion[1]. Studies show that about 33% of the world population suffer from insomnia and 10% of them are in chronic stage [2]. Furthermore, 40% and 24% of male and female-identified individuals are habitual snorers, respectively [3]. This allows the sleep tech industry to grow at a rapid pace. Unfortunately, this analysis was performed before the COVID-19 crisis, thus the numbers may be affected.

There are several competitors on a market such as Muse S, Dreem, Philips SmartSleep, SleepPhones, Fitbit and Apple Watch. First is Muse S, it focuses on helping people with meditation. It tracks EEG, heart rate, breathing and body movements to help people to build a consistent meditation practice[4]. However, this device does neither focus on the sleep EEG nor does data analysis for any sleep problems, even though it tracks the EEG in general.

Dreem is another product that is designed to help the health professionals to study brain disorder so that it can be treated. It provides an easier way of collecting EEG data at home than the clinical EEG. A person can also buy it for home use, but the functionality is limited to the representation of data and telling if the user slept well or not during the night [5]. The user is free to compare the data with previous nights, but our app will do that and try to detect the problem of insomnia. It is also an expensive device for an individual to just look at the sleep cycle. Similarly, SmartSleep is also a product that measures EEG. The device tries to help the user in improving their sleeping quality. It's a drug-free sleep enhancement technology. However, It is not detecting any problems in sleep [6].

Products like sleepPhones just play uncontrolled sounds, it's like a smaller version of SmartSleep, without any EEG and data analysis [7]. Common products like Fitbit and Apple Watch track your sleep based on the body movement and heart rate. Heart rate variability

(HRV) data is combined with body movements data to determine sleep stages. These devices just show the data but do not detect any sleep disorder [8].

1.2 Scope

The document provides information to the reader regarding technical and functional requirements of the Medeor product. By elaborating and listing the specifications of each component and the system as a whole, the reader will be able to understand the product's expected functionality. All of the requirements will be categorized according to each stage of production (proof of concept, prototype and finished product).

1.3 Intended Audience

The design specification document informs the developers, testers, and executives of the design elements of this product. This serves to guide the team during the development phases of the project.

1.4 Design Classification

The stages of product development are summarized and listed in the table below:

Table 1: List of stages of development

<i>No</i>	<i>Stage Of Production</i>	<i>Encoding</i>
#	Proof of Concept	POC
#	Prototype	PT
#	Final Product	FP

To allow the reader to better understand the acronyms used in the documentation. The following format will be adapted to list all the requirements of the documentation:

Des {Section}.{Sub-Section} - {Stage Of Production}:{Item No}

Once requirements are set they are propagated over next stages, unless redefined.

2. Product Overview

Medeor has been designed as a cost-effective, robust and user friendly health monitoring system to help each user in tracking their health parameters and to improve sleep quality. This product will consist of two main parts: headband and mobile application. The Headband will be worn by the user overnight, and it will collect various sleeping data including brain activity, heart pulse and position of the head. The EEG will be responsible for monitoring electrical activity of the brain. The above data will indicate at what stage of the sleep cycle the user is in and detect any abnormal behaviour. Based on that information, Medeor will be able to play calming noises (white noise) to keep users in deep sleep. In addition, new sleeping schedules will be suggested.

The Figure 1 below describes how the entire system is expected to work and the expected design, respectively. The data from sensors is collected by a microcontroller and sent via Bluetooth. Mobile applications receive the data, analyze it & display the result to a user. Also, based on the data collected mobile application will be suggesting the sleeping schedule, play white noises.

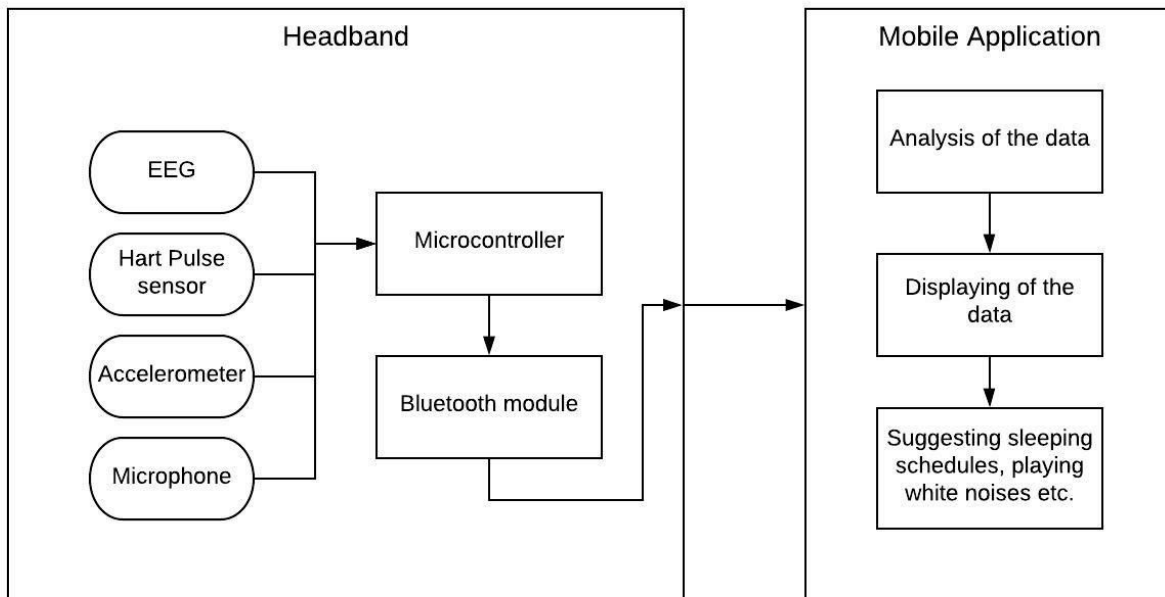


Figure 1: Medeor System Block Diagram

Figure 2 shows the sample design of the headband. It will include an embedded EEG monitoring system, pulse sensor, accelerometer, microphone, Bluetooth module and power supply. The EEG used in conjunction with the pulse sensor would provide a more reliable

analysis of the user's sleep. The embedded microphone will help to detect the user's snoring pattern and can be used to reveal the causes of spikes in brain activity.



Figure 2: Model of Medeor

The data collected from the sensors will be amplified & filtered. It is then transferred to a microcontroller and stored in a SD card for sending to the phone. The microcontroller will connect to a mobile device via Bluetooth , after which the data is transferred. The transferred data will be analyzed and the results will be displayed. The analyzed data will be stored, so it could be compared against other historical data to detect problems and to make suggestions to the user.

3. Design Specifications:

This section will outline design specifications of the Medeor product. The following subsections describe the design for the product as a whole and for each individual component.

3.1 System specifications

System design is the high-level overview of the main functionality of Medeor product. According to the functionality described above we have come up with the following designs: Des 3.1 - POC: 1; Des 3.1 - POC: 2; Des 3.1 - PT: 4. Also, we want to make sure that our headband doesn't interrupt the user sleep experience. The headband should operate over the night for, at least, 12 hours, thus we need a power supply. Considering that and the fact that our product will be wearable on head, the Medeor headband should be safe.

Table 2: POC Design Specifications for the System

<i>No</i>	<i>Design ID</i>	<i>Design Specification Requirements</i>
1.	Des 3.1 - POC: 1	The product shall collect, process and display data from EEG, accelerometer sensor, hart pulse sensor and snoring detector
2.	Des 3.1 - POC: 2	The microcontroller & application shall be able to establish Bluetooth connection

Table 3: PT Design Specifications for the System

<i>No</i>	<i>Design ID</i>	<i>Design Specification Requirements</i>
3.	Des 3.1 - PT: 1	The headband shall be comfortable for overnight use
4.	Des 3.1 - PT: 2	The headband shall be autonomous for at least 12 hours
5.	Des 3.1 - PT: 3	The headband shall be safe for the use
6.	Des 3.1 - PT: 4	The application shall suggest how to improve sleep quality

3.2 Physical Specifications

Medeor's headband should be able to fit the majority of people. After conducting our research on the analysis of human head shapes and sizes [9], we have determined the design specifications for the headband.

The headband includes an enlargement which will have all the electronics and a power supply located on it. As the headband is wearable and will be in contact with the human skin over long periods of time, it should have a soft cloth on the inside. Also, the headband should be cleanable, since it will be in contact with the skin and the drops of sweat could be absorbed.

According to the market search of the competitors [4] - [7], we decided the headband should be price-competitive and weigh less than 200 grams.

Tables 4 and 5 include design specifications for the headband:

Table 4: PT Design Specifications for the Headband

No	Design ID	Design Specification Requirements
7.	Des 3.2 - PT: 1	The headband shall have the mean circumference of 55cm
8.	Des 3.2 - PT: 2	The headband shall be adjustable within 6cm range
9.	Des 3.2 - PT: 3	The headband shall have enlargement on the forehead to contain hardware parts. The dimensions: 5.5cm width & 7.5cm length & 1.5cm depth (see Figure 2)
10.	Des 3.2 - PT: 5	The headband shall have a soft cloth on the inner side
11.	Des 3.2 - PT: 6	The headband shall have a rigid plate in the enlargement, which will be a mounting point for electronic components
12.	Des 3.2 - PT: 7	The headband shall have a control button

Table 5: FP Design Specifications for the Headband

No	Design ID	Design Specification Requirements
13.	Des 3.2 - FP: 1	The headband shall cost less than \$350, to be competitive on the market
14.	Des 3.2 - FP: 2	The headband shall weight less than 200 grams
15.	Des 3.2 - FP: 3	The headband shall be cleanable

3.3 Hardware Specifications

This section includes hardware design specifications for the following sections: sensors, Bluetooth module, microcontroller and power supply.

3.3.1 Sensor specifications

3.3.1.1 EEG

Background on EEG:

EEG is a method for measuring the Electrical signals of the brain [10]. This is possible because the neurons communicate with each other using electrical impulses. An EEG is therefore useful in determining if there are any spikes in electrical activity as it indicates some kind of brain disorder.

Electrodes:

There are two types of non invasive electrodes, Wet and Dry. Wet electrodes are most commonly used in clinical settings while Dry electrodes have been developed for specific products in home use. Special dry electrodes are also being used for performing faster EEG in clinics as deployment of 10-20 EEG international system takes time [11].

While there are still conductivity issues with dry electrodes, companies such as Muse S are delivering their own dry electrodes for their product. Our product will use the typical 3M Red dot electrodes which are 4x4cm, as they are easy to acquire and use. Then we will cut the tape on the sides and reduce the size down to 1x1 cm, thus it can be plugged into the headband. Later in the final product we can consider to create our own electrodes.

Measurements:

The waves in the brain can be differentiated on the bases of frequency. Different wavelengths characterize the stages of the brain from awake to deep sleep [12].

The picture on the next page (Figure 3) shows different stages of sleep and each stage is differentiated on the basis of frequency of wave being captured. Before a person falls asleep there are frequencies greater than 14Hz and when the user lays down to sleep, he enters into stage 1. Stage 1 is the relaxed stage which has frequencies of 8-13Hz, Stage 2 is light sleep which has frequencies between 3-7Hz and stage 3 is the deep sleep with frequencies between 0.5 - 3Hz. REM is the rapid eye movement stage in which eyes are rotating under the eyelids and brain frequency increases slowly over the time of about 90 minutes [12]

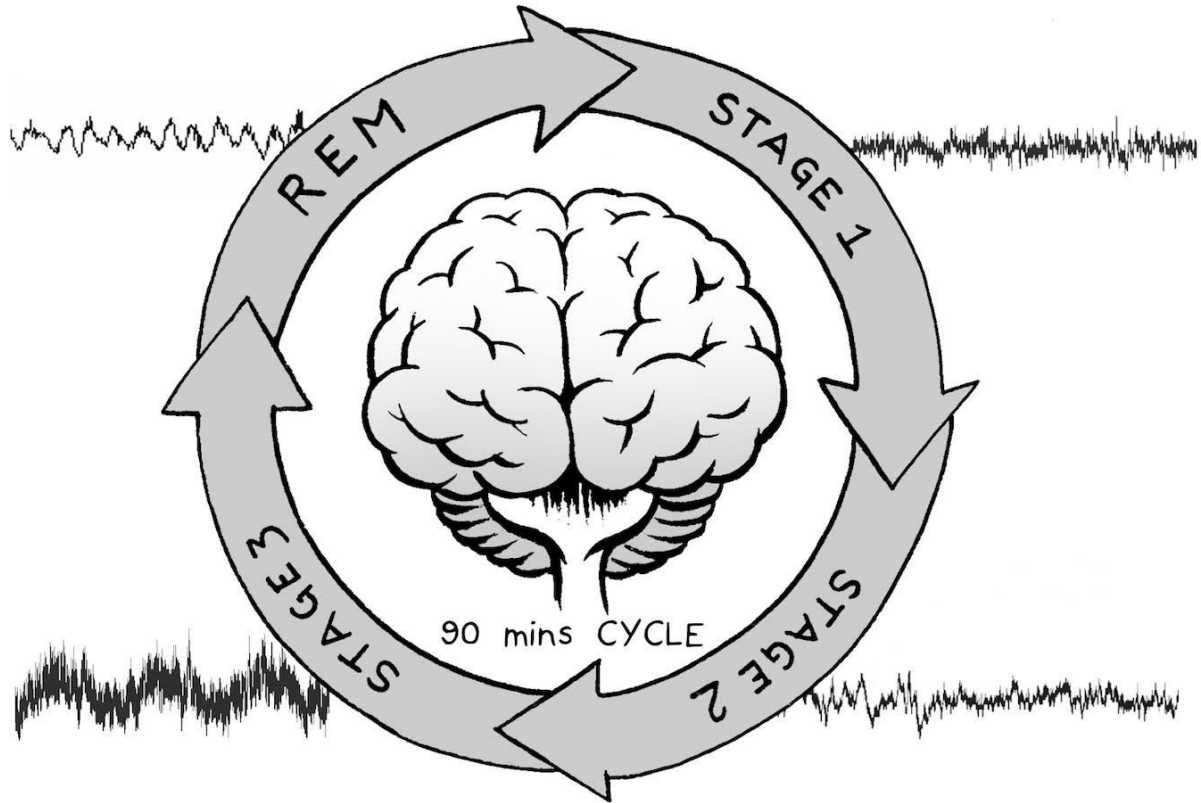


Figure 3: Different stages of Sleep Cycle
Source: Adapted from[12]

So, our product will detect frequencies between 0.5Hz to 16Hz as these are the waves produced while sleeping and at 17Hz, we start the low pass filtering. Moreover the typical value of an EEG input signal is 10uV to 100uV and we need to amplify this signal to mV, so that the arduino can read it [13]. To detect these waves, we need a circuit which can amplify the input and reasonably filter out the noise, anything greater than 50Hz. The Diagram for Layout of amplification circuit is shown below in figure 4 :

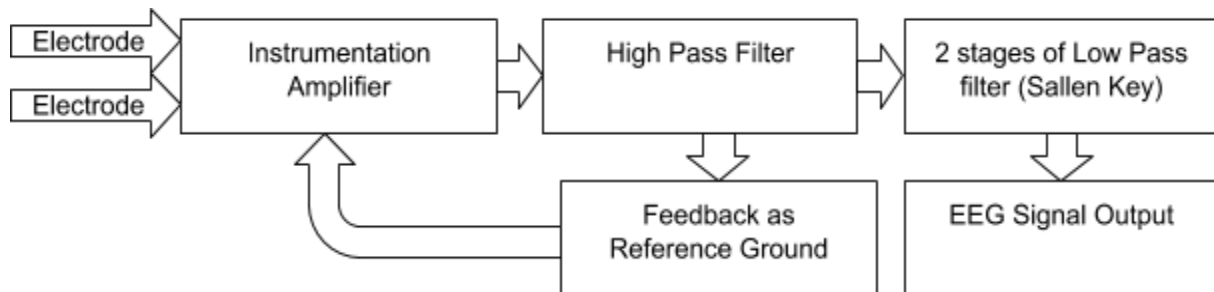


Figure 4: Layout of Amplification Circuit

Explanation of Circuit:

Instrumentation Amplifier:

The first stage of amplifier is Instrumentation amplifier with a gain of $6V/V$, as shown in figure 5.

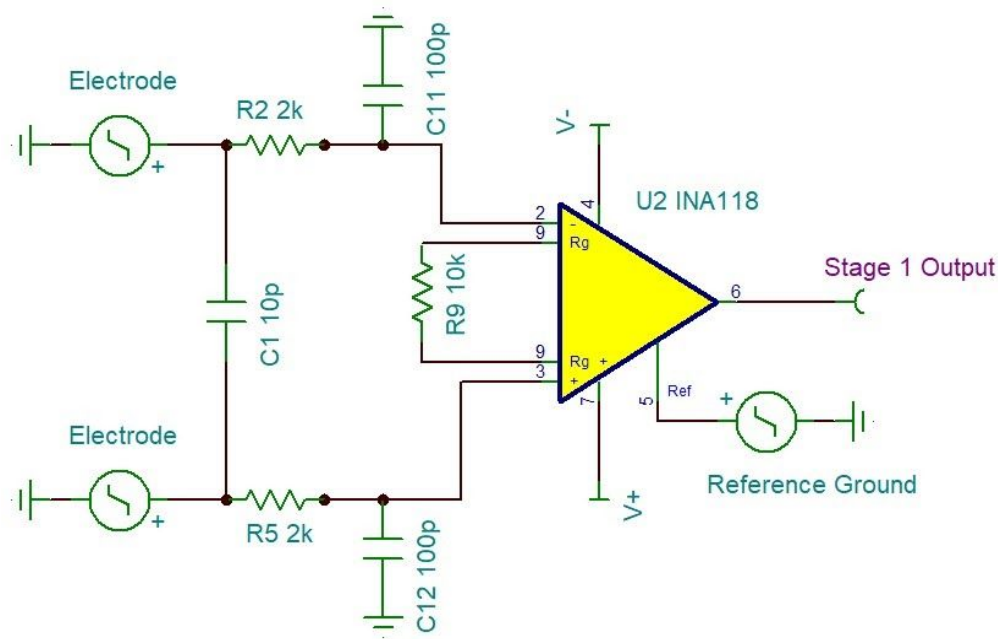


Figure 5: Stage 1(Instrumentation Amplifier) of Circuit in Detail

It takes input from 2 electrodes which are attached to the forehead. There is a 100pF capacitor connected to each input terminal to ground the common mode noise. The 10p between both inputs is to suppress the differential mode noise. The amplifier takes feedback from the 2nd stage as a reference ground which reduces the DC components in the output voltage. This amplifier has a common-mode rejection ratio (CMRR) of 110dB which effectively suppresses the common mode signal which can disturb the differential output.

High Pass Filter:

Figure 6 shows the second stage of the circuit is a non inverting high pass filter with a gain of $200V/V$ and a cut off frequency of 0.2Hz. The capacitor connected to the output of the first stage will remove any DC offset in the input to the second stage. Output from this stage is used for feedback as reference ground.

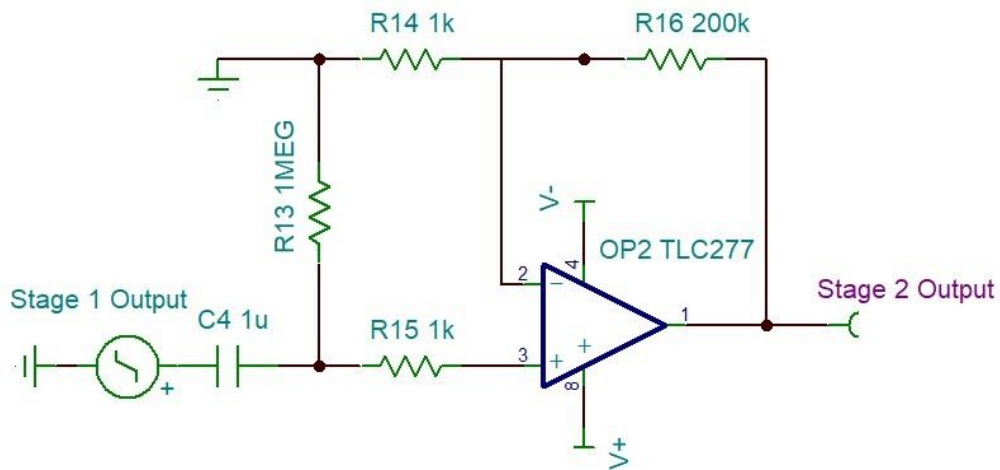


Figure 6: Stage 2(High Pass Filter) of Circuit in Detail

Feedback as Ground:

Figure 7 shows the feedback stage where the output signal from the 2nd stage is filtered with a low pass filter which has a cut off at 0.5Hz and a gain of 0.01V/V. As we are interested in the low frequencies, low frequencies have higher gain for reference ground voltage than the high frequency waves such as 60Hz which has gain of 0.00025V/V, to be taken as reference ground for instrumentation amplifier. The 1µF capacitor reduces the DC component in the output of 1st stage. It is also helpful in getting rid of a reference electrode which is attached to the ear. Thus, saves money on the production side.

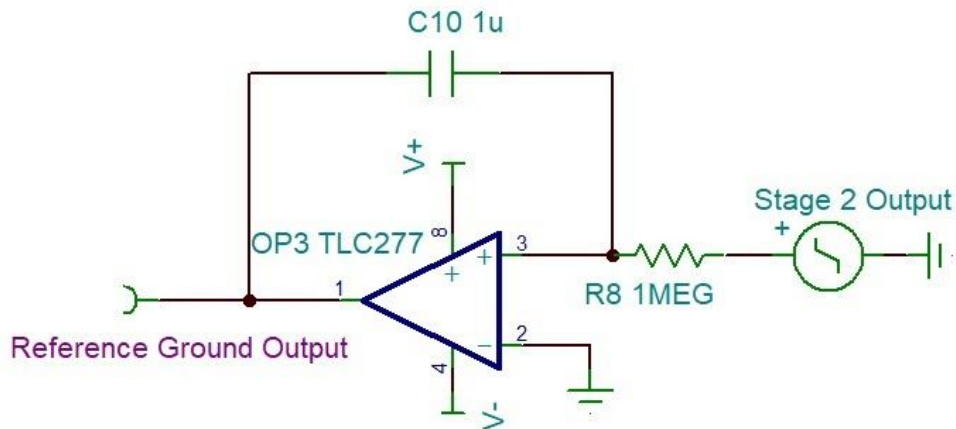


Figure7: Feedback as Reference Ground Circuit in Detail

2 Stages of Low Pass Filter:

Figure 8 shows the 2 stages of low pass filters are being used to suppress the high frequency noise with a cut of 17Hz. 2 stages drop the gain at a rate of 55dB per decade. This quick drop is essential as we want high enough gain for the low frequency inputs and very low amplification for the high frequency noise which is higher than 50Hz. Using 50Hz as an aim also reduces the power noise of 60Hz, which is on the power lines and gets leaked into the circuit.

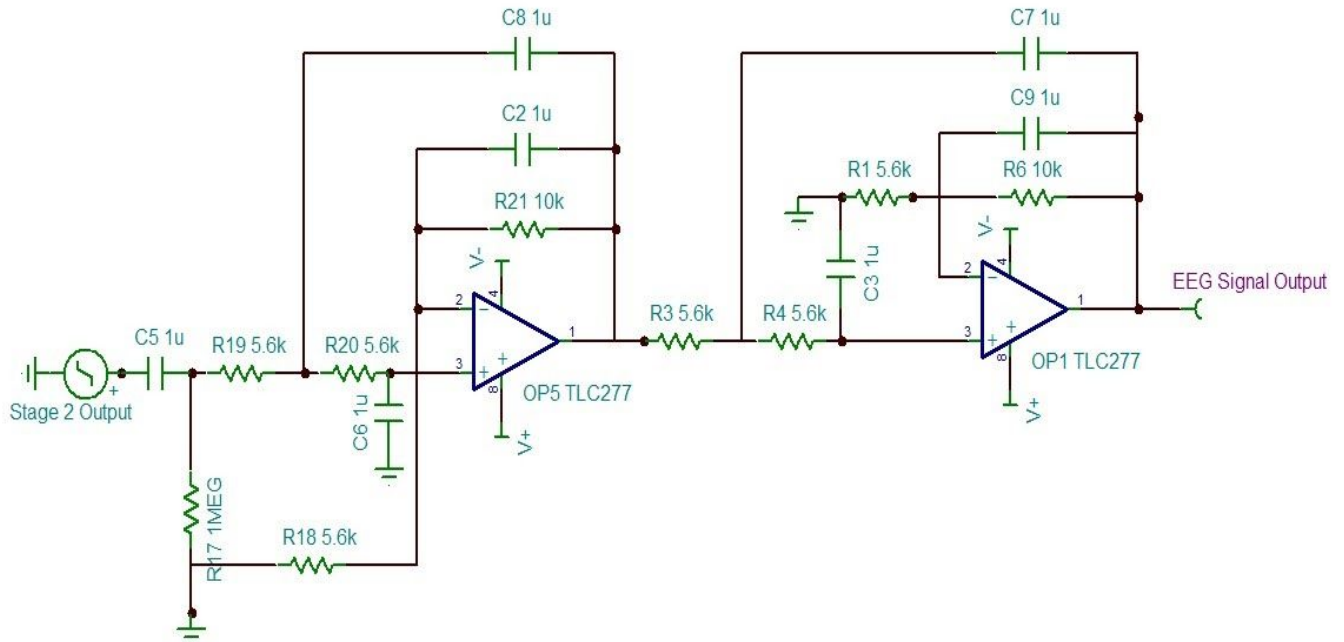


Figure 8: Stage 3(2 stages Low Pass Filter) of Circuit in Detail

EEG Signal Output:

We expect that our microcontroller will be able to read an analog signal as low as 3.3 mV. Thus, the output signal should be amplified by a gain of 64dB (1585 V/V). This will give an output in the range of 15.85mV to 158.5mV for an input range of 10uV to 100uV. The gain for our amplification circuit is about 64dB up to 16Hz and starts to decay down to 20dB for 50Hz. So, the noise, which has the higher frequency, gets suppressed.

Table 6: POC Design Specifications for Amplification Circuit

No	Design ID	Design Specification Requirements
----	-----------	-----------------------------------

16.	Des 3.3.1.1.1 - POC: 1	Amplifier shall have gain of 64dB (1585 V/V), so that minimum signal 10uV input = 15.85mV output
17.	Des 3.3.1.1.1 - POC: 2	Amplifier shall operate at 9V to easily see all the output signals for high voltage inputs of blinking
18.	Des 3.3.1.1.1 - POC: 3	Differential Op-Amp shall have CMRR of 110dB
19.	Des 3.3.1.1.1 - POC: 4	High Pass Filter shall suppress the low frequency noise of anything smaller than 0.2Hz and remove any DC offset that is there in the circuit.
20.	Des 3.3.1.1.1 - POC: 5	Low Pass Filter shall have cut off at 17Hz and drop it at rate of 55 dB/decade
21.	Des 3.3.1.1.1 - POC: 6	Low Pass Filter shall suppress the high frequency noise of anything larger than 50Hz with a gain loser than 20 V/V

Table 7: FP Design Specifications for Amplification Circuit

No	Requirement ID	Description of the requirement
22.	Des 3.3.1.1.1 - FP: 1	Circuit shall operate at a range of 3.0V - 3.3V power supply for low power consumption and to reduce heat release
23.	Des 3.3.1.1.1 - FP: 2	Circuit has Gain of 1585 or higher
24.	Des 3.3.1.1.1 - FP: 3	Circuit will suppress the high frequency noise with a gain less than 11V/V

The table below lists the requirements for electrodes:

Table 8: POC Design Specifications for EEG Electrodes

No	Design ID	Design Specification Requirements
25.	Des 3.3.1.1.2 - POC: 1	The electrodes shall be highly conductive to pick up brain signals from the forehead
26.	Des 3.3.1.1.2 - POC: 2	The electrode shall have contact area of 1x1 cm with the skin

3.3.1.2 Heart Pulse sensor

The heart pulse is an important part of human life and, especially, when sleeping. We would like to measure it using a heart pulse sensor that will be placed on the headband such that it is in direct contact with the user's skin. The SEN-11574 model by sparkfun has been selected. The sensor operates on 3V and has a diameter of 1.6cm, which is small enough to be used in our product, and is compatible with our microcontroller (Arduino Pro Mini) [14]. LED light, that is located in the white heart is right above the ambient light sensor, APDS 9000. The pulse sensor contains 3 pins which are used to connect to the ground, power and output (BPM signal). Since, The pulse sensor has the circuitry for detecting signal, amplifying the signal and noise cancellation, we do not need to add any additional circuit [15].

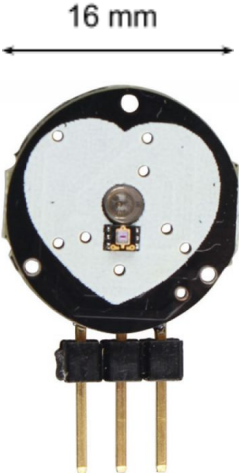


Figure 9 : Overview of the pulse sensor

The sample connection of the Pulse Sensor (SEN-11574) to the Arduino microcontroller is shown below (Figure 10).

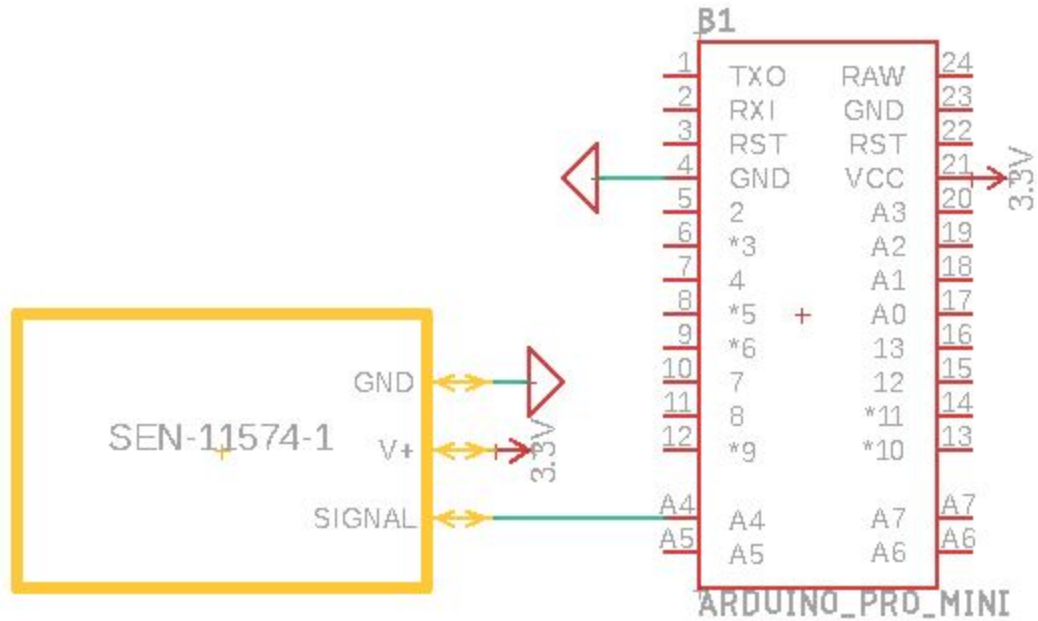


Figure 10: Pulse sensor connection circuit

The sensor needs to detect the pulse in the head, therefore it should be placed where blood flow is easily detected or near the surface [14]. Pulse near the temples and at the forehead are easily detected as shown in the image below, figure 11:

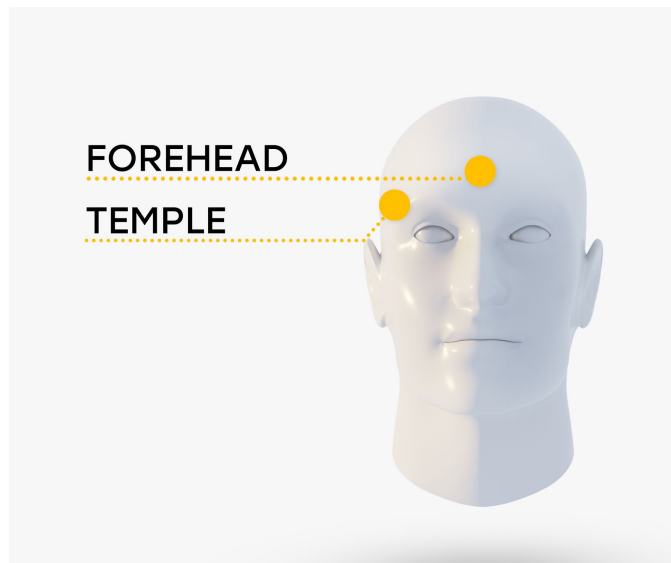


Figure 11: Image of possible pulse detection areas on the face

Explanation of circuit:

From the diagram, we observe that the SEN-11574 is a plug-and-play heart-rate sensor for Arduino. The sensor detects the light reflected from the vein and transmits electrical signals. When there is a blood flow, more light gets reflected thereby creating a higher voltage output. This pulsating signal passes through a built-in amplifier and filter stage for noise reduction, to remove unwanted signals. The output analog signal is picked up from the BPM Signal terminal. SEN-11574 has a built in amplification & noise cancellation circuit [16].

The sensor is powered by a 3-5.5V power source with an output 0.3-Vdd V. Therefore, there is no need in external amplification of the output signal either for a voltage divider [17]. Also, it operates safely within the [-40; 80] °C range.

The sensor has to be small, so it can be located in the headband, so it can be in a solid contact with the forehead. Thus we are limited on dimensions. The SEN-11574 has the diameter of 0.625 cm & a thickness of 0.15 cm [14]. The current price is 25\$ per unit, but we are sure it can be decreased for production state.

Table 9: POC Design Specifications for Pulse sensor

No	Design ID	Design Specification Requirements
27.	Des 3.3.1.2 - POC: 1	Shall work at a range of 3.0V - 3.3V for low power consumption
28.	Des 3.3.1.2 - POC: 2	Shall have a max current of 6mA to protect the LED
29.	Des 3.3.1.2 - POC: 3	The sensor shall be placed directly on the head (preferably forehead/temples) to detect pulse
30.	Des 3.3.1.2 - POC: 4	Diameter shall be 0.7 cm
31.	Des 3.3.1.2 - POC: 5	Thickness shall be 0.2cm
32.	Des 3.3.1.2 - POC: 6	Shall perform on board noise reduction and amplification
33.	Des 3.3.1.2 - POC: 7	Shall output an analog BPM signal to Microcontroller in mV range
34.	Des 3.3.1.2 - POC: 8	The temperature range shall fall in range -40 to 80 °C

Table 10: FP Design Specifications for Pulse sensor

No	Design ID	Design Specification Requirements
35.	Des 3.3.1.2 - FP: 1	Should less than 16\$ as that's the normal, market price
36.	Des 3.3.1.2 - FP: 2	The temperature range shall fall in range -40 to 80 °C

3.3.1.3 Snoring detection sensor

According to the research [18], the snoring can be caused by: Sleeping position; Nasal obstruction; Bad habits (alcohol, cigarettes, drugs); Cold temperature and dry atmosphere; Overweight; Dust & Allergies and Aging.

The snoring causes people to wake up, so it diminishes sleep quality. Detecting the snoring with a microphone will allow us to suggest a possible solution & provide better understanding of EEG readings. Snoring frequency is up to 1500Hz & power < 100 dB therefore the microphone should be able to determine such bandwidth [17]. As well, we are looking for a lower power consumption, thus we have to minimize the operating voltage to 3.3 V. We have selected SPW2430 as the microphone shown in figure 12.

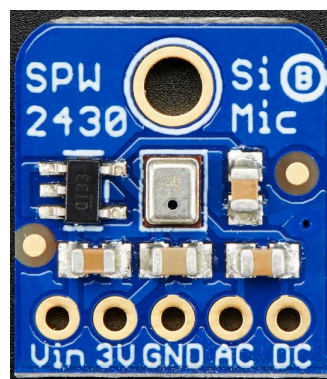


Figure 12: SPW2430 Microphone chip

The microphone doesn't have a built in amplifier circuit and cannot be directly connected to arduino. Because the output signal is about 2mV resolution and lots of noise [19]. For such purposes we don't need an Op-Amp, since we don't need the perfect fidelity and we just need to amplify the output to the 40-100mV range, so the gain is between 20 V/V to 50 V/V (22 to 34 db). The transistor amplification circuit provides this opportunity at a lower cost. We implemented an additional amplifier circuit as shown on the picture below (Figure 13) with an amplification circuit with a gain of 28 dB.

The sensor will be located in the headband, so the size of it has to be small. According to the "Adafruit" [20], the dimensions are 1.58cm x 1.41cm x 0.29 cm, which satisfies our needs. Also, it operates safely within the following temperature range -40 to +100 °C [21].

has a small size of 1.778 cm x 1.778 cm which is small enough for our product. The sensor is able to handle 10,000 g shock survival. And have an excellent temperature stability from -40 to 85 °C.

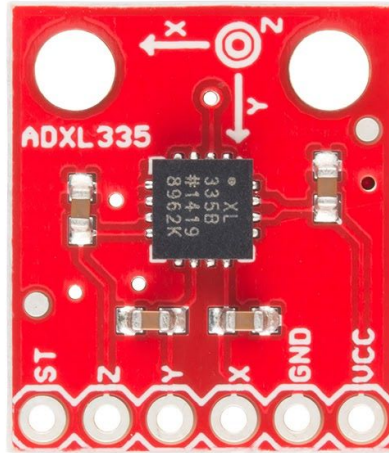


Figure 14: ADXL335 Accelerometer

The Arduino supplies 5V when it is connected to the regulated voltage (USB). In order to protect the circuit we implement a voltage divider to bring the 5V input Vcc from the Arduino to 3.3V using a 2.2k with 3.3k resistor, as the ADXL335 can only handle up to 3.6V (Figure 15).

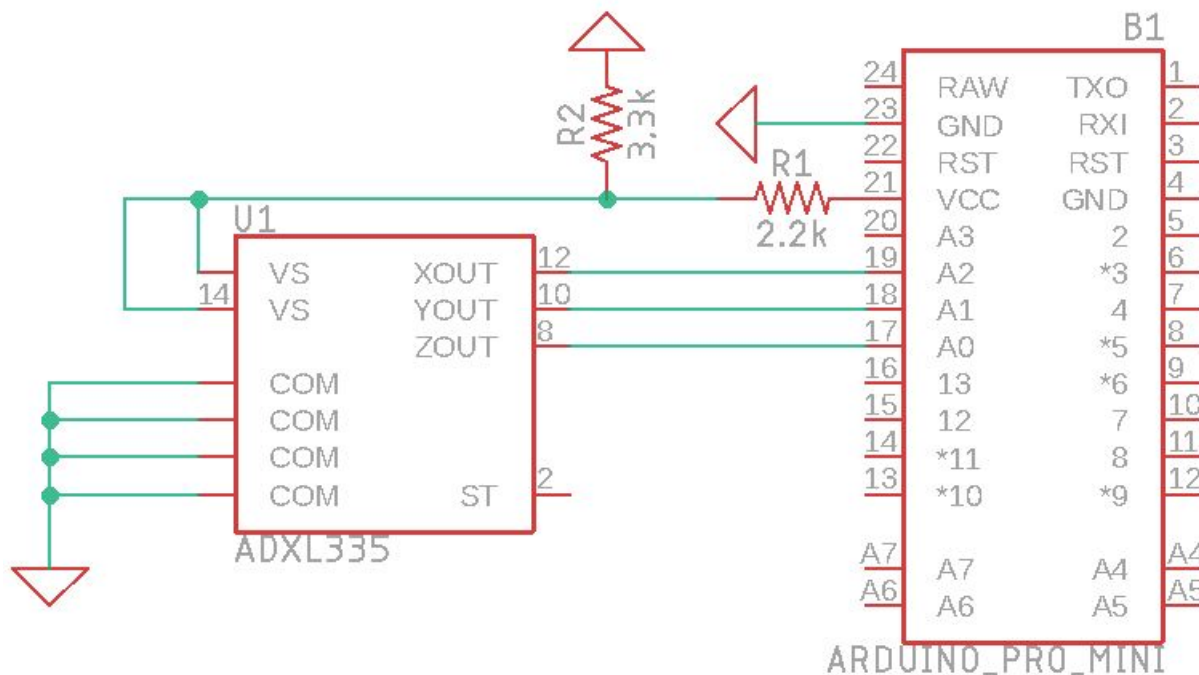


Figure 15: ADXL335 connection circuit

Table 12: POC Design Specifications for Accelerometer sensor

No	Design ID	Design Specification Requirements
44.	Des 3.3.1.4 - POC: 1	Accelerometer shall output signal to microcontroller in range of mV
45.	Des 3.3.1.4 - POC: 2	The voltage divider shall be implemented
46.	Des 3.3.1.4 - POC: 3	Accelerometer shall operate at a range of 3.0V - 3.3V
47.	Des 3.3.1.4 - POC: 4	Accelerometer shall survive excessive force of 10,000g
48.	Des 3.3.1.4 - POC: 5	Accelerometer shall have the following operation range: -40 to 85°C

3.3.2 Microcontroller Specifications:

Medeor will require a processing unit to be located on the headband. Limited space will restrict the size of the microprocessor. According to our market research [23], and requirements considered earlier, we defined the dimensions to be less than 4.5x2.0cm. Furthermore, the controller should operate on 3.3V due to minimizing the power consumption, which will lead to longer operating life and will minimize power-supply requirements.

Based on our research [24], Arduino has a simple topology making it the most feasible for our project. Arduino has real-time and analog capabilities, which increases the sensor compatibility. The tradeoff of using Arduino is the “Multitasking”, fortunately, this problem can be solved using Protothreading.

The board that has low power consumption and satisfies the above design was chosen. This board is an Arduino Pro Mini 328 which operates at 3.3V, 23µA (without load) and 8MHz [25]. It has 6 analog pins, which is enough for our design. The temperature operating range is -40 to 105 °C. The maximum current draw is 200mA. The board is shown on a Figure 16 below:

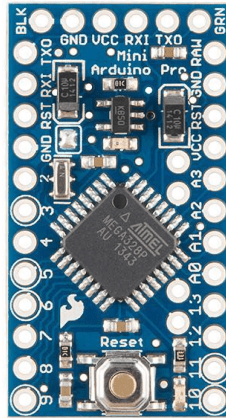


Figure 16: Arduino Pro Mini

The microcontroller will collect data from sensors and save it on the SD flash drive. We expect that the user will transfer data at least as often as once per week. As well we do not expect our data to take a lot of space, we estimate that the 1GB is enough. Also, the price for MicroSD cards are relatively cheap, about 12\$ per 32 GB SD drive and less [26].

Table 13: POC Design Specifications for Microcontroller System

No	Design ID	Design Specification Requirements
49.	Des 3.3.2 - POC: 1	Microcontroller's dimensions shall be 3.3x1.8cm
50.	Des 3.3.2 - POC: 2	Microcontroller shall operate at a range of 3.0V - 3.3V
51.	Des 3.3.2 - POC: 3	Microcontroller shall supply a range of 0V - 3.3V
52.	Des 3.3.2 - POC: 4	Microcontroller shall have 6 analog input terminals
53.	Des 3.3.2 - POC: 5	Microcontroller shall collect signal from the sensors through analog input ports
54.	Des 3.3.2 - POC: 6	Microcontroller shall connect to the 1GB SD card
55.	Des 3.3.2 - POC: 7	Microcontroller shall connect to Mobile device using a Bluetooth module
56.	Des 3.3.2 - POC: 8	Microcontroller shall have the following operation range: -40 to 105°C

Table 14: PT Design Specifications for Microcontroller System

No.	Design ID	Design Specification Requirements
57.	Des 3.3.2 - PT: 1	Microcontroller shall be powered with a 3.3V battery in the headband
58.	Des 3.3.2 - PT: 2	Functionality to clean the memory shall be implemented

3.3.3 Power Supply Specifications

Considering the maximum current draw for Arduino Pro Mini (200mA) [23] and a minimum of 10 working hours, we can estimate the capacity for the power supply:

$$200\text{mA} * 10\text{h} = 2000\text{mAh}$$

Therefore, the product should have at least 2000mAh battery to last for 10hours (over night) with a maximum current consumption. However, we expect the drain to be lower, so this will extend the operating time & reserve some capacity for degradation & efficiency boost. The battery has to be replaceable and rechargeable from the docking station and should have at least 300 cycles. The Li-Ion battery DTP603450 [27] satisfies our need and have the following dimensions 5.08 x 3.35 x 0.59 cm. The temperature range is between -25 to 60°C.

Table 15: POC Design Specifications for Power Supply

No.	Design ID	Design Specification Requirements
59.	Des 3.3.3 - POC: 1	The PC shall power the Arduino Board
60.	Des 3.3.3 - POC: 2	The battery (or pair) of 3.3V shall power the EEG Circuit

Table 16: PT Design Specifications for Power Supply

No.	Design ID	Design Specification Requirements
61.	Des 3.3.3 - PT: 1	The battery shall have max discharging current of 0.2A
62.	Des 3.3.3 - PT: 2	The battery shall be rechargeable
63.	Des 3.3.3 - PT: 3	The battery shall have charging time at most 180 min
64.	Des 3.3.3 - PT: 4	The battery shall have voltage of 3.0V - 3.7V

65.	Des 3.3.3 - PT: 5	The battery shall be Lithium-Ion battery
66.	Des 3.3.3 - PT: 6	The battery shall have capacity should be high enough (2000mAh) to power the head bandage overnight or longer
67.	Des 3.3.3 - PT: 7	Battery life shall be 300 cycles or longer at room temperature
68.	Des 3.3.3 - PT: 8	The battery shall be thin and flat, so the user's sleeping won't be affected about: 5.08 x 3.35 x 0.59 cm (Thickness * width * length)
69.	Des 3.3.3 - PT: 9	The battery shall be replaceable
70.	Des 3.3.3 - PT: 10	Battery shall have the following operation range: -25 to 60°C

3.3.4 Speaker Specifications

The headband should have a speaker, which will play a sound and stabilize the brain activity. The sound should not interfere with anyone's sleep. This speaker should be small, so it can be easily placed close to the ear. Speaker's quality is good enough to not produce any noises (signal to noise ratio of 20 dB) [25]. The extreme quality is unnecessary due to functionality (playing background noises over night), so the price can be minimized. We have a tiny speaker from a headset and we plan to use that for our final product. In case that does not work out, small speakers are easily available at Lee's Electronics, which we can just connect and play.

Table 17: PT Design Specifications for Speaker

No.	Design ID	Design Specification Requirements
71.	Des 3.3.4 - PT: 1	The speaker shall operate on low voltage (3.3V - 3.7V) for low power consumption
72.	Des 3.3.4 - PT: 2	The speaker shall be less than 50 mm in diameter
73.	Des 3.3.4 - PT: 3	The speaker shall have height less than 3mm
74.	Des 3.3.4 - PT: 4	The speaker shall have SNR at least 20dB

3.3.5 Wireless Connectivity Specifications

We decided to use connection via Bluetooth because we are expecting the user to use our product in the areas that don't have Wifi .We needed a modem with low power consumption and to meet this requirement the BLE modules are better options than SSP ones. Also, since we want to transmit a small amount of data at higher speed the BLE modules are 10 times faster than other Bluetooth profiles , also they cover longer distances around 1km.

BLE HM-10 (Figure 17) was selected for the proposed design with a built-in antenna. The operating range is +2.5 - 3.3V [28], thus it requires a voltage divider similar to an accelerometer. The dimensions are relatively small, so it can be easily placed into the headband (2.7cm x 1.3cm x 0.22 cm). We might consider the smaller alternative. The operating temperature is from -20 to 95 °C.

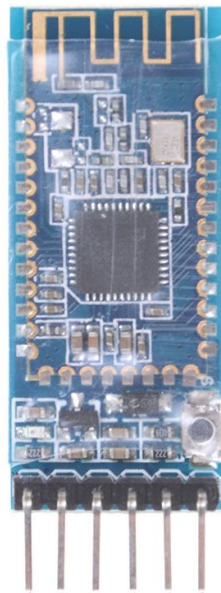


Figure 17: BLE HM-10

Also, the RX pin of this bluetooth is sensitive to higher voltages (>3.3V), thus to prevent the damages we have to introduce another voltage divider. The circuit is presented below:

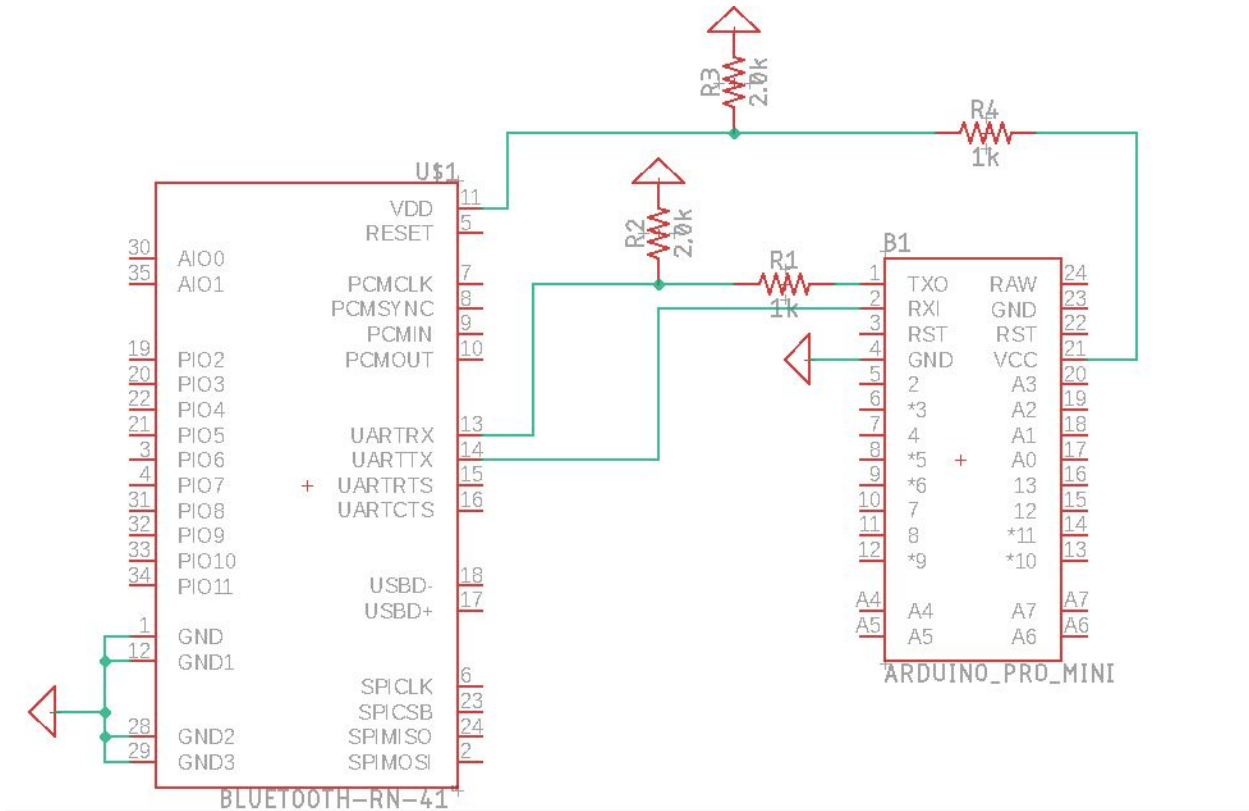


Figure 18: Bluetooth connection circuit

Table 18: POC Design Specifications for Wireless Connectivity

No.	Design ID	Design Specification Requirements
75.	Des 3.3.5 - POC: 1	The modem shall powered from 3.3V to 5V
76.	Des 3.3.5 - POC: 2	The modem shall consume less than 10 mA, for BLE for low power consumption
77.	Des 3.3.5 - POC: 3	The modem circuit shall include UART [29]
78.	Des 3.3.5 - POC: 4	The modem shall have built-in antenna
79.	Des 3.3.5 - POC: 5	The Android device shall supports BLE
80.	Des 3.3.5 - POC: 6	Bluetooth shall have the following operation range: -20 to 95°C

3.4 Software Specifications

Software will play a significant part in the product, as it is important that the user has a smooth and user-friendly experience. Users will be able to track their sleeping cycles, level of sleep and any abnormalities on a screen of their cell phones. The design specifications in this section focus on two separate software programs: on microcontroller and on mobile device. Each of the design specifics are chosen carefully to provide the end user with a fast and convenient system.

3.4.1 Microcontroller Software Specifications

As we have determined that the Microcontroller of our choice is Arduino Pro Mini, we will be using Arduino IDE for the development. All of the code for the Microcontroller must be written in C++. Arduino code is referred to as a sketch. The sketch can be verified and uploaded to the board using the IDE. The Arduino is not supporting multithreading, thus we might have an issue with simultaneous collection of data from sensors. This can be resolved using protothreading & frequency binding.

The software of the Microcontroller shall be able to collect the data from all of the available sensors. As the signal is received as an analog input (voltage), it must be formatted into a consumable form. The next step will be to save the data in the internal storage for later use. It is also important to check and maintain Bluetooth connection with the phone to transfer the data. Basic logic of the data flow is described in figure 19. According to the workflow shown in figure 19, design specifications have been selected for various stages of the product development.

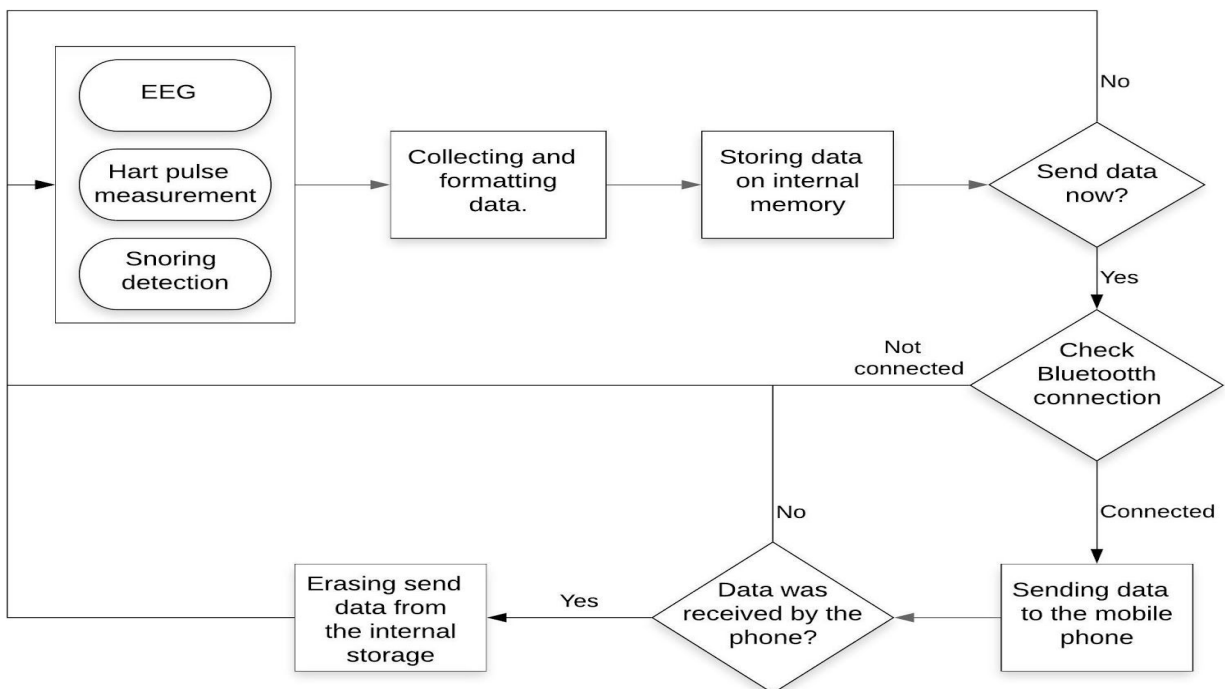


Figure 19: Data Flow in a Microcontroller System

Table 19: POC Design Specifications for Microcontroller Software

No.	Design ID	Design Specification Requirements
81.	Des 3.4.1 - POC: 1	Software shall collect and process signals from the sensors
82.	Des 3.4.1 - POC: 2	Software shall handle Bluetooth connection
83.	Des 3.4.1 - POC: 3	Software shall transfer data via Bluetooth

Table 20: PT Design Specifications for Microcontroller Software

No.	Design ID	Design Specification Requirements
84.	Des 3.4.1 - PT: 1	Software shall be able to store data in internal storage
85.	Des 3.4.1 - PT: 2	Handshake protocol shall be implemented to check if data was delivered to the phone

Table 21: FP Design Specifications for Microcontroller Software

No.	Design ID	Design Specification Requirements
86.	Des 3.4.1 - FP: 1	Storing data shall be memory efficient with little to no impact on performance
87.	Des 3.4.1 - FP: 2	Software shall be able to check if sensor is non responsive (broken)
88.	Des 3.4.1 - FP: 3	Software shall be updated over-the-air programming (OTA)

3.4.2 Mobile Application Software Specifications

The software application accompanies the headband and is designed to be used in conjunction with it thereby, providing the end user with useful information. Figure 20 below shows the expected basic workflow for the application. The application receives data via Bluetooth, stores it locally, and analyzes the recorded data. The recorded data is then displayed to the user through a graphical representation. Furthermore, the user can set the frequency of the data, that is if they want to view daily, weekly or monthly data. To add onto that, the application will emphasize on important readings, give some recommendations, and suggest a sleeping

schedule. The future development expects interaction with a user in sleep. Such as playing the background sound to interfere with brain activity.

The mobile application will be developed in Android Studio and programmed in Java and XML to present readable and understandable data from the sensors and indicate sleep cycle, deep sleep and suggestions to improve their sleep.

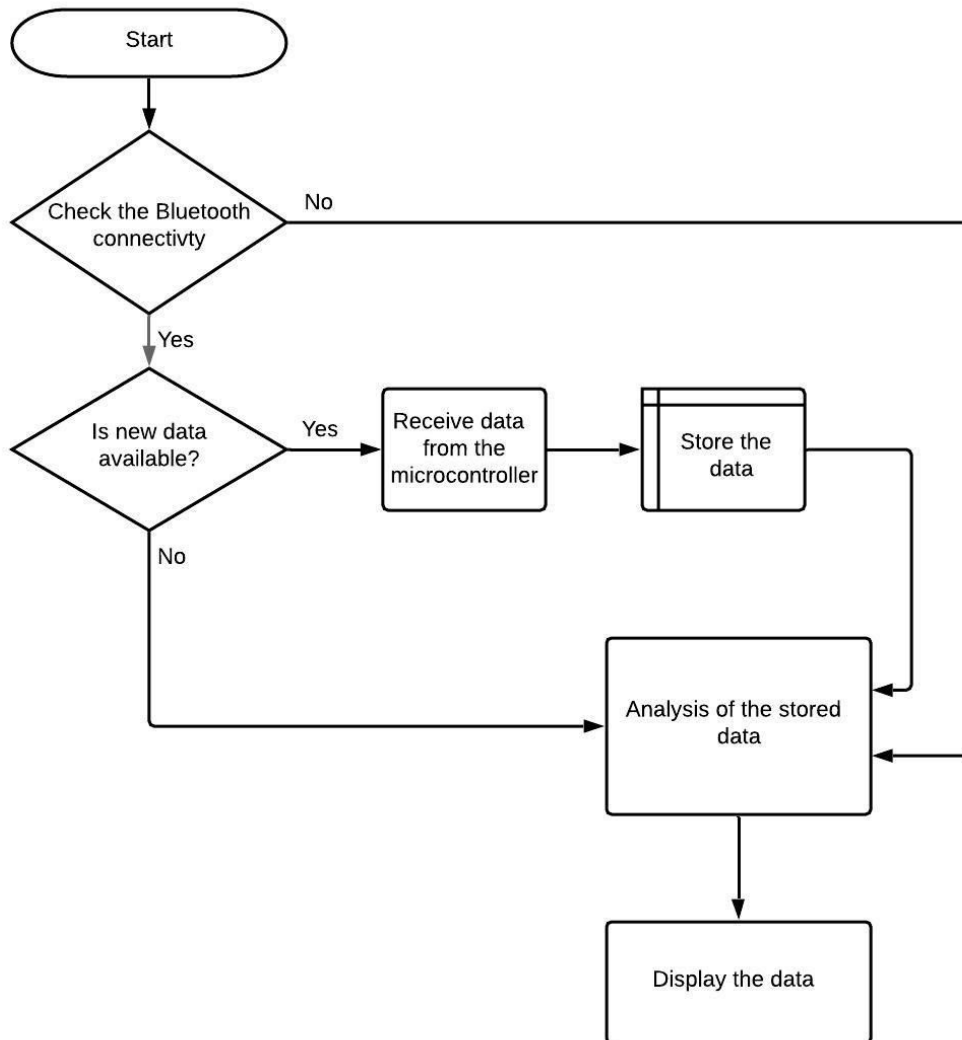


Figure 20: Layout for Mobile Software

Front-end

The 4 main components designed in the application are the: Home, Dashboard, Statistics and Settings pages. The home page displays the start button, where if the user chooses to track their sleep, can click on it and given there is a connection, the session will start recording. The Dashboard contains features such as setting an alarm, recommendations and a progress report. Statistics offers the viewers a graphical representation of each of their sensor readings and

displays important data. Finally, the settings page allows the user to modify some of the application's features to better suit their preferences.

Back-end

For the back-end of the application, we are planning to store data locally, since Android provides support for apps to use SQLite databases for data storage. We will fetch data from a database on the targeted device and assign this data to the UI element which is the Dashboard layout of Medeor, to graph the data to the user.

Table 22: POC Design Specifications for Mobile Application Software

No.	Design ID	Design Specification Requirements
89.	Des 3.4.2 - POC: 1	The application shall be available for devices with Android version 8.0 and higher.
90.	Des 3.4.2 - POC: 2	The application shall connect to Arduino via Bluetooth BLE
91.	Des 3.4.2 - POC: 3	The application shall read & display received data using the MPAndroidChart library
92.	Des 3.4.2 - POC: 4	The application shall distinguish types of brain waves

Table 23: PT Design Specifications for Mobile Application

No.	Design ID	Design Specification Requirements
93.	Des 3.4.2 - PT: 1	The application shall inform the headband to start collecting data, when prompted by user
94.	Des 3.4.2 - PT: 2	The application shall distinguish sleeping cycles based on data from EEG
95.	Des 3.4.2 - PT: 3	The application shall analyze the data that has been sent to discover any unusual pulse/breathing/brain activity
96.	Des 3.4.2 - PT: 4	The application shall store data locally on the phone using libraries in Java and SQLite
97.	Des 3.4.2 - PT: 5	The application shall suggest the sleeping schedule based on recorded data
98.	Des 3.4.2 - PT: 6	The application shall play calming music when you are in deep sleep

Table 24: FP Design Specifications for Mobile Application

No.	Design ID	Design Specification Requirements
99.	Des 3.4.2 - FP: 1	Statistics page will display the sensor readings via graphs created using the MPAndroidChart library.
	Des 3.4.3 - FP: 2	The application shall store data locally using SQLite and on the Firebase cloud

4. Conclusion

Medeor is aimed to be a health tracker for individuals aiming to improve their daily routine by monitoring their sleep cycle and other health parameters. Our product is a cost-effective, robust and user friendly system designed to help those struggling with insomnia. To provide a safe and comfortable headband, we have listed the requirements needed to achieve as such.

By implementing up to date technology and efficient algorithms, Medeor aims to provide a reliable method to help monitor the user's health. The electrical components used in the final product have been carefully designed to provide all the necessary features in a space confined configuration. To add onto that, safety and sustainability requirements have been listed to further improve the efficiency of the expected product.

As part of Sleep Glory Technologies Inc. we strive to provide a reliable, safe and eco-friendly product to our consumers through innovative and efficient design requirements and features, as outlined in this document.



Appendix A

Acceptance Test Plan

This appendix documents and tracks the necessary information required to effectively define the approach to be used in the testing of the Medeor. The targeted audience is the whole team as well as some portion of this document may on occasion be shared with the stakeholder whose input/approval into the testing process is needed .

For the proof of concept stage, our team will require to prove and benchmark the main concepts of the project.

The goal of the proof of concept is to :

- Collect the brain activity data using EEG
- Collect hart pulse data
- Collect position data with accelerometer
- Store collected data on microcontroller
- Transfer data from microcontroller to mobile app
- Mobile app shall be connected to the headbands
- Mobile app shall be able to display data from the sensors

1. User Testing

Date:
Test Name: Privacy document
Test Description: The user should not miss our privacy document
Expected Outcome: When the user logins first time the pop-up “Privacy Document” should appear. The user has to agree or disagree with it. Application cannot be used unless the agreement is approved.
Actual Outcome:

Date:
Test Name: Support page
Test Description: The user should be aware of our support page. The feedback info should be

included in the about section of settings

Expected Outcome: About section should contain the feedback email and/or number.

Actual Outcome:

2. Hardware Testing

Date:

Test Name: Power and Bluetooth Test

Test Description: Click the power button and see if the LED turned on. Open the app and connect to device

Expected Outcome: If the LED turns on then it is powered on and power connection is working. If the device gets connected to the app in less than 3 tries, then the bluetooth module inside the device is working.

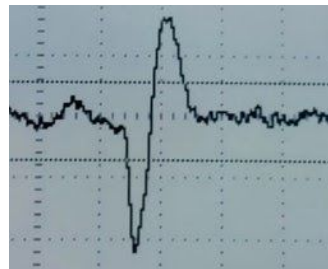
Actual Outcome:

Date:

Test Name: EEG Signal

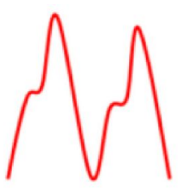
Test Description: Power on the device and then wear on your head such that the electrodes touch your forehead. Make sure the device is connected to the accompanied App.

Expected Outcome: While blinking you should observe the following pattern being recorded by the app or an oscillograph which looks like this.



Actual Outcome:

Date:
Test Name: Accelerometer Signal
Test Description: Power on the device and make sure the device is connected to the accompanied app. Rotate the device slowly and compare the data that is being recorded
<p>Expected Outcome: You should see output in this format as you rotate the device. x,y,z indicate position of product in the respective axis. As well you should be able to see the Roll & Pitch angles.</p> <pre> x = -1.12g y = -1.14g z = -0.60g Roll = 62.09 Pitch = 28.08 x = -1.06g y = -1.11g z = -0.56g Roll = 63.27 Pitch = 27.55 x = -1.06g y = -1.09g z = -0.56g Roll = 62.96 Pitch = 27.55 x = -1.12g y = -1.12g z = -0.60g Roll = 61.78 Pitch = 28.08 x = -0.80g y = -1.30g z = -0.36g Roll = 74.29 Pitch = 24.48 x = -0.29g y = -1.24g z = -1.24g Roll = 45.03 Pitch = 76.55 </pre>
Actual Outcome:

Date:
Test Name: Heart Pulse Signal
Test Description: Power on the device and then wear on your head such that the electrodes touch your forehead. Make sure the device is connected to the accompanied App and relax to get resting heartbeat.
<p>Expected Outcome: There should be a pattern as shown below being recorded by the app and check the heartbeat number that is being output by the app and check if its within the range of 60 to 100bpm.</p> 
Actual Outcome:

Date:
Test Name: Microphone Signal
Test Description: Power on the device and make sure the device is connected to the accompanied app. Play the recorded sound of snoring near the device.
Expected Outcome: Check if the soundwave is being plotted in the app or oscillograph.
Actual Outcome:

Date:
Test Name: Speaker Test
Test Description: Power on the device, wear it and be in a reasonably quiet area for this test. Make sure the device is connected to the accompanied app. Play a song using the app and listen if the sound is being played at the headset
Expected Outcome: If you can listen to the sound and it is clear then it is a pass, otherwise fail
Actual Outcome:

3. Software Testing

Date:
Test Name: App Navigation
Test Description: User should be able to navigate using the NavBar
Expected Outcome: By clicking on a button in the NavBar the user will be redirected to an appropriate page
Actual Outcome:

Date:
Test Name: Displaying data
Test Description: When the user goes to Statistic Layout. User should be able to see the graph for each sensor

Expected Outcome: If the graphs for each sensor is there its a pass otherwise is a fail

Actual Outcome:

Date:

Test Name: Starting session

Test Description: When the user clicks on “Start Session” the session should begin.

Expected Outcome: The application has to start the log of actions and display it on the home page.
The headband should start to work (Green LED).

Actual Outcome:

Date:
Test Name: Pairing of devices (Automatic)
Test Description: When the user opens smartphone application it should prompt button
Expected Outcome: It will prompt the “start session” on the home page
Actual Outcome:

Date:
Test Name: Pairing of devices (Manual)
Test Description: When the user pushes a turn on button the headband should go into pairing mode. Application should be able to pair with it.
Expected Outcome: The pop-up with all available devices will show up and the user should be able to select an appropriate device.
Actual Outcome:

4. Mechanical Testing

Date:
Test Name: Stretch test
Test Description: The headband should be stretchable
Expected Outcome: When the headband is pulled away by sides, the headband should stretch up to 6 cm without deformation.
Actual Outcome:

Date:
Test Name: Temperature test
Test Description: The headband should operate according to the minimum range of temperatures stated in design spec
Expected Outcome: The headband should operate safely within the -25 to 60 °C
Actual Outcome:

Date:
Test Name: Shaking test
Test Description: The headband should operate after excessive shaking applied
Expected Outcome: The headband should operate safely after excessive shaking applied to it. The accelerometer should display reliable data.
Actual Outcome:

Date:
Test Name: Heavy collision
Test Description: Putting the battery on the platform, using 10KG heavy hammer free drop from 1M height onto the fixed headband [30]
Expected Outcome: No fire
Actual Outcome:

Appendix B

User Interface Design

1. Introduction

The software application that accompanies Medeor will be used by the end-users to help them monitor and track their sleep, heart beat and snoring. The appendix describes the design details of the application's user interface, and analyzes each of the design elements based off of Don Norman's "Seven elements of UI" interaction that are listed below [#]:

1. Discoverability
2. Feedback
3. Conceptual Models
4. Affordances
5. Signifiers
6. Mapping
7. Constraints

The Appendix will dive into each of the elements and explain how the application and headband closely follow each of the requirements. Medeor is intended for use for those suffering from insomnia and other sleep-related issues. Therefore, the end-users will likely range from pre-teens to the elderly. As a result, the prototype designed will allow users, who have little to no expertise, to navigate through the application and manipulate the headband easily.

The majority of people hold a smartphone, therefore our application will be made discoverable by containing features that are common amongst most smart mobiles. This adds on to the user friendly feature as most users will have already been exposed to the app's UI elements and will easily navigate through the application.

1.1. Purpose

The purpose of this appendix is to inform the reader (internal development & UI teams) of the user design features of the application and headband, and their corresponding functionality.

1.2. Scope

The scope of the document focuses on the UI elements of the application prototype as well as physical appearance headband. That is, the reader will be informed of the prototype's features and functionalities. Furthermore, the appendix discusses the knowledge/ expertise the end-user is required to have to work with the prototype, both the headband and the software application. Finally, we will discuss how our application abides with the Engineering Standards.

2. User Analysis

Medeor is intended to be a cost-effective sleep and health monitor. Therefore, the target market consists of people varying in age. We expect our users to have little to no expertise in using similar devices, thus the user experience will have to be very intuitive.

Furthermore, most people have come into contact with smart devices, and therefore will have enough expertise to use headband and navigate through the application. The Graphical User Interface (GUI) will be user-friendly and will have design elements similar to other pre-existing applications.

2.1. Headband User Analysis

Medeor's sensing component, the headband (see Figure 21) shall behave as the majority of bluetooth connected devices, such as headphones. Users will likely have a lot of background experience using these devices and will be accustomed to the user experience therefore we are required to use the same practices. Otherwise, users might find the device difficult to use and deter from using it.



Figure 21: Model of Medeor's headband

Headband is a data collecting device, so it needs to be worn on the head by the user to ensure that the sensors can function correctly. As described above, the connectivity shall be very simple, on par with other bluetooth devices. A long press on the button will turn on and off the device, pressing a button twice will allow the user to pair a new device via bluetooth. In addition, the headband will have an LED light to signify device status. Remaining battery percentage and available software updates could be checked through the mobile application.

Also, the headband is designed to fit the majority of the humans' heads, as it will be adjustable. The inner side of the headband will be made of a soft cloth material, so it is comfortable to use over extended periods of time. The material will be cleanable as well.

2.2. Application User Analysis

The application part of the product is introduced on Android platform and relies on the "Android user interface and navigation" documentation [31]. Google has designed the most common UI practices which are followed by the majority of the development community. Writing the application using those guidelines will ensure that the user will find the functionality in the expected places. In addition, our target users are most likely to use the application at night, right before bedtime, therefore, the color scheme of the product is required to be calming without having bright elements. We will provide an opportunity of setting an alarm from an application, since this functionality is a necessity for our product. We will predict the sleeping schedule and suggest the better wake-up time, which will increase the user experience. We are planning to have a feedback section in future, which will gather the user experience and suggestions to improve the decision making in future.

2.2.1. Proposed User Experience

The section focuses on the user experience and the flow of the entire application. Figure 22 displays the first layout the user sees when launching the application. This page presents the name of the application, the logo and our slogan. As this is a loading page, no action is required from the user. The loading page might contain an animation of a user wearing the headband. This allows for the entire application to start up.

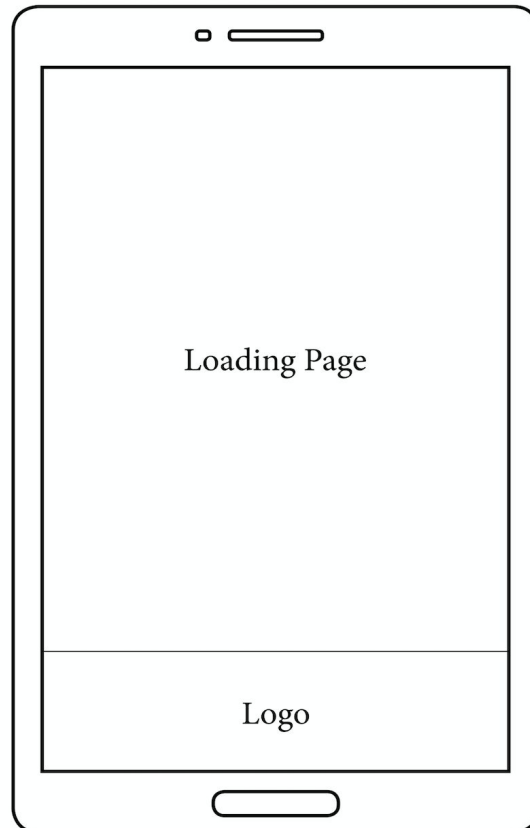


Figure 22: The Loading Page of Application

Figure 23 represents the navigation toolbar, that helps users to navigate to different pages easily. Each tab is highlighted to show which page the user is on.

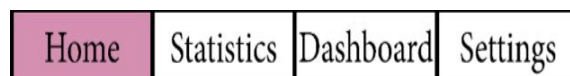
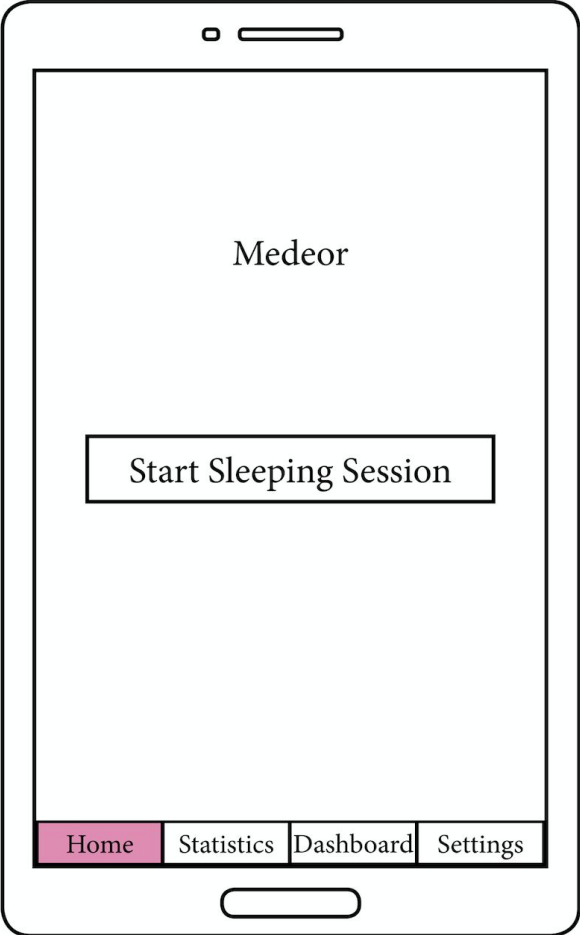


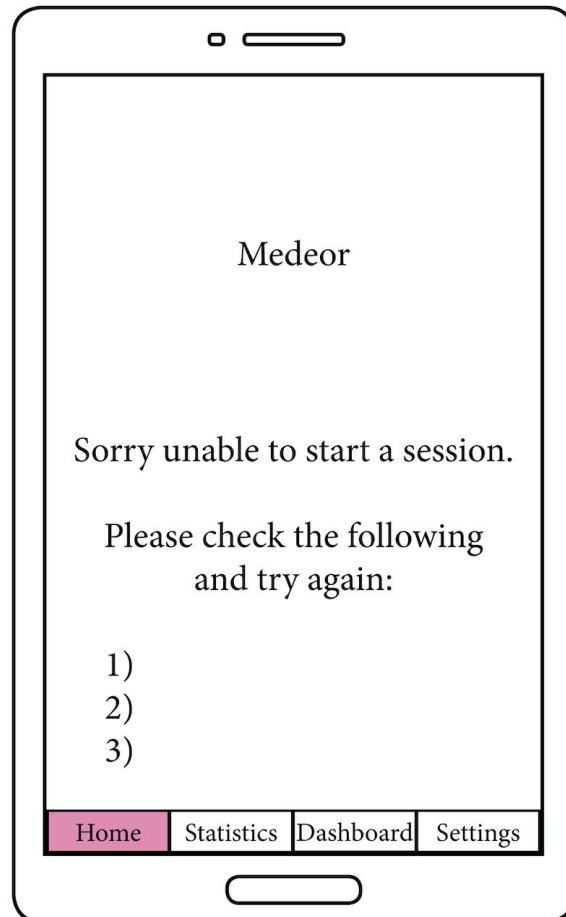
Figure 23: Navigation Toolbar

The home page in Figure 24 displays the start button. If the device is unable to connect, an error message is prompted , Figure 25. Otherwise, the user is able to start the session by clicking a button “Start Sleeping Session”. The application will send a message to the headband to start collecting the data. The button will disappear and the log of action will be displayed on the current page. However, the user is still able to navigate to the other pages via the navigation toolbar even if they don’t click on the button or the connection fails.



Figures 24: The Home Page Layout

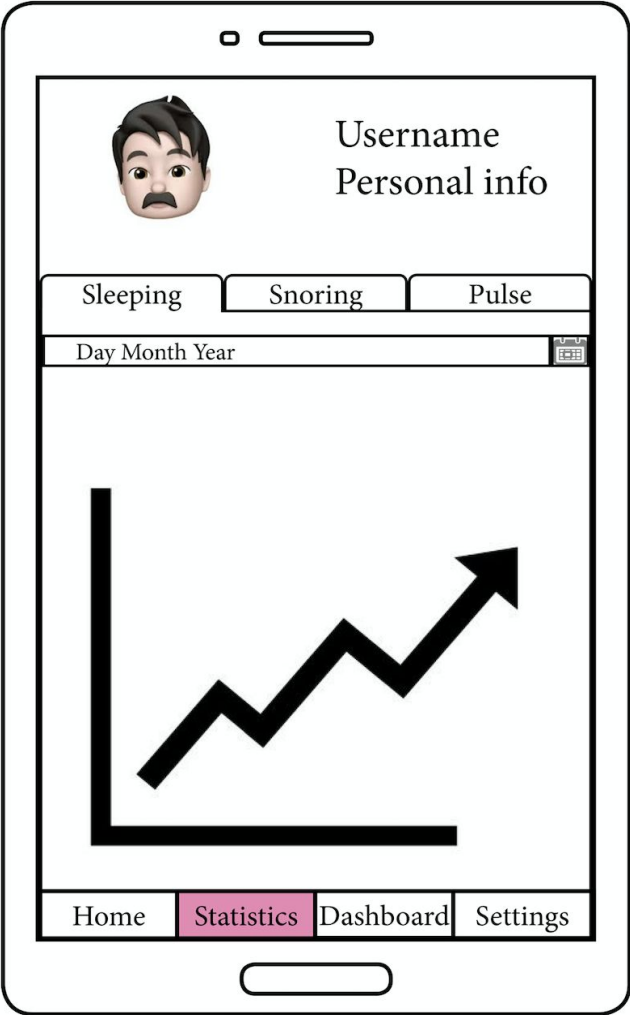
As stated above, Figure 25 presents that the home page will display an error message to inform the users that the headband is not connected. The prompt instructs users on possible troubleshooting methods to fix the problem.



Figures 25: The Home Page Layout with error message

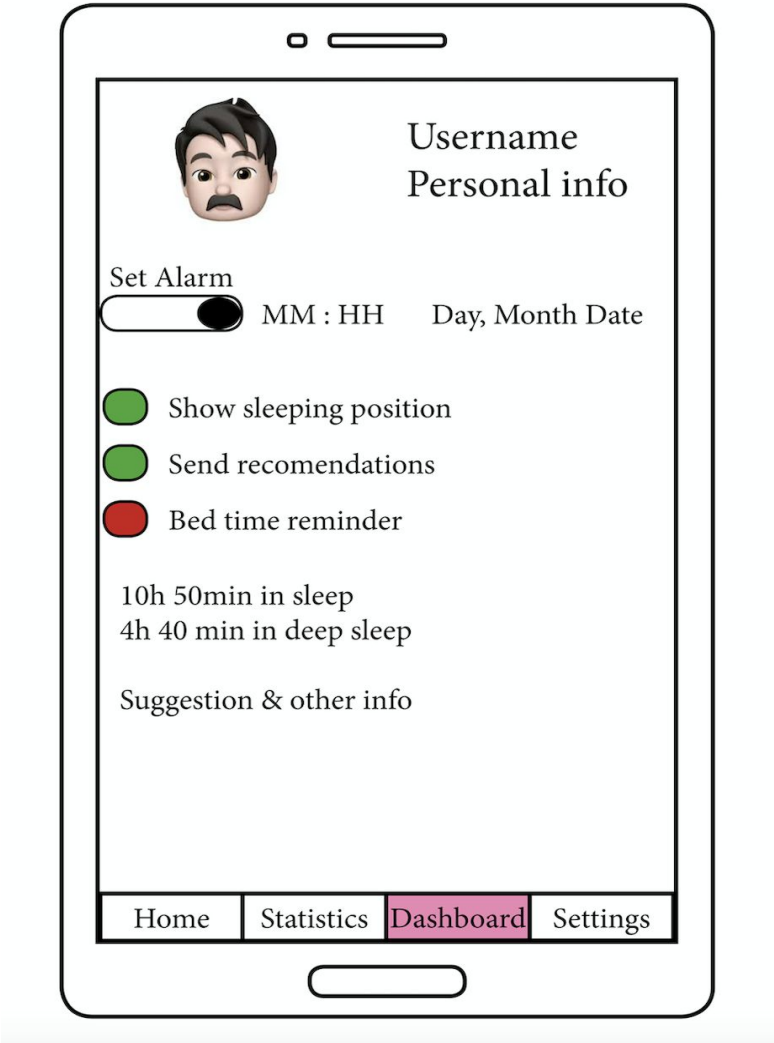
Figure 26 shows the layout of the “Statistic” page, you can observe it since the “Statistic” button is highlighted. This page contains another navigable tabs bar which allows the user to jump to any sensors result they want to look at.

In this layout we have three different graphs from the sensors, each graph represents important data, such as sleeping quality & position, breathing rate, pulse rate. The user info is also located on the top of a screen. The data received from the microcontroller will be analyzed, so it can be visualized and presented to an end user. Moreover, another functionality of this layout is an ability to see previous data by selecting the day or a range that they would like to observe.



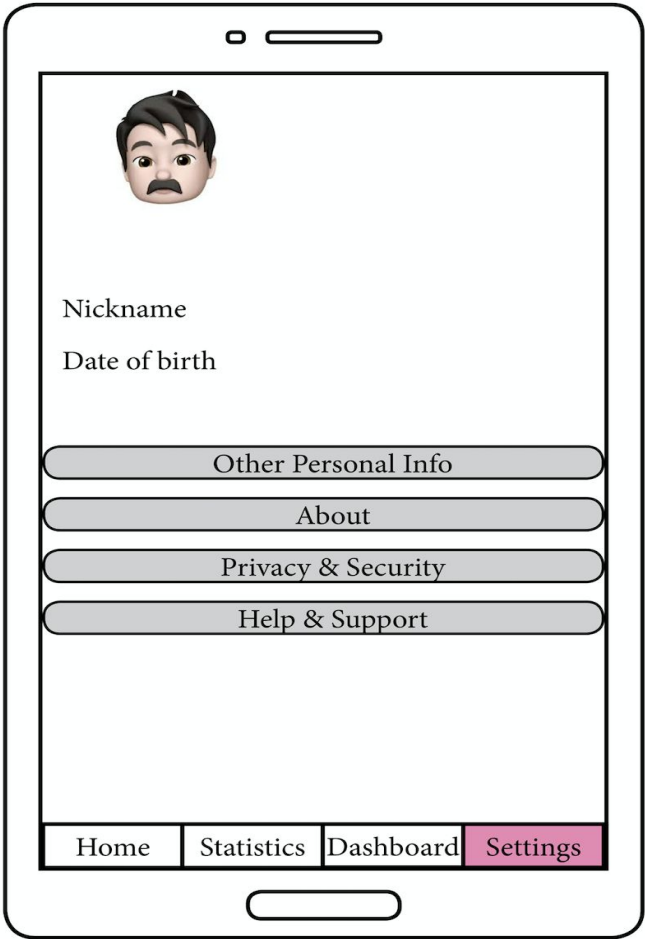
Figures 26: The Statistics Layout

In Figure 27, the “Dashboard” button is highlighted as we are in “Dashboard” layout. It contains features such as setting an alarm, showing a sleeping position, recommendations and a progress report. One of the functionality of the layout is to demonstrate the duration of sleep, hours spent in a deep sleep. Similarly to “Statistics” this page will have a short info about the user.



Figures 27: The Dashboard Layout

Figure 28 shows the “Settings” layout. The main functionality is to store users information such as DOT, Full Name, Height, Weight, and other personal information that can be important for the reading and the user has given to the application. Secondly, it contains information about the application, Terms & Conditions, and Help & Support. So, the user will be able to read the Privacy and Security agreements, and ask for support.



Figures 28: The Setting Layout

2.2.1 Proposed Design

Based on the UX layout the design of each of the pages have been created to closely match the requirements and flow. The Simple UI had been developed using Android Studio.

Figure 29 displays the proposed user interface design of the home page of the mobile application. It clearly displays the start session button and is surrounded by a minimalistic design to avoid distracting the user. The background color chosen is to ensure that the user is not disturbed by bright colors that could further inhibit their sleep. Studies have shown that Purple has a calming effect on the nerves and the mind [32]. Furthermore, the image chosen is placed above the start session button as a means of directing users to the button.

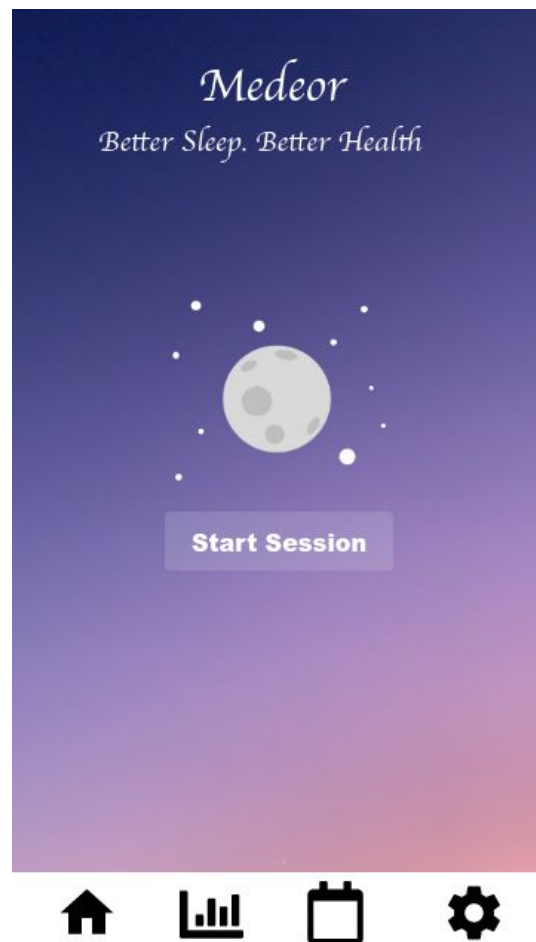


Figure 29: Homepage Design of the Software Application

Users can click on the button to start recording data. If there has been no established connection with the device, the user views an error message, as shown in figure 30. The pop up message alerts the user that the application is unable to start recording the data and provides possible solutions. The placement and theme of the pop-up message chosen follows a default style, thereby preventing users from being confused on what to do next. To add onto that, users are provided with two options: to either retry or cancel. The buttons are highlighted in blue to make the features more visible and obvious to the end user.

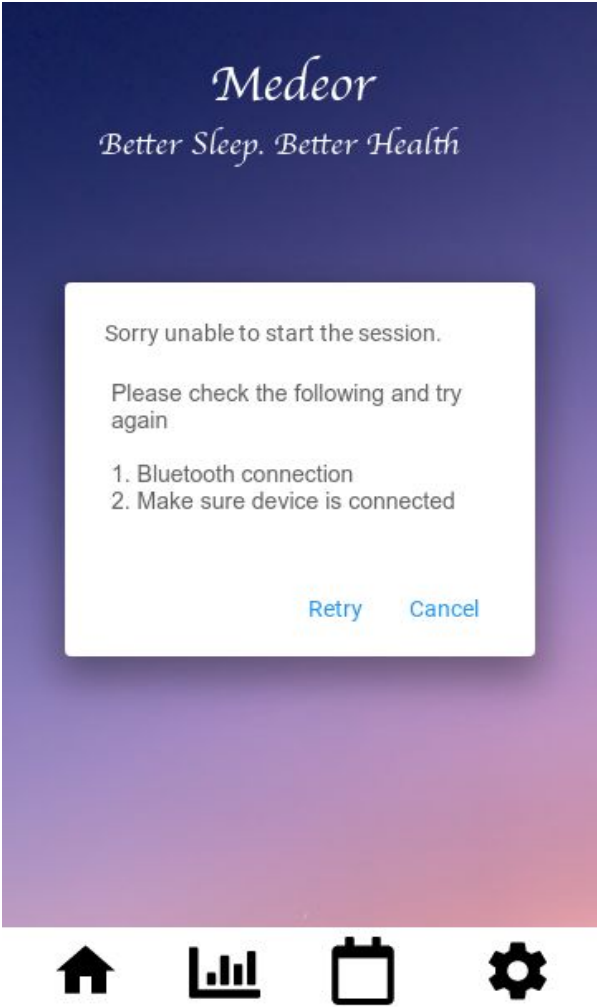


Figure 30: Error message displayed on Home Page

Figure 31 displays the statistics page. The user is able to view graphical data collected from sensors. Since the application records 3 sensor readings: sleep cycle, pulse and snoring data, there are three menu options for them to select from, depending on which they prefer to see. The buttons representing each graph are placed on top. When a user clicks on a specific button, it is emphasized by having its bottom border removed. The design of these options make it clear to the user which page they're on and has been adapted by other various applications, therefore increasing the likelihood of them having experienced this particular feature priorly. Moreover, users can select a specific date or a range to view.

The Sleep Cycle graph clearly presents the timeline on the x-axis and sleep stages on the y-axis. This allows them to identify their sleep cycle without having any medical knowledge. The pulse and snoring graphs will have a similar layout with varying y-axis labels, for example, they will be able to view their BPM for the pulse graph.

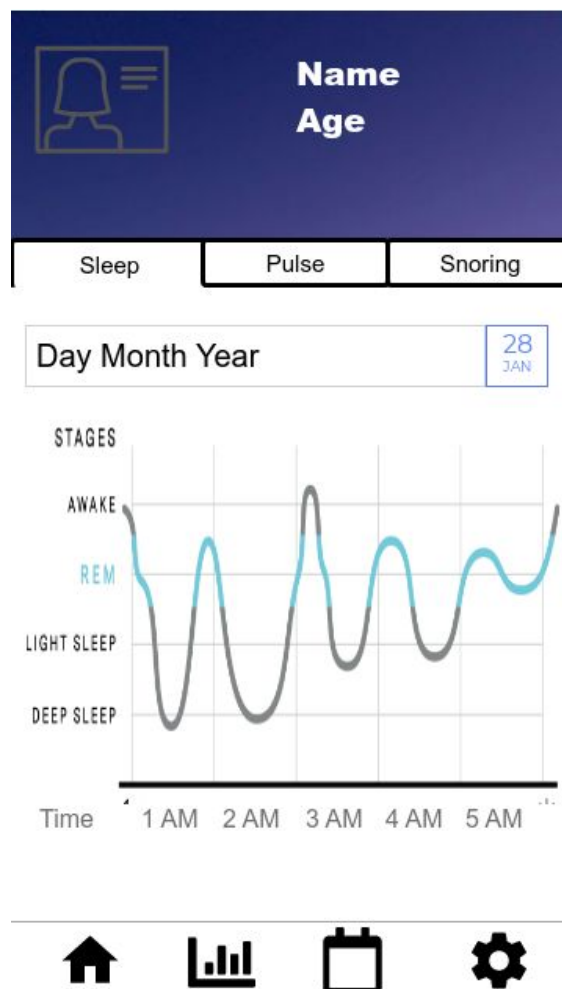


Figure 31: Sleep Cycle Graph on Statistics Page

Figure 32 displays the Dashboard page with a number of action items. Firstly, they are able to set an alarm with a toggle switch. By implementing a toggle switch, which is green when “switched on” and grey when “switched off”, the user is able to swiftly change the alarms on/off settings. They can also set the alarm time to their preference by clicking “Edit” which is placed above the alarm time. This configuration prevents clustering of information on a single page.

Furthermore, users are able to select a number of actionable items such as displaying a sleeping position, sending pop-up notifications, setting a bed-time reminder. Selection is done via radio buttons which change to a green color when selected and grey when unselected. The page is divided into sections by incorporating a line divider. This avoids confusion amongst users and directs them to the appropriate section with little to no trouble.

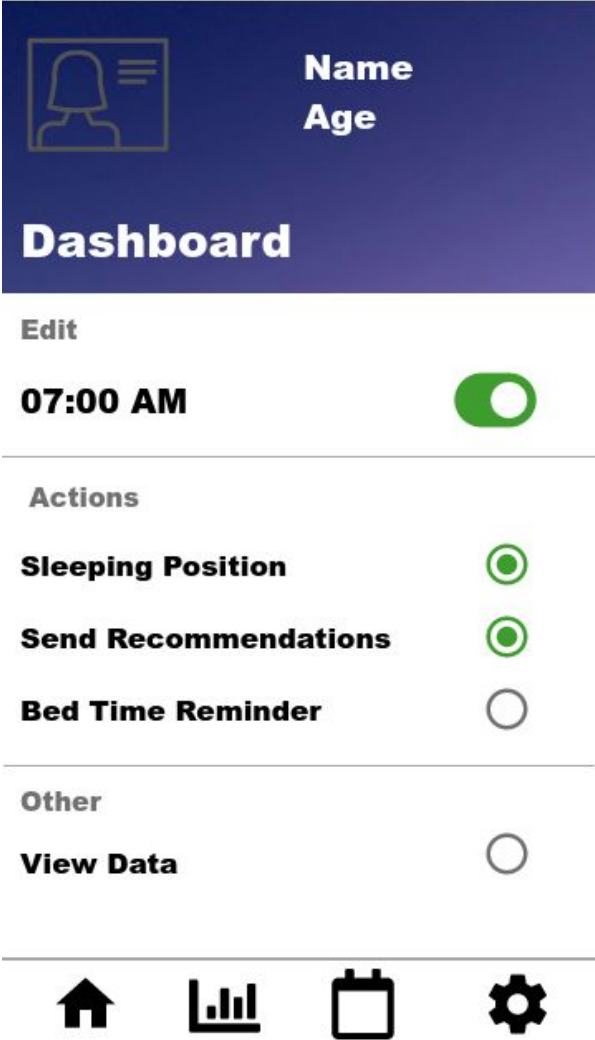
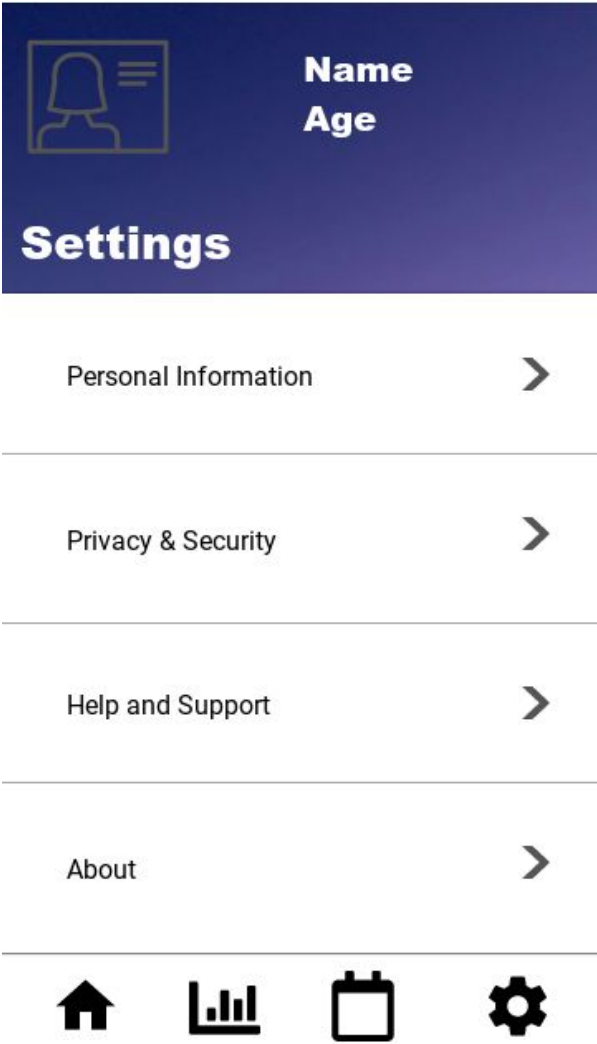


Figure 32: Dashboard Design

Figure 33, displays the proposed design of the settings page. Users view their personal information on the header of this page such as, their full name, age, etc. The page contains 4 different menu options: Personal Information, Privacy & Security, Help and Support and About. Each of the options are separated by a divider and have an arrow indicating to the user that they will be taken to another page corresponding to the option they click on.

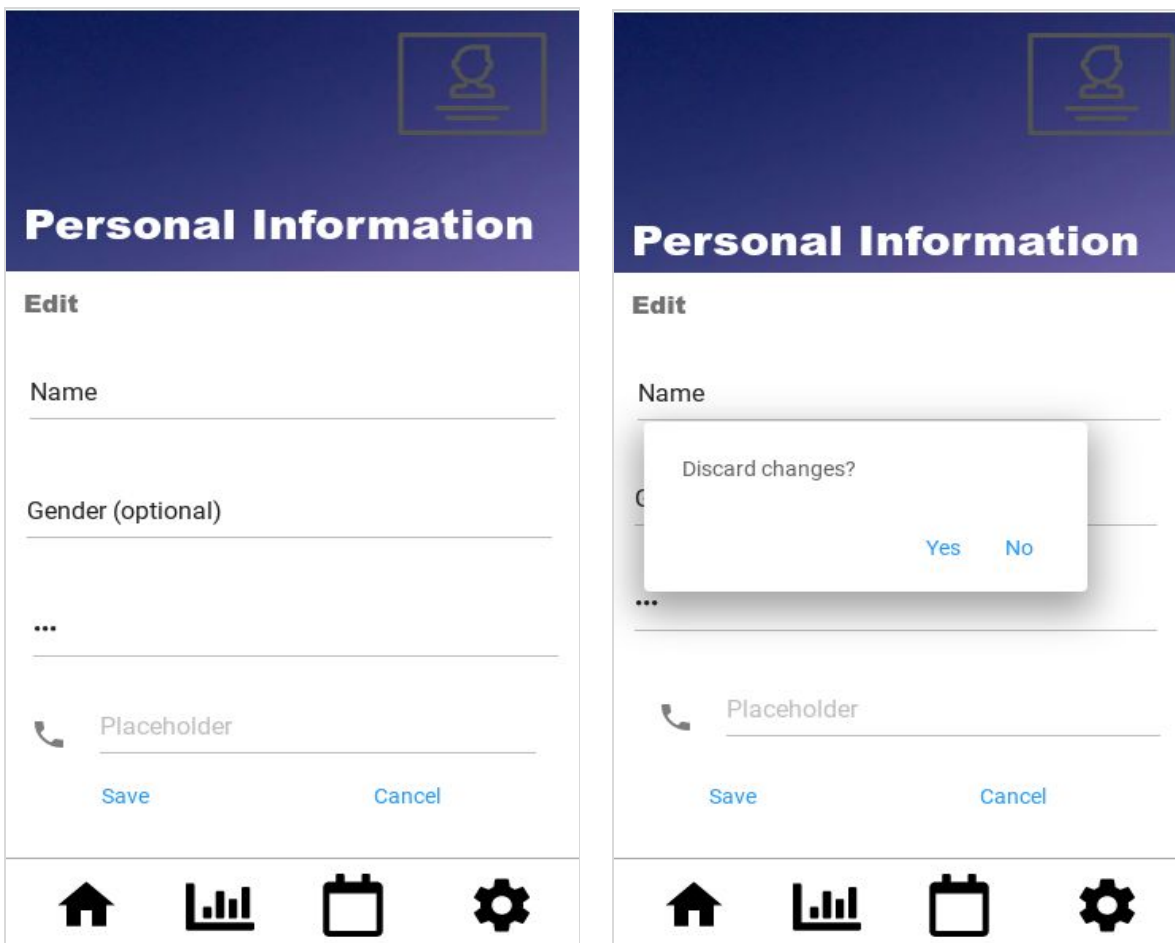
The simplistic design allows anyone navigating through the page to reach their desired location with no complications. This ensures that the elderly will be able to quickly adapt to the theme. Additionally, due to the small number of buttons and well labeled options, users can quickly understand the page layout and it's functionality.



Figures 33: Settings Page

Users will be able to view and edit their personal data as shown in Figure 34. Figure 34 is the proposed design of the page when the user clicks on the “Personal Information” menu option from the settings page. At first they will be able to see the already entered information on each of the fields, however if they want to modify the data they are presented with an edit option on top. This design is similar to that of Dashboard and therefore, the user will understand its functionality and spot it easily. Actionable items such as “Save” and “Cancel” are highlighted in blue to indicate to the end user that it is clickable.

If the user chooses to discard the changes, they can click on the cancel button at the bottom of the page. They will then be presented with a prompt asking the user to confirm the action as shown in figure #. This redundancy is introduced to prevent users from accidentally modifying or losing their changes.



Figures 34: Edit Profile page(left) and Prompted Message (right)

3 Technical Analysis

This section focuses on diving into Don Norman's "Seven elements of UI" of both the software application and headband, and how both the components meet the minimum requirements to provide the end user an easy and comfortable experience using the product.

3.1 Discoverability

Discoverability focuses on ensuring that the important functionalities or features of the product are made visible and obvious to the user. It determines the level of ease at which the user demonstrates their capability to identify/locate the UI components in their first interaction with the product [33].

3.1.1 Headband

Figure 21 shows the design of the headband. The power button is placed at the front of the device and is easy to locate. It's operation is standard and intuitive: a long press will switch the device On and Off, while the double short presses will allow the device to enter pairing mode.

3.1.1 Software Interface

The application is designed to ensure that a first time user will easily navigate through the pages and features. Firstly, when the user lands on the main page they view the "Start Session" button. There are no other buttons that can confuse a first time user. To add onto that the navigation toolbar is located at the bottom of the page to ensure that the user is able to explore other pages without much difficulty. This navigation is common on Android devices. The icons representing each page closely match what they're intended to display, thus the navigation should be clear. However, if users have any questions they can always reach us and ask for support..

3.2 Feedback

Feedback focuses on clearly informing the end user of what action they've taken and what happens when they use a certain feature.

3.2.1 Headband

Headband will have an LED light that will allow for checking the status of the device (green light for On, no light for Off, flashing green light for Paring). This functionality will be described in the user guide, which will come with the product. Checking the remaining battery percentage and other system preferences will be realized through the application.

3.2.2 Software Interface

Every single action that might be done without user interference will be performed. If the user opens an app the application will try to connect to the headband automatically. However, if there is need in a user input, e.g. change of personal information then the user will be asked for

verification. Another feature that complies with the feedback element is the navigation toolbar, where if the user clicks on a specific icon, it is highlighted to show which page they've landed on. In general, buttons or icons are highlighted when the user clicks on them (and gray when disabled), and/or a pop-up message is displayed, so the ambiguity should not happen.

3.3 Conceptual Models

The conceptual model of a design should inform the user of how the system works that leads to them to have better understanding about the flow of the application.

3.3.1 Headband

The headband will operate like the majority of the wireless devices such as, headphones and speakers, so prior experience with those devices will make the user comfortable with this device. Also, very simple controls will allow for a quick conceptualization of the device behaviour.

3.3.2 Software Interface

The application incorporates iconography to clearly indicate to the user what each feature is supposed to do. For example, if the user intends to go to the settings page, the navigation toolbar clearly displays the icon that accurately represents it. Any questions can be resolved in the Help section of the settings.

3.4 Affordances

Affordance is a property of the product which specifies which actions can be done with it.

3.4.1 Headband

The headband is a self-explanatory device, as it should be worn on the head.

3.4.2 Software Interface

Our application ensures that the pages are not overcrowded with buttons and that each feature is clearly labeled. Also, we are trying to take the best practices of other Android applications to our product, so the design is friendly to the user. For example, when viewing the graphs of each of the sensor readings, the user is presented with an option to view data from a specific date/range, The icon is represented with a calendar (a design implemented by various other applications) and therefore the user is aware to click on it, to set a specific date.

3.5 Signifiers

The presence of proper signifiers will communicate to the users how the device operates.

3.5.1 Headband

The shape of the headband and labeling on the inside of it will indicate the correct way to put it on the head. To add onto that, usage of the common UI elements, such as power symbol, will provide users with a smooth experience. Also, the headband will have an LED light that will allow for checking the status of the device (green light for On, no light for Off, flashing green light for Pairing). This will be included in the user guide as a part of deliverable.

3.5.2 Software Interface

Medeor application's signifiers will follow a simple design for users to understand that is adopted world-wide. Icons in the navigation toolbar have been clearly designed to direct users to the appropriate pages. That is, when they come across a settings icon they're aware of which page they'll be directed to.

On the Statistics page, the buttons representing each of the graphs are clearly labeled to indicate the button that directs them to the appropriate pages. The Dashboard icon will take users to the dashboard layout to show the details about users sleep such as duration and time with suggestions to improve their sleep.

During the loading of the app we might show an animation on how to wear the headband.

3.6 Mapping

Mapping is a critical concept in the design and layout of controls and displays. In our design, we emphasize on natural mapping of controls.

3.6.1 Headband

As the headband has only one control button and it is located at the front of the device, it is very easy to locate. Also, its operation is straightforward, and will be explained in the user guide, for users with previous experience with other wireless devices.

3.6.2 Software Interface

The goal of this system is to be as user friendly as possible. An area where we incorporate good practice of mapping is the settings page. Next to each menu option there are arrows placed to indicate to the end user that they will be taken to another page when selected. Overall, the design is using iconography which is commonly seen these days.

3.7 Constraints

In order to reduce the operator error and increase the usability of the design, we introduced constraints to the actions that can be performed by the users.

3.7.1 Headband

Largest constraints have been put on the headband, as the user has very limited amount of actions. Single button will allow the user to switch the device On and Off, and put it in Pair mode. No other actions are permitted. Data analysis and display are realized on the application.

3.7.2 Software Interface

To avoid overcomplicating the design we've incorporated a few constraints on the application. Firstly, we've limited the number of buttons on each of the pages to provide simplicity and efficiency. This ensures that the end user is not overwhelmed with the applications functionality but is easily able to operate it. Secondly, any important actions that might be caused accidentally are prompted twice.

4 Engineering Standards

Our project focuses on ensuring that the end user gets the best experience from using the headband and mobile application in a cost-effective manner. However, our prototype prioritizes safety and sustainability measures that is, we ensure that the end user is not impacted negatively from using the product.

The table below lists the Engineering Standards our prototype follows with references to each specific code. The table lists a number of Engineering Standards indicating how the symbols, icons and buttons on the screen should be represented. To add onto that, it describes how an application relaying medical information should be presented to the end user to avoid misleading them.

Table 25: List of Engineering Standards

<i>Engineering Standard</i>	<i>Description</i>
ISO/IEC 24755:2007	Information technology — Screen icons and symbols for personal mobile communication devices [34]
ISO/IEC 11581	Information technology — User system interfaces and symbols — Icon symbols and functions — Part 5: Tool icons [35]
SO/IEEE 11073-10472:2012	Health Informatics — Personal health device communication — Part 10472: Device specialization — Medication monitor [36]
ISO 9241-210:2019	Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems [37]

5 Usability Testing

5.1 Analytical Usability Testing

This section allows the development team to run and test the headband and mobile application and focus on the user interface. From performing these tests, the team will be able to come across any issues that are in the design. It also reveals difficult to complete tasks and confusing language.

5.2.1 Headband

1. Hold the power button. The headband turns on LED light indicator after being switched on
2. Push the power button twice. The headband flashes the LED light indicator while looking to pair via Bluetooth
3. Select headband in the bluetooth menu on the smartphone. The headband turns on LED light indicator after it's connected via Bluetooth

5.1.2 Mobile Application

1. The Privacy & Security document is presented to the user upon registration
2. Application clearly displays the navigation options
3. The icons on the navigation toolbar indicate which page is selected
4. The "Start Session" button highlighted only if the headband is connected
5. Graphs on "Statistics" page are clearly labeled
6. The received data is analyzed and processed
7. Information and settings on "Dashboard" page are clearly labeled
8. "Setting" page contains the Privacy & Security document.

5.2 Empirical Usability Testing

It's a major key to evaluate a product by testing it with representative users. During the proof of concept stage, the focus of the team is on the initial design, specification and verification of the application and headband testing. Unfortunately, due to COVID 19 we will have limitations in our testing methods. As a result, we might not be able to interact with target customers and testing will have to be done internally.

Empirical method of testing the product identifies issues by observing empirically the interaction of users with the interface of our product. When properly collected, the data from the survey can be very valuable to the team, as it will reflect real world use cases of the product. Unfortunately, this method heavily relies on the number of users that participate in the testing. More participants will uncover more problems and bugs. Below are the strategies and questions to answer for the empirical usability testing part.

5.2.1 Headband

The headband will have to go through extensive testing by the team members. They should use the headband overnight for a few days to determine any problems with the design. During this time, the headband should be reliable and safe. No mechanical damage should appear from the everyday usage. Also, the team has to test disaster recovery measures. Unfortunately, the number of headbands might be limited, so testing will be slower. Also, it will rely on team members only.

Each tester and/or target user should also answer the following questions:

1. Does the headband fit the user?
2. How easy is it to put the headband on?
3. Is the headband comfortable to wear overnight?
4. Is the interface intuitive?

5.2.2 Mobile application

The mobile application will also be tested by the team members. Fortunately, the mobile application could be installed on multiple devices and tested by multiple people (potentially by target users as well). Also, the team can load a mockup data into the phone to test all of the functionality that does not require the headband. Doing so, the team will minimize potential errors.

The team must address all of the edge cases and ensure that disaster recovery methods are working as expected.

Each tester and/or target user should also answer the following questions:

1. How easy is it to connect a headband to the phone?
2. Is the data displayed in a consumable form?
3. How would you use the displayed data?
4. Have you used suggestions on the “Dashboard” page?
5. What other information would you like to see about your sleep?
6. What additional analytics would you like to see?

6 Conclusion

Medeor product consists of two main components: headband and mobile application. The team has worked to deliver user interfaces and appearance for both parts.

The headband design was completed using 3DS MAX software. It was designed according to the results of our research on the analysis of human head shapes and sizes [38]. All of the parts of the headband were carefully designed. In order to deliver the appearance prototype, the team has to finalize the material selection for the headband, as the research is ongoing. In addition, internal location of the components can not be fully done at this stage, as some of the circuitry is at the POC stage and will decrease in size for the PT stage.

The team has also worked on the user experience for the mobile application (refer to section 2.2.1). All of the main functionality was considered and step by step workflow was presented and agreed with all of the team members. The next step was to create a detailed user interface and design for the application (see “Proposed Design” section under 2.2.1). The team has already started implementing the application using Android Studio and all of the pages are already coded (presented during progress meeting #2). As the team will conduct more empirical and analytical testing, the design is expected to change to fix the potential bugs. Additional functionality might be added, as the features are implemented. However, the UX of the application should stay the same. In order to deliver a proof-of-concept prototype the team needs to finish software testing and ensure that all of the possible workflows and edgcases are covered. Moreover, we will make sure to provide documentation that outlines the intended usage, safety and troubleshooting information of the product. We will include the overview and flow of the system.

References

- [1] "Sleep Tech Devices Market value to cross \$27 billion by 2025: Global Market Insights, Inc." [Online]. Available: <https://www.globenewswire.com/news-release/2019/11/05/1940912/0/en/Sleep-Tech-Devices-Market-value-to-cross-27-billion-by-2025-Global-Market-Insights-Inc.html>. [Accessed 11 Jun 2020].
- [2] "Insomnia and Its Impact on Physical and Mental Health,". [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3972485/>. [Accessed 11 Jun 2020].
- [3] "Snoring - Overview and Facts". [Online]. Available: <http://sleepeducation.org/essentials-in-sleep/snoring/overview-and-facts>. [Accessed 11 Jun 2020].
- [4] Muse. 2020. *Muse™ - Meditation Made Easy*. [online]. Available: <https://choosemuse.com/muse-s/>. [Accessed 7 July 2020].
- [5] Dreem. 2020. [online]. Available: <https://dreem.com/understand>> [Accessed 6 July 2020].
- [6] Philips. 2020. *Smartsleep Deep Sleep Headband | Philips*. [online]. Available: <https://www.usa.philips.com/c-e/smartsleep/deep-sleep-headband.html>. [Accessed 7 July 2020].
- [7] SleepPhones. 2020. *Fall Asleep Faster Headphone*. [online]. Available: https://www.sleepphones.com/fall-asleep-faster-headphone?gclid=CjwKCAjwxqX4BRBhEiwAYtJX7RfgtEhRBFxQQ_dafDrdLFSj6kncarelfKWcARnoes-AE-KZ1jErRRoCyKMQAvD_BwE. [Accessed 6 July 2020].
- [8] Fitbit Help. 2020. *How Do I Track My Sleep With My Fitbit Device?*. [online]. Available: https://help.fitbit.com/articles/en_US/Help_article/1314> [Accessed 6 July 2020].
- [9] "(PDF) Analysis of Human Head Shapes in the United States," *ResearchGate*. [Online]. Available: https://www.researchgate.net/publication/264024487_Analysis_of_Human_Head_Shapes_in_the_United_States. [Accessed: 13-Jul-2020].
- [10] S. Tong, *Quantitative EEG analysis methods and clinical applications*. Boston: Artech House, 2009. [Online]. Available: <https://ebookcentral-proquest-com.proxy.lib.sfu.ca> [Accessed 11 Jun 2020].

- [11] P. Ian G. Campbell, "EEG Recording and Analysis for Sleep Research," [Online]. Available:
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2824445/>. [Accessed 14 Jun 2020].
- [12] "Experiment: EEG-Record from the Human Brain", *Backyardbrains.com*, 2020. [Online]. Available:
<https://backyardbrains.com/experiments/EEG>. [Accessed: 07- Jul- 2020].
- [13] Aurlien, H., Gjerde, I., Aarseth, J., Eldøen, G., Karlsen, B., Skeidsvoll, H. and Gilhus, N., 2020. *EEG Background Activity Described By A Large Computerized Database*.
- [14] "Pulse Sensor Pinout, Configuration & How Pulse Sensor Works," Pinout, Configuration & How Pulse Sensor Works. [Online]. Available:
<https://components101.com/sensors/pulse-sensor>. [Accessed: 12-Jul-2020].
- [15] "Heartbeat Sensor Circuit Diagram Working with 8051," EIProCus, 14-May-2020. [Online]. Available:
<https://www.elprocus.com/heartbeat-sensor-circuit-daigram-working-with-8051/>. [Accessed: 12-Jul-2020].
- [16] J. Murphy, Sparkfun. [Online]. Available:
<https://cdn.sparkfun.com/datasheets/Sensors/Biometric/PulseSensorAmpd-Schematic.pdf>. [Accessed: 10-Jul-2020].
- [17] "PULSE SENSOR," *WORLD FAMOUS ELECTRONICS llc*. [Online]. Available:
[https://media.digikey.com/pdf/Data Sheets/Pulse Sensor PDFs/Pulse_Sensor.pdf](https://media.digikey.com/pdf/Data%20Sheets/Pulse%20Sensor%20PDFs/Pulse_Sensor.pdf).
- [18] K. Davis, "Snoring: Causes, remedies, and treatment", *Medicalnewstoday.com*, 2018. [Online]. Available:
<https://www.medicalnewstoday.com/articles/303834>. [Accessed 15 Jun 2020].
- [19] "Adafruit Silicon MEMS Microphone Breakout - SPW2430." [Online]. Available:
[https://media.digikey.com/pdf/Data Sheets/Adafruit PDFs/2716_Web.pdf](https://media.digikey.com/pdf/Data%20Sheets/Adafruit%20PDFs/2716_Web.pdf). [Accessed: 10-Jul-2020].
- [20] A. Industries, "Adafruit Silicon MEMS Microphone Breakout - SPW2430," *adafruit industries blog RSS*. [Online]. Available:
<https://www.adafruit.com/product/2716>. [Accessed: 13-Jul-2020].
- [21] *Top PortSiSonicTMMicrophone*. [Online]. Available:
<https://www.mouser.com/datasheet/2/218/SPW2430HR5H-B-1290924.pdf>. [Accessed: 10-Jul-2020].

- [22] "Analog Devices." [Online]. Available:
<https://www.sparkfun.com/datasheets/Components/SMD/adxl335.pdf>. [Accessed: 10-Jul-2020].
- [23] A. Romaniv, "Microcontroller selection", Gitlab.com, 2020. [Online]. Available:
<https://csil-git1.cs.surrey.sfu.ca/capstone-1194-group-7/capstone/-/issues/29>.
[Accessed 15 Jun 2020].
- [24] "Arduino Pro Mini Pin Diagram, Technical Specifications, Alternative and How to Use It", *Components101.com*, 2020. [Online]. Available:
<https://components101.com/microcontrollers/arduino-pro-mini>. [Accessed 15 Jun 2020].
- [25] Srivastava, S., Chandra, M., & Sahoo, G. Speaker identification and its application in automobile industry for automatic seat adjustment. *Microsystem Technologies*, 25(6), 2339–2347. [Online]. Available:
<https://doi.org/10.1007/s00542-018-4111-z> [Accessed 15 Jun 2020].
- [26] *Amazon.ca*, 2020. [Online]. Available:
https://www.amazon.ca/SanDisk-Ultra-Carte-micro-adaptateur/dp/B073JWXGNT/ref=asc_df_B073JWXGNT/?tag=googleshopc0c-20&linkCode=df0&hvadid=292991886665&hvpos=&hvnetw=g&hvrnd=6423735456092842156&hvpone=&hvptwo=&hvqmt=&hvd ev=c&hvdvmdl=&hvlocint=&hvlocphy=9001527&hvtargid=pla-348080513499&psc=1.
[Accessed: 11- Jul- 2020].
- [27] "Lithium Ion Battery - 1Ah," PRT-13813 - SparkFun Electronics. [Online]. Available:
<https://www.sparkfun.com/products/13813>. [Accessed: 13-Jul-2020].
- [28] "HM-10 DataSheet," HM Bluetoothmoduledatasheet . [Online]. Available:
[https://people.ece.cornell.edu/land/courses/ece4760/PIC32/uart/HM10/DSD TECH HM-10 datasheet.pdf](https://people.ece.cornell.edu/land/courses/ece4760/PIC32/uart/HM10/DSD%20TECH%20HM-10%20datasheet.pdf). [Accessed: 10-Jul-2020].
- [29] Kevin M. Lynch, Nicholas Marchuk, & Matthew L. Elwin. [2016]. Chapter 11 - UART. In *Embedded Computing and Mechatronics with the PIC32 Microcontroller* (pp. 159–176). Elsevier Inc. [Online]. Available:
<https://doi.org/10.1016/B978-0-12-420165-1.00011-1> [Accessed 15 Jun 2020].
- [30] Y. qin, "Product Specifications," *Data Power Technology Limited*, 27-Nov-2017. [Online]. Available:
<https://cdn.sparkfun.com/assets/5/6/e/1/5/SPE-DTP603450-1000mah-3.7V-En-1.0V.pdf>.
[Accessed: 10-Jul-2020].

[31] "User Interface & Navigation | Android Developers", *Android Developers*, 2020. [Online]. Available: <https://developer.android.com/guide/topics/ui>. [Accessed: 08- Jul-2020].

[32] P. by D. Przybyla, J. W. A. says: J. Says: N. of Y. B. says: K. D. Says: J. says: D. R. says: J. says: and P. says: "Purple Color Psychology - Purple Meaning & Personality," *Color Psychology*, 17-Nov-2019. [Online]. Available: <https://www.colorpsychology.org/purple/>. [Accessed: 13-Jul-2020].

[33] M. Rouse, "What is discoverability (in UX design)? - Definition from WhatIs.com," *WhatIs.com*, 13-Nov-2016. [Online]. Available: <https://whatIs.techtarget.com/definition/discoverability-in-UX-design>. [Accessed: 13-Jul-2020].

[34] "ISO/IEC 24755:2007," ISO, 21-Jul-2017. [Online]. Available: <https://www.iso.org/standard/41525.html>. [Accessed: 13-Jul-2020].

[35] "ISO/IEC 11581-5:2004," ISO, 28-Jul-2017. [Online]. Available: <https://www.iso.org/standard/40060.html>. [Accessed: 13-Jul-2020].

[36] "ISO/IEEE 11073-10472:2012," ISO, 16-Nov-2018. [Online]. Available: <https://www.iso.org/standard/54364.html>. [Accessed: 13-Jul-2020].

[37] "ISO 9241-210:2019," ISO, 04-Jul-2019. [Online]. Available: <https://www.iso.org/standard/77520.html>. [Accessed: 13-Jul-2020].

[38] "(PDF) Analysis of Human Head Shapes in the United States," *ResearchGate*. [Online]. Available: https://www.researchgate.net/publication/264024487_Analysis_of_Human_Head_Shapes_in_the_United_States. [Accessed: 13-Jul-2020].