Tailoring personalized breathing rhythms of a Sleep Robot : An interactive data loop design

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Abstract

The thesis aims to investigate how the Sleep Robot system (a Sleep Robot, its application, and servers) can adopt a data-enabled loop to make optimal use. The research has three main objectives: (1)understanding the needs and concerns of using the Sleep Robot system in different user profiles, (2)building a data loop of the Sleep Robot system with subjective and objective data, and (3) identifying the design principles of long-term engagement in a data loop.

To answer the research question and fulfil the objectives, the thesis adopted a four-diamond design process. In the discovery phase, the research reviewed the literature on personal informatics and sleep solutions, then plotted the Somnox data ecosystem. In the refining phase, the user research was performed to obtain profound insights, create a journey map, and user profiles by using a sensitizing diary, fetching data from servers, creating data visualization, and conducting interviews. The user research found that users stick to standardized breathing settings without engaging themselves in self-experimenting with breathing settings due to the lack of guidance and support. Thus, the project's design goal is to let users feel guided and at ease during self-experimenting different breathing settings.

By going through creative sessions and user testing in the developing phase, the research found out four essential design elements to achieve design goal: (1) step by step learning experience, (2) dynamics of breathing rate, (3) growing together through empowering the breathing recommendation system, and (4) breathing with a specific goal which reflects causes of poor sleep. Eventually, the proposed design integrated these four elements into three levels of personalized breathing rhythms, including customized breathing, optimized breathing, and contextualized breathing.

In the evaluation phase, the proposed design was evaluated through user scenarios and high-fidelity prototypes. The results showed that users highly appreciated the guidance and ease through measuring personal conditions to tailor three-level breathing rhythms. This study emphasizes the transition role of the proposed concept from three-level of personalized breathing with a data loop and, ultimately, toward the adaptively synthesized breathing.

Acknowledgement

To supervisors
First of all, I would like to express my gratitude to the Chair of my project, Natalia. You are passionate and dedicated to guiding me to reframe the research structure, refine user testing, and reflect who I am as a designer. I was super impressive about the reflection that we had: striking a balance between design intuition and rationales.

Secondly, I would like to thank my mentor, Jacky. When I was concerned about the limitation of technology, you taught me to look into the big picture of the Somnox data ecosystem, identify the gap, and bridge the gap. Besides, your honest and constructive feedback facilitated me to re-question the research process and to reconstruct my thoughts.

Moreover, I will always be grateful to my mentor from Somnox, Julia. Without you, I may not be able to start this journey. You are thoughtful, engaging, and proactive in mentoring me throughout the project. Thanks for always helping me connect with people, giving me critical feedback, and provoking me to reflect the design process.

To Somnox team
You are a pro sports team! I want to thank Job's supports for letting me dive into the Somnox data ecosystem and the software team's explanation to help me understand the breathing algorithms within the Sleep Robot system. Besides, I would like to appreciate Baginda and Lianne's engagement in the project and broaden my knowledge in the commercial aspect. Furthermore, I would especially like to thank Kelly and Muriel for bringing me the scientific knowledge of sleep and breathing. Your positivity and optimism brightened my days during the project.

To Somnox users
Although this period of research in pandemic was filled with many ups and downs, I was able to conduct research and get valuable insights from Somnox users. Thanks for your enthusiasm for participating in the study and giving me a chance to understand different perspectives of feedbacks.

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Last but not least, I externally thank my friends and family. It was quite difficult to work alone at home when my thought got tangled. Discussing with my graduating classmates helped me to learn from you and adapt my approaches. Besides, working from home was quite challenging for me to maintain the work-life balance. I want to thank my friends and family to encourage me to take rest, continue my hobbies, and explore new things during the graduation project.

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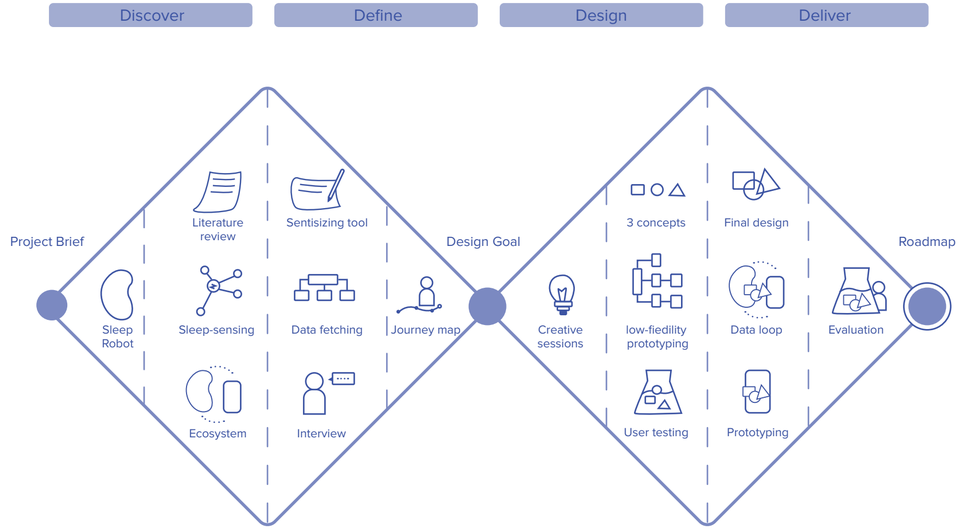


Ch1 introduces insomnia, the Sleep Robot system and problem statements. Ch2 reviews the research on personal informatics, sleep sensing technology and investigates Sleep Robot ecosystem.

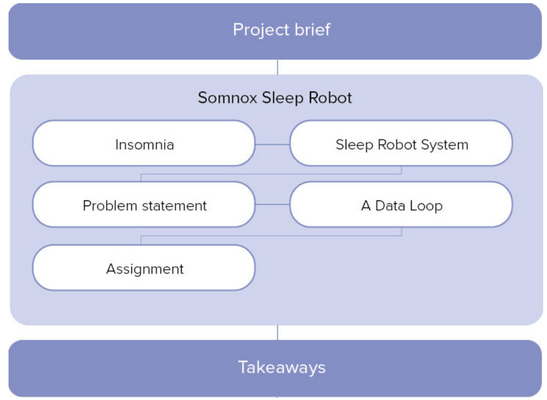
Ch3 conducts user research by creating a sensitizing diary, fetching data from servers, visualizing data, doing interviews, and analizing collected data. Finally, a journey map and user profiles scope down the design focus into a design goal.

Ch4 ideates wider spectrum of ideas, generates three concepts with low-fi prototype, and conducts user testing. Key design elements will be verified if they reach the design goal.

Ch5 intergrates the verified design elements into the final design. The data loop and user flow of the design are prototyped. Ch6 evaluates the user flow and validates the design hypothesis. Ch7 draws a conclusion and plots a roadmap for future work.

1. Introduction

This chapter aims to provide an overview of the project context. First, it presents background information on insomnia, including symptoms, causes, treatments, sleep solutions, and the Sleep Robot. Then the problem statement introduces the scope and the research questions. To conclude, it presents the assignment with three main objectives.



1.1 Insomnia

Insomnia

One-third of a person's life is spent on sleeping; however, approximately one out of five people globally suffer from insomnia (Buysse DJ, 2013), which significantly impacts their health and quality of life.

Insomnia is a common sleep disorder that can make people difficult to fall asleep or to stay asleep, cause people to wake up too early and to difficulty get back to sleep. (Mayo Clinic, 2016) Difficulties in initiating or maintaining sleep and non-restorative sleep with the accompaniment of decreased daytime functioning, mood disturbance, reduced energy, or impaired attention for at least four weeks is defined as insomnia. (Baglioni, 2010)

Sleep disorder

According to Mayo Clinic (2019), sleep disorders are conditions that lead to changes in the way that people sleep. Sleep disorders could be grouped into different categories that explain why sleep disorder happens or how it influences people. The common types of sleep disorders include insomnia, sleep apnea, restless legs syndrome, and narcolepsy.

Causes of insomnia

The causes of insomnia usually arise from stress, life events, or habits that interfere with sleep. Insomnia could also be caused by mental health disorders, medications, caffeine, or alcohol intake. Some risk factors may lead to insomnia, such as being a female or being older than 60. (Mayo Clinic, 2016)

Consequences of insomnia

Insomnia could lead to daytime tiredness, sleepiness, irritability, depression, anxiety, difficulty in focus, concentration, or memory, and thus reduce working performance and quality of life. (Mayo Clinic, 2016)

Treatments on insomnia

Changing sleep habits or lifestyles and tackling the factors associated with insomnia can help people with insomnia disorder to have a better sleep. The treatment includes sleep medications and cognitive behavioral therapy. Taking sleep pills is an accessible choice, which may help people with insomnia sleep better. Yet, it can have side-effects, for example, causing daytime drowsiness, dizziness, or irregular heartbeats. (Mayo Clinic, 2018) Cognitive-behavioral therapy was proved to have higher effectiveness in treating insomnia than prescribing medication in a range of six months. (Mitchell, 2012) CBT-I is a non-pharmacological approach to treat insomnia, such as stimulus control therapy, relaxation techniques, or sleep restriction. (Mayo Clinic, 2018)

1.2 Sleep solutions

Background

Sleep solutions could include both clinical and non-clinical approaches. In clinical settings, medical experts not only prescribe sleep medications but also apply sleep monitoring devices. It ranges from subjective tools - sleep diaries to sleep-monitoring accessories such as polysomnography (PSG), a gold standard for objectively measuring sleep characteristics. In non-clinical settings, there are booming meditation applications, sleep-tracking devices such as wearables or smartphones, and products with breathing features in the market.

Sleep Robot

Outstandingly, Somnox creates soft robots (Figure 1) - adopting breathing regulation and audio to help people with sleep problems fall asleep faster, get deeper sleep, and wake up with refreshments, which assists people in achieving relaxation and guides them to fall asleep naturally. Somnox application works as a remote control of breathing settings. There are three features of breathing settings (Figure 2), including breathing program selections (sleeping, napping, and relaxing), manually controlled breathing setting, and adaptive breathing (which senses users' breathing rate and reacts accordingly). With breathing therapy, sleep robots could be considered as one of cognitive behavioral therapy to improve sleep.

somnox®
realizing dreams

Breathing movement

The sleep robot creates a tangible movement of breathing. The breathing could be adjusted in Somnox application.

Soothing sound

Different sound could be selected in App. Besides, personal music could be added into the SD card.

Affection

The breathing movement provides affective needs for sleeping.

Comfort

The soft material like a pillow lets people feel comfortable to hold.

Figure 1. Somnox Sleep Robot

Figure 2. Somnox Sleep Robot Apllication

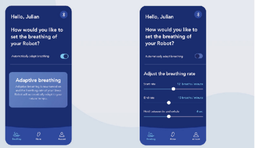
Breathing Programs

	Sleeping	Napping	Relaxing
Breathing Ratio (inhale : exhale)	1 : 2	1 : 1.5	1 : 2.5
Start Rate (RR)	12	13	9
End Rate (RR)	6	7	5

Breathing programs

Three standard breathing programs (as shown in the diagram) are provided for users to use, including sleeping, napping and relaxing. Each program is designed with different breathing ratio, start and end breathing rate (breaths per minute).

Breathing Settings



Breathing settings

Apart from that, users could adjust the breathing settins either in manual or automatical manner. Users can adjust start rate, end rate and duration of breathing manually. Users can also select adaptive breathing setting, namely, a Sleep Robot could senses user's breathing rate and reacts accordingly.

Data-driven Revolution in Sleep

Data-driven approaches have become more globally accessible in the industry, so as the sleep health. A sleep diary is traditionally used as the golden standard for subjective sleep assessment; however, the activity requires efforts and high cognitive loads to recall the memories during sleep. Since the sleep stage is unconscious, it is hard for people to capture those fragments to create a holistic understanding of sleep.

Thus, sleep-sensing technologies and data-tracking devices play essential roles in minimizing the efforts of tracking sleep data and capturing the unconscious parts of sleep activities. Moreover, it contributes to personal sleep health by identifying sleep patterns, giving personalized recommendations, or facilitating the adoption of healthy sleep habits. (Ravichandran, 2017)

To better understand the sleep-solution market, a broad spectrum of products were investigated and categorized into four quadrants. (Figure 3) The products in the first quadrant could track sleep data, but do not have treatment on sleep. It mainly shows data visualization. In the second quadrant, users not only could track sleep data but also obtain therapy from the products. In the third quadrant, the products could give treatment to users; however, users could not track their sleep data and gain insights from them.

Figure 3. Data-driven sleep solutions

1.3 Problem Satement

Somnox

Somnox is developing a new generation of a Sleeping Robot system, including a Sleep Robot, an application, and platforms to achieve their missions. Besides, Somnox formulates a data team and plans to bring the data into the design process for iterating products and identifying design opportunities.

Regarding data technology, Somnox can measure data by sensors (accelerometer) and collect data from servers (Intercom and Firebase). For instance, the data from servers is used to create business strategies; the accelerometer is used to measure users' breathing rate and react to it. However, the data are mainly for back-end operation instead of utilizing it as a personalization tool on individual sleep goals. It creates an opportunity for this graduation project to understand how users interact with Sleep Robots and applications through exploring data.

Target Users

The sleep problems that users suffer arise from various factors, including aging, emotional states, diseases, and stress. Somnox has identified two personas: the empty nester (senior adults) and the stress ablator (younger adults). The primary users of sleep robots are women aged from 50 to 70, which are accidental early adopters. Some of them often consider sleep robots as buddies. However, the younger adults (30-50) with higher technological literacy and stress-induced sleep issues have different and higher expectations, and they prefer cool functions that fit their images.

The strategies of using a sleep robot system will differ and depend on user groups such as causes of sleep problems, lifestyles, and context. The research will focus on senior adults because they have more severe and long-term sleep problems. The senior adults need more guidance and support - a feedback loop while using Sleep Robots to achieve their goals (relaxation, better sleep, etc.).

Empty nester

Stress ablator

Scope

Several profiles of use are observed based on different using contexts (lifestyles, sleep problems, emotion states) and users' goals (power napping, relaxing, sound sleeping, etc.). However, the user profiles have not been taken into account in the management of the Somnox Sleep Robot's different functionalities. For example, users do not know or feel confident managing the breathing setting correctly because they found it difficult to determine the start and end rate of breathing and needed more information to set the breathing rate for specific user goals correctly. Users do not have a clear understanding of which breathing programs go well and not well on their goals (sleep, relaxation, etc.), namely, the lack of feedback loop between breathing and users' goals.

Research Questions

Thus, the functionalities of Sleep Robots need more guidelines and supports for users and then provide users benefits as they intended. Since everyone has different goals, expectations, lifestyles, and breathing patterns, it is crucial to understand " How to help users to make better use of sleep robots according to their needs ? ", which can be broken down into "How do users interact with Sleep Robots and applications? ", " What are the needs different in different user profiles? ", and " How to provide actionable tips or insights to users and encourage them to act accordingly? ".

How to make optimal use of a Sleep Robot according to individual needs?

How do users interact with Sleep Robots and applications?

What are the needs different in different user profiles?

How to provide actionable insights to users and encourage them to act accordingly?

1.4 A Data Loop

Understanding individual differences and addressing individual needs is significant in healthcare, which is known as personalized healthcare. (Ravi, 2015) Sleep robots provide standardized breathing programs and give the flexibility for users to adjust breathing settings. The adjustable breathing setting adds value to personalized healthcare but lacks a data loop to collect individual needs and provides personalized breathing rhythm.

Objective monitoring will let users obtain personalized feedback for health and well-being purposes and disease prevention. (Perez-Pozuelo, 2020) The study introduces a five-step digital sleep framework (Perez-Pozuelo, 2020), which comprises data acquisition, data storage and curation, data processing, modeling, and applications. It covers the path from data collection to when insights are used for applications. The shown path (Figure 4) is what the Somnox system currently lacks. Thus, there are no personal recommendations on breathing for individual sleep goals.

To create personalized applications and recommendations, a data loop within the Somnox system must be built. For example, utilizing a tool that helps people collect personally relevant information for self-reflection and obtaining self-knowledge is called personal informatics. It opens the opportunity for this project to dive into a five-stage of personal informatics, consisting of preparation, collection, integration, reflection, and action. (Li et al., 2015)

Regarding the adaptability of intelligent solutions, namely tailoring personal breathing programs for users according to individual variations, it is essential to create a data feedback loop. By establishing a feedback loop, the solution can begin to realize the effects of its adaptations. Therefore, it can use trial and error approaches to optimize its adaptations. (van Kollenburg et al., 2019)

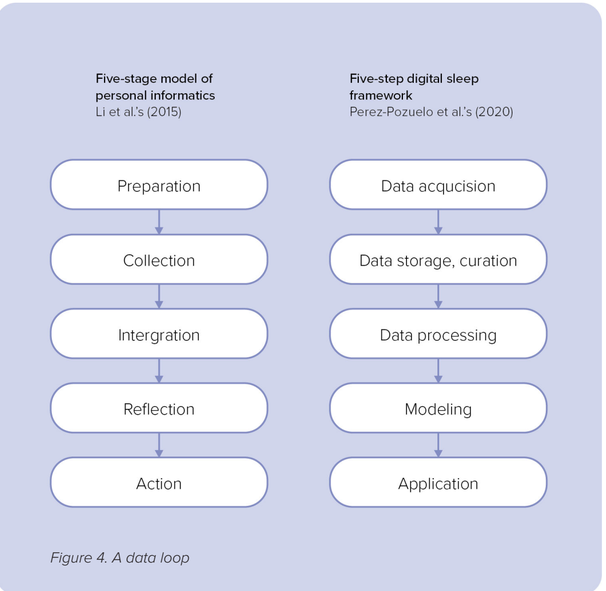


Figure 4. A data loop

1.5 Assignment

The goal of the graduation project is to provide guidance and support for users to make better usage of sleep robots and thus have a better sleep by designing a data-enabled loop. The goal can be achieved by the following objectives:

1. Understand the needs and concerns of using a Sleep Robot from user profiles

User profiles (factors of sleep problems, expectations, goals, literacy of technology) will be created to understand what kinds of guidance and support should be given to users. Besides, a journey map can be plotted out to understand user behaviors, the friction of interactions, and ideate possible user scenarios through exploring the data from servers and cultural probing.

2. Build and explore the loop of using a Sleep Robot with subjective data and objective data

An experimental prototype can be developed to explore how users interact and experience with their robots. By combining contextual data and sensor data, a data loop can be built to explore what kind of data can be collected and presented to users. Thus Somnox can provide useful tips and insights for users to make better use of their sleep robots and improve sleep for healthy living.

3. Identify interaction design principles to ensure long term engagement in sleep data loop

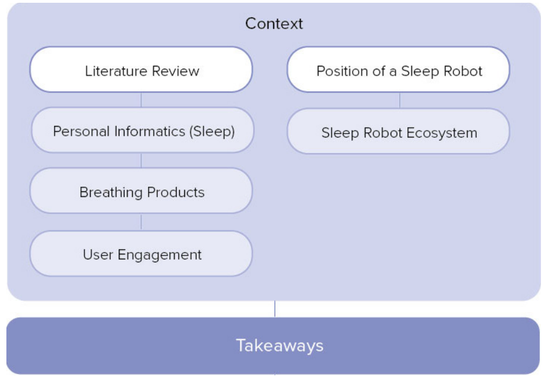
To maintain the data loop of using a sleep robot in the long term, users' engagements in the data loop will bring rich and diverse data because they will do things repeatedly with proper engagement. Thus, the user engagement loop is essential to be looked into by identifying interaction design principles.

Takeaways

- Prevalence of insomnia has increased globally, the paradigm of the sleep solutions has expanded from the clinical setting (e.g., medication) to non-clinical settings (wearables or breathing products)
- Sleep is an unconscious activity; gathering sleep data and constructing a data loop has significantly become an approach to uncover sleep problems.
- The Sleep Robot system did not have a data loop of sleep and breathing, thus, which can not benefit users to make optimal usage of the Sleep Robot.
- Exploring data interaction and identifying design principles to promote users' engagement in the data loop are the design spaces for better use of a Sleep Robot.

2. Context

Chapter 2 aims to firstly understand the personal informatics of sleep, including self-experimentation, sleep-tracking technology, and its benefits, challenges, and opportunities. Second, it exhibits the effects of breathing practices on insomnia and the position of a Sleep Robot among breathing products. Afterward, it narrates a data architecture system in the healthcare domain and plots a diagram that presents the data ecosystem of the Sleep Robot.



2.1 Personal Informatics of Sleep

Personal informatics

Personal Informatics (PI) systems, " that assist people in gathering personally relevant information for the purpose of self-reflection and gaining self-knowledge" (Li et al., 2010).

Personal informatics is a tool that helps people to collect data for self-monitoring. The increased popularity of personal informatics has led to the development of sleep tracking in smartphones. (Nediyana et al., 2016)

Self-experimentation

According to Ravi's study (2015), the study considered self-experimentation as a subset of self-tracking. To better understand how the self-experimentation works, five studies were gathered and summarized into an overview of the self-experimentation framework (Figure 5).

Type of data

Nediyana (2016) summarized an overview of five types of data that are available on the market, including psychological parameters, physiological parameters, symptoms behaviors, daily tasks/management, and movements/locations.

Within each type of data, the data could also be categorized into subjective data and objective data. Subjective data could refer to the self-report data such as mood or contextual experience. Objective data refers to the number which could be collected by sensors or servers.

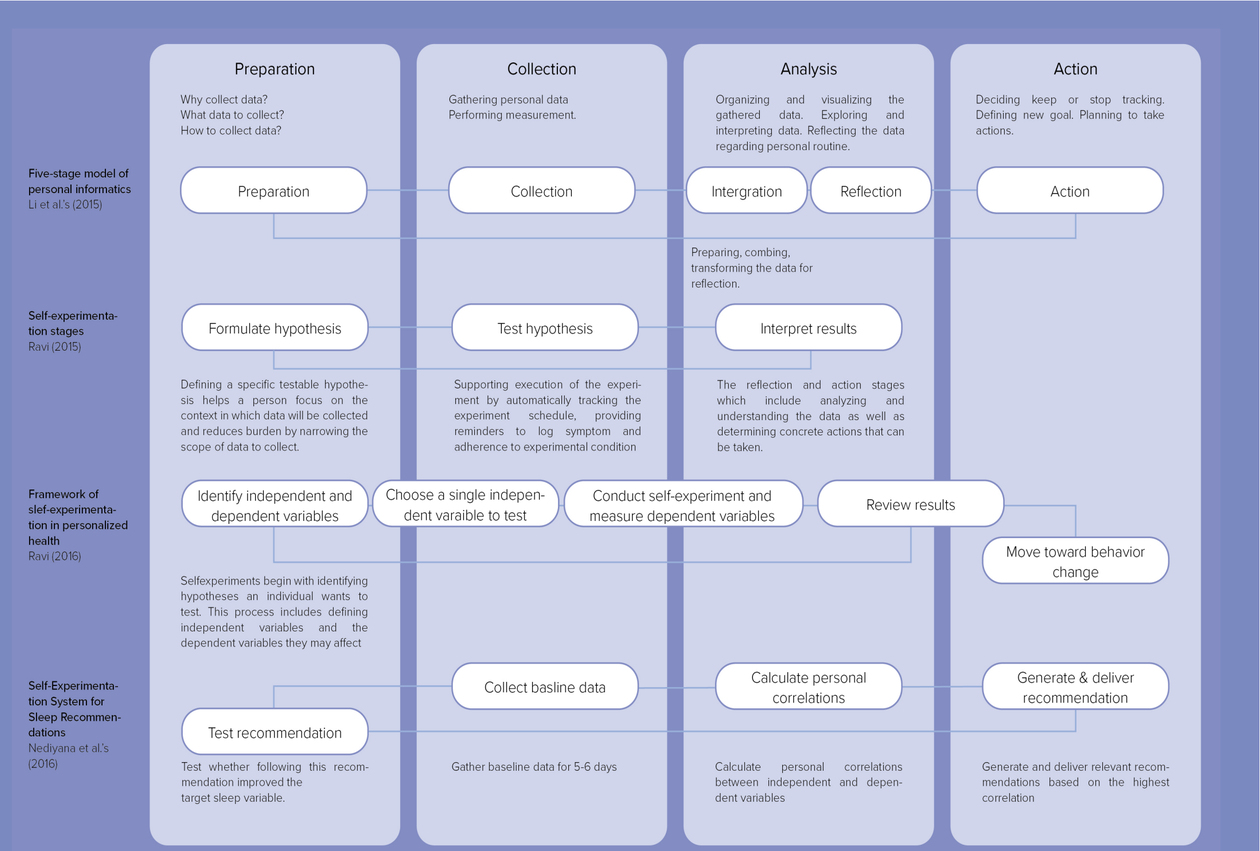


Figure 5. An overview of the self-experimentation framework

Sleep sensing technology

Sleep diary requires people to record what Sleep diary has been considered as the golden standard for subjective sleep assessment. As the sleep diary requires people's efforts and time, the consumer sleep-tracker becomes popular and compensates for the effort and time spent writing sleep diaries.

In clinical fields, polysomnography (PSG) is a diagnostic tool for measuring sleep structure and diagnosing sleep disorders. (Lauren, 2018) Recently, consumer sleep-tracking technologies such as wearables have been increasingly popular such as smartwatches, smartphones, or rings. The wearables contain sensors that can detect body movements and biosignals. (Liang, 2020)

A study concludes a framework of emerging sleep-sensing technology. (Perez-Pozuelo, 2020) The framework comprises six emerging sensing technologies. (Figure 6) First, embedding bed sensors can be applied to monitor physiological processes such as body movements, breathing, and cardiac activities. Second, EEG can be used to measure brain activity to classify sleep stages. Third, smartwatches and fitness trackers can measure movement signal and heart rate. Fourth, mobile phone sensing with gyroscope, microphones, and accelerometer can track sleep patterns. Fifth, the ultrasound sensors can detect body movements and breathing patterns during sleep. Last, radio-signal approaches can capture physiological signals without physical contact by sending a radio wave toward people and detect the bounce-back signals.

In the current development of sleep robots, Somnox has accelerometers that can detect users' breathing movements to know users' breathing rates only when users hold sleep robots close to their chest while sleeping.

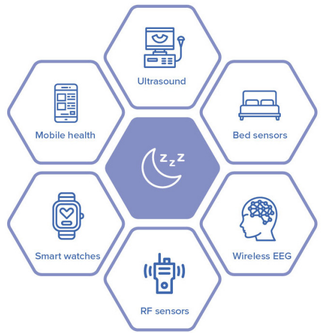


Figure 6. Framework of sleep-sensing technology

Trade-off of Sleep Monitoring

Perez-Pozuelo 's study plots a trade-off chart of sleep-sensing technologies regarding the accuracy and user burden. (Figure 7) The top left quadrant is the optimized approach to collect accurate data and minimize users' burden.

Sleep robots will locate in the bottom left for two reasons. First, users can only measure breathing rate while using sleep robots, and the measurement only takes place in a certain period instead of the whole sleep period. It leads to lower accuracy and a non-holistic view of users' sleep patterns. Second, the mechanism of breathing movement measurement reduces the accuracy of data because users may put sleep robots away when using it.

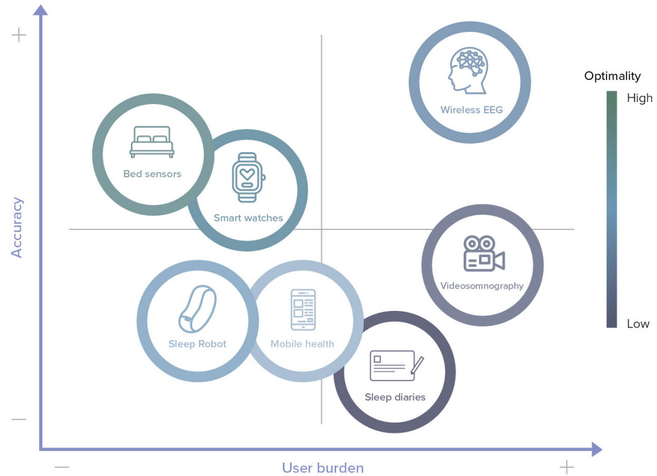


Figure 7. Trade-off of sleep-sensing technology

Benefits of sleep-tracking technology

Sleep sensors work as facilitators to promote awareness and motivate people to improve sleep, behaviors, and adopt healthy habits. Besides, the data from sleep-tracking has the potential to help medical experts work with patients who have sleep disorders to manage or identify sleep conditions. (Ravichandran at el, 2017)

The sleep tracking technology has the opportunities to help people to reflect on what factors influence their sleep, and thus target the factor to improve sleep hygiene. (Liang at el, 2020)

Challenges of sleep-tracking technology

Such consumer sleep-tracking technology may both benefit and undermine collective or personal sleep health. (Ko et al., 2015). The challenges include technology transparency, not giving actionable insights, not providing personalized suggestions.

First, regarding technology transparency, the sleep trackers remain a blackbox that prevents users from constructing a correct conceptual model of how the technologies work. (Liang at el, 2020)

Second, it is unknown how users perceive the data and how it relates to the experienced sleep. If the displayed data do not align with the subjective experience, it will lead to low perception on accuracy and value of the device, thus the targeted behavior change could not be achieved.

Opportunities of sleep-tracking technology

According to Ravichandran's suggestions (2017), the study suggests to include subjective sleep quality assessment, contextual sleep quality with journaling, focus on actionable feedback, give feedback in ranges instead of a single value point, and increase the transparency of algorithms.

In Nediyana's study (2016), it recommends increasing adherence, helping users help themselves, personalizing micro-experiments, and empowering users through computation.

From Liang's study (2020), the study identifies three opportunities to enhance sleep-tracking technology's credibility. It includes supporting people to construct sleep knowledge, increasing the transparency of device mechanisms and validity, and Identifying objective measures that are relevant and knowable to each user.

2.2 Breathing

Breathing

According to Cleveland Clinic, the reasonable respiration rate for adults at rest is between 12 and 20 breaths per minute. The abnormal respiration rate is under 12 or over 25 breaths per minute while resting. However, breathing patterns differ among people and may be influenced by pain, emotion, body temperature, sleep, body position, activity level, and diseases.

Breathing techniques

Growing studies present that slow and deep breathing techniques have been used in addressing stress, affective mood, pain, asthma, and training concentration. The slow and deep breathing techniques have been widely applied in physical and mental disciplines such as yoga, meditation, Qi-Gong, or Tai Chi.

The slow, deep, regular breathing helps promote a parasympathetic system that stimulates rest and relaxation (Schacter, 2011). Additionally, slow and deep breathing could help to produce melatonin (Harinath K, 2014), an essential hormone that helps to initiate sleep (Hardeland, 2006). A fast, shallow, and irregular breathing fast lead to sympathetic activation (Kox, 2014), the excitation of the sympathetic nervous system would let people be overactive (De Zambotti M, 2013).

A study (Ravinder, 2018) shows that slow and deep breathing (0.1 Hz) could work as the treatment of insomnia, which is highly effective in initiating sleep and facilitating falling back to sleep.

Breathing Products for Sleep

The booming trends of willingness and mindfulness lead to increasing self-care products, especially medication applications that apply breathing exercises. Apple Watch launched a breathe application that reminds users to stop and take a breath via haptic vibrations. Fitbit also released a Relax App to give its users opportunities to engage in breathing exercises. (Kressbach, 2018) Headspace application also teaches people meditation and mindfulness through guided audio and visual instructions. Differently, headspace develops sleep-based guided meditations, which provide users' chances to relax body and mind, and have a restful sleep.

Apart from application-based solutions, breathing exercises are also embedded in some products such as Somnox sleep robots, Muse, Philips sleep and wake-up light, Dodow, and Moonbird. Muse, with multiple sensors, detects brain activity and heart rate and interprets users' mind activity to provide personal guidance. Muse originally focused on meditation; it also extends its focus to cover sleep. Philips sleep and wake-up light utilize light-guided breathing to help people relax and wake up refreshed. The product also offers an application for users to customize their sun-setting environment. Dodow combines soft blue light and breathing features to guide the body to calm and relax. Its portability and non-physical contact make itself different from other products. Moonbird, a new product that has the most similar product feature with a sleep robot. Moonbird allows people to do breathing exercises in a palm with a hand. The embedded PPG sensor (photoplethysmogram) can measure heart rate to create personalized breathing rhythm through calculation from algorithms.

A diagram (Figure 8) was made to position breathing products based on personalization and sleep focus. Personalization is defined as the provided breathing exercises that can adapt to individual differences. For example, Moonbird can create personalized breathing by measurement of heart rate and calculation of breathing algorithms. Sleep robot is placed in the transition between customization and personalization because its application allows users to set breathing rhythms manually. The sleep robot could adapt to users' breathing rate but not yet achieve full personalization.

Figure 8. Position of breathing products regarding sleep focus and personalization

2.3 Data System Architecture

Data Architecture for Healthcare

A study proposes a data architecture for healthcare domains as presented in Figure 9. (El aboudi, 2018) It consists of four layers, from data, storage, processing, and analytics to visualization layer.

According to the data architecture, Somnox gathers data from sensors within seep robots, its application (via intercom), and websites in the data layer. Somnox has sought a data warehouse to store heterogeneous data sources. Through google analytics and firebase, the collected data is processed and visualized in Somnox's dashboard.

Data Analytics

Generally, there are four types of analytics (figure X) in the healthcare domain: descriptive, diagnostic, predictive, and prescriptive analytics. (El Aboudi, 2018)

Descriptive analytic is defined as describing and reporting current situations. For example, Somnox uses histograms and charts to describe active users' events and used breathing settings.

Diagnostic Analytic aims to articulate the reasons for occurred events and the factors that trigger the event, for example, applying clustering methods and decision trees. However, this analytic does not exist in the Somnox system yet. This process is mainly done by qualitative research, utilizing focus groups, for instance.

Predictive Analytic assists in predicting future events, identify trends. This is typically built by utilizing machine learning techniques. Somnox does not have this analytic, but has great enthusiasm for it, especially in the business aspect.

Prescriptive analytic aims to make optimized decisions by proposing appropriate actions. Somnox is particularly interested in providing personalized breathing rhythms and tips for users to improve sleep.

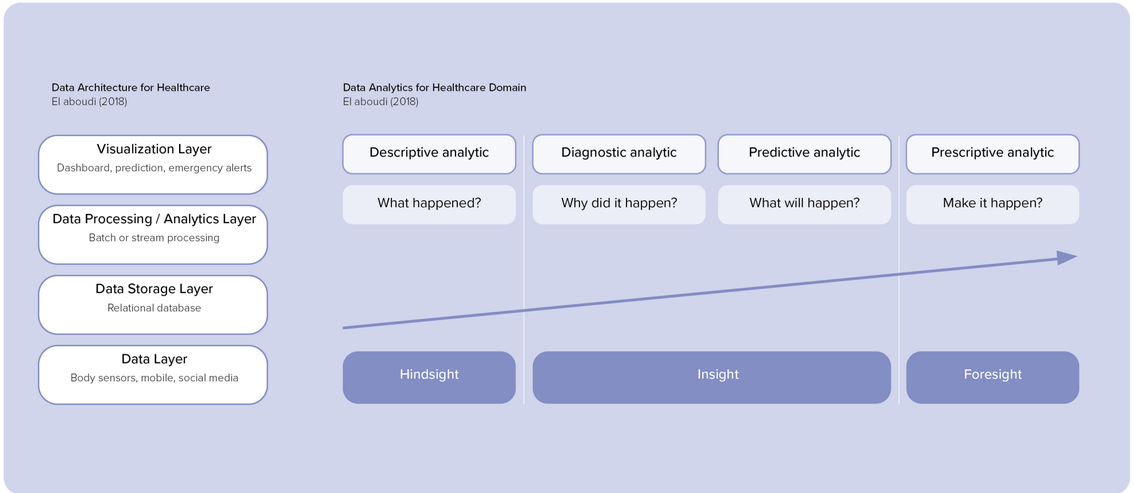


Figure 9. Data architecture and data analysis in healthcare domain

Somnox Data Ecosystem

Somnox data ecosystem (Figure 10) includes data sources, the way of collecting, storing, and delivering data as well as its visualization.

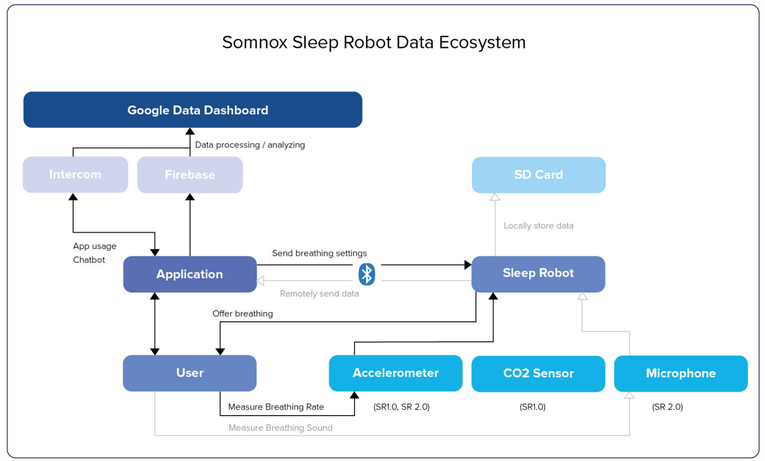


Figure 10. Somnox Data Ecosystem

Insights from Somnox Dashboard

The breathing programs, including sleeping, napping, and relaxing, were used in the APP, about 83%, 5%, and 12%. (Figure 11) It reveals that users do not make full usage of breathing programs.

Users prefer to set the setting once. The breathing rate setting from 12 to 6 is the most frequently used setting, (Figure 12) which is the default setting, as well as the setting for the sleeping breathing program. As defined by Somnox, the average BPM of people is 12, and the ideal relaxed breathing rate for sleep is 6. It shows that users barely try to customize their breathing settings, and they are less motivated to try out different breathing settings.

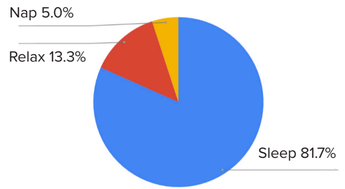


Figure 11. The percentage of used breathing program

	BPM (start → end)	# Current users
1.	12 → 6	82
2.	8 → 6	23
3.	9 → 5	19
4.	10 → 6	15
5.	9 → 6	12
6.	7 → 6	10
7.	9 → 7	9
8.	10 → 7	8
9.	10 → 8	8

Figure 12. The overview of used breathing settings

Limitations

There are some limitations, including the reliability and validity of sensor data. It is not only because the Sleep Robot only uses one accelerometer to measure the breathing rate in a particular duration, but also because users do not hold Sleep Robots tightly for sensors to measure data. Moreover, the sensor data from the accelerometer in the current Sleep Robot has not been collected and stored yet, but it will be able to store data in the SD card. Last, the collected sensor data from users cannot be sent remotely to the servers, but a customized prototype can achieve this feature. Otherwise, users will be requested to send the data from the SD card to Somnox before getting their consent.

2.4 User Engagement

Engagement

Personal health tracking devices have increasingly become popular. However, the abandonment rate of wearables is high. The study found the reasons for abandoning self-monitoring, including technological condition, motivation, health domain, and adoption method. Moreover, the abandonment significantly relates to user behaviors and lifestyles. Thus, the study suggests considering the user's circumstances, the intention of using a wearable, and what feature can provide adoption in the long term. (Fadhil, 2019)

Live informatics acts as a new model of personal informatics (Figure 13). (Epstein, 2015) It integrates lapse and resumption with the personal informatics model with the consideration of behavior change goals.

- **Deciding**: Users decides to track personal data
- **Selecting**: Users selects a tracking tool
- **Tracking and Acting**: The phase consists of three simultaneous steps: collection, integration, and reflection
- **Lapsing**: Users stop actively using the tracking tool because of four categorized factors: forgetting, upkeep, skipping, and suspending
- **Resuming**: a short term lapse

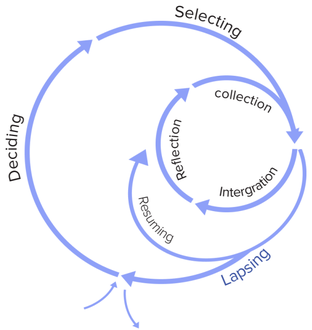


Figure 13. Lived informatics (Epstein, 2015)

Engagement in a data loop

The prior studies indicate that ensuring long-term engagement is a big challenge of self-monitoring. Without user engagement, the data loop will not sustain. To establish a sustained data feedback loop, keeping users engaging in the process is essential to deal with. According to a study, it recommends three implications of designing for engagement. (Ruben, 2015)

The first approach is designing for different levels of readiness. It suggests considering human's current motivation stage and referring to Prochaska's and Velicer's stages of behavior change, as shown in Figure 14. The study found that readiness is a significant predictor of adopting personal informatics because the adoption rate is higher in the preparation and contemplation stage than in the precontemplation and maintenance stage.

The second approach is designing for a multilayered and playful goal setting. An attainable daily goal could lead to low adherence. The study suggests that a multiple and simultaneous goal setting could fit with the complexity of daily lives. Moreover, persuasive methods could be applied to increase the perceived importance of maintaining challenging goals with consideration of attainability.

The third strategy is designing for sustained engagement to prevent lapse. It suggests creating checking habits since frequent and straightforward interactions on a dynamic content can lead to sustained engagement. Also, It recommends to transit glances into reflective engagement by providing well-crafted and tailored content, such as personalized insights.

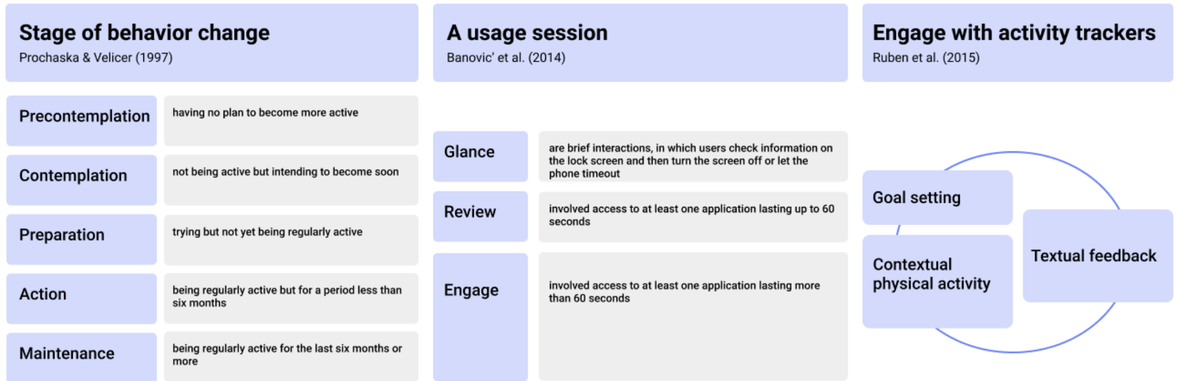


Figure 14. Designing for sustained engagement (Ruben, 2015)

Takeaways

With the research review on sleep monitoring and understanding of the Somnox data ecosystem, a summary is drawn to answer parts of the research questions.

- How do users interact with Sleep Robots and applications?

From the Somnox data dashboard, users mainly use the sleep robot for sleep instead of relaxation and napping. Besides, users mainly stick to the factory breathing settings without adjusting it on the mobile application. Nevertheless, the contextualized interactions of using a sleep robot and adjusting breathing settings on the application were missing. The contextualized interaction with a Sleep Robot system will be uncovered in the user research phase.

- How to provide actionable tips or insights to users and encourage them to act accordingly?

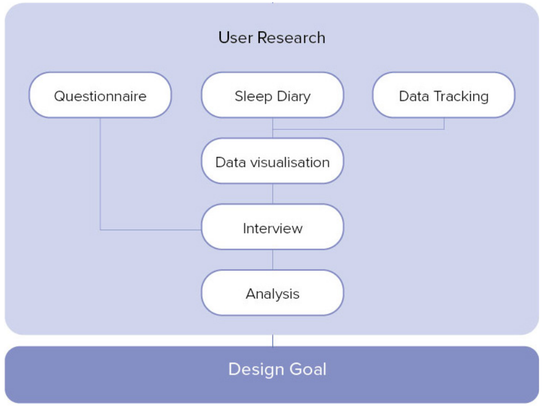
By comparing the Sleep Robot with other sleep solutions, the sleep robot system lacks a data feedback loop to personalize individual needs on improving sleep. The obtained knowledge of personal informatics of sleep and data architecture provides a framework for the Sleep Robot system to build a new design. However, the interactions of subjective and objective data within the Sleep Robot system needs further research.

- What are the needs different in different user profiles?

Though the activities in chapter 2 do not answer the question yet. This chapter gives a cue that self-experimentation may help to make better use of a sleep robot. Moreover, it indicates two existing user groups: one sticks to the factory setting, and another tries out different breathing settings.

3. User Research

Chapter 3 aims to obtain profound information on how users interact with a Sleep Robot and its mobile App. First, a sensitizing sleep diary acts as a tool to capture subjective data; meanwhile, Intercom works as the platform to fetch objective data (e.g., breathing settings) from the mobile App. Next, interviewing to fill the gap between subjective and objective data by listing questions and providing personal data visualization. Finally, analyzing the collected data to create insights and a journey map, then defining the design opportunities with a design goal.



3.1 Procedure

General information

The previous chapter on exploring the sleep context and sleep activity remained and raised some questions to be discovered and explored further.

List of questions:

- **What are the intentions of using a Sleep Robot?**
- **How do users interact with a Sleep Robot and its mobile application?**
- How do users approach breathing settings in the mobile App?
- What are the users' experiences with the breathing feature?
- **What do users perceive data tracking (objective, subjective) within the Sleep Robot system?**
- What is the data loop to improve sleep?
- What are the possible data interactions?
- **What are the needs different in various user profiles?**

To discover the needs in different user profiles, here are three indicators to investigate by observing Somnox users.
(1) Self-experimenting: Users try out different breathing settings or programs
(2)Affective needs: Users have strong affection with the Sleep Robot, for example, associating it with a family member or a pet.
(3) Data-tracking: Users have tracking tools to monitor personal data.

The user research study was performed by involving users and stakeholders from Somnox. There were eight users involved in user research. Four users participated in the whole research process, one female user involved in the questionnaire and an interview. The rest of the users were only involved in the questionnaire. All of the participants were dutch females.

3.1.1 Sleep diary

A one-week sleep diary (Figure 15) works as a sensitizing tool to understand users' sleep context, sleep goals, daily activities, bedtime routines, and scenarios of sleep robots. It acts as a tool for participants to monitor their sleep and daily activities manually. Apart from that, some pictures were provided to let users collage about what they think about sleep, breathing, and what they imagine about the future experience with sleep robots.

Like the following, each day, participants had different assignments and daily activities. The time started from the past, present, and ended with the future.

Day 1: Sleep problems, factors of sleep problems
Day 2: A bad sleep and a good sleep
Day 3: The experience with sleep robots
Day 4: Breathing and its metaphor
Day 5: Relaxation and its metaphor
Day 6: Envision the future experience with sleep robots

Figure 15. Sleep diary (Appendix B)

3.1.2 Data tracking

Data tracking was performed to collect breathing settings that users used during the sensitizing week. The collected data includes used breathing programs, start rate of breathing, end rate of breathing, duration of breathing, duration of audio, and their timestamps. The data was retrieved from the servers (e.g., Intercom) based on the users' emails used to sign up for the Somnox App. Table 1 is an example of the data fetching.

Wenying usage data

event_name	fields	to_timestamp
"selected_breathing_program"	{"date": 1584998820, "program": "Sleeping", "audio_on": true, "audio_duration": 5, "breathing_duration": 20}	2020-03-23 21:27:00+00
"connected_sleep_robot"	{"date": 1584998776}	2020-03-23 21:26:16+00
"selected_breathing_program"	{"date": 1584914874, "program": "Relaxing", "audio_on": true, "audio_duration": 5, "breathing_duration": 10}	2020-03-22 22:07:54+00
"connected_sleep_robot"	{"date": 1584914859}	2020-03-22 22:07:39+00
"selected_breathing_program"	{"date": 1584913668, "program": "Relaxing", "audio_on": true, "audio_duration": 5, "breathing_duration": 20}	2020-03-22 21:47:48+00
"connected_sleep_robot"	{"date": 1584913636}	2020-03-22 21:47:16+00
"selected_breathing_program"	{"date": 1584653613, "program": "Relaxing", "audio_on": true, "audio_duration": 15, "breathing_duration": 30}	2020-03-19 21:33:33+00
"connected_sleep_robot"	{"date": 1584653557}	2020-03-19 21:32:37+00
"selected_breathing_program"	{"date": 1584567987, "program": "Relaxing", "audio_on": true, "audio_duration": 10, "breathing_duration": 15}	2020-03-18 21:46:27+00
"connected_sleep_robot"	{"date": 1584567961}	2020-03-18 21:46:01+00
"selected_breathing_program"	{"date": 1584481442, "program": "Sleeping", "audio_on": true, "audio_duration": 10, "breathing_duration": 20}	2020-03-17 21:44:02+00
"selected_breathing_program"	{"date": 1584481392, "program": "Sleeping", "audio_on": true, "audio_duration": 10, "breathing_duration": 20}	2020-03-17 21:43:12+00
"selected_breathing_program"	{"date": 1584481385, "program": "Sleeping", "audio_on": true, "audio_duration": 10, "breathing_duration": 20}	2020-03-17 21:43:05+00
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"selected_breathing_program"	{"date": 1584443637, "program": "Relaxing", "audio_on": true, "audio_duration": 10, "breathing_duration": 10}	2020-03-17 11:13:57+00
"connected_sleep_robot"	{"date": 1584443614}	2020-03-17 11:13:34+00
"selected_breathing_program"	{"date": 1584443601, "program": "Relaxing", "audio_on": true, "audio_duration": 10, "breathing_duration": 10}	2020-03-17 11:13:21+00
"selected_breathing_program"	{"date": 1584394315, "program": "Sleeping", "audio_on": true, "audio_duration": 10, "breathing_duration": 10}	2020-03-16 21:31:55+00
"selected_breathing_program"	{"date": 1584394298, "program": "Sleeping", "audio_on": true, "audio_duration": 10, "breathing_duration": 10}	2020-03-16 21:31:38+00
"connected_sleep_robot"	{"date": 1584394261}	2020-03-16 21:31:01+00
"selected_breathing_program"	{"date": 1584394252, "program": "Sleeping", "audio_on": true, "audio_duration": 10, "breathing_duration": 10}	2020-03-16 21:30:52+00
"connected_sleep_robot"	{"date": 1584304699}	2020-03-15 20:38:19+00
"selected_breathing_program"	{"date": 1584304032, "program": "Relaxing", "audio_on": true, "audio_duration": 10, "breathing_duration": 10}	2020-03-15 20:27:12+00

Table 1. An example of data tracking from the mobile application

3.1.3 Data visualization

After receiving sleep diaries and the data from Intercom, data visualization (Figure 16) was performed manually on Figma to present users' subjective experience and objective data. The subjective data includes mood before and after sleep, and sleep score. The objective data includes sleep hours, sleep efficiency, times of waking up through the sleep, whether using sleep robots or not, and breathing settings. The data visualization intended to understand how users interpret the relationships between subjective data and objective data, and to steer conversations in order to discover more contextualized information in the interview.

Figure 16. Data visualization during the sensitizing week

3.1.4 Interview

The aims of the interview were to understand users' experience on sleep monitoring, how users interact with sleep robots, how users approach breathing settings, and to know what data interactions they are looking forward to. Additionally, the data visualization was used as a material to evoke conversations on data and the behaviors behind the data during the interview.

Interview questions

Motivations of improve sleep
- What are your sleep problems?
- What is a good sleep for you?
- What do you want to achieve by improving sleep?

Sleep diary
- What is your experience with writing a sleep diary?
- What do you like? What do you dislike? Why?
- Generated questions from each filled sleep diary

Sleep robots
- How do you experience a sleep robot?
- How do you interact with a sleep robot?
- When do you use the sleep robot?
- What do you perceive the role of your sleep robot?

Breathing
- What is the experience of breathing with a sleep robot?

Breathing settings
- What breathing setting do you use?
- How do you adjust breathing settings?
- How often do you adjust breathing settings? Why?

Data visualization
- What do you get from the data visualization?
- What do you think about data visualisation?

Data-tracking
- Why do you use wearables? What do you track?
- What are your experiences with your wearables?
- How do you interact with the displayed data?

3.2 Analysis

Procedure

A list of research questions as follows was written down at the beginning of the analysis. The raw data from the questionnaire, sleep diary, interviews, and server data were first interpreted in a designed template. The template was color-coded by different users and was labeled by different topics. Second, the interpreted data was clustered to answer the research questions. (Figure 17)

1. What are users' sleep problems? What do users want to achieve by improving sleep?
2. How do users perceive their sleep quality as important?
3. How do users experience the breathing with sleep robots?
4. How do users experience when adjusting breathing settings in the App?
5. How is the self-monitoring process?
6. What is a feedback loop to improve sleep (achieve user goal)?
7. What are the possible data interactions?

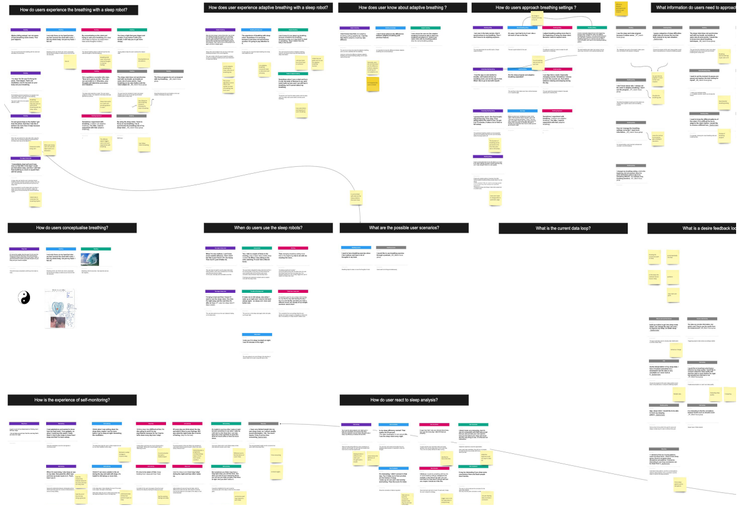


Figure 17. Analysis process (Appendix C)

3.2.1 Findings | Sleep

Sleep problems as pandora boxes

When it comes to sleep problems, the symptoms that people suffer are various and different. (Table 2) According to the survey that Somnox has, around 58% of participants who have sleep problems reported they frequently wake up during the night, about 47% of participants reported that they have restless sleep, 42% of participants had trouble falling asleep. In the user research, every participant has their own sleep problems which have arisen from different causes. As shown in the following table, people have different sleep problems and causes. There are a lot of factors in people's lives that could lead to poor sleep, however, it is hard to reveal what the root causes are because the causes of sleep problems are like pandora boxes. Thus, it is difficult to tackle sleep problems.

The factors of sleep problems could be categorized into five categories, including physical disturbance, mental disturbance, medical issues, lifestyles, and environmental issues. The physical disturbance could include chronic pain, headache, and back pain. Mental disturbances include anxiety, depression, or traumatics. The medical issues could be the side-effects of taking medication for certain illnesses. The lifestyle such as stress from work, eating habits, or sedentary lifestyle could also influence sleep. Last, environmental issues like light, noise, or temperature also influence sleep.

Table 2. Overview of participants' symptoms

	Sleep problems	Possible causes
P1	P1 frequently wakes up through the night and falls asleep difficulty.	It arises from taking wrong medication for back pain.
P2	P2 frequently wakes up through the night and has restless sleep.	It is induced by burnout , headache and brain rumination.
P3	P3 frequently wakes up during the night, her sleep is not restful and also hard to fall asleep.	It is caused by mental disorders and past scary experiences.
P4	P4 frequently wakes up during the night, her sleep is not restful.	She has a busy job and rheumatism disease.
P5	P5 has difficulty in falling asleep and frequently wakes up through sleep.	It is due to the past job that needs to take night shifts.

Why to unbox the sleep pandora box

The motivations for improving sleep differ from person to person (Table 3), it depends on people's life goals. By understanding users' motivations to improve sleep, it helps to leverage users' needs and thus create blueprints for users.

Table 3. Overview of motivations

P1	I don't need to do that (use SR) twice a night anymore. I still take medication and I want to get rid of it. P1 wants to be independent and autonomous.
P2	If I sleep better, I am a better person. I can be more inspired to make things. I like to make a lot of things. Sometimes, I want to be fast with my son. I want to be more patient. If I am more relaxed, I think it should be fine. P2 wants to be creative and productive to produce stuff and be more patient to build a good relationship with family. She also desires to be relaxed, so she could have more relief.
P3	Waking up rested with energy to start the day freshly. She desires to be stable and secured by removing the fear. The refreshment and energy also helps her to overcome the fear.
P4	To feel healthier. Or in the morning that you have a rest or not tired. Or feel less tired at the end of the day. If you have a good sleep, then it's easier to continue work without feeling tired. A good sleep helps her to be productive and prepared for the whole day, which makes her feel a sense of achievement and helps her to become successful.
P5	Making a specific amount of sleep hours, it's very personal how many hours of sleep you need. She desires to have regular bedtime and thus helps her to be prepared for her work.

Develop personal scale to measure sleep

The definitions of a good night's sleep are personal due to the various sleep problems and diverse life goals. (Table 4) While evaluating sleep quality, people use different criteria to measure, including sleep hours, times of waking up through sleep, or the feeling after waking up. P1 and P5 focus more on sleep itself, and the rest (P2, P3, P4) consider how they feel after waking up. Interestingly, P2 and P3 require better emotional states to support their mental needs.

With the understanding of users' criteria to evaluate their sleep, it helps to generate personal scales to measure whether their sleep is improved by using sleep robots. Having a personalized ruler, it makes individual sleep goals clear and also makes the progress of sleep improvement measurable.

Table 4. Overview of participants' symptoms

P1	Less awakening times and short awakening period
P2	Ease of falling asleep, less awakening tims, peaceful and calm mood, quick wake-up without snoring, being fresh and harmony in the morning
P3	Without bringing thoughts to bed, internally stable and restful, refreshment after waking up
P4	Sleep hours, sleep quality, good feeling in the morning, reflection on the work performance
P5	Regular bedtime schedule, specific sleep hours

3.2.2 Findings | Breathing Experience

The breathing exercise helps to shift focus

" I not only focus on my head but also my feet connect the earth with roots. I feel my whole body, not just my head. I feel all." _P2

Breathing lets P2 feel all, which compensates the fact that she always does not take into account how she feels. The breathing with a sleep robot not only helps her to stop thinking in her head, but also shifts the focus from mind to body.

" By concentrating on the robot and trying to calm your breathing, (the sleep robot helps to improve my sleep when I have some thoughts in my brain.)" _P3

Breathing practice with a Sleep Robot helps to shift the focus from the external thoughts to internal breathing.

Muscles remember the breathing rhythms

"I'm just gonna keep to the rhythm I got from the sleep robot." "I could put that pillow away, and then I still had that breathing so much in myself that I still fell asleep."_P1

The user's body could memorize the breathing rhythm from a sleep robot, and which thus helps the user to fall asleep autonomously.

Pre-breathing exercise shorten the time to get used to the breathing movement

" I've done Tai Chi and Chi Kung for years. That helped. That's not meditation, but it's focused on your body and your breathing. I immediately slept well and it was even so that after a few days I could put that pillow away." _P1

Pre-breathing exercise experience, for example, from other sports, helps to get used to the breathing movement from a sleep robot.

Adaptive breathing is a puzzle

" I don't know how that (non-adaptive breathing setting) used to be. I had the idea that it (adaptive breathing) was different."_P1

" I don't know what are the differences between adaptive breathing (and previous feature)" _P2

" It should be able to detect my breathing and adapt to it. Does it detect from the belly or the sound? " _P4

Generally, users did not know the difference between adaptive breathing and non-adaptive ones. Even though P4 knows the adaptive breathing could detect and match her breathing, she did not know how and what the sleep robot detects.

Adaptive breathing is not powerful as I expect

“ Sometimes it is annoying because it just does not synchronise up when I’m going to pay attention to it.” _P2

“ Sometimes the breathing becomes so slow, so it may think I’m dead or something. “ _P4

“ I noticed that when I go to bed and halfway through the program I am not asleep yet, and I start breathing faster again, that he (SR) doesn’t adjust well then. “ _P1

The adaptive breathing detects the user’s breathing rate by measuring the movements while the user is breathing. The users felt annoyed while the sleep robot does not synchronize well with their sleep. First, it is due to the position and how tight the users hold the sleep robot. Second, it is because of the linear reduction of breaths per minute in the breathing algorithm.

Expect a miracle happens without self-engagement

“ The sleep robot does not synchronise well with my breath, we breathe at the same rate at some points. I kept breathing on my own rhythm until the robot adapted to me.“ _UAB

The user expected that the sleep robot would automatically guide her to sleep without engaging herself to synchronize her own breathing with a Sleep Robot.
Nowadays, people are spoiled by instant gratifications through the internet. People turn to have immediate effects from using a product.

3.2.3 Findings | Using scenarios

Sometimes, the sleep robot is not the choice

“ When I’m very restless, I can’t have much outside influence. Then I don’t feel like it and I find it (SR) too heavy. Then he(SR) just irritates me. “ _P1

“I’m lying in bed and then I know if I want to use the sleep robot. One time it’s right away and the next time it’s after an hour.” _P1

“ Not always in the mood for the sleep robot. Sometimes you just don’t want anything. “ _URT

Users need their own space to be with their own, instead of using a sleep robot as a mediator.

Doing things simultaneously

“ I did it a couple of times in the evening. (Use a sleep robot outside the sleep context) So When I was sitting on the sofa, watching TV or I felt a little bit tense. “ _P4

“ I would like to use breathing practice through podcasts. Sleep robot is a buddy, do not use the sleep robot in bed. “ _USO

Some users found it was easier to synchronize the breathing while they focus on something else, for example, reading while breathing with a Sleep Robot.

Fear and loneliness reinforce the affective needs from a sleep robot

“ Respiration has always worked for me, especially my husband’s. I could put my arm on his belly, and then I fell asleep with his breathing and his snoring.” _P1

“ That (changing breathing setting more than in the beginning) has to do with me needing him more.” _P3

“ (It would be good to use a sleep robot during the day)You’re very alert during the day. I live in a care facility, and when you hear a different sound, you already sit up straight and think: what is that?” _P3

Being the autonomous problem-solver

“ I don’t need to do that (use SR) twice a night anymore. I still take medication and I want to get rid of it.” _P1

“ after a few days I could put that pillow away, and then I still had that breathing so much in myself that I still fell asleep.” _P1

After six months of using Sleep Robots, the users prefer to independently tackle the sleep problem without relying too much on sleep robots. Experienced users wish to develop autonomy and independence while addressing their sleep problems.

Making optimized usage of my sleep robot

“ Learning everything I need to make the best use of my sleeping buddy.” _UQ

“ I think the sleep robot can be used for much more than sleep. He’s a buddy to me.” _UQ

Users perceive that they have not yet made optimal use of the sleep robot.

3.2.4 Findings | Breathing Settings

Breathing settings give a cue of users’ sleep problems

“ I had the app on and started to breathe, and looked at how my breathing went, and set the app to that. What I like to go to bed with myself.” _P1

“ (the final breath) stayed that way. If it’s okay, I’ll be asleep before the robot is out. I’ve got it at 70 minutes, it takes a lot of time to fall asleep.” _P1

“ I use App twice a week. Especially changing sounds. Sometimes I choose to leave the sounds out. And switch between relaxing and sleeping during the day. “ _P3

The duration of breathing setting in a sleep context could be identified as the time that users take to fall asleep.

Making the choice connected to personal goals

“ I used the sleeping and relaxing breathing program for sleep and relaxation because apparently it made sense. “ _URT

“ I guess categories of sleep difficulties might help me choose the one that feels closest to my own situation.” _UQ

“ 83% users use the “ sleep” breathing program instead of other programs.” _Server Data

Currently, there are only three breathing programs (sleep, relax, and nap). Users turn to choose the one which is close to their goals. However, there are different sleep problems as the goal to improve sleep, such as reducing anxiety, making the brain empty, or reducing pain. It indicates that users want to choose a breathing program that fits their sleep problems.

Uncertainty hinders explorations

“ How do I manage the breathing settings correctly? I need more information.” _UHD

“I don’t know about ratio. I always set the robot in adaptive breathing. I don’t use the program.” _URT

“ I’ve found it difficult to find the correct settings” _UQ

“ The BPM setting from 12 to 6 is the most frequently used setting, which is the default setting as well as the setting for the sleeping breathing program.” _Server Data

Users felt unsure and unconfident to set and find the breathing settings for themself. First, it is due to the limited knowledge of breathing techniques. Second, users lack the guidance to find better breathing settings. This uncertainty prohibits the users to explore the better settings for themselves and makes users stick to the default settings.

A guidance is needed to find (better) breathing

“ Try as much as possible to improve my sleep and gain insight into how my sleep is progressing and where there are areas for improvement.” _UQ

“ I haven’t figured out how this (breathing setting) works yet, but to be honest, I haven’t put a lot of effort into it.” _UQ

“ Guidance on finding the better breathing settings .I feel like I haven’t gotten this right yet. ” _UQ

“ The app should be able to make settings adaptations according to collected data.” _UQ

Users have trouble finding suitable or better breathing settings for themselves. Support or guidance could be provided to help users find better breathing settings for themselves.

Affection and Freshness facilitates explorations

“ I perceived my sleep robot as a friend, Jhonnie.” _P3

“ I adjust breathing setting now more than in the beginning of using my sleep robot. Because I want to explore more with Johnnie (her sleep robots).” _P3

“ I only change in the beginging.” _P4

P3 has relatively high affective needs from her sleep robot due to mental disorders. She likes to be together with Johnnie and explore what else she could do with Johnnie. Most users turn to adjust breathing settings in the beginning as they are enthusiastic about the new coming sleep robots.

Prefer to remain same after finding suitable breathing

“ I have no idea what else to set. No (there is no need to try other settings,” _P1

“ I change the breathing settings less than in the beginning because I have already find the suitable breathing” _P2

“ I only change in the beginging.” _P4

“ I changed my breathing setting a lot in the beginning, but not anymore. Now it is good. Sometimes grab an app to try something different. For example, long breathing (duration).” _Uso

Users have low engagement in the mobile App in the long-term. One reason would be that they perceive the breathing setting as a good one and reluctant to change.

Users without self-experimenting breathing turn to drop

From the questionnaire, P5 and P6 never or rarely adjust breathing settings in the App. They have already dropped the usage of sleep robots. In comparison with users who do self-experiment on breathing settings, they are more satisfied with the sleep robots.

3.2.5 Findings | Self-monitoring

Make unconscious part accessible

“ And the smart watch also helps to know how I sleep and that I’ve been asleep. “_P1

“ And the heartbeat is recorded (by samsung smart watch), everything is recorded, I like that.” _P1

“ (Writing a sleep diary) It’s helpful. How many times do I wake up? But also the influence of my sleep problems. However, I found it difficult. I don’t like that way because I have to remember how much time I awake and how much time I sleep. ” _P2

“ Of every day you think about the day, and what it does to your feelings. But also what the night looks like in terms of feeling. (help me the best)” _P3

“ But sometimes you think I may have a long night’s sleep, you still feel tired . But when you look at your measuring device you can see you woke up quite a few times at night. And you didn’t notice it.” _P4

Users found it hard to access unconscious parts of sleep such as how many times the users stay awake or light sleep. The users would prefer to automatically get access to the unconscious parts by a device without taking too much effort.

A mirror to reflect

“ When I’m exercising, I also keep an eye on my data. How great the effort was and how my body reacts to it.” _P1

“ I think if I am more outside in the air during the day and walk with dogs, it’s helpful to fall asleep or more time.” _P2

“ It’s helpful to see how often I wake at night but also sometimes to see when I wake up I still don’t or feel tired, then I can look back why this is and think oh yeah did I drink too much coffee or have too much stress.” _P4

Self-monitoring helps users to reflect what went well and not well to improve their sleep.

But making the reflective mirror is a hassle

“ I don’t want to write a sleep diary. Too much hassle.” _UQ

“ Only if not too time consuming.” _UQ

“ In P1’s sleep diary, she took screenshots of sleep monitoring from the application of her smartwatch” _P1’s sleep diary

People do not like to do manually self-monitoring as it takes time and cognitive efforts to remember and record. Some people consider it a hassle. Reducing the hassle of self-monitoring would increase people's willingness to do self-monitoring.

I need evidences to take actions

“ When I’m exercising, I also keep an eye on my data. How great the effort was and how my body reacts to it.” _P1

“I think when I was writing down the sleep diary, maybe I can try more before I go to sleep at night. Something like meditation.”_P2

Seeing the relationship between vital signals and her efforts (exercise) gives P1 a sense of achievement or a sense of being healthy. It shows that people need some evidence to prove their efforts are effective, thus, they will take action next time.

Or finding a positive correlation between daily activity (such as meditation) and better sleep in a diary triggers P2 to take actions to achieve better sleep.

Sleep diary is part of sleep therapy

“ It was part of a therapy. I tracked how long it took to fall asleep and the times I woke during the night. That is all fine, but it did not help me at all.”_UQ

“ I’m also going to send it to my psychiatrist, because for her I had to write down every day how I slept.” _P3

3.2.6 Findings | Data Interaction

How is my sleep progress going?

“ Try as much as possible to improve my sleep and gain insight into how my sleep is progressing and where there are areas for improvement.” _UQ

“ The Somnox now gives no real feedback. As. such that it fails badly. I want to know how I can improve.”_UQ

Users need to know how their sleep progresses as feedback and that gives a hint for them to think about how they can improve sleep.

Tell me what to do next

“ The data can provide general information, but what’s next? How to use the result from the measurements? ” _UAB

“ It would be interesting to see if any conclusions can be drawn from it.” _UQ

“ It may be interesting if you draw some conclusions there and teach people how it works.” _P4

Though the data informs the facts or results of a particular activity, presenting a direction that users could head toward adds one layer of meaningfulness.

Subjective experience excel objective data on human’s behavior

“ Of course it (data tracking from wearables) is not 100% accurate. Then I knew myself that I had been really awake before. I can lie very quietly. And then the watch records that I slept, but then I was awake. Only then I lie dead still. “ _P1

“ I woke up at 5 am and I was turning and turning. Thus the sleep score is lower. “_P2

While the users interpreted the meaning behind the objective data, it adds one more layer regarding user behaviors and contextualized information.

Strike the balance on collecting subjective data

“ Because if you get a message every day or every two days, it will be quite annoying of course.” _P4

“ When will it be sent? It’s during the night or the day?” _P2

It is essential to strike the balance between collecting users’ subjective experience and the manner of collecting data. Collecting subjective data in a suitable manner at the right time will make the data loop from users sustainable.

A communication tool with medical experts

“ Yeah, and then you can use it (data visualization). Because doctors often ask how you sleep, and then you keep it here and you can show it.” _P3

“ The sleep diary was part of a therapy. I tracked how long it took to fall asleep and the times I woke during the night. ”_UQ

The data visualization could serve as a communication tool with medical experts.

“ A day doesn’t go well, you can look back to a day when it did go well and see: maybe I should do it like this.” _P3

A desire of data integration among devices

“ And the heartbeat is recorded (by samsung smart watch), everything is recorded, I like that.” _P1

“ I don’t like the feeling (fitbit) on my wrist while I’m sleeping. So I don’t measure my sleep. If Somnox can measure my sleep and send it to fitbit, then it would be nice.” _P4

For people who use wearables to track their health-related data like heart rate, steps, or sleep, it shows that they desire to integrate the collected data together.

3.3 Journey map

The user journey map (Figure 18) presents user goals, actions, experiences, touchpoints and the time sepnt of using a Sleep Robot. The aims of the journey map were to combine the fragemented understandings into a entire user experience journey, to convey the findings with collaborators, and to identify the pain points as well as the opportunities.

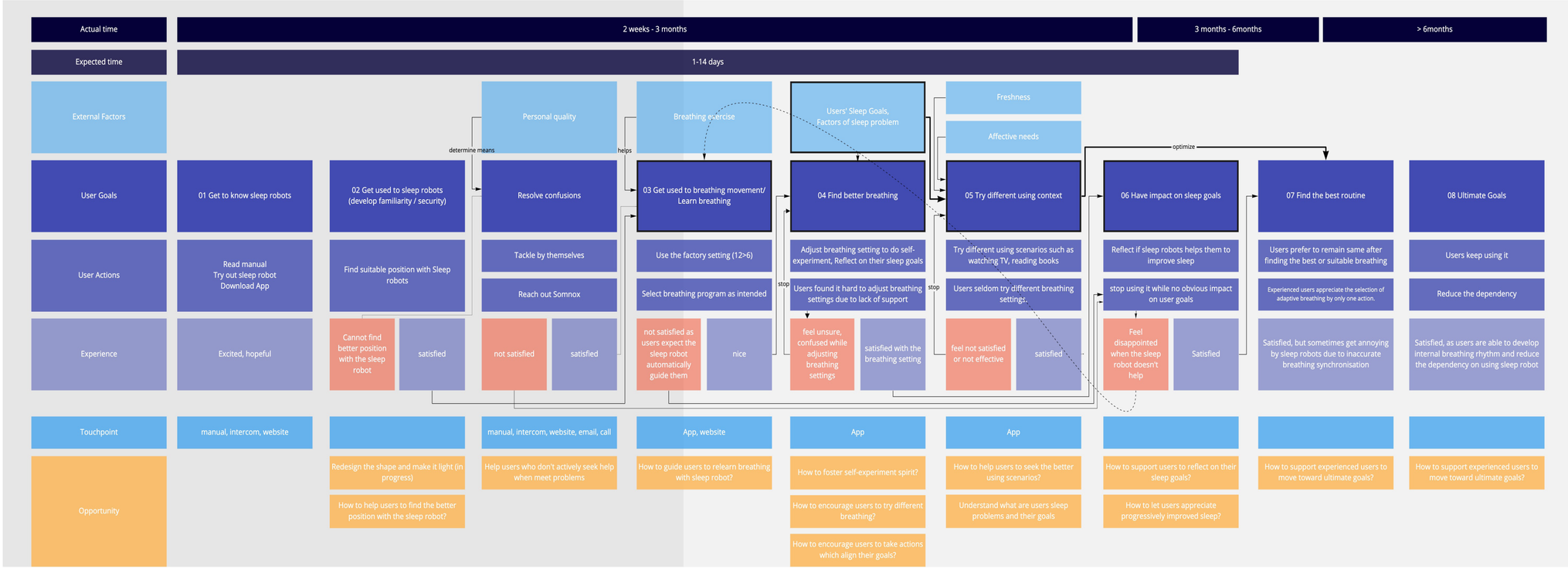


Figure 18. User journey map

Two User Journey Paths

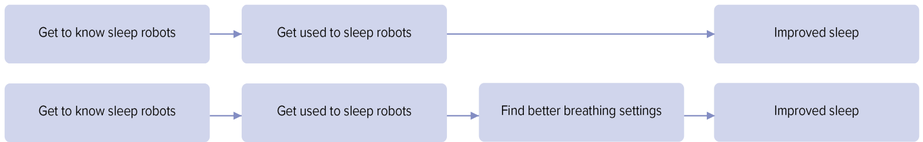


Figure 19. Two user journey paths

There are two paths in the plotted user journey map (Figure 19). Users have the goal of getting to know and be used to the sleep robots, especially the function and position, at the beginning of the using phase. In the first user journey path, users do not take into account the goal of finding better breathing settings. They expect to have improved sleep without engaging themselves with sleep robots. In the second path of the user journey, users take into account the goal of finding better breathing settings. (Figure 19)

3.4 Conclusion

Neglecting the experimenting process of breathing

Users expect to have a good sleep without considering the experimenting process with sleep robots, mainly on breathing. Most users spend time getting used to their sleep robots on their bed or holding positions with sleep robots. However, most users neglect the importance of experimenting with breathing movement from Sleep Robots and jump to the goal of having a good sleep.

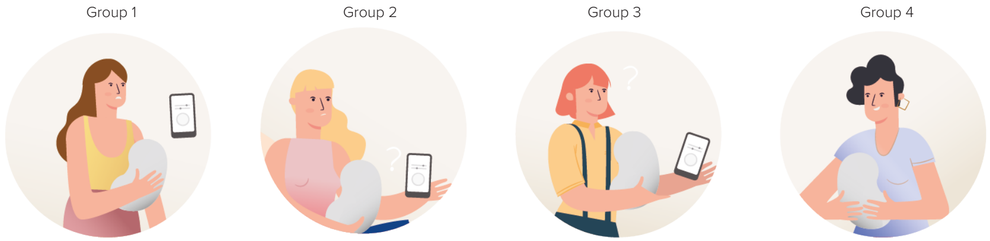
Benefits of self-experimentation of breathing

The more experiments that users do with Sleep Robots, the higher the chance users can find suitable breathing with sleep robots. By conducting self-experimentation with breathing, users could know what settings go well for them, helping them achieve their individual goals and improve sleep.

Lack of feedback loop in the user journey

The whole user journey indicates that Somnox could not know the sleep progress and uses phases from users. When users face specific difficulties while using sleep robots, it is hard for Somnox to provide immediate feedback to users. Therefore, users have to seek help or information, such as a call, a chatbot, or an email. People who passively deal with the difficulties they meet while using sleep robots turn to quit using sleep robots without tackling the problems.

3.5 Design Opportunities



Perceived value on experimenting

No	Low	Medium	High

Experimenting Experience

Group 1	Group 2	Group 3	Group 4
The G1 users do not perceive the value of experimenting with breathing settings. They expect the sleep robot could automatically guide them to sleep without self-engagements.	The G2 users perceive the value of experimenting with breathing settings. However, they are unsure whether if they manage it correctly. The uncertainty hinders them from exploring further.	The G3 users are still experimenting with different breathing settings to find better or suitable breathing settings. However, they are unsure of where and what they can improve.	The G4 users have already found suitable and right breathing settings for themselves. They are satisfied with the impact brought by sleep robots. Their sleep has been improved considerably, but not yet reached their ultimate goals.

Experiment Phase and its opportunities

Before experiment	*Start of experiment*	*During experiment*	*Personalised breathing settings*
Convey value of experimenting	Reduce threshold of experimenting different breathing settings, shorten decision time	Provide feedbacks on used / next breathing settings and sleep progress	Provide different breathing exercises

Figure 20. Four user groups

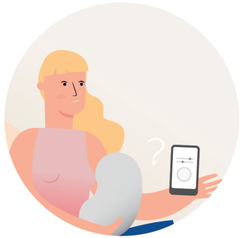
The analysis of user research identifies four user groups (Figure 20) with different needs and concerns while using the Sleep Robot system. Some users reported that the slider was easy to adjust and try out. The slider design is quite intuitive for some users to set the breathing. Those users (G4) finally find the suitable breathing settings for themselves and gradually stop doing self-experimentation on breathing.

However, other users could not find the best breathing settings for themselves, and thus, they feel that they did not make optimized use of their sleep robots or think the sleep robots do not work for them, and thus they quit using sleep robots. These users could be categorized into three groups.

The first group of users (G1) expected that sleep robots would automatically guide them to sleep without engaging themselves to explore the better way of using sleep robots. There is a lack of " why" they could engage themselves and experiment with sleep robots.

The second group of users (G2) tried to adjust breathing settings but stopped experimenting with the breathing or did not start experimentation. Because they found it challenging to ensure their breathing settings are correct. Such uncertainty hinders them from exploring different breathing settings and doing experiments on breathing.

The third group of users (G3) have tried to adjust breathing settings and experiment with the breathings, but they still cannot find the best or proper breathing for themselves according to their use goals. They still feel the used settings are not the right one for themselves. Additionally, they complained that there is no feedback loop for the used breathing settings and how the breathing settings reflect on their sleep progress.



Current experience

unsured, confused, long decision time

unsured, no feedback

Examples

“ How do I manage the breathing settings correctly? I need more information.” _UHD
“ I’ve found it difficult to find the correct settings” _UQ
“ I haven’t figured out how this (breathing setting) works yet, but to be honest, I haven’t put a lot of effort into it.” _UQ

“ Guidance on finding the better breathing settings .I feel like I haven’t gotten this right yet. ” _UQ
“ The app should be able to make settings adaptations according to collected data.” _UQ
“ Try as much as possible to improve my sleep and gain insight into how my sleep is progressing and where there are areas for improvement.” _UQ

Desired experience

ease, guidance, understandable, support

confidence, support, feedback (visible progress), guidance (a cue of what I can do next)

Figure 21. Targeted user groups

Design Focus

To scope down the focus of the project, this project does not address the first group because the value of experimenting with the breathing setting was not adequately conveyed to them. It arises from various problems, including the technology literacy of using apps or exceeding expectations on sleep robots. The last user group was also not the design focus because they have already found suitable breathing settings for themselves. Therefore, the project will focus on the second and the third user groups (Figure 21) as there are more opportunities to deal with the second and third user group on the perspectives of a data loop.

3.6 Design Goal

Let users feel **at ease** and **guided** during **self-experimentation** in order to explore (more) breathing settings for individual goals on improving sleep.

At ease
- Feel confident
- Feel relaxed
- Without feeling nervous
- Without feeling anxious
- Reduced time in decision making

Guided
- Experience the progress
- Know what to do next
- Feedbacks

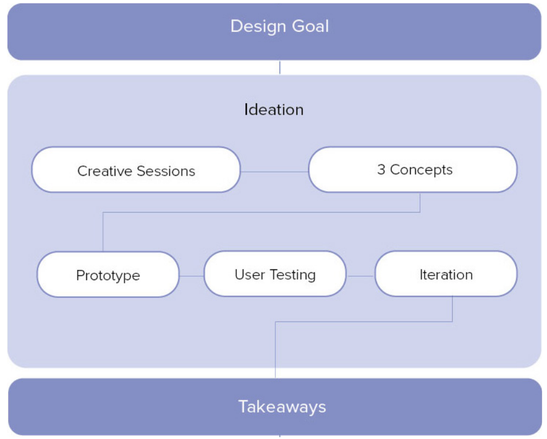
Self-experimentation on breathing
- Try out different breathing settings and experiment on themselves to find better breathing settings

Takeaways

- The mechanisms of Sleep Robot's sensing technology is a blackbox for users, the transparency of the breathing technology is unclear for users, thus, users expect Sleep Robots would adapt to them without engagement.
- Personalized breathing is crucial to develop because users have unique breathing patterns over time, different causes of sleep problems, and diverse lifestyles. However, achieving personalized breathing rhythms is still a hassle within the current sleep robot ecosystem.
- Finding better breathing through self-experimentation is attainable, however, the process of self-experimentation lacks guidance and ease to support and motivate users.
- Creating and sustaining a data feedback loop by stimulating users to self-experiment of trying different breathing settings would enhance the breathing algorithms, and thus increase the adaptability of the Sleep Robot system in the long term.

4. Ideation

The ideation phase included a couple of phases, brainstorming, a creative session, three concepts generation with lo-fi prototype, and user testing. First, brainstorming was done to explore ideas and a creative session was organized to create a wider spectrum of ideas through a diverse team. Next, three concepts with distinguished characteristics were generated for user testing. Three low-fidelity prototypes were made to verify whether particular elements reach the design goal. With the results from the user testing, the concepts could be iterated into the final design.



4.1 Ideations

Brainstorming

In the brainstorming session (Figure 22), the design goal was broken down into five “how might we” questions. A wide variety of ideas was generated based on each question, then, brain sketching was applied to visualize shapes of ideas. Four design components were eventually generated, including a goal-driven journey, a lab experimentation, a right antidote, and a community-based inspiration.

- How might we let people feel at ease?
- How might we let people feel guided?
- How might we do self-experimentation?
- How might we let people explore more?
- How might we fit individual goals?

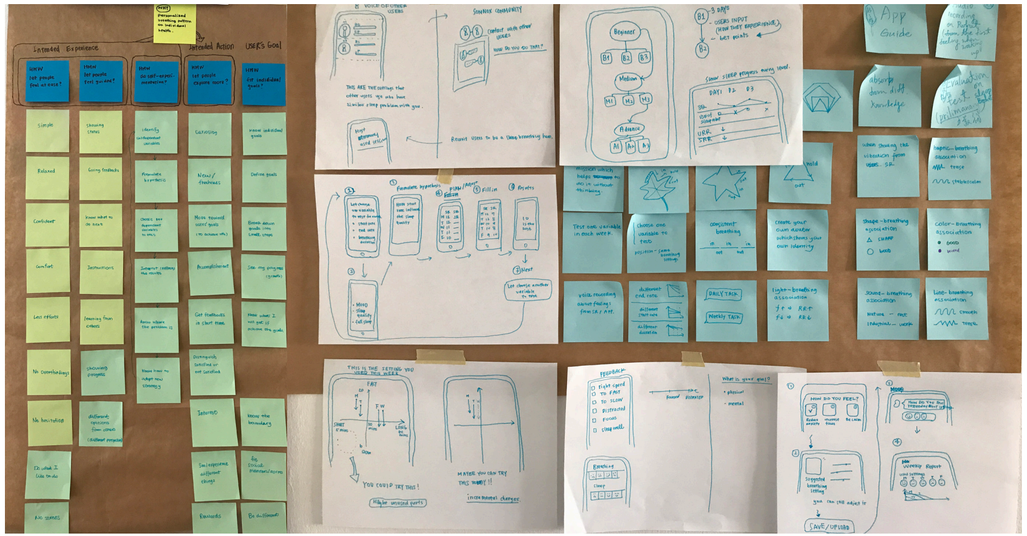


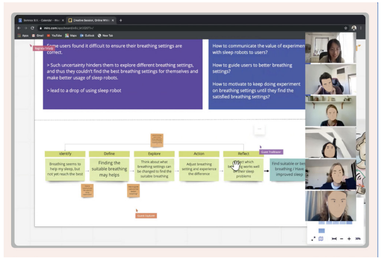
Figure 22. Brainstorming

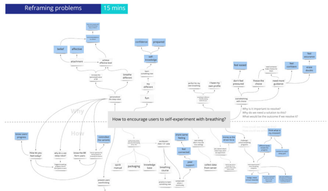
Creative session

The two-hour creative session (Figure 23) was held to share the results from user research to Somnox and brainstorming with them. The participatns include a UX researcher, a designer, an energineer, a marketing and a breathing scientist. The session consisted of two parts: problem reframing and ideas finding. The aims of the session were to reframe the given problem statement ” How to encourage users to self-experiment breathing?” and then generates ideas accordingly.

In the problem reframing part, participants were asked to share their own experience about self-experimentation. Second, participants were asked to purge their first thoughts of solving the problems. Third, the “ ladder of abstractions” technique was applied to explore the context of problem statements and the possible solutions spaces. Then, participants wrote down “ How to “ questions to capture the essential or inspiring parts from the diagrams of “ladder of abstraction”. Then, participants were asked to vote on the most inspiring “How to” questions to deal with. Last, the problem statement was reframed to “ How to help/guide/educate users to personalise their breathing settings to help them experience the progress and feel more confident and relaxed about their settings?” .

In the ideation part, participants are asked to ideate based on the reframed problems and clustered all the ideas in the C-box which is a tool to sequence the ideas on feasibility and originality. After the session, I clustered all the ideas into nine directions.





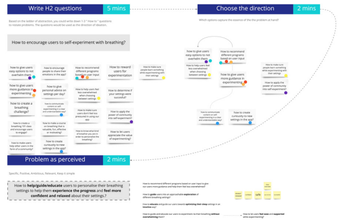


Figure 23. Creative session

Directions

Goals drive the direction of the journey

- Goal settings could give humans cues on the direction of the path. A goal is the component of personal development. By setting sleep goals, people could clearly know what they want to achieve.
- A goal-driven journey could bring guidance to people about where they are heading toward.

A lab experimentation

- Through identifying independent and dependent variables, people could formulate a hypothesis and test it through experimentation. For example, formulating a hypothesis between breathing parameters and breathing experience.
- The structural way of experimentation could lead to guidance.

Find the right antidote

- Reporting specific feedback is the right antidote to deal with the facing problems. If users are not satisfied with the breathing rhythm, asking users to give specific feedback is a way to improve breathing rhythm.
- A right antidote that tackles a particular problem could let users feel at ease.

Community facilitates inspirations

- By building a Somnox community, it may facilitate interactions among users to exchange thoughts on using sleep robots or adjusting breathing settings. Users could get inspiration to adapt others' approaches to their own ways.
- A community-based interaction could let people feel confident and not lonely to try out different things.

Acknowledge the value of self-experimentation

- It is important to convey the value to users who do not consider " self-experimentation of breathing" as their goals during the journey. Because if they start the journey of self-experimentation on breathing, they could find better breathing settings for their own goals.
- Recognizing the value of the self-experimentation would be the first step to urge users to do self-experimentation with breathing settings.

The voice from other users is powerful

- Sharing the stories from other users who are doing self-experimentation is more persuasive to encourage users than from Somnox.
- What the alliance said could let people feel more relaxed because they are in the same boat.

Need a reference point

- Users feel connected to people who have shared the same sleep problems. The choice of breathing settings could be referred to as other users' cases. For example, a restless brain, an overactive mind, or a fearful mind.
- A reference point could provide guidance to people because people could adjust based on the consideration between the reference point and themselves.

Lower the entry-level of self-experimentation

- To reduce the barriers of self-experimentation, evoking curiosity, providing recommended breathing settings, making self-experimentation fun for users could help to encourage more people to try out.
- Lower threshold of doing self-experimentation could let users feel at ease to start with.

Follow intuition

- Let users just try it out without overthinking their choice on breathing settings, for example, revealing the settings from beginner to advanced, making the experimentation simple as started.
- Intuitive decision without overthinking on exploring and trying could let people feel ease to try out.

Create missions and plan steps

- Helping users to establish goals and missions of self-experimentation could help to increase the motivation of doing self-experimentations.
- A concrete plan with small concrete steps could let people feel guided and at ease to pursue their goals.

Reduce the fear of inevitable aspect

- By setting it in the right mindset, it could help to reduce the fear of uncertainty. For example, telling people that failure could happen but it doesn't harm. Letting users know that finding suitable breathing settings is progress which takes time and effort.
- Resilience would be the essential component to let people feel at ease or relaxed to keep experimenting.

Accomplishment drives the progress

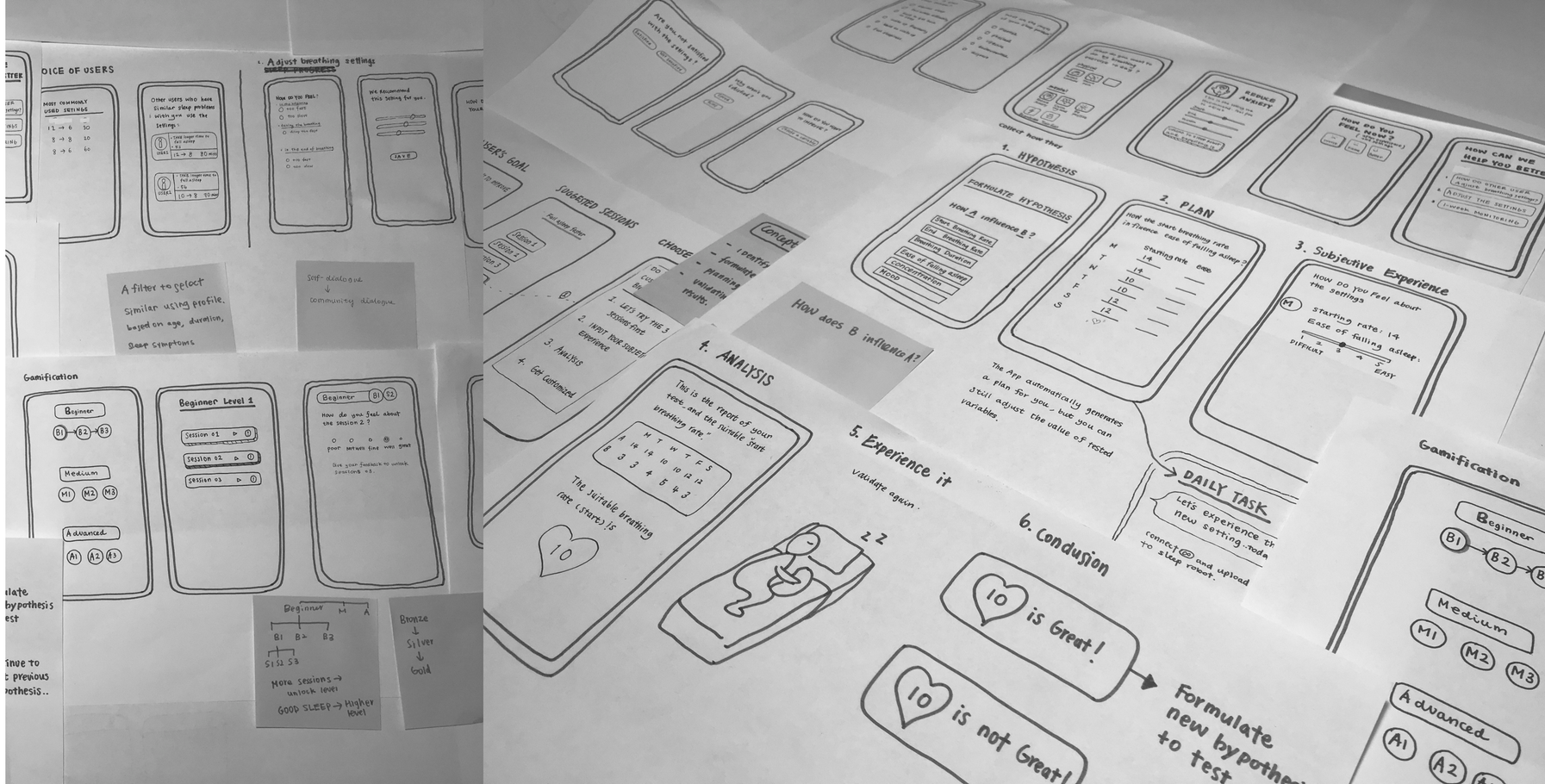
- Through giving users a sense of accomplishment, it would help to motivate users to engage in self-experimentation. For example, creating a checklist, a progress bar, highlighting the unused breathing settings.
- The proportion of accomplishment could make users guided on where they are.

Include subjective experience into a feedback system

- Within the data system, Somnox not only collects objective data such as used breathing settings but also subjective data such as users' mood and experience. Based on the input from users, Somnox can provide personalized suggestions accordingly.
- Users could feel guided on reflecting on their subjective experience while self-experimenting with the breathing.
- setting sleep goals, people could clearly know what they want to achieve.

4.2 Three concepts

The ideas from the creative session and brainstorming were combined and blended into three concepts.



4.2.1 Concept A | Connected breathing

Concept A (Figure 24) stresses the value of making goals while breathing with Sleep Robots specific. The goals are categorized into two groups, including mental and physical. Within the mental category, users could use Sleep Robots for reducing stress, anxiety, or loneliness, and so on. Within the physical category, users could use the Sleep Robots to relieve pain and headache.

For each goal, there are three breathing sessions to achieve users' goals. If users were unsatisfied with the breathing sessions, the application would provide two options for users to make their breathing settings better, including looking at how other users set their breathing settings and looking at their own recorded breathing patterns.

A1: Making the breathing goal specific and individual to guide users reflects how they want to improve their wellbeing or sleep. Visualizing the choices to let users feel relaxed to choose their goals.

A2: Providing three breathing sessions for each breathing goal trigger users to explore different breathing settings.

A3: Asking users' feedback to know how they experience the settings lets users feel guided when reflecting the session and lets users feel at ease when choosing from three options.

A4: Letting users look at how other users are setting to trigger explorations, providing scales of age and gender lets users feel at ease to see others' settings.

A5: Recording users breathing and showing users breathing lets users feel guided when looking and reflecting their breathing. The provided tips for users to improve breathing settings would let users feel guided to know what to do next. Users will feel at ease if they can use the recommended breathing settings from the App.

A6: The documented used breathing setting could give a sense of guidance on what they have already tried and what they plan to try.

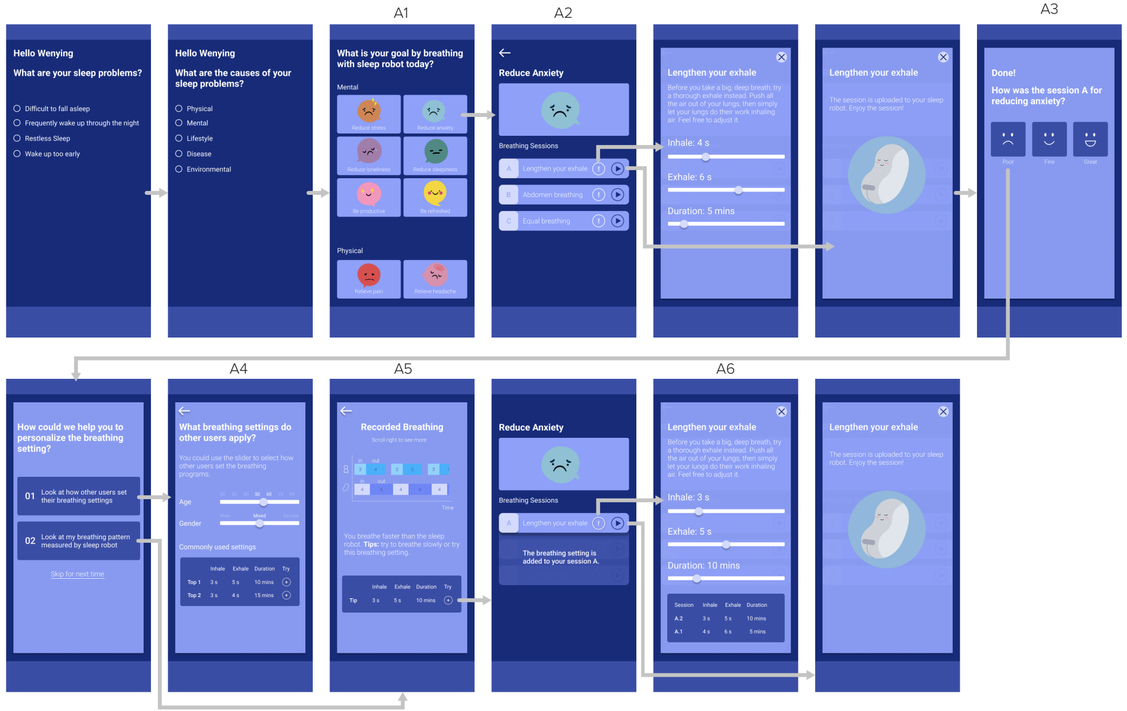


Figure 24. Concept A

4.2.2 Concept B | Lab curator

Concept B (Figure 25) focuses on experimentation itself, in the beginning, the application will ask whether users are satisfied with the breathing settings or not and guide users to pinpoint which part do they want to improve their breathing settings by showing a list. I formulated the list from the user research. The list provides possible factors of unsatisfied breathing settings, for example, exhale is too long or end breathing rate is too slow. After users select one option, the application will automatically generate a 3-day experimentation plan for users, users can look at the overview of the plan and adjust it accordingly.

Next, users will set a reminder to upload new settings to their sleep robots during the experimentation period. On each experimentation day, the application will ask users to report their daily mood and satisfaction level in each breathing setting.

At the end of the experimentation, users will get a final result and a small report. If users still feel the breathing settings are not good enough, they can always do experimentations again.

B1: A list of specific factors of unsatisfied breathing settings is provided for users to select. During the selection, it intends to guide users to reflect on what is going on with their breathing settings.

B2: The three-day experimentation could let users feel relaxed to do the experimentation to find a better breathing setting.

B3: Showing the experimentation settings transparently intends to let users feel step by step to do the experimentation. The freedom of adjusting the plan intends to let users feel confident and relaxed to do experimentation.

B4: The collection of mood is included to identify what would be the best breathing setting. The progress of the experimentation intends to give feedback for users.

B5: The collection of satisfaction levels on breathing settings intends to trigger/guide users to reflect or think about what could be adjusted.

B6: The recommended breathing settings intend to give feedback for users from the experimentations. Moreover, the provided report intends to trigger users' exploration of how their mood influences satisfaction or how the settings influence experience.

Figure 25. Concept B

4.2.3 Concept C | Treasure map

Concept C (Figure 26) is designed as a game to guide users through different programs. In the first phase, users have to fill the small questionnaire to calculate a sleep condition indicator as a baseline. In the second phase, users can measure and know their breathing rates, and then users can unlock the breathing programs from beginner breathing settings to advanced breathing settings.

In the third phase, users can set their sleep goals and have recommended breathing settings from the application which is based on information from the small questionnaire and the measurement from the Sleep Robot. In addition, the application will show the sleep progress, including sleep score and status of sleep goals, to users every two weeks.

C1:The unlocking experience is designed to let users feel step-by-step and trigger users' curiosity about the locked programs.

C2: The function of measuring the breathing rate is to let users feel guided while managing breathing settings.

C3: The adjustable breathing settings intend to trigger users' explorations on breathing with different breathing rates.

C4:The aims of setting a sleep goal are to guide users to know where and how they want to improve their sleep.

C5: The application will be based on Sleep Robot measurement and the information from the small questionnaire to recommend breathing settings for users. It intends to let users feel confident trying out different breathing settings and let users feel guided when receiving feedback from the application.

C6: The shown progress of sleep score and sleep goal is designed to let users / Somnox have sufficient feedbacks on how the users' sleep progress.

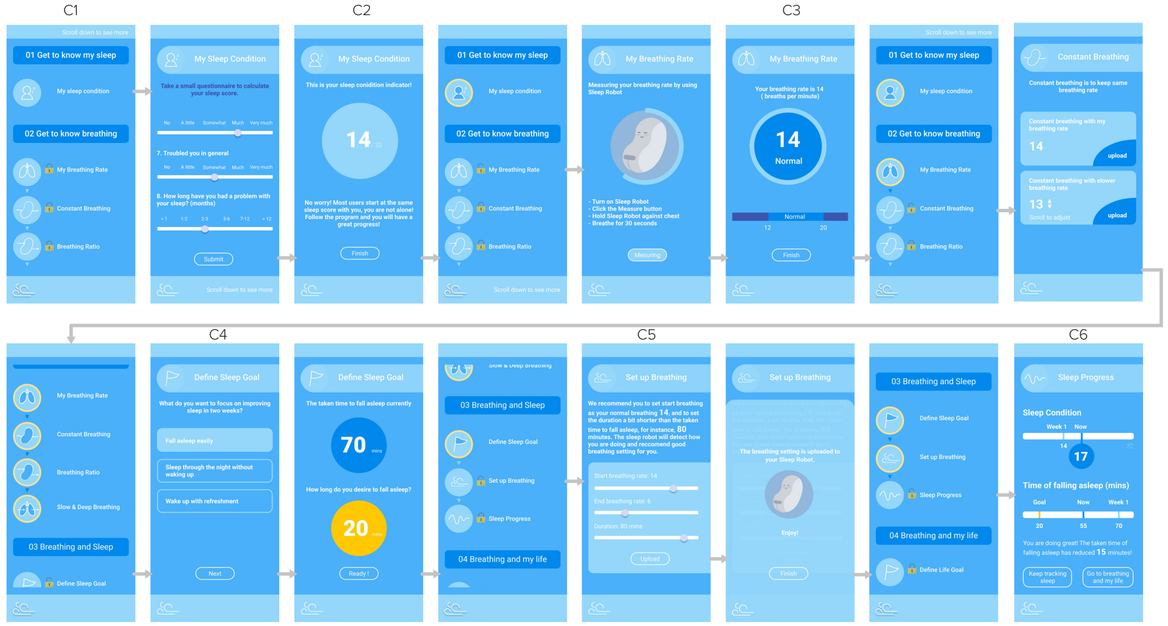


Figure 26. Concept C

4.3 User testing

After coming up with three concepts, four users were recruited to participate in user testing. The aim of user testing was to find out if the design achieves the intended effect and to understand the needs and concerns from users while experiencing the three concepts.

4.3.1 User test method and setup

Users walked through the concept with the voice guidance from Wenying. After experiencing each concept, users were asked to share their thoughts with guided interviews and to evaluate the concepts with an evaluation scale. The three concepts were tested by four participants in different orders as the Table 5 shows. A slide and three prototypes were used as protocols for user testing via a software platform called Zoom. (Appendix D) The aim of slides was to show the instructions of the user testing. And the three low-fidelity prototypes with some working navigational buttons were made in Figma, thus, users could click the button to go through the flow of the screens. By sharing the URL link with the participants, users could interact with the three prototypes.

1. Interview Questions:

- How do you think this concept helps you (or not) to explore different breathing settings?
- What specific elements in the concept do you consider useful to help you find out the right breathing setting for you? Why?
- What do you miss in this concept to make you feel motivated to explore breathing settings till you find your optimal?

P1	A > B > C
P2	B > C > A
P3	C > A > B
P4	A > C > B

Table 5. Order of user testing

2. A scale to evaluate the three concepts:
Users were asked to rank the three concepts in three scales. (Figure 27)

- At ease means that users feel relaxed, confident or not stressful.
- Guided means that users feel step-by-step and have feedback.
- Trigger explorations means that users want to know and discover more.

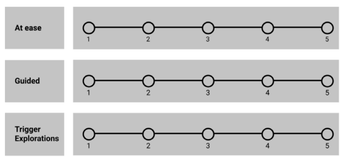


Figure 27. Three scales

4.3.2 Insights from user testing

Insights from concept A

Users feel motivated when the options are connected to them
Users felt connected and motivated while seeing the choices that reflect their own situations, for example, reducing loneliness. (Figure 24. A1)

Users do not always have specific goals for breathing
Providing different breathing goals for users triggered them to explore different breathing settings. Especially, reducing loneliness and relieving mental or physical tension. However, users do not always have specific goals while breathing with Sleep Robots, they just want to sleep better or they just do not want anything. Besides, users who don't know their causes of sleep problems found it hard to choose a specific goal, thus, they preferred to have an option called sleep better. (Figure 24. A1)

Having a reflective moment while rating score
Rating the used breathing lets users reflect the breathing experience and let the App system recognize how the users experienced and enable the system to provide suggestions. (Figure 24. A3)

Other people could act as reference points, but not relevant to me
Though it gave a sort of reference point to look at what other users set breathing settings. Users were mostly not interested in that because they thought everyone is unique. Others' sleep situations could not apply to users themselves. (Figure 24. A4)

Revealing the unconscious part sparks enthusiasm
Measuring and knowing breathing rates and patterns highlight the unconscious part, and also give users information on how users can use the data. The comparison between the user and sleep robot gives users a view of what is not going well and gives chances to reflect and adjust accordingly. (Figure 24. A5)

Respect individual difference while giving tips
According to recommended tips, users desire their breathing setting will be respected and understood by the sleep robot, especially the pause. Don't push users to follow Sleep Robot's breathing pattern, but seek the balance between them. (Figure 24. A6)

Insights from concept B

The more specific I am, the better results I get
Users liked the fact to choose one factor to experiment because the more specific they are, the more correct of the experiment results they could get. However, the provided list was complicated for one user. (Figure 25. B1)

I'm ready and resilient for the experimentation
The automatically generated experimentation was valued by the users as they thought the experimentation is interesting to try out, even though when the result is not good, they can do the experimentation again. Besides, users thought the application became more interactive. (Figure 25. B2)

Start with easy tasks, then design by my own
Users would like to follow the plan of experimentation instead of adjusting the plan by themselves because some users thought the sleep robot knows better than themselves, or they wanted to try out the plan first and then adjust the plan. (Figure 25. B3)

Collecting mood is like a warm greeting
Users loved the feature of collecting their mood by choosing emojis. Users thought the experience of reporting mood is like a warm greeting from a Sleep Robot, thus, users felt the App was more interactive. (Figure 25. B4)

The final result works as a guideline for me
Users thought the sleep robot helped them to find better breathing settings by recording the used breathing settings, mood, satisfaction, and then suggested the best breathing setting for them. It is helpful for users as they said they can easily forget what breathing setting they have used and what the experiences of the settings are. And it works as a guideline for them. (Figure 25. B6)

Insights from concept C

Appreciate information comes gradually
Users liked the gradual process of getting to know breathing, learning, and knowing what Sleep Robot does to them during unlocking. It is better than all the information coming together at the same time. (Figure 26. C1)

Feel conscious while knowing the baseline
Filling the sleep condition indicator to generate a sleep score lets users feel conscious about their sleep patterns. (Figure X. C2)

Need assistance on my dynamic breathing rate
It's good to measure breathing rate because breathing rates may change every day or be influenced by mood. Then it could help to set the breathing setting correctly, thus, users said they don't need to guess their breathing rate. (Figure 26. C3)

Setting a sleep goal makes a clear focus
Setting a sleep goal made users clear on what they wanted to improve because users mentioned they often missed that part and found it hard to prioritize sleep goals. (Figure 26. C4)

The objective data navigate the perception
Knowing the sleep progress subjectively and objectively is pretty important. The objective experience serves as a validation tool of subjective experience. Knowing the meaning or the mechanisms of generated objective data helps people to tolerate the inaccuracy of the objective data from devices. (Figure 26. C6)

The approach from insights to final concept

Since the insights from user testing were extensive, the approach that I concluded the user testing was to verify design components and its intended effects. By connecting users' feedback with the assumption of each design element, it not only led me to verify the assumptions of each design element but also revealed which idea had the potential to develop further at the end of the conceptualizing phase. Meanwhile, the innovation sweet spot was also considered, the intersection of desirability, feasibility, and viability.

The design tool called a list of requirements was used to extract essential ideas for developing the final concept. The list of requirements included six aspects. The first three requirements were the intended effects from design goals, including feeling at ease, feeling guided, and triggering explorations.

Each design element had its intended purposes in terms of the design goals. The process was documented as the diagram (Figure 28) shows. If the intended effect was achieved, the color will stay the same as the original color. If the assumption of design elements could not be supported by users' feedback, the transparency of color would be increased. This was also applied in the last three requirements.

The last three requirements covered desirability, feasibility, and viability. Desirability was defined as the quality of being desirable from users, which was evaluated by how many times the idea was mentioned as helpful and useful for users themselves to self-experiment breathing settings. Feasibility was considered as the effort to easily implement the ideas, especially in the technology aspect. Viability was described as the survival of ideas in the long term, regarding business models. The feasibility of the idea was evaluated by the discussions with software engineers, and the viability of the idea was evaluated by discussing with designers and marketing.

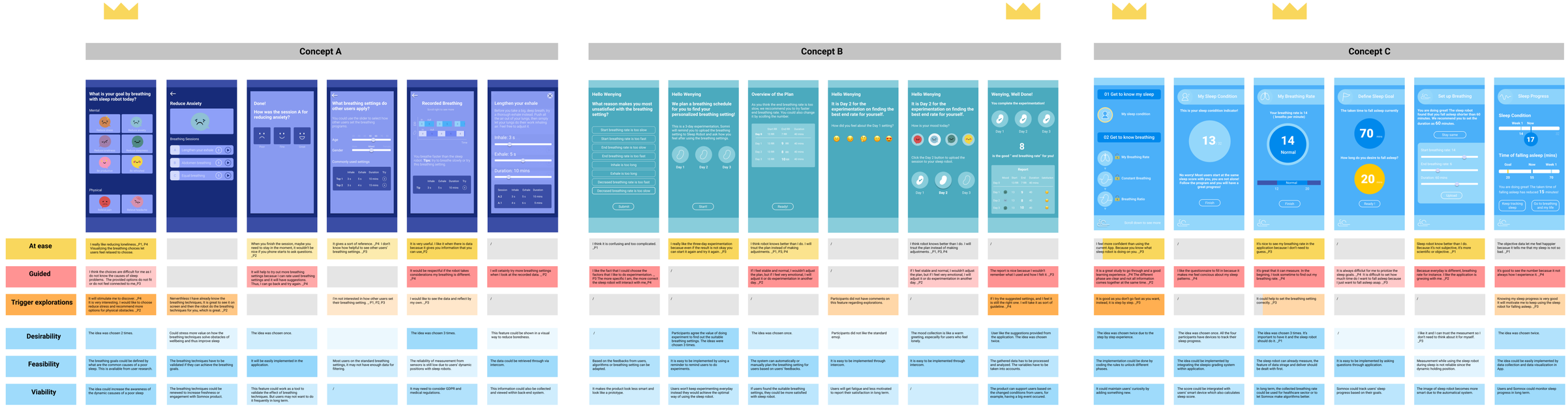


Figure 28. From user testing to final concept

Results

Eventually, four design elements (Figure 29) were selected to further develop the final concept based on users' feedback and the evaluation on the list of requirements.

First of all, users highly appreciated the step-by-step process of absorbing information regarding breathing. Because users felt more confident about breathing with sleep robots and they thought they could do it at their own pace. Additionally, users considered step by step guidance as a good learning experience since users could intake information gradually.

Second, regarding manually setting the breathing setting, users greatly valued the feature of measuring breathing rate by a sleep robot since the limited knowledge, lack of confidence, and the dynamic breathing rates, which hindered users to explore more breathing settings. With the automatic measurement of breathing, users thought it made the setting easier because they did not need to guess or think too much about it. It reduced the uncertainty of adjusting breathing settings, thus, the threshold of trying out would be minimized. Besides, by knowing the dynamic breathing rates, users have more curiosity about trying new settings.

Third, to personalize the breathing settings, users reported that they could not remember what went well and not well. Thus, users felt supported while reading a report with information about user settings or satisfaction level, and they felt guided when seeing the suggested breathing settings. Generally, users trusted more on what device suggested them to set rather than managing the breathing settings by themselves. Besides, users considered trying-and-erroring in the journey of finding personalized breathing settings with sleep robots as growing together. Even though the suggested breathing rhythm wouldn't work perfectly, the process of experimenting served as a guideline.

Last but not least, to try out more breathing techniques based on breathing goals, visualization of users' conditions would stimulate them to discover. The two groups of breathing goals, including mental and physical, guided users to reflect on what the causes of their sleep problems were. Users also reported that the options which had strong connections with them attracted them to choose without considerations.

Step by step
- Feel more confident
- Do it at my own pace
- Good learning experience

Breathing Measurement
- No need to guess / overthink
- Reduce uncertainty
- Dynamic breathing rate

Breathing rhythm suggestion
- Work as guideline
- Trust more on device
- Growing together

Breathing Goals & techniques
- Stimulate discover
- Reflect a poor sleep
- Close connection

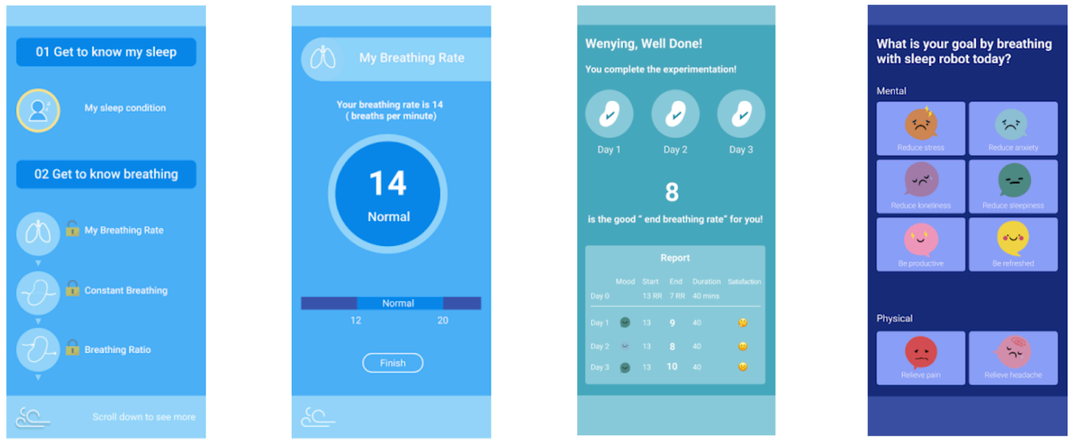


Figure 29. Four chosen design elements

Takeaways

- The design process from ideations toward three concepts applied a blending strategy with my own assumptions, while the design process that went from three concepts toward the final concept had a backup from user testing.

- Step by step was perceived as a good learning experience of breathing with the Sleep Robot because of the gradual information intake.

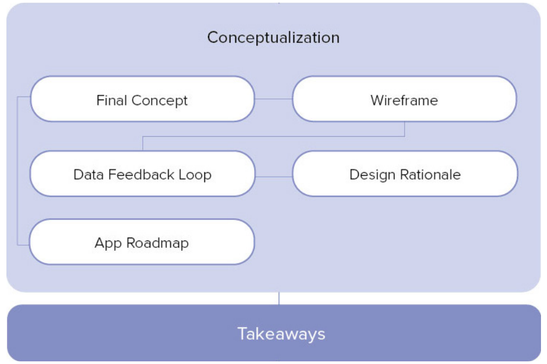
- Users desired to know their breathing rate and patterns since they recognized their dynamic breathing patterns and also wanted to reduce uncertainty while adjusting breathing settings.

- The recommendation system of tailoring breathing settings was considered as a partner to grow together with.

- The breathing goals that address either mental or physical problems of sleep triggered users to discover and reflect the possible causes of sleep. They felt connected when chosing breathing settings.

5.Design

The chosen four design elements from user testing, including step by step, breathing rate measurement, breathing setting suggestion, and specific breathing goals, are combined into the final concept. Chapter 5 aims to conceptualize and detail the chosen four design components with a clear rationale and establish the flow of the data loop. In the end, the App roadmap shows the transition role of the proposed design.



5.1 Final Concept

From the user research, some users did not recognize finding better breathing settings as a step within the user journey or did not know how to start finding a better breathing rhythm. To tackle it, making the journey of finding better breathing rhythms tangible and visible via step by step is significant to communicate the value of self-experimentation with breathing. The journey consists three steps. (Figure 30a)

To begin with the journey of finding better breathing rhythms, users had insufficient knowledge of the relationship between breathing and sleep when they try to adjust breathing settings manually. For example, the common question that users had was," What is my breathing rate (during sleep)?" To address the question, the feature of measuring sleep condition and breathing rate overtime aimed to provide users opportunities to know more about themselves. (Figure 30b)

Figure 30. The storyboard of design (a, b)

In the existing application, users had low confidence in setting the breathing correctly and unsure whether the breathing setting was the best. To deal with the uncertainty that users had, the features of getting customized breathing and optimized breathing rhythms with the reference of their conditions intended to make them feel at ease and guided through trying out different breathing rhythms. (Figure 30c)

For those users who found or not yet found the optimized breathing settings were interested in discovering different breathing exercises in day time or evening. As the causes of poor sleep may arise from the accumulated stress during the daytime, some breathing exercises during the daytime would bring benefits for users. The feature of exploring breathing exercises with mental and physical categories would be offered after users trying out different customized breathing. It works as a reward after users self-experimenting various breathing settings. (Figure 30d)

Figure 30. The storyboard of design (c, d)

5.2 Wireframe

To have a general blueprint of the final concept, a wireframe is plotted with critical screens, navigational elements, and the system's hierarchy. (Figure 31)

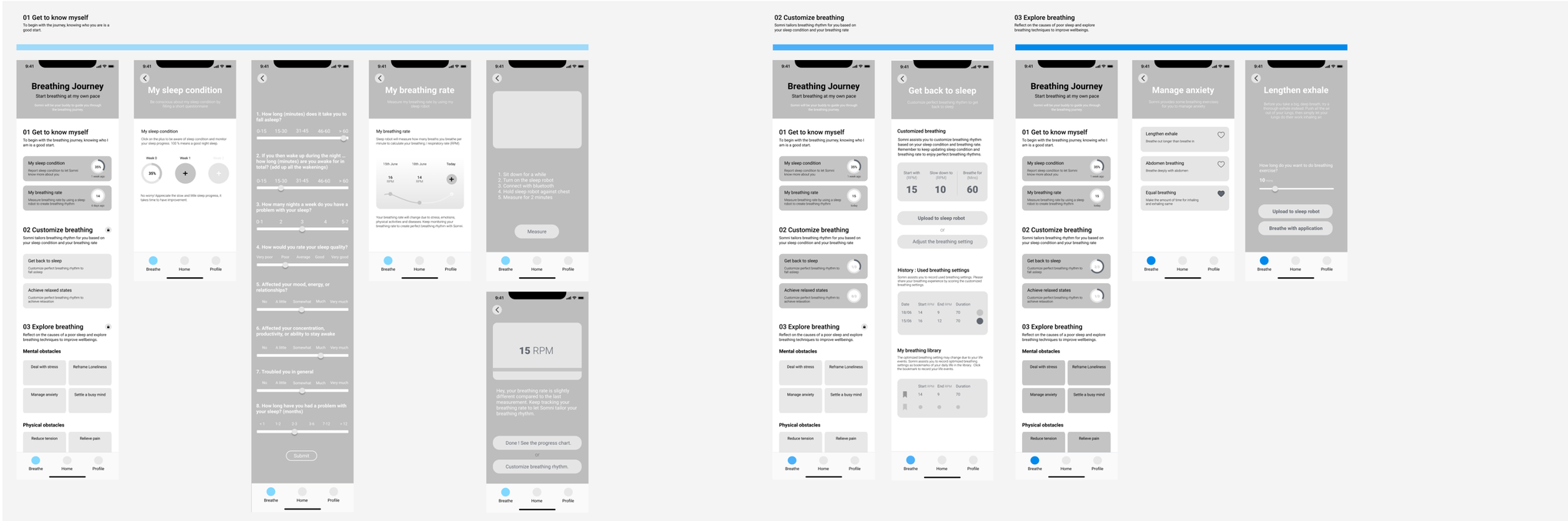


Figure 31. Wireframe of design

5.3 Data Feedback Loop

To tailor optimized breathing rhythms, a data feedback loop is crucial to construct, including input data, data processing, breathing algorithms, and the reward system. (Figure 32)

Regarding the resources of input data, sleep condition, users' breathing rate (or respiratory rate), and the purpose of breathing are taken into accounts as materials. The user's breathing rates could act as the start breathing rate of the breathing algorithm, the taking time to fall asleep could act as the duration of breathing, and the purpose of breathing could determine the breathing ratio and end breathing rate.

With the inputs, the existing breathing algorithms could be adaptive to individuals and thus be able to create customized breathing rhythms for individuals with higher levels of personalization. Also, the rating system of used breathing settings could be applied as the material to validate the data processing and breathing algorithms.

Apart from the data loop, the reward system plays an essential role in maintaining the loop. After users experimenting with different customized breathing settings, they could obtain access to explore different breathing techniques based on the chosen breathing goals. The reward is one of the elements to engage users in the data loop. The other elements of engaging users in the data loop will be described in detail in the next subchapter.

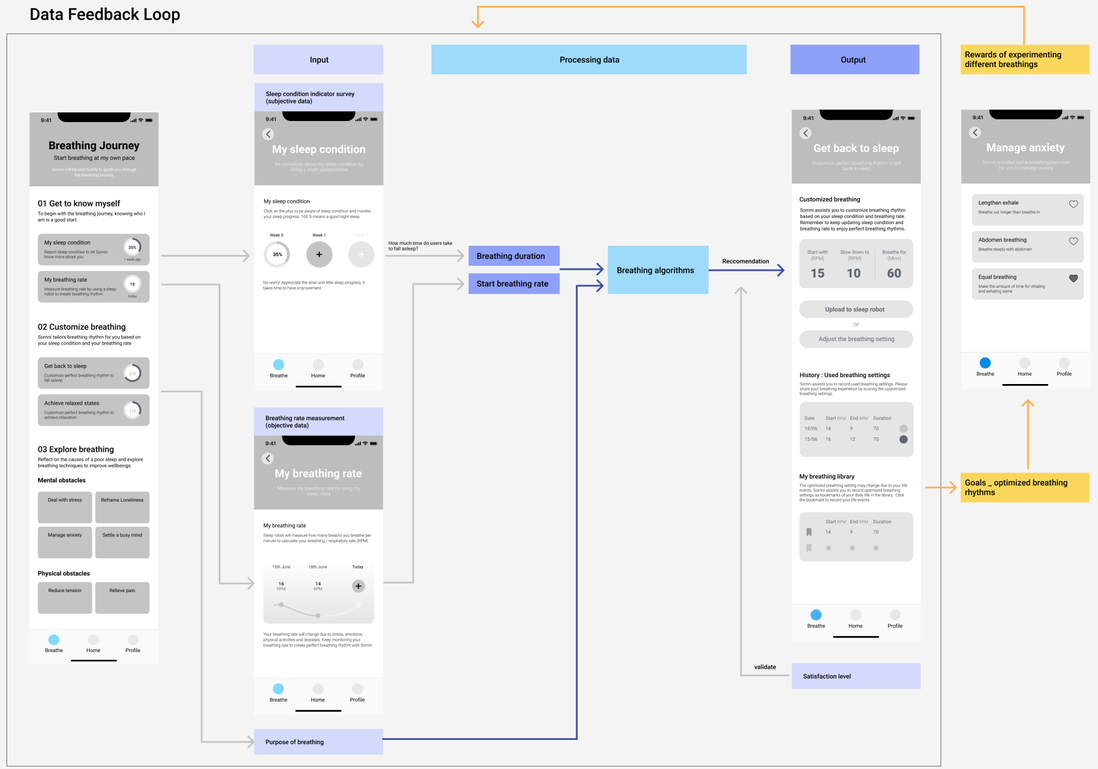


Figure 32. Data feedback loop

5.4 Design Rationale

In this subchapter, explicit documentation of the reasons behind the decisions when designing the concept. The first eleven design rationales were formulated based on the previous user testings and assumptions. The last three design rationales were created based on literature reviews, which promoted engagement in the data loop.

Unlocking experience step by step

The breathing journey is divided into three phases to give users guidance on obtaining knowledge about their sleep and breathing instead of letting users flow in an information sea. The aim of locking the second and third phases is to motivate users to follow the guideline by triggering their curiosity on non-disclosure programs. (Figure 33)

The three phases of breathing journey

The journey consists of three phases: getting to know personal conditions, customizing breathing, and exploring breathing. The three phases are determined by the previous user research, which indicated three user scenarios over time while using the application. The first user scenario that new users encountered was, “ what is my breathing rate? Do I set the breathing setting correctly?” The second user scenario that users faced was, “ Is this the best or the right breathing setting for me?” And then, the next user scenario that users met was, “ What else I could try out?” The designed path of the breathing journey will let users feel guided when pursuing optimized breathing settings.
(Figure 33)

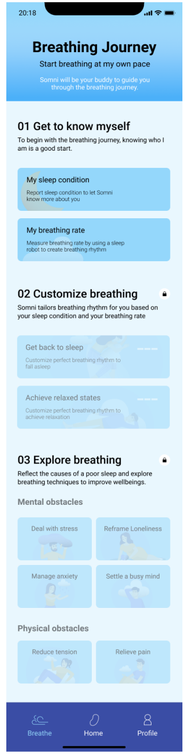


Figure 33. Breathing Journey

My sleep condition

Generating a sleep score by filling a sleep condition indicator survey brings two benefits. First, users could become aware of their sleep and could connect breathing with their sleep. Second, Somnox could know the baseline of users’ sleep conditions and know the effects of breathing technology.By reporting subjective sleep experience to generate an objective sleep score, users feel guided to reflect their sleep. Moreover, the data of sleep condition could be used as the input to tailor customized breathing rhythms. (Figure 34)

My breathing rate

Measuring the breathing rate not only lets users know their breathing rate to adjust breathing setting easily but also as an input for breathing algorithms to create customized breathing rhythm. Knowing the unconscious part lets users feel guided to explore more or different breathing settings. (Figure 35)

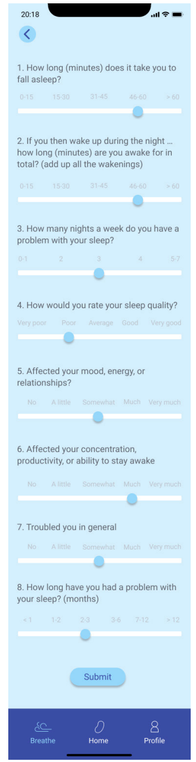


Figure 34. Sleep condition

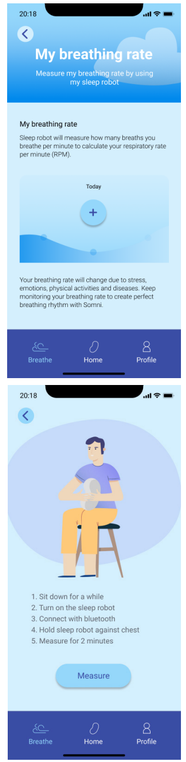
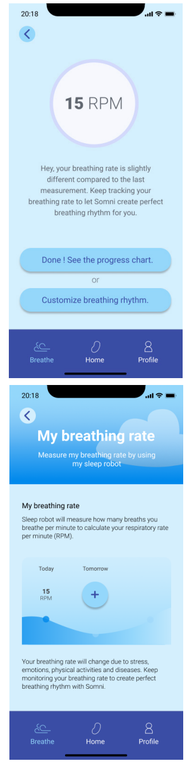


Figure 35. Breathing rate



Monitoring progress of sleep/breathing rate

Monitoring the sleep progress will give users a sense of " how is my sleep going while using a sleep robot? " and allow Somnox to monitor the effect that sleep robots bring to users. Monitoring the progress of breathing rate along with the chart will let users notice the dynamics of breathing rate and trigger users to try out different breathing settings. (Figure 36)

Automatically generate breathing settings

The feature lets users feel at ease without overthinking breathing settings. Users could either follow the suggested breathing settings or adjust breathing settings by themselves since participants mentioned that they would like to follow the device first and then adjust by themselves. Besides, users will feel more confident to use the breathing setting, which is automatically generated by the system, rather than to use the one set by themselves. (Figure 37)

History of used breathing settings

The aim of showing the used breathing setting with a rating system is to show users' history to let them feel guided while trying out different breathing settings. For example, they could remember what breathing setting went well and not well. Based on that, users could reflect on it and determine which breathing setting to use. (Figure 39)

Rating system to get optimized breathing

With the rating system to report the subjective experience of the customized breathing, the sleep robot system could calculate and recommend the optimized breathing rhythms for users. The way to finding optimized breathing is guided and at ease through self-measurement of sleep condition and breathing rate as well as the rating system. Users will feel growing together with the system. (Figure 38, 39)

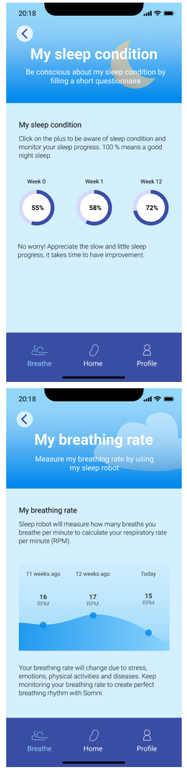


Figure 36. Monitoring

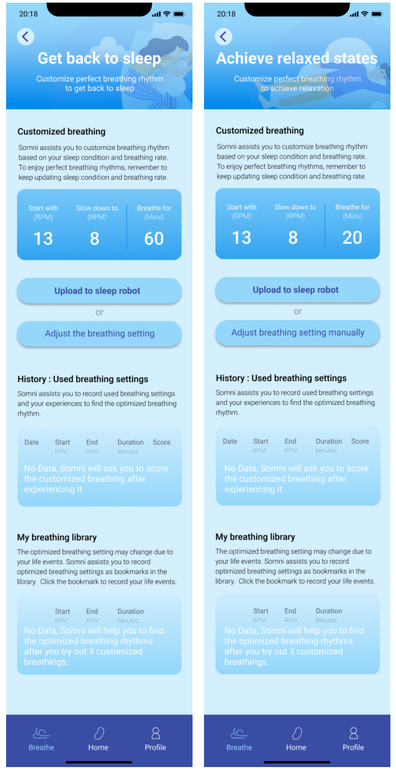


Figure 37. Automatically customized breathing

Figure 38. Trying out customized breathing and Rating

Figure 39. Optimized breathing

Rules of unlocking phase 3

Before unlocking phase 3, users have to try out three breathing settings at least and rate their satisfaction levels. The locked phase 3 motivates users in the loop of trying different breathing settings to find the optimized one. (Figure 40)

Breathing goals

The aim of having breathing goals is to let users reflect on the causes of their poor sleep. Thus, users could address the specific obstacles of poor sleep. The breathing goals are categorized into mental and physical obstacles, including dealing with stress, reframing loneliness, managing anxiety, settling a busy mind, reducing tension, and relieving pain. Users feel at ease to try out different breathing techniques by reflecting on the causes of poor sleep. (Figure 40)

Breathing techniques

According to breathing goals, the provided breathing exercises could be used with a Sleep Robot and within its application. The feature of breathing in the application is to shift the role of application toward a 7/24 tool. Users could do breathing exercises more during the daytime. Apart from that, users could also favorite breathing exercises. That feature aims to reduce the threshold of selecting a breathing exercise. (Figure 41)

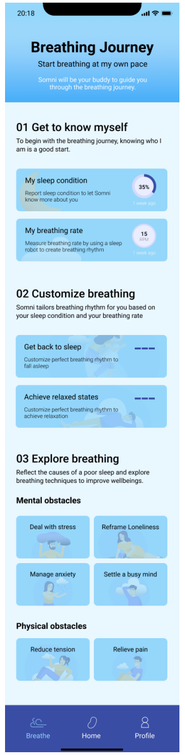


Figure 40. Unlocking phase3

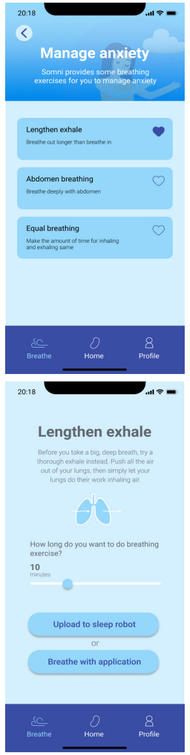


Figure 41. Explore breathing

Different levels of readiness

Ruben's study suggests to consider human's current motivation stage. For example, users in the precontemplation stage are often unaware of their inactivity, thus, they are unwilling to change behaviors. Thus, in the breathing journey pannel, the status of sleep condition, breathing rate and customized breathing setting are shown to users. For example, a sleep score with the latest measured date is designed on the program as a glance to let users be aware of the level of activity. (Figure 42)

Multi-layered goal settings

The feature of progress charts is designed on the customized breathing programs. After users accomplish the goals of experimenting at least three different breathing rhythms on sleeping and relaxation, users could unlock the third phase of breathing journey. During the experimenting, users could see their progress of trying out different customized breathings. (Figure 42)

Checking habits

The small graph designed on my sleep condition and my breathing rate aims to create checking habits. Since brief and frequent interactions can lead to sustained engagement.

Besides, the feature " my breathing library " stores the optimized breathing settings with individual bookmarks to record contextual data such as family, work, and health conditions, which provides an opportunity to reflect the optimized breathing setting may change due to their life situations. In the long term, users can tailor their breathing setting based on the recorded life bookmarks. With the experience of experiments, user will come back to change breathing setting when they find their breathing rate changes . (Figure 42)

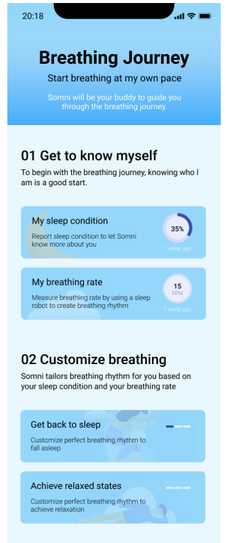


Figure 42. Design for engagement

5.5 App roadmap

The session of creating the vision for the Somnox application was accomplished with two Somnox designers. (Figure 43) It aimed to incorporate the proposed concept and existing ideas to align with users' needs, technology capabilities, and resources.

The existing ideas from all participants were noted down, categorized into different groups, and relocated in a timeline. Afterward, three phases of the Sleep Robot system and mobile application's role were illustrated to envision the future vision. (Figure 44)

At the current stage, the Somnox application plays the role of a remote controller, which delivers breathing settings to sleep robots. Besides, the present experience of the Sleep Robot system still stays in the setup stage due to inadequate data infrastructure.

The roadmap envisions that the mobile App shifts from a remote controller to educational guidance on breathing, then a 24/7 tool, and eventually, a digital twin that provides personal tips or value for users to achieve better sleep.

Figure 43. App roadmap photos

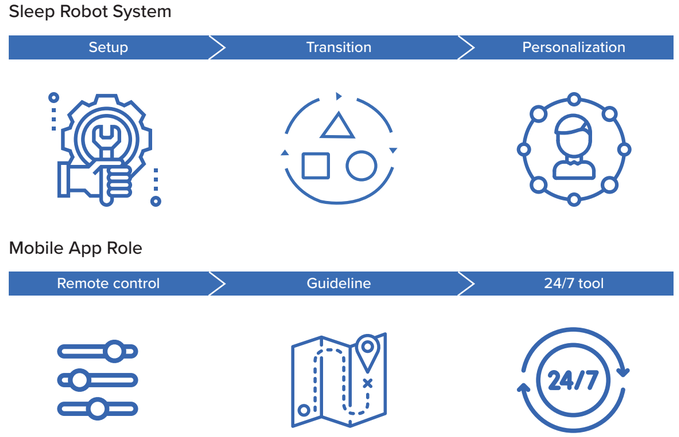


Figure 44. App roadmap (three stages)

5.6 Summary

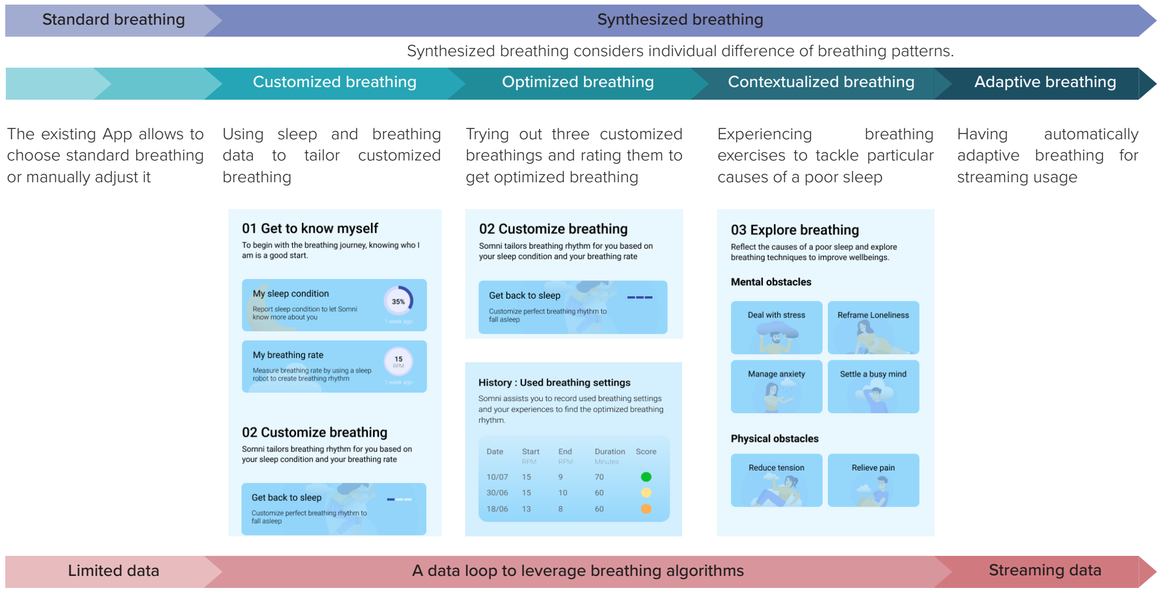


Figure 45. Standard breathing and synthesized breathing

Standardized breathing is the claimed breathing rhythms for achieving relaxed states without considering the individual differences. In comparison, synthesized breathing merges personal breathing patterns and standard breathing rhythms.

Synthesized breathing consists of four levels of personalization: customized breathing, optimized breathing, contextualized breathing, and adaptive breathing.

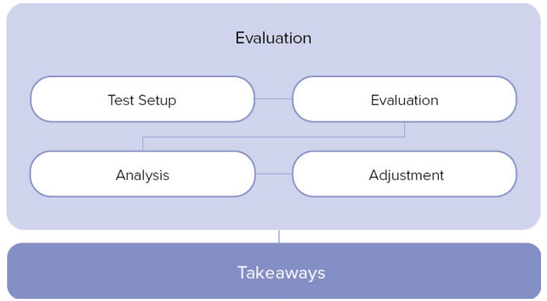
The proposed concept covers the first three levels of personalization as the figure 45 shows. A data loop through the proposed concept could help to leverage the breathing algorithms by collecting relevant data.

Takeaways

- The breathing journey with three steps in the breathing panel of the mobile App is a mirror of the existing user journey map.
- By defining the data input and output, the data feedback loop could support the breathing journey of self-experimenting to find optimized breathing.
- Considering the elements of engagement is essential to maintain and sustain the data loop in order to find personalized breathing rhythm over time.
- The transition of the application road-mapping highlights that the role of the proposed concept is heading toward personalization.

6.Evaluation

Chapter 6 primarily aims to evaluate the proposed concept if it achieves design goals. By validating the design hypothesis and user flows with user scenarios and interactive prototypes, what went well and not well were documented, and adjustments were made to polish the design.



6.1 Evaluation setup

Protocol

Five user scenarios were created to let participants immerse themselves in the scenarios, and an interactive prototype was provided for participants to try out, then opinion scales and open questions were used to evaluate the design hypothesis as well as the user flow. The scenarios, prototype, survey, and questions were integrated into a user testing platform called Maze. (Appendix E)

Scenarios

There were five scenarios that outlined a storyline using a sleep robot from day 1 to day 150. The first four scenarios illustrated the possible scenarios that users may encounter during experimenting with different breathing settings, including facing anxious or tense situations. It intended to validate users' experiences and flow while facing obstacles of falling asleep. The fifth scenario depicted the unexpected life event in long-term usage. The last scenario aimed to discover potential interactions with the proposed concept in the long-term.

Scenario 01

After users try out the factory breathing setting, users find that they cannot keep up with a start breathing rate with the sleep robot; thus, they need to customize the breathing rhythm of sleep robots. (Figure 46)

- To what extent do you consider this order as a desirable guiding experience?
- Could you explain what actions you take to get the first customized breathing?
- Regarding the flow of getting customized breathing, I feel more guided. (scale from 1 to 5) Why?
- Regarding getting customized breathing, I feel more relaxed. (from 1 - 5) Why?
- Regarding using customized breathing, I feel more confident. Why?

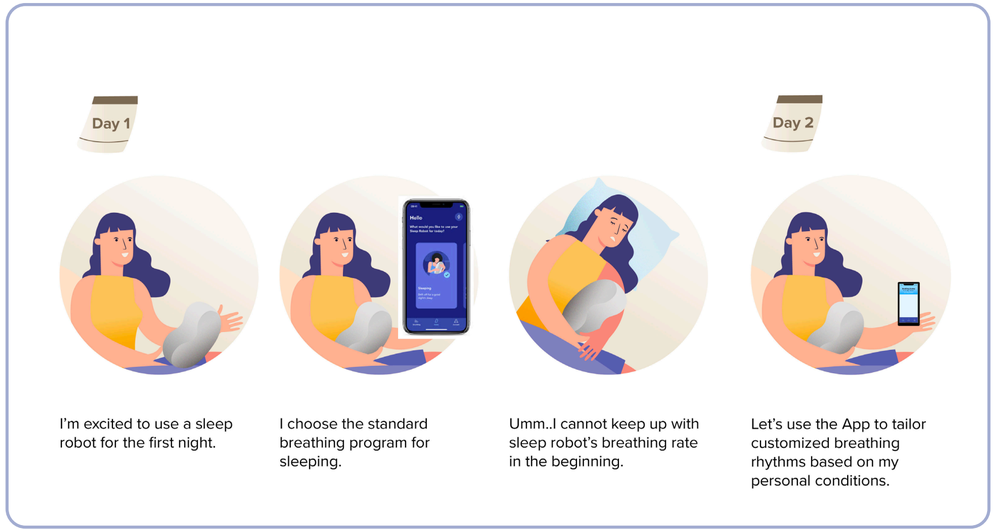


Figure 46. Scenario 1

Scenario 02

After using the first customized breathing, users found they could not breathe as slow as their sleep robots. Because users recently are anxious about getting infected with the COVID-19 during the pandemic. (Figure 47)

- Try out the prototype to customize second breathing rhythm
- What will you do to tackle the problem in the Application?
- I feel guided through self-measurements (sleep condition and breathing rate) to tailor new customized breathing. Why?
- I feel insecure to use the new customized breathing after realizing the first customized breathing is not good for me. Why?

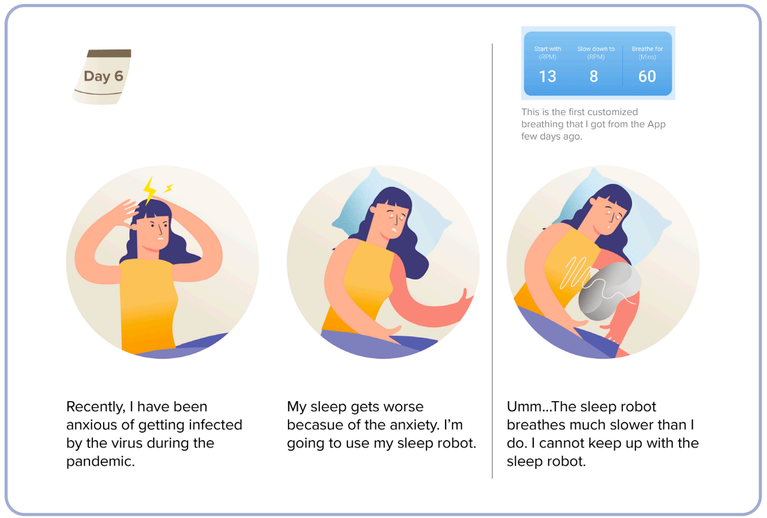


Figure 47. Scenario 2

Scenario 03

After using the second breathing rhythm, users thought the breathing rhythm was good. However, users feel tense and guess they may not sleep well tonight because they do not receive the important call in the morning. (Figure 48)

- What will you do in the App when you guess you may have a poor sleep tonight?
- I feel guided to tailor new customized breathing which adapts my personal conditions (for example, tense or insecured). Why?
- I feel relaxed to tailor new customized breathing when I have uncertainty whether my sleep quality will be tonight. Why?

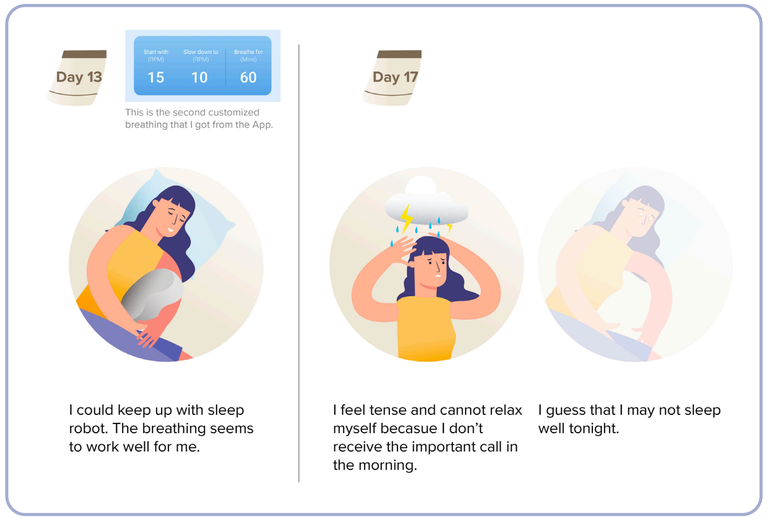


Figure 48. Scenario 3

Scenario 04

After users tried out three customized breathing, users start wondering what the optimized breathing rhythm is. To appreciate users' hard work on experimenting with different breathing, breathing exercises are provided to them as rewards. (Figure 49)

- Could you explain how you get the optimized breathing rhythm in the new App? Why?
- I feel confused to get the optimized breathing rhythm while reading the history. Why?
- I feel at ease to get the optimized breathing rhythms after trying out 3 customized breathing rhythms. Why?
- Participants try out the breathing exercise in the application.
- I feel guided to reflect on the causes of my poor sleep when selecting a breathing option. Why?
- I find it difficult to choose provided breathing programs. Why?

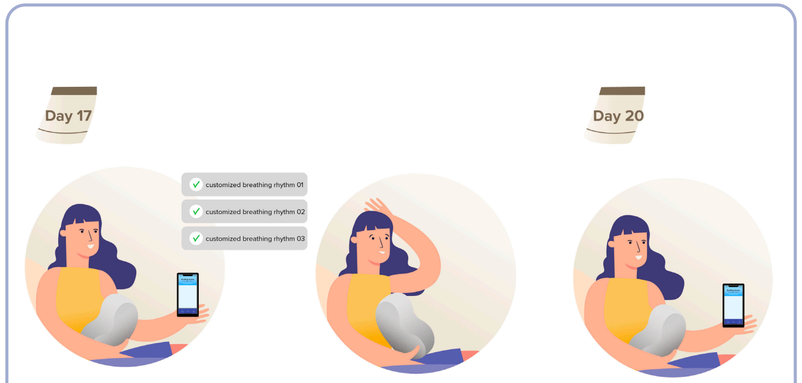


Figure 49. Scenario 4

Scenario 05

After using the optimized breathing rhythms for a few months, users have slept well. However, users' emotions unexpectedly change, and sleep qualities also differ. (Figure 50)

- Overall, I feel at ease to try out different breathing in the application. Why?
- What are the pros and cons of using this new application design?
- What would you describe to introduce this new application to other users?

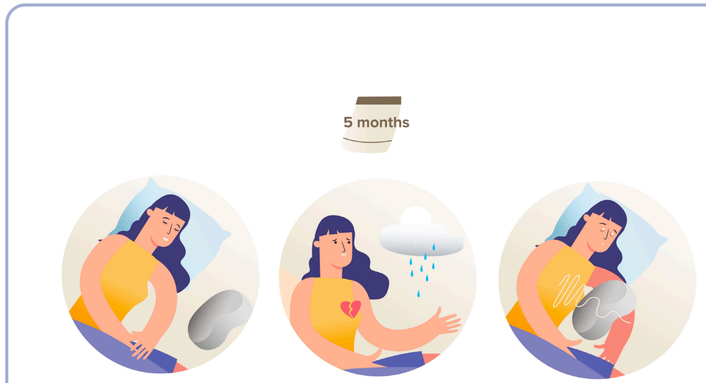


Figure 50. Scenario 5

6.2 Results

Demographics

Seven participants (Figure X) were recruited to join the online user testing sessions via Zoom. The age of the participants ranged from 25 to 70. Four participants were the users of the sleep robot; the rest of the three participants were not the current users of the sleep robots. For those three participants, the sleep robot's function and application were walked through to understand the sleep robot system better. Two participants have profound knowledge of data and meditation, respectively. The other participant was the potential user of the sleep robot; the participant has already physically experienced the sleep robot for both sleep and relaxation.

Executive summary

The summary of the evaluation results includes three parts: " what went well?" "what did not go well?" and " other findings." First, the summary concluded " what were the positive outcomes from the evaluation?", " what features did participants appreciate?" and " what original design assumptions were validated?". Second, summarizing what did not go well, for example, " what major issues were found?". Third, noting down, " were there other useful insights taken from the research that was not necessarily good or bad?" as other learnings.

The analysis was done in an excel sheet and Miro; the details of the analysis phase were documented in Appendix X.

6.2.1 What went well?

Getting customized breathing

Design hypothesis: Getting customized breathing for sleep through self-monitoring of sleep condition and breathing rate, letting users feel guided and at ease.

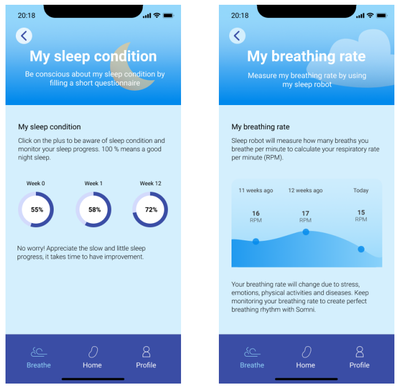


Figure 51. Self-measurement and tangible feedback

Self-measurement gives guidance and drives self-study

Self-measurement of personal condition, including sleep conditions and breathing rate, let participants better understand setting breathing rhythms and themselves. (Figure 51)

" The general flow gives me more guidance and I felt worth trustful because I filled in my condition. The App analyzes it and gives me suggestions based on my conditions."_P2
"It makes sure that you do the self-study instead of just doing self-measurement. "_P6

"I would much likely to go through the steps rather than adjust it with my hypothesis in the current App. The guiding process of flow does not hand over me, instead it feels informative and clear. You're not begging the head of people for white paper information. But you are giving people the opportunities to understand the influences on their sleep. It feels like the App is trying to justify itself and telling people how is the App going to use the

Increased transparency on how the sleep robot do to users

The personal measurement itself gives participants a sense of trust and transparency about how the sleep robot does for the users in the breathing aspect. The concrete results from the measurement gave the participants a feeling of personalization and tangible feedback. (Figure 51)

" After trying out the new App, I get to know my sleep and breathing rate, therefore, I think it is much helpful because I can know what my breathing is. I don't have a mental load in the new design. I have more confidence in doing (new design) rather than thinking (in the existing App)."_P3

"The proposed one is clever because the user is setting initial conditions from the calculating, and a flow that helps users calm down and go to sleep. It is clear that there is a measuring period and executing period."_P6

Different levels of control (follow or overwrite)

The needs for controlling information or decisions differ from user groups. Senior users prefer to follow the recommended steps and suggestions, and users with higher tech-literacy require a higher level of control. (Figure 52)

The flexibility to tailor breathing rhythms is well considered to control the information. (Users could use the customized breathing rhythm, but also can manually adjust it)

"If the setting doesn't work, I would manually overwrite it. It is important that I can control the decision."_P5

"In these two phases, I tried out 3 customized breathings, but it is not adjusted by myself. It feels like feeding (analogy) by the App. I would expect to manually change it sometimes."_P4

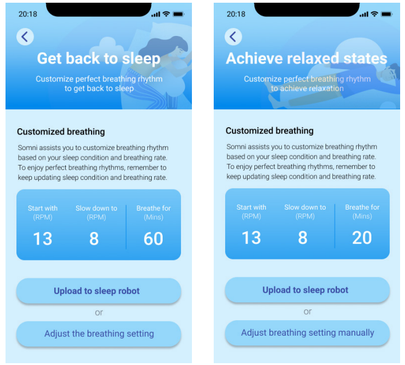


Figure 52. Custimized breathing (automatically or manually)

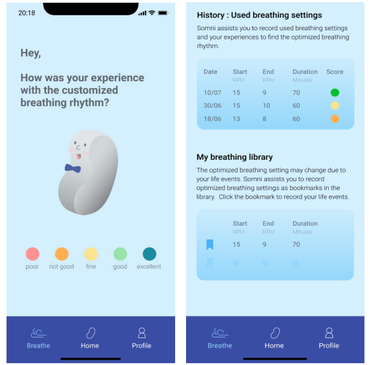


Figure 53. Rating system and optimized breathing

Getting optimized breathing

Design hypothesis: The journey to get optimized breathing through self-monitoring and rating is secured, and the needs differ from personas.

A proved action enhances the security of trying a new thing

A proof lets users feel secured and reduce the uncertainty to try and explore new breathing rhythms.

"It is much easier because you don't know what the starting rate is and optimal breathing rate is. So you need to try and error in the existing App. And now probably it will be much easier to get an optimal breathing rate. So I prefer to use the new option._P7"

"I feel secured to use the new customized breathing and know that the first customized breathing is no longer fit me because it is validated by the system" _P6

"It validates my perception of reality through doing self-questionnaire and measurement, which makes me more secure to use the new customized breathing because it validates my perception and experiences. it is a reinforcement of how I perceive life"_P6

Optimized breathing has different interpretations

From the evaluation, it is evident that participants had different interpretations of the optimized breathing. Senior users defined optimized breathing as fixed and stable breathing rhythm, and users with high-tech literacy perceived optimized breathing as dynamic rhythms that adapt to their changed conditions. (Figure 53)

"I would like to get the optimized breathing in a week. If I find it, I want to keep it. I took a week to find the currently optimized breathing. If I found it (breathing rhythms of sleep robot) less or more, I adapt to it. "_P5

" I would accept the best one after three measurements, but I would love for my optimized one to keep updating based on any upcoming measurements that I take. I would love the optimized breathing changing over time."_P6

Getting contextualized breathing

Design hypothesis: Getting contextualized breathing by reflecting causes of poor sleep is guided. Having contextualized breathing by selecting a breathing exercise is relaxed.

Selecting breathing goals based on causes of poor sleep is guided and connected

Participants started reflecting on what were the sleep obstacles while choosing the provided options (mental and physical obstacles); thus, they felt guided on categories and connected when the options resonated with them. (Figure 54)

" I feel guided to reflect the cause of my poor sleep when choosing the obstacles. I choose to settle a busy mind because when I wake up during the night, it is always something in my mind that I cannot get rid of."_P1

Breathing exercise as rewards after self-experimenting is a positive reinforcement

It was a motivated and pleasant experience to get breathing exercises as rewards because they want to try something new after finding the optimized breathing rhythms. (Figure 54)

"I love it! such positive reinforcement. This (mental/ physical obstacles) is awesome. The physical obstacles are something that Fitbit cannot do...I will pick all this at different times."_P6

"I think it is easier to try out and maybe to make me use the App more."_P7

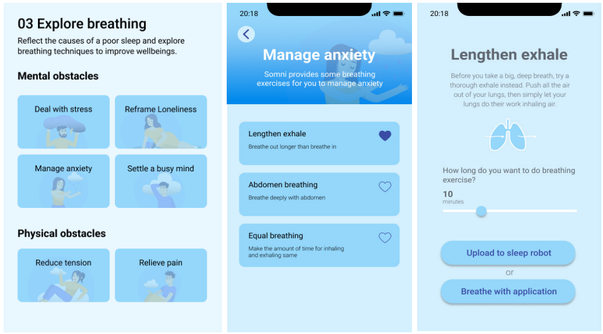


Figure 54. Sleep obstacles, breathing goals, and breathing exercises

6.2.2 What did not go well?

Getting customized breathing:

Users were not clear about the mechanisms of tailoring breathing rhythms for relaxation

When evaluating the prototype with the second and third scenarios, some participants confused about tailoring breathing rhythms for the relaxation because of the unclear user flow and information. (Figure 55)

"I thought customized breathing was only for sleep because (after measuring RPM) the screen directed me to sleep. I don't know how it works for relaxation."_P7

"I don't feel guided to create new customized breathing because of the lack of information on mechanisms of tailoring breathing for relaxation and the risk to overwrite existing sleep breathing rhythms."_P6

Getting optimized breathing:

Lack of information on optimized breathing

Users do not fully realize they could get optimized breathing while trying out different customized breathing and rating them because the information that participants had was not sufficient. (Figure 55)

"I missed the information that I needed to try out at least three customized breathing in order to get the optimized one."_P2

Adjustment: In the rating screen, the app could help users to understand they can get optimized breathing by rating their experience on used customized breathing.

Getting contextualized breathing:

The mental obstacles are somehow overlapping

The distinguishment among mental options is a bit difficult; users may feel anxious about which option they should pick. Therefore, users may need to prioritize their obstacles while choosing one option. (Figure 55)

"If I get anxious, I probably have no clue about mental obstacles."_P6

"I think" deal with stress" and "manage anxiety" are related. Because when I feel stressed, I feel anxious. When I feel anxious, I feel stressed. I cannot clearly distinguish the two options."_P2

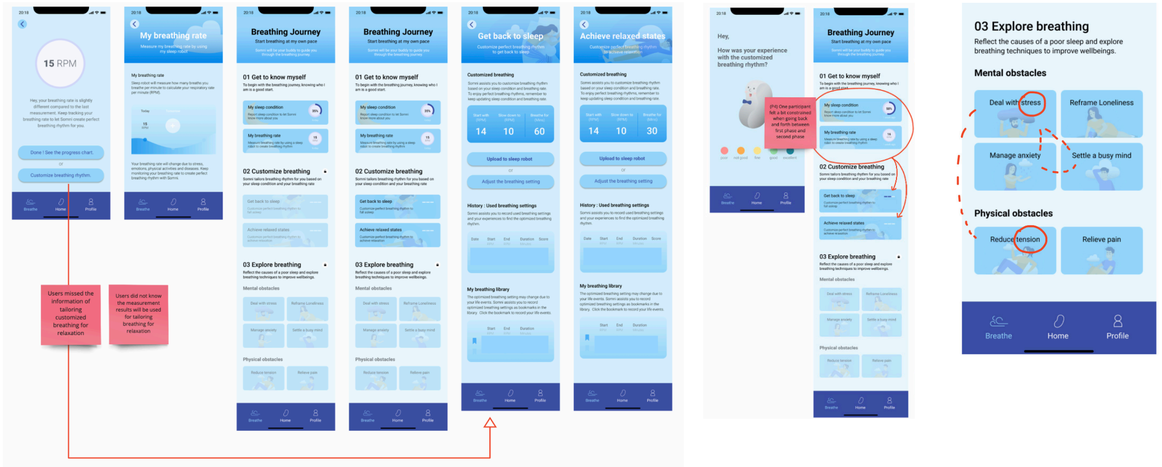


Figure 55. What did not go well

6.2.3 Other learnings

Unveil breathing rate for users

A number to represent users' breathing rate is still too abstract for people to understand. A breathing pattern over time may help users to interpret and learn from it. (Figure 56)

"It could refer to the Fitbit relaxation mode. Showing users what breathing rate looks like by plotting a graph over time and people can visually compare their breathing rate between relaxation and anxiety."_P6

"I became tense as the breathing is increasing (when seeing the progress chart)"_P1

It is essential to reconsider what information is necessary to provide for users. For example, whether users need to know the information, or they breathe with the sleep robot without knowing some information. (Figure X)

Participants were wondering "is this my breathing rate?" Or "is this the breathing rate that I'm going to breathe?".

The mechanisms of calculating optimized breathing

Most participants questioned the mechanisms of getting optimized breathing rhythms, such as how the collected data be processed to recommend optimized breathing. (Figure 56)

"But I would have a bit of doubt on the optimized breathing setting because sometimes my condition is extreme, for example, I'm stressed. And the system recognizes the breathing setting that works for my stressed condition as an optimized one but it is not the condition that I would always have. It is not a regular condition that I would encounter."_P2

"The App didn't take into account the variety of daily experience. The rating system is considering the average experience of the usage instead of the daily base."_P7

Non-linear breathing journey provides flexibility, but lack of guidance

Participants chose different paths to get new breathing settings. In scenario 3, for example, there were three paths to get new breathing, two participants chose to measure breathing rate for tailoring breathing rhythms of sleep, one participant selected to measure breathing rate for tailoring breathing of relaxation, and the rest participants opted for the relaxation program without measuring breathing rate. (Figure 56)

P1 and P7 chose the first path because they only used the sleep robot when going to sleep. P6 chose the second path because that is what Fitbit does. P4 selected the third path because P4 did not want to overwrite the breathing rate, which is already suitable for sleep. It was apparent that the non-linear breathing journey has its flexibility to satisfy users' different needs.

Participants did not always know there are different paths they could choose when encountering the problems as shown in scenarios. For instance, in scenario 2, there are three paths to tailor customized breathing, including measuring the current breathing rate to tailor breathing for sleep, measuring both sleep condition and breathing rate to tailor breathing rhythms for sleep, or manually adjusting breathing rhythms in the sleep program. (Figure X)

" How am I going to get a new one? There are quite some options (3 paths), I don't feel guided there."_P4 (scenario 2)

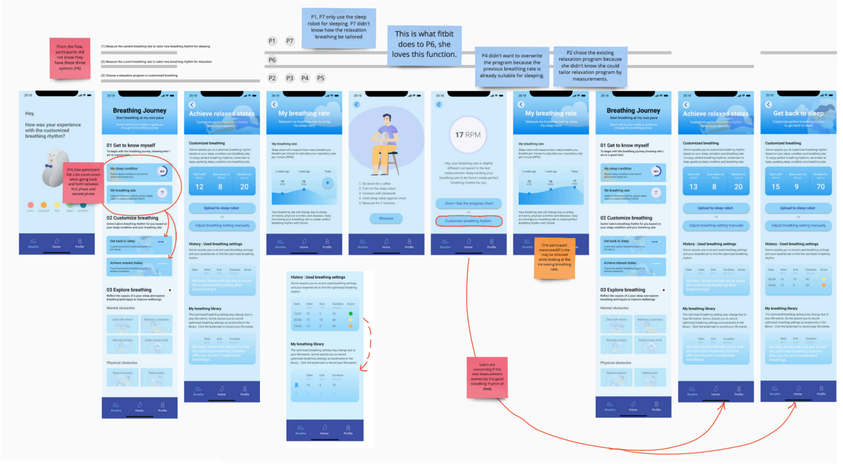


Figure 56. Other learnings

6.3 Adjustment

Having an understanding of what did not go well, this subchapter proposed to adjust two core components of tailoring customized breathing and optimized breathing.

First, as participants reported, they did not know they could tailor breathing rhythms for relaxation by measuring breathing rate. Besides, when participants found a suitable breathing rhythm for sleeping but felt tense in the day time, they did not want to measure the breathing rate to tailor breathing rhythms for relaxation. Because they did not want to overwrite the breathing algorithms.

To solve this concern, an adjustment was made on the screen after measuring the breathing rate. Users could decide whether they want to use the updated breathing rate to tailor breathing rhythms for sleeping or relaxation. Therefore, users could have a clear picture of how to tailor breathing rhythms for both sleep and relaxation. (Figure 57)

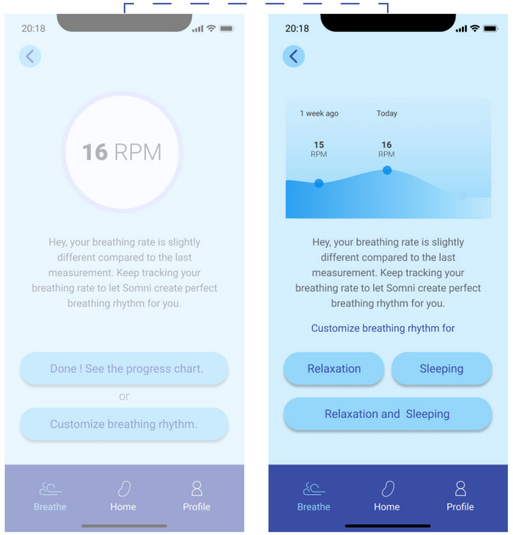


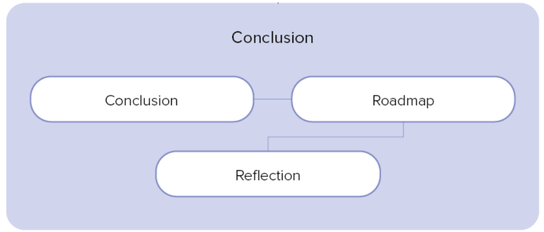
Figure 57. Adjustment

Takeaways

- Participants found it confident and guided to get customized breathing through self-monitoring and self-study.
- Participants appreciated contextualized breathing exercises as rewards because it worked as a positive reinforcement to encourage self-experimentation.
- Using scenarios to evaluate user flows surprisingly uncovered hidden issues, for example, an unknown mechanism of tailoring breathing for relaxation.
- Senior users tend to follow the instructions and maintain the optimized breathing, while younger users require a higher level of control and favor dynamic and adaptively personalized breathing rhythms.
- The concept of showing the number of breathing rate could be abstract for new users to understand. A visual comparison of breathing between relaxed and stressed conditions could help users realize the breathing rate.
- Non-linear breathing journeys brought flexibility to satisfy different users' needs but lacked guidance to start a new breathing journey.

7.Conclusion

Chapter 7 concludes what the key findings that answered research questions and design goals are. Afterward, it indicates the limitations and contributions of this study. Moreover, I illustrated a roadmap of the proposed concept for future work. In the end, I wrote down personal reflections of the design process.



7.1 Conclusion

Problem statement
The initial aim of the project is to help users to make optimal use of Sleep Robots by creating a data-enabled loop. Because most users stuck to the factory sleep breathing program and found it hard to adjust the breathing setting manually. Second, the adaptive breathing mode, which detects users' breathing and reacts to it accordingly, does not work well due to the limitation of sensing technology. Users could not experience optimal breathing rhythms with full considerations of personal breathing patterns.

Looking at current sleep solutions on the market (Ch1), data-driven resolutions have become significantly important due to inaccessible, unconscious, and complicated sleep activities. Though Sleep Robot has sensing technology of breathing, it does not has sufficient, reliable data and a holistic data loop to understand users' sleep activities and individual needs.

Answers to research questions
- How to help users to make better use of Sleep Robots according to individual needs on improving sleep?

First, chapter 2 reviewed personal informatics, sleep-sensing technology, and breathing products. Compared to other products, sleep Robots have low accuracy on breathing data collection and result in a low level of personalization. It reveals the direction of being data-driven and personalized to fulfill individual needs.

Second, the user research (Ch3) found that the element" self-experimentation" is substantial for users to find a better-personalized breathing rhythm. However, quite some users found it challenging to start self-experimentation of breathing settings on the current sleep robot system because of the lack of support and feedback. Thus, the aim of the project was scoped on stimulating users to try out different breathing settings with sufficient guidance and ease.

Answers to design goals
- Let users feel at ease and guided during self-experimentation in order to explore (more) breathing settings for individual goals on improving sleep.

(Ch4) Three concepts were developed and tested during the ideation phase to verify if the design components leveraged guidance and ease. Four design elements were verified: step-by-step learning experience, measurement of dynamic breathing rate, breathing rhythm recommendations, and contextualized breathing exercises. These four essential elements were integrated into a breathing journey within the breathing panel of the mobile application.

(Ch5) The final proposed design is to stimulate users to try out different breathing rhythms and tailor personalized breathing rhythms in three levels (customized breathing, optimized breathing, and contextualized breathing) through the design of an interactive data loop.

Chapter 6 evaluated the design hypothesis by creating an interactive prototype and user scenarios. Participants found it confident and relaxed to explore different breathing rhythms with guided and transparent steps. Besides, participants identified the issues of the user flow for tailoring relaxation breathing rhythms. That was addressed with the design adjustment at the end of chapter 6.

Limitation
Due to the limited time and remote evaluation, the time aspect and immersive interaction of using the proposed design could not be adequately tackled. For instance, participants could not experience sleep condition monitoring and breathing measurement in real life over time. Thus, the research could not capture more abundant data while users interact with the proposed ecosystem of the sleep robot. For future work, Somnox could send the proposed design to users and investigate how users interact with it with a holistic view.

Contribution
With the comprehensive research and design solutions in three levels of personalized breathing rhythms, the project contributes to the company and the academic domain in the following aspects.

The literature review helps to define the position and trade-off of the Sleep Robot among sleep and breathing products. It identifies the future directions of providing personalized experience in improving sleep.

The user research applied a data-enabled methodology on investigating the interaction between users and the Sleep Robot system. The collection of subjective and objective data provides a broader spectrum of gathering rich contextual experience. It could act as the foundation for conducting sleep research in the company and academic domain.

The proposed design envisions the transition role from standardized breathing toward synthesized breathing with a high level of personalization. Before achieving full personalization, the proposed design serves as the media to construct a data loop for leveraging breathing algorithms and satisfying individual needs.

7.2 Roadmap

Future work (Roadmap)
To better communicate desired outcomes and milestones of tailoring breathing rhythms and reach them, a roadmap is plotted with considerations of users' needs, business goals, and technologies. The roadmap consists of three phases within five years, shifting from setup to adaptation, and ultimately to personalization. (Figure 58)

The first phase is about building a data warehouse to support breathing algorithms by aggregating data from different sources, such as the sleep robot, application, and website, into a data store. Meanwhile, a workbook for self-experimentation on breathing setting will be designed to guide users to find better breathing rhythms according to their sleep behavior and breathing patterns. The next substantial step is to provide a breathing consultancy service, which refers to objective data from a data warehouse and subjective data from users' workbooks. With this service, users could enjoy better breathing rhythms for better sleep, and Somnox could determine the crucial variables which highly influence breathing experience. After having a holistic view of how users self-experiment with the breathing settings, a report could be documented to handover the second phase of the roadmap.

The second phase focuses on the adaptation of breathing algorithms. The breathing algorithms could be improved by objective and subjective self-experiment data from the warehouse and workbooks, respectively. Apart from previous self-experiment data, the data of users' breathing rate and sleep could be integrated to empower breathing algorithms. To collect users' breathing rate, it is necessary to develop a breathing measurement function for a sleep robot. Furthermore, to collect sleep data, questionnaires and wearables are the primary means.
Regarding gathering the data, the General Data Protection Regulation is highly suggested to investigate. At the end of this phase, the feature of tracking data on the application will be released to add more value to users as a guideline of self-study. Last but not least of the second phase, breathing exercises that solve particular sleep obstacles will be researched and validated.

The third phase emphasizes personalization, which is the trend of the healthcare domain. To achieve that, more reliable and streaming data from sensors should be collected to perform synchronized breathing rhythms better. For example, data from a microphone sensor that detects snoring while sleeping could reinforce with data from the accelerometer. Because it can increase the reliability and accuracy of sleep sensing technology, besides, users could access the breathing exercise with particular effects on sleep obstacles and approach the sleep robot system more in the daytime. Thus, the application will shift from the role of a guideline to a 7-24 tool.

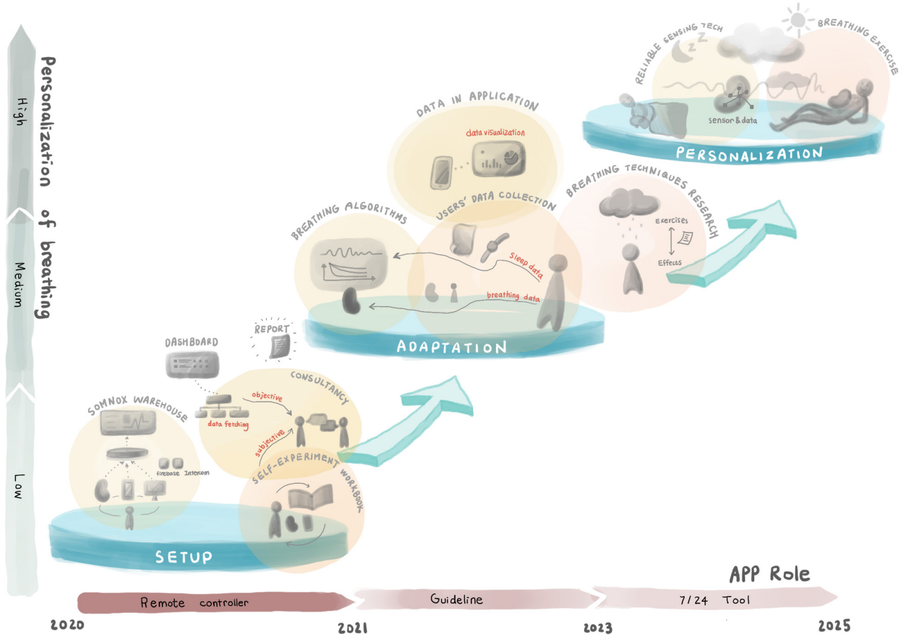


Figure 58. Roadmap

7.3 Reflection

As a designer, I love to reflect on the design journey and document the impressive learning moments to seek a better strategy for enhancing inadequate qualities and sharpening my strengths. (Figure 59)

R1: Make the scope specific and concrete
At the beginning of the project, I focused on the entire sleep data system, including collection, analysis, visualization, and personalized insights. However, the focus was too ambitious within the limited timeframe. Supervisors suggested me to be specific and concrete on the research; thus, I discussed with the Somnox team to scope down the focus on the breathing aspect.

R2: Consider necessity of research
Though utilizing sensitizing diaries, fetching data were impressive to obtain rich information. It took an unexpected time to accomplish. That provoked a reflection on considering the necessity and effectiveness of using a particular approach. Besides, it triggered me to question the research, " Do I need this information?" " If so, how am I going to use the gathered information?.

R3:Analyze data to answer questions
After gathering information, I blindly listed the findings and insights. The logic line was cut due to the activity. In order to patch the logic line of the research, I was suggested to re-analyze the data and to answer the research questions. This process reminded me to keep research questions in mind when doing research.

R4: Talking with people facilitates reframing
I created a user joureny map after analyzing the user research. I illustrated what I found and talked to people, people's questions provoked me to think and the discussions reiterated my thoughts. Suprisingly, the activity assisted me to summarize the key findings and reveal the design focus.

R5: Blending strategy is gray area
It was difficult to describe the blending strategy from small ideas to three concepts because the process is not transparent by trying and erroring the combinations of ideas. To ensure the authenticity of the combinations, I sought inspirations from the design analogy, which is brewing my favorite flavor of the coffee. I did experiments on coffee brewing outside the research context to capture the sense of design.

R6: Balance between intuition and rationale
From the extensive user testing results, I was not able to decide on a design direction. Thus, I revisited the connection between the design hypothesis and user feedback to extract the verified design elements which could contribute to the design goal. The process

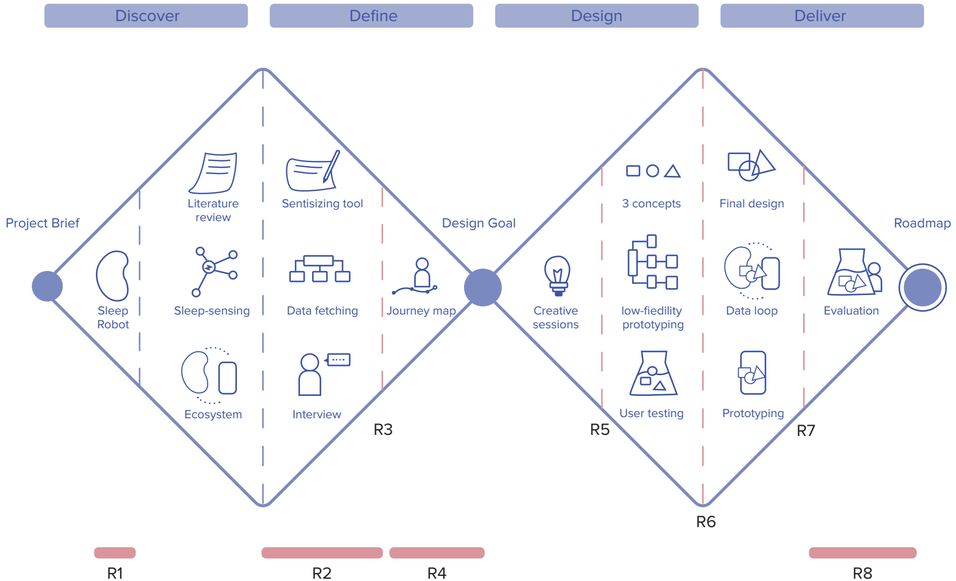


Figure 59. Reflection on the design journey

gave me a lesson: user testing is not only for iteration, but the evidence to support my design decisions. As a designer, it triggered me to strike a balance between intuition and proved rationale.

R7: Immerse myself to create scenarios

After proposing a design with verified design elements and assumptions, I mapped out the risk assumptions that were crucial to be validated. I intended to focus on testing the UX flow; however, the created evaluation plan tended to verify the user interface. Through immersing myself in using the design, I mapped out the possible user scenarios that users may encounter.

R8: Optimize the use of design tools

I was quite fulfilling using accessible and useful online design tools such as Figma, Maze, and Miro. It helped me to lubricate the flow of online user testing, user testing analysis, and communications with collaborators. These tools not only make the design process efficient but also sustainable.

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Appendix B

Sleep Diary for user research (Chapter 3)

DAG 1 (dd / mm)

Beschrijving van mijn slaapproblemen:

Hoe ziet mijn kamer eruit?
(schets of neem foto's van uw slaapomgeving)

Mogelijke oorzaken van mijn slaapproblemen:

Zo beïnvloeden mijn slaapproblemen mij:

P.3

DAG 1 (dd / mm)

Ik stond vanmorgen op om: _____

Ik ben naar bed gegaan om: _____

Totaal aantal slaapuren: _____

Mijn dagelijkse activiteiten: (werk, cafeïne,maaltijden hebben, oefening, gebruik elektronica, lezing, gebruik een slaaprobot en de App, televisie, douchen gegevens verzamelen over smartwatch...)

Activiteiten: Wat moet ik vandaag doen?	Activiteiten:
Stemming / Gevoelens: Hoe ervaar ik het?	Stemming / Gevoelens:
Redenen: Waarom ervaar ik het zo?	Redenen:

Mijn bedtijdroutine:

Ik val in slaap:

erg makkelijk — makkelijk — normaal — moeilijk — erg moeilijk

Ik werd wakker gedurende het slapen:

vaak
minuten

Mijn slaap werd verstoord door: (mentale of fysieke factoren)

Slaap score: (1-10)

Toen ik wakker werd, voel ik me...

P.4

DAG 2 (dd / mm)

Slechte slaap is voor mij...
(gebruik tekst, afbeeldingen of tekeningen om het uit te leggen)

Goede slaap is voor mij...
(gebruik tekst, afbeeldingen of tekeningen om het uit te leggen)

P.5

DAG 3 (dd / mm)

Wat heb ik gedaan om mijn slaapproblemen op te lossen?

- ☐ yoga
- ☐ oefeningen doen
- ☐ volg mijn slaapgegevens
- ☐ slaap medicijnen
- ☐ melk drinken
- ☐ anders: _____

Wat waren mijn verwachtingen toen ik de slaaprobot kocht?

Hoe heb ik mijn slaaprobot de eerste twee weken ervaren? (slechte ervaring / goede ervaring)

Slechte ervaring met mijn slaaprobot:
(gebruik tekst, afbeeldingen of tekeningen het uit te leggen)

Goede ervaring met mijn slaaprobot:
(gebruik tekst, afbeeldingen of tekeningen het uit te leggen)

P.7

DAG 4 (dd / mm)

Ademhalingsoefening helpen mij om ___ te bereiken ...

Ik heb ademhalingsoefening nodig als ik dat ben...

Hoe was de ervaring met het synchroniseren van je ademhaling met een slaaprobot?

Metafoor van ademhaling:
(gebruik tekst, afbeeldingen of tekeningen het uit te leggen)

P.9

DAG 5 (dd / mm)

Ontspanning helpt me om ____ te bereiken...

Ontspanning

Ik heb ontspanning nodig wanneer ik _____ ben

De manieren om mij te maken ontspannen zijn ...

Metafoor van ontspanning:
(gebruik tekst, afbeeldingen of tekeningen het uit te leggen)

P.11

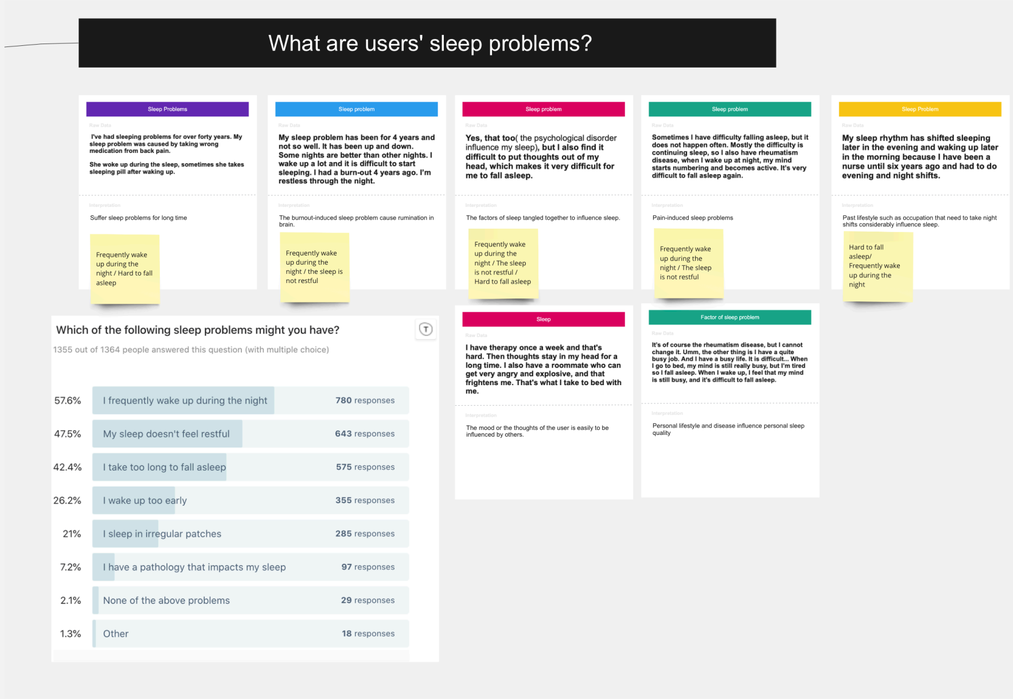
DAG 6 (dd / mm)

Hoe kan ik de betere versie van mij zijn door mijn slaaprobot te gebruiken?
(gebruik tekst, afbeeldingen of tekeningen het uit te leggen)

P.13

Appendix C

Analysis of user research (Chapter 3)



What do users want to achieve by improving sleep?

Sleep Goal

Raw Data

But I don't need to do that (use SR) twice a night anymore. I still take medication and I want to get rid of it.

Interpretation

The sleep has been improved, however, it is not a desired sleep for her. There is still a way to get rid of sleeping pills.
The improved sleep could become a good sleep.

Be independent

Be autonomous

Sleep Goal

Raw Data

Bad sleep is unhealthy for the body. That's why I want to improve it.

Interpretation

Be healthier

Sleep Goal

Raw Data

I mostly wake up through sleep around 2:00 am. Sometimes it takes one hour to sleep again. I'm trying to sleep better. That's my main motivation. Sleep better is becoming easy for sleep. Wake up less frequently through the night.

Interpretation

The less wake out through the night is a desire sleep. How much time do the user wake up though the time would be a useful information for the user.

Sleep Goal

Raw Data

If I sleep better, I am a better person. Creative inspiration: I can be more inspired to make things. I like to make things. More patience:Well..sometimes, I was too impatient. I want to be fast with myself or with my son. If I am more relaxed, and think it should be fine.

Interpretation

Being creative, inspired and patient are the goals to achieve by having a good sleep.

Be creative

Be patient

Remain good relationship

Be productive

Relief

Sleep Goal

Raw Data

Waking up rested with energy to start the day freshly

Interpretation

Energy

Refreshment

Secured

Stable mood

Erase fear

Sleep Goal

Raw Data

To feel healthier. or in the morning that you have a rest or not tired. Or feel less tired at the end of the day. If you have a good sleep, then it's easier to continue work without feeling tired.

Interpretation

The user desires desire a good sleep to have better working performance, productivity and efficiency.

Be healthier

Productivity

Prepared

Achievement

Successful

A good night sleep

Raw Data

Making a specific amount of sleep hours, it's very personal how many hours of sleep you need. I do not mind being awake for one hour,

Interpretation

The user desires a sleep with less time of being awake as the amount of sleep hours is less when awake time is long.

Prepared

Develop biological clock

feel normal / regualr

What is a good sleep?

Sleep Goal

Raw Data

But I don't need to do that (use SR) twice a night anymore. I still take medication and I want to get rid of it.

Interpretation

The sleep has been improved, however, it is not a desired sleep for her. There is still a way to get rid of sleeping pills.
The improved sleep could become a good sleep.

No sleep pills

Sleep Goal

Raw Data

Sleeping all the way through hardly happens. I have no judgment about that, I don't worry about that anymore.

Interpretation

The user accepts the imperfect sleep, also appreciates her own efforts on improving sleep.

wake up less through the night

A good sleep

Raw Data

Period when I'm awake is short

Interpretation

the period of wake-up is short

Sleep Goal

Raw Data

I mostly wake up through sleep around 2:00 am. Sometimes it takes one hour to sleep again. I'm trying to sleep better. That's my main motivation. Sleep better is becoming easy for sleep. Wake up less frequently through the night.

Interpretation

The less wake out through the night is a desire sleep. How much time do the user wake up though the time would be a useful information for the user.

ease of falling asleep

wake up less through the night

peaceful

fresh

soft

quick wake up (no snoring)

Harmony

Sleep

Raw Data

I have therapy once a week and that's hard. Then thoughts stay in my head for a long time. I also have a roommate who can get very angry and explosive, and that frightens me. That's what I take to bed with me.

Interpretation

The mood or the thoughts of the user is easily to be influenced by others.

without bringing thoughts to bed

internally stable

Sleep Goal

Raw Data

Waking up rested with energy to start the day freshly

Interpretation

restness

refreshment

reflect on tackling negative mood

A good sleep

Raw Data

So it's not always the amount of sleep but the quality of sleep and what if you wake up at night, or feel good in the morning.

Interpretation

Couple of elements determine a good sleep

sleep hours

sleep quality

good feelings

reflect on work performance

Bad sleep and Good sleep

Raw Data

Interpretation

Productivity, focus, working performance is the significant driving force to improve sleep

A good night sleep

Raw Data

Making a specific amount of sleep hours, it's very personal how many hours of sleep you need. I do not mind being awake for one hour,

Interpretation

The user desires a sleep with less time of being awake as the amount of sleep hours is less when awake time is long.

A good night sleep

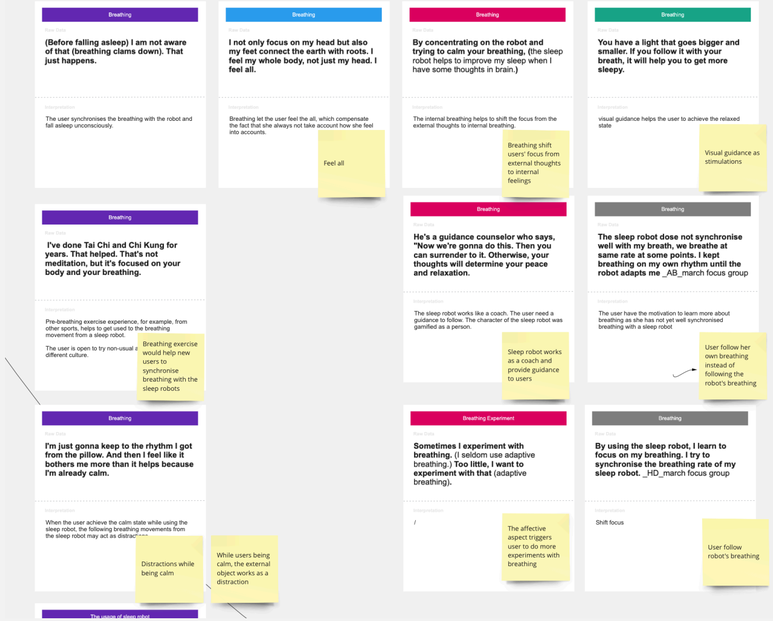
Raw Data

When I go to bed, I am awake for hours and I really feel very tired when I wake up: I always feel tired. This is mostly a problem when I have to go to work, because then I have to wake up early. If I am free, I can easily stay in bed until 12pm.

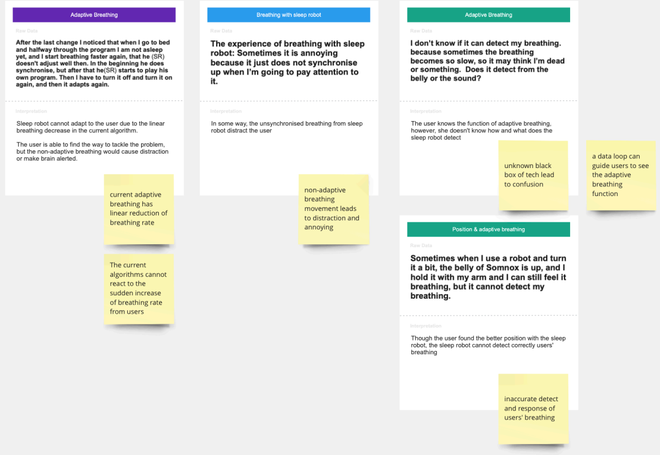
Interpretation

regular bedtime schedule

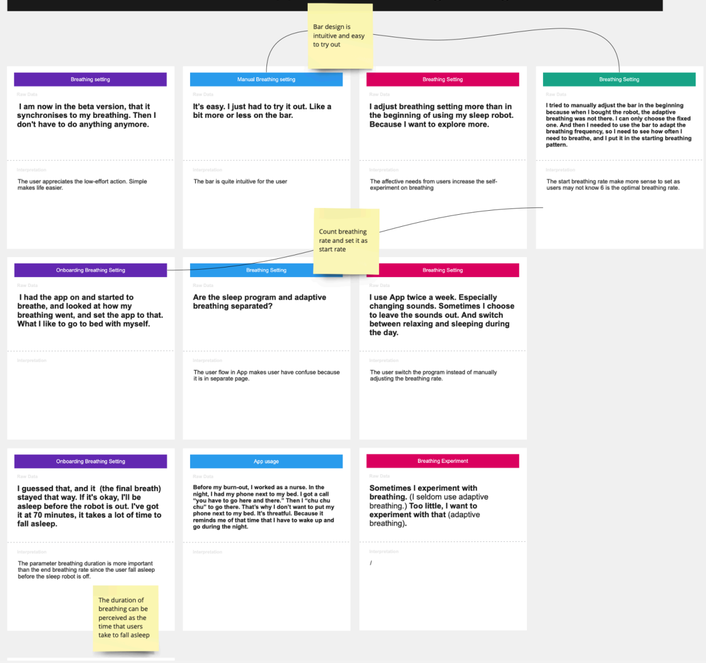
How do users experience the breathing with a sleep robot?



How does user experience adaptive breathing with a sleep robot?



How do users approach breathing settings ?



difference between participants and previous user research

What information do users need to approach breathing settings ?

Breathing

Raw Data:

I use the sleep and relax program because it makes sense. _RT_march focus group

Interpretation:

The displayed user goal on the program makes users more connected to the selection of program.

Breathing Setting

Raw Data:

I guess categories of sleep difficulties might help me choose the one that feels closest to my own situation. _Qestionnaire

Interpretation:

Choose the program let fits users' sleep problem would help to bring assurance of using the breathing program

Breathing

Raw Data:

The sleep robot dose not synchronise well with my breath, we breathe at same rate at some points. I would like to know more about breathing techniques _AB_march focus group

Interpretation:

The user have the motivation to learn more about breathing as she has not yet well synchronised breathing with a sleep robot

Breathing exercise will help to get used to SR

Breathing setting

Raw Data:

Through Somnox. I don't want too many different things for one goal. _Qestionnaire

Interpretation:

Somnox has to know what is the goal for users and design a simple way for users to achieve their goal

Having concise actions toward one goal

let users feel the program is closer to their own situation

Breathing setting

Raw Data:

I don't know about ratio. I always set the robot in adaptive breathing. I don't use the program. _RT_march focus group

Interpretation:

The limited knowledge let users go for the simple one. It takes lower cognitive load to set the breathing program

Visualise the breathing ratio

Desired Breathing Setting

Raw Data:

I want to set the moment (in-pause-out-pause) and explore the best setting for myself _AB_march focus group

Interpretation:

1. desire more dedicate setting
2. in meditation practice: pause can let body feel tension

Need detailed breathing setting

Breathing setting

Raw Data:

Beginner. It makes sense to start there. After getting used to it, I expect to prioritise Balanced, because over-thinking is an issue for me. _Qestionnaire

Interpretation:

The breathing program could be set into different levels, new user could start from the easy breathing, then unlock the next level (breathing program). Maybe it's a way to help user to unlock the level.

Start with beginner level

Breathing setting

Raw Data:

How do I manage the breathing settings correctly? I need more information. _HD_march focus group

Interpretation:

For manual setting, users may feel confused and uncertain to set the breathing

erase the confuse & uncertainty, give a feeling of assurance

Breathing setting

Raw Data:

I need to know the different patterns of the robot; if it is difficult for me to adapt to the robot rhythm, I would like to choose a different one. _Qestionnaire

Interpretation:

For example, showing the visual breathing ratio and breathing rates.

Preview of breathing program

the way of providing information

Raw Data:

A book or a website with all the info together is a lot of information all of a sudden: I wouldn't want that. I would prefer to be informed gradually in small snacks. _Qestionnaire

Interpretation:

Gradually provide needed information helps users to focus in specific thing

Gradually information flow

When do users use the sleep robots?

The usage of sleep robot

Raw Data:

When I'm very restless, I can't have much outside influence. Then I don't feel like it and I find it (SR) too heavy. Then he(SR) just irritates me.

Interpretation:

The user does not want to use the sleep robot when feeling restless, which was contradictory to the sleep robot that was aimed to design.
For the user, internally calm and stable come first.

Using Context

Raw Data:

Yes, I did it a couple of times in the evening. (Use a sleep robot outside sleep context) **So When I was sitting on the sofa, watching TV and I felt a little bit tense.**

Interpretation:

The user tried to integrate the sleep robot into her life in the evening (after a busy day), but these behaviours were hindered after she found there were some connection issues between App and sleep robot.

Freshness and excitement motivate users to explore more with the sleep robots.

Breathing

Raw Data:

That (changing breathing setting more than in the beginning) **has to do with me needing him more.**

Interpretation:

"Incubating needs and curiosity "
During the getting along with the sleep robot, the user find herself need more from her sleep robot. The pleasant experience or the curiosity triggers the user to explore her sleep robot more.

The usage of sleep robot

Raw Data:

I'm lying in bed and then I know if I want to use the sleep robot. One time it's right away and the next time it's after an hour. (P1 uses her sleep robot 4 days a week)

Interpretation:

The user also want to try on her own instead of relying on the sleep robot.

The effect of the sleep robot

Raw Data:

It helps me to fall asleep, also when I wake up at night and I need to fall back asleep again. so sleep a lot more and better now.

Interpretation:

The user turn on the sleep robot again when she wake up through night.

Desire from a sleep robot

Raw Data:

(It would be good to use a sleep robot during the day)**You're very alert during the day. I live in a care facility, and when you hear a different sound, you already sit up straight and think: what is that?**

Interpretation:

The uncertainty from surroundings keep the user alerted, she needs a support or relaxation to relieve the fear of uncertainty or to keep herself in stable mood.

using context

Raw Data:

I only use it in sleep (context) at night. I use 30 minutes in the night.

Interpretation:

The user prefers to do a lot of things in the day time, it may be hard for the user to stop and have a rest.

How do user react to sleep analysis?

Data-tracking

Raw Data:

Yes (I saw the data analysis), but I didn't get it. I think she calculated a lot, because that sleep efficiency indicates very low values. Because when I sleep, my efficiency is between 80 and 90%.

Interpretation:

When the data (sleep efficiency) was contradictory to what the user thought, the user may feel doubtful and trust more on how she experienced.

displayed data is different from what users thought lead to doubts

unsure about the definition of terms

Data visualisation

Raw Data:

Is my sleep efficiency normal? That makes the 50 percent.
(The data visualisation is not correct) **Oh.. I use the sleep robot every night.**

Interpretation:

The user feel a bit scared and doubtful from the displayed data because it is opposite to what she thought.

Data Visualisation

Raw Data:

It says here that I only use Johnnie three times, but I use him every day. I didn't fill that out properly..

Interpretation:

It seems that the user remember easily and clearly whether if she use the sleep robot or not in each day. Thus, she can quickly identify the data is wrong

Identify the inaccurate data

Data Visualisation

Raw Data:

I think it looks very interesting. And it's also bit comparable with Fitbit data except that you also provide your own opinion how you feel about your sleep and mood. And the only thing is now...It is flat and not interactive.

Interpretation:

Subjective experience would be appreciated.

when users have wearables, they will turn to compare the data that Somnox provides with the d device provide

subjective experience add one layer to data set

Data visualisation

Raw Data:

It's interesting. I didn't connect in that way. Yes it helps me to find out what are the factors of sleep.
I woke up at 5 am and I was turning and turning. Thus the score it's lower.

Interpretation:

Show the connection of data is important

help users to build the connection between what they do and how is the sleep

Data Information

Raw Data:

I think so (I could do something with the info of used breathing settings)**, because if, for example, a day doesn't go well, you can look back to a day when it did go well and see: maybe I should do it like this.**

Interpretation:

Seek what went well and not well, if it went well, it helps the user to adopt the strategy.

trigger users to do her sleep diary in analytical way

Data visualisation

Raw Data:

It may be interesting if you draw some conclusions there and teach people how it works.

Interpretation:

The user is curious what are the conclusion for the sleep data analysis.
She may miss the piece conclusion or wha

not just showing data, but draw a conclusion

Data visualization

Raw Data:

If you look at people who have difficulty to read graph, or abstract items. It would be especially interesting. For example, if people can look at the usage of a sleep robot, to compare the sleep score between a day with sleep robot and a sleep without a sleep robot.

Interpretation:

Everyone has their own way to interpret visual language, thus, the interpretation of an abstract icon would be very different.
A noticeable comparison may help users who have difficulty to read the graph to understand the message which is aimed to deliver.

provide (visual) guidance to look at graph

Data Visualisation

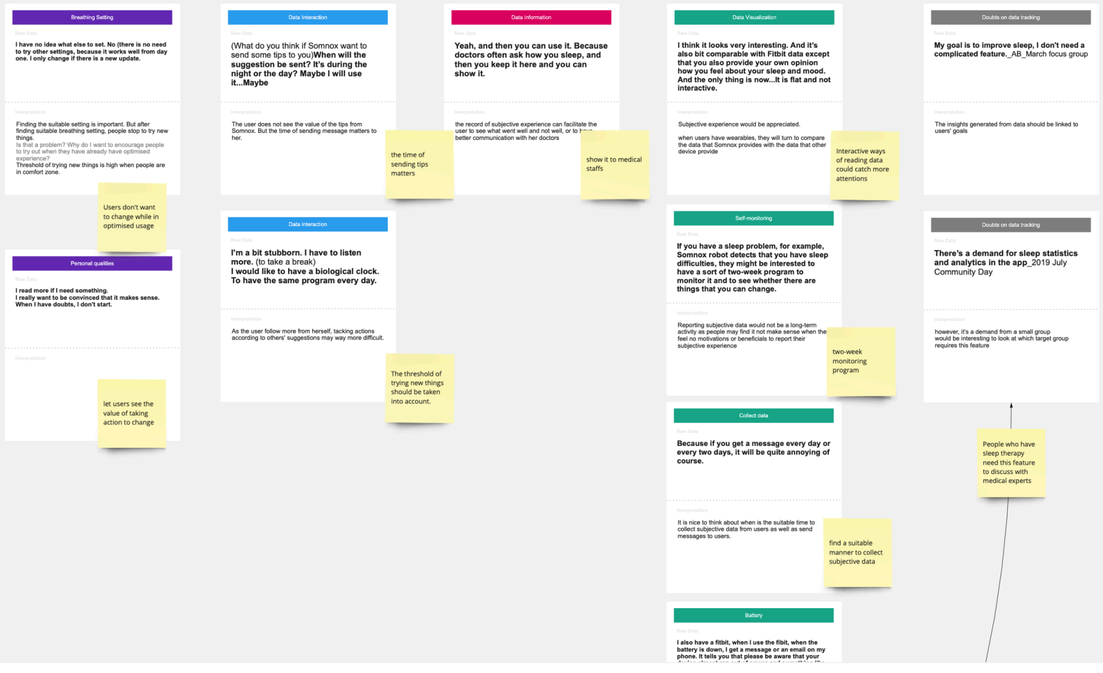
Raw Data:

What I also notice is that..I think might be several items that correlate quite a lot. For example, the mood after wake up and sleep score. I don't know if that is a case. But if you have a lot of data, you may see that the data correlates very high . It might also consider to leave one out and to even make it simple.

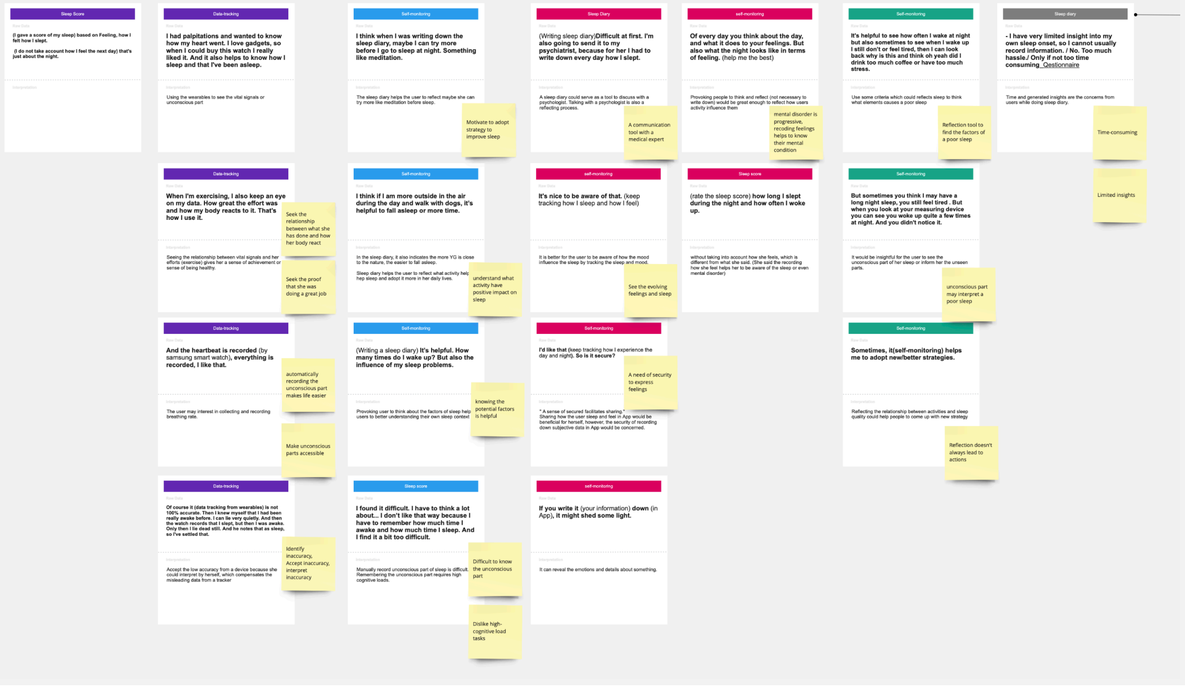
Interpretation:

The relationships among data could be done by Somnox, instead of letting users to interpret by themselves. Simple and concise data helps users to process the data

What are possible data interactions?



How is the experience of self-monitoring?



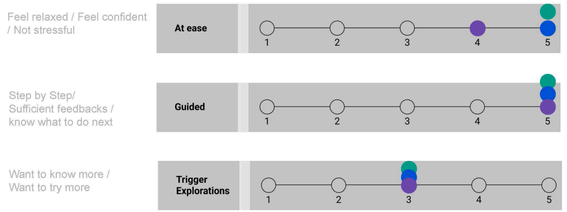
Appendix D

User testing protocol and analysis (Chapter 4)

Agenda

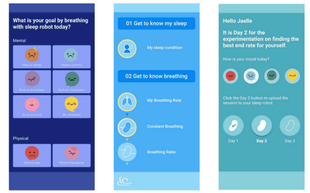
1. Introduction: 5 mins
2. Concept 1 : 10-15 mins
3. Concept 2 : 10-15 mins
4. Concept 3: 10-15 mins
5. Q&A: 5 mins

Concept _Feedbacks



Overview

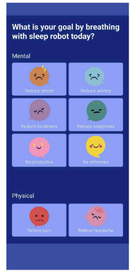
1. Jaelle tries three concepts (Wenying guides by voice)
2. Jaelle gives feedbacks
3. Note: The three concepts are not fully functioned (Beta version)



Concept 1

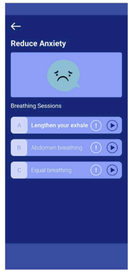
1. Specify the purpose of breathing / Other users / Breathing pattern
2. Jaelle tries the prototype
   a. I **have** had sleep problems and **felt anxious recently**, thus, I couldn't sleep well. I want to use the sleep robot to relieve and sleep better. **However,** I still feel anxious and **unsure about the used breathing setting.**
   b. Open the link
   c. Choose One option in page 7
   d. Go back to page 7 and try another option

P.3



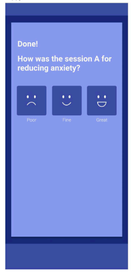
Choosing a goal of using sleep robot

P.4



Providing different breathing sessions for one goal

P.6



Reporting satisfaction of breathing session

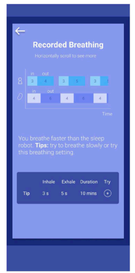
Concept 1_Feedbacks

- How do you think this concept help you (or not) to **explore different breathing settings**?
- What specific elements in the concept do you consider **useful** to help you find out the right breathing setting for you? Why?
- **What do you miss** in this concept to make you feel motivated to explore breathing settings **till you find your optimal**?

P.8

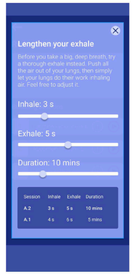
Looking what other user do / Using others' breathing settings

P.12



Recording breathing pattern / Suggestions from App

P.10



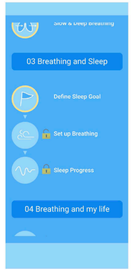
Having a list of used breathing setting

See prototype: https://www.figma.com/proto/fG0BM9uPIhDvxxt6KHo-QT8/3-concepts?node-id=1%3A5&scaling=scale-down

Concept 2

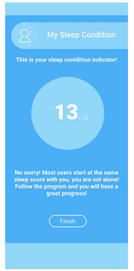
1. Make it like a game / Sleep score / Sleep progress
2. Jaelle tries the prototype
   a. **" I have been trying the sleep robot for few months, but I have limited feedbacks on how my sleep progress went and how breathing influences sleep"**
   b. Open the link

P.1



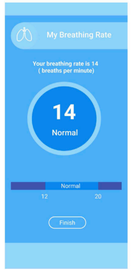
Unlocking programs into different phases

P.3



Filling a questionnaire to calculate sleep score

P.7

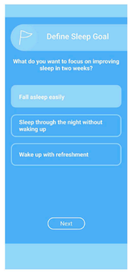


Measuring and knowing breathing rate

Concept 2_Feedbacks

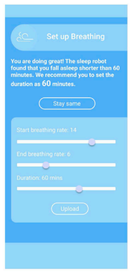
- How do you think this concept help you (or not) to **explore different breathing settings**?
- What specific elements in the concept do you consider **useful** to help you find out the right breathing setting for you? Why?
- **What do you miss** in this concept to make you feel motivated to explore breathing settings **till you find your optimal**?

P.14



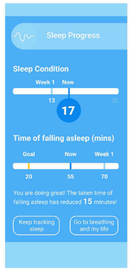
Defining goals

P.20



Getting suggestions based on the measurement from sleep robot

P.25

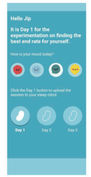


Knowing my sleep progress visually

See prototype: https://www.figma.com/proto/fG0BM9uPIhDvxxt6KHo-QT8/3-concepts?node-id=1%3A3&scaling=scale-down

Concept 3

1. Identify problem / generate a plan for experimentation / results
2. Jaelle tries the prototype
   a. **" I'm not satisfied and not feeling right about the breathing setting that I use. I think it is because of the end rate is too slow. How could I deal with this? "**
   b. Open the link
   c. Day 1: my mood is okay but not good
   d. Day 2:
      i. I feel a bit doubting about the setting
      ii. My mood is bad today

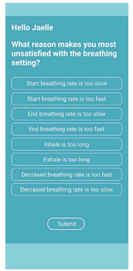


Concept 3_Feedbacks

- How do you think this concept help you (or not) to **explore different breathing settings**?
- What specific elements in the concept do you consider **useful** to help you find out the right breathing setting for you? Why?
- **What do you miss** in this concept to make you feel motivated to explore breathing settings **till you find your optimal**?

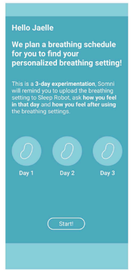
See prototype: https://www.figma.com/proto/fG0BM9uPIhDvxxt6KHo-QT8/3-concepts?node-id=34%3A173&scaling=scale-down

P.2



Reflecting the problems

P.4

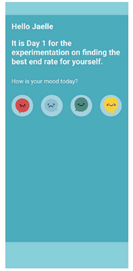


Generating a plan for experimentation

P.6

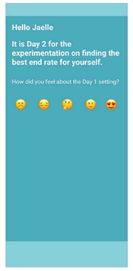
Adjusting plan

P.7



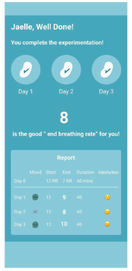
Reporting mood for proving experimentation

P.10



Reporting satisfaction on breathing settings

P.15



Getting a result / Reading report

Concept A

Concept B

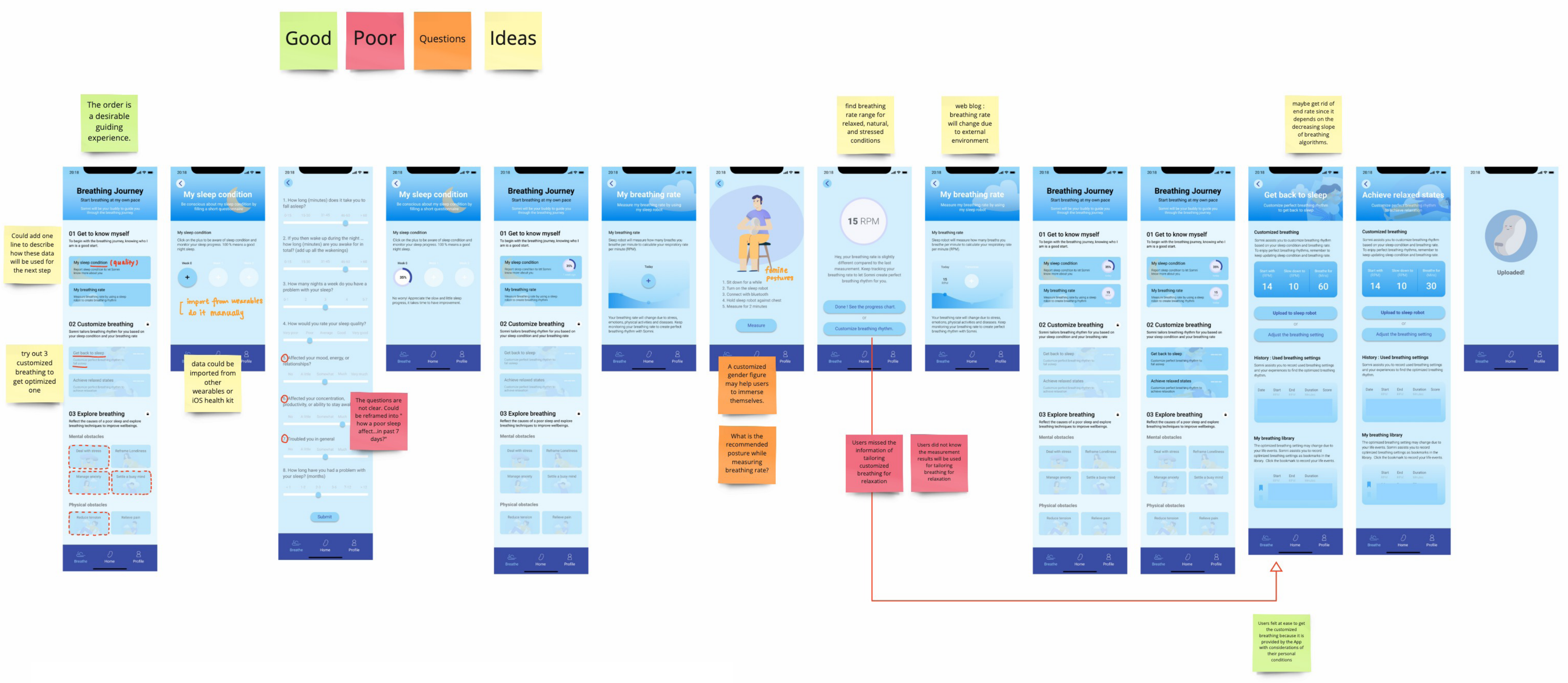
Concept C

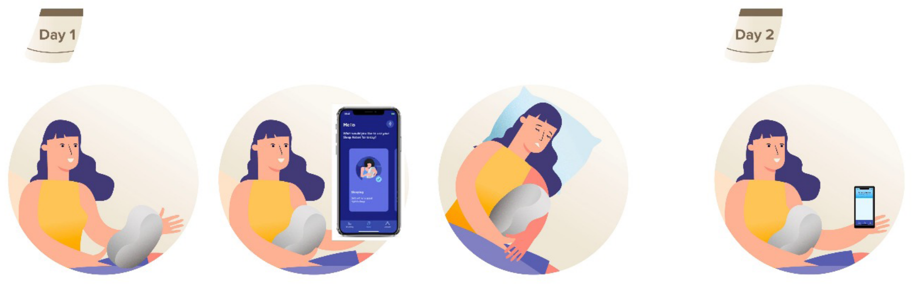

Concept A
Concept B
Concept C
Guided
At ease
Trigger explorations
Main Features and hypothesis
Participant 1
Participant 2
Participant 3
Participant 4
Summary

Appendix E

Final evaluation (Chapter 6) protocol and analysis

Design (Prototype)



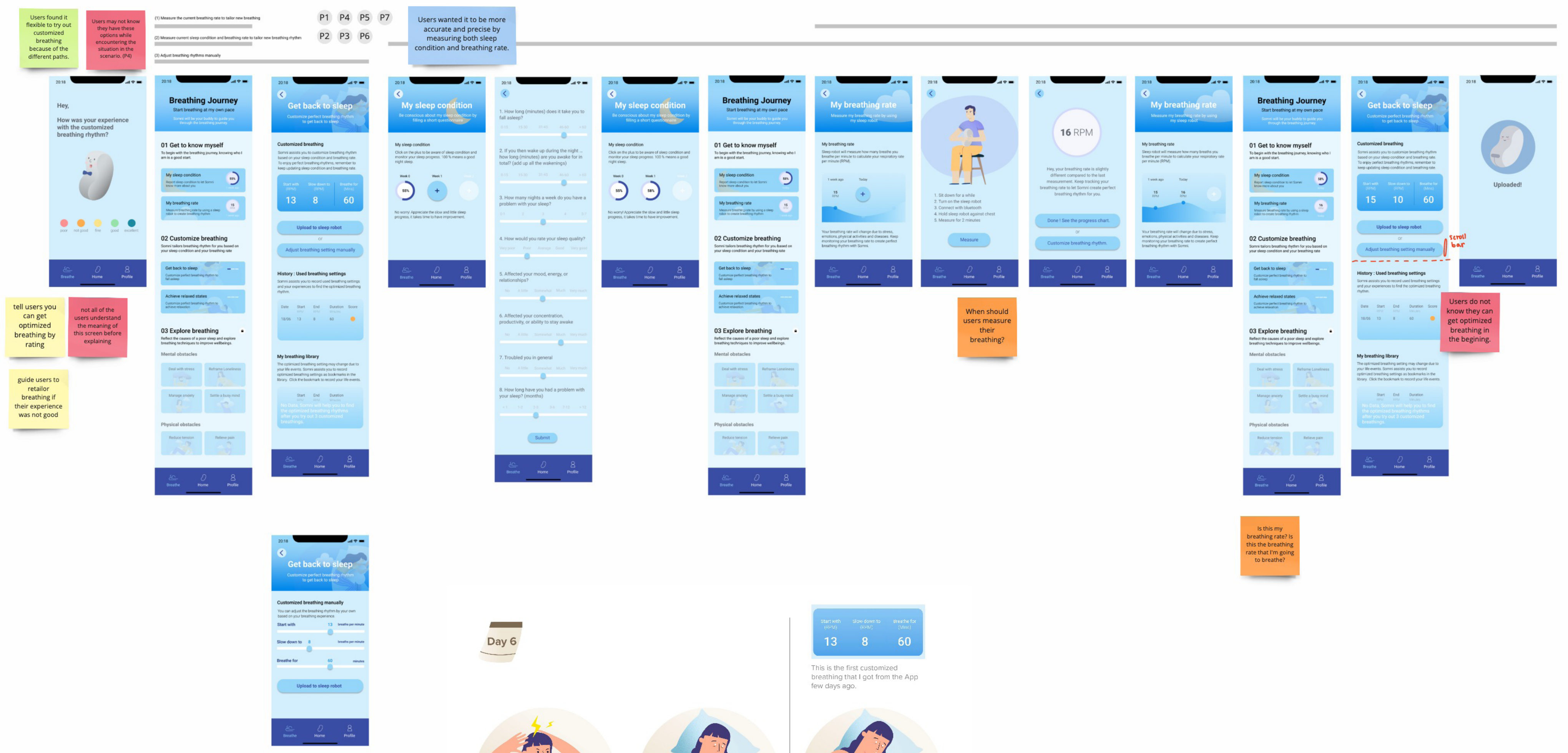


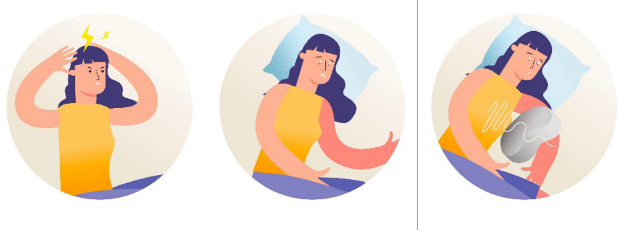
I'm excited to use a sleep robot for the first night.

I choose the standard breathing program for sleeping.

Umm..I cannot keep up with sleep robot's breathing rate in the beginning.

Let's use the App to tailor customized breathing rhythms based on my personal conditions.

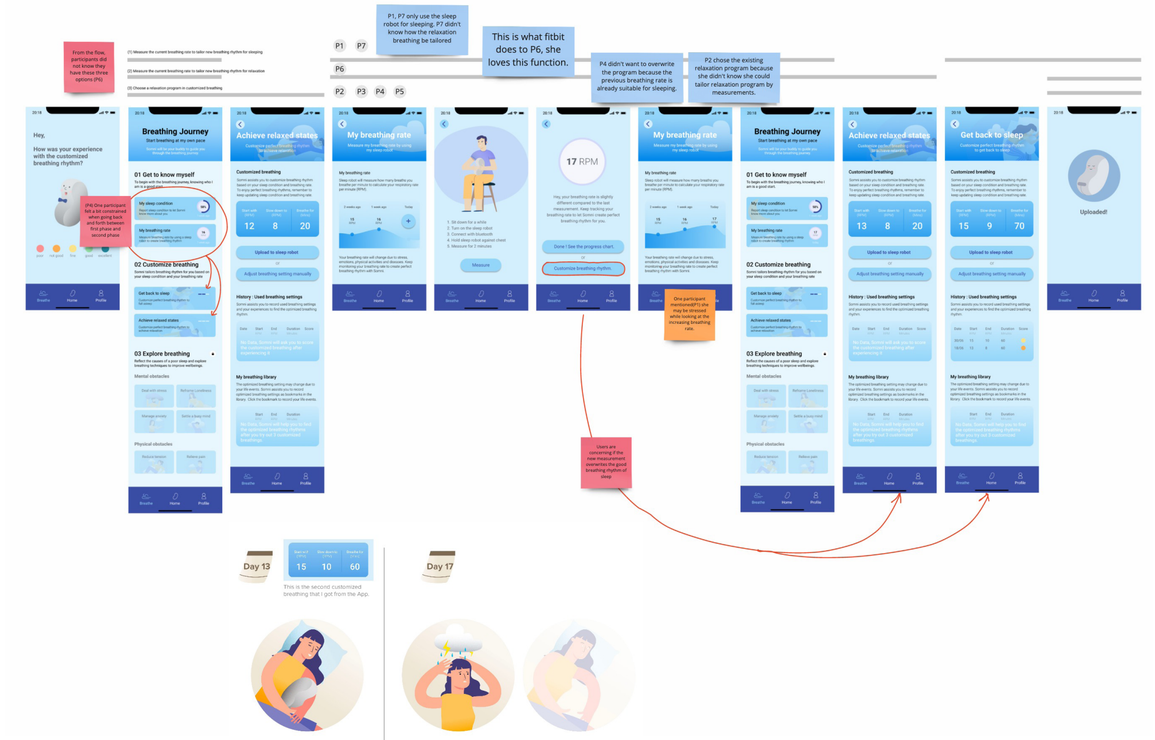




Recently, I have been anxious of getting infected by the virus during the pandemic.

My sleep gets worse becasue of the anxiety. I'm going to use my sleep robot.

Umm...The sleep robot breathes much slower than I do. I cannot keep up with the sleep robot.

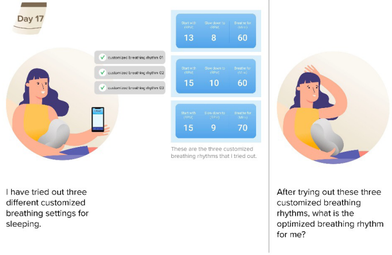

From the flow, participants did not know they have these three options (P6)
(1) Measure the current breathing rate to tailor new breathing rhythm for sleeping
(2) Measure the current breathing rate to tailor new breathing rhythm for relaxation
(3) Choose a relaxation program in customized breathing
P1, P7 only use the sleep robot for sleeping. P7 didn't know how the relaxation breathing be tailored
This is what fitbit does to P6, she loves this function.
P4 didn't want to overwrite the program because the previous breathing rate is already suitable for sleeping.
P2 chose the existing relaxation program because she didn't know she could tailor relaxation program by measurements.
P1
P7
P6
P2
P3
P4
P5
(P6) One participant felt a bit constrained with the back and forth between first phase and second phase
Hey,
How was your experience with the customized breathing rhythm?
Breathing Journey
Start breathing at my own pace
01 Get to know myself
02 Customize breathing
03 Explore breathing
Achieve relaxed states
Get back to sleep
My breathing rate
17 RPM
Done ! See the progress chart.
Customize breathing rhythm.
Uploaded!
Users are concerning if the slow measurement prevents the good breathing rhythm of sleep.
One participant mentioned(P1) she may be stressed while looking at the increasing breathing rate.

Day 13
This is the second customized breathing that I got from the App.
I could keep up with sleep robot. The breathing seems to work well for me.

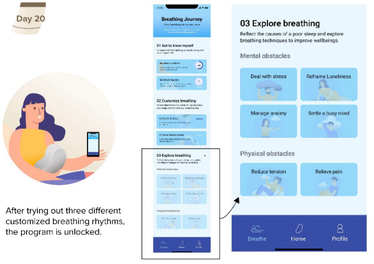
Day 17
I feel tense and cannot relax myself because I don't receive the important call in the morning.

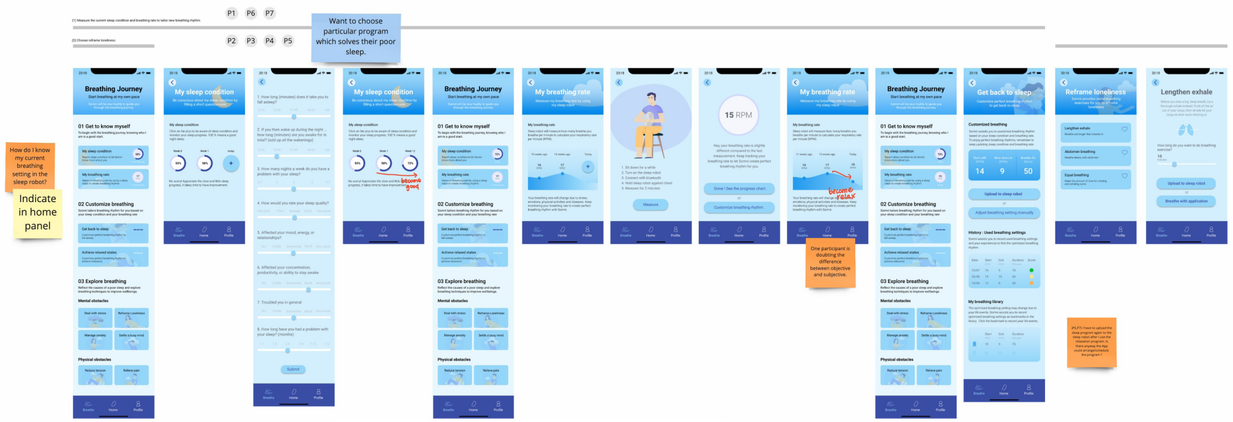
I guess that I may not sleep well tonight.

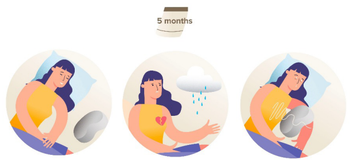

Hey,
How was your experience with the customized breathing rhythm?
Participant did not know they could get optimized breathing during trying out APP.
Could tell users they could get optimized breathing by rating their experience with customized breathing
Breathing Journey
Start breathing at my own pace
01 Get to know myself
02 Customize breathing
03 Explore breathing
Get back to sleep
How do users know what is the current breathing setting they use
How to create optimized breathing?
How to upload optimized breathing to SR?
How to record book mark? manually or automatically?
Users like the fact they can get the optimal breathing rhythms.
Calan'Garda : When finding the optimal breathing, they prefer to keep it rather than change it
Thomas: They like to have updated optimized breathing rhythms because their lifestyle are more dynamic
Optimized breathing ? or personalized breathing?
Manage anxiety
Lengthen exhale
Could it do both with robot and App?
Can I get a feedback on what if I breathe correctly?
Could have some images to show how to hold sleep robot when doing breathing exercises.
promote day time usage of sleep robot
Find the provided options are overlapping, thus difficult to distinguish/ment becomes difficult.
Could let users choose multiple obstacles, to find out the best breathing exercise for users
Participants were all enthusiastic on the breathing exercise.
Could the breathing exercise be revealed in the beginning?


Day 17
These are the three customized breathing rhythms that I tried out.
I have tried out three different customized breathing settings for sleeping.

After trying out these three customized breathing rhythms, what is the optimized breathing rhythm for me?


Day 20
After trying out three different customized breathing rhythms, the program is unlocked.
Breathing Journey
03 Explore breathing
Reflect the causes of a poor sleep and explore breathing techniques to improve wellbeings.
Mental obstacles
Deal with stress
Reframe Loneliness
Manage anxiety
Soothe a busy mind
Physical obstacles
Reduce tension
Relieve pain





I have slept well after using the optimized breathing rhythm.

Recently, I have been quite sad and lonely because I cannot meet with my friends due to the outbreak of virus.

I cannot manage it well and thus my sleep get worse. However, sleep robot does not recognize my condition.