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Master's Thesis
Academic Year 2018

# Tranquility Base: A Portable Respiration Intervention Tool to Induce Calmness

Keio University Graduate School of Media Design

Jiayi Liu

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Jiayi Liu

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Abstract of Master's Thesis of Academic Year 2018

# Tranquility Base: A Portable Respiration Intervention Tool to Induce Calmness

Category: Design


## Summary

In recent years, there is a rising interest in utilizing persuasive and behavior change technology to develop mindfulness products with the goal of improving the user's mental wellbeing, however, there are little product focus on the prediction and intervention of panic attacks. Scientific evidence shows a respiratory pattern as an important physiological indicator leading up and during a panic attack, therefore, it is feasible to develop a prediction system to help individuals suffer from panic disorder to be aware of the proceeding to a panic attack, and receive intervention as early as possible before the actual panic episode. Tranquility Base is a portable respiration intervention system that were designed to help panic disorder patients through day-to-day life through panic prediction and adaptive biofeedback delivered through haptic guidance.



Keywords:

Biofeedback, Respiration, Haptic, Interactive Design, Panic Disorder



Keio University Graduate School of Media Design

Jiayi Liu

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Thank you mom, for being my friend and mentor, for being my most strongest and solid support, for listening to me, and growing up with me together. I LOVE YOU (WO AI NI)! Thank you dad, we don't talk much, but I'm always your little girl and I love you.

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# Chapter 1
# Introduction

## 1.1 Background

This work explores a possible solution for inducing calmness and improving mental health by utilizing wearable biofeedback and haptic technologies. Though can be applied to a broad range of wellbeing-related topics, the research primarily focuses on individuals suffer from panic disorder. Panic disorder involves spontaneous panic attacks that occur repeatedly[1]. Unlike expected panic attacks that are often triggered by a specific situation or certain kinds of phobia, spontaneous panic attacks often happen abruptly, in absence of clear cues or triggers (Meuret et al. 2011) [2], making it almost impossible for the person to prevent the happenings of the symptoms. In a result, most individuals suffer from panic disorder also developed anticipatory anxiety, living in constant fear of another panic attack that might strike at anytime anywhere.

Scientific evidence shows respiratory pattern as an important physiological indicator leading up to, and during a panic attack. Meuret's research had indicated that a significant cardio-respiratory instability had been detected during the hour preceding the onset of a spontaneous panic attack well ahead of the persons perceiving of any symptoms. Some of the major symptoms of panic attacks also associate with respiration, such as shortness of breath and dizziness.

Furthermore, practicing paced breathing have been proved to be one of the most effective methods to slow down the heart rate during a panic attack, and train our body to better react to stress in the long run. A voluntarily controlled paced breathing session is helpful for inducing calmness (Grossman 1999) [3].

## 1.2 Motivation

In recent years, there is a rising interest in utilizing persuasive and behavior change technology to develop commercial products with the goal of improving the users mental wellbeing, ranging from mobile applications that provide paced breathing guides, to immersive room-scale installations that employ various cues to encourage slow breathing. However, most of the products are required to be manually activated by the user, and the effectiveness of the breathe practice session often depend upon the users full attention. This marks a huge challenge for the individuals suffer from panic disorder. Once a panic attack starts abruptly, fear and psychological discomfort may result the person to lose the will and judgment of acknowledging the necessity of starting a paced breathing session. Most of spontaneous panic attacks happens randomly anytime anywhere, it can happen during commute, while sleeping, in the office, on the plane, etc. Therefore requires a portable intervention such as mobile applications. Unfortunately, mobile applications lack biofeedback functions in general, which often requires the user to set ideal breathing rate manually, or worse, only provide a standard breathe interval, which had been proved to have little effect on inducing calmness. It is also extremely hard to require a person during a panic attack to stay focused to the exercise, forcing themselves to stare at a mobile phone screen while freaking out.

The lack of paced breathing guidance that specially designed for individuals suffer from panic disorder motivated this thesis. Study shows that it is possible to design an algorithm for wearable devices to predict panic attacks ahead of the time, with a precision rate up to 93.8% (Rubin et al. 2015a) [4]. Therefore, it is entirely feasible to design a respiratory intervention tool that is able to predict incoming panic attacks, sending notification to the users ahead of the time, and employ paced breathing sessions while the users still have full control of their cognitive process, reduce or stop the progression of a panic episode.

## 1.3 Objective

This research aims to design a respiration intervention tool specifically for the individuals suffer from panic disorder. The tool should be able to predict panic attacks and provide immediate intervention to help user regain normal breathing pattern. The goal of the tool is to ease the anxiety of unperceived and sudden strike of panic attacks, giving the user extra time to react, and hopefully stop the progression of the attack through effective intervention.

## 1.4 Outline

The upcoming chapter engages a literature review on panic disorder and its physiological manifestation and the crucial role of respiration in the context of panic attacks. The review also examines the existing designs and products that aim at providing breathing interventions and the technologies that made them possible. A technology review is also being conducted in order to show that the proposed design is feasible. The third chapter explains the design process, laying out the design objective of **Tranquility Base**, an unobtrusive respiration intervention tool to induce calmness. A full description of the design concept with concept sketching, stakeholders, service ecosystem, target persona, and use case. Chapter 4 introduces the prototype of **Tranquility Base**, provides the detail of a user study, demonstrating the results. The final chapter summarizes the findings of the study and provides future directions.

## Notes

1 `https://www.msdmanuals.com`

2 Meuret, Alicia E. and Rosenfield, David and Wilhelm, Frank H. and Zhou, Enlu and Conrad, Ansgar and Ritz, Thomas and Roth, Walton T. (2011) Do Unexpected Panic Attacks Occur Spontaneously? in *Biological Psychiatry 70*, no. 10 (July 23, 2011).

3 Grossman, E. (1999) Breathing-control Lowers Blood Pressure (BP). in *American Journal of Hypertension 12*, no. 4 (1999): 143.

4 Rubin, Jonathan, Hoda Eldardiry, Rui Abreu, Shane Ahern, Honglu Du, Ashish Pattekar, and Daniel G. Bobrow. (2015) Towards a Mobile and Wearable System for Predicting Panic Attacks. in *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp 15, 2015.*

# Chapter 2
# Literature Review

## 2.1 Panic Disorder and Respiration

### Panic disorder

Panic disorder is a type of anxiety disorder occurs frequently among the general population. People with panic disorder suffer from reoccurring spontaneous panic attacks that happen unexpectedly without obvious causes, and little to no indication (Meuret et al. 2011). During a panic episode, people experience a wide range of distressing physiological sensations, including fast heartbeat, chest or stomach pain, breathing difficulty, weakness or dizziness, sweating, feelings of unreality and fear of dying. Among all the symptoms, shortness of breath is one of the most commonly reported during a panic attack. (Mcnally et al. 1995) [1] While some panic attacks are triggered by feared situations such a fear of public transportation or dense crowd, other attacks may happen "out of the blue". (Gannon 2010) [2] The latter are categorized as spontaneous panic attacks, as they could happen in situations that are perceived by the patient as "safe" situations without clear identifiable precipitating indicators. In a result, people suffer from panic disorder often find themselves strike by random panic attacks through out their daily lives, responding to the discomforting symptoms suddenly dropped upon them with apprehension. The feeling of lacking of control and physical distress make the patients feel powerless and confused. The fear of not knowing when and where the next attack might happen raises the physiological activation, leading to a higher risk of new attacks, creating a vicious circle.

As a worldwide problem, panic disorder affects around 2.5% of the population at some time of their life.(Craske and Stein 2016)[3] The median age of onset for panic disorder is 20-24 years.[4] An online survey conducted by University of Minnesota shows an alarming finding that 13% of collage graduate student are suffering from depressive or anxiety disorder.(Eisenberg et al. 2007)[5] As a graduate student that graduated from U of M and myself, I feel the need of contribute in improving the mental wellbeing of my peers.

### Cause of panic disorder

Although the cause of panic disorder is not universally agreed upon, abnormalities in respiration preceding the onset of a panic attack have been found by researchers both in the lab and in the wild. Cognitive model proposes that panic attacks are results from a catastrophic misinterpretation of change of bodily sensations (Clark 1986)[6]. This means a person with panic disorder are more likely to interpret a physiological discomfort as life threatening compared to others, such as perceiving minor chest pain as the sign of heart attack, or interpret the feelings of short of breath as impending suffocation. Imagine the sensation of breathless that commonly happen during bodily exercise such as running and swimming, a person would perceive it as harmless, knowing that it will eventually fade away after a while, and simply regain the regular breathing pattern by having a short break and voluntarily slow down the breath. However, a person with panic disorder will perceive the shortness of breath as a threat, which causes apprehension that worsen the body sensation even more, causing the person to interpret such sensation as catastrophic, thus creating a vicious loop that eventually cause a panic attack.

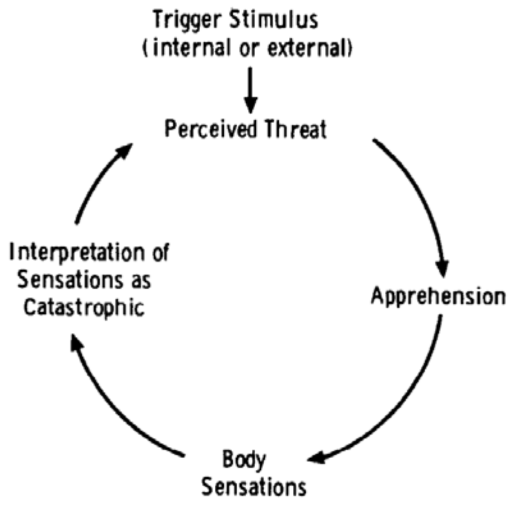


Figure 2.1: A cognitive model of panic attacks. Credit: https://www.researchgate.net

Proof of this model can be found in variety cases of provocation tests of panic attacks. By provoking sensations of breathless through sodium lactate infusions (Liebowitz 1984) or triggering hyperventilation through voluntarily breathe as deeply and rapidly for some minutes (Spinhoven et al. 1992), the sensations felt in the tests are similar to the symptoms during a naturally occurring panic attack. Both studies shows more panic disorder patients panic than controls panic.

The cognitive model of panic disorder explains why spontaneous panic attacks happen randomly even when a person marks an environment or an event as safe - the trigger is not the environment or the event itself, but the catastrophic interpretation of bodily discomfort that may arise so randomly and widely in our day-to-day life. Note that this model indicates that the very beginning of a panic attack is even ahead of the onset of hyperventilation, but the occurring of somatic symptoms that are being interpreted by panic disorder patience as threatening.

## Physiological changes leading up to a panic attack

By definition, a spontaneous panic attack occur out of blue, accordingly, the physiological arousal or instability should occur during the attack but not preceding it. However, the cognitive model of panic disorder indicates significant autonomic irregularities would occur before the onset of spontaneous panic attacks.

Several previous researches has shown that significant physiological changes occur as early as one hour before of the onset of panic attacks, without being aware of by the panic patient.Significant changes of respiration patterns were detected prior to the onset of panic attacks, as the patient getting closer to the actual attack, a significant drop in tidal volume can be observed, followed by a sudden increase, marking the minutes leading to the onset of an attack were dominated by changes of respiration. These bodily changes all happen prior to the onset of seemingly spontaneous panic attacks that were reported by the patients as abrupt and unexpected. Another research conducted by Rosefield et al. utilized change-point analysis to show that prior to the panic attack episodes, there were unique changes in cardio-respiration that can not be found in non panic attack control periods (Rosenfield et al. 2010).

## 2.2 Predicting Panic Attacks

The works mentioned in 2.1.3 show that the physiological changes leading up to the onset of spontaneous panic attacks are unique and detectable, therefore it is theoretically feasible to predict panic attacks up to one hour before the onset through monitoring the changes in physiological measurements. To achieve this goal, the changes of physiological signals should be continuously monitored in order to collect enough data to train a prediction model. This makes the data collection in the lab difficult, due to the limited amount of time they can monitor.

There are a few study that conduct continuous monitoring of physiological changes preceding the onset of panic attacks in a real world setting. One particular study conducted by Cruz el al. proposed a wireless wearable sensor to be attached to the users, continuously collecting and analyzing the physiological data (Rubin et al. 2015b). The subjects were also instructed to manually report the onset of a panic attack through mobile phones. The result shows that a major difference in heart rate and breathing rate can be detected between pre-panic and non-panic intervals. The system successfully collected data and monitored the subjects for 3 weeks, change points were observed in respiration rate twenty minutes before the onset of reported panic attacks. This means the prediction model can send out notifications of an arriving panic attack up to twenty minutes preceding the onset. By performing immediate intervention such a paced breathing exercise, the person will have extra time to bring the respiration rate back to normal, claim the control over their own body, and no longer live in the fear of not knowing when the next panic attack might strike.

## 2.3 Technology Driven Methods of Panic Attack Intervention

The design proposed in this thesis aims at creating a device that can predict the onset of panic attacks by analyzing the physiological data collected from the user. When a prediction is being made, the device will immediately starts the intervention process before the actual panic attack onsets. Since the most common bodily changes are related to cardio-respiration, the intervention at such stage would mainly focus on guiding the user to slowly bringing down their respiration rates. Accordingly, this section mainly focuses on respiration rate related intervention.

### Mobile applications

Up until the year of 2018, there had been over 165,000 health-care applications available to both Android and Apple platforms, most of which provide education, instructions, guidances and training sessions of respiration intervention. However, while the developers of the applications often claim their product to be beneficial to the users, there is little research on their quality. A systematic review of claimed-to-be mindfulness-based iPhone mobile applications was conducted, aiming at evaluate the quality of these applications using MARS scale, a tool for classifying and assessing the quality of mobile health applications (Stoyanov et al. 2015). Among the 700 applications being evaluated, very few had ratings on the MARS scale, and only one application was supported by empirical evidence. The research concluded only 4 percent of the 700 applications actually provided mindfulness training and education, and that there was a lack of evidence for the effectiveness of the applications (Mani et al. 2015).

However, evidence of the effectiveness among the applications that received high ratings on MARS scale can still be found. Firth et al. conducted a meta-analysis of researches on the effects of psychological interventions delivered through mobile applications. The analysis shows that some applications can, if done right, reduce anxiety (Firth et al. 2017). Other research argues for the placebo effect of the applications, suggesting that the reason users keep using the applications that seem to be ineffective and claiming them to be effective might due to the placebo effect such application provided (Torous and Firth 2016). This suggest the application designers to investigate into the features that might potentially emphasize the placebo effect, such as personalization options, data feedback loops, and gamification. For example, an application providing audio guide augmented with visualization is proved to have better results in breathing training compared to an application with only audio guide (Chittaro and Sioni 2014).

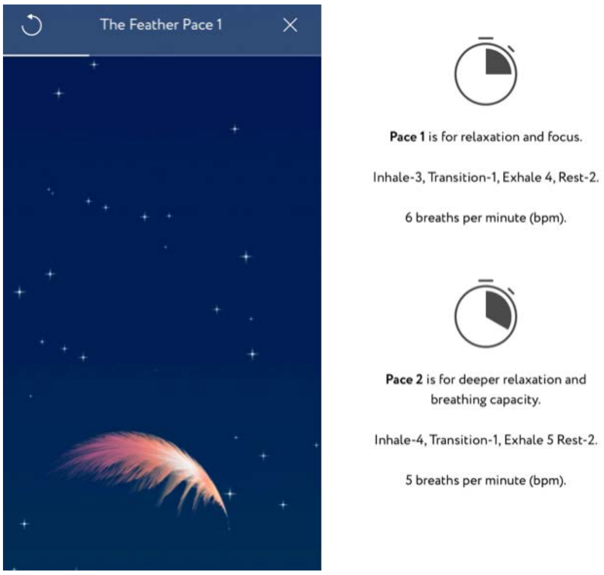


Figure 2.2: MyBreath App: audio guidance, visual cues and text instructions. Credit: https://www.breathresearch.com/mybreath/

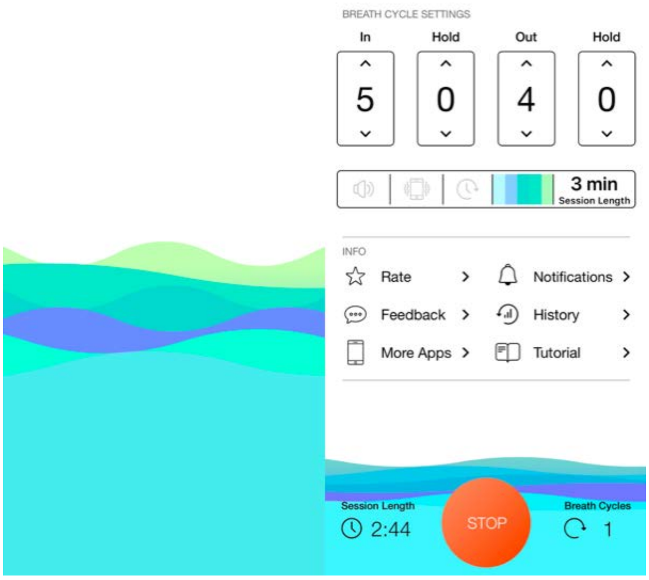


Figure 2.3: Breathe +: audio guidance, visual cues, adjustable breathing sessions. Credit: https://itunes.apple.com/us/app/breathe-simple-breath-trainer

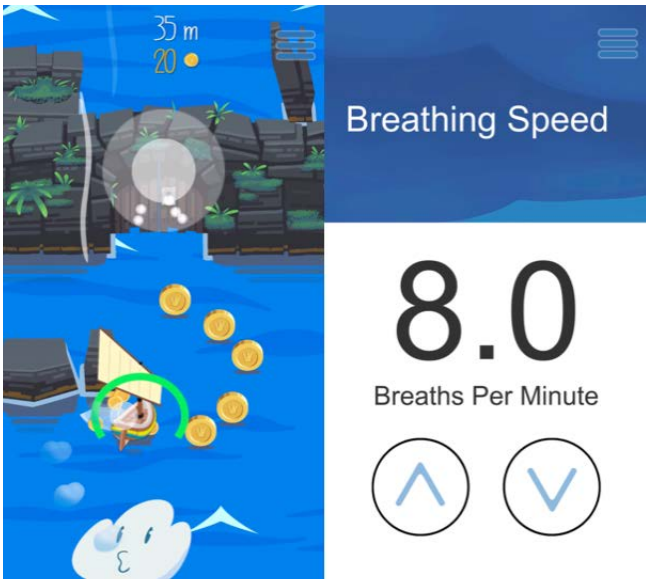


Figure 2.4: Flowy: gamified audio guidance, visual cues, adjustable breathing sessions. Credit: https://www.wired.co.uk/article/flowy

## Biofeedback based products

According to Tim Guays Web Publishing Paradigm, there are four levels of interactivity, and each of them builds up on the previous level (gua 2199):

- Navigational: The most basic form of interactivity, focusing on fundamental tasks of navigation.
- Functional: The user interacts with the system to accomplish a set of goals, receives feedbacks on their progress, or lack of thereof, towards the goals.
- Adaptive: The system allows the users adapt the system to meet their personal goals, or even their personality.
- Collaboration: People are able to work together through system mediated communication in ways that not otherwise be possible.

Accordingly, the products that utilize biofeedbacks sensors can also be distinguished into different categories based on different levels of interactions they provide. The majority of the biofeedback products offer functional interactivity.

There has been a rising trend among researchers to develop sensors that can capture the physiological data of the users, respiration rate being one of the most important aspects of the measurement. Systems with embedded sensors such as The LifeShirt (Wilhelm et al. 2003) and Zephyr BioHarness (Nazari et al. 2018) have been popular tools for researchers and clinicians to captures data preciously in the labs.


Figure 2.5: The LifeShirt (left) and Zephyr BioHarness (right). Credit: http://www.lifeshirt.com/

A handful of applications or products are commercially available by providing similar yet more portable sensors. HeartMath has introduced product called The Inner Balance. It composed of an application and a sensor. The bluetooth sensors are to be attached to the users ear, record and analyze Heart Rate Variability. The application displays the HRV data on the screen, and offers visual and audio guidance for breathing. The company Bellabeat developed a smart jewelry, Leaf, which can track the users daily activities through motion sensors. All the data are being recorded to a mobile application wirelessly connected to the jewelry. Leaf also provides paced breathing guides during which it captures respiration. Prana is another product that was designed to rapidly activate the bodys relaxation response through proper diaphragmatic breathing and good posture. The sensor can be worn in the waist, tracking the users posture and breath patterns, sending notifications to the users mobile phone when it recognizes the user may need to adjust their posture or start a guided breathing session.


Figure 2.6: The Inner Balance (left), Leaf (middle), Prana (right). Credit: https://store.heartmath.com/innerbalance

Last but not least, the Apple Watch is another excellent example of products that provide functional interactivity. The application Breathe will send notifications to the users several times a day to remind a paced breathing session. During the session, the watch provides audio, visual and haptic guides on the screen. The app records the users heart rate, which is later being displayed on the screen after the session.


Figure 2.7: the Apple Watch Breathe app. Credit: https://www.apple.com/shop/buy-watch/apple-watch

To the best of my knowledge, there is no commercially available product that provide adaptive interactivity through biofeedback. However, several early stage ideation had been introduced in various studies to suggest the use of adaptive interactivity. An adaptive interactive project called Breathe with the Ocean was introduced to explore the idea of creating personalized respiration rate through biofeedback. A BVP and Respiration sensor was used to continuously analyze the optimal respiration rate of the user, while the a Touch Blanket which provide haptic feedbacks adjust the breathing guide accordingly, accompanied by light and audio cues (Dijk and Weffers 2018).Researchers have pointed out that it is important for the paced breathing services to provide personalized respiratory guides. In fact, a lack of personalization can make a user feel dizzy and uncomfortable if the guide provided doesnt match with his/her comfortable breathing rates, sometimes it might even induce hyperventilation. It is to be noted that people have different breathing patterns and optimal respiration rates.

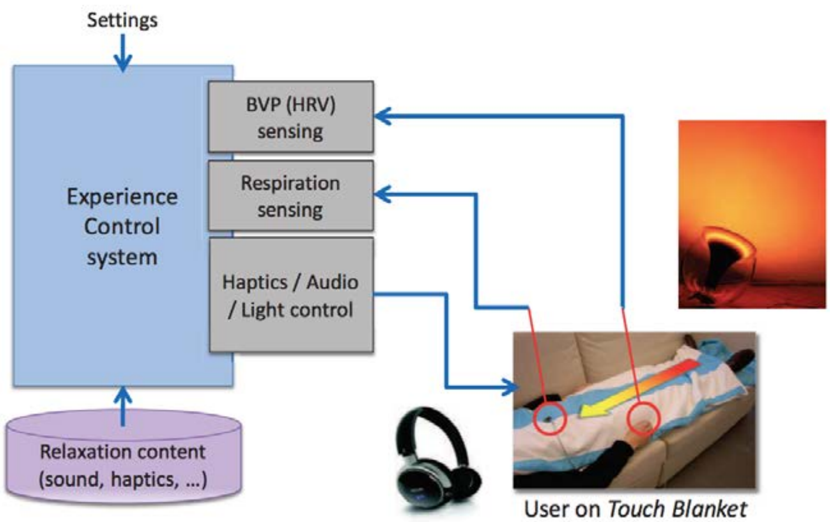


Figure 2.8: system architecture of Breathe With the Ocean. Credit: https://repository.tudelft.nl/

## Immersive environment and responsive objects

Expanding the scope over mobile applications and portable sensors, there have also been several attempts on cultivating immersive mindfulness experience. This includes the interactive environment and responsive objects. The Sonic Cradle presented by iSPACE Research Lab is an immersive device that completely suspend the body in a darkened sound chamber, encouraging peaceful mindfulness meditation. The user was instructed to wear breath sensor and lie in a hammock. As the unfold of the session, the user was able to progressively control the sound being played in the chamber through their own respiration. A user test found that the interactive experience Sonic Cradle provided had more effects on the user compared with a normal non-interactive breathing session in a dark room.

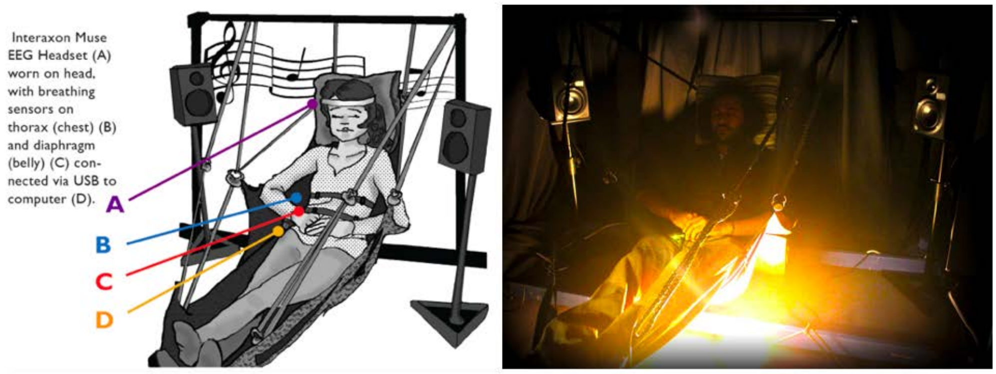


Figure 2.9: Sonic Cradle. Credit: http://ispace.iat.sfu.ca/project/sonic-cradle/

Levo is a responsive mental health companion developed by Quinonez. Although only presented as a concept design. Levo provided a potential direction for designing a stand-alone invective object for panic disorder patients. Levo consists of haptic feedbacks and heating unit, roll around the space automatically, providing companionship similar to a pet. When receiving distress signals from the band worn by the user, Levo rolls to the user to keep them occupied. When the user picks it up, it will provide a guided paced breathing session with light, heat and haptic guidance. Levo can also encourage the user to exercise when it notices there is not sufficient movement around the room.

## 2.4 Discussion

Through detailed literature review, we can conclude that there is a lack of commercially available product that can provide a comprehensive caring and intervention for the panic disorder patients. First of all, there is no product that is able to

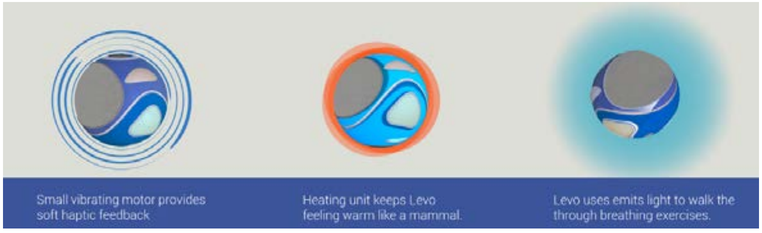


Figure 2.10: concept sketch of Levo. Credit: http://www.marcoqu.com/levo/

predict the onset of a panic attack, while it is being proved to be possible in the lab, and it will significantly prolong the time the patient have to get prepared for the upcoming panic attack, or relief the symptom before the onset. Secondly, most of the mobile application requires to be manually turned on in order to have a breathing session, and a lack in personalized breathing pattern may cause dizziness and even hyperventilation. Although some apps offers an adjustable respiration rate, the UI is still quite confusing, and it is nearly impossible for the user to not go through a series of trail and error with the slide bars to finally understand their optimized respiration rate. Lastly, most of the biofeedback products are merely on the level of functional interaction, the projects that include adaptive interaction features are usually too large to be carried around, which is especially troublesome for a panic disorder patient, given the fact that the onset of an attack is unpredictable.

# Notes

1 `https://www.msdmanuals.com`

2 Meuret, Alicia E. and Rosenfield, David and Wilhelm, Frank H. and Zhou, Enlu and Conrad, Ansgar and Ritz, Thomas and Roth, Walton T. (2011) Do Unexpected Panic Attacks Occur Spontaneously? in *Biological Psychiatry 70*, no. 10 (July 23, 2011).

3 Grossman, E. (1999) Breathing-control Lowers Blood Pressure (BP). in *American Journal of Hypertension 12*, no. 4 (1999): 143.

4 Rubin, Jonathan, Hoda Eldardiry, Rui Abreu, Shane Ahern, Honglu Du, Ashish Pattekar, and Daniel G. Bobrow. (2015) Towards a Mobile and Wearable System for Predicting Panic Attacks. in *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp 15, 2015.*

# Chapter 3
# Designing the Tranquility Base

## 3.1 Design Objective

In the previous sections, I discussed the strong connection between panic disorder and respiration:

- Respiratory irregularity is the most commonly reported symptom during the onset of panic attack.
- Cause of panic disorder may be due to the patients catastrophic misinterpretation of changes of bodily sensations, leading to a hyperventilation that eventually develops into a spontaneous panic attack.
- Significant changes of respiration patterns can be detected up to one hour preceding the onset of panic attacks.

I also explored the role that technology has played in predicting, monitoring, and influencing respiration patterns. However, after examining different approaches of using applications, biofeedback sensors and interactive environment and objects to induce respiration, I noticed that there is a lack of commercially available product specially designed for panic disorder patients that is able to provide a comprehensive care both preceding and during the onset of panic attacks. This inspired Tranquility Base, a portable respiration intervention tool to induce calmness for the people suffering from panic disorder.

Tranquility Base is a service system aiming at monitoring and predicting the onset of a panic attack, notifying the user of an approaching episode, and providing immediate intervention that help restore normal respiration pattern, and inducing calmness. The ultimate goal of Tranquility Base is to intervene the progressing of panic attack at the early stage, break the vicious circle of panic disorder from both psychological and physiological perspectives. Psychologically, an early notification gives the patient sufficient time to be prepared for the panic attack, taking away the longstanding intense feelings of apprehension or impending doom of a sudden onset. Physiologically, the immediate intervention sets to break the positive feedback loop by bring respiratory pattern back to a normal state, preventing the onset of hyperventilation.

## 3.2 Ethnography

In order to understand what are the most important features to be included into the design of Tranquility Base to better serve the purpose of reducing the severity of panic attacks, several fieldworks had been conducted, all revolving around the topic how people interact with the world and technology when they are under stress?

### Fieldwork Sadie

I met my first fieldwork master Sadie at Haneda airport in August 11, 2017. We were on the same flight bound for Shenzhen, China. This was Sadies first time ever to travel to China. Sadie is an intern designer at a startup company. She was born and raised in Tokyo, and never traveled overseas before. Sadie had a history of spontaneous panic attacks.

The flight was leaving around 6:45 pm. Sadie arrived at the airport around 5:15 pm, carrying her luggages, on a smaller luggage, a fish pillow was hanging upside down from the handle. Sadie went to the kiosk to check her big luggage and get the boarding pass. However, she was informed that there was a problem with her booking. Her flight was going to make two connections before arriving Shenzhen. The first was Osaka, the second being Seoul. It turned out that she had to change airport in Seoul to catch the next flight, but she didnt have a visa for Korea, so she was not allowed to leave the first airport. She suddenly became very nervous and didnt know what to do, she gasped and didnt know how to response. But immediately, she was told that they can easily book another flight from Seoul to Shenzhen for her, leaving from the same airport, without any extra fee. She nodded her head. As she left the with the new ticket, face still red. She slowed down and looked at her boarding pass, and deep breathed several times, and went back to calm.

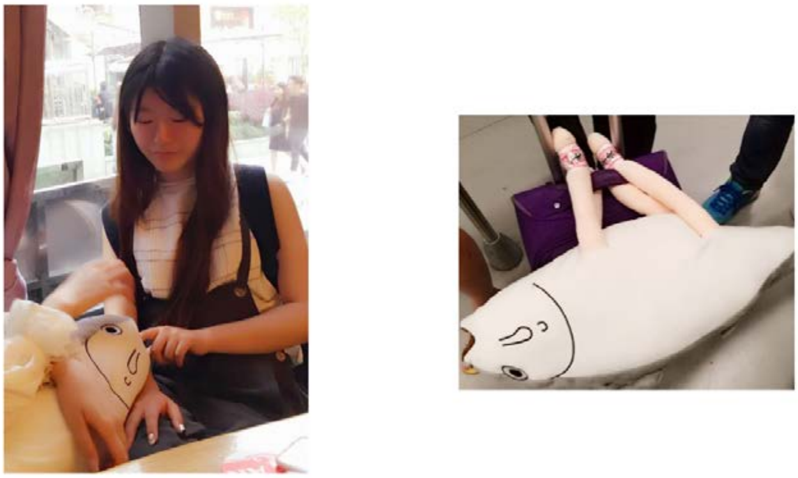

Figure 3.1: Fieldwork master Sadie and her fish pillow

She passed through the security check, found the boarding gate, sat down in one of the chairs, and immediately puled out her sleep mask and started napping, she untied the fish pillow on the smaller luggage, held it tight while she napped. It seemed like she was very tired from staying up late. She continued to sleep through the first flight (holding her pillow), and woke up on time to finish the dinner before the plane began to land in Osaka.

When she was about to check on the next flight from Osaka to Seoul, she found out that the next plane had a weight limitation of carry-on luggage. She frowned at the sign, and put her luggage and pillow on the scale. In a result, her luggage was too heavy. This means that she either had to throw away something, or pay a rather expensive fee.

She stood in front of the scale for several moments, and quickly collected everything with her, and went back to her seat. She unzipped her luggage, stopped, took a deep breathe, and took out everything in it. After emptied her luggage, the first thing she packed back was her fish pillow. The pillow itself occupied a lot of room of a small luggage, but she still managed to pack most of her valuables back. She left behind two books and a box of chocolate. This time the luggage passed the scale.

During the flight from Osaka to Seoul, a minor panic attack happened. It was all of sudden - no turbulence, no obvious trigger. Sadie started to lost control of her hands, and started fidgeting. I noticed the problem, and asked if she was ok. She replied, Its ok. Just a little. I can deal with it. She then rang the flight attendant for a cup of water. She continued small fidgeting, but controlled it pretty well. During the entire time, she was grasping her fish pillow. At one point, she started to fiddle with the four thin legs of the pillow, sliding her hands up and down it repetitively. I noticed that she consciously tried to sync her breathe with the movement of her hands. Slowly, she fell asleep.

The plane arrive in Seoul Incheon International Airport. As I was going to another airport for the next flight and she got to stay in the same airport, we waved goodbye - well, I waved her goodbye, and she waved back hold one of the legs of her fish pillow. This marked the end of my first fieldwork.

## Takeaway: The Power of Comfort Object

During the fieldwork, I observed a strong bonding between Sadie and her pillow. She carried the pillow with her, held it while she slept, thought of taking care of the pillow first when she was facing the struggle of getting rid of things. And last but not least, the pillow provided her with comfort during a minor panic attack. Her hand interacted with the pillow with a rhythmic movement, and this led to a voluntary paced breathing exercise that eventually steered her away from the worsening of the symptoms.

In fact, Sadies connection with her pillow is a common psychological behavior both among children and adults. For children, it is always a security blanket, for the adult, it can be variety of things, ranging from a piece of jewelry to, in Sadies case, a weirdly crying fish pillows with four dangling legs. Sadies pillow is a comfort object for her, providing psychological comfort especially in unusual situations. She trusted her pillow and had developed a breathing practice through the pillow to cope with her panic attacks.

The striking influence the comfort object has upon people should be remembered when design a system for respiration intervention. It proved that a tangible object might provide a more realistic feeling and more immediate comfort for the user compared to a mobile phone application. It is also to be noted that it is for the best for the object to be small, as least smaller than Sadies pillow for it to be more mobile, get less trouble in the public, and occupy less room in the suitcase in case you need to pack it up.

## Fieldwork Himalaya

The second fieldwork took place in March 3rd, 2018. The location of the fieldwork is the startup company, Himalaya's office I worked in. For this fieldwork, I wanted to explore how people interact with technological object that was designed to interact with people. I also wanted to understand how multiple people interact with one device. The reason I chose the office as the location of my second fieldwork was because at the time we had just launched an application in Japan, everyone worked under immense pressure of pushing the project forward. Therefore, the office had provided me with a room full of fieldwork masters that had been in a state of pressure for quite a while. The major fieldwork master I picked for this fieldwork, was our CEO Gary. He is a very serious guy and very passionate about his work. He had been under a lot pressure since the launch of the application.

In order to make a more fitting observation, I manipulated the office environment a little bit by putting an unboxed Intelligent Speaker with virtual assistant on one of the tables. The Speaker developed by my company, with functions similar to Alexa or Google Home. The final product had been mailed to our office for a while, but since everyone was so busy with their work, nobody bothered to even unpack the delivery box. I simply took the box out of the delivery box, and put it on the table during lunchtime. The result was almost immediate. As soon as my colleagues noticed the box on the table, they all started to gather with curiosity. One suggested to open the box and the other agreed. They opened the box and took out the speaker, putting it down on the table and took pictures of it. Everyone was enjoying the moment and was admiring the design of the speaker.

Figure 3.2: Fieldwork Himalaya

Then, Gary walked into the office. Hes attention was attracted by the people. He walked to everyone and asked what was going on. People showed him the speaker. He immediately became very interested and suggested set up the speaker. He rushed to the router of the office and checked the WIFI password. He then connected the speaker to the WIFI, and connected it to his phone. The speaker was activated, and greeted everyone with Hello! Gary smiled and looked around everyone and asked what should he do next. Another colleague had been reading the user manual, and suggested to command the speaker to play a song. Gary nodded and said loudly and clearly to the speaker, Play something from Jay Chou. The speaker answered Yes, master and started playing the song. Gary was impressed by it, and cheered happily.

Figure 3.3: Happy Cheering

After trying out the speaker, people resumed to work, with the speaker still playing songs on Garys playlist. The atmosphere of the office became much lighter and happier due to the music, people were still working hard, but occasionally sing a along to the songs, or stopped working for a brief moment to ask random questions to the speaker, such as whats the best Ramen shop in Tokyo? or Whens the next Giants game? The speaker was not quite intelligent to give perfect answer for each question, but people didnt seem to care. They were delighted that the speaker could keep them accompanied. Gary kept switching songs and adjusting the volume of the music. He would work for about 15 minutes, and stopped to mess with the speaker for a while, and went back to work. As the afternoon continued, Gary had to turn off the speaker eventually, and said It was a bit distracting. The office went back to silence. However, when Gary left for toilet, people activated the speaker again, but this time only asked it to playing some light meditative music. It was to our surprise that when Gary came back, he didnt even notice that people had put the music back on. The end of the office hour marked the ending of second fieldwork.

## Takeaway: Intrusive vs Supportive

The second fieldwork vividly demonstrated how people interact with an technological object that was specifically designed to engage interaction with human beings. It is very interesting that the speaker had been ignored, left in the shipping package in the corner of the office because everyone was busy. I think the main reason is that the speaker was not something that is essential in the office life, therefore it is very easy to be ignored in a busy period of time. However, when people were provided with a chance to actually engage with the speaker, they definitely loved it.

The fieldwork master Garys interaction with the speaker was very interesting. First, he was attracted by the people gathered around the speaker. When he got interested with the speaker, he first interacted with it according to the user manual, and then started to mess around to try out random functions. The speaker got him engaged for a while, but when he realized that the song being played had became a bit annoying, his first choice was not to skip songs, but to turn if off completely. This was very interesting, because it is common for people to turn off the device completely instead of trying out some less aggressive solutions when they feel like being annoyed by the technology. However, when the speaker was turned back on but this time played light and non-intrusive music, Gary hardly even noticed it. In fact, for the time the speaker was playing ambient music, the overall atmosphere of the office turned out to be the best. People were not distracted or annoyed by the speaker, and the music helped lift up peoples mood significantly. This fieldwork was inspiring in the way it showed it is very important to carefully design the interaction to an extent that the system provide support to the user, without being intrusive and annoy the user.

## 3.3 Concept Design

### Target Persona

The two fieldworks observes how people under pressure react with the world and technology. According to the findings, two target persona were developed to represent the key values and behaviors of the main users of Tranquility Base. Although the original purpose of Tranquility Base is to develop a wearable mobile system that helps predict and cope with the onset of panic attacks, the fieldwork strongly suggested that the scope of the user should be expanded to everyone that have had been lived or worked in a stressful situation. Since one of the main goals of Tranquility Base is to ultimately prevent the onset of panic attack, it should be able to prevent it both from a short-term and a long-term. Once we stretch the time period, all the people that is living under pressure should be included and kept in mind when designing Tranquility Base. This consideration had been addressed in the process of developing target persona.

David (Figure 3.4) is a student pursuing his PhD degree in physics in University of Seattle. He grew up in a small town called Duluth in Minnesota. Moving the Seattle was the first time he lived in somewhere outside his town. He got his first panic attack back in freshman year of college and has been getting attacks on and off since. However, he doesnt take medication since he thinks what he has was not too serious. He goes to Yoga every week and found meditation very useful. He doesnt use paced breathing applications because in general he doesnt like phones. David wants a device that can provide similar comfort as a yoga studio, but can be carries around with him, as he loves exploring the city by going to random new places. He doesnt want to be held back by panic attacks happen out of no where.

Jessica (Figure 3.5) is a 33-year-old female working in TV show production industry. Her life revolves around work. Sometimes she works up to 20 hours a day. Jessica loves her job, but maybe a bit too much. She would continuous to work in front of her computer, to the point that her back hurts severely. Recently, Jessica found her had start to lose patience when communication with people more and more often. She hopes to have a device that can remind her to take it easy and slow down.

**Name** David Holliday
**Age** 26
**Sex** Male
**Current City** Seattle
**Hometown** Duluth
**Occupation** Lab assistant

"I really don't like cellphones. During one panic attacks I freaked out and threw my phone against the wall. It's too cold, I couldn't bear looking at it."

**Personal Profile**

David is a PhD student in University of Washington. He was born in Duluth, Minnesota, and spent most of his life there, until he moved to Seattle four months ago to pursue his PhD degree in physics. He loves reading and music. His first panic attack happened on his freshman year of college. Since then, he had been having panic attacks on and off, especially when he find him self on public transportations, or been working to much for some while. He doesn't take medication, but does Yoga every week.

**Motivation**

Although suffered from panic disorder, David loves walking around the city, discovering new places. But sometimes a panic attack happen out of nowhere and always catch him off guard. When the panic attack happens, wherever he was at, he had to head for home. This made him very much frustrated. He doesn't understand what causes the panic attacks, and find him easily embarrassed on the situation of having an attack in the public. He finds peace through practicing yoga, but it would be awesome if he has something to cope with him that he can carry around.

Figure 3.4: Target persona: David

**Name** Jessica Albarn
**Age** 33
**Sex** Female
**Current City** Tokyo
**Hometown** New York
**Occupation** TV Producer

"The only reason I haven't experience a mental meltdown is that my work doesn't allow me to."

**Personal Profile**

Jessica is a full-time TV show producer working at Ameba TV. She had been working there for 4 years. She job is to produce English speaking news for this large online TV network. Everyday, she wakes up at 6 and work almost non-stop during the day. She is used to irregular schedule as she always has to work extra hours. She has severe back pain due to sitting in front of the computer for too long, editing the content. She doesn't have anxiety problem, but she does starts to feel less and less happy and content at her life.

**Motivation**

Jessica loves her job, but sometimes she forget about work-life balance. When she work for too long, she find herself become cranky and mean at her co-workers. And this bothers her a lot, because she no she is a sweet person, the only reason for her to act that way is because the pressure of work. Ideally, she want to remain calm, and remember to slow down the pace. But she simply doesn't know how. She has an Apple Watch which will remind her to stand up for some minute, or stop the work to do a breathing exercise. But she found it difficult to focus on each session.

Figure 3.5: Target persona: Jessica

### Concept sketching

Tranquility Base is a system that serves as the users mental health monitor and guardian in day-to-day life, protecting the user from the onset of panic attacks. The basic flow of the system is described in the concept sketching (Figure 3.1).

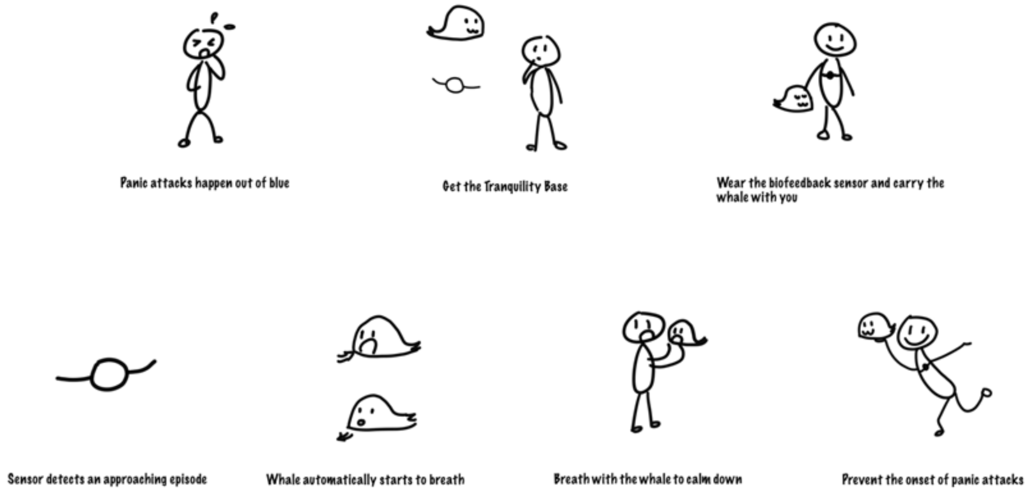


Figure 3.6: Concept Sketching: The Tranquility Base

The main components of Tranquility Base are a wearable sensor and an independent portable device small enough to be carried around by the user. As described in the concept sketching, the sensor is to be worn on the users body, continuously recording and monitoring their physiological data. The device is connected with the sensor via bluetooth. The device remains still most of the time, merely as an accessory, however, as soon as the signal picked up by the sensor is being determined as the indication of the onset of a panic attack, the device activates - or comes to life immediately, and starts to breathe slowly. The actuator inside the device moves up and down, mimicking to breathing movement of a real animal. The user will then notice the movement of the device, naturally, they will understand that there is a possibility that a panic attack is on the way. The device will then lead the user to do a paced breathing exercise, and seamlessly adjust the respiratory rate to best adapt to the users physical condition through biofeedback. Once the system determine the users respiration going back to normal, the device stops moving, resuming to original state.

## 3.4 System Design of Tranquility Base

As illustrated in Figure, the System Tranquility Base is made of three components: a biofeedback sensor that is designed to be worn on the user, a mobile phone application that collects and analyze the data, and a haptic breathe guiding device that is about the size of a palm. The sensor constantly collects raw physiological data of the user, sends it to the application. The application analysis the data with prediction algorithm. When the algorithm determine the data indicate the preceding of a panic attack, the device is automatically activated by the application, alerting the user and lead the user through a paced breathing session via haptic guides. When the users physiological data resumes to be normal again, the device finishes the intervention and stops the movement.

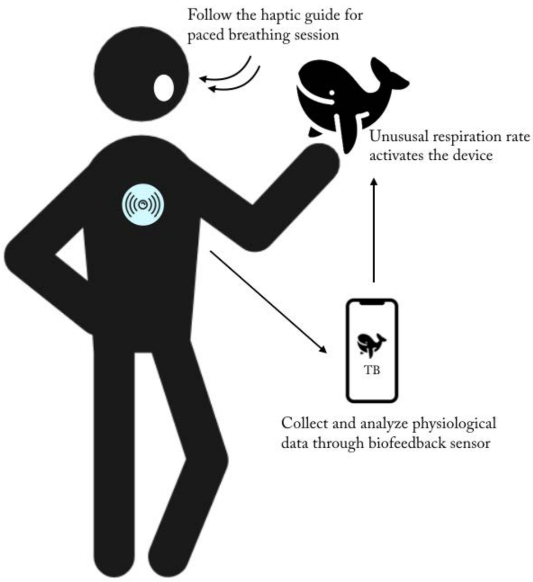


Figure 3.7: System design of Tranquility Base

## Biofeedback sensor

The sensor is the critical component of Tranquility Base. It is attached to the users body and constantly tracking parameters that are relevant to detect panic attacks. The data it collects mainly focus on Respiration Rate since it has already been established in the previous sections as one of the most important variables preceding and during the panic attacks. Other then the Respiration Rate, the sensor also measures heart rate variability and other physiological performance factors. The sensor is mounted to a strap to be worn on the lower part of the chest in order to measure physical and biomechanical movements. The sensor light, and runs on power-saving battery, it is connected to the mobile application via bluetooth, transmitting all the raw data directly to the application ready to be analyzed.

## Mobile Application

The role of the mobile application is to provide a bridge between the sensor and the device. In order to predict an approaching panic attack, the system need to continuously analyze the data since important physiological changes might happen up to one hour preceding the onset of a panic episode. Therefor, as the sensor and the device have limited processing ability, a mobile application has been added to the system to serve the role as the hub that store and analyze the data. The application is also the command center of the system, communicating the sensor and the device, and make the prediction and the decisions such as the proper time to activate the device, or the suitable respiration rate for the user.


Figure 3.8: Main functions of the mobile application

The design of the application should be as simple as possible, as the major interaction the user have with the system should be with the physical device. Therefore, unlike most of the mindfulness applications in the market, the Tranquility Base application does not provide a paced breathing guide on the application itself, but instead encourage the user to interact with the physical device. In an ideal scenario, the user download the application to their phones, connect the sensor and the device to it, and can just simply forget about it during the day. There are some exceptions, though. When the user wants to have a paced breathing session when the system does not detect an approaching panic attack, the user can activate the device through clicking one single button on the application. On the event of a failed intervention (the user still get a panic attack after a paced breathing session, or failed to follow the session), the user can access the application to speed dial his or her emergency contact. The application also provides educational articles and useful tips to raise awareness of a better mindfulness.

### Physical Device

The physical device is the most important component of Tranquility Base. It is the primary interface to communicate with the user. The device provides breathing interventions in the event of a detected incoming panic attack. As I mentioned before, the key design criteria of the device is to make it a comfort object that can be carried around by the user, providing comfort and sense of security, guiding the user through the breathing sessions.

The inspiration of the shape of the device came from the name of the project. The name Tranquility Base was originated by the site on the Moon made famous by the first moon landing of human kind. The base is located in the south-west corner of the lunar lava-plain called Sea of Tranquility. This inspired the image of a peaceful, giant whale gracefully swims through the sea of the mind inside peoples head, protecting and guiding them through harsh emotional storms. Note that the should not be confused with another well-known whale once swam through the space that only ever existed for a short minute (http://findamonologue.com/spermwhale/).

The whale is wirelessly connected to the mobile application via Bluetooth, with actuator inside. The whale activates on the event of the detection of a preceding panic attack, its body expands and contracts slowly, mimicking the movement of a breathing animal. The user then can push his or her hands on the whale, actually feeling the rise and fall of the breath of the soft whale. The user can also simply put the whale on any surface and watch it breathes. The goal of the whale is to provide guidance to help the user to slow down the respiration rate. The intervention is delivered through respiratory feedback. Initially, the breathing pattern of the whale matches with the actual breathing pattern of the user, therefore letting the user start of the paced breathing session from comfort zone. It then slowly increases the interval between each exhale and inhale, subtly guiding the user to slow down their breathing too. The whale continues to slow down the pattern, until the point that the user can no longer slow down. When the whale notices the comfort limit of the users respiration, it will speed up the pattern to match with the users pattern, and proceeds to breath at a stable speed, until the user's respiration rate is stabilized.

## 3.5 Prototype

### Wearable sensor

Although there are many commercially available sensor in the market that can tracker physiological data to some degree, such as Fitbit and Apple Watch, a major concern is that a sensor wore on the wrist may not provide precise respiration data, which is essential for predicting the onset of panic attack. On the other hand, a chest-worn Zephyr Bioharness sensor can provide precise data. Due to the high prize of the Zephyr sensor, for the prototype stage, I made a simplified DIY basic strap respiration sensor. Part of the strap is made of a conductive fabric, when the users chest expands and contracts as he breathes, the resistance changes. The change of resistance is translated into analog signal read by Arduino. After filtering out the noise, the respiration data can be collected through this simple sensor.

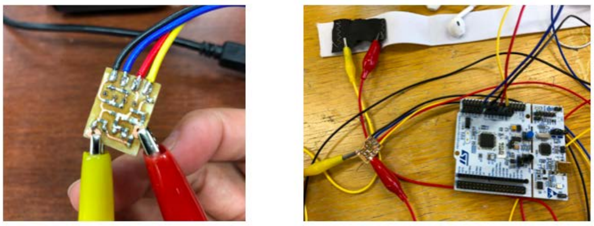

Figure 3.9: Basic Respiration Sensor Strap

After some preliminary user testing to test the accuracy of the sensor, a finalized version of the strap is built as seen in Figure 3.10. The strap has a independent mini battery and a built-in Bluetooth to make the data transaction to the application completely wireless.

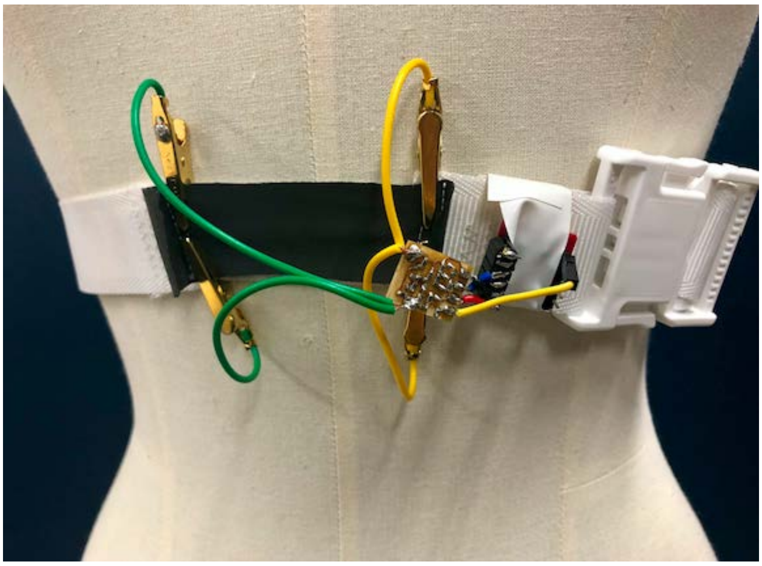

Figure 3.10: Final prototype of the wearable sensor

## Mobile Application

After identified the main functions of the mobile application, a minimalist user interface had been developed. The application is divided into three parts: My Base, Mind Diary, and Support.

My Base is the main landing page of the application. On the upper part of the page, the name of the user is being displayed. The user will also receive a message from a random user of the Tranquility Base as a form of support. The message is assigned to the user randomly, after being filtered for potential harmful or hateful message. The user can leave a message by force touching the upper part of the screen. The message randomly appear on another users feed. The middle part of the screen shows the Daily Tranquility Base Report, such as the connection statues of the sensor and the whale. It also displays the users daily physiological status, ranging from calm, to stressful, to depressed. The status is determined by the overall physiological data collect within that day. Weekly summary is also being provided, showing how many times had the whale being activated. The total respiration practice time is also being displayed. On the bottom, there is an icon of the Tranquility Base, the user can activate the whale to start a paced breathing session anytime and anywhere he wants. After the user press the button, the screen will not change, but the whale will be activated, thus transferring the concentration of the user from the mobile phone screen to the physical object.

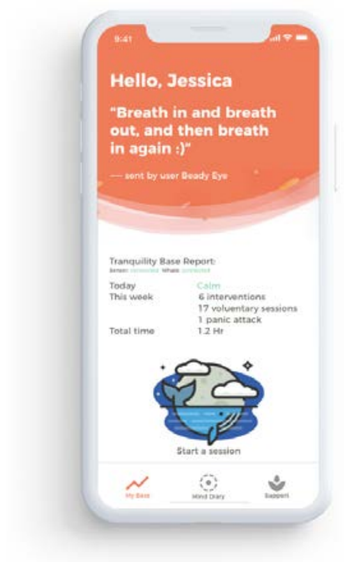


Figure 3.11: Application: My Base

Mind Diary is the page through which the user can view their daily history of respiration sessions via the calendar on the upper half of the screen. By clicking the date on the calendar, the user is able to check his average respiration rate, predicted panic attack episode, and the times of voluntary breathing sessions, etc. On the lower half of the screen, there is a simple emotion and stress tracker for the users to report their felt emotions and stress level. On one hand, the simply log can be a simply way of keeping a mind diary; on the other hand, the self-reported data is very valuable to the algorithm to be compared with the real-time physiological data at the moment the user write down their felt emotion. The Mind Diary can also be downloaded by the patients psychiatrist as a reference when making diagnoses. The subjective and the objective data being collected and recorded in the Mind Diary also have great research purpose, as the data can be continuously collected in a long period of time, which is usually difficult to require in a lab setting.

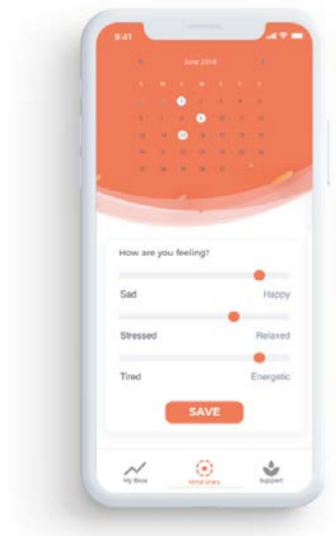


Figure 3.12: Application: Mind Diary

Lastly, the Support page is where the user can access to all kinds of information, health tips and emergency contacts. Although the goal of Tranquility Base is to conduct intervention before the actual onset of a panic attack, theres no one hundred percent guarantee that the invention is effective all the time. Because there are a lot of variables other than respiration rate that can affect the evolving of a panic attack episode. For example, at the time the whale activates, the user might be distracted by something else on hand and does not follow the breathing guide, or that the algorithm fail to detect the happening of a panic attack. Should the actual panic attack happens, and the paced breathing intervention failed to calm the user down, the Support page provides an alternative that encourage the user to seek outside comfort or ask for help. The user can set up his emergency contacts on the upper part of the screen. The emergency contact selected can be the users close friend, family, or psychiatrist. The emergency contacts avatar will show up on the screen, and by simply pressing the avatar, the application will automatically dial the contacts number for the user to seek help. The bottom half of the page served as a information hub. The application with provide the user with useful information and tips that help shape a better understanding of panic disorder. The application will also provide the information of the psychiatrist and the telephone number of nearby clinics if the user wants a visit.

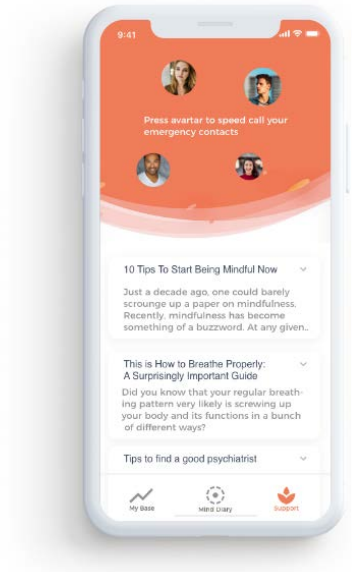


Figure 3.13: Application: Support

## The Whale

### Haptic prototype and user test

In order to understand which kind of haptic design can provide a better breathing intervention, an early stage prototype that simulates the actual breathing movement of an animal was developed to be compared with a commercially available haptic device that provide vibration-based guides.

For the prototype, a mechanism that translate the rotation movement of a mini DC motor to linear movement has been constructed, as illustrated in Figure 3.14. Then, the motor is being placed inside of a box, the top is attached to a piece of fabric. When the motor is activated, the mechanism pushes up and drags down the surface of the box, as shown in Figure 3.15. The movement is pretty subtle to be visible by naked eye, but can be clearly felt by hands. The size of the box is as big as the size of a palm, allowing people to put their hand entirely on top of it, so that they can feel the rise and fall of the surface, mimicking the movement of an actual breathing animal.

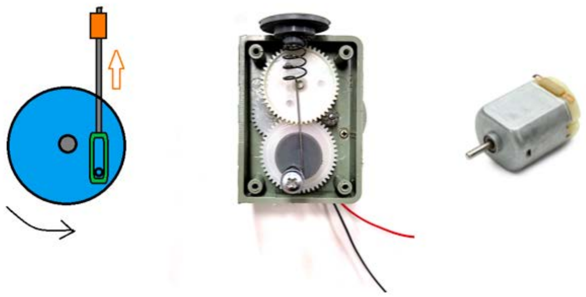

Figure 3.14: Linear Movement Mechanism

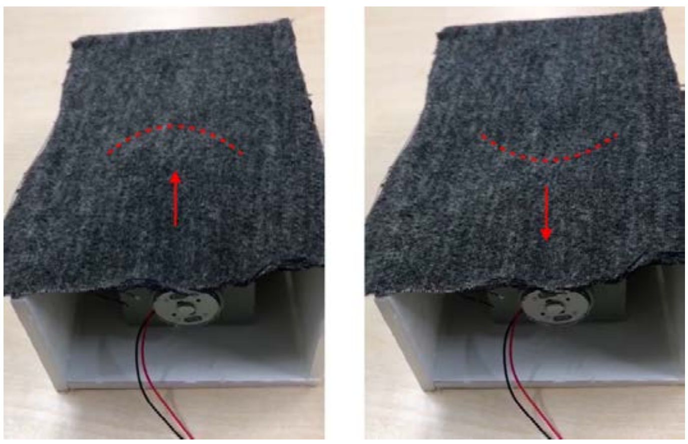

Figure 3.15: Prototype Box

For the haptic test, the Application Breathe+ has been selected as the control of the test, as the application comes with a vibration function. The vibration occurs at the starting point of inhale, and vibrates again fro exhale, as indicator for the user. An iPhoneX that has the application downloaded and set has been attached to another identical box, under the soft fabric.

Three participants were recruited for the haptic test. The breathing cycle of both box has been set to be completely identical 7 breaths per minute. The only variable of the test is the different types of haptic feelings the two boxed provided. The participants were asked to finish a 2 minute paced breathing exercise for each box. During the test, the participates were required to close their eyes, and focus on the haptic feelings they receive from the box, and breath accordingly. The procedure of the test can be summarized as follows:

1. Short introduction of the two types of haptic guidance provided by the boxes
2. User will do a two-minute paced breathing exercise on the vibration box
3. Take a break for one minute
4. User will do a two-minute paced breathing exercise on the breathing box
5. Short survey
6. Test finish

Figure 3.16: Haptic user test

All of the three participants were in favor of the box that provides breathing-like haptic. One participant said, *"It made me feel like I was petting a sleeping cat"*. All of the three participants felt the breathing box was more natural than the vibration box. The reasons that people preferred the breathing box include: *"the guidance provided by the breathing box was gradual and continuous, so after some one or two cycles I was able to predict the timing, it felt more easy to follow"*; *"the breathing box provided a guide that has direction, I naturally synced my breath with the movement, whereas for the vibration box, I was not familiar with what the vibrations were supposed to mean, so it took extra thinking"*. Another participant described the feeling of the breathing box as *"seemed like I was touching a wave"*. However, the participates made some critical remarks, too. One said that the movement was *"too subtle"*, it required his full attention to focus on the box, and for a while during the test, his thought had drifted away. Whereas since the vibration box provided strong vibration as indicators of when to exhale/inhale, it provided a stronger guidance. Another participants said the change of direction of the breathing box seem kind of abrupt, he suggested that it would be better to include a short pause after the inhale, and then proceed to exhale.

Another important observation from the test was that, one participant claimed to feel *"a bit dizzy"* after she completed two sessions. This coincidently proved the necessity of developing personalized breathing guides according to each individuals physical ability. The breathing interval used in this test had been recognized as the standard paced breathing interval, but even being tested among three people, it was proved to be not universally suitable.

### Whale prototype

Based on the findings of the haptic prototype user test, some radical changes was made when developing the physical prototype of the whale. According to the feedback, the breathing movement of the previous prototype was too subtle, requiring extra attention when doing the breathing exercise. This could be a potential drawback for the panic disorder patients, as the patient should bare minimal mental burden on the event of the detection of a incoming panic attack. Therefore, a new mechanism has been designed with the goal of providing stronger and more obvious movement than the previous prototype.

As shown in Furgure 3.17, the new mechanism is composed of a servo motor with extended arm on one side mounted on a rectangular-shaped acrylic surface. The surface in connected by two semiellipse-shaped pieces. When the servo is being activated, the arm swings up, lifting the acrylic piece, as the servo arm go down, the pieces close back together. Together, these pieces forms a structure that can open and close like a clam. This new mechanism can open as much as

45 degrees angle.

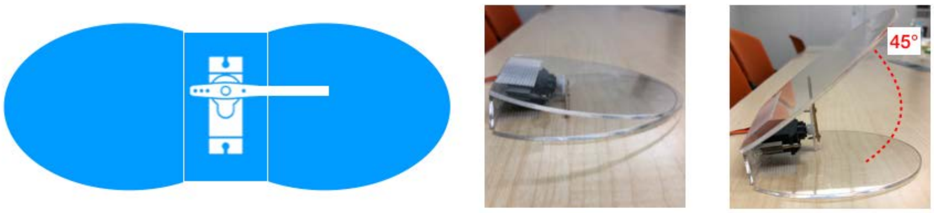


Figure 3.17: New Mechanism

The servo is connected to an Arduino that constantly receives data from the respiration strap sensor. The Arduino reads the value of the detected resistance of the strap, then translates the perimeter into the scale of the arm of the servo motor. The servo control in Arduino is displayed below:

```
val = analogRead(potpin);// reads the value of the potentiometer
val = map(val, 0, 1023, 0, 179);// scale it to use it with the servo
myservo.write(val);// sets the servo position according to the scaled value
delay(15); // waits for the servo to get there
```

After connected the servo with the respiration strap sensor, the biofeedback display is finished. The movement of the mechanism is precisely controlled by the breathing pattern of the person who wear the strap sensor: when the person inhales, his chest expands, the mechanism opens; when the person exhales, his chest contracts, the mechanism closes. The feedback is demonstrated in the figure below.

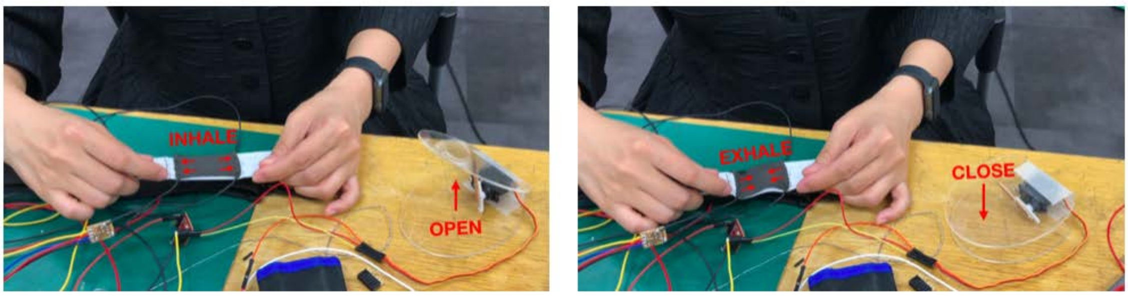


Figure 3.18: Biofeedback Display

After the biofeedback display had been tested and the servo angle being adjusted to proper angle to mimic the breathing appearance of an animal, a store bought whale toy was modified to be the final prototype user interface. A battery and bluetooth had been added to transform the mechanism into wireless device. A zipper had been added to the back of the toy, making it easy for placing the mechanism inside of it. A layer of cotton had been carefully rapped around the mechanism, topped with cotton above it, making sure that when the user touch the device, they dont feel the mechanism inside of it. In order to keep the breathing of the whale within a realized range, the servo movement had been tuned down so that the shape of the whale does not distort during the movement.

Meet Quill, the whale swims across the Tranquility Base, a companion and a guardian for the users mental health, a guide and a mentor to lead and teach the user to use respiration control as a weapon against panic attacks. (YAY!)

Figure 3.19: The whale: Quill

## Tranquility Base

The complete prototype of the Tranquility Base system is displayed below: a wearable sensor that is wrapped around to the users lower chest to collect raw data, an mobile application that collects the data from the sensor and analyze to make prediction of approaching panic attacks and send command to activate the whale; and a whale Quill" that serves as the interface of the system to guide the user through paced breathing sessions.

The Mobile Application is the bridge that connects the sensor and the whale together. The application receives the raw data from the respiration sensor and


Figure 3.20: Tranquility Base final prototype

translate the raw data into breathing rate data. The respiration is then being represented using vector magnitude unites. The application runs a change point analysis on the collected data, monitoring the number and location of significant change points in the time-series. As the sensor collects more and more data during the time when the user is not experiencing panic attacks, a personalized regression model is constructed. When a irregular respiration pattern occurs, the algorithm compares the detected vector with the model. The difference between the actual data collected and the expected data marks the preceding of panic attack.

After the application determined that there is an approaching panic attach, it sends signal through Bluethooth to wake up the whale. Another way to activate the whale it when the user manually opens the application and press the "start breathing session button".

Once the whale has been activated, it got immediately connected with the strap sensor through the application. The servo motor embedded inside of the whale receives analog signal of the expansion and the contraction of the user's chest movement, and translates it into the opening and the closing of the shell-shaped mechanism. Expansion equals to opening up the mechanism, contraction means closing down. This causes the whale Quill to mimic the movement of breathing in and breathing out. As the movement of the whale and the breathing pattern of the user is synced, the biofeedback interactive breathing intervention starts. The flow of the intervention is shown in Figure 3.21.

At the start of the breathing intervention, the movement of the whale is set to sync with the actual breathing pattern of the user. After the session starts, the whale will sync with the user's breathing pattern for 10 more seconds, and

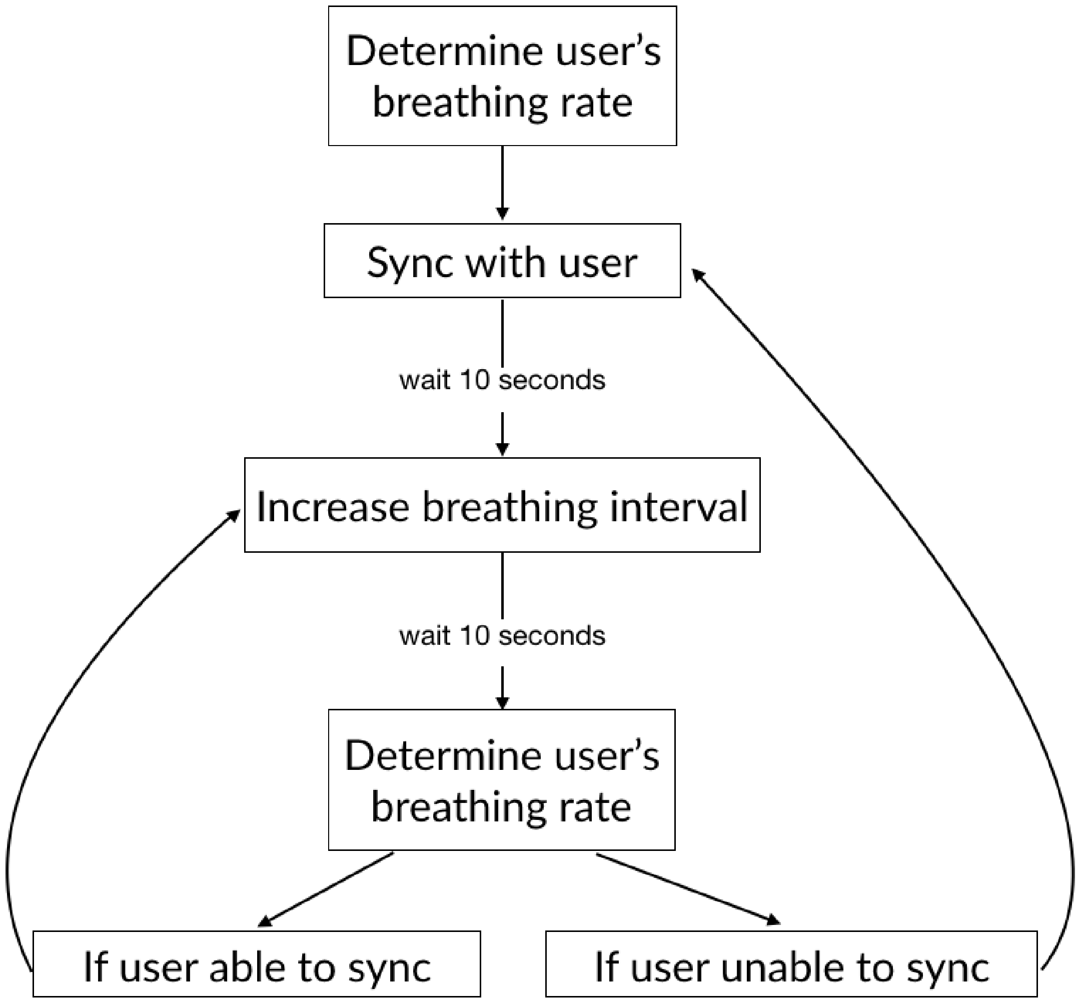


Figure 3.21: Biofeedback Intervention

then slowly increase the interval of the mechanism. The user is encouraged to sync his breathe with the new pattern of the whale. After another 10 seconds, the system check the user's new respiration rate and compare it with the breathing rate of the whale. If the user does not sync his breathe fully with the whale, the system will wait for 10 more seconds for the user to catch up. When the system determines the user successfully sync his breaths with the movement of the whale, the interval of the whale is increased again, encourage the user to slow down his breathing rate even more. The loop will continue to the point that the user reaches the idea breathing pattern for respiration exercise (7 breathe per minute). If the user is never able to reach the ideal breathing pattern, the system will sync the breathing pattern of the whale with the final respiration rate of the user. After the final breathing rate being synced, the whale continues to provide steady breathing guide for another minute, then the intervention session stops.

# Chapter 4
# Validation

In order to understand how users respond to and interact with the Tranquility Base system and to test the efficacy of the biofeedback intervention, the prototype being developed in previous chapter had been used with which the participants tested during a lab study. This chapter explains the study set up and the deployment, and analyses the result from the user tests.

## 4.1 Objective

There are two objectives of the user study. The first objective is to evaluate the efficacy of the biofeedback intervention provided by the Tranquility Base: Do users prefer the haptic breathing guidance provided by the Tranquility Base over the standard vibration-based guide? Do users prefer manually start a paced breathing exercise, or have a automatically activated intervention whenever the system decide that it is necessary? How do the user feel about the adaptive breathing intervention? Can it lead the user's breath pattern to an ideal rate more effectively than a functional biofeedback guide?

The second objective is to evaluate the user experience of the Tranquility Base system as a whole: Does the user prefer the experience the Tranquility Base system provides compared to other mindfulness products that are commercially available? How do they interact with the system when they are in the mind state of panic? Will the user's anxiety to be relieved by the breathing guide provided by the system?

It should be noted that the focus of the user tests was to explore the design aspect of the Tranquility Base through iterations. Therefore, instead of focusing on the functionality of the system, the test is conducted in the wizard-of-oz method, keeping a human in the loop to make sure the participants of the tests get the full experience that are intended to be delivered by the system.

| | Stress Level | Paced Breathing Experience | Method Used |
|---|---|---|---|
| 1 | High | Some | Yogic Breathing |
| 2 | Medium | None | None |
| 3 | Medium | Some | Flowy App (Phone) |
| 4 | High | A lot | Breathe App (Watch) |

Table 4.1: General Information of the Participants

## 4.2 Biofeedback Intervention Test

A total number of N=4 participants had been obtained to voluntarily finish two sets of user tests, one focuses on the different feedback between standard vibration type of breathing intervention guidance versus the breathing type of intervention guidance. Another set of the test focuses on testing th effectiveness of the adaptive biofeedback intervention.

### Study protocol and deployment

Before the test, the participants were asked to finish a short questionnaire on their self-identified general level of stress. The Perceived Stress Scale (PSS) questionnaire had been used to determine if the participants have low, medium, or high self-perceived stress level in the past month. The participants were asked to answer questions regarding their familiarity with paced breathing exercise, how often do they practice paced breathing exercise in the past month, and that if there were any mobile applications of other paced breathing guiding products being used during the exercises. Table 4.1 summarizes the stress level of the participants, their experiences regarding paced breathing exercise, and the method they used during the practice.

The user test is looking at two independent variables: functional or adaptive biofeedback intervention; vibration or analog haptic intervention. Combining the two variables, a total of four different device outputs were decided to be the user cases of the test:

- Manual-Vibration: The user can manually decide the breathing interval of the device before the session start. The user may not adjust the interval once the session starts. During the session, the device provides haptic vibration guidance.

- Manual-Breathing: The user can manually decide the breathing interval of the device before the session start. The user may not adjust the interval once the session starts. During the session, the device provides breathing guidance.

- Biofeedback-Vibration: The device automatically collect the respiration rate of the user, and adjust the breathing interval accordingly, slowly increasing the interval with the aim of keeping the breathing rate within the comfortable range of the user. During the session, the device provides haptic vibration guidance.

- Biofeedback-Breathing: The device automatically collect the respiration rate of the user, and adjust the breathing interval accordingly, slowly increasing the interval with the aim of keeping the breathing rate within the comfortable range of the user. During the session, the device provides breathing guidance.

The study lasts for two days, each day, the participants complete two sets of user tests. The participants were asked to come to the common area of the school where the couch is located. After collecting the pre-test questionnaires, the participants were instructed to put on the wearable sensor strap. Then the participants was asked to perform a 3-minute long mild hyperventilation provocation test. After the test, the participant was asked to perform a paced breathing exercise for 5 minutes using the device. After the exercise, the participant was asked to remove the strap sensor. Then the participant was asked to finish a short post-test questionnaire and a short interview. Then the test finishes.

At the end of the second day, after the participants finish all four sets of user tests, an exit interview was conducted to let the participants discuss the overall experience of the device and to point out which use case is their favorite. In addition to that, the participants were asked to freely add any other comments about the device.

## Results

All participants experienced all four different breathing guides. After each session, they were first asked to provide quantitative feedbacks regarding each ways. Questions such as "what do you liked about this mode?" "what do you disliked about this mode?" "what kinds of difficulties did you experienced during the paced breathing session?". Then, the participants were asked to fill in the Stress Arousal Checklist to identify their stress level after each session. The participants were also asked to mark their felt relaxation level on a scale to represent their subjective relaxation level. After finishing all four user tests at the second day, the participants were asked to choose their most preferred mode.

- Manual-Vibration: Three out of four participants gave negative comments about this interaction mode. The main reason was that the users had a really difficult time deciding their ideal breathing intervals, therefore when the session starts, the participants found themselves hard to breathe comfortably according to the guidance. One participants reported feeling headache two minutes into the session, resulting the session being terminated. Another participant comments, "It is so surprising that all this time I had no idea about how fast I breathe - one would presume that it is such an obvious answer, given the fact that we are breathing all the time." One participant gave a positive feedback, "I like it. Because I know that in yoga practice the ideal breathing interval is 12 times per minute, so I simply put that number down. I like that the device vibrates according to the breathing in and out, it give me clear guidance to follow, even if I'm closing my eyes."

- Manual-Breathing: All four participants strongly preferred this mode compared to the first one. All the positive feedback were about the change of interaction haptic guides. One participant said, "now the whale feels alive! I think this way it feels much more like a pet, whereas the vibration only felt like a simple guide with no emotions." Another participant gave the similar comment, "I somehow feel more connected with the device when it moved this way, and I think it feels more natural, because I can just breathing in and out following the lead of the whale. When I try to synchronize my breathe with the vibration, it was kind of hard to stay focus and sometimes I breathe reversely or mess up the rhythm. Once I got messed up, it was very difficult to adjust back."

- Biofeedback-Vibration: The two sets of user test on the second day focuses on the effect of the biofeedback guidance. At the beginning, the participants showed confusion when asked to simply activate the device without making any adjustment to the breathing interval. After the device being activated, two participants noticed that the device is breathing in a similar rate according to their breathe at the moment. Another two, however, didn't notice the synchronization between the device and their own breathe. As the breathing rate of the device starts to slow down, one participant asked, "It's slowed down! Am I supposed to follow it's lead?" After receiving the yes" answer from the author, the participant tried to synchronize her breathe with the whale. She closed her eyes and quickly adapted to the new breathing interval. "It's almost effortless." She commented.

- Biofeedback-Breathing: The forth interaction received general praising from the participants. One noted, "This is the most natural guidance! There is definitely less to think about when the device just provide you with the adaptive guidance, and the rise and fall of the back of the whale remind me of the tide of the ocean." Another participant remarked, "It feels like the device is trying to communicate with me through a non-verbal interaction.". One participant, thought, complained that toward the end of the session, the interval became "a bit too slow and hard to catch up with."

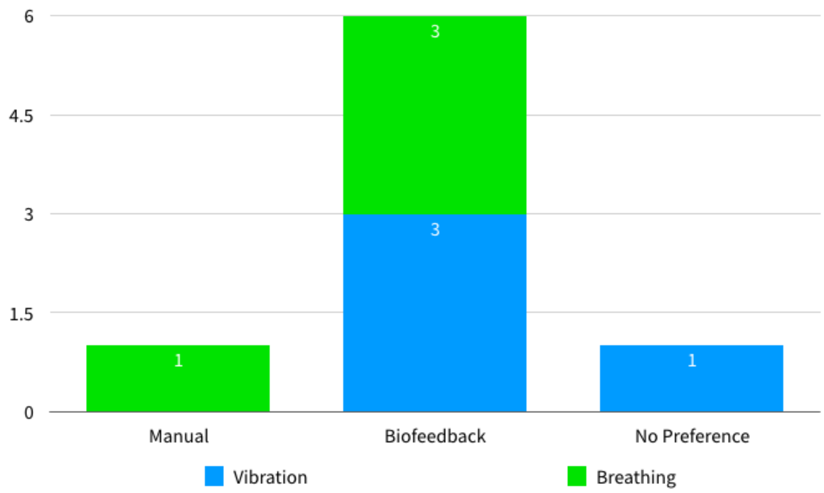


Figure 4.1: Preferred Mode

Figure 4.1 shows the preferred mode of paced breathing guides of the four participants after the two-day user test. The majority of the participants preferred the Biofeedback approach of the breathing guide compared to the simple predetermined breathing interval. Most of the participants preferred the breathing guide compared to the vibration guide.

To calculate the subject increase of the relaxation level of the participant before and after the breathing session, the participants were asked to fill in the Stress Arousal Checklist after each session. The data gathered was then being calculated and the change of the stress before and after each session had been found.

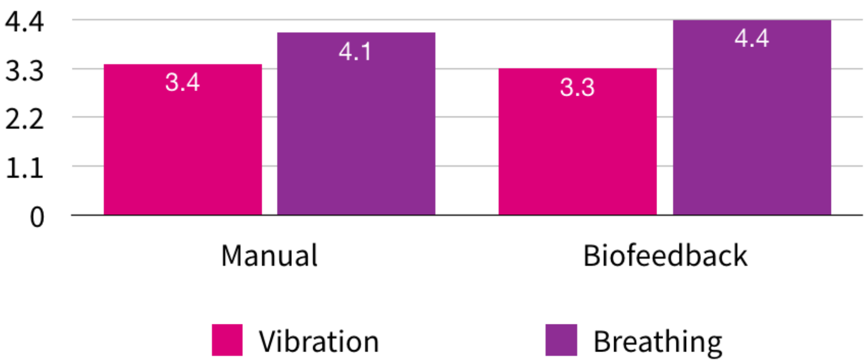


Figure 4.2: Subjective Increase of Relaxation Level

Figure 4.2 shows that all four sessions increases the level of relaxation of the participant, yet among which the breathing guide helped the participants felt more relaxed compared to the vibration guide. However, there were no obvious difference between the manual breathing interval set and the biofeedback guide, although thought the verbal feedback from the participants, they generally preferred the biofeedback approach.

The respiration data collected by the strap sensor also shows the overall impact of the breathing guidance provided by the device. From Figure 4.3, one can find that the breathing interactions helped the participants to further slow down their respiration rate compared to the haptic guide. Similar to the increased level of relaxation, the biofeedback interaction did not see obvious improvement in the effectiveness of decreasing the participants' breathing rate. However, as the participants stressed that the biofeedback mode felt "more natural" compared to manual control, one may still argue that the biofeedback interaction provided a better user experience and made the paced breathing session more enjoyable for the participants.

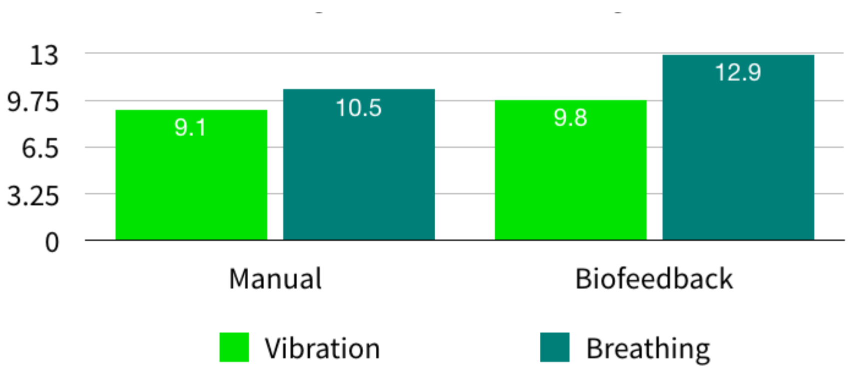


Figure 4.3: Average Decrease In Breathing Rate

## 4.3 User experience test

The user experience focuses on studying how the user of the device interact with it under a stressful situation. For this test, N=5 participants was recruited. Since it is difficult to find participants that has pre-existing condition of panic attacks, a test that aimed at provoking the rise of stress level were being conducted in a safe lab environment to best simulate a panic-attack-like situation. The Sing-A-Song Stress Test had been utilized to achieve this goal.

### Study protocol and deployment

The protocol of the test is described as follows.

1. User enter the classroom without knowing what the test was about. The author asked the participants to "do a little favor" of watching a video in an empty room.

2. After the user sit down in the chair, they were asked to put on the sensor strap and a fitbit watch. The laptop was open in front of the user, and the device had been close to the laptop in visible range of the participants. However, there were no information provided to the participants regarding the usage of the device.

3. The author instructed the participant to try to stay focus on the video, and notify the user that toward the end of the video, there is going to be a task asking the participate to finish. The author reassure the participant that the task was not hard and the video does not contain scary content.

4. The author plays the video.

5. The video contains a three-minute-long reading of a random piece of text,

with relaxing background. After three minute, the reading was suddenly stopped, a text appeared on the screen, with a machine voice reading out loud, "Task: start singing a song aloud when the counter reaches zero, keep sitting still until that moment. "

6. A 30 second counter shows up on the screen.

7. When the counter reaches 0, the participants were expected to sing a song out loud.

8. If the participant failed to sing the song, the experiment is terminated. After the participant finishes the task, the device is activated. The participants are then being instructed to try to slow down their breathing rate following the lead of the whale.

9. After a three-minute paced breathing session, the device is stopped.

10. The participants are instructed to take off the sensor and Fitbit, and conducted a verbal interview to discuss the overall experience.

11. Exit interview.

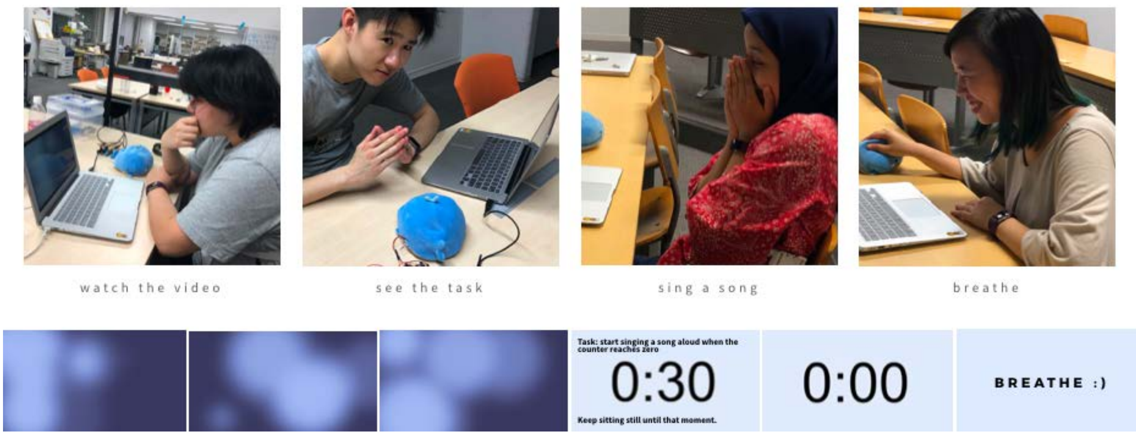


Figure 4.4: Sing-A-Song Stress Test

## Result

As a result, four participants finished the task and sang a song when the timer stops. One participant failed to do so, therefore the data had been removed. Figure 4.4 describes the process of the test and the reaction from the participants at different point of the video. When the video read the random text, the participants begin as a little bit confused, but then started to sit back and relaxed as listening to the reading. One participants started giggling a little because she doesn't understand the purpose of the test and found the experience amusing. When the instruction showed up on the screen, the participants all had strong reactions. One of the participants raised his head and stared at the author in surprise. Another participants started laughing even more, as she now figured out the purpose of the experiment. Another participants started panicking immediately, and looked around while murmuring, "oh my god, what should I sing? What should I sing? Can I sing the national anthem?" When the counter reaches zero, the four participants all started to sing immediately. It was amusing thought, to found out two of them started singing "Happy Birthday", suggesting that the song was indeed very, very popular.One of the participant even reaches her hand to the device before it got activated, to search for comfort unconsciously.

After the participants finish singing, the author remotely activated the device, and the device started to breathe. The author instructed the four participants to follow the breathing of the device and try to slow down their breathing rate following the guide of the device. All participants followed the instructions. They started to put their hand on the device, petting it, and closed their eyes to calm down. All participants successfully slowed down their respiration rate within the three minutes of the paced breathing session.

The respiration rate and heart rate data of the participants during the entire test had been recorded, and was shown in Figure 4.5. From the graph we can see the BRP and HBP has similar pattern during the test. The appearance of the task marked a increase in respiration rate and heart rate. Furthermore, the countdown counter successfully increased the stress level of the participants within a very short period of time. The respiration rate and heart rate peaked around the time when the timer reaches zero. As the participants began the sing, both rates slowly drops, indicating that after the task starts, the participants felt not as stressed compared to the moment when they were waiting for the start of the singing.

After the device being activated, one can notice that there were a small peak right after the activation, suggesting the activation of the breathing guide actually increased the breathing rate and heart rate. This was due to the activation being sudden, and the immediate movement startled the participants a bit. However, a text that suggesting the participants to start the relaxation exercise appeared on the screen right after the activation, which immediately made the participants realize the purpose of the device, therefore eased their tension from the sudden activation. The respiration rate and heart rate both decreased as the participants started to do the paced breathing exercise.

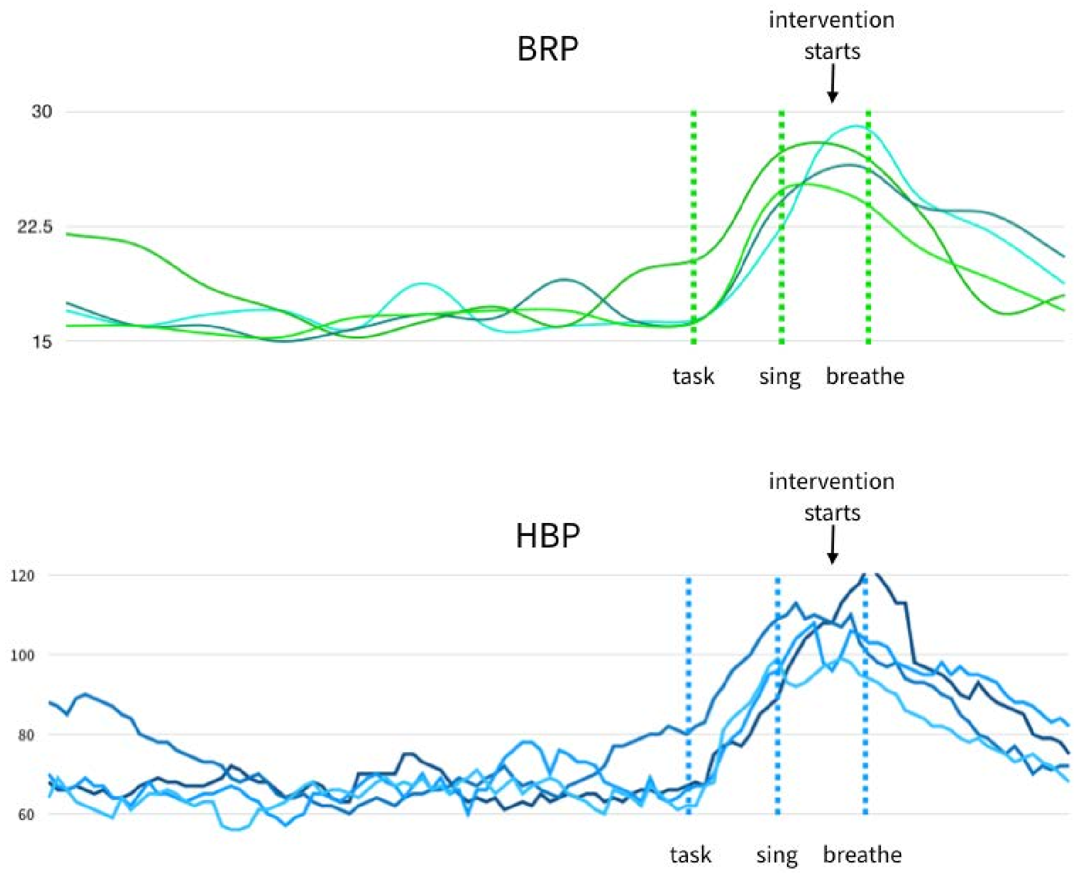


Figure 4.5: Breathe Rate Per Minute and Heart Beat Per Minute

# Chapter 5
# Conclusion

## 5.1 Conclusion

In this paper, the author offered the design of a system that offers paced breathing guides for the people in stressful situations. By utilizing breathing haptic guides through adaptive biofeedback adjustment, the system is able to help the user to slow down their breathing rate and subsequently gradually reach a calm state of mind.

The user tests indicates that compared to the vibration-type-of breathing guides which had been widely used in most commercially available products, the breathing mechanism that mimics the actual breathing movement of an animal could better provide comfort and calmness to the user who was under a stressful situation.

There was a potential of the effectiveness of adaptive biofeedback that help better determine the optimized respiration rate for the user, and provide personalized breathing guide for each different user.

## 5.2 Limitation

During the development of the prototype and the user test, two limitation had been observed. Since the three components of the system was connected via Bluetooth, a mild delay had been observed during the test. The bluetooth connected had been consequentially removed from the system, adding back the wire connection in the middle of the test to reduce the delay between the user's breathing and the syncing movement of the whale.

Another limitation was due to the noise of the servo motor. Although the motor was wrapped with cotton, there were sound sound can be heart when the servo arm moves. As one participant of the user test described, *"the whale sounds* *like a frog"*. Actually, the motor being used in the first prototype made almost no sound compared to the servo motor. However, it was much more difficult to sync the motor with the breathing pattern of the user compared to using the servo. Other kinds of mechanism should be tested in the future work, creating a interface that has lesser noise.

## 5.3 Future work

The prototype presented in this thesis engages with a single user. The only connection the user have with other users through the system is the random message the user can send and receive via the application. However, during the post-test interview, the test participants reacted to this function very positively, since it gave them the sense of the feelings that their are other people share the same problem and concern as they do. For the future work, the community aspect of wellbeing support should be explored. For example, the user interface can also display the presence of other users, creating a virtual shared space for the users of the system to collectively overcome panic attack. A simply installation of LED lights on the back of the whale can be considered as the next step of the system. When there are other users using the device, the LED will light up, showing the user that they are not facing the panic attack alone.

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# Appendix

## A Perceived Stress Scale Questionnaire

A more precise measure of personal stress can be determined by using a variety of instruments that have been designed to help measure individual stress levels. The first of these is called the Perceived Stress Scale.

The Perceived Stress Scale (PSS) is a classic stress assessment instrument. The tool, while originally developed in 1983, remains a popular choice for helping us understand how different situations affect our feelings and our perceived stress. The questions in this scale ask about your feelings and thoughts during the last month. In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer fairly quickly. That is, dont try to count up the number of times you felt a particular way; rather indicate the alternative that seems like a reasonable estimate.

For each question choose from the following alternatives:

0 - never 1 - almost never 2 - sometimes 3 - fairly often 4 - very often

l. In the last month, how often have you been upset because of something that happened unexpectedly?

2. In the last month, how often have you felt that you were unable to control the important things in your life?

3. In the last month, how often have you felt nervous and stressed?

4. In the last month, how often have you felt confident about your ability to handle your personal problems?

5. In the last month, how often have you felt that things were going your way?

6. In the last month, how often have you found that you could not cope with all the things that you had to do?

7. In the last month, how often have you been able to control irritations in your life?

8. In the last month, how often have you felt that you were on top of things?

9. In the last month, how often have you been angered because of things that happened that were outside of your control?

10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

Figuring Your PSS Score

You can determine your PSS score by following these directions:

First, reverse your scores for questions 4, 5, 7, and 8. On these 4 questions, change the scores like this:

0 = 4, 1 = 3, 2 = 2, 3 = 1, 4 = 0.

Now add up your scores for each item to get a total. My total score is.

Individual scores on the PSS can range from 0 to 40 with higher scores indicating higher perceived stress.

Scores ranging from 0-13 would be considered low stress.

Scores ranging from 14-26 would be considered moderate stress.

Scores ranging from 27-40 would be considered high perceived stress.

The Perceived Stress Scale is interesting and important because your perception of what is happening in your life is most important. Consider the idea that two individuals could have the exact same events and experiences in their lives for the past month. Depending on their perception, total score could put one of those individuals in the low stress category and the total score could put the second person in the high stress category.

# B Stress Arousal Checklist

Please use the number 1 to 5 to rate how much you identify with the following adjectives at the moment:

1. I feel active
2. I feel up-tight
3. I feel lively
4. I feel bothered
5. I feel distressed
6. I feel tense
7. I feel calm
8. I feel sleepy
9. I feel contented
10. I feel relaxed
11. I feel sluggish
12. I feel energetic
13. I feel uneasy
14. I feel worried

On the scale between 1 to 5, how much do you feel relaxed at the moment.

# C Introduction Interview

1. How do you feel about your general level of stress?
2. What do you try to do to relax? Any specific practices?
3. What else do you like to do to manage stress?
4. Do you have any experience in deep breathing techniques?
5. Do you use any type of technology to assist in stress management?

# D General Feedback Interview

1. How was your overall experience today?
2. What did you like?
3. What did you dislike?
4. Do you have any other comments you would like to add?