User Interface Design for Breathing Wearable

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21-07-2018
Final Version

Abstract

'As easy as breathing' is a saying that falsely implies breathing to be simple. Shallow breathing is a physical condition connected to stress, anxiety disorders, asthma, hyperventilation and pneumonia. Still is this condition not rare since it is unconsciously done by majority of people. A solution and a health alleviator for this is abdominal breathing. It was found to that abdominal breathing loweres blood pressure, heart rate, promotes clearer thinking, relieves stress, increases metabolism and supports detoxification in the body. Since abdominal breathing needs to be trained actively the breathing wearable 'Airleviate' has been developed.

The purpose of 'Airleviate' is to supply users with feedback about their breathing so that they are supported in their training to turn abdominal breathing into a habit. In order to give feedback is 'Airleviate' using respiratory inductance plethysmography (RIP) to measure breathing and machine learning algorithms to analyze the measurements.

This purpose of this graduation project was giving 'Airleviate' and interface for the user to interact with and show the feedback in an appropriate way. The to be answered research question is: *'How should the GUI of a breathing wearable be designed giving visual feedback to optimize breathing patterns and guide to habit formation of healthy breathing?'*

It was found that RIP is the best non-invasive measuring technique, habit formation can be supported by goal setting and biofeedback is very useful in terms of abdominal breathing. A market research found that there are a lot of apps and devices offered but no comparable one is developed yet.

Using this knowledge a first mock-up of a mobile phone application was developed, which contained several different data visualizations. This mock-up was reviewed by two different user experience experts. The reviewed concept was followed by developing a working prototype with Dart, so that the code can be compiled for Android and iOS. The result is shown in Appendix K. Briefly described does the user set a goal with the app, can see a flower representation of how well he is doing towards the goal, can see in depth data on timing, breathing frequency and periods and can compare measurements in terms of goals and timings of abdominal breathing.

This prototype was then tested by 5 pairs of users to encourage the communicativeness between the subjects. Results from these tests were obtained via filming, observations during testing and a survey filled in by the users at the end. The results showed that the app was generally understood well, intuitive and enabling reflection on breathing. Weak points were that explanations were partially distracting, too long or ignored by users.

The conclusion of this was that the research question is answered by the app supporting abdominal breathing, being mobile and simple, implementing goal setting and tracking and minimizing cognitive workload, giving several graphs and supplying clear explanations.

Recommendations given for future work are mainly realizing a real time connection between RIP belts, classification and GUI. Furthermore should the classification and GUI be fused into one program. Having these two given a real time analysis and feedback should be implemented into the system.

Acknowledgements

I would like to thank several people for their time, dedication and support toward this project. At first I would like to thank my supervisor Erik Faber. He was very attentive to give good support and guidance especially by frequent personal meetings and support on content. Next I would like to thank my client Ben Bulsink who made it possible to work on such an interesting project and who was taking a lot of time to give elaborate feedback.

Furthermore I would like to thank my critical observer Geke Ludden and Armağan Karahanoğlu for taking time to give me elaborate feedback on my design concepts.

I would also like to thank Arnav Mundkur, who has been working on the classification algorithms, who worked together with me closely and supplied the data to be used for the GUI.

In addition are my thanks going out to all the participants of my group brainstorm, interviews and usability test, who gave great support in shaping the prototype.

Finally I would like to thank Peter Bastiaan den Boer for supporting the coding process a lot. Without him making such a great working prototype would have not been possible.

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Chapter 1- Introduction

Shallow breathing, also called breast breathing, is a pattern to suck air into the area of the chest using the muscular structure between the ribs instead of using the diaphragm to inhale air deeply into the lungs [46]. The condition of breathing shallowly is seemingly done unconsciously throughout the day by the majority of people. It repetitively occurs that shallow breathing is named as a cause for several unhealthy conditions. Since shallow breathing does not allow the air to reach the lower parts of the lungs, which has the highest concentration of blood vessels for gas exchange, respiratory problems come along with this pattern of breathing [46]. Most commonly connected are issues like stress, anxiety disorders, asthma, hyperventilation and pneumonia [47].

The Key figures on health pocketbook [21] states that 39.1% of the European population feels stressed on a regular basis. Moreover did Eurostat [22] publish in 2016 that mental and behavioural disorders are one of the greatest disease category in the EU. This is a quite relevant issue since the number for most in-patient bed days for mental and behavioural disorders in the EU has been second most right after circulatory system diseases [22].

However simple methods might already be a solution for minor troubles or a useful prophylactic action. When the diaphragm is used to breathe, called abdominal breathing or diaphragmatic breathing, the downwards movement of diaphragm and its contraction enable a full expansion of the lungs. Due to this a maximum oxygenation can be reached by a breath. As a result there are several positive side effects like, lowered blood pressure[1], lowered heart rate[2], promotion of clearer thinking, stress relieve[3], increased metabolism, support of detoxification in the body[4].

This chapter will give at first an introduction into which problem is actually to be solved by this graduation project. Afterwards important repetitively occurring terminology will be elaborated on in a context analysis. This is followed by an explanation of the wearable that will be further developed during this project. Then the research question and its sub-questions will be stated. And finally an outline of the report is supplying the structure of the following document.

1.1 Context analysis

The necessity of giving a context analysis with explanation of important and repetitively used terminology should not be neglected to give a clearer idea of each statement. By this means following there will be short explanations of that terminology.

1.1.1 Diaphragmatic breathing & abdominal breathing

These two terms are interchangeable expressions for a type of breathing that is mainly used promoting more effective aeration of the lungs by a downwards movement of the diaphragm during inhalation and an upwards movement during exhalation[23]. So this breathing pattern's ventilator work is by the biggest parts executed with the diaphragm [23]. Since the contractile force of the abdominal muscles is used to elevate the diaphragm [24] it is also called abdominal breathing.

1.1.2 Biofeedback

Biofeedback is a treatment giving a patient feedback on his or her physiological information [25]. The patient gets usually shown a screen normally unaware body data that can help to create a different thinking about the shown body process [25]. This mental state involuntarily seems to lead to an extended control about body functions and is used for a variety of conditions and diseases [25].

1.1.3 Graphical User Interface

GUI is the short term for graphical user interface and following it will be referred to as GUI. It is a user interface that is consisting of graphical components like windows, icons and buttons [26]. An interface is the point of interaction between people and technologies [54]. Because of the variety of digital devices a GUI needs to be designed for the correct type of input like touch screen, mouse and keyboard, voice, remote controls or voice [26]. Since each input type supports different commands like swiping or pinching for touch screen the design has to be adapted [26].

1.1.4 Respiratory Inductive Plethysmography

The also RIP called method of monitoring of respiratory parameters in respect to thorax area and abdominal area [27]. It utilizes two elastic belts, one strapped around the thorax close to the area of the nipples and a belt strapped around the abdomen on height of the navel [28]. Both of these belts contain a long copper coil which's inductance changes by the thoracic and abdominal movements while breathing [27]. This technique enables a thoracic cross-sectional measurement giving information about ventilatory parameters like tidal volume and respiratory patterns [28]. In chapter 2.2 RIP is more elaborated on and a visualization of it can be seen.

1.2 The wearable device

For the wearable having the project name 'Airleviate' the GUI will be developed for is measuring breathing with two elastic inductive belts meaning it is made use of the before explained RIP method. By expansion of the belts it can measure breast as well as belly breathing. The separation of both types of breathing enables the wearable to be used for even more accurate feedback on breathing patterns. The so far developed prototype battery powered wearable breathing sensor with daylong data storage including an accelerometer as well as the availability time stamping data with a Real Time Clock. The aim of the wearable is that behaviour can be trained effectively supported by giving biofeedback and result into habit formation.

The wearable is developed by Ben Bulsink, who is an independent product developer. He gathered experience in bringing rough product ideas to live for 30 years already. He has a background in measurements technology. He successfully developed a game timing device and RFID based object tracking technology on a game board. The complete chain of development and production is known by him.

1.3 Problem statement

Since the wearable does only measure breathing so far, the tackled problem of this graduation project is providing users of a breathing wearable with useful feedback. The techniques of abdominal breathing can be unlearned by meditation training, Tai Chi or Yoga as well as breathing training wearables. But still so far there are no developed products using Respiratory Inductive Plethysmography. To use such measurement technique the biodata needs to be classified and classified data needs to be translated into useable information for a user. It is necessary to supply the user with a GUI giving all necessary data to improve on the breathing habit and support the formation of a new breathing habit. Such feedback and GUI need be shaped in a way that they get an easily usable tool for a casual user. For transforming the biodata into a useful tool for a casual user of the wearabele, it is crucial to develop a UI supporting certain ways of habit formation but be still visually appealing and informative.

1.4 Research Question

Building forth on the above given problem statement a research question was formulated.

- **How should the GUI of a breathing wearable be designed giving visual feedback to optimize breathing patterns and guide to habit formation of healthy breathing?**

To support answering this research question four sub-research question were formulated.

- Which technique is the optimal one supplying healthiest breathing?
- How should the GUI be presented to the user in regards to user experience and technical requirements?
- Which methods of user motivation can keep a user practicing to reach a set long term goal?
- How can instruction impulses to optimize breathing be presented in the most effective way?

1.4 Outline

Here an outline of the whole report will be supplied. In chapter 1 – Introduction the reader is introduced into the topic of the graduation project and base knowledge is supplied to understand terminology and the purpose of the project.

Chapter 2 is covering the background research that was conducted. The background research is split into two parts, namely the literature research and the market research. The literature research is giving scientific information about breathing, measurement techniques, biofeedback and habit formation. The market research elaborates about existing devices and applications for health or breathing training. This knowledge shall be used as bases for the ideation phase.

This is followed by Chapter 3 which provides an overview of all the methods and techniques that were used during project. The creative technology design process, which is used for this project, is elaborated

on as well as single methods that were used. The purpose of the chapter is to understand the process of answering the research question.
Chapter 4 describes the Ideation phase. In this phase are the conclusions of chapter 2 taking into account for creating different application ideas. By using the methods and techniques that are described in chapter 3 a final concept is chosen. The goal of this chapter is generating several creative ideas to choose from for the most feasible concept.
Chapter 5 describes the specification phase. Within this phase are the functionalities of the chosen idea described. Several diagrams will visualize these functionalities. The goal of this chapter is to understand the functional structure of the application, which is necessary to develop the prototype.
Chapter 6 covers the realisation phase. This phase elaborates on the development of the prototype. The goal of this chapter is to give an understanding of made choices during the development process.
Chapter 7 describes the evaluation phase of the project. Within this phase functional as well as usability tests and their results are described. The goal of this phase is to evaluate how well the developed prototype is fulfilling its purpose and how well it is picked up by users.
Chapter 8 is the final chapter that gives conclusion and recommendation for future work. The goal of the chapter is to sum up and conclude the whole project in reference to the research question and make recommendations for successors of the project.

Chapter 2 – Background Research

For reaching the goal that is aimed for by the project a state of the art research in combination with background research needs to be conducted. The purpose of such research is giving a sophisticated background for the following up ideation phase. By that means background research is given on physiology, habit forming, biofeedback and RIP as well as state of the art devices and mobile applications are presented.

2.1 Physiology

2.1.1 General Health

When discussing breathing patterns and especially focusing on abdominal breathing the most useful question to answer is: 'What benefecial effect does abdominal breathing have on your genral health?' In this context 'general health' will mean common body circumstances or systems, so that the effects of abdominal breathing on these will be investigated on.

The effects of abdominal breathing on healthy individuals have widely been studied, as Kawai et al [4] did in 2015. Main focus of the study has been the lymphatic drainage and the body substance levels that increase or decrease with drainage. Lymph drainage is an essential part of the body's defense mechanism [4]. The conducted experiment found that by practicing abdominal breathing in a laying supine position for a time span of 30 minutes is significantly decreasing the total proteins, red blood cells, white blood cells, platelets, albumin and antidiuretic hormone in every subject's blood [4]. Furthermore abdominal breathing was found to be more effective in lowering the level of anti-diuretic hormone than other lymph drainage method [4]. When the lymph system is working correctly it induces immune defence, so that the drainage effect of abdominal breathing can be said to have a positive effect on the general health. However Kawai et al [4] investigated mainly on a general drainage effect by abdominal breathing as well as only comparing it with manual drainage by lower extremities massage.

Postprandial oxidative stress, meaning the production of toxic metabolic products [6] after a meal, is a condition that not only comes along with diabetes, smoking or athlete's diets but also effects healthy individuals [5]. Taking this into account Martarelli et al [5] investigated on the influence of diaphragmatic breathing after eating on plasma levels of glucose, insulin, reactive oxygen metabolites and biologic antioxidant potential. The subjects involved in the study either conducted 40 minutes of abdominal breathing after a meal or just had to read a magazine for the same time span [5]. Afterwards it was found that abdominal breathing seemingly did improve the subject's health situation not only by reducing the heart rate but also by reduction in glycemia as well as increase in antioxidants levels and insulin production [5]. Although these values sound promising in terms of general health, Martarelli et al [5] suggests abdominal breathing as interesting procedure for diabetes, obesity and smokers although the experiment was conducted with healthy subjects.

A different case study conducted by Martarelli et al [7] focused on exercise induced oxidative stress. According to the connection of oxidative stress and a variety of conditions like heart diseases, arthritis,

hypertension, atherosclerosis and aging [7], the stress level was measured by determination of cortisol and melatonin levels. The study was conducted with professional athletes, who were examined to be healthy, in the preparation phase for a 24 hour bike race [7]. The diaphragmatic breathing was performed for an hour shortly after and intensive training session [7]. Next by taking blood plasma samples melatonin and cortisol levels were determined [7]. Martarelli et al [7] found the relaxation created by diaphragmatic breathing to increase the melatonin level and decrease the cortisol level. This leads Martarelli et al [7] to suggest diaphragmatic breathing to be an appropriate recovery procedure in long terms for athlete's free radical activity. Nevertheless there was no direct measurement of free radical activity as well as it was stated that further research on this is necessary.

Counting in not only body responses to the general health but also mental wellbeing Ma et al [8] decided to investigated on these in 2017. In addition to the in other studies already measured cortisol influence in healthy adults, Ma et al [8] also searched for a connection between diaphragmatic breathing and attention as well as affects. As result the half of the 40 subjects being trained for 8 weeks, showed significant higher attention in comparison to the baseline, lower physical stress indicated by cortisol as well as psychologically measured less negative affects [8]. However the seemingly promising results lead only to state a general supportive function of diaphragmatic breathing.

In contrast to the supposed beneficial findings for improving the general healthy it seems that abdominal breathing is in some cases also more useful than medication. Kaushik et al [9] found that the treatment of migraines with propranolol 80mg in comparison to abdominal breathing has no significant difference. Nevertheless the less abdominal breathing practiced for a time span of a whole year showed a significant greater prophylactic effect than the medication [9]. In fact the resurgence of migraines using the medication was 38.54% and the resurgence with abdominal breathing treatment was 9.37% [9]. Although the usefulness of abdominal breathing for migraines is not directly tackling general health it could be said that the preventive effect is beneficial for the general health.

Taking all this into account it could be said that abdominal breathing has not only a beneficial effect on the general health in terms of physiology and psychology but also shows to be a promising preventive treatment for certain issues.

2.1.2 Symptoms and Illnesses

Given that migraine is an illness that can be treated prophylactically by diaphragmatic breathing, this leads to symptoms and illness than can be influenced or treated with practicing such. The question for this part of the review is 'Which symptoms or illnesses can be treated or alleviated with abdominal breathing?'

Several physiological positive effects in terms of treating symptoms and illnesses have been found during studying abdominal breathing. To begin with not only migraines [9] as mentioned earlier before but also the rumination syndrome which is a very little understood gastrointestinal disorder was found to be treatable with abdominal breathing [10]. Chitkara et al [10] found that diaphragmatic breathing can help to reverse the habit of abdominal wall contraction, which is a symptom for rumination syndrome that is

connected to the regurgitation. As a result of that treatment 30% experienced complete resolution of the problem while 56% reported an improvement [10]. Considering the complete resolutions abdominal breathing might be called a cure for the illness.

Likewise Chronic Obstructive Pulmonary Disease (COPD) has also been found to be an illness to be co-treatable with abdominal breathing [11]. The subjects of the study experienced increase in lung volume, respiratory motion and SpO2 and a reduction in respiration rate [11]. Nevertheless [11] claimed the diaphragmatic breathing for COPD to be of value as supporting treatment in respiratory rehabilitation programs.

Besides these physiological symptoms to be treated Wang et al [1] found that slow abdominal breathing decreases the systolic blood pressure for subjects having prehypertension. Furthermore to these finding Cheng et al [12] detected on women in preterm labor using abdominal breathing not only a decrease of blood pressure but an increase of oxygen saturation, peripheral skin temperature and decrease of anxiety. And so this gives the possibility of not only treating physiological issues but also mental issues.

In addition Yu and Song [13] investigated further on women in preterm labor and demonstrated abdominal breathing to decrease Ritodrine and Atosiban (drugs known in connection with preterm birth) as well as lowered stress and state anxiety. [13] suggested abdominal breathing as effective nursing intervention for pregnant women in preterm labor. Since these studies only take preterm labor into account it would be interesting to see whether anxiety under different conditions might be treatable with abdominal breathing.

Chen et al [2] did such a study with 46 subjects investigating the general effects of diaphragmatic breathing on anxiety. It was found that diaphragmatic breathing was an easy relaxation technique that could be used to alleviate symptoms of anxiety, heart rate and breathing rate [2]. Furthermore Chen at al [2] reported no negative side effects were found and suggested to use diaphragmatic breathing for anxiety level of care recipients in clinical and community settings [2]. Additionally Kim and Kim [14] supplied a study trying intervention on mental health and leukocytes number for hemopoietic stem Cell transplantation patients. The exercise group had to perform abdominal breathing training for 30 minutes every day for 6 weeks. Although abdominal breathing did not show any effect on the number of leukocytes not only a reduction of anxiety symptoms but also on depression symptoms was claimed [14].

Considering the variety of symptoms and illnesses that can be improved or treated by practicing abdominal breathing and addressing not only physiological but also psychological issues, the praxis seems to be of good use for clinical treatments. As it was found in an interview with Parviz Sassanian, a traditional Chinese doctor, can breathing be used to treat eczema, diabetes, fears and anxiety. Furthermore can breathing be used to influence the personality according to Parviz Sassanian. The interview notes from the interview with Parviz Sassanian can be found in Appendix C.

Although having such a big variety of positive effects in terms of abdominal breathing it is never quite clear in which time span such need to be practiced. The effects for diaphragmatic breathing seem to be so impactful nevertheless does there not seem to be a clear time span that is needed to reach certain effects. First all before mentioned studies were mainly investigating on a particular symptom or illness to

cure. However all these had very different designed experiments with very different approaches of training abdominal breathing timewise. Kim and Kim [14] used an approach with daily 30 min training for 6 weeks, Ma et al [8] were training abdominal breathing in 20 sessions for 8 weeks and Kaushik et al [9] let the subjects train abdominal breathing over a long term with decreasing frequency of guidance and followed home practice in a total period of a whole year. Additionally an expert interview with Ineke Ter Hedde, who is a singing coach also teaching breathing, stated that there is no clear point when to observe beneficial health effects. Nevertheless Ineke Ter Hedde stating, that she usually lets her students train breathing for a whole year, as well as Kaushik et al [9] showing only an advantage over medication between the time of training half a year to a whole year, gives an indication of abdominal breathing being to practice long term. The interview notes from the interview with Ineke Ter Hedde can be found in Appendix B.

Considering the conduced literature review on physiology the optimal way to tackle mental as well as physical symptoms should be treated with abdominal breathing in combination with biofeedback when it is considered to search for improvement optimizing breathing patterns. This can be concluded from not only the finding that first of all abdominal breathing has a beneficial effect on general health in terms of physiology, psychology and general prevention but also can be used for goal oriented clinical treatments of symptoms or illness.

2.2 Respiratory Inductive Plethysmography

The before briefly explained respiration measurement technique called RIP is not only the so far used method by Ben Bulsink for his wearable but also needs to be validated by background research as an appropriate method of measurement. Actually it was investigated on non-invasive respiratory measuring methods. Cohen et al [29] stated that RIP was during several different manoeuvres like motion artefact, simulated airway obstruction, yawning, snoring, apnea, and coughing has been the most accurate method in comparison with other non-invasive ones. Although Cohen at al [29] conducted their study around 20 year ago it still seems valid, since Retory et al [30] claimed in 2016 RIP to be a method sufficiently accurate to evaluate tidal ventilation variation during mild and moderate activity. Moreover RIP showed also to be a promising technique for respiration measurement during activity as a mobile device [31], which is not to be neglected as important point concerning the wearable that is to be developed.

Figure 2.2 [35]

2.3 Habit forming

Since the breathing is done by somebody for as long as they live, it is most probably an individual's oldest habit. Therefore it is a major point to actually know how a new habit can be formed to reach the objective to changes somebody's breathing pattern towards improvement. Furthermore it is really important to make an improved breathing pattern a habit to sustain such a breathing pattern to result into health benefits. A first process to support successfully forming habits is setting a link between a thought and an action [**18**]. Meaning that there is not only set a goal but also a mental simulation of process leading to the outcome is modelled by the individual trying to form the habit. A controlling mechanism for self-monitoring the process is a functioning tool [18]. In addition an if-then action plan for habit forming can improve automaticity of processes [**19**]. While mentally simulating the process of forming the new habit planning certain actions in connection with other actions or happenings create automaticity [19]. Automaticity by linking temporal overlapping activities decreases the cognitive effort to maintain a habit [**20**]. A key could be linking habits to other habits since forming new habits are disrupted by not routine shaped periods like vacation [20].

2.4 Biofeedback

Biofeedback is a treatment giving a patient feedback on his or her physiological information [25]. The patient gets usually shown a screen normally unaware body data that can help to create a different thinking about the shown body process [25]. This mental state involuntarily seems to lead to an

extended control about body functions and is used for a variety of conditions and diseases [25]. In connection with medical studies and abdominal breathing the word biofeedback appears repetitively. In most studies abdominal breathing training was combined with given biofeedback. Due to this and especially because of its connection to the Graduation Project the following question should be answered: 'What is the meaning of biofeedback concerning efficacy of abdominal breathing training?

Morris et al [3] researched on the home use of biofeedback also in combination to breathing. The feedback was aimed to be used as home therapeutic concept. The results claimed to be promising for delivering state-of-the-art psychotherapies in a non-stigmatizing fashion to many people who otherwise would not have access to therapy [3]. Furthermore Wang et al [1] explicitly searched for the difference between abdominal breathing training with and without biofeedback. Seemingly the positive effects of the breathing training were even enhanced by using biofeedback meaning that not only systolic blood pressure but also diastolic blood pressure was decreased with using biofeedback [1].

Furthermore when keeping in mind there is a GUI to be created it is also relevant to investigate in which presentation of biofeedback has the biggest impact to support the training of abdominal breathing. Considering how to visualize a breath in general a variety of possibilities could be contemplated. Two possible designs have been compared by Chittaro and Sioni[**15**]. The breath visualization as in sphere shape was investigated on in comparison to a wave visualization under terms of efficiency for breath training. As the wave form showed in all ways to be more effective than the sphere due to its property of giving a better overview for the breathing pattern over time. An overview of the breathing pattern overtime in the way of watching your history and sharing it with a community was found extra positive compounds for a breathing application [**16**]. Taking that into account an extra possible improvement of that way visualizing biofeedback would be adding motivation with gamification [16]. Gamification being a method of adding more meaning to biofeedback visualization was studied by Wollmann et al[**17**] with the finding that even though the multitasking factor of gamification decreases initial effectivity of training, it is preferred by users.

2.4.1 Conclusion

Concluding all this abdominal breathing does not only show to be beneficial for the general health with its effects on detoxification, metabolism and oxidative stress, but also seems to be very useful for treating several symptoms and illnesses. Abdominal breathing turns out to be the healthiest breathing pattern. Additionally RIP as non-invasive accurate respiration measurement method seems to be applied for such a wearable. Also it could be said getting biofeedback while being trained abdominal breathing improves the efficacy of positive effects and will therefore be an important part in the development of the project. Furthermore biofeedback for breath should be presented in wave form and gamified if possible.

2.2 Market research

Another very important aspect for the state of the art research is a market research to see actual products that have already been developed or find inspiration. It is curial to take a look into other applications as well products for developing successfully a GUI for Ben Bulsink's wearable. Therefore following there will be devices and application be presented on health, relaxation and breathing. The applications that are coming along with devices will not be mentioned again in the segment of applications. The apps and devices were chosen by their functions or designs to be useful inspiration in later phases of the project.

2.2.1 Devices

The devices as well as its apps will be explained and how they are sensing bio data and how they are supposed to help the user and specialties about them will be emphasized.

2.2.1.1 Spire stone

The Spire stone is a small device that has to be clipped to the belt. Using an accelerometer and algorithms the Spire stone is capable of tracking the users breathing. The Spire stone has to be connected to the Spire mobile phone app so that one can observe his or her breathing. It is supposed to keep the mind and body in sync by constant breath measurements and it reacts to sudden changes by suggesting relaxation exercises as part of the app. In addition the Spire stone claims to track body exercises as well as progress on these. As it can be seen in the picture below does the app work with the wave form visualization of the breath and offers app internal relaxation and breathing exercises. The measurements are conducted by using an accelerometer.

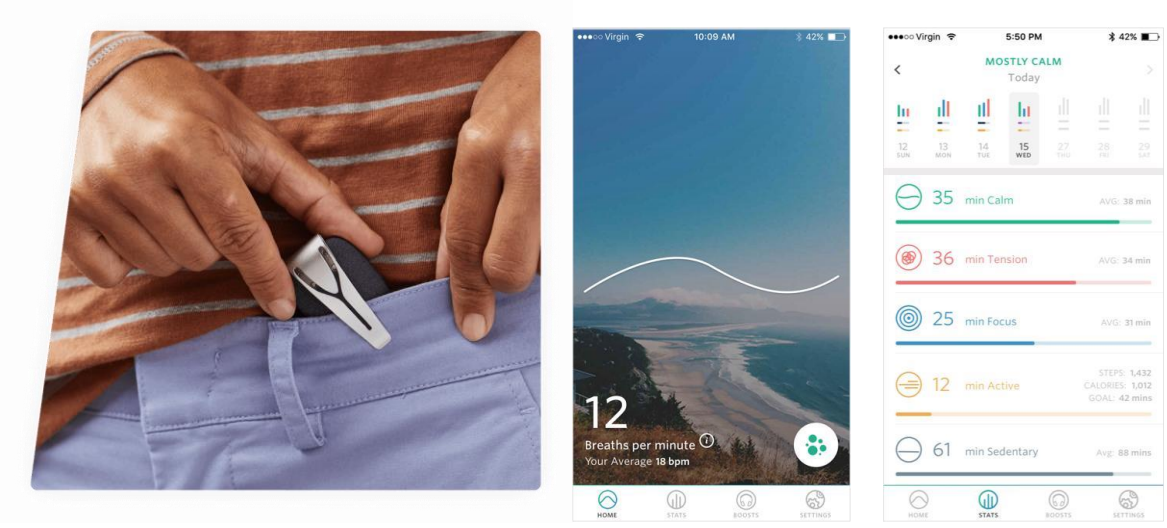
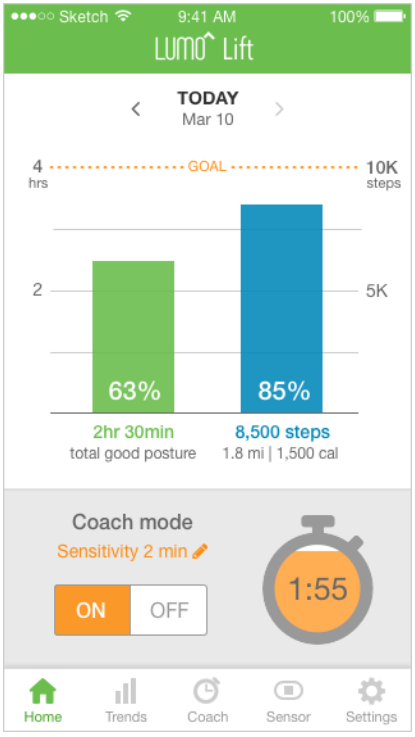


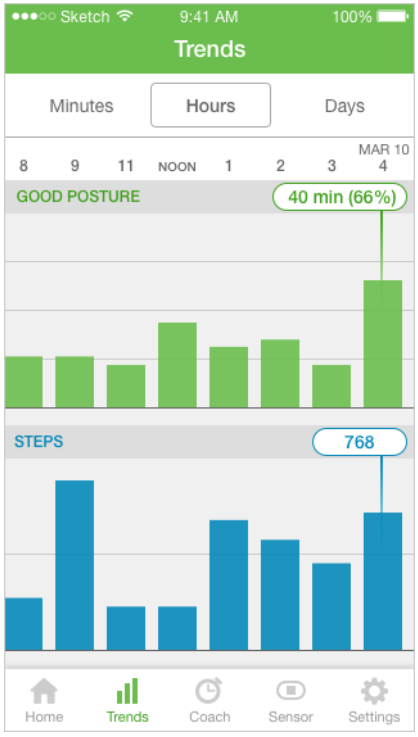
Figure 2.2.1.1 [33]

2.2.1.2 LUMO Lift

The posture correcting device called LUMO Lift makes also use of a combination of device and mobile

app. The device that is connected via Bluetooth with your phone carries a accelerometer that is clipped to the clothes close to the collar. This way the LUMO Lift tracks the body posture and can remind user to sit straight. Additionally, the LUMO Lift also measures physical activity and provides statistics about it. In the first place the LUMO Lift does not directly seem to be too interesting for a market research, still for the project it is of relevance since its app underwent a major redesign [32] in terms of aesthetics and functionality, which can provide useful information for the GUI development. All measurements are done by an accelerometer.



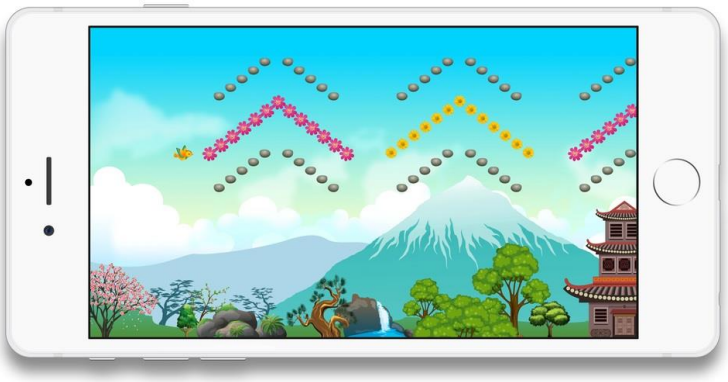


[34][32][32]

During a user research conducted by the designer in charge several problematic factors were found. A major point of concern in the eyes of the users was missing detail on their Trend page [32]. The users wanted to be able to gather more detailed information about their activity and posture on a minute base during the day [32]. Since there will be no real time feedback this is a point really to take into account for the design process. Moreover several users had troubles with too hidden functions of the application [32], which should definitely not be neglected during the design process and also tested with users. Finally it has also been a problem that data was hard to compare in the old design and therefore made it hard to monitor the progress over time [32]. This fact should certainly be taken into account developing the design in terms of functionality especially since before it turned out that monitoring the progress is a key factor for habit forming.

2.2.1.2 Prana

Prana is a device that could basically be described as a combination of LUMO Lift and Spire Stone. It also measures the breathing and by that the stress level as well as informs the user about sitting in bad posture. As the Spire Stone it is clipped to the belt and works with an accelerometer as measurement method. Furthermore the application also provides breathing and relaxation exercises. However the extra feature that is provided by the Prana is the gamification of a breathing exercise. The user has to manoeuvre a bird through obstacles while collecting flowers, which is controlled by the breath. Below you can see the game and the device.



2.2.1.2 [36]

2.2.1.3 Zensorium Self

Another device is the Self by Zensorium, which comes with the look of a smart watch. The Self is supposed to give an accurate picture of the stress levels by using an optical sensor to measure pulse pressure. Furthermore an accelerometer is built in to supposedly give feedback about your activity and your sleep. The Self works independently from other devices like a phone. Zensorium Self shows that an UI oder GUI can not only be provided by including a smart phone.

Figure 2.2.1.3 [37]

2.2.1.4 FocusBand

The last device to be introduced is the FocusBand. It works with a 2 channel EEG system and tries to teach control over several mental states by neurofeedback. By measuring brain waves information on mental state is given and using a phone application in combination with the FocusBand is supposed to teach how to reduce stress and cognitive anxiety. Moreover there are several additional applications for different purposes like finding focus or calming your mind, which are gamified and an example can be seen on the left.

Figure 2.2.1.4 [38][39][39]

2.2.2 Mobile Phone Applications

In addition to the commercial devices that have been discussed before there are also a lot of mobile phone applications on mindfulness and breathing exercises. In the following these apps will be introduced, functions described and elaborated on how they try to help. Furthermore if there are design specialties these will be described.

2.2.2.1 BreathingZone

The app analyses the breathing rate of the user with the phones microphone. Afterwards the user can set a goal of breathing rate he wants to go for and will be guided towards this by a virtual voice coach. The user can decide on the length of the sessions, background sounds and the look of the animated breathing guide. Additionally weekly targets can be tracked. The app claims to lower blood pressure and heart rate by using it.

Figure 2.2.2.1 [40]

2.2.2.2 Prana Breath

The Prana Breath app gives the user the possibility to train 8 different breathing patterns and even gives the users the possibility to create their own patterns. Additionally can the users plan out their own whole training schedule and set reminder for the sessions. The breathing sessions are supposed to support meditation and have long term effects like better thinking, anxiety relieve and decreases frequency of illness. The app also provides big statistical overviews to keep track of the progress.

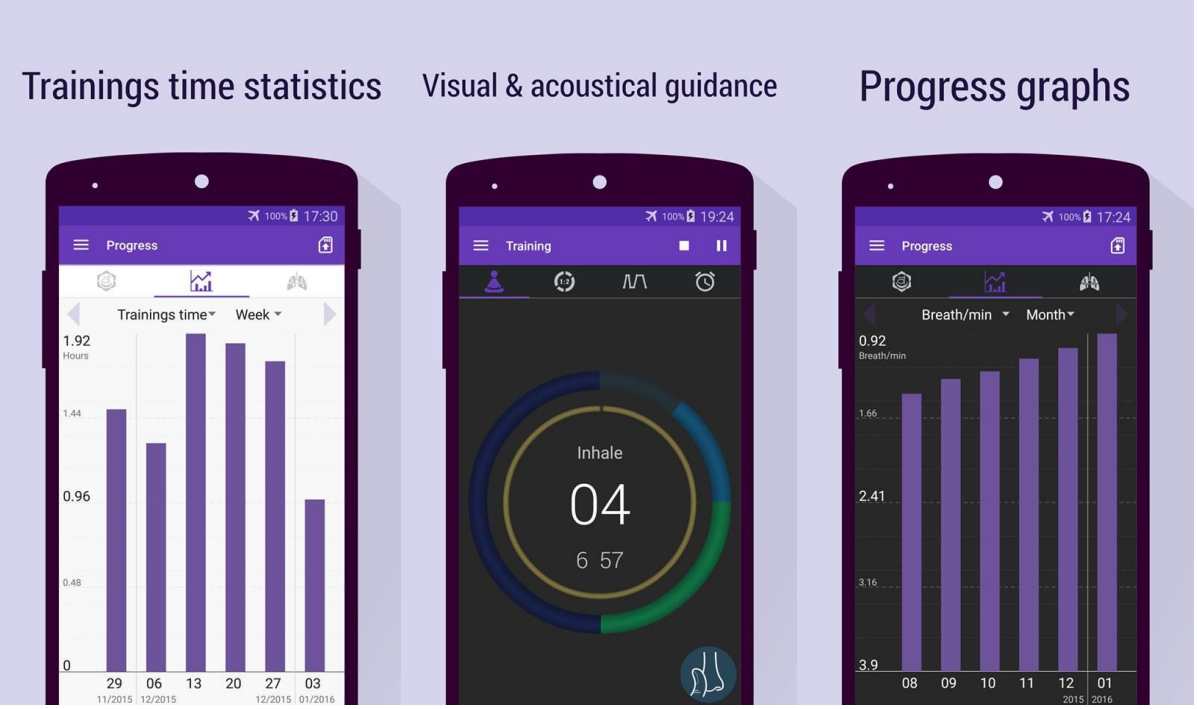


Figure 2.2.2.2 [41]

2.2.2.3 Breathe2Relax

Breahte2Relax mainly focuses on teaching abdominal breathing for health purposes and stress management. It guides you through training of abdominal breathing to improve certain conditions and was described to be suitable for tandem use with clinical healthcare workers.

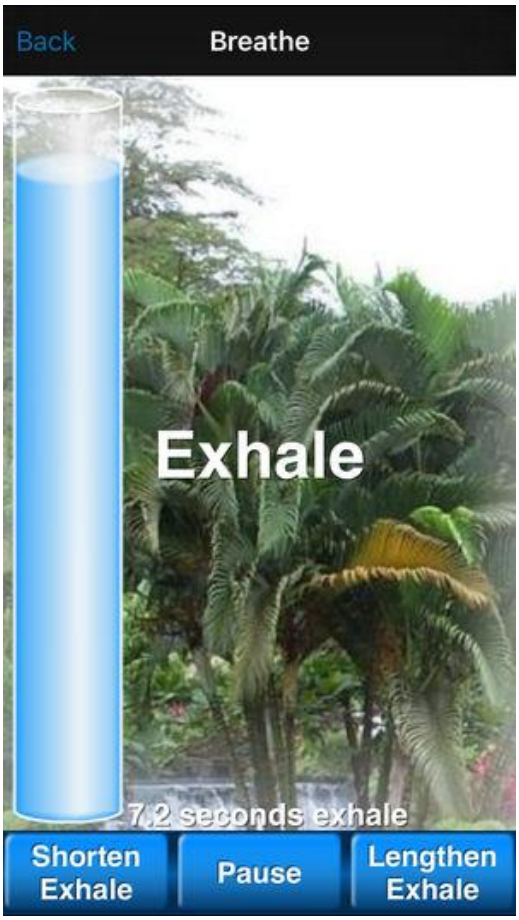


Figure 2.2.2.3 [42]

2.2.2.4 Box Breathing

The application called Box Breathing only focuses only the breathing pattern after which it is named. Nevertheless the app provides statistic overviews that might be useful as inspiration and also make use of gamification by leveling up over time.

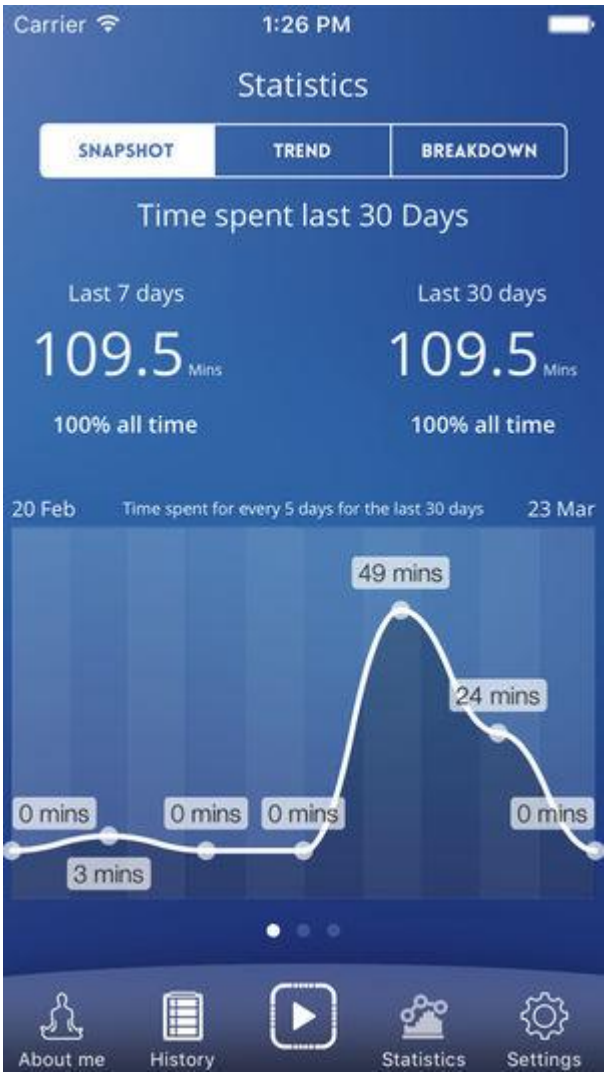


Figure 2.2.2.4 [43]

2.2.2.5 BellyBio

The unique feature of this application is that abdominal breathing is sensed by putting the phone on your belly while practicing. The accelerometer built in the phone is used to sense how you are doing with the breathing pattern. Additionally the breathing conducted by the user is shown in a wave form which was stated earlier to be a more effective way than in a circular shape. Nevertheless the app does require belly breathing was learned already as well as placing the phone correctly on the belly.

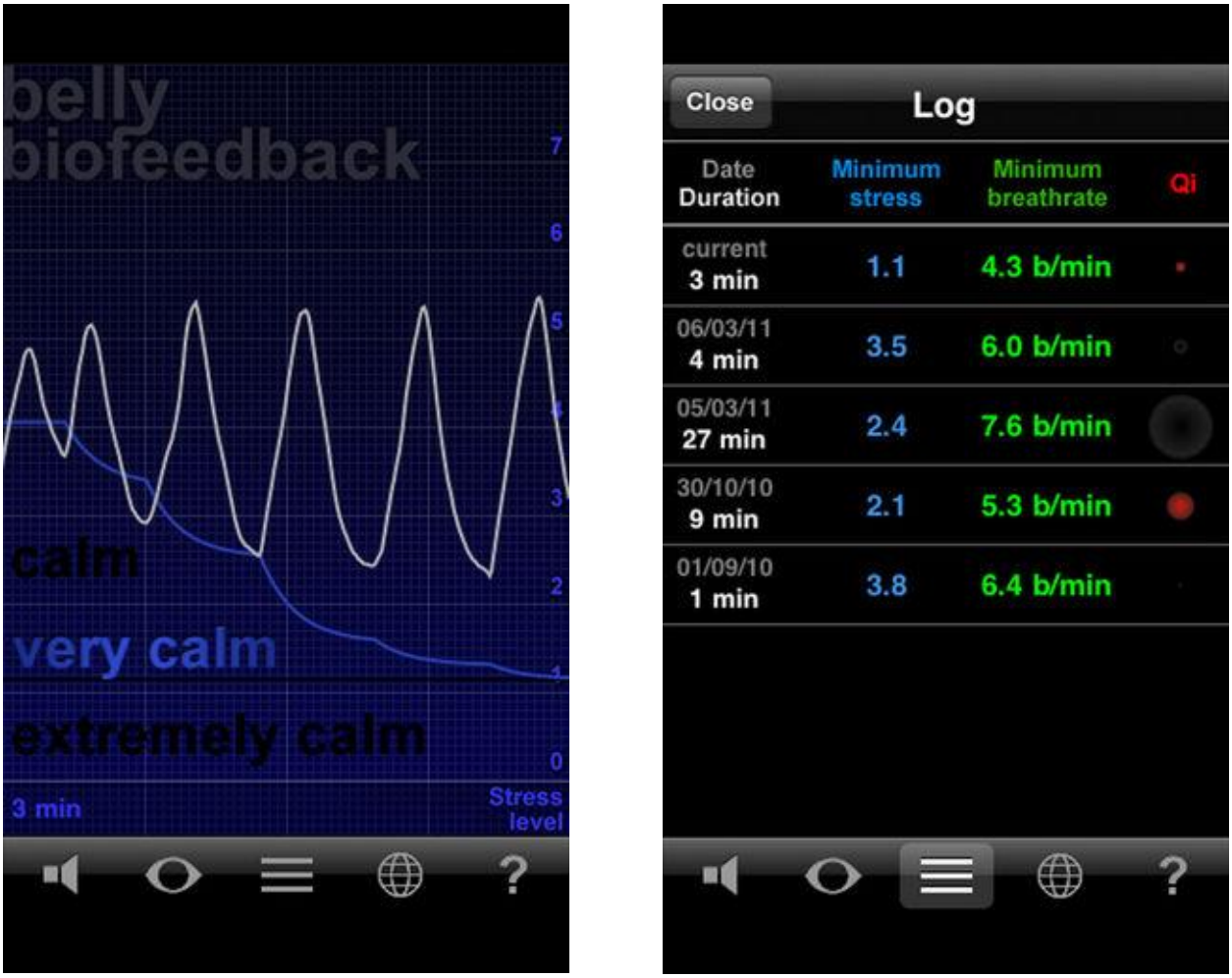


Figure 2.2.2.5 [44]

2.2.2.6 Meditation Studio

The app is offering over 200 guided meditations guided by different teachers and separated into different topics. The app tries to improve people's lives on different layers meaning physical, mental and social. The courses are divided into different diving steps starting with essentials, going over to uncovering happiness and getting finally to changing habits. This part is really interesting because it is aimed deep enough to change habits. Self-made meditation schedules and progress monitoring are implemented as well. Finally there is also the possibility to stream the app via Chromecast, so that it can be used at different devices. It might be an interesting feature to look into and to consider for the breathing measurement device.

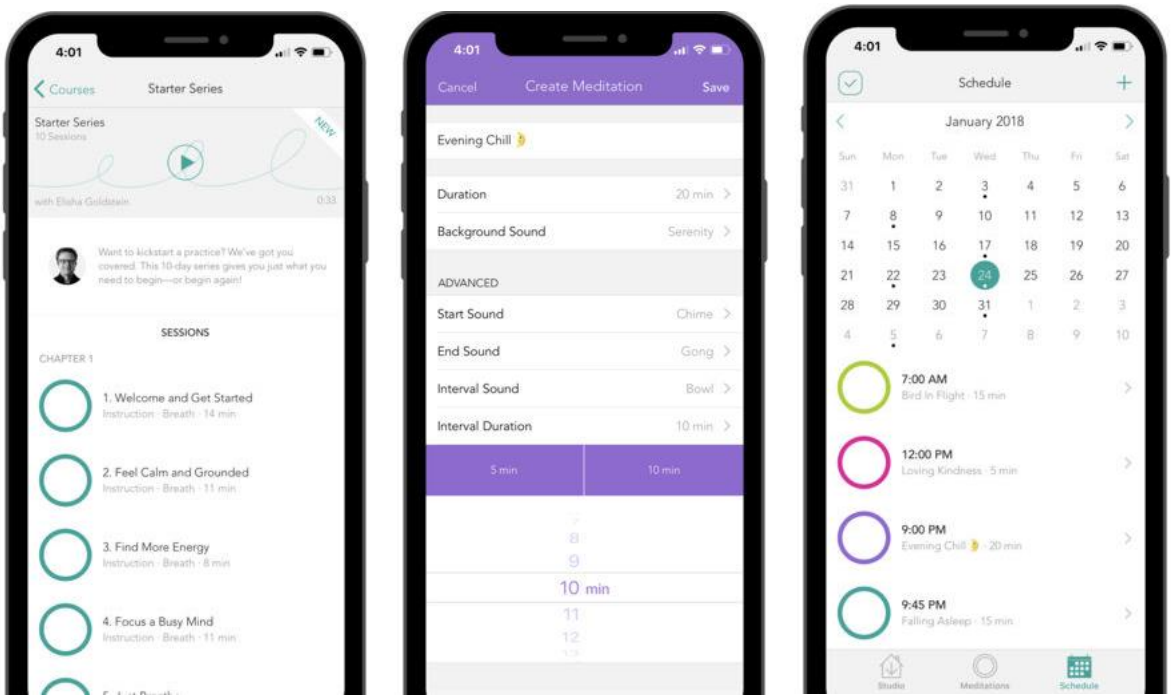


Figure 2.2.2.6 [45]

Concluding the found state of the art, it can be seen that the most developed looking application are generally using brighter colors that are going into the direction of pastel. Still all colors are still chosen so that they can be distinguished clearly. Furthermore shapes and colors are also picked in such way, that they clearly rise from the background and are easily able to be spotted. Shapes in general are kept simple so they are easy understandable and simplify the menu or the shown data to be grasped as quickly as possible. Simple icons are used as well for menu points. In terms of functionality menus should be clear and show buttons obvious, for which icons could be used. Giving accurate enough data and a clear overview of the progress is a key element for the GUI. Furthermore was gamification found in

several app like Box Breathing, Focus Band apps or Prana. Considering to implement gamification elements should not be neglected during creating ideas for a concept.

2.3 Conclusion

In conclusion a lot of useful insights can be taken from the first phase of the Project into the next phase, called ideation. In this part key essentials for further work will be discussed.

To begin with the first sub-question of the research question could be answered by the background research. It turned out that diaphragmatic breathing is the healthiest way of breathing in terms of effects on general health and health issues. By the variety of effects it was shown that it is relevant to develop such a breathing measurement wearable to support the development of healthier habits. Furthermore RIP turned out to be the best non-invasive method for measuring chest and belly breathing and therefore be the optimal measurement solution for the wearable. In addition it turned out that no comparable commercial product has been developed yet so that there is also room for improvement for the branch of breathing health devices. The novelty of the measurement method for home use should not be neglected. Besides the novelty the state of the art investigation showed that there is a great variety of devices and application on the market. This could be an indication for the need of such home use health devices and underline even more the device to be developed further.

Moreover the background researched showed the relevance of a well-designed and developed graphical user interface. The biofeedback turned out to be an improving factor for the effect of diaphragmatic breathing, so it has to be presented in the best possible way. Not only the biofeedback but also strategies to support habit formation have to be included into the GUI. This means goal setting and progress monitoring will be essential parts to be included into the interface. By this means statistics of the data play a big role for giving best possible overview and monitoring of progress, which was also wished by users of other devices. It should be considered to show the user general info but maybe also precise information about their breathing pattern in relation to the time. If a creative way can be found it could also be tried to implement outcome simulation for optimal habit forming. In terms of the biofeedback gamification should definitely also be considered to be integrated into the user's surface to keep a drive towards habit forming up. Due to the fact that the biodata cannot be shown real time the ways gamification was implemented in the shown applications cannot be realized. Therefore gamification will be considered but has to be implemented in a smart creative way. In general the LUMO redesign's key elements, expert and user interviews should be used as supportive tool for the ideation phase and later be tested against by usability tests. Since not only functionality but also aesthetics play a big role in the design process for a GUI a clear colour pallet inspired by the bright pastel-like interfaces of other applications will be considered for the interface design. Furthermore simple forms and icons can be considered to be implemented, as these were seen in most of the applications.

Chapter 3 - Methods and Techniques

This chapter will give an overview of the variety of methods and techniques that will be used during this project to work towards a working prototype and answering the research question.

3.1 Creative Technology design process

As a guideline for this project 'A design process for Creative Technology' [48] was used to follow a clear structure for the design process. It is a suitable example to follow for the process of developing and designing a graduation project for Creative Technology students. A visualization of this process can be found in Figure 3.1. The structure of it is alternating divergent-convergent. The divergent phase an open design space is define, whereas the convergent phase consists of reduced design space leading towards finding a solution. Iterations of the design can theoretically be repeated as many times as wished. Furthermore the process has four phases, namely the ideation phase, specification phase, realisation phase and evaluation phase. The purpose of the ideation phase is creating ideas and coming up with a concept of a prototype. During the specification phase functionalities are supposed to be described to give a structure upon which the prototype can be build. In the realisation phase the prototype will be developed based on the functional structure and the concept. The final phase, evaluation is supposed to validate whether the prototype is working properly. In addition is the prototype tested by users to also validate the user experience.

3.1.1 Ideation phase

The first phase of 'A design process for Creative Technology' is the ideation phase. The beginning of the phase starts with a creating ideas and the phase ends with an elaborate product idea based on preliminary requirements. Sources of inspiration for this product idea could be technologies, user needs and creative ideas. Regarding this project the technologies are related to the second sub-research question, the user needs would refer to the third sub-research question and creative ideas relate to the fourth sub-question. Methods used in the ideation are brainstorms, interviews and iPACT analysis, which are described later.

3.1.1.1 Technology

The technology that will be used to realize the GUI still has to be determined during the Ideation phase. Created ideas need to determine whether they fit for a design within a mobile device like a tablet or mobile phone or whether implementing a screen into the wearable might be a better solution. Furthermore also a non-graphical user interface could be developed and has to be considered. Possible technology solutions will be considered during the brainstorms which will be explained later on in the Methods and Techniques chapter.

3.1.1.2 User Needs

In the beginning there will be a stakeholder analysis conducted. Later in this chapter the stakeholder analysis will be further elaborated on. In addition to determine the user needs interviews with possible users are conducted. These are supposed to get a better understanding of what feature the user might prefer for the interface. The information gathered from the interviews and stakeholder analysis will be used to form personas.

3.1.1.3 Creative Ideas

The background research conducted will be the first reference point to inspire the process of finding creative ideas. The findings on habit formation, biofeedback as well as already existing applications and wearables provide some insights on possible ways to approach the solution. To concretize these insights into novel ideas for an interface solution an individual brainstorm followed by a group brainstorm session are going to be conducted.

Finally all gathered information of this phase will be processed to tailor a final product idea. This idea will be presented with first sketches of the interface to give a first understanding of the design. Followed by this is the first Iteration of list of Requirements the interface has to fulfil is given.

3.1.2 Specification phase

The generated product idea of the Ideation phase is going to be the basis for the specification phase. During this phase all different functionalities the system will have are going to be determined and elaborated on. The method to explain such functionalities will be functional system architecture by providing visualization and verbal explanation of the system's functions and interaction between the user and the interface. Based on the elaboration of the systems structure a reiterated and updated list of requirements will be presented.

3.1.3 Realisation phase

During the realisation phase the first prototype for the interface will be build. This prototype is going to be based on the most recent list of requirements as well as the functional architecture of the specification phase. Which frameworks are used for creating this prototype and how they are used for the realisation are explained. Furthermore it is explained how the design choices changed during the realisation due to certain factors. The built prototype can be used as tool for the evaluation.

3.1.4 Evaluation phase

The purpose of the evaluation phase is to test whether the prototyped interface meets all the requirements given during the development phase. Based on the findings it can be determined which parts of the interface have to be changed or improved. The evaluation phase is split up into two parts which are a functional test and usability testing. The functional test will be fully conducted by the author

and is investigating whether all functions are working. During the usability test the prototype is going to be presented and tested by possible users from the target group. The usability test will focus on quality factors and non-functional requirements that are supposed to be met by the prototype. Based on this a reflection on the prototype's positive and negative aspects will be given.

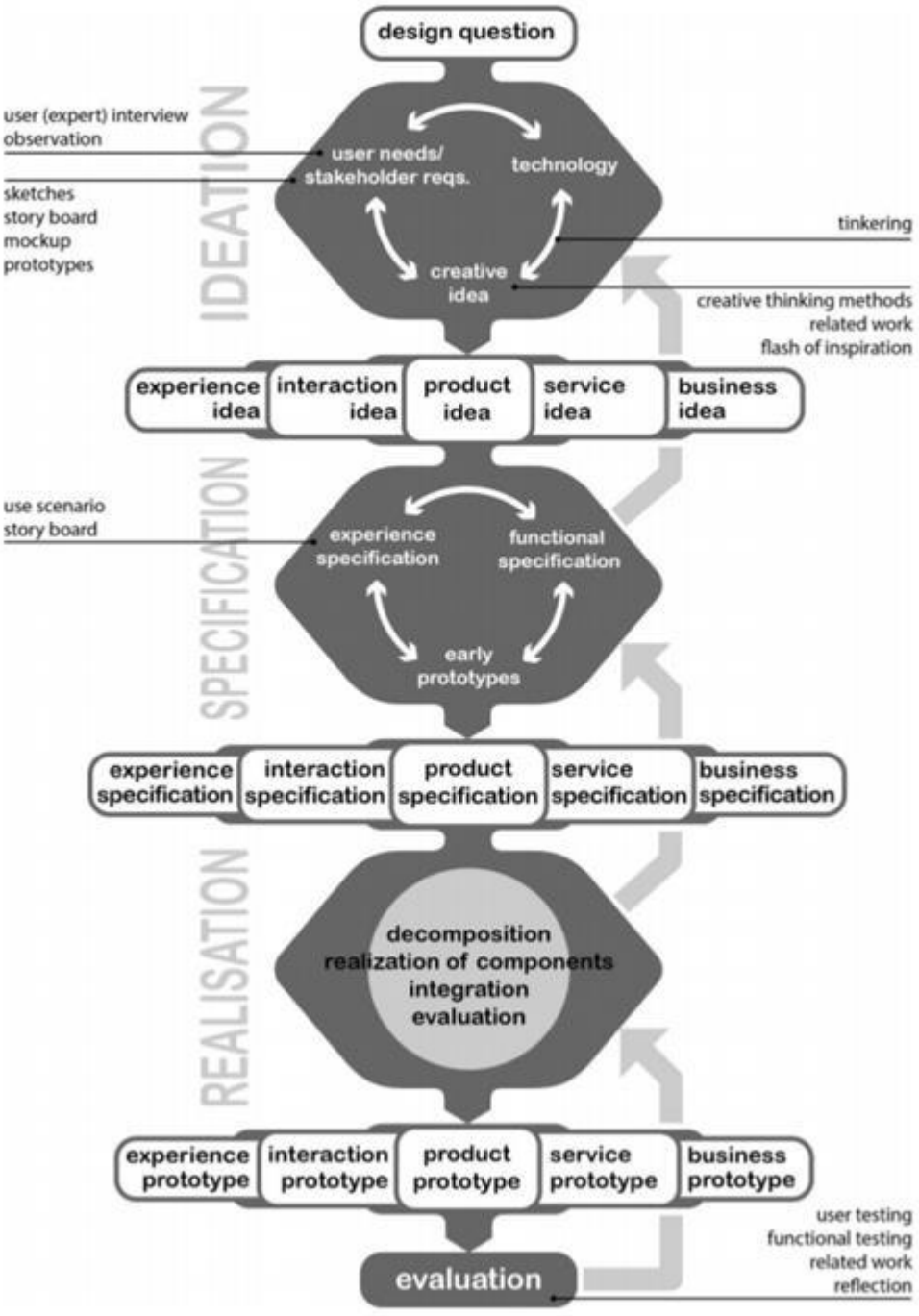


Figure 3.1

3.2 Brainstorm sessions

For the generation of novel ideas on how to present biofeedback to the users and keep them motivated to work towards habit formation, two different brainstorm sessions will be conducted. First an individual brainstorm session will take place to generate first ideas of features for the interface and will be based on information found during the background research. The brainstorming was approached in a free manner to generate of constant flow of ideas. An individual brainstorm is conducted since it was found that individual brainstorms produces more ideas than group session in regards to simple problem [55].

Followed by the individual brainstorming a group brainstorm session was conducted, since not only simple problems have to be solved. A variety of several international students with different cultural and educational background was gathered to support creation of different ideas [55]. The group was brought together at a special brainstorming facility that provides a big round table that can be written on and rotated. In the beginning the group was familiarized with the rules of brainstorming and a basic introduction to the wearable and problem was given [55]. Afterwards an open exchange of drawings, notes and general ideas was supposed to encourage inspiration [55].

3.3 Stakeholder analysis

A stakeholder analysis was executed on the project. The purpose of identifying the stakeholders is to understand their power and interest in the project, which is useful to determine their importance in the development process.

In this project stakeholders that are part of an organisation can be defined by “any group or individual who can affect or is affected by the achievement of the organisation’s objectives” [49]. Sharp [50] is using an approach that focuses on requirements engineering and has four categories of stakeholders:

- **Users:** people, groups or companies that have an interactive relationship with the system or device. Users use the products with the system like information or results.
- **Developers:** people developing the system and are involved in the research and development processes of the system
- **Legislators:** people specifying guidelines that are affecting the development and/or operation of the project
- **Decision-makers:** financially controlling and managing people or groups of developers and user organisation.

All categories of the stakeholders involved in this project will be named. It is followed by a rating on influence and interest (high, medium, low) each stakeholder has on this project. The results will be visualized in a graph to give a clearer idea of how stakeholders have to be classified in terms of importance.

3.4 Interviews

In the ideation phase an important source of information on user's needs are interviews. After generating first ideas the purpose of conducting the interviews is to find the relevance of these ideas for the user. Taking this into account several unnecessary features could be avoided and improve the efficiency of the development process. Interviewees will be people being generally interested in abdominal breathing and wearables or applications in supporting habit formation.

Three different techniques can be used for conducting interviews. These are structured, semi-structured and unstructured interviews [51]. A structured interview consists of a predetermined set of questions that is not altered during the process of conducting it, meaning only these questions will be answered. In a semi-structured interview a predetermined set of questions is prepared, but open-ended questions are supposed to encourage a dialogue between interviewee and interviewer. One advantage of this interview style is that certain questions are answered but also new arising questions can be answered as well. An unstructured interview could be compared to a guided conversation. The interviewer is having an open conversation with the interviewee about the topics he addresses. An advantage is that a free and open talk is held but it is also easy to get off topic with this technique.

For the interviews that will be conducted during the ideation phase a semi-structured approach will be applied. Since in the ideation phase a number of ideas has to be openly created but also go towards finding a final idea, the interviewer shall address important topics but also have an open exchange about these topics. Therefore the author will prepare a set of questions to discuss but also encourage interviewees to give in their ideas about certain topics. In addition is the semi-structured approach easily reproducible and consistent since certain questions are clearly predefined.

In addition in later phases of development there will be expert interviews be conducted to review designs created by the author. Therefore two experts in the field of user experience will be consulted. The experts will sit together the author and walk through the concept and current design drafts. Based on this feedback for improvement will be gathered to optimize the user experience.

3.5 iPACT & FICS

An important part during ideation and specification is writing scenarios to explain the system from different angles. Within the ideation phase the iPACT method, which focuses on the user's perspective, will be used. For the specification phase the FICS method is applied to describe the concept from the system's perspective.

3.5.1 iPACT

'intention, People, Activities, Context, Technologies' [52] is what the iPACT stands for and are the five sections it describes. In the intention it is clarified which goals the system has towards the user. The people section is giving a description of users by personas. The activities section briefly describes for which activities the system is beneficial for the persona. Afterwards the technology section elaborates on the technology that will be used for the system. Finally user scenario taking all above sections into account is written to describe the concept from the user's view.

3.5.2 FICS

The term FICS is an abbreviation for 'Functions, Interactions, Content, Services' [52]. The functions section gives an explanation of the functionalities and events of the system. In the interaction section it is described how the user is interacting with the system. In the content section the information transmission of the system will be given. The service section will give a description of the systems services. Finally a use scenario is written but from the perspective of the system.

3.6 Functional system architecture

The information given by the above explained iPACT and FICS scenarios will be used to derive the functional system architecture. This method is used to provide an overview of all functionalities the idea created in the ideation phase will have. The functional system architecture is making use of a layered system describing functions. For this project it will be made use of three different depth levels.

The first level focuses on description of in- and outputs of the prototype. Within the second level different functionalities of the system are described. The third level shows a decomposition of each function that was described in the second level. The functional system architecture is making use of block diagrams to visualize the levels and relations of different parts in these levels. In these block diagrams the blocks will represent functionalities and arrows represent data flow. The results from the functional system architecture will be used as basis for the realization of the prototype. By developing the prototype accordingly to the functional system architecture it facilitates the realisation by decomposition into functional entities.

3.7 Requirements

The requirements state certain objectives that are tried to be fulfilled with the project. With the requirements the author is deriving his objectives from the knowledge he is gaining via the above mentioned methods. By the end of the ideation phase a preliminary requirement set is defined and therefore gathered information is translated into objectives for the prototype development. At the end

of the specification phase the list of requirements is updated in a second iteration, which is based and prioritized on the knowledge gained during that phase. Finally after the evaluation phase the list of requirements is updated a last time to give an indication or requirements for future work. Within the list requirements will be determined to be functional or non- functional. The functional requirements are describing what the system is doing whereas the non-functional requirements are describing how the system is performing meaning it focuses on usability. Furthermore the single points on the list will be prioritized using the MoSCoW method [56]. This method categorizes the requirements into functions the system:

- **Must** have these requirements to be a successfully realized project
- **Should** have these requirements if possible to improve the project for a user
- **Could** have these requirements if it does not affect another requirement to be not fulfilled.
- **Won't** have at this time and will be left out, however could be implemented in the future.

By this prioritization it is clarified on which points to focus first in the realization for the prototype.

3.8 Evaluation

As soon as the prototype has been developed is has to be evaluated. There will be two ways the prototype is going to be evaluated. At first a functional test will be conducted by the author to determine whether all functional requirements were met or not. Furthermore more a usability test will be conducted with potential users which will be used to check the non-functional requirements on validity.

3.8.1 Functional testing

The functional testing is supposed to take place before the prototype can be tested with a user. This is due to the necessity that functionalities are working so that the user will be able to get an appropriate idea of the prototype. Since functionalities have to be checked on whether they meet the functional requirements determined at the end of the specification phase, is it possible that the author conducts the test without external entities. In terms of the outcomes it is crucial that all 'Must' requirements are met. Furthermore it would be preferred that 'Could' and 'Should' requirements are met as well. At the end of the functional testing it needs to be determined whether enough requirements are fulfilled to go on to a usability testing.

3.8.2 Usability testing

The second stage of the evaluation will be the usability testing. This test will mainly focus on qualitative than quantitative data, since there is only a part of the wearable to develop and evaluate. Part of this usability test will be observing the test subjects, afterwards test subjects will be filling out a survey to give written comments and ratings on the prototype. The RIP belts will be present at the test and also be involved so the scenario seem more realistic to the

test subjects. Furthermore the tests will take place in pairs and recorded to generate a more loose exchange of thoughts and emotions in regard to the interface. This approach is a suggestion by the user interaction design expert Geke Ludden.

Chapter 4 – Ideation

In the following chapter the ideation phase of the project will be described. Its goal is it to generate a variety of ideas, conceptualise these and find an idea to develop further. At first the analysis of the stakeholders will be given. Afterwards results from brainstorms and interviews will be presented. Also the final idea found during the Ideation will be explained. This will be followed by who will use the application and in which way it should be used. Finally, preliminary requirements will be defined that the final idea will have to meet.

4.1 Stakeholder Analysis

There are several different stakeholders involved in this project. These are identified and explained below using the method described in chapter 3.3.

4.1.1 Users

There are many potential users of this service (diaphragmatic breathing training using RIP) can essentially be anyone wishing to improve their breathing and experience the physiological benefits of this breathing technique. Young children can be using this to ensure a varied breathing routine. Students and adults may use this to service to reduce anxiety caused by their studies or work respectively. Athletes can offset oxidative stress using this service to train diaphragmatic breathing. Physiotherapists and specialists may include this service as part of a treatment against asthma, dysfunctional breathing in general, and anxiety. It can also be used to train diaphragmatic breathing for the purpose of martial arts, yoga or meditation; thus novices in those disciplines are potential users too. The decision on the actual user will be made in chapter 4.4 during the iPACT.

4.1.2 Developers

This system has two developers other than the author of this report: Ben Bulsink who is the main developer and creator of this service, and Arnav Mundkur who will be developing the classification script used to analyze the collected data. The last developer is the author (Florian Naumilkat) who is working on the user interface that provides motivational feedback to the user.

4.1.3 Legislators

Farmatec is the Dutch organization overseeing medical devices being registered to be sold on the market in the Netherlands (Business.gov.nl, 2018). The prototype and service would need to be registered with them in order to be allowed to be sold on the Dutch market. Other legislators include groups such as lawyers and medical policy advisors. These two groups go hand in hand as policy makers themselves can be lawyers or work closely with lawyers in order to establish laws restricting or permitting the use of the service.

4.1.4 Decision Makers

The client of this project, Ben Bulsink is a decision maker as his goal and vision will guide this project. The supervisor and critical observer, Erik Faber and Geke Ludden are decision makers in the project as they are overseeing its progress and providing feedback and suggestions on improvements where necessary. Furthermore do they set the time frame of the project. Arnav Mundkur, a fellow student studying Creative Technology is also a decision maker, as classification algorithm are to be employed and design and code the script which will be essential for displaying data in the GUI. Finally the author of this paper, Florian Naumilkat, is a decision maker in terms of features from the data will need to be extracted and provided for the interface, the details of which will be are needed will be discovered during the specification phase.

Each of these stakeholders was rated in terms of influence and interest. The results can be seen in Table 4.1 and are also visualized in Figure 4.2.

Stakeholder	**Category**	**Interest**	**Influence**
Children	User	Low	Low
Students	User	Medium	Low
Working adults	User	Medium	Low
Patients	User	Medium	Low
Specialists	User	Medium	Low
Medical Policy Advisors	User/Decision Maker	Medium	High
Lawyers	User/Decision Maker	Medium	High
Farmatec	Decision Maker	Medium	Medium
Arnav Mundkur	Developer/Decision Maker	High	High
Florian Naumilkat	Developer/Decision Maker	High	High
Geke Ludden	Decision Maker	High	High
Erik Faber	Decision Maker	High	High
Ben Bulsink	Decision Maker/Developer	High	High

Table 4.1: All stakeholders rated in terms of interest and influence

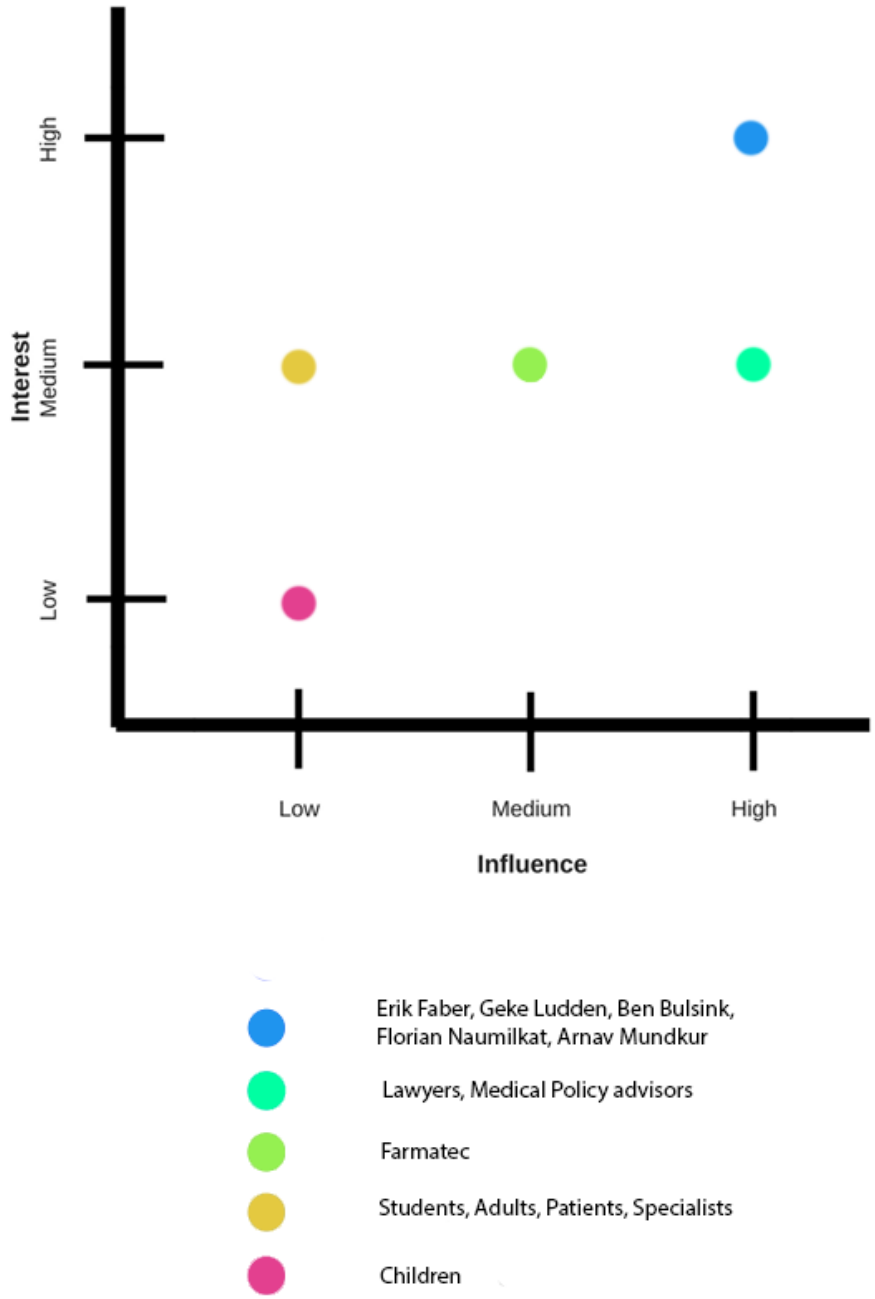


Figure 4.1: Chart showing the influence level and interest level of each stakeholder

To sum up the findings of the stakeholder analysis, the author, Florian Naumilkat, supervisor and critical observer Erik Faber and Geke Ludden as well as client Ben Bulsink and fellow developer Arnav Mundkur are the most important stakeholders. Although lawyers and medical policy advisors are important stakeholders, due to the scope of this project, they will not be approached. Students and adults, in the form of teachers, are easily available and will therefore be interviewed, to understand the needs of a regular user.

4.2 Brainstorm sessions

The first method to create ideas during the Ideation phase was conducting two brainstorm sessions as described in chapter 3.2. These were focused on how to design feedback as part of the GUI to motivate users of the wearable to keep using it. First an individual brainstorm session has been performed by the author, which was followed by a group brainstorming. Although during the ideation phase restrictions are not supposed to be made regarding idea creation, did it happen that ideation focused on a GUI. Reasons for that were the findings of the market research mostly giving inspirational input on GUIs.

4.2.1 Individual Brainstorm

The approach used for the individual brainstorm was very freely meaning ideas have been noted down as a result of a constant flow of ideas without structure, which can be seen in the Appendix D. The result of this brainstorm session will be presented and explained below. The main purpose of individually brainstorming was preparation for the group brainstorm session.

The first very important finding of this individual session has been design principles to follow during the design process. As a taught course in earlier stages of the author's study programme Human Factors gave important design principles to follow for developing interfaces [54]. These principles were decided to be taken into account as guideline for further development. In addition also problems due to the graphical representation of an interface are given.

4.2.1.1 Human Factors design principles:

- Visibility
    - People can see (hear, feel) what actions are available and what the system is currently doing.
- Consistency
- Familiarity
- Affordance
    - Affordance is the design aspect of an object which suggest how the object should be used; a visual clue to its function and use.
- Navigation
- Control (Natural Mapping)

    - Make it clear who or what is in control and allow people to take control.
    - Control is enhanced if there is a clear, logical mapping between controls and the effect that they have. Also make clear the relationship between what the system does and what will happen in the world outside the system.
    - Natural Mapping - The degree to which the form of the interface is isomorphic [corresponding or similar in form and relations.] to the 'form' of the functional output of the device
- Feedback
    - Rapidly feedback information from the system to people so that they know what effect their actions have had. Constant and consistent feedback will enhance the feeling of control. what is the system doing? What is the result of what I just did?
- Recovery
- Constraints
    - "Provide constraints so that people do not try to do things that are inappropriate. In particular, people should be prevented from making serious errors through properly constraining allowable actions and seeking confirmation of dangerous operations". HOWEVER: It is not just about 'inappropriate', it is primarily a principle about 'helping people to decide what to do'
    - Constraints are structures in the environment that help us to select the right action. Constraints reduce the number of possible actions. This makes the task of deciding what to do easier.
- Flexibility
- Style
- Conviviality
    - Interactive systems should be polite, friendly, and generally pleasant

4.2.1.2 Problems with GUIs:

- GUI ignores rich interaction possibilities of body
- GUI invites passive reception instead of active involvement
- GUI (often) demands cognitive effort (thinking)
- GUI uses conventions and metaphors that need to be learned and understood

Based on the found principles further ideas were developed such as giving the GUI a low navigational complexity including flat layering of the different pages to reach. Furthermore the system is supposed to constantly show whether it is measuring or not to keep the user informed about the current processes. This part should definitely come with the internal possibility to switch the measurement on and off keeping the user in control.

To avoid misleading results also instructions on how to put on the belts of the wearable correctly should be supplied in the GUI. Most definitely as part of the first time use screen but also as a re-reachable page within the GUI.

The LUMO Lift redesign showed that statistics are an essential part of the feedback, so for the GUI breathing activities should be given in a very general and uncomplicated way. The user can be supplied by a time line of the measured period and show the statistics throughout this period to track the abdominal breathing behaviour down to certain moments. The value of total hours of abdominal breathing could be compared to the values of the past days giving an idea of progress. Furthermore general history of this value could be saved to be compared and also be shown in a progress curve. This could be combined with showing the progress toward a long term goal. By this means the screens of first start should implement setting a long term goal with wished to be reached goal in which time.

Additionally the set long term goal could be sequenced into smaller sub-goals set by the user and be adjustable to unforeseen happenings or developments. This goal setting and sub-goal setting could be done with a therapist or doctor when used in a medical environment. Set sub-goals could furthermore be used to integrate levels, rewards, achievements or batches as elements of gamification to motivate the user. These features could support habit formation as it was found in chapter 2.3.

During meetings with the client and other students working on the project it occurred that calibration might be necessary. To implement a calibration the first time use could also implement a 5 minute abdominal breathing session in different positions with clear instructions to the user or therapist to guide this session. Also a trainings mode could be implemented to give feedback on abdominal breathing about a short period of time. This training mode could be combined with a planning tool that syncs with the users calendar.

Since Arnav Mundkur is working on the data classification from the RIP signals it needs to be determined which variables for statistics are important. It was discussed with Arnav that longest period of diaphragmatic breathing might be important or the total amount of diaphragmatic breathing. In connection to this it also needs to be known if the user sets his or her goal on total amount of diaphragmatic breathing or the length of time he or she sticks to it. When determined the information needs to be passed on to Arnav Mundkur.

4.2.2 Group Brainstorm Session

Followed by the individual brainstorming a joint group session was conducted. Therefore 8 international students from different study fields met up in a special brainstorming facility providing a round white board table that can be rotated. This enables everyone to write down their ideas freely but also open to everybody to encourage a constant exchange. Photo documentation of the white board as well as the group brainstorming can be seen in the Appendix E. The session started with explaining the brainstorming rules to the group followed by an introduction of the wearable. The results shown after more than an hour of group brainstorming are elaborated below. It appeared that during the group brainstorm session a mobile phone application was focused on. Points that were addressed during the brainstorm were user motivation, gamification, performance tracking and statistics.

As in the individual brainstorm it also came up that individual goal setting should play a role or be maybe conducted with a therapist. Furthermore it was said that the therapist should set the goal inside the GUI for the user. In addition to this giving the possibility to set sub-goals should be given to the user.

A very important point during the group session was the motivation by compensation meaning to give something back to the user for good performance to motivate. It was said that it needs to be fun and useful. Suggestions for this have been unlockable rewards such as badges, achievements, sub-goals, artworks, cooking recipes or even knowledge about the positive effects of abdominal breathing. So that the user slowly is able to gain more knowledge about not only how his breathing improves but also general health aspects. Giving awareness in general about the advantages for abdominal breathing was suggested to be implemented.

Aligning the user's development with a development inside the application was an extra idea. The idea of an avatar representing the user's development with evolving by reaching sub-goals was expressed. Visualizations of this could be a body getting fitter, evolving or restoring art pieces, a world/micro cosmos, climbing a mountain, a track that the avatar is running along, sky with moon and sun, lungs changing colours and appearance, a messy room tidying up, a growing garden and starting as a Tai Chi novice and turning into a master. This Tamagotchi like gamification element shall lead to connecting with the avatar. Not only an avatar but also sounds or a song evolving during progress was mentioned. Since a big variety of options came up also being able to adjust this as expressed as a possible feature. Furthermore adjusting this automatically by asking for the user's motivation for using the wearable at first use could be possible.

Another idea has been implementing an energy bar that is filled up by performing abdominal breathing well. Charging the energy bar would be connected to a game that can only played as long as the energy bar remains not empty.

Next to motivation a major point discussed was tracking performance of the user. A quality factor simplifying the data for the user that could easily be combined with the avatar idea came up. In addition a leader board to compare/compete with other users could make use of this or being able to compare with the average of age groups. Also the visualization of percentage of diaphragmatic and chest breathing was discussed. Ideas for this were a heat map on body or torso, a yin & yang symbol or a clock showing times as well as percentage.

Also mentioned was the possibility of bringing up push notifications triggered by inputs about the activity of the user or analysing as user's daily routine with the calendar or syncing directly with the calendar. The push notifications should remind to breathe abdominally.

Moreover it was discussed to also synchronise the user's calendar to the application to show the agenda in combination with a time line that shows which breathing was practiced at which times. This way agenda linked time stamps would add to the time line. Another approach suggested was giving the user the possibility to put time stamps themselves to be able to track back why which breathing was practiced at certain times. Added to this was to simplify these stamps with just setting emojis time stamps.

In terms of data and statistics several other points were mentioned such as maybe adding the breathing frequency as information, letting the user decide on how to archive data so it can be reviewed but also being able to compare different periods or different days in general.

All in all the two brainstorming sessions generated a lot of different ideas for a GUI that could be implemented in a phone application. It showed that statistics are really important as well as being able to compare these as part of the user's progress overview. Gamification elements as motivational aspect reoccurred and its visualizations were discussed quite intensively.

4.3 Interviews

To gather further insights on the generated ideas, applications preferences, general GUI appearance and experience on wearables or health applications, interviews with three different people but possible users were conducted. Semi-structured interviews were conducted as described in chapter 3.4. One assistant professor working with wearables and two students interested in the project were interviewed. All of them used technology for health purposes and are generally interested in wearables. The interviewees were asked about their positive and negative experiences with health apps or wearables and their internal motivation to use these. Also questions about GUIs in general and liked elements were asked. Furthermore questions about certain ideas from the brainstorming were asked and the interviewees were encouraged to share their own ideas. The interview notes can be found in Appendix F, G and H.

4.3.1 Angelika Mader

The first interviewee was Angelika Mader an assistant professor at University of Twente. She is in general very interested in wearables and also purchased several in the past. Her interest comes from her profession as she is currently with a team researching and developing a wearable for posture correction and breathing and finds acquisition of biodata regarding daily activities very interesting.

She purchased the Spire [33] and Fitbit [57] already and used both, but stopped using them. Problems she encountered with the Spire were malfunctioning of sensing when biking or sensing stress when watching exciting series. She also disliked that the app was not integrable with other apps. The Fitbit has been problematic for her since it had to be constantly connected to the internet, which was a problem at certain places. Furthermore was the screen badly readable in sunlight and some sensors were malfunctioning as well.

Points that Angelika really emphasized were that textual and statistical feedback got too common nowadays and too much cognitive workload is coming along with it. Due to this she does not really like GUIs for wearables in general. In her eyes most important is haptic feedback in real time. Added to this the haptic feedback should not be too complicated to not rise cognitive workload again. Furthermore she liked the feedback to be designed as subtle as possible for fellow people.

If regarding to a GUI Angelika thinks green and blue to be appropriate colours and seeing an overview of abdominal breathing periods so that the user can reflect on these.

4.3.2 Alexandros

The second person to be interviewed was Alexandros, a 30 years old Creative Technology student, how is practicing Tai Chi for 3 years and currently doing a ketogenic diet, meaning a low carb and high fat diet [58]. He is generally interested in improving his mind and body balance and following a healthy lifestyle.

At this point he is using an application called Lifesum [59] for his diet to keep track. A major point he likes about the application is that it is not using hidden payments or is restricting certain options with a paywall. Furthermore, he likes that the application just needed input for once and uses a machine learning algorithm from then to adjust to the user. In addition the minimalistic style of the application appeals to him.

Generally speaking Alexandros likes apps being adjustable to fit for the user but supplying too much adjustability is a downfall in his eyes since it distracts from the purpose and he does not want to spend a lot of time on the app. Instructional feedback is also a critical point for him since it might make you look too much at the app. The instructional feedback should be integrated into the user's routine so it does not disturb at inappropriate moments.

Achievements or unlocked rewards would not motivate him since he does not see it as a challenge to achieve something in the application but for himself. But he could imagine inspiring or motivating Qigong quotes as unlockable but he would neither work towards unlocking these than improving himself.

In terms of visualization an avatar representing his progress or how he is doing in general at the point appeals to him as long as it does not make him look too much at the phone. It would be important to have the avatar on the starting page because clicking through menus would be annoying for him. Colours he would like to be used for the GUI would be pastel tones and calming colours like blue, green, crème and egg shell.

He also doubts that he would use self-notifications on the timeline to recall certain moments. He does not like to document himself neither clicking a lot around in a menu. If he would use it, it would have to be not more than two clicks in the application. Moreover he would not like it to interfere with him to tell him to watch out for his breathing.

Regarding statistics Alexandros likes to see when diaphragmatic breathing was practiced to be able to reflect on the day including how long these periods were. Additionally he would like to know how well he did in general on a day to get something like a rating for that day. Still he would like simplified data at first and getting more accurate statistics in deeper layers.

4.3.3 Marie

The final interviewee was Marie, a 20 years old Psychology student regularly practicing meditation for 3 years already. Experiencing great advantages ever since she started meditating made her interested in the project. She is making use of meditation to resolve stress, to fall asleep, treat some anxiety and reach realizations about life.

Marie is using two different apps as support for meditation as this point. One is called Insight timer [60] and the other one Calm [61]. She mainly uses Insight timer and likes about it offers a big variety of meditation programmes, is theme oriented, very adjustable to personal needs and giving clear explanations. She is not really using Calm since it had to be connected to a Facebook account which she dislikes. In general she dislikes too much connectivity with other applications or other people regarding her meditation. Insight timer also gives you the possibility to meditate with others which she switched off because she prefers anonymity.

Her reaction towards instructional feedback is very positive. In her opinion it can enhance the experience since it is also necessary for her to use guided meditations with her applications. In comparison milestones, batches or rewards are not interesting for her at all. The pressure that could come up with these achievements would stress her. Achievements within the app are not her goal but achievements for herself and she does not want to be stressed to reach her goal but be self-centered.

However Marie likes to have an avatar representing her progress and thinks it might add up to her motivation. Visually she would like to see pleasing calm pictures and natural colours like earth tones and blue.

Regarding the self-notifications on a timeline she finds it very interesting but does not know if she would keep doing it since she can reflect and remember the day well enough in the evening. She would prefer to note it down if something is wrong for the whole day like being sick. Furthermore she also thinks that noting it down could maybe break a flow.

In terms of statistics Marie would first of all like to see how she is general doing since it is most important for her but still likes to have as much as possible data implemented.

4.3.4 Conclusion

During the interviews several insights could be found. Two of three interviewees gave as reason to stop using a wearable or app that it is not adjustable enough to their needs. In addition the other interviewee emphasized that he is using an app for a diet since it is applying well to his needs. This means that adjustability and matching the user's needs are important.

Giving a lot of input to the GUI by the user or having a lot of interaction time with the technology was found to be negative for all interviewees. Features that need repetitive user input were disliked by Alexandros and Marie and Angelika emphasized that feedback should have a low cognitive workload.

Also simplicity seemed to play a role for the interviewees since Angelika mentioned feedback should not be too complicated and Alexandros said he would like a minimalistic design and would like to give input to apps only once.

Visually did all interviewees suggest light colours for the GUI as well as using blue or green since the colours appear calming to them.

In regards to the features of the app it came up that, self-notifications on time lines seemed to be a promising feature but seemed also to be not interesting enough to make use of it. All interviewees stressed that they would not use it. Still it was stated that giving a single note for a whole measurement would be done. Moreover achievements were only partially interesting for the interviewees but came up in both brainstorms. Alexandros and Marie stressed that achievement or rewards would not motivate them to improve their breathing but Marie would feel rather pressured to achieve.
However the progress visualization with an avatar was generally picked up as a good feature. In case of this avatar representation it was suggested to put it on the first page of the GUI to minimize the time spend on the app.

4.4 Final idea

The goal of the Ideation phase is to come up with a final idea followed by a first list of requirements. All the insights that were gained during the background research as well as in the interviews, brainstorms and stakeholder analysis were taken into account to create a final idea for the interface. The choice to develop a mobile phone application is motivated by several aspects. First of all did all the sources taken into account for the background research on biofeedback give such feedback through a graphical user interface. To ensure keeping the background research's validity a more abstract or different form of interface like haptic, sound, light or voice was passed on. Additionally is the wearable restricted by not giving real time feedback yet. This leads either to a high cognitive workload or a low content of information for the user if another interface type would be applied. Furthermore is taken into account, that there is a high accessibility of mobile phones for most users. In addition does the mobility of a mobile phone play along with the idea of wearables to be mobile. Moreover is the market research of more value for inspiration when developing an app because most products were a wearable combined with an app or a standalone app.

Good input was supplied by the market research, brainstorm sessions and interviews to develop a GUI within a mobile phone application. At first the general idea of gamification by a leader board or giving out rewards for certain performance was dropped to keep the user focused on himself. Nevertheless the idea of an avatar representing the personal progress towards the goal will be implemented due to the positive resonance during the interviews. This supports minimizing the cognitive workload when reaching out the app for the first time so that the user is less forced to spend time on the application. Since giving in depth data came up during the brainstorm, seemed to be partially interesting for interviewees and was an important aspect during the LUMO Lift redesign process, there will be an overview with more accurate data implemented. Additionally a screen showing progress toward the self-determined final goal and sub-goals with respect to the last measurements will be included. The

goals are supposed to be set by the user to support habit formation for which it turned out to be very important to define goals. Furthermore a history to compare different datasets from several days will be provided to give a more accurate overview about the breathing patterns throughout the day and last days. Notifications, any synchronization to the calendar and time stamping were dropped due feasibility and the feedback during the interviews. Finally a switch, which will actually not be functioning, will be implemented due to the importance in Human factors to show what the system is doing and giving the option to switch it off anytime. The purpose of this is to supply the structure for future work when the wearable will be able to be connected to the app.

4.4.1 Graphical User Interface

Based on the choices of ideas discussed above a first mock up prototype was created. Adobe Experience Design was the design tool of choice for the first visual presentation. The basic home screen can be seen in Figure 4.4.1 – 1, the other basic screens can be seen in Figure 4.4.1 – 2. The whole overview of all screens can be seen in the Appendix I. As it can be seen will the home screen show the avatar in form of an emoji to give a quick indication about the progress. This emoji changes from a bit sad face up to a very happy face within 4 steps. Three of these steps are smiling faces to rather evoke positive than negative emotions towards the app. Moreover is the switch placed on the main screen to reach it quickly and quick buttons to navigate to the Statistics and Goal screen are placed on the left and right. Clicking the top left opens a navigation window.

Figure 4.4.1 – 1: Home screen

The Statistics screen shows the abdominal to chest ratio for the whole last measurement and a scrollable timeline giving 5 minute intervals that are either categorized as abdominal breathing or chest breathing. With this screen the user is supposed to reflect on his breathing throughout the whole measurement. In the Goal screen the user will be presented how close the amount of abdominal breathing of the measurement is to his goal. In addition it will be by a bar graph how the user did in respect to his final and daily goal for the last five days. Within the History screen there will also be a bar graph which was inspired by the LUMO Lift app. It shows the measurements of the last 5 days and at which times abdominal breathing was executed by the user. This way the user can identify patterns of abdominal breathing that show over several days and can adjust his breathing behaviour based on these. Finally it is to say that the main colours for the application that have been chosen are a white and blue tone due to the colours found in the examples and the interviewees recommendations.

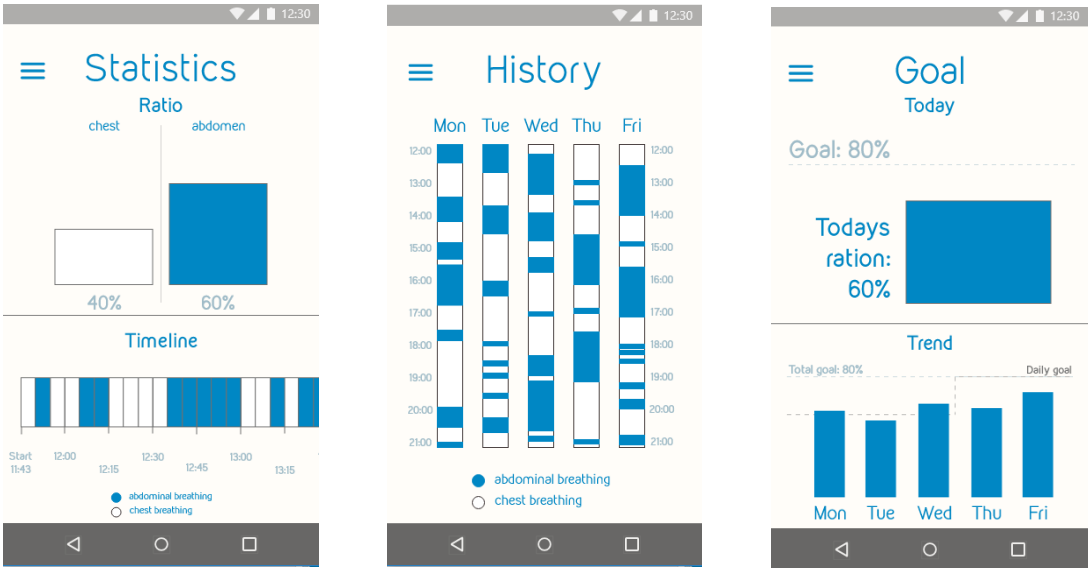


Figure 4.4.1 – 2: Statistics, History and Goal Screen

4.5 iPACT

In this section iPACT method as described in chapter 3.5 will be used to give an explanation from the user's perspective user.

4.5.1 Intention

The system's intention is to give people feedback on their breathing pattern to support personal development into the direction of making abdominal breathing a habit. By this means the intention is to internally get into the habit of breathing abdominally for the user to such an extent that the wearable gets obsolete.

4.5.2 People

This part shows 5 different potential users since a big variety of people could be interested in the wearable for different reasons. Later a motivated choice for one person who uses the wearable in the scenario will be made.

4.5.2.1 Pablo

Pablo is a 23 year old Amsterdam based Web-developer, who is very determined to live a healthy life style. Not only does he visit the gym four times a week as part of his routine but has also renounced using public transportation and instead relies on his bike. Furthermore, he follows a strict diet he has put together with help of a diet coach and is only purchasing organic ingredients so he can cook his own healthy food. Since Pablo's lifestyle is absorbing a lot of time he tends to feel stressed out. Therefore he started with quick meditation session to keep a healthy calm mind. For planning out his healthy lifestyle as well as staying informed about the newest trends he is making use of mobile apps. For Pablo is the wearable a really efficient way to keep track of the breathing for every day. After a while using the wearable he realized that he got more stress resistant.

4.5.2.2 Joana

Joana is the owner of a local organic food market stall in Amersfoort. During the week she wakes up early to buy her goods and opens her stall in the area around Amersfoort on a daily basis. She is very convinced to offer her customers local, healthy food and is a vegetarian herself. To keep up with the busy lifestyle she tries to keep her spirit balanced. As a Buddhist and an advocate of traditional eastern theories and medicine, Qigong and meditation is part of her daily routine. Joana knows about the effect the state of her mind can have on her body and her general well-being. Since he is not very familiar with wearable technologies was her first reaction on the wearable was sceptical. But after a recommendation from a friend she tried it out and realized that reflecting on her breathing got easier and abdominal breathing is more and more implemented in her life.

4.5.2.3 Michael

Michael is a 15-year-old boy going to the IB-Middle years programme of the United world college Maastricht. He is an introverted child that tends to stay home. He likes technology very much and spends a lot of time on his computer but also building computers himself. Michael would very much like to spend more time trying out different sports but due to his chronic asthma, his options with regards to physical activity are very limited. He is very interested in sports such as surfing and snowboarding, but is just virtually following these activities watching YouTube and playing videogames. To enable himself to be more physically active, he tried several different breathing therapies to get his condition more under control. At a breathing therapy he got introduced to the wearable by his therapist. Using abdominal breathing showed some beneficial effects for Michael already. To also improve his abdominal breathing without his therapist he started using the wearable. The breathing therapy in connection with the wearable made is possible for Michael do mellow longboarding, which was a big emotional milestone for him.

4.5.2.4 Daphne

Daphne is a 25 year old student doing her masters in Embedded Systems at the University of Twente. She spends long afternoons and some of her weekends at the library, pouring over previous lectures. She suffers from fear of failure due to her intense study, and does not participate in any extracurricular activities. Daphne has tried using meditative apps in order to help her maintain her calm but is not having much success with them. She is not only interested in tracking and training apps, but the biodata processed by them. She is unsatisfied with the existing apps available as they do not allow for viewing of the raw data. Daphne really enjoys that the wearable is analyzing date for her and visualizing it in an easy understandable way. Since she uses the wearable she has to spend less time on reflecting on her breathing and in addition her anxieties about failing decreased.

4.5.2.5 Rick

Rick is a 34 year old Science teacher at the Rivers International School in Arnhem. He teaches Science to the 2nd and 3rd grade students. His students are rarely interested in his material and are usually playing pranks on each other or staring out of the window. Rick has developed a short temper due to this and regularly loses his patience with his students. When Rick isn't correcting essays or exams, his enthusiasm for technology manifests itself as he pours over articles on the verge.com about the latest in wearable technology. He loves tracking his movement and never goes anywhere without his FitBit. Rick spends his time experimenting with new wearable technology and tracking his activity and recording biodata. He

uses his smartphone to download accompanying apps to view statistics of his activities after a long day. Rick loves that he can get more in depth data about his breathing and connects it with his other wearable to reflect even more on his body performance. But actually he would prefer to get even more data on his breathing. Additionally he realized he got somehow calmer since he has been using the wearable.

4.5.3 Activities

The wearable will be used by people in their everyday life like at work, household activities or leisure activities. During a period of time the wearable will measure the breathing pattern. After measuring for a certain period the user will be able to use the interface to receive feedback on his breathing.

4.5.4 Context

In the beginning of the project two possible contexts for the wearable were discussed. It shall either be used at home by a person to generally improve on their breathing pattern or be part of a medical environment in combination with a breathing therapist to treat symptoms. During further progress of the project and meetings with Ben Bulsink it was decided to focus on domestic usage.

4.5.5 Technology

The technologies used in the system are RIP, which was explained in chapter 2.2, classification algorithms and an application to give feedback based on the classified data. The application will be running on a smart phone using iOS or Android. The RIP will measure the users raw breathing data, the classifier will analyse the raw data and turn it into useful information for the feedback system. The application is going to process the classified data into visual feedback like an avatar or graphs.

4.5.6 User Perspective Scenario

For the user perspective scenario the choice fell on Pablo. Within the before mentioned meetings with Ben Bulsink it was not only decided to go for domestic usage but also to choose young adults with interest in health and breathing as target group. Therefore the choice fell on Pablo due to his age and lifestyle as well as his interest of using technology.

Getting up at 6 o'clock turned into an easy task for Pablo since he likes to finish his workout before going to work. After dressing he takes the wearable and places the abdominal band around his navel and thoracic band over his chest and under his armpits. This routine is followed by his breakfast preparation. Usually Pablo is mixing a fresh smoothie for breakfast containing vegetables, fruits and nuts. This enables him to quickly consume his breakfast after the preparation phase while he is packing his bag for the gym. Afterwards he quickly gets into the basement picking up his bike and leaves for his 20 min bike ride from Amsterdam Bijlmer to Amsterdam Zuid.

On his way Pablo realizes that he forgot his gym membership card on the dining table. While weighing the odds whether they let him in without the card he remains heading towards the gym. After two minutes he decides not to risk it, since he will be sitting in a chair at work all day. Pablo is now racing as

fast as he can home, quickly grabbing his membership card and racing to the gym. Very stressed out he reaches the gym, changes quickly, takes of the wearable and starts with his workout. When he is finished he showers, dresses and gets back to his bike quickly to head towards work.

Since Pablo's gym is close to his office he arrives quickly. However when he is searching for his employee ID card he realises he forgot to put the wearable back on. Angry at himself he places the belts on him again. Nevertheless reminded by the belt he takes some deep breaths and goes in.

Lately Pablo did well at work and hopes for a promotion to team leader. Due to this he is even more engaged in his work and tries to keep laser focus on realizing the client's wishes in the most accurate manner. Furthermore, Pablo tries to support his colleges when they are stuck with a certain task or need feedback. At work Pablo's mind is totally wrapped around his job but in the small breaks between tasks he asks himself whether he was breathing abdominally focuses on it for short before he goes back to his tasks. Since Pablo feels such a responsibility towards his job he tends to do overtime. Pablo is leaving the office at 7.30 pm.

Satisfied but also exhausted does Pablo head on his bike towards Bijlmer. He arrives at his local grocery store to get new ingredients for the next few days. At the store he meets Bram, the store owner and friend of Pablo's, and tells him about the article he read on the benefits of abdominal breathing and shows him the wearable he currently uses to keep track of it.

Around 8.30 pm Pablo arrives home and starts to cook dinner and prepares lunch for the next day, so that he has a healthy food solution at work. Next to cooking and eating he checks his favourite blogs and websites like WIRED, Gizmood, the Verge, Bites of Wellness, Fitful Focus and Peanut Butter Fingers. Afterwards, Pablo connects the wearable to his computer to analyse his data and get ready for bed. In bed Pablo is opening the app to check how well he did today. The avatar shows a sad face meaning he did not too well today. Checking out his statistics he realises in the morning he did not do well and recalls the stress he had. Around work time he can see several periods of abdominal breathing but they tend to be short. For the evening he sees a longer period of abdominal breathing and connects it will his talk to Bram and being reminded to breath with the abdomen. When Pablo compares his measurements of the last days, he realises that he might have to focus a bit more on breathing at work since he always can see some periods of abdominal breathing but they tend to be short. Furthermore Pablo checks his process towards his goals and sees today he did not reach his daily goal, but is not doing too bad in general lately. After checking his breathing Pablo goes to bed to be ready to get up early again tomorrow.

4.6 Requirements 1st Iteration

As a first design was developed the first list of preliminary requirements needs to be determined. The first iteration of requirements was created with respect to all finding during the background research and the ideation phase. Following are the requirements named and prioritised according to the MoSCoW technique.

Must

1. Minimize the cognitive work load of the user by simplifying data into an easy understandable representation of user's performance
2. Show the ratio between diaphragmatic and abdominal breathing for the entire measurement
3. Show the user within minute intervals whether he was practicing abdominal breathing
4. Give the user the possibility to choose a certain ratio of abdominal breathing as final goal
5. Give the user a graph that shows how well he is doing in regards to his goal

Should

6. Give the user the possibility compare timelines of the last five measurements
7. Give the user a graph that shows how well he is doing in regards to his goal for the last five measurements to visualize his progress
8. Let the user choose smaller sub-goals as steps to work towards the final goal
9. Base the design on bright colour as well a blue to make it fit the health theme
10. Minimize the amount of design elements to avoid distraction from information
11. Keep all information reachable within 3 clicks to minimize the time that has to be spend using the app

Could

12. Implement facts on advantages or effects of abdominal breathing to read it up
13. Changeable themes for the representation of abdominal breathing performance

Won't

14. Show the feedback in real time
15. Give the user always the possibility to switch the wearable off
16. Give direct instructional feedback how to improve abdominal breathing
17. Show calibration screen working cooperating with the classifier's calibration process
18. 5 minute training session giving feedback about performance when actively practicing DP
19. Give the user the possibility to label timeline with time stamps of emotional state
20. Self-notifications on a timeline to recall emotional state of a certain moment in reference to breathing performance
21. Synchronize to the calendar and push notifications depending on calendar schedule
22. Synchronize to the calendar and automated marking of timeline with calendar entries

The preliminary list of requirements shows a lot of points for the 'Won't' section. It should be justified why parts are knowingly left out to be implemented.

Point 14 showing real time feedback is a point that would preferable not be left out but has to be left out due to technical constrains. The wearable is not at the development phase that RIP belts, classification and GUI are able to exchange data automatically. Data exchange has to be done manually and partially with wire connections, which does not fit the idea of a wearable. Point 15 is directly connected to the reasoning of point 14. Without a direct connection between RIP belt and GUI it is not possible to implement a function to switch off the wearable. Still is a not working switch already implemented in the first mock-up to pave the way for future work. Furthermore, is point 16 also connected to the missing fusion of RIP belts, classification and GUI. Without having a constant connection of RIP belts to the classifier, which would instantly classify the data for the RIP belts, then sending the classified data to the GUI, it is impossible to give a user direct feedback his current breathing. Point 17 regarding a calibration was also passed on due to the classification and GUI still being separate components. Additionally training sessions were also left out since the purpose of the GUI is supporting habit formation at this point. Implementing training session could extend the scope of the project. Point 19 and 20 regarding setting references on the timeline were both left out due to the findings of the interviews, showing that the feature is not really necessary. The points 21 and 22 which cover a synchronization between calendar apps and the GUI were passed on due to time constrains to not extend the scope of the project.

Chapter 5 – Specification

During the specification phase the focus will lie on the functionalities that were determined during the ideation phase. The first part will treat the FICS scenario for which the system will be contemplated from the systems point of view. This point of view contains functionalities and user interaction. Subsequently a functional system architecture will be given. The functional system architecture is based on the FICS and provides a more elaborate explanation of functionalities. Finally this is leading to a adjusted, refined and prioritised list of requirements.

5.1 FICS

This section describes the system by using the FICS method, which was explained in Chapter 3. The system is described by this method from the point of view of the designer and developer.

5.1.1 Functions

The system has several important functions. The first one is preprocessing the data incoming from the classifier. The second one is storage of data and goal settings, the third is graph compiling to visualize the data and the last one is the navigation to reach all the different screens.

5.1.2 Interactions

The user will interact with the system by pressing buttons and scrolling through graphs. With these tools the user will give input to the system. Is interacting with the user by visual or textual feedback.

5.1.3 Content

The app will show the user an avatar-like representation of his performance towards his goals. Graphs comparing different measurements in regards to the goal and moments of abdominal breathing. Furthermore can the user scroll through the last measurement on a minute interval basis and see when he breathed abdominally.

5.1.4 Services

At this point does the service need no extra services except being supplied with classified data.

5.1.5 System perspective scenario

For this scenario the persona of Pablo will be used as in the iPACT method. This time the scenario will be written from the system's perspective and focus on the part when Pablo is interacting with the app. In addition an activity diagram will visualize the user system relationship of Pablo and the wearable, which can be seen in Figure 5.1.5.

Pablo starts launching the application, which leads to the software loading the application. From there on the first shown to Pablo is the instruction how to put on the belts. Then Pablo either decides to quit with using the wearable or puts on the belt as instructed and presses to continue. This leads the Software to load the goal setting screen and when it is displayed Pablo either decides to quit using the wearable or enters what he decides on to be fitting goals. These settings will be saved by the software

and will load the home screen. From here on Pablo is wearing the wearable for a day or a certain measurement period or decides to quit using the wearable. If Pablo decides to wear the wearable, he opens the application after measuring. The software is collecting the data from the classifier followed up by processing and saving it. Afterwards is the software is loading and displaying the home screen and the avatar with it. With this information does Pablo reflect on his breathing. Now Pablo can decide whether he likes to quit, go back to wearing the wearable for a measurement period or seek for extra information. The last option can be done in three ways, namely opening the daily review, history or progress screen. Each of these screens will in case of being selected be loaded and displayed, which leads back to reflection on breathing by Pablo. Pablo can now go on with reiterating these steps, till he quits using the wearable because it is not necessary anymore or for other reasons.

By the activity diagram are the activities of the user and the system in respect to each other visualized. It is separated into three different parts, which are the user, display and software. In the diagram it can be seen, that the user actions are represented in yellow, the visible system or display is represented in purple and the invisible software background of the system is represented in green. The rhombus blocks are standing for decisions that can be made by the user.

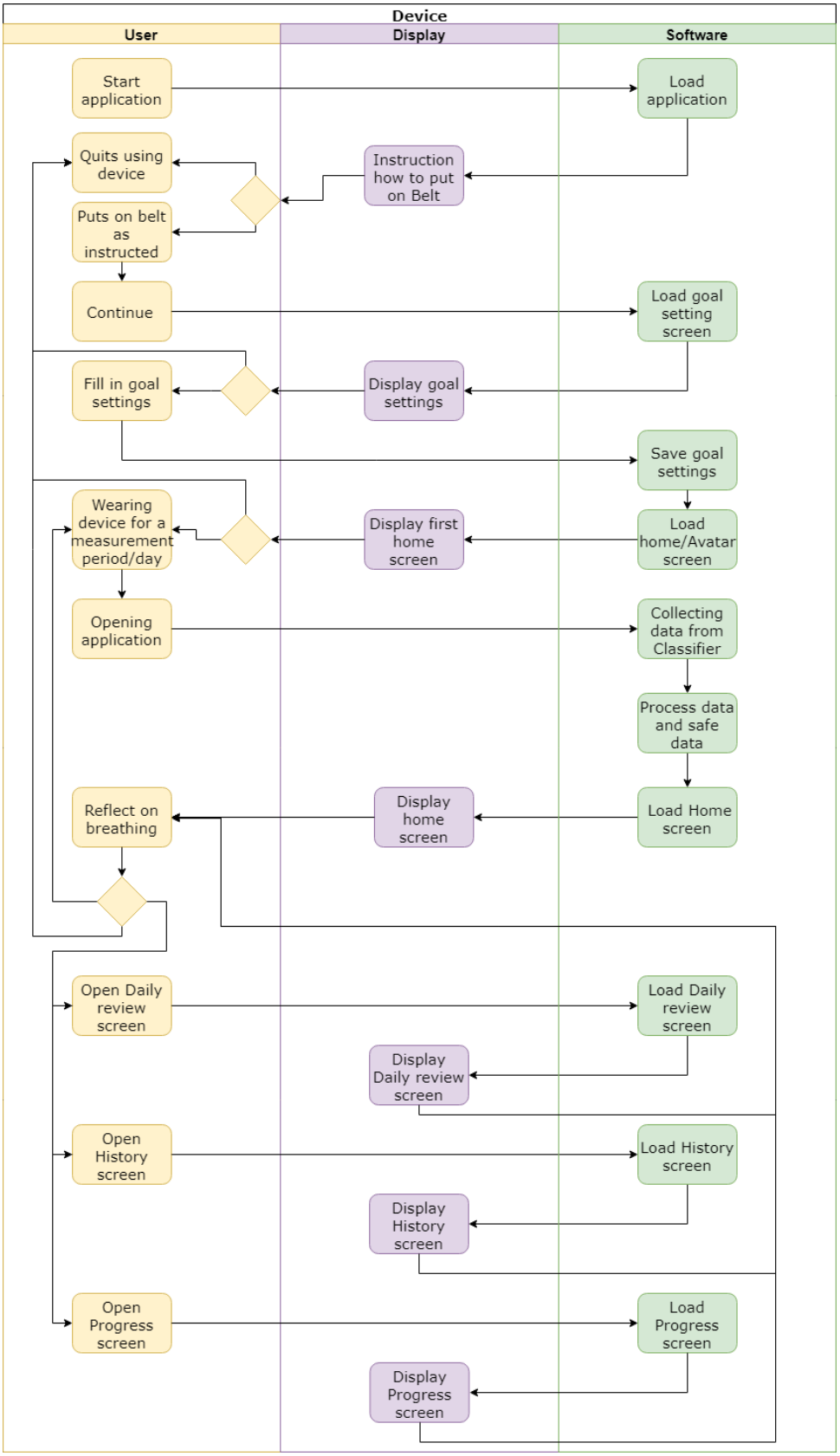


Figure 5.1.5: Activity diagram

5.2 Design expert review

After developing a first mock-up prototype and during the specification phase an expert called Armağan Karahanoğlu was consulted to review the GUI. Armağan Karahanoğlu is an assistant professor at the University of Twente in the Department of Design, Production and Management. With her research she is mainly focusing on understanding user experience of persuasive and health care technology and the development of creative solutions for changing and sustaining behaviour. At his moment she is interested in improving the positive experience of amateur athletes. Due to her profession Armağan was able to give a lot new input about the current state of the design.

During the expert meeting a big variety of possible improvements in terms of the current GUI were elaborated on. A major point that was discussed was the structure of the screen. Proposed was giving the screen a more clear separation of elements. Therefore the screens title as well as the navigation should be separated from the informative middle section of the screen. In addition it was mentioned to place the navigation at the bottom of the screen to constantly show a user which other screen are available to be opened. Furthermore the bottom navigation bar could show icons which recur next to the screen title. This way the user will be supplied with a more clear structure as well as memorability of screens and continuity within the app is increased. In addition it seemed to be necessary to add explanations within each screen for clarification purposes. Such explanations could be added right under the screen title to keep the clear structure.

Moreover the placement of the on/off button was criticized to be too inviting for a user after receiving general information on his breathing. Also the smiley face in general was recommended to be changed into a more theme fitting visualization. However it was further recommended not to over-do the visualization, since designers tend to do this during the first developing processes. Concerning the graphs within in the app Armağan suggested to supply more detailed feedback to the user. Nevertheless it should be one graph per screen or implementing the option to scroll down so that the user can focus on a single graph easier. In terms of functionality of the graphs it proposed to implement zooms and layer graphs on top of each other. Finally Armağan suggested to make use of more colours and their meaning that is trained to people, like red and green.

The expert review with Armağan Karahanoğlu turned out to be a useful tool in regards to further developing the GUI. Feedback on structure, placement of design element, graphs and colours is useful information for a revision of the design.

5.3 Design revision

Since the expert review lead to a great amount of possible improvement ideas the GUI design was revised. This design revision should lead to a more user friendly concept and improve the user's experience. During the revision a major redesign of the application took place and the following changes were made. The entire redesigned app can be seen in Appendix J.

One of the points of criticism was missing information supplied to the user. Taking that into account not only every screen and graph was endowed with an explanatory text but also two start up screen were added. So that with starting the app the first time, the user has to put in a final goal, a daily goal and the steps the daily goal increases when it was accomplished. Followed by a screen to give such input an informative screen showing the user how to put on the wearable was added. Both screens can be seen underneath in Figure 5.3 – 1.

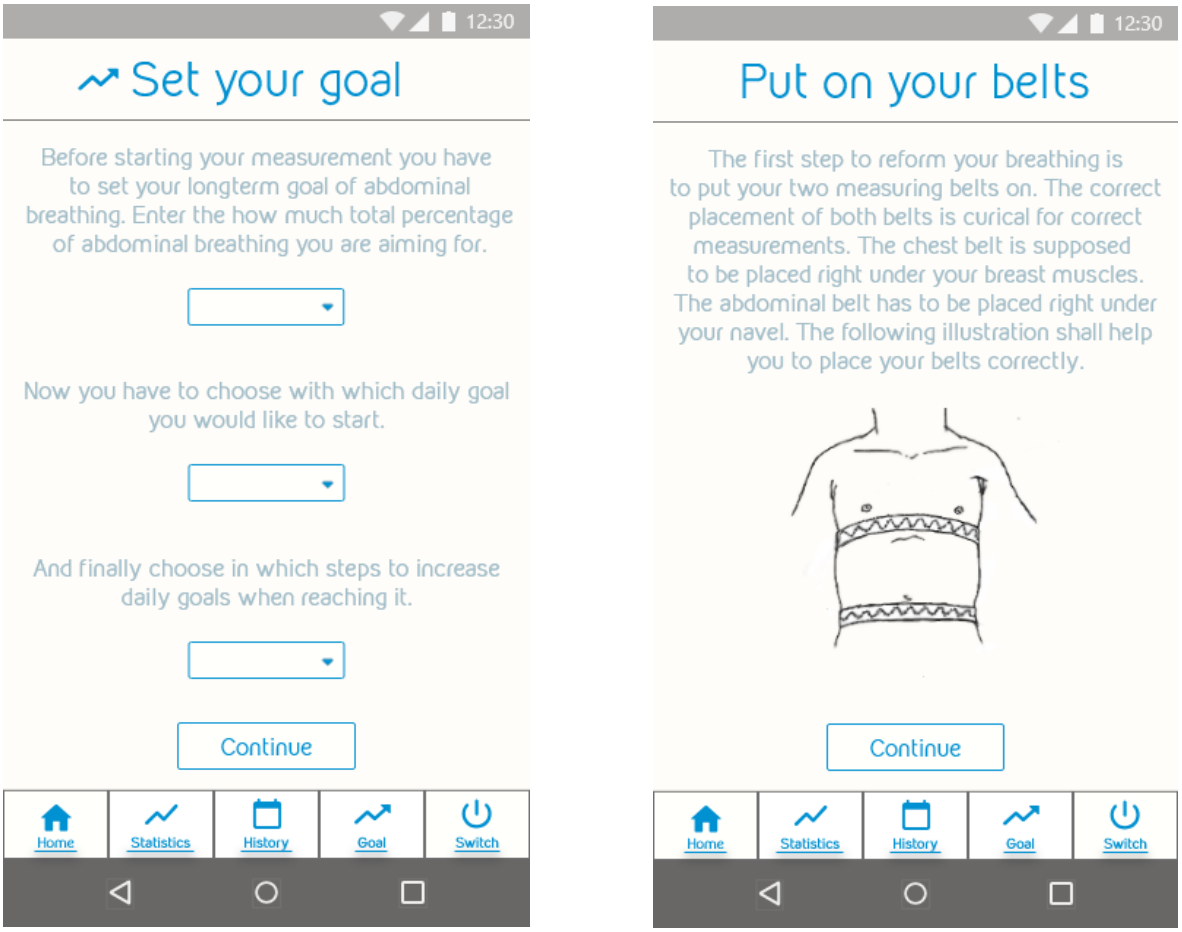


Figure 5.3 – 1: Start-up screens

As it can be seen was the general structure of the screen be adapted to the expert's suggestions. The screen title was separated, a navigation bar at the bottom was added and furthermore are the icons in the navigation bar continuously shown next to the tile of each screen. An exception at this point is the the 'Put on your belts' screen since it cannot be reached again within the usual app. In addition was the visualization of the user's progress redesigned into a flowering garden that gets greater by the user getting closer to his goals or reaching them. An overview of the visualization is shown below in Figure 5.3 – 2. The smiley face was exchanged by a flowering garden and the comments on the users

breathing wear also separated from the visualization itself. The flowers are supposed to fit the theme since a flowering plant stand for vitality.

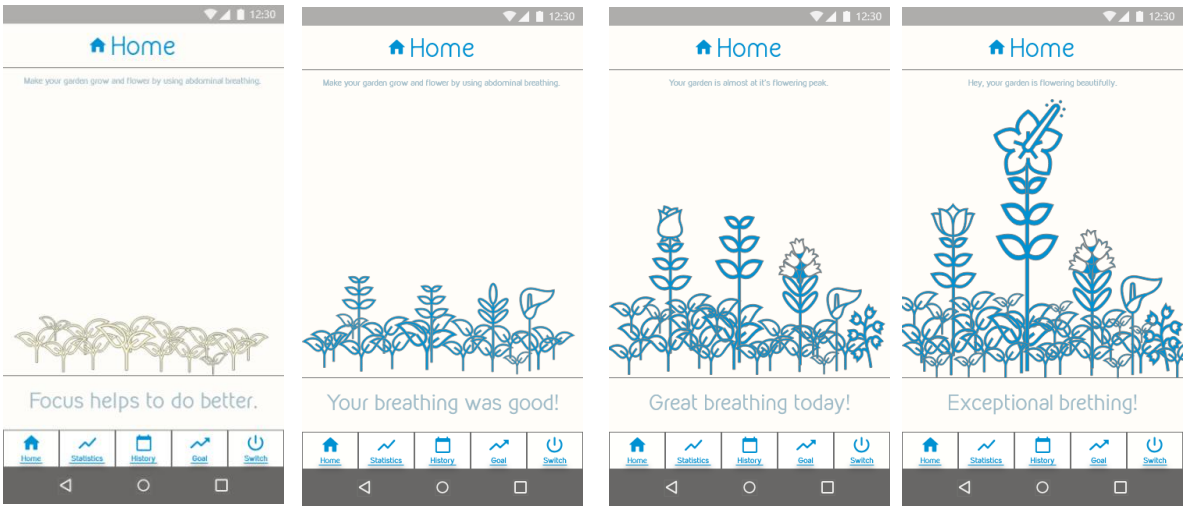


Figure 5.3 – 2: Flowering garden visualization

Moreover were most graphs updated and some were added. The design of the Goal section was based on the design of the History section, which was not fundamentally changed. The new design supports continuity throughout the design and is supposed to follow the advice of showing one main graph per screen. Furthermore were the graphs of the Statistics screen were updated. The graph on the Ratio is expanding horizontally and the Timeline was widened. Added graphs on this screen are the Breathing frequency and Moments graphs, which can be seen in Figure 5.3 – 3.

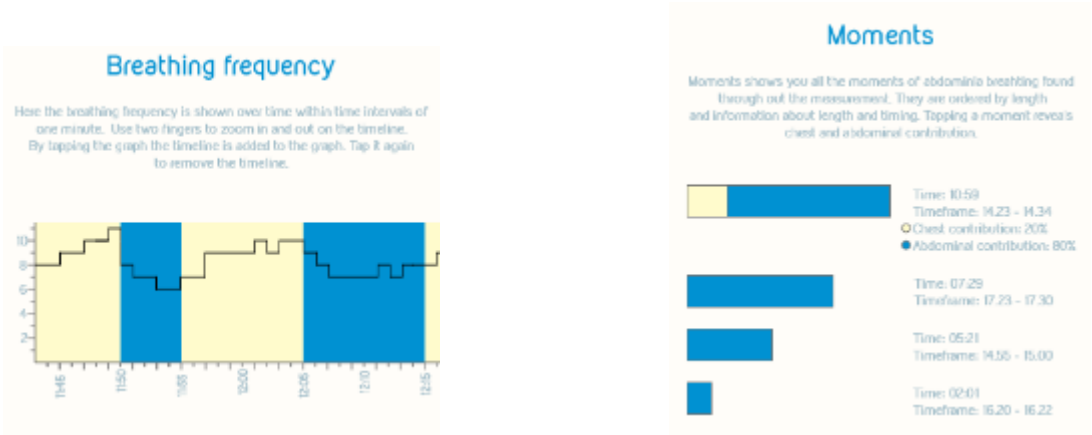


Figure 5.3 – 3: Breathing frequency & Moments, new features in statistics screen

The Breathing frequency graph shows the user his breathing frequency throughout the whole measurement for 1 minute intervals. By tapping the graph can the user place the timeline graph above the breathing frequency to reflect on a connection of breathing frequency and breathing pattern. The also added moments graph is giving the user moments he was practicing abdominal breathing

continuously and sorts them by duration. If the user taps the horizontal bar he can not only see the time and timeframe of the moment but also how much he was using his abdomen and chest while practicing abdominal breathing. The vertical block divided into chest contribution and abdominal contribution in reference to their ratio. Since the Statistics screen is showing several graphs it shall be a screen to scroll down and be able to inspect the graphs appropriately.

Additionally as it can be seen above was another colour added to the colour pallet of the application. Since blue is a fitting colour for the theme of breathing it was left as it is but a pastel yellow tone was added. The choice fell on such a tone due to two reasons. The first reason is that during the interviews it turned out that bright pastel tones would be most fitting for an app on breathing. The second reason is that red as suggested colour might convey too much of a negative emotion to the user. Even though the user is breathing with his chest he shall not get the feeling of something being wrong and raise concerns about the health. Therefore the choice fell on a more neutral pastel yellow tone.

Finally the on/off switch was implemented in a total different way. The switch got its own screen which can also be seen in the bottom navigation bar. In addition the screen was sized up and the text explaining whether the wearable is switched on or off is not part of the switch itself anymore. These changes ensure that there is direct relation between the feedback and switching the wearable on or off.

The information that was gathered during the expert review was converted into a revision of the GUI design. The new design is supposed to be an improved user experience. Since also functionalities were updated was this design taken as basis for the functional system architecture.

5.4 Functional system architecture

The architecture of the system will be described within three layers or levels. Level 0 is a top level overview of the system whereas level 1 is showing a more detailed overview of the functionalities within the system. Level 2 then is a decomposition of these functionalities to show sub-functionalities interact with each other. The functional system architecture is visualized using block diagrams within which arrows refer to data flow and blocks refer to functions.

5.4.1 Level 0: Inputs and Output

The level 0 architecture is the most simplified version of the system and supplies only and overview of the inputs and outputs of the system. The visualization of this architecture can be seen in Figure 5.4.1. The Level 0 has two inputs for once the classified data that is supplied by another part of the wearable and the user controls that are given by the user when interacting with the app. The output of the prototype system is the display showing feedback to the user.

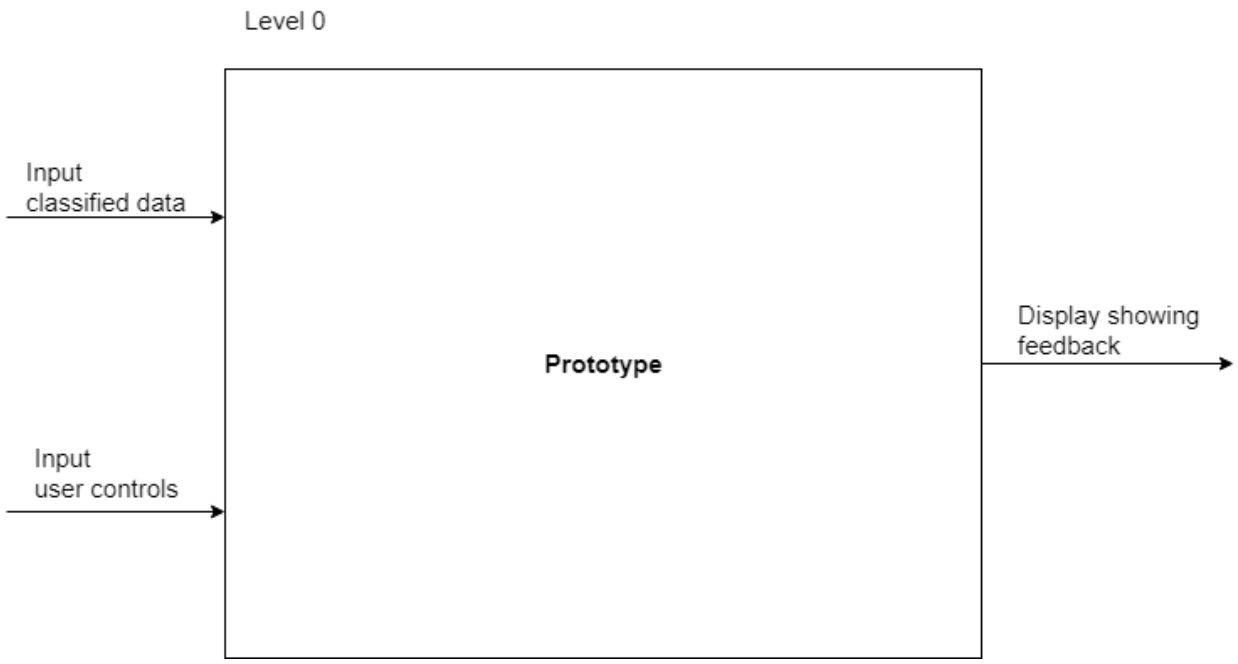


Figure 5.4.1: Level 0 functional system architecture

5.4.2 Level1: Functions

A more detailed view of the level 0 is the level 1 view. This view is actually showing the features inside the prototype and how these lead towards the output. The block diagram of Level 1 can be seen in Figure 5.4.2.

Starting with the input of classified data it is going into the data pre-processing. As the name already says are parts of the classified data further processed to make it useable for other functions. The function of 'Data preprocessing' will be explained further within the Level 2 section. From the function processed data goes then into the data storage. At the data storage data is only saved and supplied to other functions. The 'Goals' function is giving as well as receiving data from the data storage. Depending on the control input and the data about the abdominal breathing ratio for a whole measurement supplied by the data storage, does the function give data to the data storage about the user's progress. The user controls are also going into the 'Switch' function, which was only implemented as groundwork for later phases of the project, when the wearable and the application can be connected. As soon as this connection is established the user is supposed to switch of the wearable using the app but at this point the dashed line does indicate that there is no output so far. Furthermore does the user control input also go into the Navigation function, which has the purpose to give the user to navigate through the app. The 'Navigation' gives information on which screen is currently selected to the 'Graph compiler'. Based on the screen selection and the breathing data supplied by the data storage does the 'Graph compiler' build graphs and so show the feedback to the user.

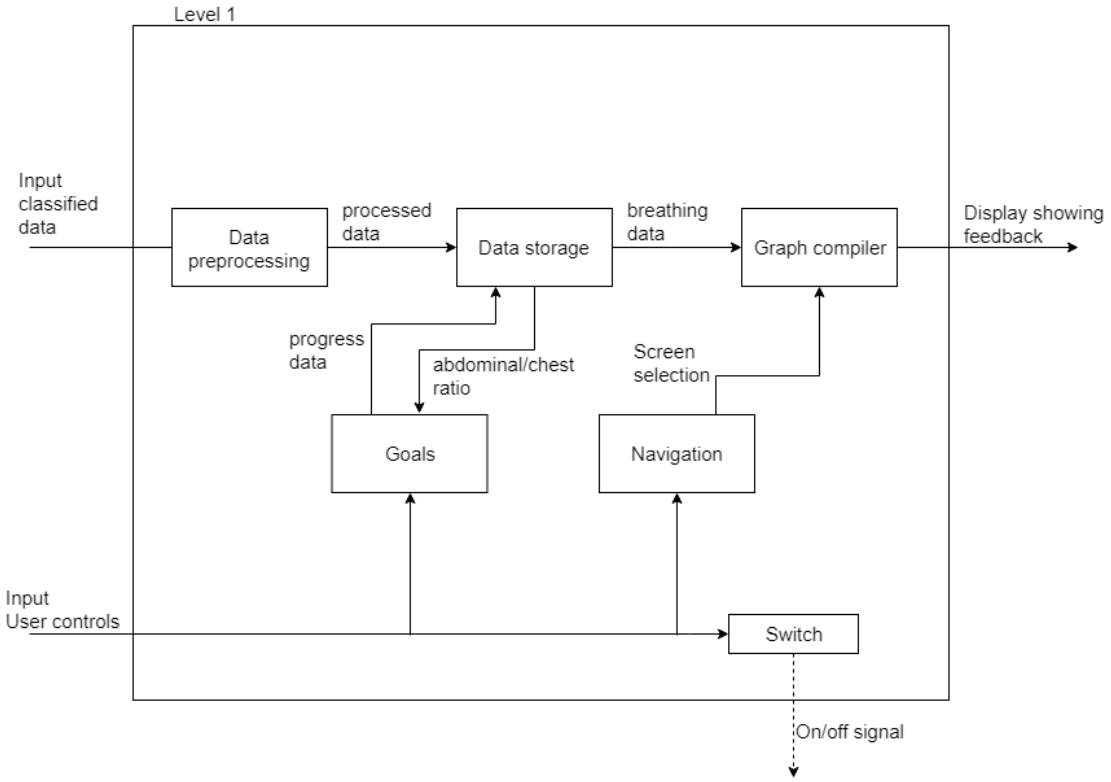


Figure 5.4.2: Level 1 functional system architecture

5.4.3 Level2: Sub-functions

Within the Level 2 architecture of the system are the functionalities broken down into sub-functionalities to give a more elaborate explanation of how these functionalities are supposed to work. Since there were several updates of the design as well as some functionalities during the realisation it can occur that parts like the chosen screens seem not familiar with the design of the ideation phase. To get an accurate idea on what the architecture is based see for the final design in the Appendix J. In addition is a specialty in the Level 2 visualization to be explained, meaning several arrow heads pointing at another arrow. This can for instance be seen in Figure 5.4.3.3 and means that only one of the data flows goes on as output.

5.4.3.1 Data preprocessing

The input into the 'Data preprocessing' function is the classified data which is at first formatted from arrays into strings by the 'String formatting' sub-function. From that first formatting are abdominal contribution values flowing into the sub- function called 'Diff. Abdominal and chest' that calculates all the chest values in reference to their abdominal value. Furthermore are the float numbers like the breathing frequencies or the percentage of abdominal breathing turned into integers by the 'Integer formatting' sub-function to give the user easier readable numbers. Finally, the minute intervals are within the segmentation sub-function assigned to be abdominal or chest breathing. The data from these

three functions are now coming back together with the classified data in strings and build the pre-processed data output.

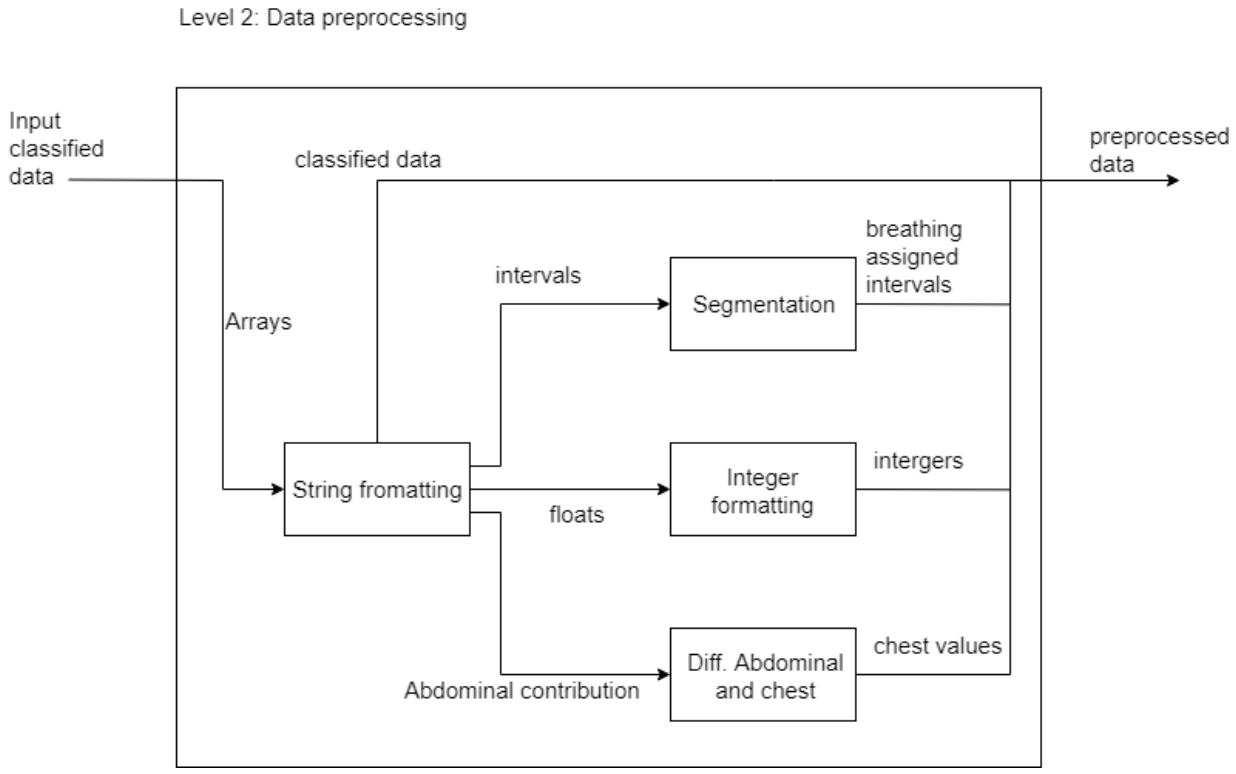


Figure 5.4.3.1: Level 2 data processing architecture

5.4.3.2 Goals

The goals function does consist of three sub-functions namely the ‘Final goal’, ‘Current daily goal’ and ‘Increasing steps daily goal’. Input for all three sub-functions is the user controls, meaning the user does decide on a final goal, a daily goal and with which steps to increase the daily goal when reaching it. The other inputs for ‘Current daily goal’ are the ratio of abdominal and chest breathing for a whole measurement, with which is determined whether the goal is reached. When the daily goal is reached that information goes to ‘Increasing steps daily goal’ and depending on the step the goal increasing with an update with the new daily goal is sent to ‘Current daily goal’. The information about the final goal and the daily goal gets together and builds the progress data.

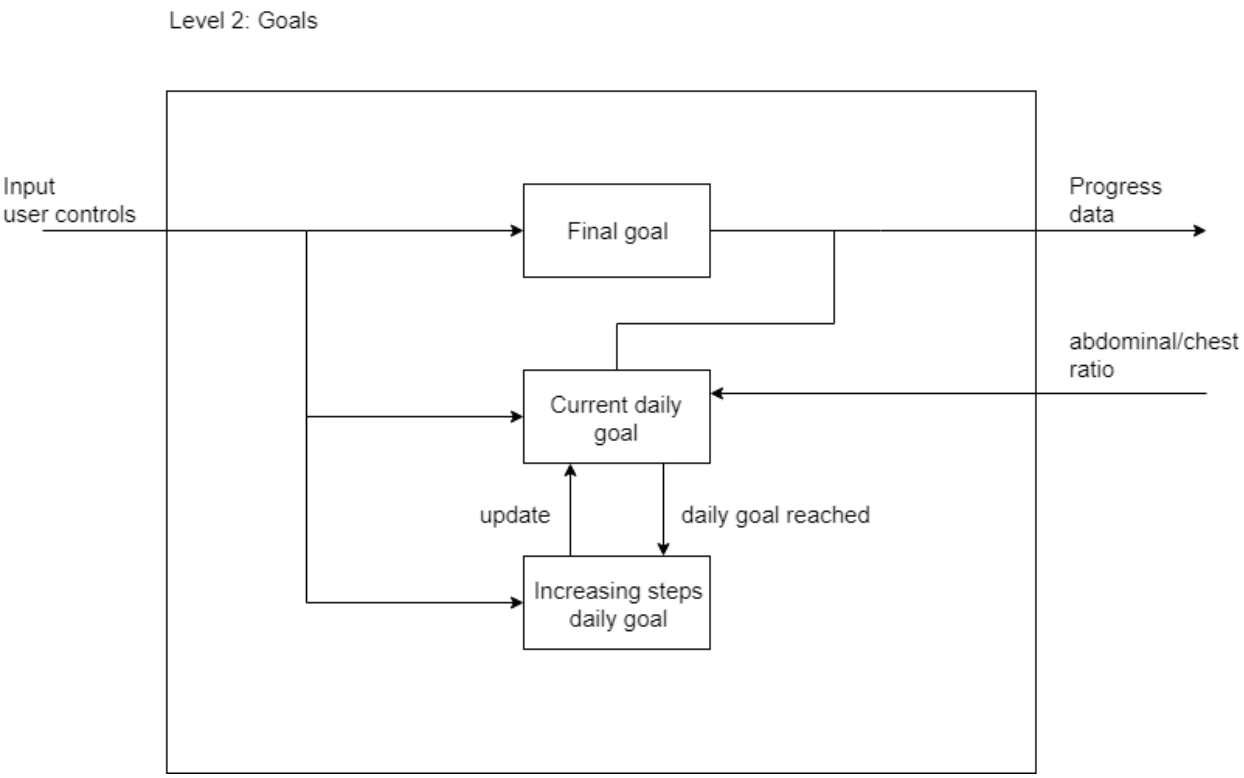


Figure 5.4.3.2: Level 2 Goals architecture

5.4.3.3 Navigation

Input for the Navigation function is the user controls. With the Navigation bar does the user decide on which screen will be pictured in the app. This will either be the ‘Home screen’, ‘Progress’, ‘Daily review’ or ‘History’. Since only one screen can be selected only the screen selection info of the one selected screen will be sent as output of the ‘Navigation’ function.

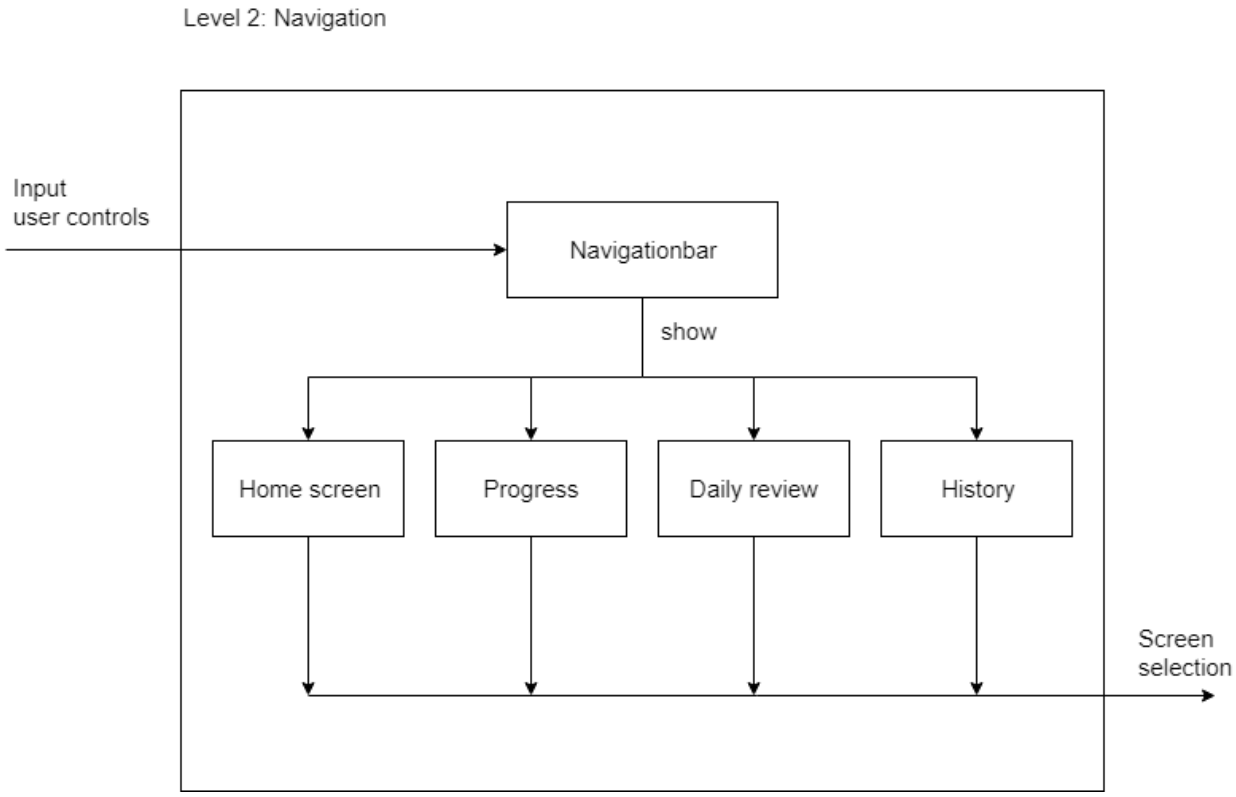


Figure 5.4.3.3: Level 2 navigation architecture

5.4.3.4 Graph compiler

The graph compiler is the most complex function within the system. Inputs of the function are the screen selection from 'Navigation' and breathing data from 'Data storage'. Different parts of the breathing data are going to different sub-functions or graphs that have to be compiled within the 'Graph compiler'. The progress data is going into the 'Avatar' sub-function which is generated based on the values the user reached in respect to his goals. The 'Avatar' sub-function is shown feedback on the display if the home screen is the selected screen. The ratios of abdominal and chest breathing for the last 5 measurements as well as the daily goal and the final goal are the send breathing data to the sub-function 'Goal bar graph'. The 'Goal bar graph' showing the ratios in respect to the goal is the feedback shown on the display if the progress screen is selected. When the screen daily review is selected are several graphs shown, namely 'Ratio bar graph', 'Timeline', 'Breathing freq. bar graph' and 'Moments sorted bar graph'. These graphs are once showing the ratio of total abdominal breathing and chest breathing in bars next to each other and uses the data of abdominal and chest breathing, second a timeline with coloured intervals indicating whether abdominal or chest breathing was practiced at certain times and is supplied with the interval data, third a timeline showing the breathing frequencies in bars for each minute which also get their colour assigned by the timeline and is supplied with the breathing frequency data and finally several bars sorted by length indicating the length all periods of abdominal breathing which is supplied with the breathing data on time, duration and abdominal/chest ratio of these moments. The 'History bar graph' is a sub-function that is supplied with the breathing data of the abdominal and chest breathing intervals of the last 5 measurements. These Intervals are shown in bars next to each other and are scaled to time. The feedback displayed is 'History bar graph' if the screen selection data is 'History'.

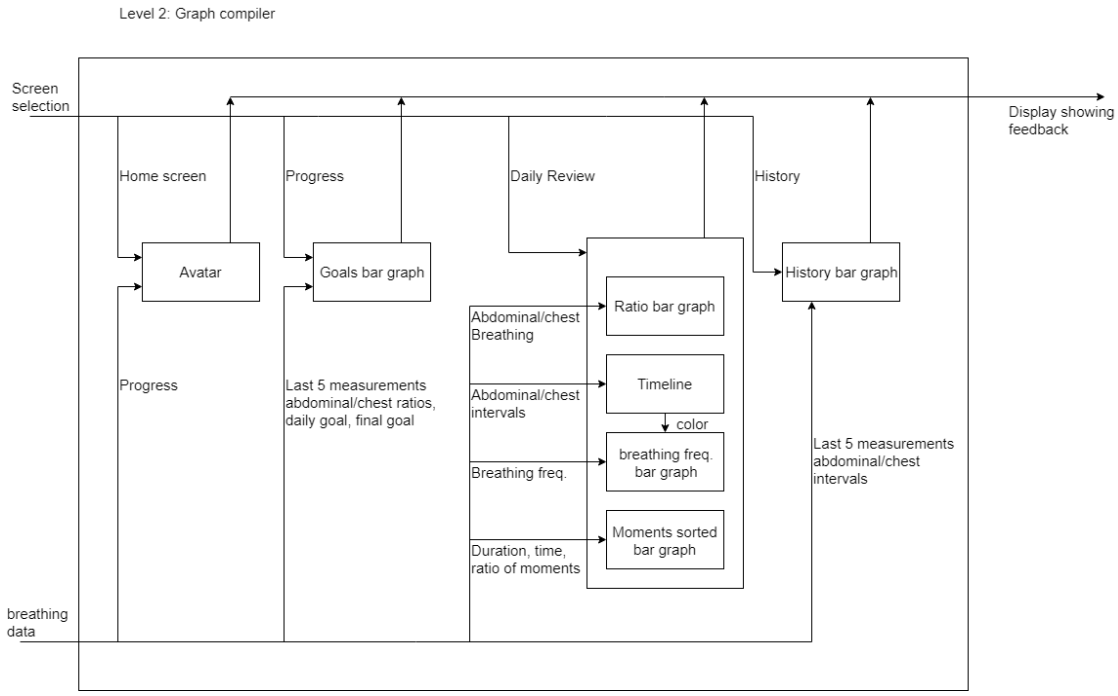


Figure 5.4.3.4: Level 2 graph compiler architecture

5.5 Requirements 2nd Iteration

With taking the finding of the specification phase into account will an updated version of the list of requirements be created. For the second iteration of requirements is the labelling of functional and non-functional requirements added.

Must

1. Minimize the cognitive work load of the user by simplifying data into an easy understandable visualization of user's performance (non-functional)
2. Show the ratio between diaphragmatic and abdominal breathing for the entire measurement (functional)
3. Show the user within minute intervals whether he was practicing abdominal breathing (functional)
4. Give the user an intuitive app structure to navigate through easily. (non-functional)
5. Supply the user with understandable graphs to make it possible for the user to reflect on his breathing. (non-functional)
6. Explain how to put on RIP belts correctly (non-functional)
7. Give the user the possibility to choose a certain ratio of abdominal breathing as final goal (functional)
8. Give the user a graph that shows how well he is doing in regards to his goal (functional)

Should

9. Give the user the possibility compare timelines of at least the last five measurements (functional)
10. Give the user a graph that shows how well he is doing in regards to his goal for the last five measurements to visualize his progress (functional)
11. Let the user choose smaller sub-goals as steps to work towards the final goal (functional)
12. Base the design on bright colour as well a blue to make it fit the health theme and give distinction between positive and negative (non-functional)
13. Use guiding but not demanding explanations within the app to support the user understanding information. (non-functional)
14. Minimize the amount of design elements to avoid distraction from information (non-functional)
15. Keep all information reachable within 3 clicks to minimize the time that has to be spend using the app (functional)
16. Increase the sub-goals automatically when it's reached by a value the user picks (functional)

Could

17. Implement facts on advantages or effects of abdominal breathing to read it up (functional)

18. Show the breathing frequency to give more in depth information about certain moments (functional)
19. Changeable themes for the representation of abdominal breathing performance (functional)

Won't

20. Show the feedback in real time (functional)
21. Give the user always the possibility to switch the wearable off (functional)
22. Give direct instructional feedback how to improve abdominal breathing (functional)
23. Show calibration screen working cooperating with the classifier's calibration process (functional)
24. 5 minute training session giving feedback about performance when actively practicing DP (functional)
25. Give the user the possibility to label time line with time stamps of emotional state (functional)
26. Self-notifications on a timeline to recall emotional state of a certain moment in reference to breathing performance (functional)
27. Synchronize to the calendar and push notifications depending on calendar schedule (functional)
28. Synchronize to the calendar and automated marking of timeline with calendar entries (functional)

Chapter 6 – Realisation

In this chapter is described how building up the GUI will be realized. During this phase the mock-up prototype will be turned into a working prototype that will be supplied with the classified data. The prototype is based on the structures shown in the functional system architecture and the activity diagram presented in chapter 5 (Specification). At first the used programming environment is described. This is followed by another expert review on the GUI design. Finally the construction and implementation of the graphical user interface is described.

6.1 Software

On the technical side for the realisation three major components were decided on to realize the app. First of all for the coding environment it was decided for Android Studio [62] as it is an integrated development environment that supports the development for Android OS devices. The reason that the author does only possess an Android device made the decision for this environment. In addition Flutter [63] was used as framework for the project. Flutter is an open-source mobile application framework invented by Google, which supplies a high performance engine, Libraries and specific design-widgets. Since these parts of the framework can speed up the developing process Flutter has been chosen. The programming langue that is recommended to be used in connection with Flutter is Dart [64]. It is also a language created by Google aimed to run applications fast and has the advantage, that Dart code can easily be compiled for Android as well as iOS. Given that the application is supposed to be further developed after the Project and that the author has only limited prior knowledge in coding the choice for the language fell on Dart. Furthermore, Dart and Flutter were recommended due to the above named reasons to the author by Peter Bastiaan den Boer. Peter is a Computer Science master student at the University of Twente. He is experienced in developing applications and participated different Hackathons in the past.

Bastiaan gave major support to the author in terms of turning the mock-up prototype into working code. Long consultation hours and coding sessions with Bastiaan and the author lead to a successful realisation.

6.2 Design expert review #2

During this realisation process another design expert review took place. For this expert review the critical observer Dr. Ir. Geke D.S. Ludden inspected the current design of the GUI as well as the hitherto app.

Since the prototype has not been completely built at that moment the expert was consulted, did she inspect once the app as far as it was developed and the mock-up prototype. From an intensive dialogue with the expert a variety of possible improvements emerged. The insights about the improvements will be listed below:

- Sections in the bottom navigation bar could be ordered differently, so that 'Goal' is placed to be the second section from the left to fit order the seeks information
- Sections could also be renamed meaning 'Goal' will be called 'Progress' and 'Statistics' will be changed into 'Daily Reflection' to clarify shown information within the section
- Descriptive texts within goal setting were found to be too impolite of the user and advised to be rephrased to enforce the user less
- Illustration showing how the belt should be placed on the body was suggested to be aligned with style of the whole app for continuity purposes
- Implementing a goal indication for users without any knowledge of how to set an appropriate daily and final goal when using the wearable for the first time
- Implementing a video that shows and explains all states of the Home section flowers for clarification
- Renaming 'length' in Moments graph into 'duration'
- Revise explanatory texts of most graphs for clarification on the given information
- Home section should only show one explanatory text to avoid repetition

The purpose of all the suggested changes was to improve the user experience of the application. Mainly the user's needs and clarifying information were major aspects to improve on for the experience. The author was taking all recommended improvements into account and tried to implement these during the realisation of the prototype.

6.3 Final prototype

In the process of coding time was a major constrain for realizing the app. Since not only time but also other challenges were to overcome choices influencing the design and functionalities were made with the focus on creating an app being useable for usability tests.

The two major challenges that were to overcome during programming were once importing the data sets with classified data by Arnav Mundkur. In the early progress of coding it appeared against expectations, that .txt is a not accepted file format by Dart. The consequence was that the data files had to be transformed into .json files. Still the data formatting within this .json file did not match the standardized .json file. To make the data useful inside the programming framework the data had to be reformatted, which was a time consuming process.

The second major challenge to overcome was creating all graphs manually. The advantage of this procedure is that the functionalities and looks of the graphs could be kept almost identical to the mock-up. Nevertheless the disadvantage coming along with this procedure is that a lot of time is consumed by figuring out the correct pixel rations, sizes, labelling and placement. Using libraries of existing graphs could have speeded up the development process of the app tremendously.

Although these challenges were taking a lot of time during development also implemented libraries of flutter and dart were used to speed up certain processes during development so that an existing navigation bar or icons could be implemented easily. With the start of programming the application it also occurred that the app needs a name. As consequence of this it was given the project name 'Airleviat' as a pun of air and alleviate.

Due to all these and other factors several changes differing from the suggestions given by the expert were made as it can be partially seen in Figure 6.3. These changes are functional as well as non-functional. Screenshots of the complete Prototype can be seen in Appendix K. The following list is giving changes made during the coding process and their justification.

Figure 6.3: Home screen Airleviate prototype

- Different navigation bar due to easy widget implementation via flutter
- 'Goal' section renamed into 'Daily Review' since 'Daily Reflection' was too long for the navigation bar
- New icons for some sections so they fit the section names better and are more distinguishable
- Goal selection is made via a slider due to visualizing the chosen number better, decrease of time needed for input and quick implementation
- Changing biggest flower due to ambiguity of illustration
- Top in blue to underline blue more as primary colour of the application
- Secondary colour changed into an pastel orange tone due to visibility issues of pastel yellow on a phone screen
- In progress section only current daily goal due to saving different daily goals would have taken too much time
- Steps in which daily goal increases was left out due to time constrains of making and implementing vs necessity
- Breathing frequency graph consist of bars due to saving time with the approach
- Tapping and showing single measurements in History and Progress were left out due to time constrains of making and implementing vs necessity
- Implementing a video showing and explaining all states of the Home section flowers was left out due to time constrains of producing the video
- Zooming in and out in graphs would have been taking a long time due to the graphs being manually created and was passed on because of time constrains

Since most of the changes made during the realisation phase are connected to time constrains, can several points of the list be considered for future work. Although a lot of changes were suggested by the expert and a lot of changes were made during the realisation, did the prototype stick rather close to the created mock-up of the specification phase.

To give an understanding how the application was created some pseudo code will be given for the 'Goal Setting' screen. The code for 'History' screen, 'Goal setting' and the breathing frequency in the 'Daily Review' can be seen in Appendix O.

6.3.1 Pseudo code 'Goal setting'

Importing packages and data

Setting up interactive StatefulWidget (dynamic)

Setting up variables of StatefulWidget
get daily goal
set daily goal as variable
state of widget set to daily goal value

Get final goal
set final goal as variable
state of widget set to final goal value

Setting up initial state of widget when no value is given yet
daily goal is 50
final goal is 80

Build widget
based on numbers
return widget
return bar on top of the screen saying 'Set your goals'
return instruction text for final goal
return slider 0-100
slider position on daily goal
set final goal value to state value of slider
return instruction text for daily goal
return slider 0-100
slider position on daily goal value
set daily goal value to state value of slider
return continue button if first time app started
else return go back button
return navigation bar

Setting up page with statefulWidget
show stateful widget

Chapter 7 – Evaluation

In this chapter the prototype that was developed in the realisation phase, will be evaluated and tested on its validity in terms of the requirements. At first a functional test will be conducted by the author to check whether the functional requirements are met. The functional test is followed by a usability test, which involves possible users testing the prototype under determined conditions and checks on the non-functional requirements. Hereafter, a conclusion from both evaluations will be supplied and finally, an updated set of requirements will be given which can be used for future work.

7.1 Functional Test

First part of the evaluation is a functional test that was conducted by the author. The purpose of this test is to check whether enough functional requirements are fulfilled to test the app with users. All the 'Must' requirements from the list should be met in order to use it for further tests. The 'Should' and 'Could' requirements are preferred to be met. In the following table 72374 all functional requirements are listed and it is examined for each requirement whether it was met by the prototype.

#	Requirements	Checked off
	Must	
2	Show the ratio between diaphragmatic and abdominal breathing for the entire measurement	X
3	Show the user within minute intervals whether he was practicing abdominal breathing	X
7	Give the user the possibility to choose a certain ratio of abdominal breathing as final goal	X
8	Give the user a graph that shows how well he is doing in regards to his goal	X
	Should	
9	Give the user the possibility compare timelines of at least the last five measurements	X
10	Give the user a graph that shows how well he is doing in regards to his goal for the last five measurements to visualize his progress	X
11	Let the user choose smaller sub-goals as steps to work towards the final goal	X
15	Keep all information reachable within 3 clicks to minimize the time that has to be spend using the app	X
16	Increase the sub-goals automatically when it's reached by a value the user picks	
	Could	
17	Implement facts on advantages or effects of abdominal breathing to read it up	
18	Show the breathing frequency to give more in depth information about certain moments	X
19	Changeable themes for the representation of abdominal breathing performance	

Table 7.1: Functional test

During the functional test it turned out that all the 'Must' requirements are fulfilled. The ratio is shown to the user in the 'Daily review' section, the timeline shows clearly when abdominal breathing was practiced during the measurement, the user has to set his final goal at first start of the application and in the 'Progress' section does the user see the ratios of all measurements as well as his daily and final goal in relation each other. Most 'Should' requirements were met except number 16, increased sub-goals. As discussed in Chapter 6 this feature was left out on purpose to decrease the development time needed for the application. Since the user can still adjust his daily and final goal at any point it is possible for him to increase the daily goal by choosing steps manually. Downfall of the user still being able to adapt the goal to his needs is, that with this decreased automaticity he might tend more to trick himself by changing his goal to get positive feedback. Regarding the 'Could' requirements only one out of three could be fulfilled being number 18, the breathing frequency visualized to give more in depth information. The other 'Could' requirements had to be left out due not fitting the scope of this project.
Since all 'Must' and most 'Should' requirements are fulfilled a usability testing be can conducted to validate the non-functional requirements.

7.2 Usability Test

With the usability test it shall be determined whether the prototype can fulfil the non-functional requirements. Furthermore strong and weak points as well as recommendations for future work are hoped to be found during the test. These points are especially important for this project since the scope of it is user oriented. Since the wearable still consisting of single components that are in development at the moment, does the usability test focus on quality and not on quantity. For recommendations on how to set-up the usability test Geke Ludden was consulted.

7.2.1 Test procedure

The usability test for was designed as following. People were testing in pairs of two to intensify the communication about the application and make it more explicitly and freely as compared to single-person testing. At first did the author inform the testers about the research and how the test will take place. Afterwards where the test subjects supposed to sign a form of consent for participating and being filmed during the test. The test subjects received certain tasks they had to fulfil within the app. While the subjects were fulfilling their tasks the author observed and listened to the subjects. Furthermore, he took notes and filmed the subjects. The purpose of this was being able to revise the test at a later moment and being able to also find non-verbal reactions of test subjects. The author also observed how intuitively the user can fulfil tasks. Furthermore were the subjects supposed to familiarize themselves with the application since the to be fulfilled tasks were followed by a survey. Via this survey the user were asked to rate several aspects of the application as well as gave answers to open questions on their opinion on the app. The survey consists of 16 questions and the rating system is implemented for show some quantitative data on quality and goes from 1 to 4. The purpose of this rating system was to avoid a neutral answer and force test subjects to decide for a rather positive or negative emotion towards the prototype. The tasks the test subjects had to fulfil and the questions of the survey can be found in Appendix L.

7.2.2 Test results

In the following part the results from the usability test will be presented for the observations during the users interacting with the app and for the results of the survey. All users that participated were students between the age of 21 and 31. The test results will be presented in two different parts. The first part deals with the users interacting with the app and the second part deals with the survey that was filled out after the interaction. For both parts an overview of the most relevant results will be presented. All results in detail can be seen in Appendix M and Appendix N. Finally the relevance of the conducted test and the outcome will be discussed.

7.2.2.1 App interaction

A lot of observations were made during the first part of the usability testing. Due to the size of the video recordings were only screenshots of the test sessions attached to Appendix M. For inspecting the whole video material is the author to be contacted and a screening can be arranged. Finding of the tests are the following.

It repetitively occurred that the name 'Moments' for periods of abdominal breathing practiced in a row, might be confusing or was confusing for test subjects . Renaming 'Moments' into 'Periods' was suggested to be a more clear nomenclature in this case. Also some subjects were confused by the Moments bar not being grey before tapping it like in the frequency graph. As a result from this colour coding it also appeared to confuse subjects why the bar gets split into two colours after tapping it when it was only blue before.

A second recurring point of critique was the 'Frequency' graph, which shows the user his breathing frequency for each minute of the measurement. At first several subjects did not understand what was meant by the term frequency. As soon as it was understood most subjects were asking themselves which useful information they gather from the breathing frequency. In comparison another subject emphasized this graph to be the most important one to be able to reflect whether a user was actually relaxed in a certain situation or only doing abdominal breathing.

Furthermore, the explanations of certain graphs proved to be problematic. Some subjects expressed that they were not detailed enough but others explained that they were too long so they ignored the text and only tried the app.

Last but not least it was asked by every pair of subjects whether the application shows their breathing in real time. Intuitively did the subjects expect to see a reaction to their breathing on the screen.

7.2.2.2 Survey

With the survey were the subjects giving direct written feedback on the app they tested. In the following will only the most important parts of the survey findings be summed up. All results of the survey can be found in Appendix N.

The insights of the survey are generally coinciding with the observational findings. The 'Daily review' was repetitively named as a critical aspect since parts were not understood. For each question's given rating

by the subjects the mode was calculated as being the correct way of analysis for ordinal data[53]. The mode simply explained is giving the most occurring number in an ordinal data set [53]. All modes were either 3 or 4, except the mode for the question regarding the 'Daily review', which shows this section to be one of the weakest point of the application but also how positive the rest of the app was picked up.

The second most criticized part of the application were the explanatory texts, which also goes in line with the observations. The subjects mainly found it too long and wished it to be more on point. Also giving the possibility of hiding and showing the text was suggested.

Furthermore in the open questions of the survey it also occurred that some subjects did not get the choice of the secondary colour used in the application. In terms of positive feedback many subjects filled out that the 'settings', meaning adjusting the final and daily goal, was a very useful feature for the purpose of the app. Other useful features or tools for reflecting on breathing did vary a lot for subjects. Additionally was the flower illustration representing the users progress expressed to be visually appealing and was generally liked by the subjects.

The results of the survey underline definitely that 'Daily review' and explanatory texts are critical points of the GUI design. This clearly goes in line with the observations from the app interaction of the subjects.

7.2.3 Discussion

Even though a variety of conclusions can be drawn from the results given above it must be discussed for valid the results should be taken. There are two aspects underlining why the conducted usability test should rather be considered as an indication for evaluating the GUI than as a complete insightful usability test.

First of all was the usability test was conducted with a limited amount of subjects. When consulting Geke Ludden for the test setup it was stated three pairs of subjects would be sufficient and four be the preferred amount. Although five pairs were testing the app on its usability does the amount of ten test subjects not allow to compare to a scientifically conducted research.

The second point of discussion is the ordinal rating system used within the survey. This ordinal data is comparable to the Likert scale, which is a commonly used method for ordinal data in surveys [53]. The difference between the used ordinal scale and the Likert scale is that in Likert scale there is always a neutral option that can be picked. This means that usually the subject can choose on a scale with an odd number of choices, e.g. 5 or 7. The decision of leaving out such a value was intentionally made by the author to make the subjects to decide for a stronger tendency. Since the amount of subjects does not exceed 10 did the author decide for a scaling system that shows a strong indication.

Although the above mentioned aspects indicate not to take the usability test too meaningful, it should not be neglected in terms of showing indications of the apps usability. Still were clear results found during the test, which should be taken into account for future work.

7.3 Conclusion

It is to conclude that a variety of insights were found during the usability test. These tests should be used as basis for recommendations regarding future work.

The functional test showed that most functions regarding the app are working. This leads to the conclusion that no functional flaws of the application need to be fixed. More insights could be found during the usability test.

A major insight from the usability test is that the explanations given in the app need revision. The fact that explanations were partially distracting, too long or ignored by users clearly shows that these need to be reworked and/or implemented differently. Subjects suggested hiding options to make them less distracting and emphasize focus points by using bold font. The content might need to be adjusted in a way that users without prior knowledge on breathing can understand explanatory texts. Also a clear introduction of users to the terms used in the app and the right choice of terms seems to be crucial.

Moreover was the 'Daily review' section a very critical aspects in terms of understanding. It might be possible that improved explanations could help understanding the 'Daily review' section already. Still should the revision of this part of the app be considered to optimize the user experience. Also for this aspect decreasing the complexity with show/hiding functions on graphs was suggested.

Furthermore were the adjustable goals found to be very useful for a user in terms of striving for a goal or motivation. This can definitely be useful for habit formation might be considered to be improved on in the future. In addition it was found that users used different graphs as tool to reflect on breathing. This emphasizes that a variety of different graphs being supplied might be an advantage to fit several user's needs in terms of reflection.

Finally one of the most important insights is that having real time feedback would make the app most intuitive for users since every pair of subjects asked about real time feedback.

Although it was found that some improvements on the application need to be made, it can be said that it was successful regarding functional and non-functional requirements. The users could use most of the visualizations successfully as tool for reflecting their breathing and found the app general intuitive to use. Generally was the app picked up as visually appealing.

7.4 Requirements 3rd Iteration

As a result from the evaluation is a final iteration of requirements given. These requirements can be take for future work on the GUI of Airleviate. The list of requirements is based on all the findings during the development process of the GUI.

Must

1. Minimize the cognitive work load of the user by simplifying data into an easy understandable visualization of user's performance (non-functional)
2. Show the ratio between diaphragmatic and abdominal breathing for the entire measurement (functional)

3. Show the user within minute intervals whether he was practicing abdominal breathing (functional)
4. Give the user an intuitive app structure to navigate through easily. (non-functional)
5. Supply the user with understandable graphs to make it possible for the user to reflect on his breathing. (non-functional)
6. Explain how to put on RIP belts correctly (non-functional)
7. Give the user the possibility to choose a certain ratio of abdominal breathing as final goal (functional)
8. Give the user a graph that shows how well he is doing in regards to his goal (functional)
9. Use clear and brief but not demanding explanations within the app to support the user understanding information. (non-functional)
10. Fuse the classification algorithms with the app (functional)
11. Real time connection of RIP bands and app (functional)
12. Let the user choose smaller sub-goals as steps to work towards the final goal (functional)
13. Give the user always the possibility to switch the wearable off (functional)

Should

14. Give the user the possibility compare timelines of at least the last five measurements (functional)
15. Give the user a graph that shows how well he is doing in regards to his goal for the last five measurements to visualize his progress (functional)
16. Base the design on bright colour as well a blue to make it fit the health theme and give distinction between positive and negative (non-functional)
17. Minimize the amount of design elements to avoid distraction from information (non-functional)
18. Keep all information reachable within 3 clicks to minimize the time that has to be spend using the app (functional)
19. Increase the sub-goals automatically when it's reached by a value the user picks (functional)
20. Show the breathing frequency to give more in depth information about certain moments (functional)
21. Show/Hiding option for explanatory text and graphs at 'Daily Review' (functional)

Could

22. Implement facts on advantages or effects of abdominal breathing to read it up (functional)
23. Changeable themes for the representation of abdominal breathing performance (functional)

Won't

24. Give direct instructional feedback how to improve abdominal breathing (functional)
25. 5 minute training session giving feedback about performance when actively practicing DP (functional)
26. Give the user the possibility to label time line with time stamps of emotional state (functional)
27. Self-notifications on a timeline to recall emotional state of a certain moment in reference to breathing performance (functional)
28. Synchronize to the calendar and push notifications depending on calendar schedule (functional)

29. Synchronize to the calendar and automated marking of timeline with calendar entries (functional)

Chapter 8 – Conclusion & Future work

This chapter will start by providing the comprehensive conclusion of this graduation project. At first an overview of the reached achievements during the graduation project will be given. Afterwards the main- and sub-research questions, supplied in Chapter 1.3, will be discussed and answered. Finally recommendations for future work will be given.

8.1 Conclusion

The purpose of this graduation project has been providing a user of 'Airleviate' with feedback on their breathing to support the formation of abdominal breathing as habit. Throughout the working process on the project several mile stones were successfully achieved. One of the first achievements was a background research conducted to understand breathing, the technology used for the wearable, biofeedback and habit formation. In addition to this a large variety of state of the art technology was inspected to gather information and inspiration on breathing feedback. This was followed by an intensive process of developing a concept for the GUI and creating Mock-up prototypes. These mock-ups were further improved on their user experience via expert reviews. Thereafter, the mobile phone application was successfully developed into a testable prototype. Finally the prototype was evaluated via both functional tests and double-person user tests.

All these processes were executed in purpose to answer the research question of this project. The in Chapter 1.3 state research question will be answered by the end of this conclusion. In order to answer the research question the sub-research questions will be answered at first.

The in the literature research gathered information supplies the needed information to answer the first sub-research question. *'Which technique is the optimal one supplying healthiest breathing?'* During reviewing scientific literature a lot of positive effects related to abdominal breathing were presented. Not only preventive benefits for the body and psyche were found but also the possibility of using abdominal breathing as treatment was shown. Not only scientific papers but also an expert interview stated abdominal breathing's advantages. This means that the answer to the first sub-research question is that abdominal or diaphragmatic breathing is the technique to supply healthiest breathing.

The second sub-research question, *'How should the GUI be presented to the user in regards to user experience and technical requirements?'*, can be answered from different processes. Since a wearable is a mobile device it turned out during the ideation that the GUI needs to be developed as an app suitable for a screen of a mobile device such as a smartphone. Main arguments for this choice were the restricted battery on the RIP belts and ample availability of smartphones. Furthermore, did interviews, expert reviews and evaluation show that a clean non-distracting design with blue and light pastel tones fit for the user experience. An important finding from the user tests was that clear explanations for such a complex topic as breathing are essential for optimizing the user experience.

The third sub-research question, *'Which methods of user motivation can keep a user practicing to reach a set long term goal?'*, can also be answered from several processes. During the background research, interviews and evaluation it turned out that setting goals is a key point for motivation and habit formation. This means that having a long term goal and also having different stages towards that goal

turned out to be important. Adjusting this goal to personal needs showed to be a motivational factor. Additionally monitoring the progress towards the goal was found in literature to be key as well.

Regarding '*How can instruction impulses to optimize breathing be presented in the most effective way?'* it turned out to be more complex since no real time connection between separate parts of 'Airleviate' is possible yet. The system is so far not giving further instructions to the user than he or she needs to improve in general. An important aspect of receiving feedback is to lower the cognitive workload for the user, which was realized by the flower representation. More detailed feedback had to be gathered by the user himself using the given graphs in visualizations to reflect on his own breathing. Considering reflection as an instruction impulse it was pointed out that visualizations and a clear explanation of these is key to enable reflection. Furthermore providing different visualizations showed to improve reflection for a variety of users since they tend to use different visualizations as tool. Nevertheless is it really important to realize a real time connection of system components to enable live feedback/instructions.

Summing up all the answer on the sub-research questions above the main research question can be answered, which is *'How should the GUI of a breathing wearable be designed giving visual feedback to optimize breathing patterns and guide to habit formation of healthy breathing?'*
During the research process it showed that it is a necessity for the GUI of 'Airleviate' to **support abdominal breathing** to yield in a health benefit.
Also should the GUI be **mobile and simple** which was combined in an mobile phone application.
Habit formation on breathing can be reached by **goal setting and tracking** to keep the user motivated.
And finally regarding visual feedback is it important to enable users to reflect on their breathing by **minimizing cognitive workload, giving several graphs and supplying clear explanations**.

8.2 Future work

As final step to wrap up with this graduation project the recommendations for future work will be given. The purpose of this is amongst others to guide successors of the project.

In terms of the design of the GUI there are two aspects that should be considered when working on the project in the future. The first of these two is a revision of the explanatory texts within the app. Due to understanding problems were the users partially not able to make use and understand of some graphs. The texts should be brief but clear also to users without specific prior knowledge about breathing. Furthermore , the most important terms could be highlighted with bold font. Also an explanatory video of the flower visualization could be implemented to make it most definitely clear to a user what it represents. The second aspect regarding the design is a revision of the 'Daily review' screen. It might be possible that some graphs were not understood due to the poor explanations, nevertheless were also points like having a lot graphs or having to scroll too much criticized. Implementing show/hide functions for the graphs in 'Daily review' as well as for all explanations in general could be used to arrange the screen neater.

For the technical side of the project there are also recommendations for future work. An important part would rearranging the 'communication' or data transfer from Arnav Mundkur's classification algorithm

to the application. At this point are the classified data sets received as manually arranged .txt files. Using the standard .json format could simplify the code of the application as well as speed up new implementations. Still would the code have to be adjusted for that purpose since the classified data is slightly processed in the current code.

This is also crucial aspect for the next recommendation which is connecting the single components of ‘Airleviate’, which were developed separately so far. During further development should at first the code of Arnav Mundkur and the code of the author be fused into a single program. For the wearable purpose this should most probably be done within the app, so that the classification and the GUI are mobile.

Additionally, it does make most sense to implement the classification in the app due to the advantageous battery and computing power of a smartphone in comparison to the mini controller inside the RIP belt. Afterwards a Bluetooth or comparable connection between the phone and the RIP bands should be prepared. With this connection also the already implemented switch could be realized. The final recommendation is also based on the previous ones, which is establishing real time feedback. During the tests it came up that most subjects actually intuitively expected the application to show their breathing or give feedback on their breathing in real time. In addition does a real time analysis also enable to give more appropriate and in time instructional feedback for a user, so that real time feedback should be the main short term goal of the project.

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Appendix

Appendix A - Interview Ainara Garde Martinez (Research Centre for Biomedical Technology and Technical Medicine Utwente)

Phoneoxymeter which is a pulse-oximeter on the phone. They showed oxygen saturation and beats per minute.

Baseline moved, signal frequency increased when breathing in and decreased when breathing out. Peaks of the signal was caused by the heart beat. She looked at the dips in oxygen saturation to detect sleep apnea and used the peaks in signal to get information about the heart rate.

How did you measure the breathing of the patients?

Using this sensor they developed.

How invasive did they find that measurement method?

In a game with an accelerometer and kids and an app, the kids found the accelerometer strapped to their ankle. The children didn't mind the ankle strap, but one kid found it horrible and annoying.

Which other measurement techniques did you consider and why did you not go with them in the end?

Phone accelerometer to measure physical activity. But it wasn't providing good data. She didn't really say anything about measurement techniques they stayed away from. Look into wearables that have been approved as comfortable or uncomfortable and verify it with the questionnaire they used.

What features/characteristics of the signals were important for data analysis that you extracted for the classification?

Inspiratory and expiratory time. No amplitude can be used. Maybe peak to peak time. Look at summing up the signals from the two bands, and then normalizing (dividing by the sum). So then you have a percentage and you can set a threshold at which point you say they have now switched from one pattern to another. You can sum chunks of the signal (1 minute periods) or you can do individual pairs of inspiration and expiration. Problem is both bands are used when breathing happens. Band pass filter to take out low frequency baseline drift and high frequency noise from talking.

Can you recommend any sources regarding classification of breathing patterns?

Not off the top of her head but she also said it really depended on what I was recording.

Did you encounter any difficulties while measuring the breathing?

Some artefacts completely screwed up the measurements so the signal was evaluated using a SignalQualityIndex and if it went to 0 they just ignored it because it was purely artefacts. Movement did introduce artefacts.

Is there literature about this or did you find them through trial and error?

Did you need to approach the ethical committee for your chosen method of breathing measurement?

Even for physical activity for children with accelerometer on ankle we needed ethical approval. Ethics approval in any case or work with healthy people and then it can be approved by the department.

Where is the processing of the data done? (on the phone or sent to a server)

The data processing for the sleep was done on the computer.

What type of processing do you do/What kind of AI was used for the classification? (Neural network or another method)

Linear discriminant, logistic regression models (between yes and no) gives a probability of having it or not with a threshold. Look at what you want to classify and which features. Start with a linear classifier. Be clear about what you want to identify. Frequency analysis of the envelope. Define what is belly breathing and the threshold. Normalize the two signals for a certain. Plan for the artefacts and how you will deal with them. Look in notebook for processing.

Notes from interview

When they perform the breathing exercises they can see the results afterwards.

Click on an exercise in the app and mark when you are doing the exercise so that the classifier has some context and can tell when you were intending to use belly breathing.

Start with measuring 3-4 people.

As far as wearable sensors go from her experience people found wearing an adhesive patch to be annoying. However kids found an ankle bracelet but one kid found it terrible.

An idea would be to record at specific times for example a university day. Another idea would be to record the morning. Then make the participants do breathing exercises during the lunch break. Then hopefully they will remember to breathe using their belly in the afternoon afterwards when the second round of data collection has taken place.

Look into literature on wearable technology and its intrusiveness and certified questionnaires.

Measurement scheme:

Baseline → Measurement → Intervention → Measurement

Same subject comparison, same position on their body (below navel and above nipples or something like that).

Appendix B - Interview Ineke Ter Hedde (Breathing & Singing Coach)

Teaching classical singing for 30 years. The put tension on their chest when breathing in deep and abdomen. She listens to the breathing and can sense where the breathing is blocked. The awareness of how tensed they are can help. They tense their diaphragm to breathe out. Relaxation can trigger laughter or tears as a reflex of the relaxation. We only use 30-70% of their lungs when they "breathe deeply". Breathing is still done through the lungs but the diaphragm is used to let in air and pushing out air.

Breathing is shallow usually when singing by the untrained. The back brain is the "flow brain". Breathing and awareness becomes second nature. The back is strained and parts of the body are stiff that we are not aware of because the bad breathing habit is second nature. The lungs should be expanding in all directions. Muscles are subconsciously stiff or tense.

Pelvis is supposed to be tilted up but without tensing the abdomen.

Usage of the device should be if anything, an aid to learning the actual methods.

The strap is not accurate enough, because it just measures general expansion and not in certain regions.

Everyone can sing but people are trying to sing in a certain way and therefore cannot.

Emotions are very important for breathing, stress, sadness and anxiety.
Asthma can be cured with proper breathing and abdominal breathing.
Doesn't think the device is needed because they have her.

Page 22 of the book small book.

What are the backgrounds of the people that come to you?

She is a singing teacher so it usually is in the form of coaching regarding breathing.

Why do people come to you for training?

Singing training. Usually adults.

Do they come with any complaints?

Illnesses that can be simply cured by breathing correctly. Back pain, blockades cause illnesses. Energy blockages.

Which areas of the body do your exercises target?

Situation based, calves are usually stiff. Also a case of relaxations of certain regions vs exercises.

How long do you tell your patients to practice the breathing exercises typically?

Understand and remember the best feeling. Meeting once every fortnight. Average is around a year.

How long does it usually take for a patient doing belly breathing exercises to recognize first positive effects?

It can happen any time along the path of learning.

Do you ever suggest breathing exercises working with the abdomen/belly?

More relaxation than exercise. Do less.

What are the reports of the effects of belly/abdominal breathing that you have heard?

Asthma, back pain, emotionally related stress.

What is your experience with belly/abdominal breathing in your field and in general?

Do your clients ever use apps to help train themselves or practice their exercises?

Videos but no apps. No tool with feedback.

What features would a good application need for training at home?

Where should the lower band be placed?

Difficult because of its connection to the ribs. Pull the navel through the back. Below the belly button, maybe around the hips. The chest one should be under the pectoral muscles.

Lifestyle changes?

With singing it works both ways because you are aware of your body during the activity.

Bodywise Suzanne Klappe (knows about bodily stuff in terms of cortisol)

Osteopaat

Appendix C - Interview Parviz Sassanian (Doctor of traditional Chinese medicine)

In dao, life begins with the first and ends with the last breath. Bad breathing is bad life. Breathing is tool to aid actions. Breathing applies to body, mind and spirit. Breathing for living longer, looking younger and even healing others.

Studied Chinese medicine in Utrecht. Studied accupuncture and kungfu and taichi with them.

Breathing can treat eczema and diabetes. Science isn't far enough to explain why it and acupuncture works. Difficult to pinpoint what happens because of breathing and we can only get statistical data.

Modern science looks for mechanical or linear relationships. Bodies work on the level of quantum systems. University is producing knowledge not searching for knowledge with deadlines. It's about how well you can convince others that you are right.

Breathing should be like a chi ball that expands in the front and back of the abdomen.

Get reference points of sitting, standing and walking in the beginning. Software should only pick up on the proper breathing waves.

Breathing rate determines the type of results. They should know their slowest possible breathing. He said there are natural hormonal cycles during the day but they are also affected by breathing, diet and physical activity. (Shaw et al)

Make them aware of what it is to have good breathing. Breathing is used as a form of total transformation, it can be used to change personality through gene manipulation.

Habits done over millions of years are instinct, thousands are traditions. Things done in a lifetime are habits. We live mostly as programmed robots, and we do not try many new things so the character doesn't change. Typically, people do physical character changes instead of changes coming within. Attitude is short term, character is long term.

Breathing slowly makes you calm. More serotonin and less dopamine, cortisol and adrenaline. What is really needed is weeks of continuous data.

He says that women breathe more badly than men and they do reverse breathing. Too much upper chest breathing and tension on abdomen.

Contribute to less emotional mindsets. Lots of the population is using sleeping pills or antidepressants. No future for us.

Totality. Brainwashed to think we are all individuals. Being part of the whole. Making you an individual makes you exploitable. Forms of slavery are changing but it remains present. We are consciousness incarnate. We are like a mirror for the cosmos to see itself.

If you have belief, you have power but if you do not have knowledge, you are blind. Fear motivates.

Which kinds of people come to your practice/which fields do they work in?

What are the different reasons you would tell your clients to start or increase the time they spend belly/abdominal breathing?

How long does it usually take for a patient doing belly breathing exercises to recognize first positive effects?

Again it depends on what you want to see.

What have you found/learned/experienced the benefits of belly/abdominal breathing are?

How often should people perform diaphragmatic breathing every day and for how long?

The longer the better. Mindful over casual so that the body and mind are there.

What kinds of issues can belly/abdominal breathing generally help with?

Anxiety, fear.

Are there some problems that can be completely solved with belly/abdominal breathing or is more a part of the remedy?

Do you ever ask your clients to perform belly/abdominal breathing aside from when they are meditating or always only during the activity?

Do your clients ever use apps to help train themselves or practice their exercises?

How do you teach your clients belly/abdominal breathing? Do you use different methods and if so then why?

Do you believe it should be done with a goal in mind?

Appendix D - Individual Brainstorm

Stick to human factor rules:

DESIGN PRINCIPLES:

- Visibility
    - people can see (hear, feel) what actions are available and what the system is currently doing.
- Consistency
- Familiarity
- Affordance
    - affordance is the design aspect of an object which suggest how the object should be used; a visual clue to its function and use.
- Navigation
- Control (Natural Mapping)
    - Make it clear who or what is in control and allow people to take control.
    - Control is enhanced if there is a clear, logical mapping between controls and the effect that they have. Also make clear the relationship between what the system does and what will happen in the world outside the system.
    - Natural Mapping - The degree to which the form of the interface is isomorphic [corresponding or similar in form and relations.] to the 'form' of the functional output of the device
- Feedback
    - Rapidly feedback information from the system to people so that they know what effect their actions have had. Constant and consistent feedback will enhance the feeling of control. what is the system doing? What is the result of what I just did?
- Recovery
- Constraints
    - "Provide constraints so that people do not try to do things that are inappropriate. In particular, people should be prevented from making serious errors through properly constraining allowable actions and seeking confirmation of dangerous operations". HOWEVER: It is not just about 'inappropriate', it is primarily a principle about 'helping people to decide what to do'
    - Constraints are structures in the environment that help us to select the right action. Constraints reduce the number of possible actions. This makes the task of deciding what to do easier.
- Flexibility
- Style
- Conviviality
    - Interactive systems should be polite, friendly, and generally pleasant

Problems with GUIs:

- GUI ignores rich interaction possibilities of body
- GUI invites passive reception instead of active involvement
- GUI (often) demands cognitive effort (thinking)

- GUI uses conventions and metaphors that need to be learned and understood

Navigation should be easy. Clear buttons not too many layers

Constantly show what the system is currently doing (maybe not real time feedback, but it shows that it is currently measuring)

Giving instruction in the application how to put on the belt (no misleading of how to use the belt leading to wrong results) when first use as well reachable again

Possibility to switch the measurement on and off

Statistics giving general feedback and timeline feedback through- out the day

giving a long term goal you want to work towards and show the progress in working towards this goal

total hours of abdominal breathing as a value to compare days (like a daily log)

day comparison in general also giving a history overview and maybe showing a progress curve

Trainings mode? To do abdominal breathing and giving feedback over a short period of time. To see how you do? And a planning mode for this?

Implementing Levels, rewards, batches (implementation of gamification elements)

goal setting with a certain mission (maybe a path to follow to reach a goal or subgoals) possibility to adjust the path due to unforeseen happenings
Maybe tailor that together with the doctor
Can be adjusted on the way

Functionalities: Naviagtion, Data shown

longest period of diaphragmatic breathing? Or total amount?

when using the app first time there is need of a calibration meaning practicing abdominal breathing for 5 min in different positions.

goal is the time you do DB? Or total amount?

Appendix E - Group Brainstorm Session

Rules

1. Understand that brainstorming is about generating as many ideas as possible. Save the analysis and decision-making process about which ideas to pursue for *after* the brainstorm.
2. Clearly define the objective and intended results of the brainstorm to the group.
3. Choose a facilitator and a scribe. The facilitator upholds the rules and keeps everyone on task and on time. The scribe records the ideas and disseminates them to the group.
4. Explain the rules to everyone. For example, say “Yes, and” instead of “No, but” to make sure no one’s feelings get hurt and all ideas are weighted equally. Another example, don’t bring your smartphones and laptops into the brainstorm.
5. Remember: This should be fun.

We have two scenarios:

Homeuse
And use in therapeutic environment

Results

User can set goal himself and adjust, maybe also make in combination with a therapist the goal setting inside the application

Recompensation useful on a daily base and fun

Unlockable rewards: Like badges, achievements, sub goals, recipes, knowledge (like explaining advantages), artworks

Advantages maybe explained in the application

Development of compensation while you develop yourself

Avatar development with reaching sub goals like: fit body, art, a world, climbing a mountain, a track that has to be fun a long, sun and moon, lungs changing colors and appearance, messy room that cleans itself, maybe garden that looks nicer after a while, start as novice and turn into tai chi master(tamagochi like)

Adjustable personalization for the application

Make a profile on why you are doing/using it to get motivation of a person (maybe as first setup in the beginning)

Sound that could relate to your data and evolve with it

Breathing power energy bar to be filled to play a game of going on playing a game

Tracking performance has a certain importance

% of time with chest and abdomen visualized on a body, heatmap of the body, yin & yang symbol

Stats of abdominal vs chest breathing on a clock

Push notifications in sync with calendar concerning preinput acitivies

Sub-goals can be decided by user themselves

A leader board for how improvement is or general skill in breathing

User giving to decide how to archive data so it could be looked at again

Data should be comparable from different time spans

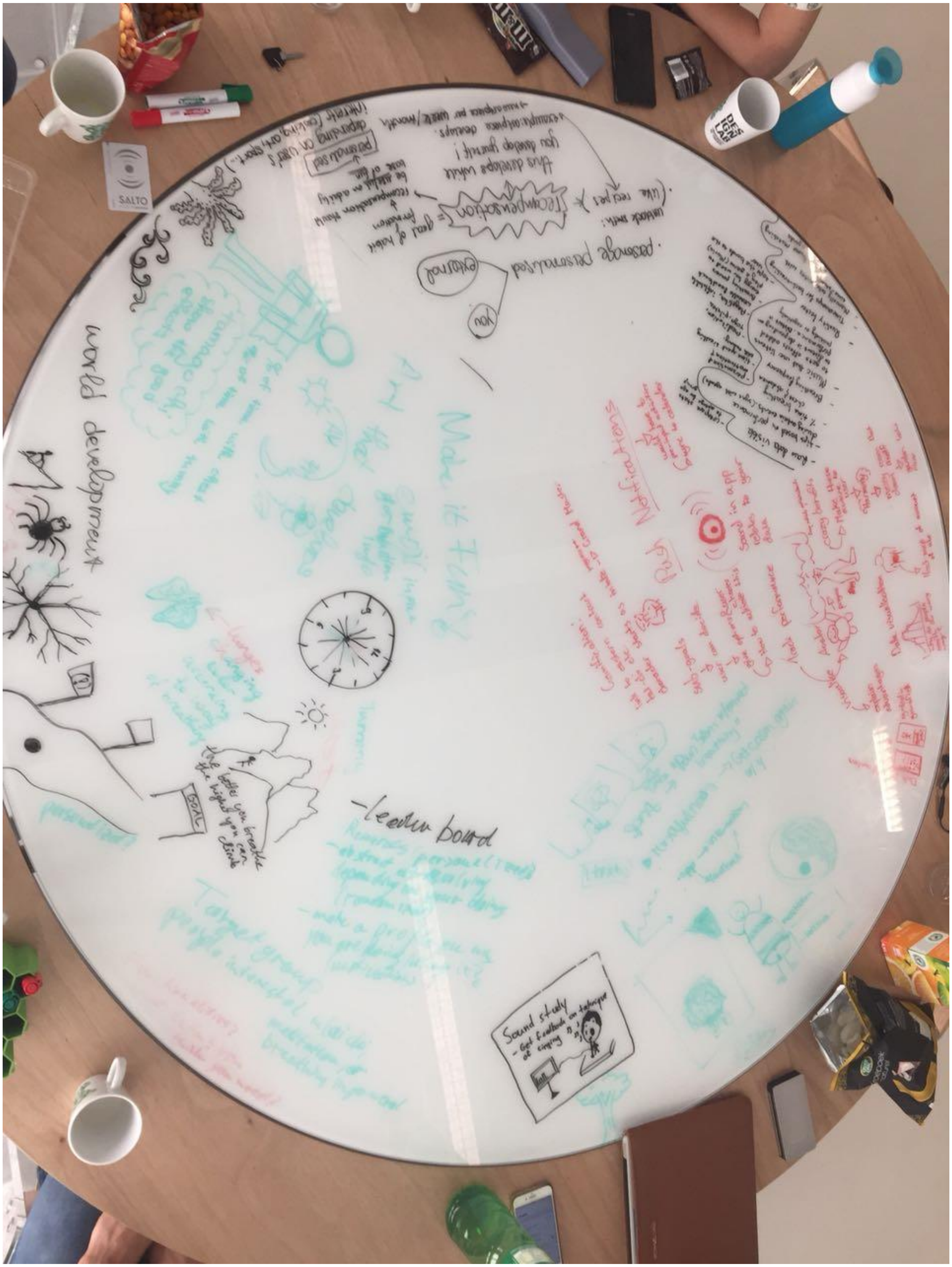
Breathing frequency

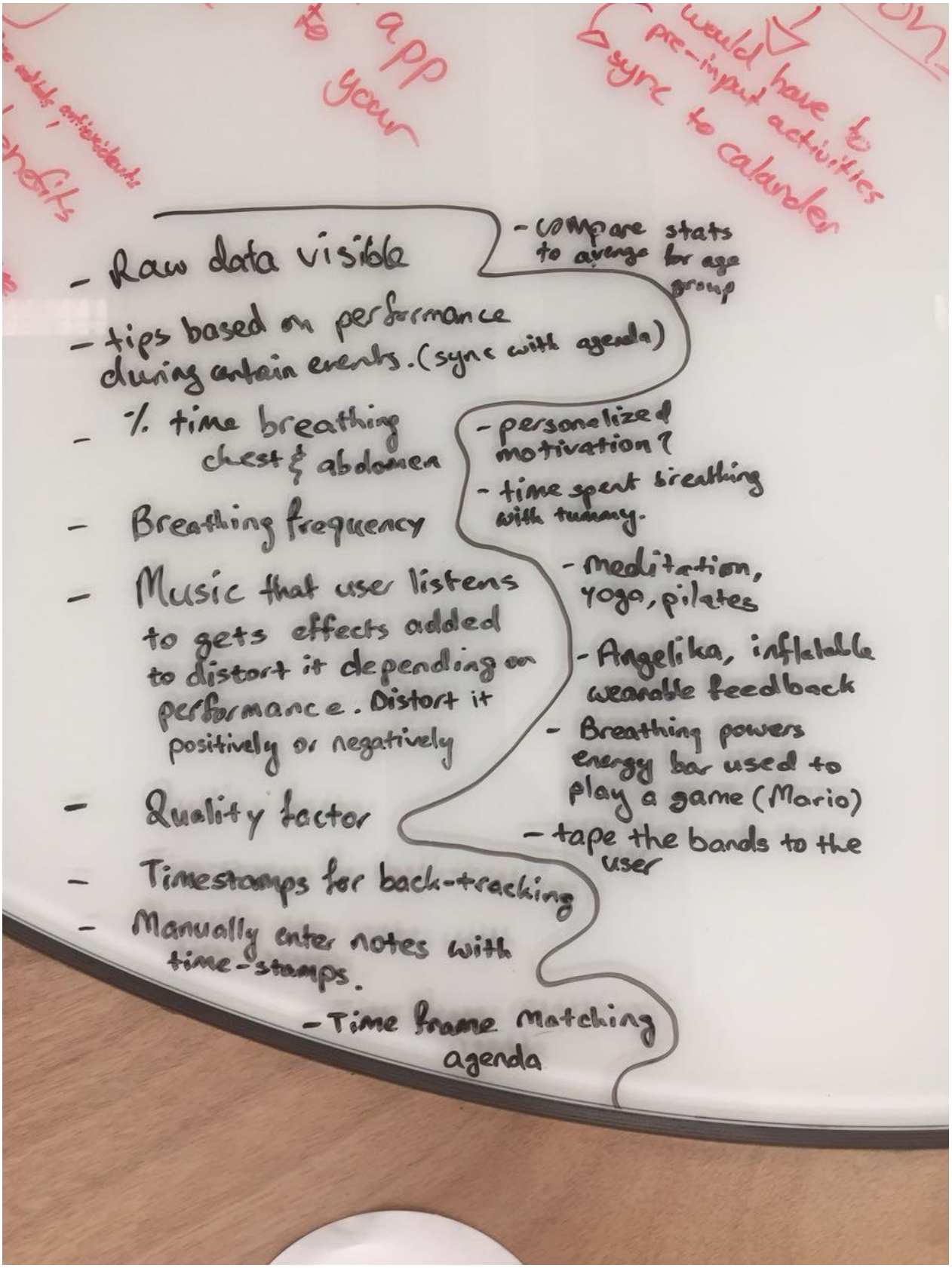
Quality factor

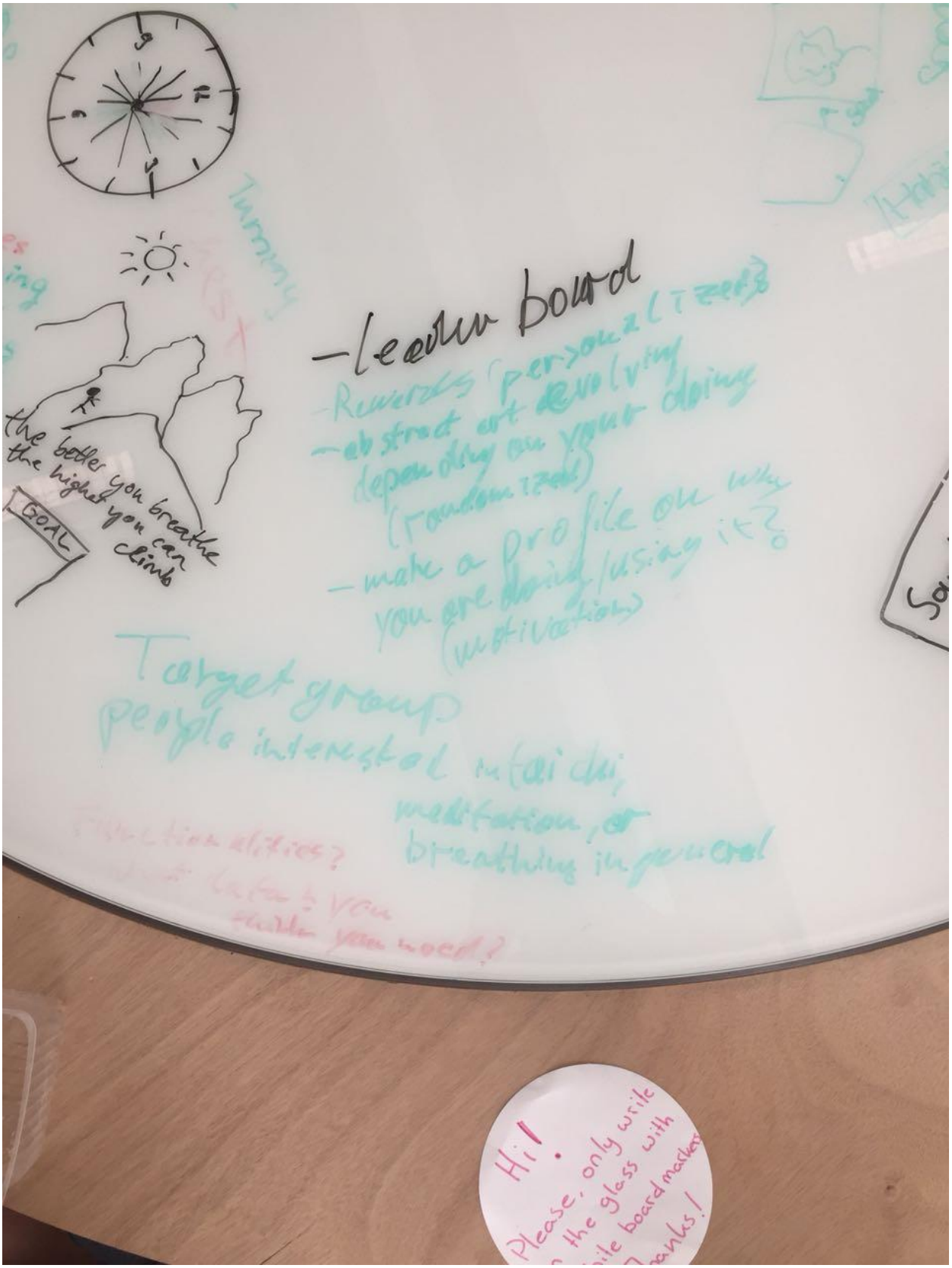
Time stamp for back-tracking with manual entered notes for the time stamps to recall what happened. Time stamps could also be just emojis

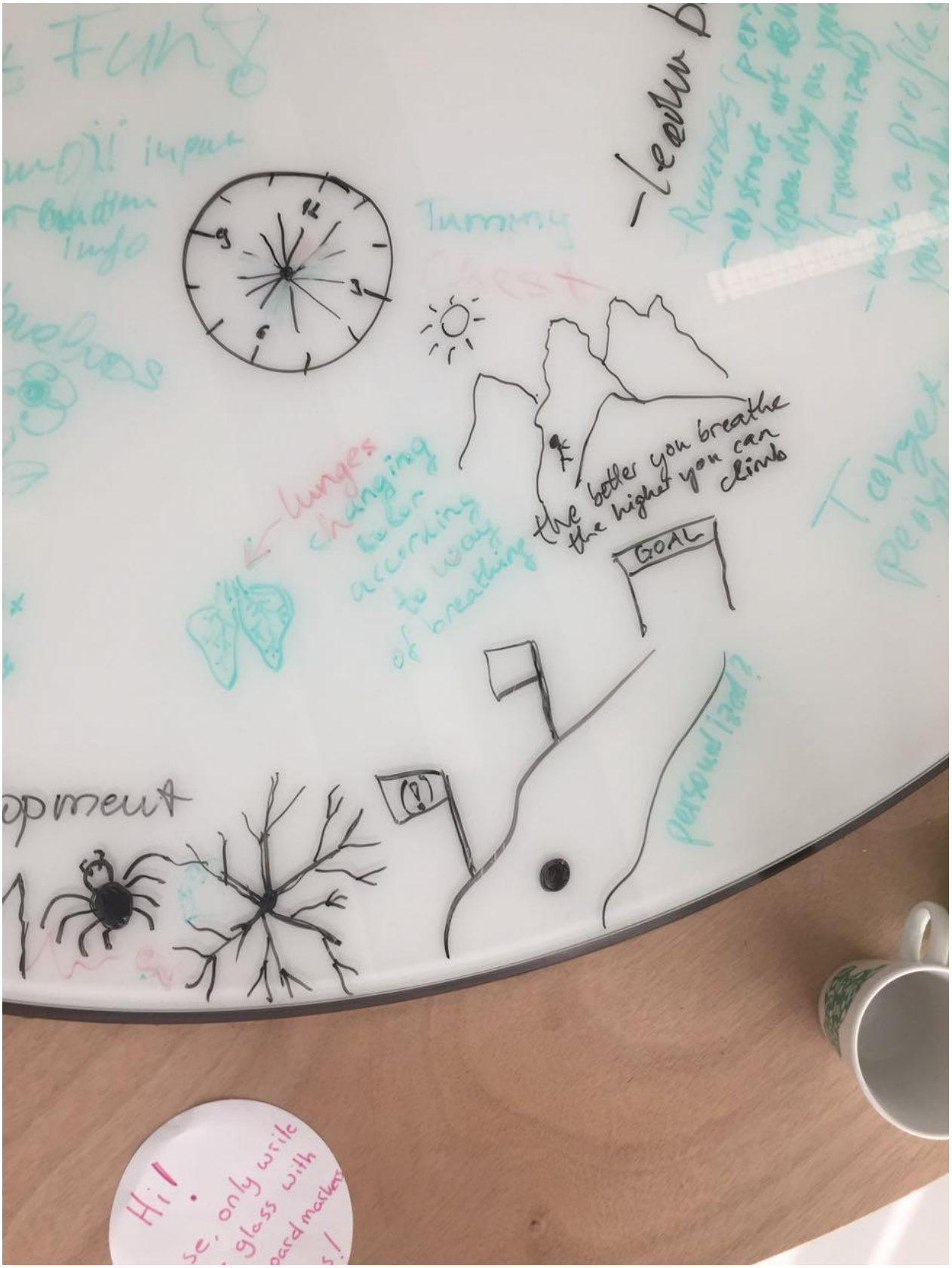
Time stamps matching agenda

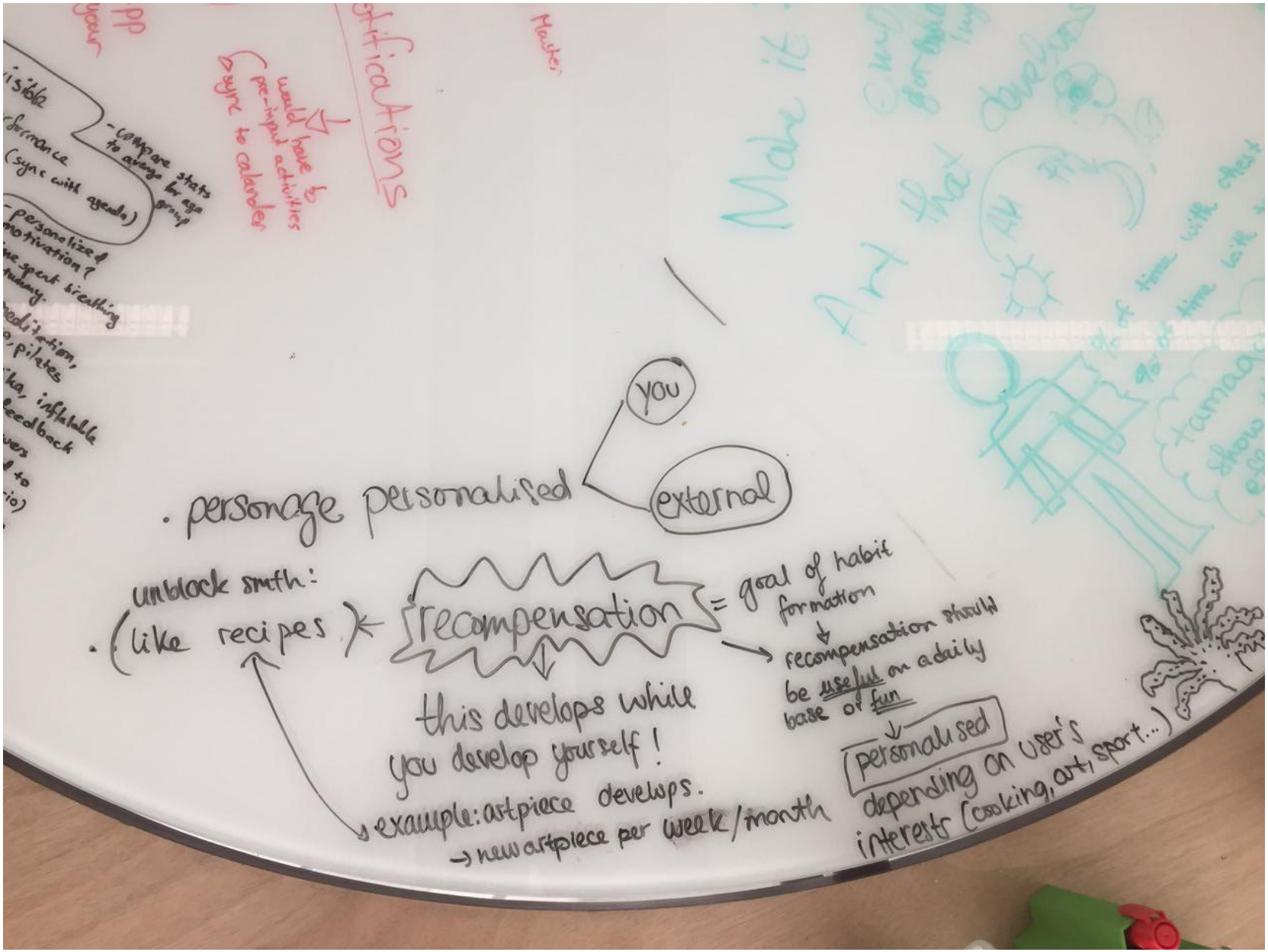
Compare stats to average for age

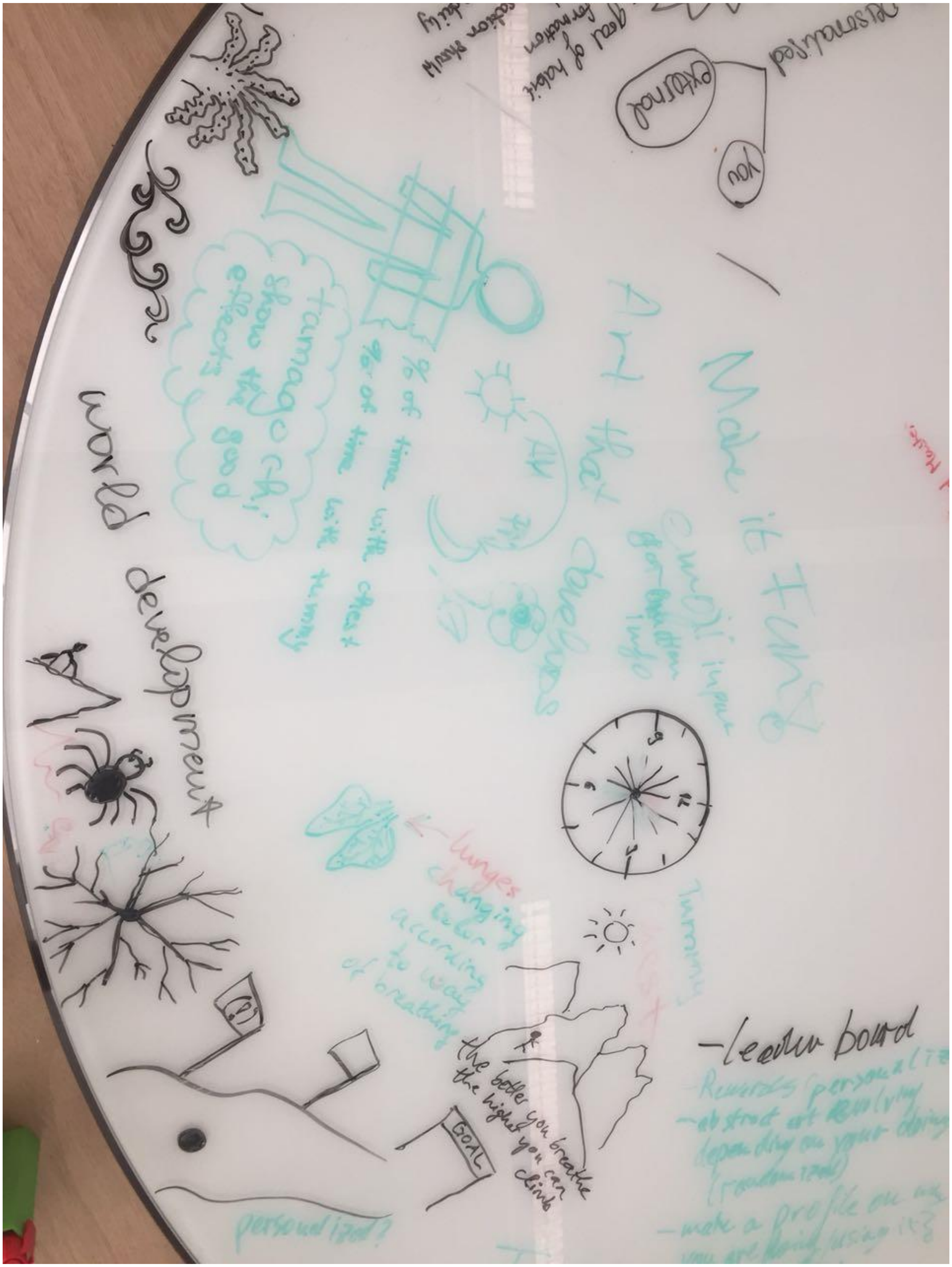

world development
Make it Fun
-learn board
GOAL
Sound study
Target group
Push Notifications


app
your
would have to
pre-input activities
sync to calander
- Raw data visible
- tips based on performance during certain events. (sync with agenda)
- % time breathing chest & abdomen
- Breathing frequency
- Music that user listens to gets effects added to distort it depending on performance. Distort it positively or negatively
- Quality factor
- Timestamps for back-tracking
- Manually enter notes with time-stamps.
- Compare stats to average for age group
- personalized motivation?
- time spent breathing with tummy.
- Meditation, yoga, pilates
- Angelika, inflatable wearable feedback
- Breathing powers energy bar used to play a game (Mario)
- tape the bands to the user
- Time frame matching agenda

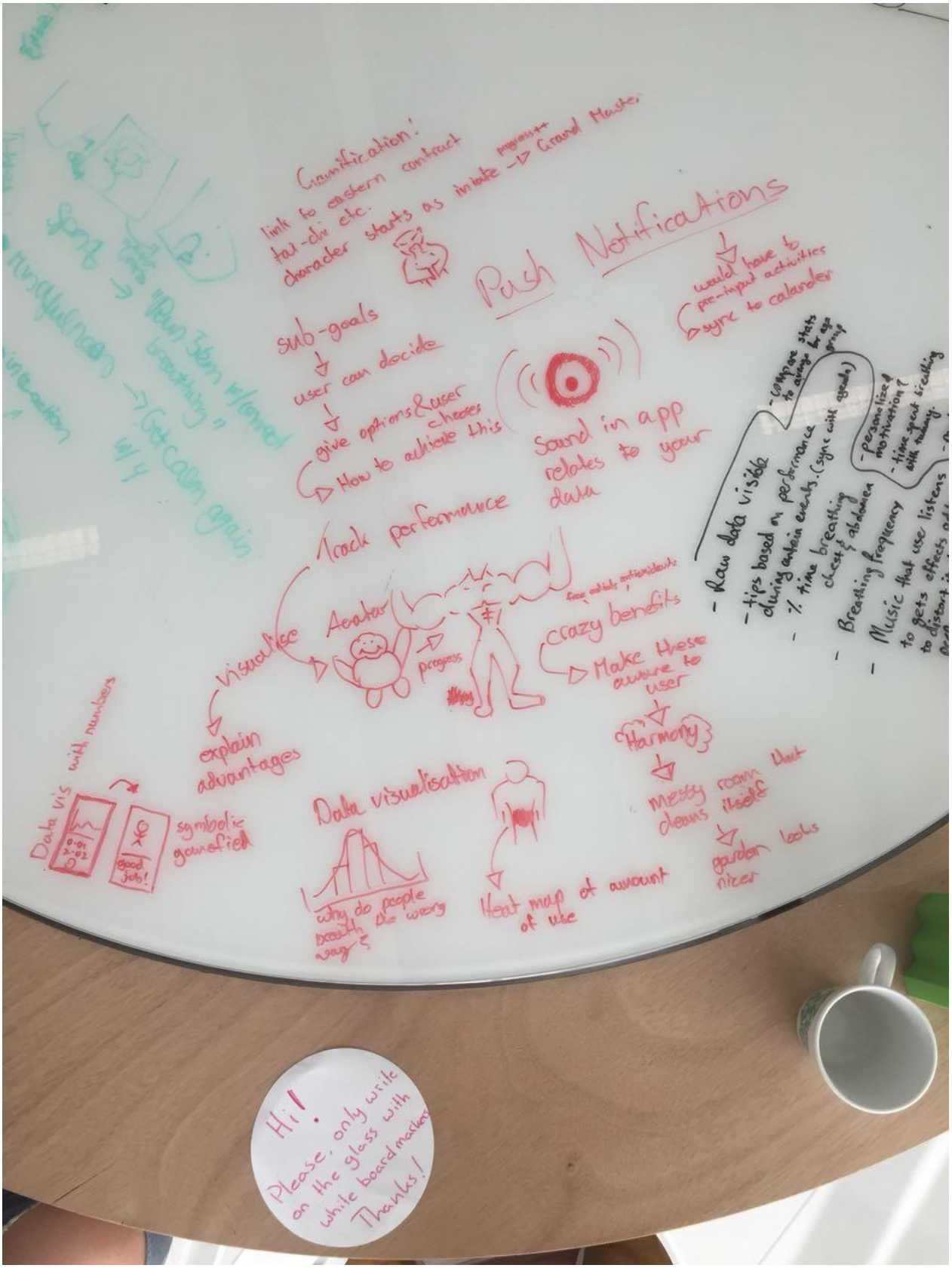

the better you breathe the higher you can climb
GOAL
Target group
people interested in
meditation, or
breathing in general
Hi!
Please, only write
the glass with

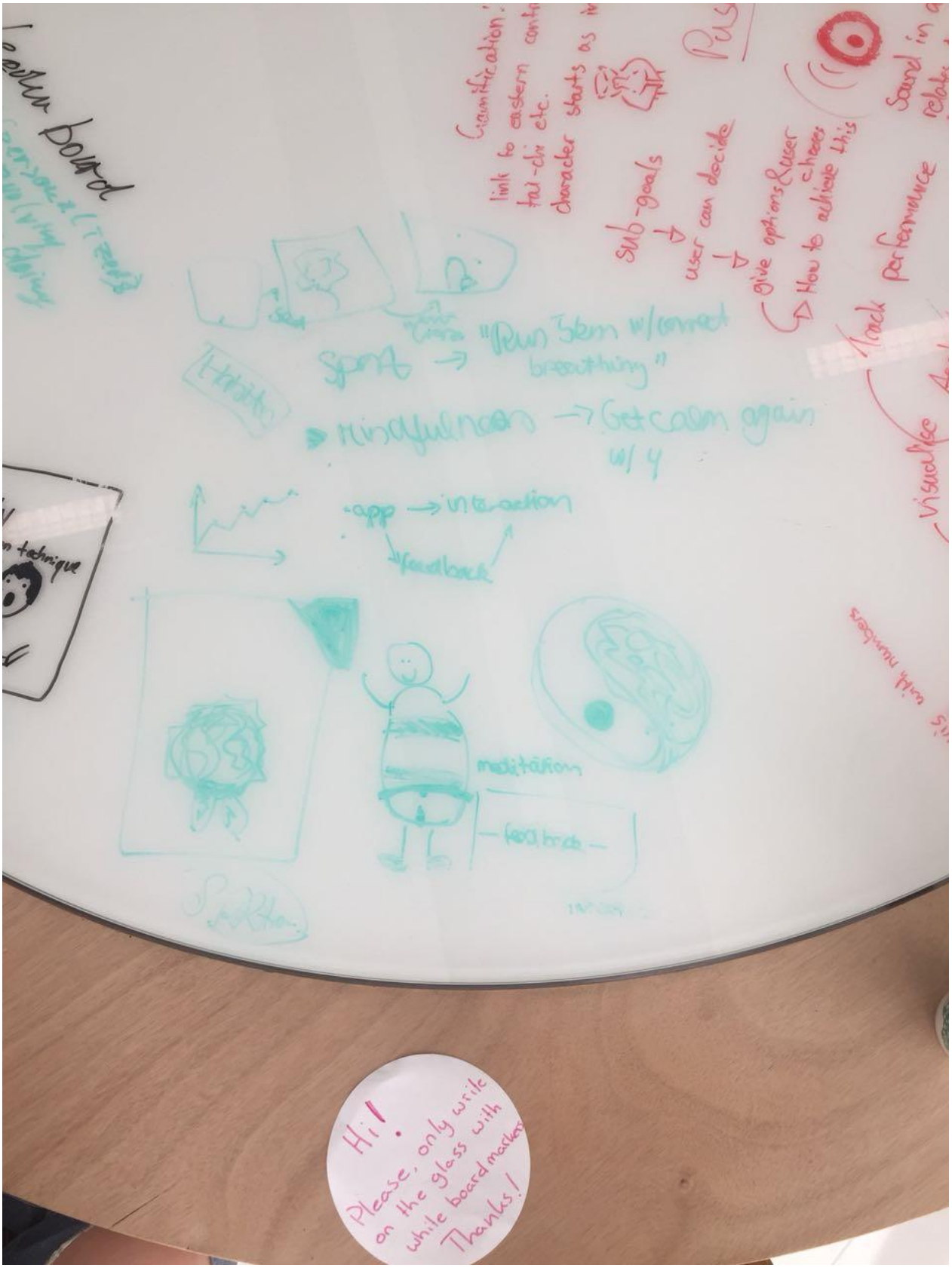

the better you breathe the higher you can climb
GOAL
lungs changing color according to way of breathing
Hi!


. personage personalised
you
external
unblock smth:
. (like recipes)
recompensation
= goal of habit formation
recompensation should be useful on a daily base or fun
this develops while you develop yourself!
example: artpiece develops.
→ new artpiece per week/month
personalised depending on user's interests (cooking, art, sport...)
would have to pre-input activities (sync to calander)
- compare stats to average by age group
(sync with agenda)



Make it Fun
world development
Personalized
external
you
GOAL
the better you breathe the higher you can climb
-leader board
personalized?


Gamification:
link to eastern contract
tai-chi etc.
character starts as infant → Grand Master
Push Notifications
would have to pre-input activities
sync to calander
sub-goals
user can decide
give options & user chooses
How to achieve this
Track performance
Sound in app relates to your data
- Raw data visible
- tips based on performance during certain events. (sync with goals)
- % time breathing chest & abdomen
- Breathing frequency
- Music that use listens to gets effects
- compare stats to others in age group
- personalized motivation?
- time spent breathing with mindfulness
visualise
Avatar
progress
crazy benefits
Make these aware to user
explain advantages
Harmony
Messy rooms
roam itself
garden looks nicer
Data visualisation
why do people breath the way they do
Heat map of account of use
Data vis with numbers
symbolic gamified
Good Job!
Hi!
Please, only write on the glass with white board marker
Thanks!


Hi!
Please, only write on the glass with white board marker
Thanks!
meditation
feedback
app → interaction
feedback
sub-goals
user can decide
give options & user chooses
How to achieve this
Track performance
Sound in
Visualize
"Run 3km w/ correct breathing"
mindfulness → Get calm again
w/ 4

Appendix F - Interview Angelika

She found the Spire was very precise. While watching Game of Thrones it kept going off. It didn't recognize when she was biking and found that she was tense. Fitbit can detect walking and cycling.

What don't you like about wearables?

Textual and statistical feedback is too common nowadays. That type of feedback is far too cognitive. It should be more real time and using haptic feedback (touch). Really wants real time feedback.

What kinds of home health devices or apps have you been using? Can you mention the best and the worst if any?

FitBit but also stopped with that. Stopped with FitBit because when the battery is empty, it stops and when it starts again it needs to connect to the internet to synchronize again even though it has bluetooth connection to the phone. Screen was not very readable in the sunlight. The barometer is completely off. Bad implementation of internet of things technology. Don't need it anymore because you are almost aware of the steps you take. Inaccurate measurements were the big reasons she stopped with various wearables. Spire wasn't integratable with other apps or technologies.

Can you give an example if a really well designed GUI and why you found it to be so?

No. Isn't particularly fond of GUIs for wearables. The real time feedback on the app for her is more quirky.

What are your experiences with them?

What prompted you to start using the device?

She thinks the acquisition of biodata regarding daily activities is interesting. She is also working in the wearable device domain.

Which parts of the Spire application did you like? Which did you dislike?

The app did not integrate with other platforms. It also didn't detect activities like biking properly.

Did you encounter problems using these devices or apps?

What are you trying to achieve with these devices and apps? Answer for each one

Is there anything you do not like about the real time feedback aspect of the Spire?

Difficult to decode all the haptic feedback and the various patterns of vibrations and their meanings. She likes the haptic feedback aspect but it was a little too complicated.

During which situations would prefer real time feedback?

Depends on the kind of feedback. Vibration is slightly noisy and disruptive. During activities requiring concentration, it isn't very handy because it disturbs the user and the people around them.

What would be a preferred way of feedback for you while using Ben's device?

Have you had experience with instructional feedback? What do you think about instructional feedback?

Reminder through haptic feedback is handy. But the user needs to be introduced and prepared for the instructional feedback.

Which colours would you feel like to fit in an application?

Green and blue represents oxygen for her. Yellow for little oxygen. Blue for clarity.

Are there any statistics in particular that you would have liked to see in the spire app that weren't there or that were there and you liked?

Overview of the periods where you were calm, so the user can reflect and identify the situations.

In what situations did you use the spire or especially pay attention to it? Did you wear it all day and just pay attention when you got notified, or did it make you subconsciously pay attention to your breathing?

She was already quite aware of her breathing. Activities where you would forget about the breathing due to exercise or yoga or other activities.

Appendix G - Interview Alexandros

He is practicing Tai Chi for several years already. Is in general interested in traditional ancient theories. Currently he is on a strict diet and uses apps for support.

Did you ever use health or training applications or devices?

Keto diet. Life sum

If it makes things easier and doesn't use paywall.

Which features of the app did you like and made you use it? Graphically as well.

Input used once and the application used it und angepasst and dich.
Machine learning.

Minimalistic is his style

Did you encounter problems using them? What did you dislike about these?

Paywalls

Measurements adjustable for me. And it can be too much as well with adjustablitiy and you don't wanna spend a lot time on the app.

What did you try to achieve with these app?

Healthier Diet
living healthier

What is your opinion on instructional feedback? (im bezug auf app)

Depends on the instruction.
instruction should not make you watch at the app constantly.

Instructional feedback if it gets your rhythm depending on training cycles.

Like it.

Which colours do you think would be appropriate or fit best for such an application?

Pastel colours
calming colors
blue and green, crème egg shell

Why would you think rewards or batches as step to be bigger goal would work or not work for you using the application?

I am not too interested in it and I would not think it changes his behaviour. Because he doesn't see it as a challenge.

HE would like quotes from Qigong. Going into the direction for meditation (maybe as unlock)

What do you think about a changing avatar representing your progress concerning your long term goal?

I like the idea and makes it easy to see progress quickly. But it makes you look a lot at your phone maybe. I don't wanna look too much at my phone.

Just short moments in the beginning or so.
Don't wanna go a lot through the menu to see this.

Would you use self-notifications that will be displayed on your daily breathing timeline?

Personally doesn't think he would really use it. He is currently making a book for his diet.

The more he has to click to safe data he doesn't like.
Not really more than two steps.

Might be a bit too much. If the app asks at some point if you where stressed

Would you prefer knowing how many periods of time you performed diaphragmatic breathing continuously, or would you rather just know the total snippets of time you spent breathing diaphragmatically all added up over a period of time?

I do not really care about for how long. I can just check out when it happened all the time.
I wanna also see how long these periods were.

I would not check it all the time.

I wanna know when. Not really for how long. And can reflect on the day.

What kind of statistics regarding your breathing would you like to see? For example: average breathing frequency, longest diaphragmatic breathing session

Average is interesting.
how much all day, I would like to have a day.
always give a lot statistics. But my aim is not to wear it anymore. So just a well done is good enough.

Details in a deeper layer
simple things first then deeper the complex stuff.

Would you actually be interested in the device? Why or why not?

Depends on different things. Like comfort and invasiveness.

Appendix H - Interview Marie

She is meditating for several years already and likes to use apps for help. She found revelations like unnecessary emotional relationships or corrupt relationships in being more mindful.

Did you ever use health or training applications or devices?

Insight timer
calm

Which features of the app did you like and made you use it? Graphically as well.

Big variety of things with inside timer
very adjustable to personal needs
theme oriented

Pleasing pictures
kategoriesation
explaination

Did you encounter problems using them? What did you dislike about these?

Doesn't like a connection to facebook that is necessary
too much connectivity
anonoumity doesn't

What did you try to achieve with these app?

Stress problems, really calming
anxiety helps for it
for falling asleep
life realization

What is your opinion on instructional feedback? (im bezug auf app)

Guided meditation is needed by her
she likes instructions

Which colours do you think would be appropriate or fit best for such an application?

Natural colors
earth tones maybe also blue
maybe things in connection with awareness
calming pictures maybe

Why would you think rewards or batches as step to be bigger goal would work or not work for you using the application?

I am not interested in milestones
doesn't want to be stressed because she wants to achieve the goal
not too much pressure
more selfcentered
achievements for myself and not for the app

What do you think about a changing avatar representing your progress concerning your long term goal?

She would like it
more motivated
likes the visualization

Would you use self-notifications that will be displayed on your daily breathing timeline?

Interesting thing
doesn't know if she keeps
thinks she can see it on her own in the evening

Maybe better if there is something really wrong like a sickness
can break a flow if not

Would you prefer knowing how many periods of time you performed diaphragmatic breathing continuously, or would you rather just know the total snippets of time you spent breathing diaphragmatically all added up over a period of time?

I think it's more important for the whole in general.
but maybe both could be useful

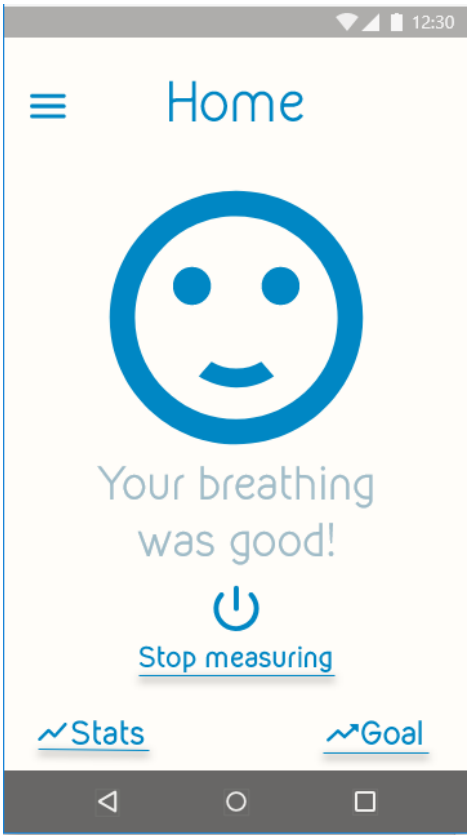
What kind of statistics regarding your breathing would you like to see? For example: average breathing frequency, longest diaphragmatic breathing session

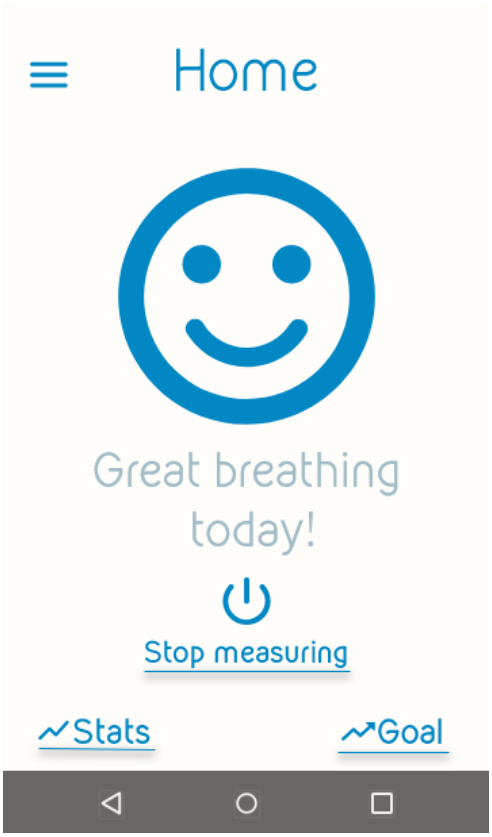
Both

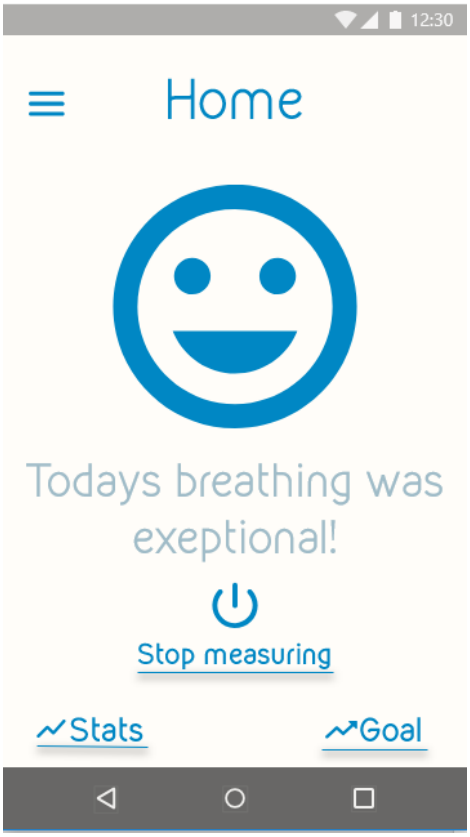
Would you actually be interested in the device? Why or why not?

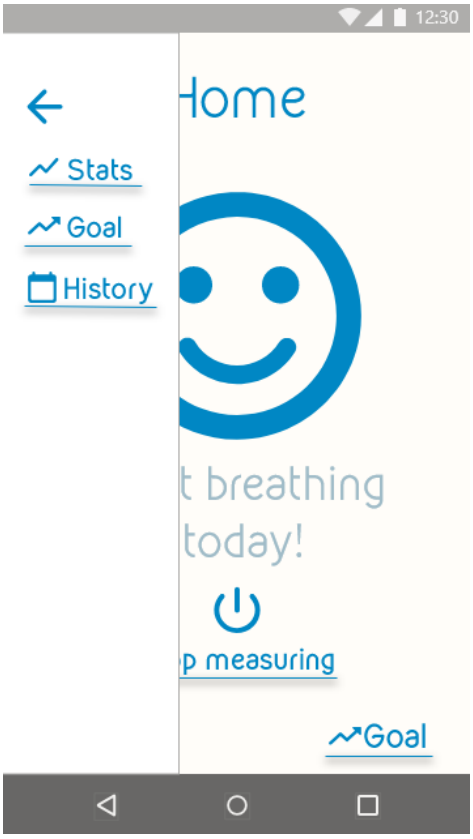
I am not sure
should not be too invasive
if she actually sees a long term goal

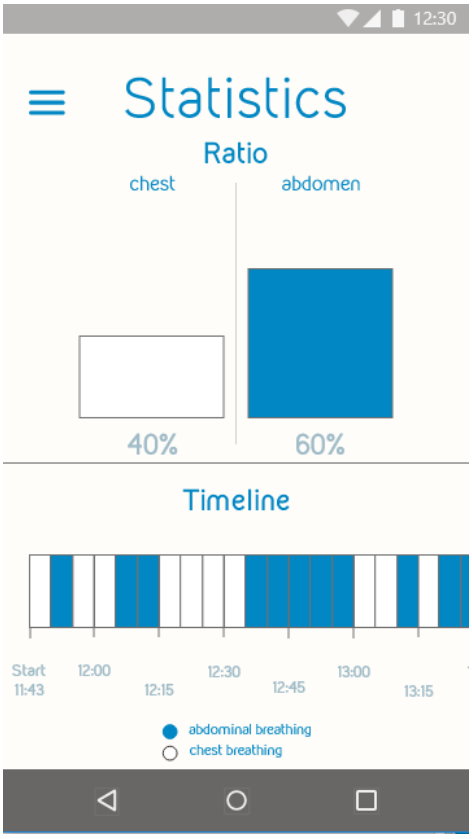
Appendix I - Mock up 1st design



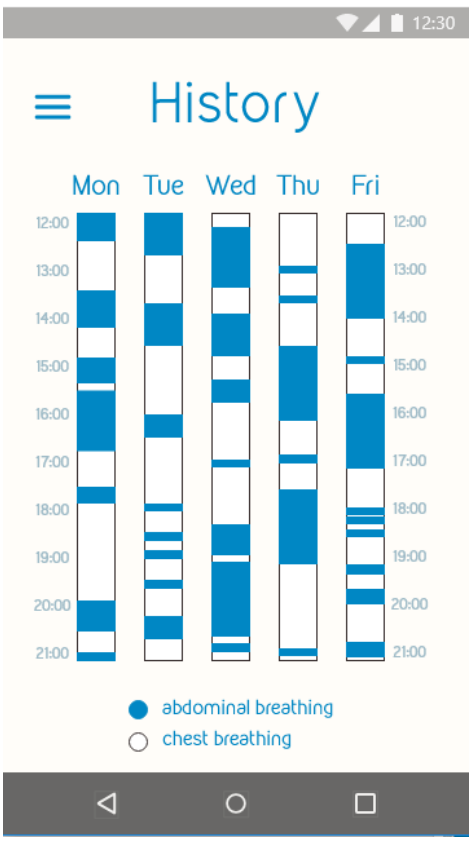


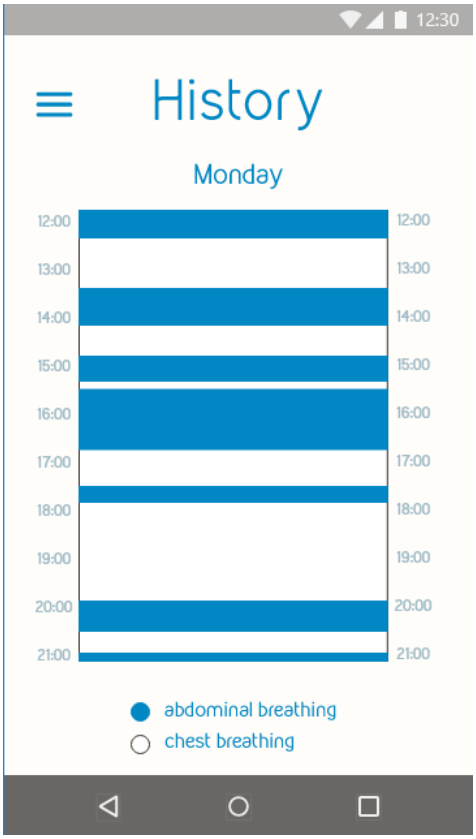



12:30
Home
Stats
Goal
History
t breathing
today!
p measuring
Goal

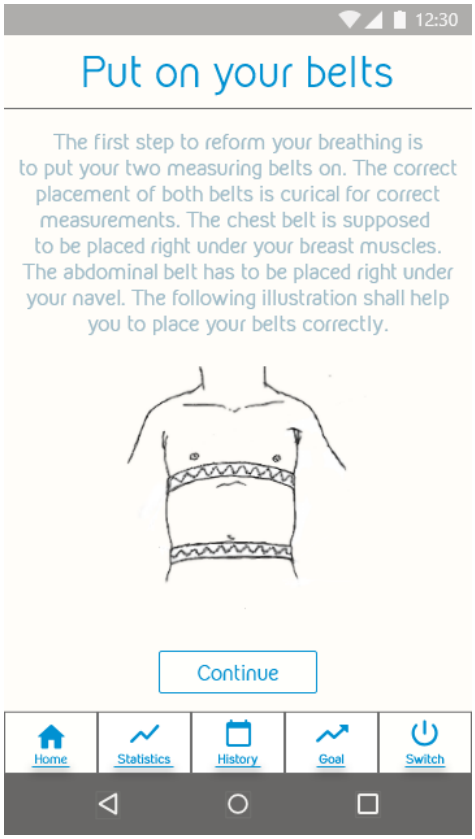

12:30
Statistics
Ratio
chest
abdomen
40%
60%
Timeline
Start
11:43
12:00
12:15
12:30
12:45
13:00
13:15
abdominal breathing
chest breathing

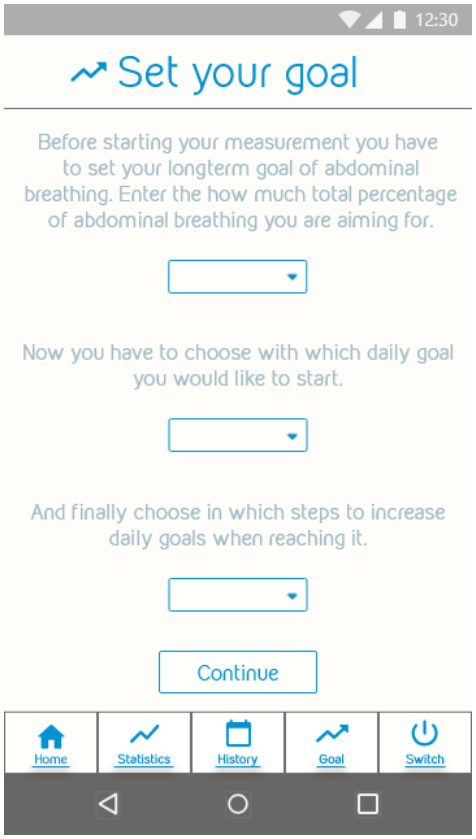

12:30
Goal
Today
Goal: 80%
Todays ration: 60%
Trend
Total goal: 80%
Daily goal
Mon
Tue
Wed
Thu
Fri

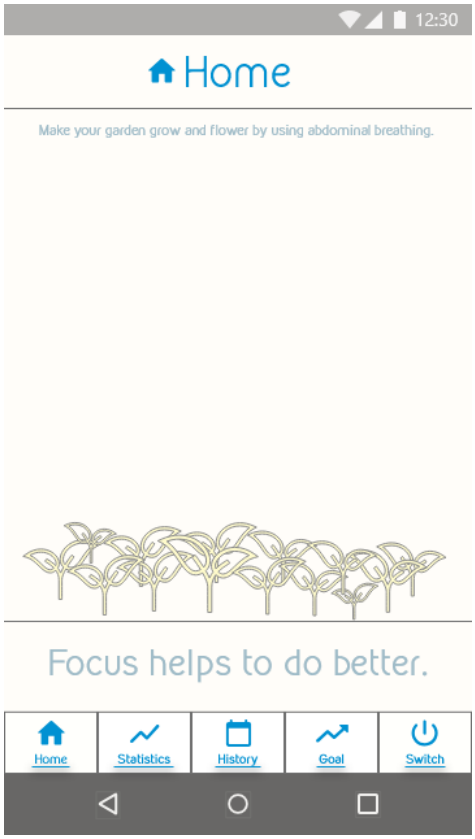

12:30
History
Mon
Tue
Wed
Thu
Fri
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
abdominal breathing
chest breathing


12:30
History
Monday
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
abdominal breathing
chest breathing

Appendix J - Mock up 2nd design iteration based on expert review with Armağan Karahanoğlu



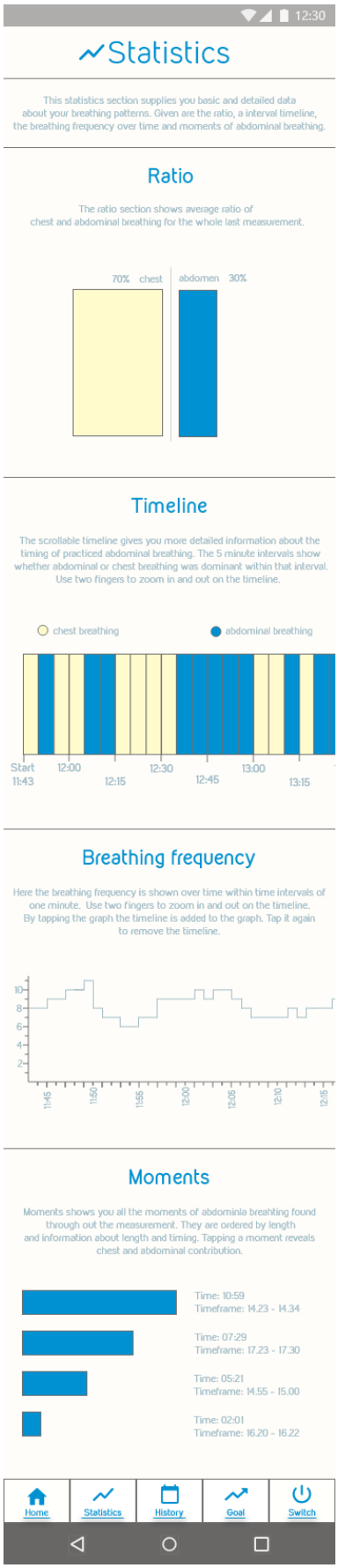


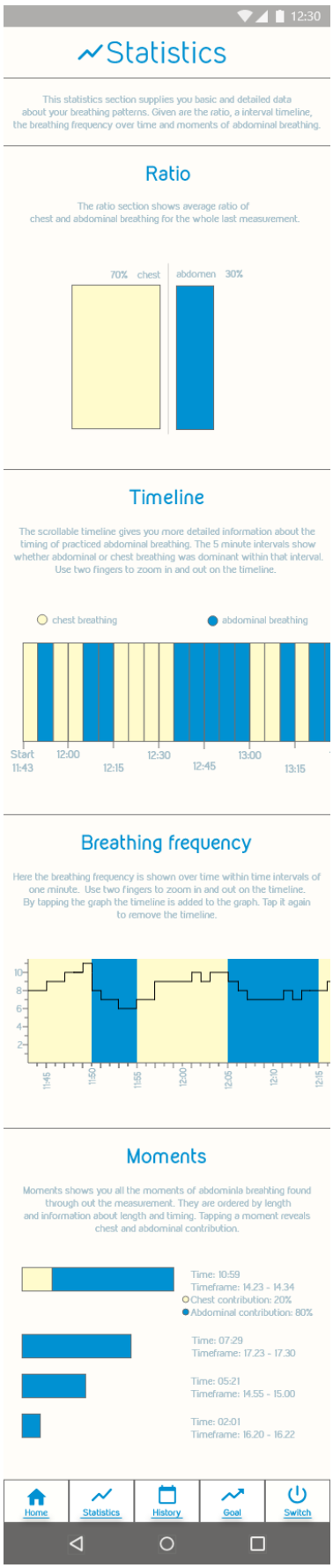

12:30
Home
Make your garden grow and flower by using abdominal breathing.
Focus helps to do better.
Home
Statistics
History
Goal
Switch

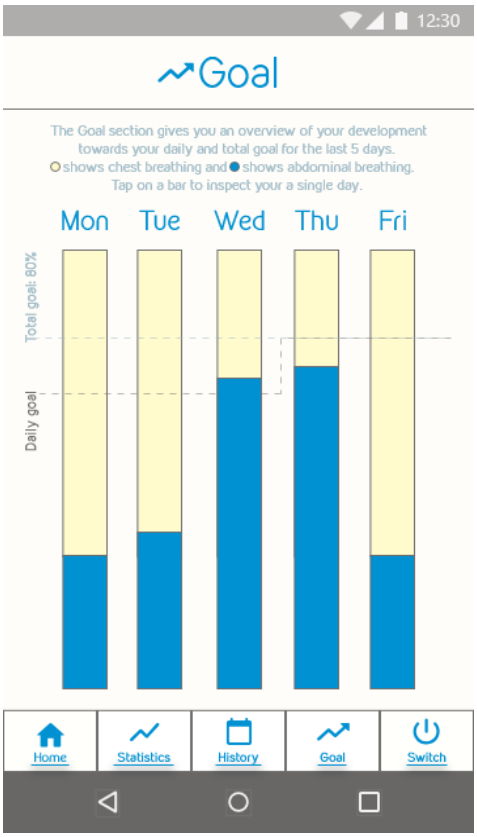

12:30
Home
Make your garden grow and flower by using abdominal breathing.
Your breathing was good!
Home
Statistics
History
Goal
Switch

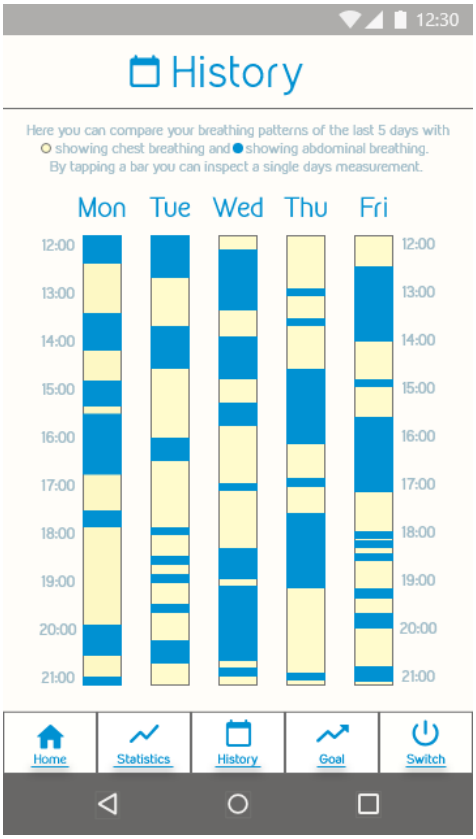

12:30
Home
Your garden is almost at it's flowering peak.
Great breathing today!
Home
Statistics
History
Goal
Switch

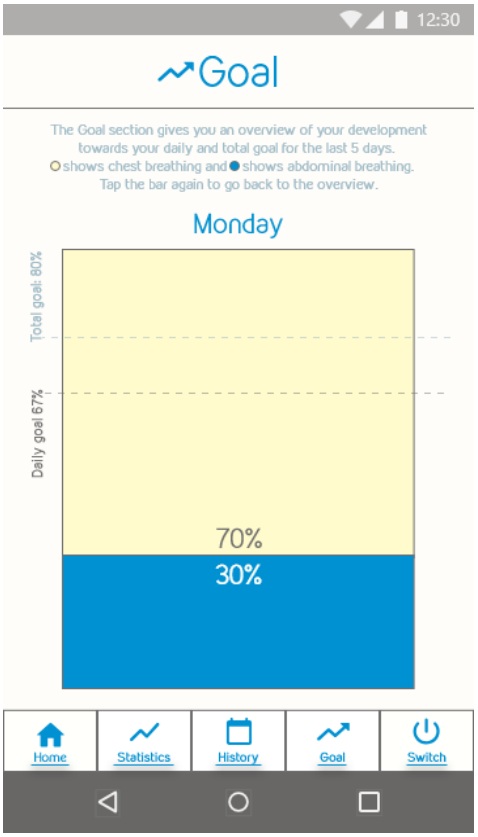

12:30
Home
Hey, your garden is flowering beautifully.
Exceptional brething!
Home
Statistics
History
Goal
Switch

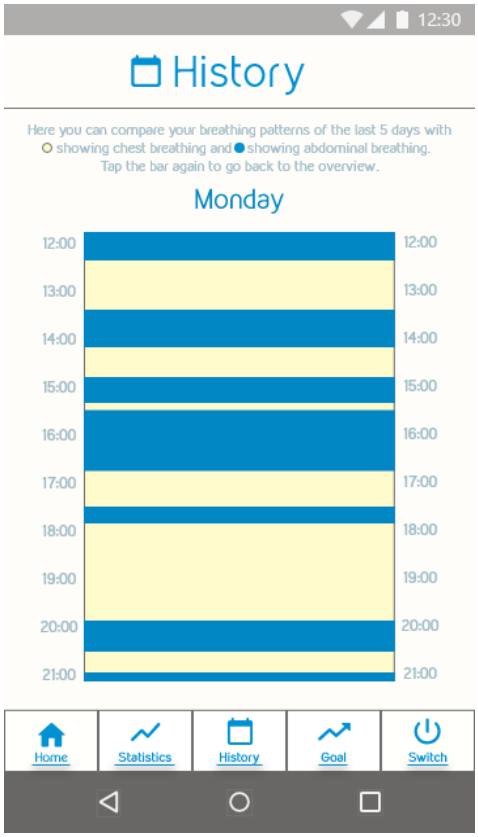

12:30
Statistics
This statistics section supplies you basic and detailed data about your breathing patterns. Given are the ratio, a interval timeline, the breathing frequency over time and moments of abdominal breathing.
Ratio
The ratio section shows average ratio of chest and abdominal breathing for the whole last measurement.
70% chest
abdomen 30%
Timeline
The scrollable timeline gives you more detailed information about the timing of practiced abdominal breathing. The 5 minute intervals show whether abdominal or chest breathing was dominant within that interval. Use two fingers to zoom in and out on the timeline.
chest breathing
abdominal breathing
Start 11:43
12:00
12:15
12:30
12:45
13:00
13:15
Breathing frequency
Here the breathing frequency is shown over time within time intervals of one minute. Use two fingers to zoom in and out on the timeline. By tapping the graph the timeline is added to the graph. Tap it again to remove the timeline.
Moments
Moments shows you all the moments of abdominla breahting found through out the measurement. They are ordered by length and information about length and timing. Tapping a moment reveals chest and abdominal contribution.
Time: 10:59
Timeframe: 14.23 - 14.34
Time: 07:29
Timeframe: 17.23 - 17.30
Time: 05:21
Timeframe: 14.55 - 15.00
Time: 02:01
Timeframe: 16.20 - 16.22
Home
Statistics
History
Goal
Switch

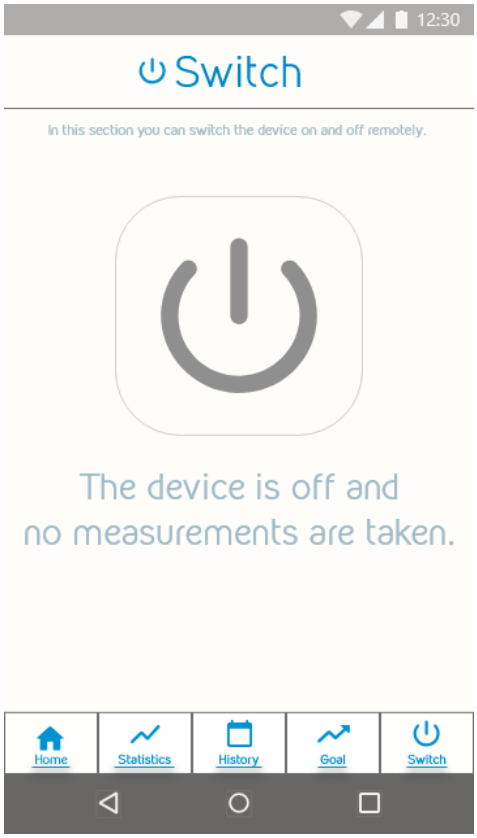

12:30
Statistics
This statistics section supplies you basic and detailed data about your breathing patterns. Given are the ratio, a interval timeline, the breathing frequency over time and moments of abdominal breathing.
Ratio
The ratio section shows average ratio of chest and abdominal breathing for the whole last measurement.
70% chest
abdomen 30%
Timeline
The scrollable timeline gives you more detailed information about the timing of practiced abdominal breathing. The 5 minute intervals show whether abdominal or chest breathing was dominant within that interval. Use two fingers to zoom in and out on the timeline.
chest breathing
abdominal breathing
Start 11:43
12:00
12:15
12:30
12:45
13:00
13:15
Breathing frequency
Here the breathing frequency is shown over time within time intervals of one minute. Use two fingers to zoom in and out on the timeline. By tapping the graph the timeline is added to the graph. Tap it again to remove the timeline.
Moments
Moments shows you all the moments of abdominla breahting found through out the measurement. They are ordered by length and information about length and timing. Tapping a moment reveals chest and abdominal contribution.
Time: 10:59
Timeframe: 14.23 - 14.34
Chest contribution: 20%
Abdominal contribution: 80%
Time: 07:29
Timeframe: 17.23 - 17.30
Time: 05:21
Timeframe: 14.55 - 15.00
Time: 02:01
Timeframe: 16.20 - 16.22
Home
Statistics
History
Goal
Switch

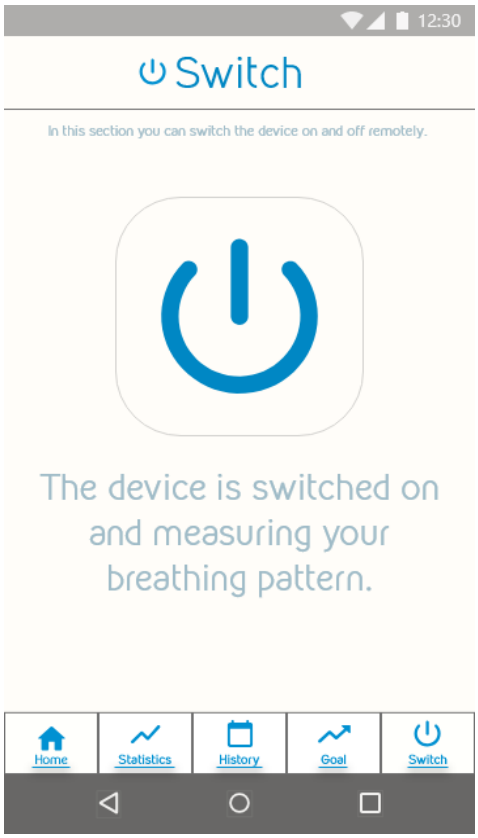

12:30
Goal
The Goal section gives you an overview of your development towards your daily and total goal for the last 5 days.
shows chest breathing and shows abdominal breathing.
Tap on a bar to inspect your a single day.
Mon Tue Wed Thu Fri
Total goal: 80%
Daily goal
Home Statistics History Goal Switch


12:30
History
Here you can compare your breathing patterns of the last 5 days with
showing chest breathing and showing abdominal breathing.
By tapping a bar you can inspect a single days measurement.
Mon Tue Wed Thu Fri
12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00
Home Statistics History Goal Switch

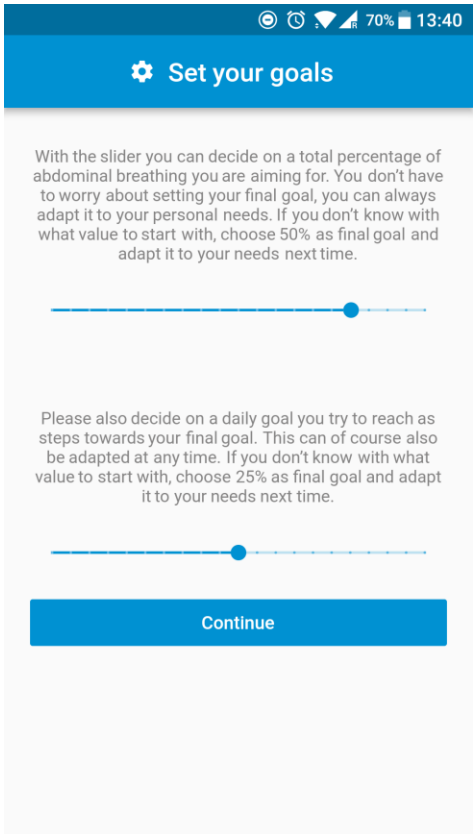

12:30
Goal
The Goal section gives you an overview of your development towards your daily and total goal for the last 5 days.
shows chest breathing and shows abdominal breathing.
Tap the bar again to go back to the overview.
Monday
Total goal: 80%
Daily goal 67%
70%
30%
Home Statistics History Goal Switch

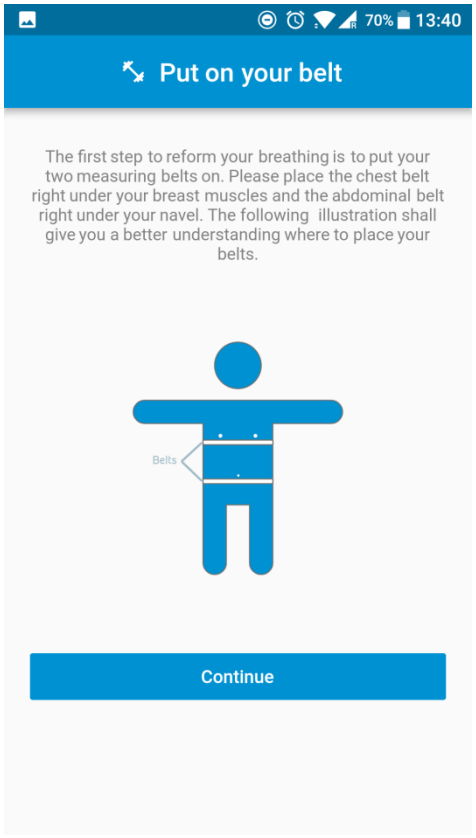

12:30
History
Here you can compare your breathing patterns of the last 5 days with
showing chest breathing and showing abdominal breathing.
Tap the bar again to go back to the overview.
Monday
12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00
Home Statistics History Goal Switch

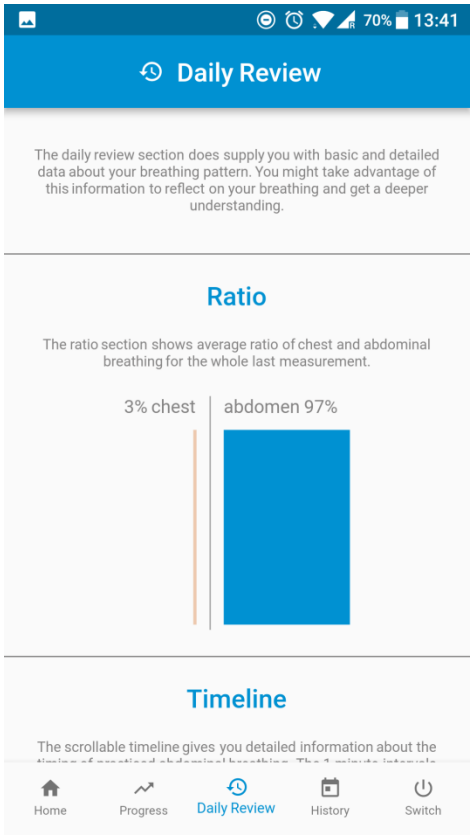

12:30
Switch
In this section you can switch the device on and off remotely.
The device is off and
no measurements are taken.
Home
Statistics
History
Goal
Switch

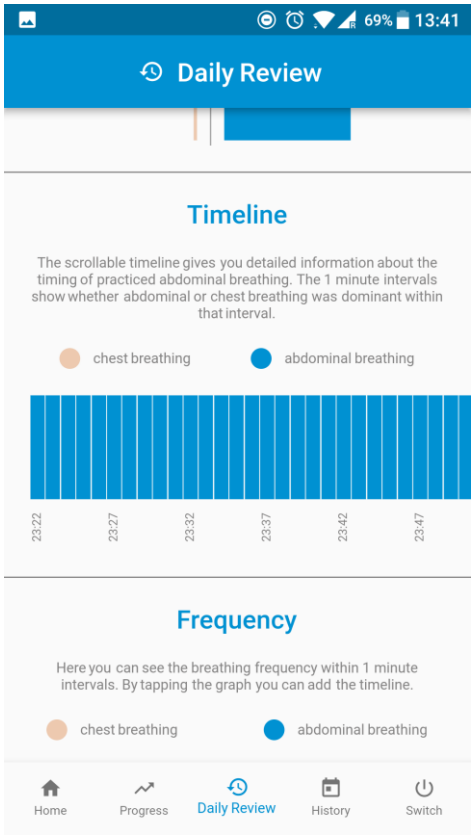

12:30
Switch
In this section you can switch the device on and off remotely.
The device is switched on
and measuring your
breathing pattern.
Home
Statistics
History
Goal
Switch

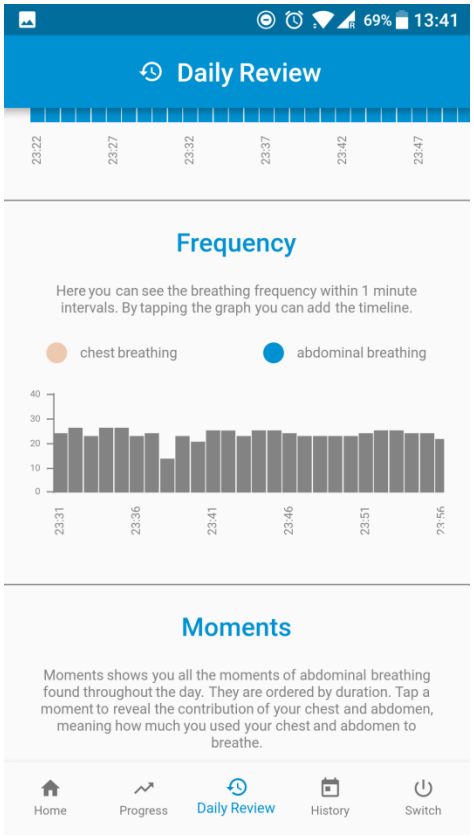
Appendix K – Airleviate Prototype

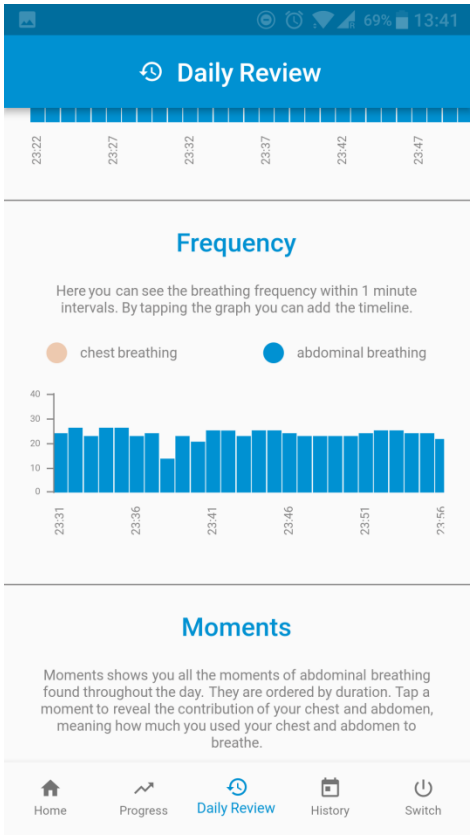


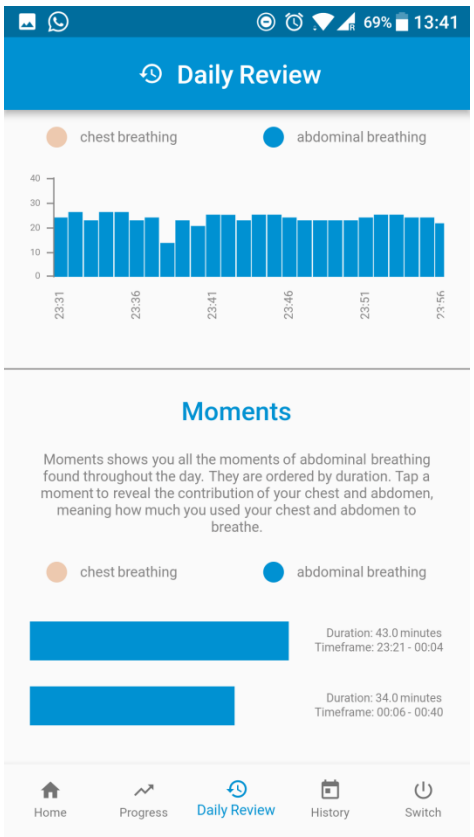


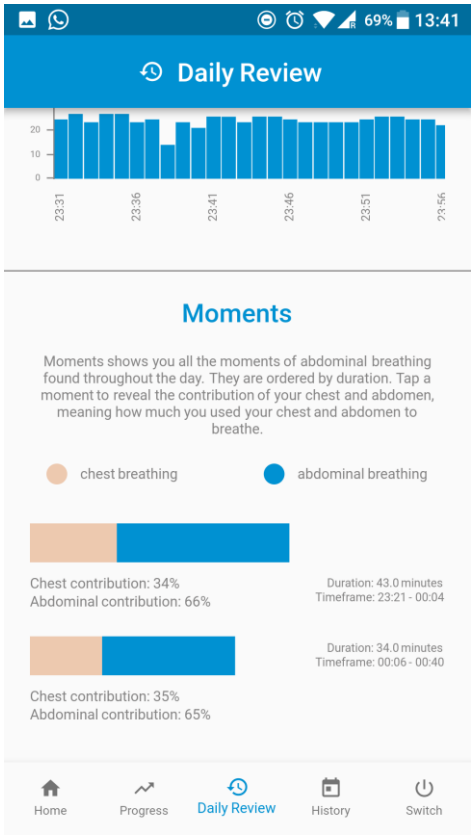


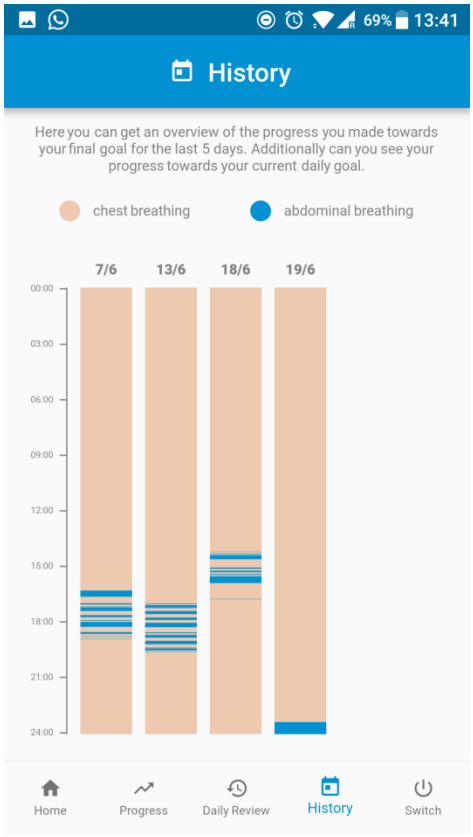

69% 13:41
Daily Review
Timeline
The scrollable timeline gives you detailed information about the timing of practiced abdominal breathing. The 1 minute intervals show whether abdominal or chest breathing was dominant within that interval.
chest breathing
abdominal breathing
23:22
23:27
23:32
23:37
23:42
23:47
Frequency
Here you can see the breathing frequency within 1 minute intervals. By tapping the graph you can add the timeline.
chest breathing
abdominal breathing
Home
Progress
Daily Review
History
Switch

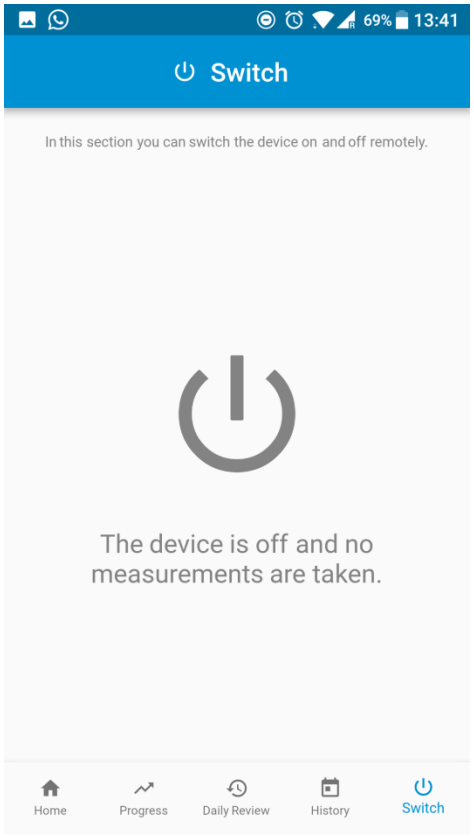

69% 13:41
Daily Review
23:22
23:27
23:32
23:37
23:42
23:47
Frequency
Here you can see the breathing frequency within 1 minute intervals. By tapping the graph you can add the timeline.
chest breathing
abdominal breathing
40
30
20
10
0
23:31
23:36
23:41
23:46
23:51
Moments
Moments shows you all the moments of abdominal breathing found throughout the day. They are ordered by duration. Tap a moment to reveal the contribution of your chest and abdomen, meaning how much you used your chest and abdomen to breathe.
Home
Progress
Daily Review
History
Switch

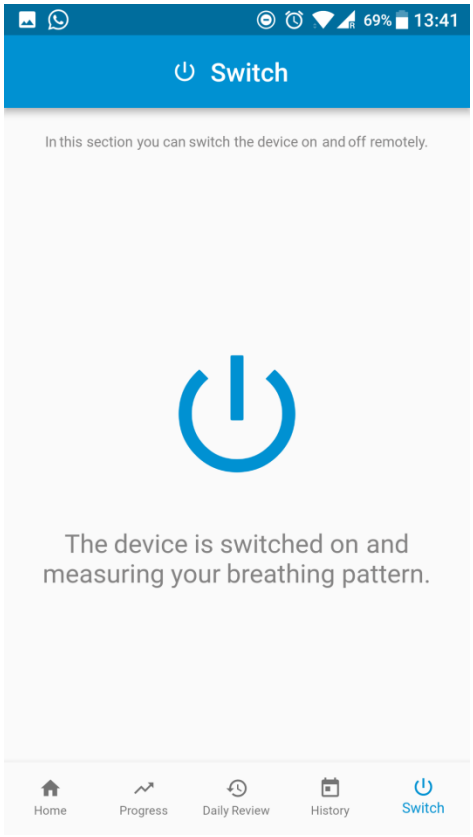

69% 13:41
Daily Review
23:22
23:27
23:32
23:37
23:42
23:47
Frequency
Here you can see the breathing frequency within 1 minute intervals. By tapping the graph you can add the timeline.
chest breathing
abdominal breathing
40
30
20
10
0
23:31
23:36
23:41
23:46
23:51
Moments
Moments shows you all the moments of abdominal breathing found throughout the day. They are ordered by duration. Tap a moment to reveal the contribution of your chest and abdomen, meaning how much you used your chest and abdomen to breathe.
Home
Progress
Daily Review
History
Switch


69% 13:41
Daily Review
chest breathing
abdominal breathing
40
30
20
10
0
23:31
23:36
23:41
23:46
23:51
Moments
Moments shows you all the moments of abdominal breathing found throughout the day. They are ordered by duration. Tap a moment to reveal the contribution of your chest and abdomen, meaning how much you used your chest and abdomen to breathe.
chest breathing
abdominal breathing
Duration: 43.0 minutes
Timeframe: 23:21 - 00:04
Duration: 34.0 minutes
Timeframe: 00:06 - 00:40
Home
Progress
Daily Review
History
Switch


69% 13:41
Daily Review
20
10
0
23:31
23:36
23:41
23:46
23:51
Moments
Moments shows you all the moments of abdominal breathing found throughout the day. They are ordered by duration. Tap a moment to reveal the contribution of your chest and abdomen, meaning how much you used your chest and abdomen to breathe.
chest breathing
abdominal breathing
Chest contribution: 34%
Abdominal contribution: 66%
Duration: 43.0 minutes
Timeframe: 23:21 - 00:04
Chest contribution: 35%
Abdominal contribution: 65%
Duration: 34.0 minutes
Timeframe: 00:06 - 00:40
Home
Progress
Daily Review
History
Switch


69% 13:41
History
Here you can get an overview of the progress you made towards your final goal for the last 5 days. Additionally can you see your progress towards your current daily goal.
chest breathing
abdominal breathing
7/6
13/6
18/6
19/6
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
24:00
Home
Progress
Daily Review
History
Switch


69% 13:41
Switch
In this section you can switch the device on and off remotely.
The device is off and no measurements are taken.
Home
Progress
Daily Review
History
Switch


69% 13:41
Switch
In this section you can switch the device on and off remotely.
The device is switched on and measuring your breathing pattern.
Home
Progress
Daily Review
History
Switch

Appendix L – Usability test design

Tasks for user

1. Put on the belt with the help of the instruction the app is giving.
2. Change your goals to final goal 100% and your daily goal to 100% and go back to the home screen.
3. Change your goals to final goal 100% and your daily goal to 55% and go back to the home screen.
4. Change your goals to final goal 75% and your daily goal to 55% and go back to home screen.
5. Compare the Timeline and Frequency graph.
6. Find out chest contribution for the longest moment of abdominal breathing.
7. Find out when the most abdominal breathing was done on 19th of June.
8. Now feel free to explore the app.

Survery

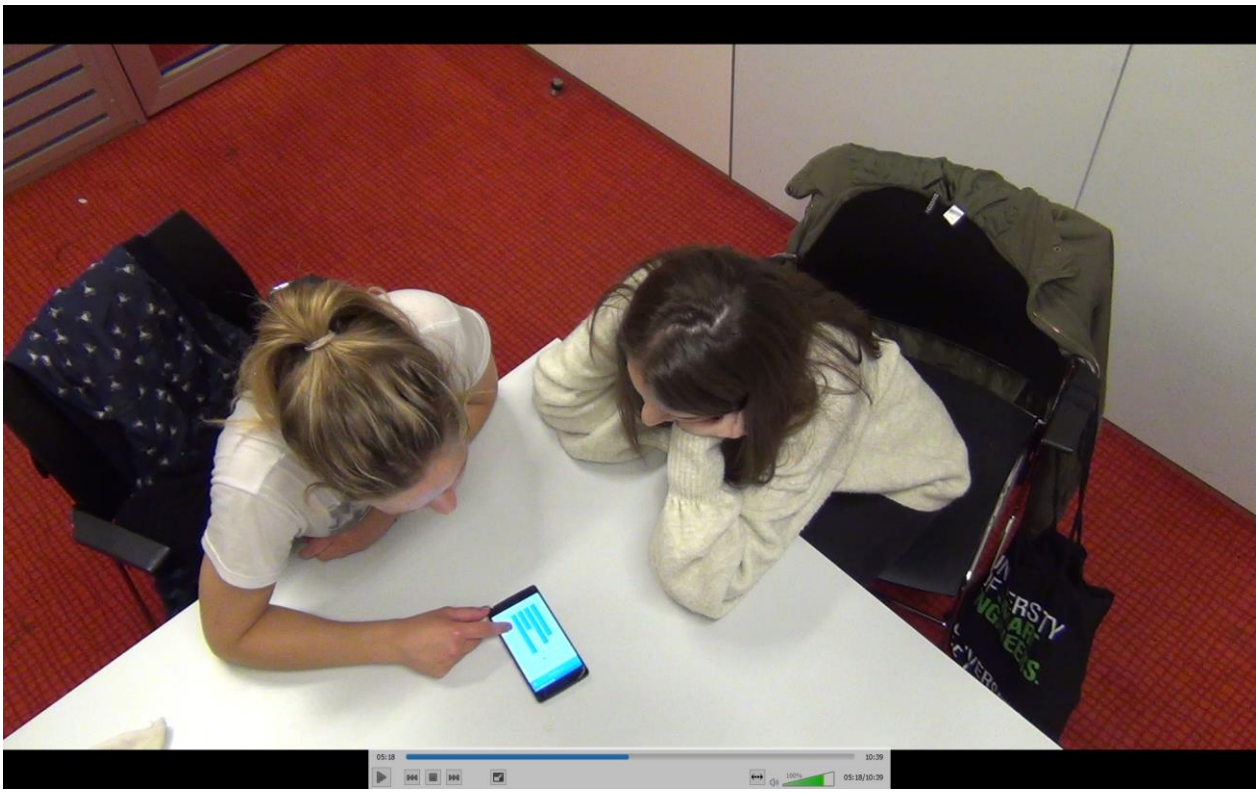
Rating from 1-4

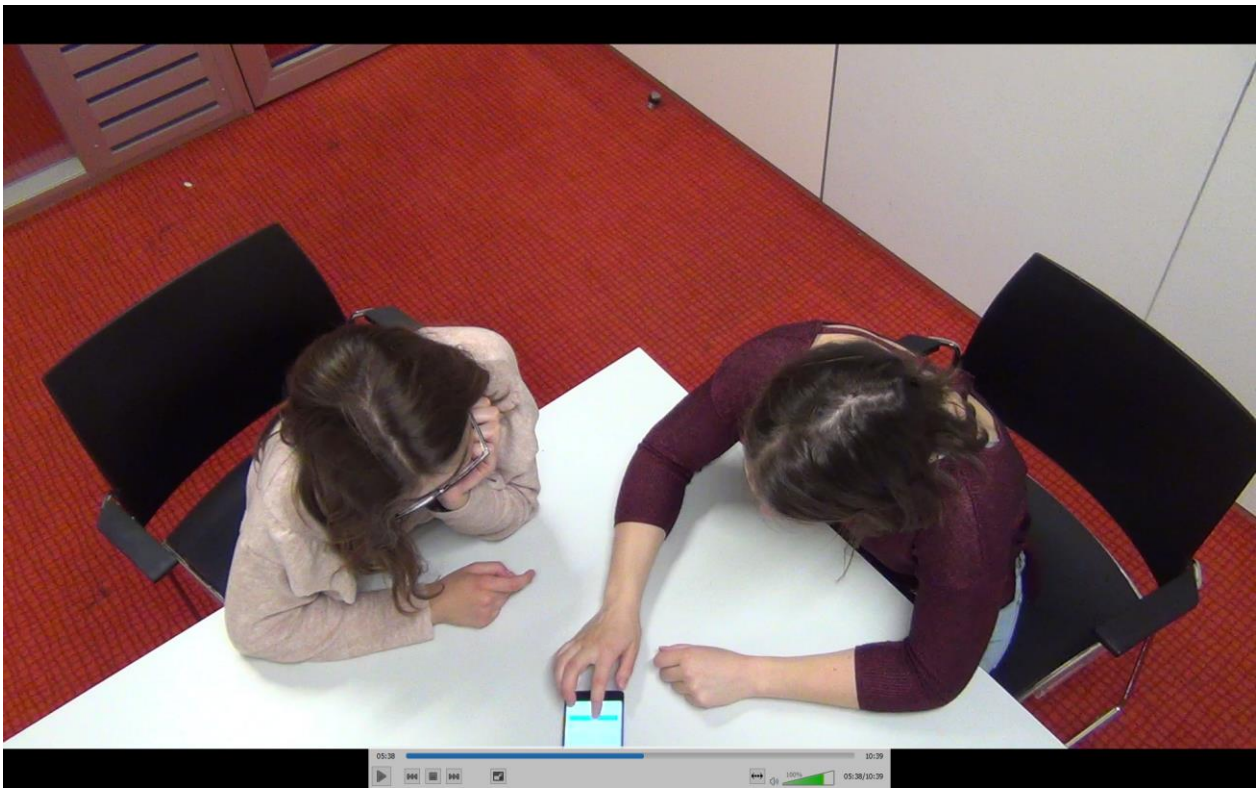
16 questions survey

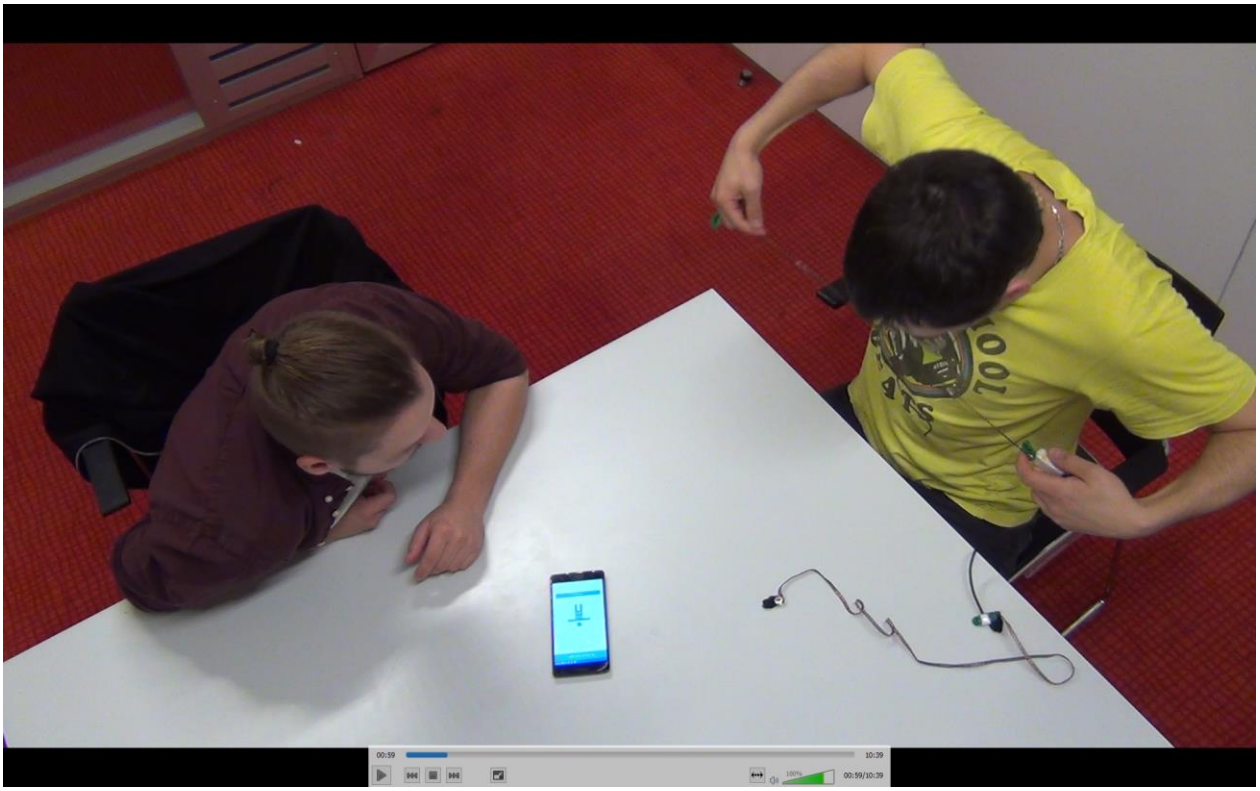
1. Rate how visually appealing you find the flower visualization.
2. How well did you understand that the flowers were representing how well you are doing in terms of the goal?
3. How understandable was the progress graph for you?
4. How understandable were the daily review graphs for you?
5. How understandable was the History graph for you?
6. Rate how much you felt like being able to reflect on your breathing with the app.
7. Did you feel like the explanation on how to put the belt was useful enough to put it on.
8. Do you find the amount of clicks to reach a function of the app appropriate?

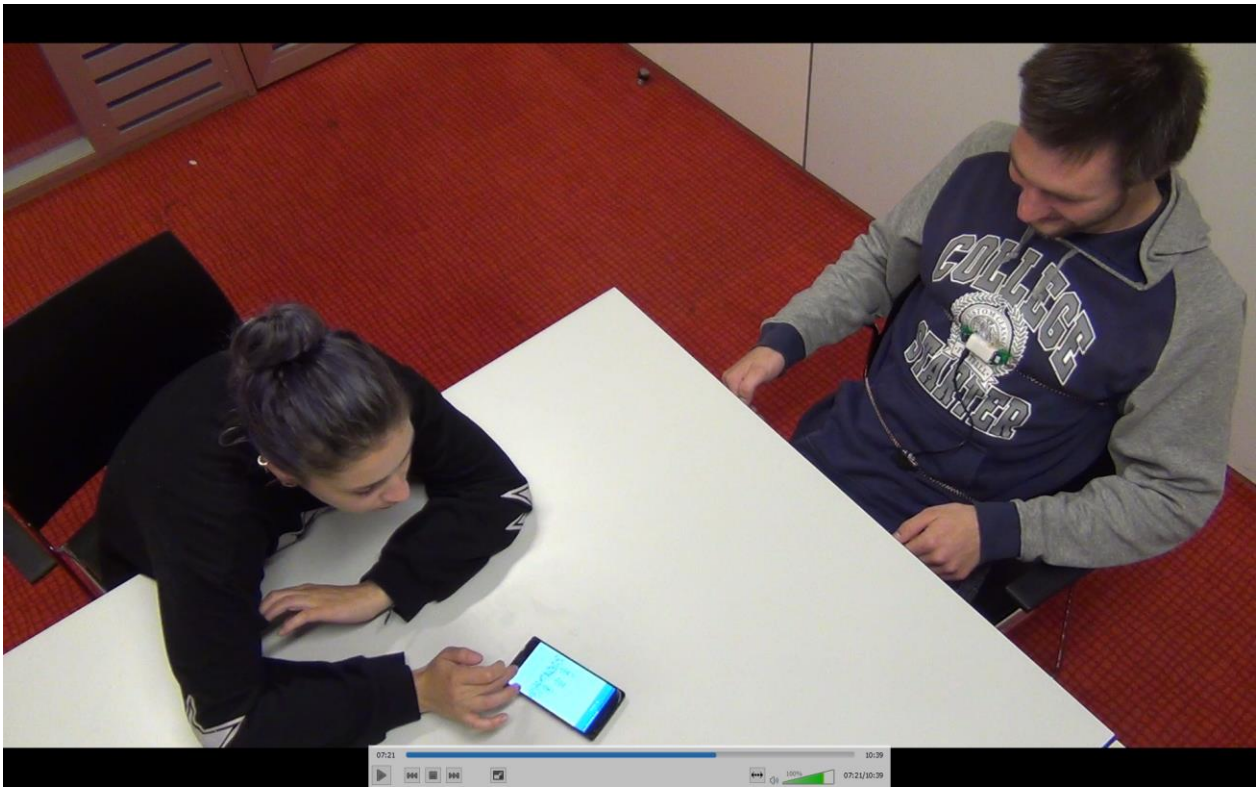
9. Rate how much you find the colors of the app fitting the theme.
10. Which colors do not fit in your opinion or are chosen poorly?
11. Rate how intuitive you find using the app.
12. Did you get distracted by some design elements? If yes by which?
13. What features of the app do you find useful and why?
14. What did you like about the interface and why?
15. What did you dislike about the interface and why?
16. What is your general impression of the application?

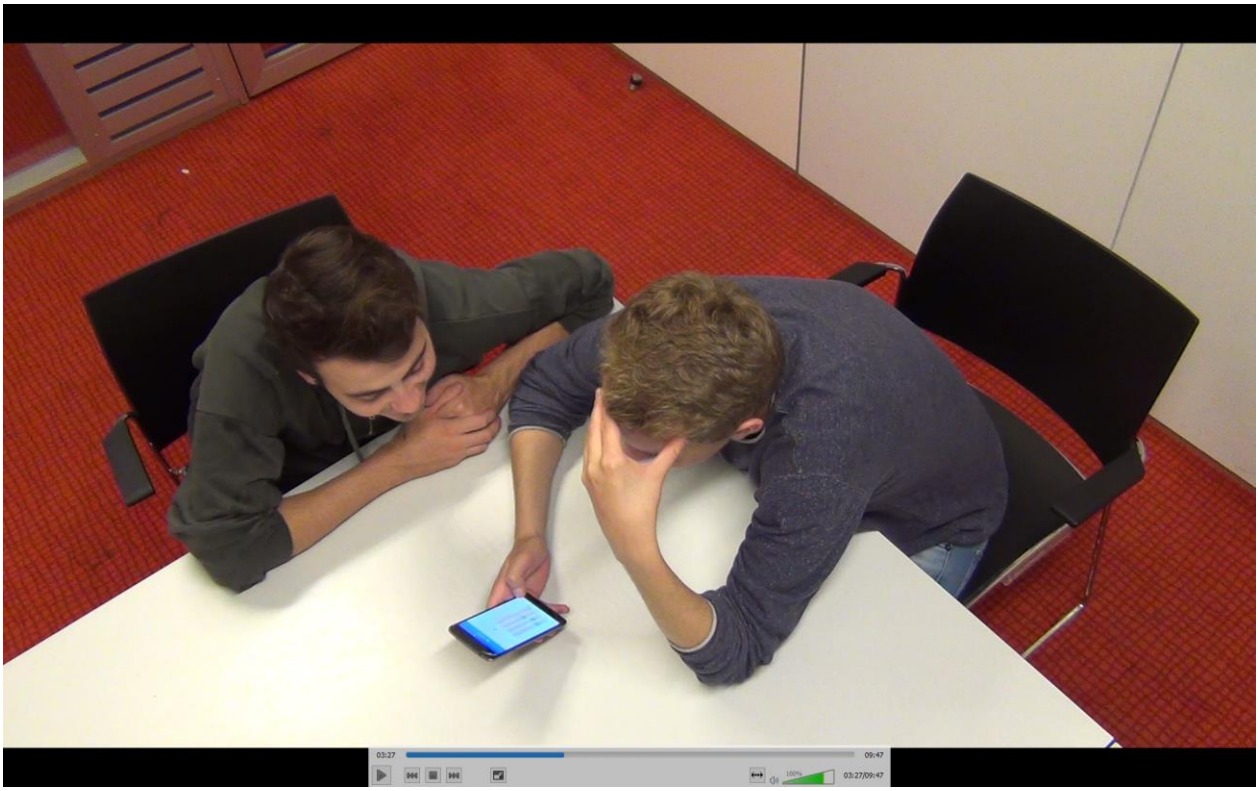
Appendix M – Usability test video recording screen shots & notes








COLLEGE
ATHLETICS



Betti & Julia

Would like real time

Maybe call moments periods

Did not understand the moments and breathing frequency

Floriane & Iris

Doesn’t think it makes sense to tap for breathing frequency

Maybe rephrasing frequency or give a better explaination

Moments graph maybe grey before you show it in two colors to make it clear

Maybe need an explanation of the different gardens

Tap each day on history to go to daily review

Really needs to be real time

Alex & Konrad (watch again)

Alex doesn’t get contribution but Konrad does

Mehr einleitungs material. Why is what important etc. what are things. What is abdominal breathing.

Asked whether it is real time

Kristoph & Max (maybe watch again)

Thought it is real time at first

Seem not to get breathing frequency and relation of timeline on it.

Kristoph übersichtlich, zuviele graphen

Irgendwie zu viel text lesen den text überhaupt nicht, sondern clicken nur rum

Max thinks more relevant frequency especially in combination with the classification into abdominal breathing and chest breathing

Moments is a bit confusing

Luca & Simo (maybe watch again)

Simo zu wenig farbe

Bei goal nochmal bold Machen worum es geht

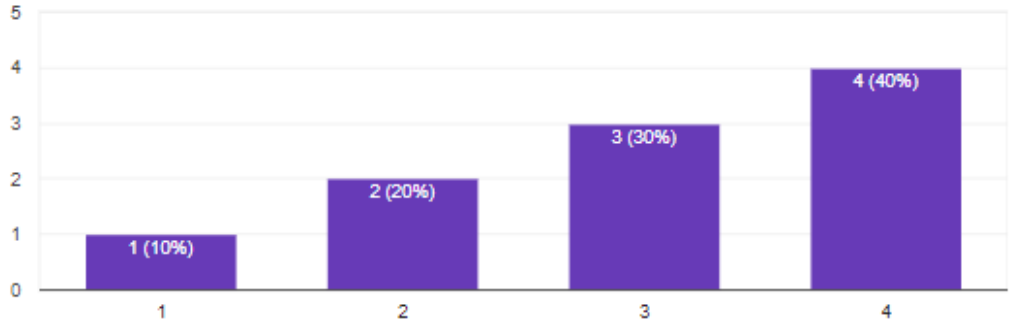
Add the timeline is not understood

Wants in frequency all the time the timeline colors

Appendix N – Survey Results

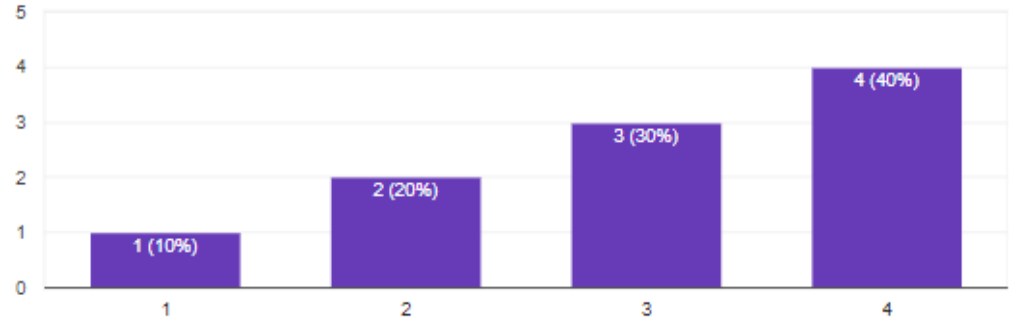
How well did you understand that the flowers were representing how well you are doing in terms of the goal?

10 responses



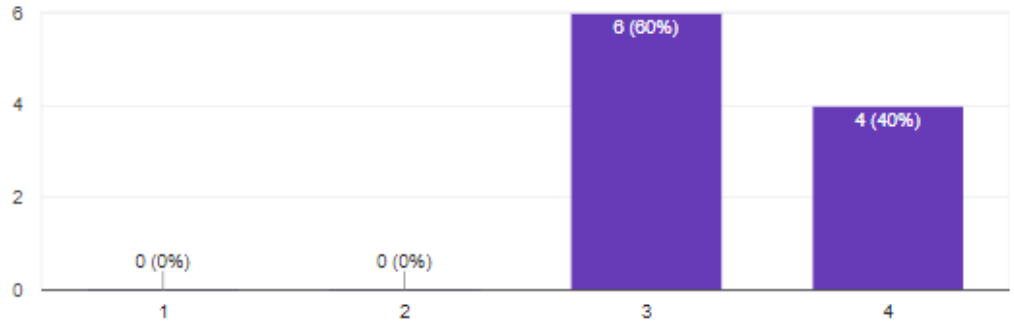
How well did you understand that the flowers were representing how well you are doing in terms of the goal?

10 responses



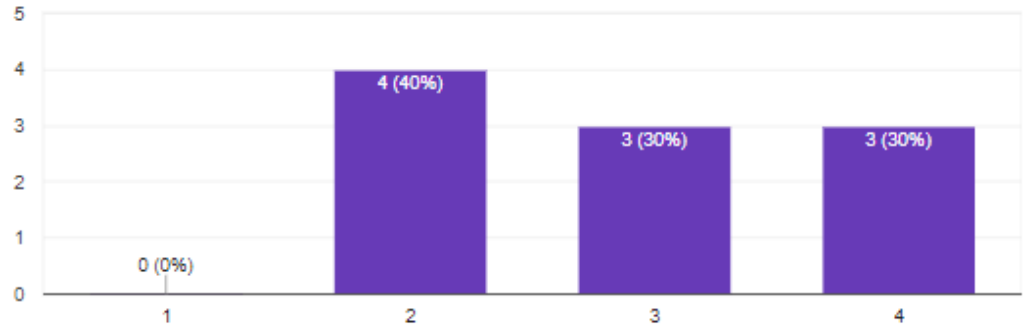
How understandable was the progress graph for you?

10 responses



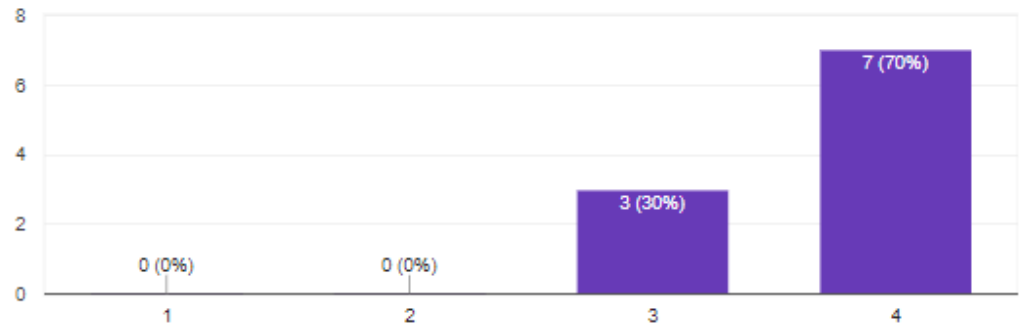
How understandable were the daily review graphs for you?

10 responses



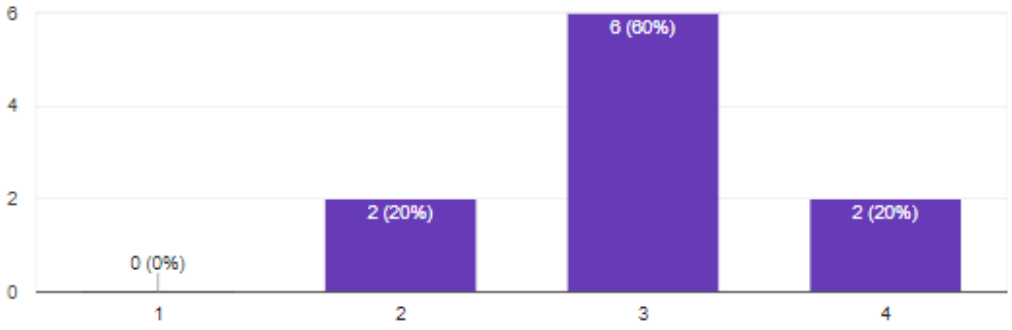
How understandable was the History graph for you?

10 responses



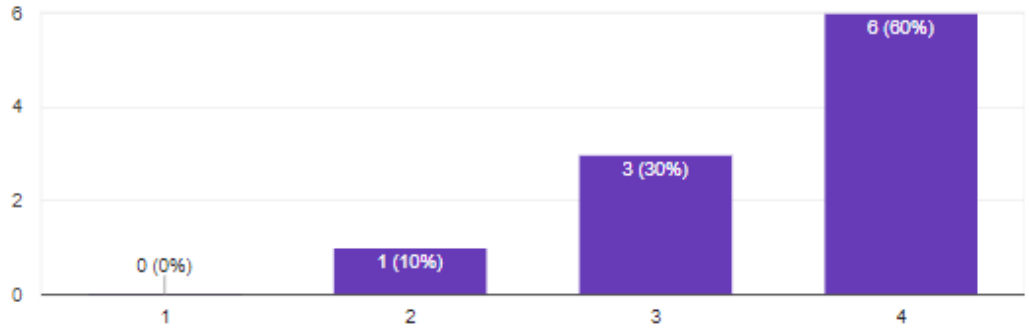
Rate how much you felt like being able to reflect on your breathing with the app.

10 responses



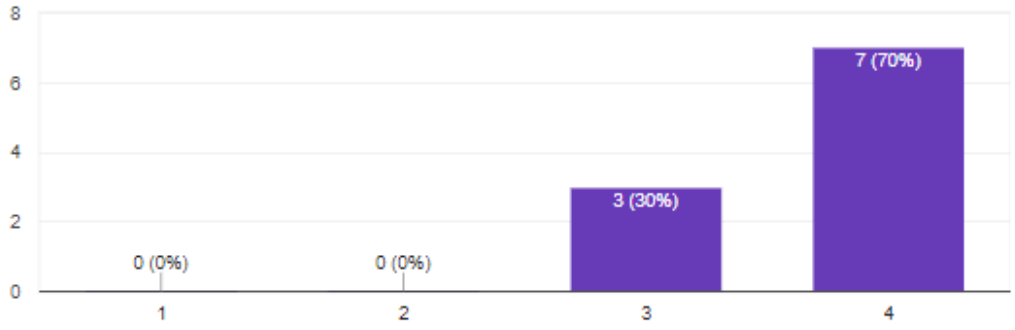
Did you feel like the explanation on how to put the belt was useful enough to put it on.

10 responses



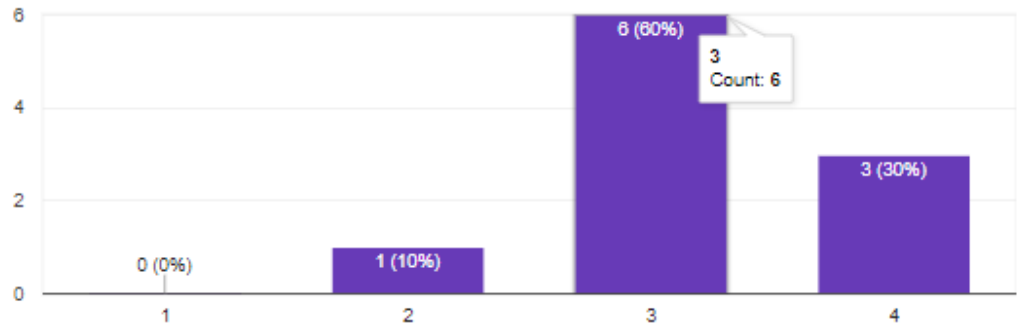
Do you find the amount of clicks to reach a function of the app appropriate?

10 responses



Rate how much you find the colors of the app fitting the theme.

10 responses



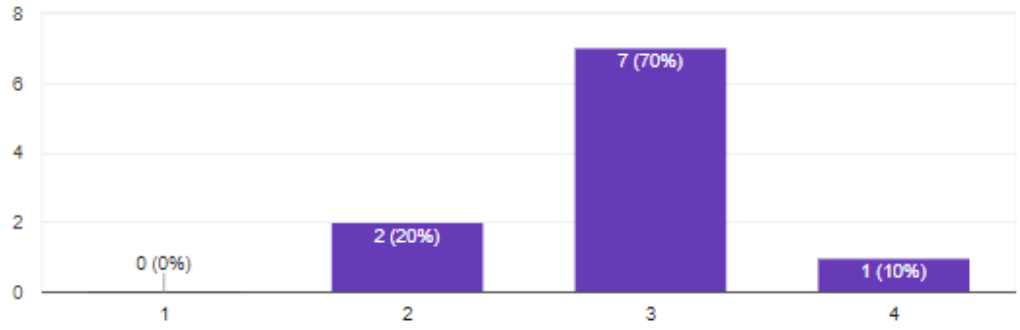
Which colors do not fit in your opinion or are chosen poorly?

6 responses

the colors match and blue makes sense but i don't understand what is meant by the skin color
The cream colour could be adjust to a more complementary tone but good that its light(pastell)
I like the colors they are subtle and do not distract from the general information
the skin colour tone is lame af
/

Rate how intuitive you find using the app.

10 responses



Did you get distracted by some design elements? If yes by which?

10 responses

not really
at first it was not clear that the dates on the progress screen are dates
There is partially too much text. It would be nice if it would be more separated from the actual graphs. Like maybe by tapping you get to see the graph and not see the text.
The fact that we have to click on the frequency graph does not seem necessary. We could just have the graph with abdominal and chest breathing already on the graph.
Settings only available in progress section?
Lots of graphs and scrolling. Having adaptable graphs would conserve space
To many options under Daily review
Flowers- visually nice but they don't deliver their function that well
x-axis timestamps
no

What features of the app do you find useful and why?

10 responses

settings - to set my long term and daily goals
the settings feature is nice
The ratio at the daily review is the best. It is brief and clear. Also visally clear.
The progress graph is really clear. I also liked the frequency graph that can be useful.
Moments showing the ration between chest and abdominal breathing
Very detailed analysis of data but the flowers representation of my progress is lacking. Maybe better to see a representation through time and not currently
I like the progress page. It is easy to understand and can be motivating while achieving the set goals
Frequency because it helped keeping an overview of how one was breathing at what time (e.g. exercise situation/ nervous situation Vs relaxed situation)
all of it
i liked the progress bars and history

What did you like about the interface and why?

9 responses

The flowers metaphor
i liked the flowers
I like the flowers, and although the colours fit, they are not the most exciting. But I understand that they are giving peace.
The way goals are showed on the progress graph.
Simple and clean
Minimalistic
Colour scheme had relaxing effect
the flow
the minimalistic design

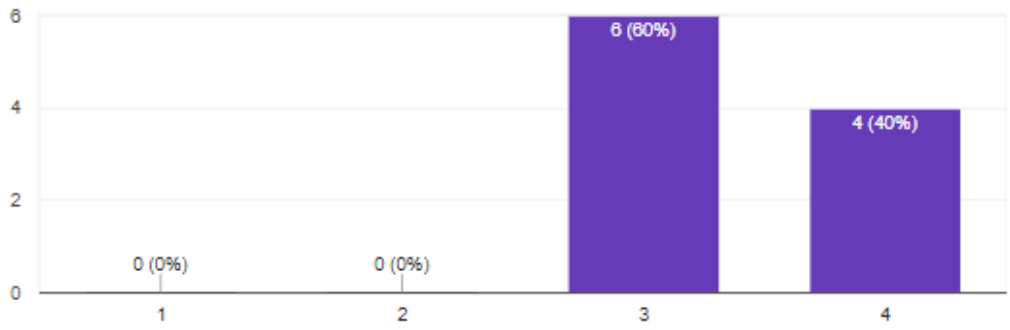
What did you dislike about the interface and why?

8 responses

I did not quite understand the Daily review Frequency and Moments. Maybe you can put more explanation or just make the explanation with easier words
on the daily review screen the 'moments' part was not clear and at first i couldn't tell the difference between 'frequency' and 'timeline'
I don't like that the daily review is all in one page. It is too much text, too many different graphs in once. Make it easier and more fun. Maybe give 4 little tabs/buttons to enter the different parts (ratio, timeline, frequency, moments).
The daily review ratio and moment graphs are not really clear for me.
To much text in general.
Too much text- boring to read; order of graphs was not meaningful
the skin color tone
nothing

What is your general impression of the application?

10 responses



	Rate how visually appealing you find the flower visualization	How well did you understand that the flowers were representing how well you are doing in terms of the goal?	How understandable was the progress graph for you?	How understandable were the daily review graphs for you?	How understandable was the History graph for you?	Rate how much you felt like being able to reflect on your breathing with the app.	Did you feel like the explanation on how to put the belt was useful enough to put it on.	Do you find the amount of clicks to reach a function of the app appropriate?	Rate how much you find the colors of the app fitting the theme.	Which colors do not fit in your opinion or are chosen poorly?	Rate how intuitive you find using the app.	Did you get distracted by some design elements? If yes by which?	What features of the app do you find useful and why?	What did you like about the interface and why?	What did you dislike about the interface and why?	What is your general impression of the application?	Total Average
Average	3.3	3	3.4	2.9	3.7	3	3.5	3.7	3.2		2.9					3.4	3.272727273
Mode(most appearing value)	3	4	3	2	4	3	4	4	3		3					3	
Median(after sorting by value it's the value standing in the middle)	3	3	3	3	4	3	4	4	3		3					3	

Appendix O – Dart code

This appendix is providing the code for three structures of the app coded with Dart. Shown will be the code of the goal setting, history and only the breathing frequency part of 'Daily Review'.

Goal setting

```
import 'package:abnominal/main.dart';
import 'package:flutter/material.dart';
import 'package:intl/intl.dart';
import 'package:shared_preferences/shared_preferences.dart';

class GoalSettings extends StatefulWidget {
  final SharedPreferences preferences;
  final bool startup;
  const GoalSettings(this.preferences, this.startup);

  @override
  _GoalSettingsState createState() => _GoalSettingsState();
}

class _GoalSettingsState extends State<GoalSettings> {
  double _dailyGoal;
  double get dailyGoal => _dailyGoal;
  set dailyGoal(double val) {
    setState(() {
      _dailyGoal = val;
    });
    widget.preferences.setDouble('dailyGoal', val);
  }

  double _finalGoal;
  double get finalGoal => _finalGoal;
  set finalGoal(double val) {
    setState(() {
      _finalGoal = val;
    });
    widget.preferences.setDouble('finalGoal', val);
  }

  @override
  void initState() {
    dailyGoal = widget.preferences.getDouble('dailyGoal') ?? 50.0;
    finalGoal = widget.preferences.getDouble('finalGoal') ?? 80.0;
    super.initState();
  }

  @override
  Widget build(BuildContext context) {
    NumberFormat noFormat = NumberFormat();
    noFormat.minimumIntegerDigits = 2;

    return Scaffold(
      appBar: AppBar(
```

```
        backgroundColor: Color(0xFF0091D2),
        centerTitle: true,
        title: new Padding(
          padding: EdgeInsets.only(right: 10.0),
          child: new Wrap(
            spacing: 10.0,
            crossAxisAlignment: WrapCrossAlignment.center,
            children: <Widget>[
              new Icon(Icons.settings, size: 20.0),
              new Text('Set your goals'),
            ],
          ),
        ),
        automaticallyImplyLeading: false,
      ),
      body: Scaffold(
        body: ListView(
          padding: EdgeInsets.symmetric(vertical: 30.0, horizontal: 20.0),
          children: <Widget>[
            Text(
              'With the slider you can decide on a total percentage of
abdominal breathing you are aiming for. You don't have to worry about setting
your final goal, you can always adapt it to your personal needs. If you don't
know with what value to start with, choose 50% as final goal and adapt it to
your needs next time.',
              textAlign: TextAlign.center,
              style: TextStyle(
                color: Color(0xFF848383),
                fontSize: 13.0,
              ),
            ),
            Padding(
              padding: EdgeInsets.only(top: 20.0),
              child: Slider(
                min: 0.0,
                max: 100.0,
                label: '${noFormat.format(finalGoal)}%',
                value: finalGoal,
                divisions: 20,
                onChanged: (double val) => finalGoal = val,
              ),
            ),
            Padding(
              padding: EdgeInsets.only(top: 60.0),
              child: Text(
                'Please also decide on a daily goal you try to reach as steps
towards your final goal. This can of course also be adapted at any time. If
you don't know with what value to start with, choose 25% as final goal and
adapt it to your needs next time.',
                textAlign: TextAlign.center,
                style: TextStyle(
                  color: Color(0xFF848383),
                  fontSize: 13.0,
                ),
              ),
            ),
            Padding(
              padding: EdgeInsets.only(top: 20.0),
```

```
              child: Slider(
                min: 0.0,
                max: 100.0,
                label: '${noFormat.format(dailyGoal)}%',
                value: dailyGoal,
                divisions: 20,
                onChanged: (double val) => dailyGoal = val,
              ),
            ),
            Padding(
              padding: EdgeInsets.only(top: 20.0),
              child: FlatButton(
                child: Text(widget.startup ? 'Continue' : 'Go back'),
                color: Color(0xFF0091D2),
                textColor: Color(0xFFFFFFFF),
                onPressed: () {
                  if (widget.startup) {
                    widget.preferences.setBool('isInitial', false);
                  }

                  Navigator.push(
                    context,
                    new MaterialPageRoute(
                      builder: (context) =>
                          new Abnominal(widget.preferences, widget.startup),
                    ),
                  );
                },
              ),
            ),
          ],
        ),
      ),
    );
  }
}

class SettingsSetupPage extends StatefulWidget {
  final SharedPreferences preferences;
  final bool startup;
  const SettingsSetupPage(this.preferences, this.startup);

  @override
  _SettingsSetupPageState createState() => _SettingsSetupPageState();
}

class _SettingsSetupPageState extends State<SettingsSetupPage> {
  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      title: 'Airleviate',
      theme: ThemeData(
        primaryColor: Color(0xFF0091D2),
      ),
      home: GoalSettings(widget.preferences, widget.startup),
    );
  }
```

History

```
import 'package:abnominal/tools/data_import.dart';
import 'package:flutter/material.dart';

class HistoryPage extends StatelessWidget {
  final List<DataEntry> dataset;
  const HistoryPage(this.dataset);

  @override
  Widget build(BuildContext context) {
    if (dataset == null) {
      return Center(
        child: Text('No data'),
      );
    }

    Map<String, List<AbdomenMoment>> history = calculateHistory(dataset);

    return new SingleChildScrollView(
      scrollDirection: Axis.vertical,
      padding: EdgeInsets.symmetric(vertical: 30.0, horizontal: 20.0),
      child: new Column(
        children: <Widget>[
          Text(
            'Here you can get an overview of the progress you made towards
your final goal for the last 5 days. Additionally can you see your progress
towards your current daily goal.',
            textAlign: TextAlign.center,
            style: TextStyle(
              color: Color(0xFF848383),
              fontSize: 11.0,
            ),
          ),
          SizedBox(height: 20.0),
          new Row(
            mainAxisAlignment: MainAxisAlignment.spaceAround,
            children: <Widget>[
              new Wrap(
                crossAxisAlignment: WrapCrossAlignment.center,
                spacing: 10.0,
                children: <Widget>[
                  new CircleAvatar(
                    backgroundColor: Color(0xFFEDC9AF),
                    radius: 8.0,
                  ),
                  Text(
                    'chest breathing',
                    style: TextStyle(
                      color: Color(0xFF848383),
                      fontSize: 11.0,
                    ),
                  ),
                ],
              ),
              new Wrap(
```

```
            crossAxisAlignment: WrapCrossAlignment.center,
            spacing: 10.0,
            children: <Widget>[
              new CircleAvatar(
                backgroundColor: Color(0xFF0091D2),
                radius: 8.0,
              ),
              Text(
                'abdominal breathing',
                style: TextStyle(
                  color: Color(0xFF848383),
                  fontSize: 11.0,
                ),
              ),
            ],
          ),
        ],
      ),
      SizedBox(height: 25.0),
      Stack(
        children: <Widget>[
          Row(
            crossAxisAlignment: CrossAxisAlignment.end,
            children: <Widget>[
              SizedBox(
                height: 350.0,
                child: Column(
                  mainAxisAlignment: MainAxisAlignment.spaceBetween,
                  crossAxisAlignment: CrossAxisAlignment.end,
                  mainAxisSize: MainAxisSize.max,
                  children: <String>[
                    '00:00',
                    '03:00',
                    '06:00',
                    '09:00',
                    '12:00',
                    '15:00',
                    '18:00',
                    '21:00',
                    '24:00'
                  ].map((String time) {
                    return Row(
                      children: <Widget>[
                        Padding(
                          padding: EdgeInsets.only(right: 5.0),
                          child: Text(
                            time,
                            style: TextStyle(
                              color: Color(0xFF848383),
                              fontSize: 7.0,
                            ),
                            textAlign: TextAlign.end,
                          ),
                        ),
                        Container(
                          height: 1.0,
                          width: 5.0,
                          color: Color(0xFF848383),
```

```
                            ),
                          ],
                        );
                      }).toList(),
                    ),
                  ),
                  Container(
                    color: Color(0xFF848383),
                    width: 1.0,
                    height: 344.0,
                    margin: EdgeInsets.only(bottom: 3.0),
                  ),
                  Flexible(
                    fit: FlexFit.tight,
                    child: Container(
                      height: 370.0,
                      margin: EdgeInsets.only(bottom: 3.0),
                      child: ListView(
                        padding: EdgeInsets.only(left: 10.0),
                        scrollDirection: Axis.horizontal,
                        children: history.keys.map((String date) {
                          List<AbdomenMoment> moments = history[date];
                          double minSize = 344 / 1440;

                          return Padding(
                            padding: EdgeInsets.only(right: 10.0),
                            child: Column(
                              mainAxisAlignment: MainAxisAlignment.end,
                              children: <Widget>[
                                SizedBox(
                                  height: 20.0,
                                  child: Text(

'${date.split('/')[2]}/${date.split('/')[1]}',
                                    textAlign: TextAlign.center,
                                    style: TextStyle(
                                      color: Color(0xFF848383),
                                      fontSize: 11.0,
                                      fontWeight: FontWeight.w900,
                                    ),
                                  ),
                                ),
                                SizedBox(
                                  height: 344.0,
                                  width: 40.0,
                                  child: Stack(
                                    children: <Widget>[
                                      Container(
                                        color: Color(0xFFEDC9AF),
                                      ),
                                      Column(
                                        children:
                                            moments.map((AbdomenMoment moment)
{

                                          int _marginTop = 0;

                                          DateTime _midnight = moments[0]
                                              .start
```

```
                                        .subtract(Duration(
                                          hours: moments[0].start.hour,
                                          minutes:
                                              moments[0].start.minute,
                                          seconds:
                                              moments[0].start.second,
                                        ));

                                    if (moments.indexOf(moment) == 0) {
                                      _marginTop = moment.start
                                          .difference(_midnight)
                                          .inMinutes;
                                    } else {
                                      AbdomenMoment _previous = moments[
                                          moments.indexOf(moment) - 1];
                                      _marginTop = moment.start
                                          .difference(_previous.start)
                                          .inMinutes;
                                    }

                                    DateTime _end = moment.start.add(
                                        Duration(
                                            minutes:
                                                moment.length.toInt()));
                                    double _dur = moment.length;

                                    DateTime _endNight =
                                        _midnight.add(Duration(days:
1));


                                    if (moment.start.isAfter(_endNight)
||

                                        moment.start.isAtSameMomentAs(
                                            _endNight)) {
                                      return SizedBox();
                                    } else if (moment.start
                                            .isBefore(_endNight) &&
                                        _end.isAfter(_endNight)) {
                                      _dur = _endNight
                                          .difference(moment.start)
                                          .inMinutes
                                          .toDouble();
                                    }

                                    return new Container(
                                      margin: EdgeInsets.only(
                                          top: _marginTop.toDouble() *
                                              minSize),
                                      height: minSize * _dur,
                                      color: Color(0xFF0091D2),
                                    );
                                  }).toList(),
                                ),
                              ],
                            ),
                          ),
                        ],
                      ),
```

```
                          );
                      }).toList(),
                    ),
                  ),
                ),
              ],
            ),
          ],
        ),
      ),
    );
  }
}
```

Breathing frequency

```
import 'package:abnominal/tools/data_import.dart';
import 'package:flutter/material.dart';
import 'package:intl/intl.dart';

class StatPage extends StatefulWidget {
  final DataEntry data;
  const StatPage(this.data);

  @override
  _StatPageState createState() => _StatPageState();
}


class _StatPageState extends State<StatPage> {
  @override
  Widget build(BuildContext context) {
    return new SingleChildScrollView(
      padding: EdgeInsets.symmetric(vertical: 30.0),
      child: widget.data != null
          ? new Column(
              crossAxisAlignment: CrossAxisAlignment.stretch,
              children: <Widget>[
                _Info(),
                Container(
                  height: 1.0,
                  margin: EdgeInsets.fromLTRB(0.0, 20.0, 0.0, 10.0),
                  color: Color(0xFF848383),
                ),
_Frequency(widget.data.breathingFrequency,
    widget.data.abdomenSessions),
Container(
  height: 1.0,
  margin: EdgeInsets.fromLTRB(0.0, 20.0, 0.0, 10.0),
  color: Color(0xFF848383),
),
              ],
```

```
            )
          : Center(
              child: Text(
                'No data',
                style: TextStyle(
                  fontSize: 9.0,
                  color: Color(0xFF848383),
                ),
              ),
            ),
      );
  }
}


class _StatCard extends StatelessWidget {
  final String title;
  final Widget content;
  const _StatCard(this.title, this.content);

  @override
  Widget build(BuildContext context) {
    return new Container(
      color: Colors.transparent,
      child: new Wrap(
        alignment: WrapAlignment.center,
        runSpacing: 10.0,
        children: <Widget>[
          Padding(
            padding: EdgeInsets.symmetric(vertical: 10.0),
            child: new Text(
              title,
              style: TextStyle(
                fontSize: 20.0,
                color: Color(0xFF0091D2),
                fontWeight: FontWeight.w500,
              ),
            ),
          ),
          content,
        ],
      ),
    );
  }
}



class _Frequency extends StatefulWidget {
  final Map<DateTime, double> breathingFrequency;
  final Map<DateTime, double> abdomenSessions;
  const _Frequency(this.breathingFrequency, this.abdomenSessions);

  @override
  __FrequencyState createState() => __FrequencyState();
}

class __FrequencyState extends State<_Frequency> {
```

```
  bool _details = false;
  bool get details => _details;
  set details(bool value) {
    setState(() {
      _details = value;
    });
  }

  @override
  Widget build(BuildContext context) {
    NumberFormat noFormat = NumberFormat();
    noFormat.minimumIntegerDigits = 2;

    return new Container(
      color: Colors.transparent,
      child: new Wrap(
        alignment: WrapAlignment.center,
        runSpacing: 10.0,
        children: <Widget>[
          Padding(
            padding: EdgeInsets.symmetric(vertical: 10.0),
            child: new Text(
              'Frequency',
              style: TextStyle(
                fontSize: 20.0,
                color: Color(0xFF0091D2),
                fontWeight: FontWeight.w500,
              ),
            ),
          ),
          Column(
            children: <Widget>[
              Padding(
                padding: EdgeInsets.symmetric(horizontal: 20.0),
                child: Text(
                  'Here you can see the breathing frequency within 1 minute
intervals. By tapping the graph you can add the timeline.',
                  textAlign: TextAlign.center,
                  style: TextStyle(
                    color: Color(0xFF848383),
                    fontSize: 11.0,
                  ),
                ),
              ),
              new SizedBox(height: 20.0),
              new Row(
                mainAxisAlignment: MainAxisAlignment.spaceAround,
                children: <Widget>[
                  new Wrap(
                    crossAxisAlignment: WrapCrossAlignment.center,
                    spacing: 10.0,
                    children: <Widget>[
                      new CircleAvatar(
                        backgroundColor: Color(0xFFEDC9AF),
                        radius: 8.0,
                      ),
                      Text(
                        'chest breathing',
```

```
                    style: TextStyle(
                      color: Color(0xFF848383),
                      fontSize: 11.0,
                    ),
                  ),
                ],
              ),
              new Wrap(
                crossAxisAlignment: WrapCrossAlignment.center,
                spacing: 10.0,
                children: <Widget>[
                  new CircleAvatar(
                    backgroundColor: Color(0xFF0091D2),
                    radius: 8.0,
                  ),
                  Text(
                    'abdominal breathing',
                    style: TextStyle(
                      color: Color(0xFF848383),
                      fontSize: 11.0,
                    ),
                  ),
                ],
              ),
            ],
          ),
          new SizedBox(height: 20.0),
          GestureDetector(
            onTap: () => details = !details,
            child: new SizedBox(
              height: 130.0,
              child: Padding(
                padding: EdgeInsets.symmetric(horizontal: 20.0),
                child: new Row(
                  children: <Widget>[
                    Padding(
                      padding: EdgeInsets.only(bottom: 40.0),
                      child: Column(
                        crossAxisAlignment: CrossAxisAlignment.end,
                        mainAxisAlignment: MainAxisAlignment.start,
                        children: <Widget>[
                          Padding(
                            padding: EdgeInsets.only(bottom: 11.0),
                            child: Row(
                              children: <Widget>[
                                Padding(
                                  padding: EdgeInsets.only(right: 5.0),
                                  child: Text(
                                    '40',
                                    style: TextStyle(
                                      color: Color(0xFF848383),
                                      fontSize: 7.0,
                                    ),
                                    textAlign: TextAlign.end,
                                  ),
                                ),
                                Container(
                                  height: 1.0,
```

```
                    width: 5.0,
                    color: Color(0xFF848383),
                  ),
                ],
              ),
            ),
            Padding(
              padding: EdgeInsets.only(bottom: 11.0),
              child: Row(
                children: <Widget>[
                  Padding(
                    padding: EdgeInsets.only(right: 5.0),
                    child: Text(
                      '30',
                      style: TextStyle(
                        color: Color(0xFF848383),
                        fontSize: 7.0,
                      ),
                      textAlign: TextAlign.end,
                    ),
                  ),
                  Container(
                    height: 1.0,
                    width: 5.0,
                    color: Color(0xFF848383),
                  ),
                ],
              ),
            ),
            Padding(
              padding: EdgeInsets.only(bottom: 11.0),
              child: Row(
                children: <Widget>[
                  Padding(
                    padding: EdgeInsets.only(right: 5.0),
                    child: Text(
                      '20',
                      style: TextStyle(
                        color: Color(0xFF848383),
                        fontSize: 7.0,
                      ),
                      textAlign: TextAlign.end,
                    ),
                  ),
                  Container(
                    height: 1.0,
                    width: 5.0,
                    color: Color(0xFF848383),
                  ),
                ],
              ),
            ),
            Padding(
              padding: EdgeInsets.only(bottom: 10.0),
              child: Row(
                children: <Widget>[
                  Padding(
                    padding: EdgeInsets.only(right: 5.0),
```

```
                    child: Text(
                      '10',
                      style: TextStyle(
                        color: Color(0xFF848383),
                        fontSize: 7.0,
                      ),
                      textAlign: TextAlign.end,
                    ),
                  ),
                  Container(
                    height: 1.0,
                    width: 5.0,
                    color: Color(0xFF848383),
                  ),
                ],
              ),
            ),
            Row(
              children: <Widget>[
                Padding(
                  padding: EdgeInsets.only(right: 5.0),
                  child: Text(
                    '0',
                    style: TextStyle(
                      color: Color(0xFF848383),
                      fontSize: 7.0,
                    ),
                    textAlign: TextAlign.end,
                  ),
                ),
                Container(
                  height: 1.0,
                  width: 5.0,
                  color: Color(0xFF848383),
                ),
              ],
            ),
          ],
        ),
      ),
      Padding(
        padding: EdgeInsets.only(bottom: 47.0),
        child: Container(
          color: Color(0xFF848383),
          width: 1.0,
          height: 77.0,
        ),
      ),
      Flexible(
        fit: FlexFit.tight,
        child: new ListView(
          padding: EdgeInsets.only(left: 5.0),
          scrollDirection: Axis.horizontal,
          children: widget.breathingFrequency.keys
              .map((DateTime moment) {
            final cIndex = widget.breathingFrequency.keys
                .toList()
                .indexOf(moment);
```

```
                                final double percentile = widget
                                        .breathingFrequency.values
                                        .elementAt(cIndex) /
                                    40;
                                return new Align(
                                  alignment: Alignment.bottomCenter,
                                  child: new Column(
                                    mainAxisSize: MainAxisSize.max,
                                    mainAxisAlignment: MainAxisAlignment.end,
                                    children: <Widget>[
                                      Container(
                                        width: 11.0,
                                        height: 80.0 * percentile,
                                        margin: EdgeInsets.all(0.4),
                                        color: details
                                            ? (widget.abdomenSessions.keys.any(
                                                    (DateTime key) =>
                                                        key.hour == moment.hour
&&
                                                        key.minute ==
                                                            moment.minute &&
                                                        key.day == moment.day &&
                                                        key.month ==
                                                            moment.month &&
                                                        key.year == moment.year)
                                                ? Color(0xFF0091D2)
                                                : Color(0xFFEDC9AF))
                                            : Color(0xFF848383),
                                      ),
                                      SizedBox(
                                        height: 50.0,
                                        child: (cIndex) % 5 == 0 ||
                                                widget.breathingFrequency
                                                        .length ==
                                                    cIndex + 1
                                            ? RotatedBox(
                                                quarterTurns: 3,
                                                child: Padding(
                                                  padding: EdgeInsets.only(
                                                      right: 10.0),
                                                  child: Text(

'${noFormat.format(moment.hour)}:${noFormat.format(moment.minute)}',
                                                    style: TextStyle(
                                                      color: Color(0xFF848383),
                                                      fontSize: 9.0,
                                                    ),
                                                    textAlign: TextAlign.end,
                                                  ),
                                                ),
                                              )
                                            : new SizedBox(),
                                      ),
                                    ],
                                  ),
                                );
                              }).toList(),
                            ),
```

```
                            ),
                        ],
                    ),
                ),
            ),
        ),
    ),
  }
}
```