An audio-visual breathing application and its benefits on human psychology (mental health)

Project Report

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Preface

The journey of this thesis has been of a lengthy process, undertaking multiple iterations, gaining support from many sources in the form of guidance and a direction from the point of its initiation, to completion. This thesis report was written in the Fall of 2020, during the ongoing pandemic, in connection to a Master thesis performed in the 9th semester of the Sound and Music Computing program at Aalborg University, Copenhagen. This thesis was supervised by Cumhur Erkut, Associate Professor, Department of Architecture, Design and Media Technology.

0.1 Acknowledgements

Before anything I wish to first and foremost thank my supervisor Cumhur Erkut, for agreeing to take interest in my project aspirations, and especially for his utmost patience toward the iterations in my ideation process. For bearing with my never ending struggles and guiding me through. Not to forget the psychological support also provided generously and patiently by him, whenever I would arrive at a mental standstill about where I stand in my progress, encouraging and pushing me to carry out research more seriously by refusing to hold my hand all the way. I feel very grateful to him for the journey I have been through, including numerous take-aways with regard to my research style, ways of encountering situations which I perceived as problematic. Not to forget when the atmosphere of the pandemic got to me, hindering my mental clarity and structural organization toward the research, and I almost gave up temporarily, he pushed me to reset to ground zero and gradually build myself there on. He successfully boosted my morale even more, by introducing me to the Breathing+ headset by Breathing Labs, which was the main inspiration for involving anxiety management and breathing techniques into my thesis. My next token of gratitude extends to my family back home in India, especially my Mother, who maintained her mental patience and sanity to boost my morale and make me all the more resilient throughout the journey. Apart from her interest toward my thesis research, she made sure not to hold my hand, of course, but rather she knew her ways of putting me into the mental zone of research through discussion and mainly the idea of asking questions fearlessly.

I also wish to extend a token of gratitude to my new found family here in Copenhagen, Denmark, in the form of my friends and social network. For their habit of discussion and especially critique from the non-computing points of view. I wish to thank my dear friend Taguhi Torosyan, an academic scholar from Vienna, who chose to guide me in the times of research for my thesis proposal. The research took place in a period of time overlapping with re-exams, where she educated and mentored me to learn the basic ways of research, academic reading and writing for my thesis proposal, especially when I was at a loss of finalizing down to one topic from an ocean of fascinating ideas. She helped me immensely through my academic reading journey. I would then like to thank my university dorm friends, who enjoyed getting into timely discussions about ideas, mini projects as well as the hard-hitting critiques and every individual perspective. I would need to genuinely also thank my dorm friends hailing from India, because of whom I maintained my sanity while being far from home, and at the same time not losing hold of my culture, especially through food. I wish to especially thank my friend João Tenera, who with complete patience offered to lend me his Occulus Go headset, because of which my fascination for Virtual Reality systems and Soundscapes shot up considerably. I also wish to especially thank Dr. Vaishali Mardhekar (Research consultant and Visiting faculty, Psychology), from Pune, Maharashtra for choosing to be involved in my expert interview phase in my thesis. By providing her professional insight and personal recommendations, she gave my thesis a boost in authenticity and strengthened my intentions through the thesis research. I wish to also thank my closest friends from India, including Tonmoy Haldar, Head of Psychology department at Maharashtra Institute of Technology, Pune, for his guidance, support and insight into the world of academia. I would also need to especially thank my Uncle, along with Thirunaavukkarasu M and Sai Prasanth, for their immense and tireless mentor-ship, support and guidance throughout my thesis journey. Last but not the least, I wish to thank Aalborg University, Copenhagen, for attempting its level best to stay open to students even in times of the pandemic. Because of which, I had a splendid environment with a beautiful harbor view to replenish my mental clarity and energy in.

Aalborg University, December 18th, 2020

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Abstract:

The current study explores the potential of breath controlled web based applications, in personal (self-help) and also possibly educational and medical contexts. In particular, it aims to examine the design and evaluation of such environment designs in formal and/or informal learning environments with respect to the possible benefits for students, educators and other stakeholders in the fields of sonic interaction design (SID), experience design (XD) as well as cognitive science, learning studies and beyond. By looking at case studies of breathing applications in a scientific context, examples and the current state of the art in breathing controlled design, it is envisioned to develop a set of iterative recommendations and/or suggestions for relevant designers, educators and potentially medical practitioners towards expanding the possibilities of learning through focus on physiological conditions.

Contents

Chapter 1

Introduction

World Mental Health day, is observed on the 10th October every year. This is an international day for the awareness, and global education on mental health as well as advocating against its social stigma. It was celebrated for the first time back in 1992, as the brainchild of the World Federation for Mental Health.[1]. The burden of mental health disorders tends to grow with considerable impacts on health and major social, human rights and economic consequences globally. These disorders include depression, bipolar, Schizophrenia, Dementia, Autism, to name a few. The Anxiety and Depression association of America, puts forward a statistic, according to the World Health Organization (WHO), where 1 in 13 individuals all over the world suffers from anxiety. WHO also reported that anxiety comes under the most common list of mental disorders with specific phobia, disorder of depression and also social phobia.[2].

There exists occasional anxiety, which is usually an expected aspect of life. And then there is anxiety disorder, which becomes a matter of concern and worry. This is because it does not go away and results in causing disruptions in personal, social and later professional life. Types of disorders include Generalized Anxiety Disorders (GAD), Panic disorder, Phobia related disorders like simple, social and agora (outside spaces), Separation anxiety and Selective Mutism (rare). These disorders are generally treatable with psychotherapy, medication or even both. Anxiety treatments are of multiple methods and individuals affected need to consult a professional in order to receive treatment best suited to them uniquely. With regard to Psychotherapy, it is a form of treatment which majorly involves communication. In order to be beneficial, it needs to be tailored to the patient's specific needs and anxiety type. Of all the forms of psycho-therapeutic treatments, Cognitive Behavioral Therapy or 'CBT', is one of them.

According to the National Institute of Public Health, an approximate 20 per-

[1]https://wfmh.global/world-mental-health-day/

[2]https://adaa.org/about-adaa/press-room/facts-statistics

cent of the Danish population (700,000 to 800,000 Danes), experience mental health problems over the course of one year. Of these problems, depression and anxiety, along with drug addiction, are known to be two most prevalent causes of mental health concerns.

Depression is known to be the most burdensome disorder in Denmark. cite Nordic welfare Every other Danish family contacted the national healthcare system due to the reason of mental health problems. An important observation made, was the correlation between mental health issues and the level of education. For instance, mental health problems prevailed most amongst individuals with mandatory school as their highest level of education, which amounts to approximately 15.1 percent. Individuals outside the labour market were observed to a distinctly higher ratio of mental health problems as compared to those employed or part of the labour market. An individual's relationship status also contributed to the portion of people who had poor mental health levels. Gender was also found to be a factor in this focus point of mental health. Considering all age groups, the percentage of women with mental health concerns (12.8 percent), is observed greater than the percentage of men (8.7 percent). The percentage of women with mental health issues (17.5 percent), in the age group 16-24, was observed to be twice as large as the percentage of men(8.2 percent) in the same age group (Sundhedsstyrelsen, 2014). Interestingly, men were observed to be at a higher risk of under treatment toward their mental health problems than women. It was also observed that the risk of under-treatment for a male increased, the lower the male's age was. These statistics are still directed toward the clinical data gathered. The data also happened to show, a distinct difference between the genders with respect to the young individual's self-reported awareness of their own mental health concerns[4]. The proportion of girls reporting their own wellbeing problems was twice as large as the boys. In contrast, younger male individual's had more frequent contact with psychiatry services due to the reason of drug-related problems. Regarding ethnic background, the percentage of people from non-Western backgrounds (20.4 percent), possessing mental health problems is more than the percentage of people from Danish or other Western backgrounds (11.8 percent). The data also showed very distinct ethnic differences in young individual's self-assessed problems and in their patterns of contact with psychiatry services. With respect to the support and services for people with mental health problems, the overall responsibility is shared between the Danish Ministry of Health as well as the Ministry of Children, Integration and Social Affairs and Gender Equality. Few key changes involved the restructuring of the mental health service processes in the past few decades in Denmark. These amendments include the disassembling of institutional psychiatry, the build up and strengthening of locally based mental health services as well as the development of measures to service the target group in the social sector. This restructure procedure was considered and implemented, taking into account

its match with the objective that individual's with mental health concerns would be able to integrate and survive peacefully with other citizens in a local environment. Five points of focus were brought to limelight by the Danish Health and Medicine Authority[3]

- It must be easier to be mentally ill, which means to change attitude and fight stigma
- It must be possible to receive rapid help
- There must be a range of services adapted to the individual citizen's needs.
- There must be a sufficiently qualified labour force.
- New knowledge will be made easily available.

It is to be noted that the above five focus points were extended in the Danish Government's action plan from 2014 : 'Equality – new focus on treatment initiatives concerning people suffering from mental illness.' This action plan also adds in a new focus, that the individuals with mental health concerns will have access to the same range of services, as those with somatic disorders, which has not been the case traditionally in Denmark[9]. Procedures such as prevention, diagnostics, treatment, monitoring and rehabilitation, are the involvements of health services in the country. These services are targeted toward mental health combined with drug problems. The therapy and treatment usually includes medicinal treatment, psychotherapy and psychosocial methods, along with psychoeducation, environmental therapy, support and rehabilitation. Offering a treatment which is effective and efficient, is a fundamental principle.

1.0.1 What problem is to be solved?

After a brief introduction, it is of course crucial to introduce to you, dear reader, of the problem to be solved at hand. The problem statements are :-

- **Statement 1** : Whether the breathing application would help the user to focus on their breath?
- **Statement 2** : Whether it will help to reduce the user's self-reported anxiety?

[3] nordicwelfare.org

1.0.2 The Hypotheses

The hypotheses stemming from the problem statements, are as follows :-

- **Hypothesis 1** : The users will find easy to practice breathing exercises with help of the designed application.
- **Hypothesis 2** : If audio-visual feedback for the breath input is provided to the user, then they will be able to focus on their breathing in appropriate manner.
- **Hypothesis 3** : Breathing exercises are effective in reducing anxiety

Chapter 2

Background Research

According to the National Institute of Public Health, an approximate 20 percent of the Danish population (700,000 to 800,000 Danes), experience mental health problems over the course of one year. Of these problems, depression and anxiety, along with drug addiction, are known to be two most prevalent causes of mental health concerns.

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Figure 2.1: Tactile Breather : Inhale activity

Figure 2.2: Tactile Breather : Inhale hold activity

2.1 State of the art

An example would be 'Tactical Breather', which is a mindfulness and breathing application for stress management, developed by the National Center for Telehealth and Technology, 2011a.[1]. This app, includes an initial introduction to tactical breathing, a practice mode for learning, settings to adjust voice gender and visual preferences and so on. The user performs an 'inhale' phase when the circle is green and grows gradually in size. The circle turns to yellow in the 'hold' phase, maintaining a constant size. And finally, in the 'exhalation' phase, the circle turns red and shrinks until it reaches its minimum size, indicated by a black circle in the screen's center. The breathing procedures also contain voice instructions with the phrases 'inhale', 'hold', 'exhale'. In this way, the app uses audio-visual modalities to connect with the user's state of mind as well as enhance their physiological response.

Another approach would be the 'wave-based' visualization. Here, a sine wave

[1]https://apps.apple.com/us/app/tactical-breather/id445893881

Figure 2.3: Tactile Breather : Exhale activity

Figure 2.4: Tactile Breather : Exhale hold activity

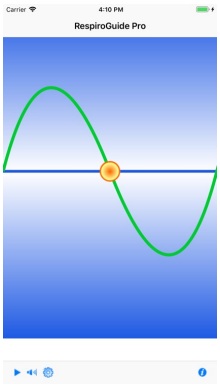

Figure 2.5: Vital-EQ Respiroguide : Sine wave guided - breathing activity

Figure 2.6: Breathing Mentor : Abdominal positioning of device containing app

is displayed as a breathing pattern, which progresses over time. This is supported by a tone, which increases or decreases in pitch to indicate inhale or exhale activity. (E.g. Vital-EQ Respiroguide[2])

Further on, there exist apps which also use pie charts, cylindrical animated figures, animated arrows and even visuals of the human body itself. The lack of studies in the past decade, around the effects of mobile breathing apps, on end users, did not allow one to conclude with substantial claims regarding how effective the above approaches were (Luca Chittoru, Riccardo Sioni, 2014). However, towards 2019, an app named 'Breathing-Mentor',was created to guide the end user to carry out deep abdominal breathing with the use of effective visualization with biofeedback on deep abdominal breathing, based on the mobile phone's accelerometer.

'Breathing+ Headset', a device which is worn as a headset by the end user, connects to a computer via standard USB connection, and operates on a low latency

[2]https://apps.apple.com/dk/app/vital-eq-respiroguide-pro/id395697237

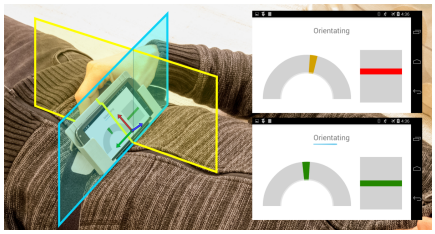

Figure 2.7: Breathing Mentor : Abdominal positioning of device containing app

breathing frequency detection system. Created out of soft polyethylene plastic, and adjustable across all head sizes. This device has been constructed and programmed in such a way, so that the four mics installed on-board calculate accurate breathing activity, eliminating noise from the environment and finally transmitting it to the computer. Data showed 97.1 percent reliability when tested on a total of 10 subjects, during non-guided free breathing, and 100 percent reliability when testing on 10 subjects during interactive paced breathing exercises.[7]. Now an individual could also simply use the in-built microphone in the typical earphone or headphone set, however a breathing monitoring device would need to capture and record a person's exhale in the most accurate and precise manner possible. This means that the acoustic power of the exhalation should be captured directly in front of the mouth, and if necessary, even the inhale going into the nostrils. The unique quality of the Breathing+ headset is that it does exactly this, since the ulterior motive of the device is to detect and monitor the person's breath activity after it is transmitted to the computer. This device has microphones very strategically positioned in order to perform the pre-programmed calculations on the exhalation power and accordingly help the participant breath much better. There are multiple applications developed by the headset's creator, Breathing Labs, which have many task based breathing activities, however all oriented around a specific breathing technique for the main purpose of relaxation and reduced anxiety. Where one application encourages the user to exhale with low acoustic power, and this threshold is helped maintained by the app through visual feedback of color levels, and another app, using the duration of the user's exhale, enables a video to run continuously and if the user stops exhaling, the video follows suit as well. So these applications do not intentionally provide take-aways in the app as to why they are made the way they are, although they do make one thing very clear to the user, which is, in order to maintain a relaxed state of mind, deep and long inhales and exhales are necessary

This device, being the main source of inspiration for this paper, contained a few very important characteristics which the author of this paper decided to utilize in context with the web application created. It is to be most importantly noted, that after first person experiences by the author of the apps by the creators of

Figure 2.8: Breathing+ headset

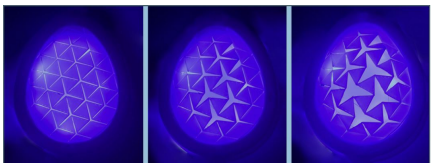

Figure 2.9: Auxetic Breath

the Breathing+ headset, were quite interesting, and insightful with regard to the creation of a new web application.[7]
Finally, using soft robotics and auxetic structures, to exhibit the visualization of the rhythmic respiratory rate, is 'Auxetic Breath', an artistic representation of human respiration especially in COVID-19 times. This technology expresses the paradigm shift from the positive to the negative association of the human mind with breath, the fundamental operation of self-sustenance.[17]

The following features were considered to be tweaked in the web application of this thesis:-

- Elimination of the Breathing+ headset from the setup, due to the preference of maintaining COVID-19 precautions.
- Preference to host the application onto a desktop computer, for the purpose of possibly increased attention span due to minimal system distractions during the performance of activities (notifications, messages, alarms,etc. which could potentially disrupt flow)

Chapter 3

Methods

The developed technology in focus of this paper, needs to fulfil certain requirements. This set of requirements is as follows :-

- User's feedback about the breathing application
- User's self reported change in emotion pre and post intervention
- User's pace of focus on their breathing rhythm

3.1 Research methodology

In order to fulfil the above set of requirements, it was necessary to first delve into the concept of anxiety, its origins and its consequences, both in physiological and mental terms. Anxiety is a huge umbrella, encompassing a wide variety of categories and target groups. It is a disorder highly co-morbid with depression, alcohol and drug abuse. After performing research in the form of not only articles, papers and applications relevant to the concept of breathing exercises to reduce instances and experiences of anxiety, we discovered elements which proved beneficial and some which seemed to be somewhat of a hindrance to the progress expected and desired. The approach utilized to observe the operation of state of the art applications, was to observe the User Experience (UX), User Interaction (UI), Visual Interaction Design (VID) and Sonic Interaction Design (SID).

- **User Experience (UX)**: How the end user experienced the technology overall, in terms of both emotion and attitude.
- **User Interaction (UI)** : How the end user experienced the interaction with the system, especially after the first initial use.
- **Visual Interaction Design (VID)**: The form of experience by the user interacting with the visual elements of the system.

- **Sonic Interaction Design (SID)** :The form of experience by the user interacting with the sonic elements of the system.

The intention of the technology developed, was to provide the end user with a safe zone, which is not a human, but a computing system built to enact the presence of a real empathetic human being. This system is activated by the end user, and continued on its own, according to the actions (input) of the end user. They could of course, choose to redo any segments which have the functionality for another attempt, though the application is built with the intention to direct and also guide. Due to corona times and budget constraints, it was decided to create a digital application, on a portable computing system. These systems are available majorly across every household, along with the availability of a microphones attached to budget to premium earphones, which is in everyone's possession. This application, in the form of a website, would take user input minimally through mouse and keyboard interaction, and majorly through sonic input mapped to visual output. Despite budget constraints, the application was still built with the goal of making a positive physiological and mental impact on the end user, which would show potential for positive future prospects to reach out to a larger target audience with more portability and user interaction sensibility.

3.1.1 Breath, Mind and Body

There exists an association between the timing of breathing along with musical organization and performance. This association, being widely known across all disciplines of art and performance, extends to various human activities, even though the fundamental purpose of breathing is a gas exchange, which is the intake of Oxygen (O2) and the ejection of Carbon Dioxide (CO2). The natural process of breathing occurs upon the contraction and relaxation of the diaphragmatic region and thoracic movement. Methods of meditative practice, such as 'Pranayama' which is the concept of breath control under the parent concept of Yoga or 'Yog', usually performed with 'Asanas', which are specific postures to be held by the individual to prepare the mind and body for stillness, usually beginning with the sitting or the 'lotus' position. An example of a pranayama is 'Bhastrika', which is focused on the strengthening of the abdominal as well as diaphragmatic muscles. The practice of this pose boosts the exchange of CO2 and O2 in the blood, making the nervous system robust as a result[10]. Previous research has proved through indications that depression and anxiety symptoms observed a considerable decrease with treatment practices involving Yogic breathing exercises. The research programs conducted also seemed to illustrate the results in the form of a sense of well-being and releases in tension[6]. This practice, which is more of a lifestyle to be followed throughout daily chores, tasks and forms of communication, requires a gradual effort supplemented by intention and also prayer, leading to a good

intensity of discipline, consistency, regularity in maintaining the body and mind through both exercise and a balanced diet suitable for each individual. Yoga has different perspectives which include spirituality, therapeutic, and developmental approaches. However, the basis of this mind-body modality lies in the fact that the physiological state of the body can affect emotions, thoughts as well as attitudes. This in fact, has a complementary effect on the body. The research of Yoga has generally returned positive indication of the impact of the practice on various outcomes. However, the majority of research carried out has pivoted on disease rather than fitness. Widely recognized guidelines of health and fitness recommend Yoga for stress relief much more than fitness.[12] It is also a highly common understanding that individuals do turn to concepts and philosophies of Yoga, especially during times of depression or other stress-related states of mind and phases of life. However to cater to an audience which is highly attune to their daily doze of instant gratification and self validation especially via social media platforms, where they tune in to feed themselves with the sense of being 'connected' with the world, especially displaying their own and viewing highlights of others, the concept of Yoga has been rather merged with modern fitness regimes and methods in order to capture attention and encourage enthusiasm toward beginning and maintaining a stable healthy daily routine for the mind and body. Research has carried out evaluations which point toward the observation that Yoga is equivalent to moderate forms of exercise, in terms of physical exertion (DiCarloet al., 1995;Rai et al., 1994;Raju et al., 1986). Evidence additionally suggests that practicing yoga has a possibility of being associated with muscle fitness, cardio-respiratory strength as well as endurance (Prasad et al., 2001;Tranet al., 2001).

3.1.2 Lifestyle changes

We humans are majorly pursuing, or rather having a preference for a sedentary form of lifestyle with regard to our professions. This could be generally due to not just typical responsibilities toward family in terms of maternal or paternal leaves, care for elder members of the family, handling sickness, but also choosing to stay home for the sake of more convenience toward daily routines and responsibilities. Most importantly to be in as close a proximity as possible in order to be able to attend immediately to family needs and any emergency situations. We all tend to choose convenience over effort wherever possible in a lowest-risk way. This type of a lifestyle, as much as having its benefits in terms of conveniences and efficiency of work flow to some extents, has an equally high risk in terms of deteriorating physical health. Although previous research has an indication that the participation of humans in sedentary activities may possibly pose as a factor of risk for disorders such as cardiovascular disease, obesity and diabetes, it is only recently that research indicates the potentiality of sedentary lifestyles in risks of anxiety and depressive disorders. Behaviors of the sedentary form are usually characterised by

the low Metabolic Equivalent Total (LMET) energy. It is to be especially noted that sedentary behavior is not void of physical activity, because they can both be occurring either together or independently of each other.[16] The experience of anxiety and other depressive disorders is largely associated with individuals who spend considerable amounts of time in expending energy towards usage of both television as well as computers, while maintaining sedentary positions for extended periods of time. Upon countless instances of witnessing human behavior around us, we have noticed both ourselves and others, to automatically direct to a television set or a portable computer and engage in activities which distract and divert our minds from any unpleasant thoughts we want to stay away from. We would also choose to practice meditative techniques and other forms of 'non-digital' and 'off-screen' engagements to divert our minds. However, again for the purpose of putting in minimal effort for mental diversion, we resort to easier practices, which tend to harm us in return. These practices result in self-limitation to direct social interaction and physical activity.

3.1.3 Intervention

Anxiety treatments have been observed in many forms, since the traditional forms of course-based learning with trainers or coaches or even with materials such as audio CDs, for the practice in the comfort of home. Past research, has also shown that deep and slow breathing exercises have a contrasting effect as compared to shallow and fast breathing focused in the chest region of the body. When a person is in the state of hyperventilation, which is generally triggered through any external stimuli, or even internally via any thought of a memory, this state can also lead to a physiological sensation resembling anxiousness as well as being panic attack symptoms. Deep breathing has been known to have a considerably large effect on the mental state during stressful situations such as job interviews, schools examinations, public speaking (stage fright) and various other forms of social interactions. The transition from conventional forms of guided meditative exercises to modern forms, which involve more portable guiding devices. This majorly includes sensor based devices, which come under the category of 'specialized hardware'. This form of hardware provides a real time adaptation of the training to the user's physiology. However, the major downside to specialized hardware is the high cost and lack of availability when necessary. This downside can be and has already begun getting compensated by smart devices. Decades of research have been around the domain of integrating the smartphone into the health economy. A smart way to curb anxiety in individuals, would be to bring about a system of intervention, which is a part of the user's daily lives and routines. The smartphone, which almost every user keeps close and protected with themselves. It is an object which a person generally wakes up to first thing in the day, performs the daily routine with a major involvement of the object, and also sets off to the night's sleep along

with it. Smartphones are well known to 'follow' their users anywhere and everywhere, so they turn out the most likely and practice intervention device to utilize and support users at any given moment. Most importantly, almost ever individual has access to a smartphone device, be it low, medium or high cost, as well as the high probability of the phone having access to free of cost applications.[3]. Smartphones are being increasingly viewed as tools of healthy utilities, rather than basic communication and entertainment devices. They are being increasingly perceived as instruments directed toward personal health improvement.

3.1.4 Visualization approach

Visualization plays an essential role, especially in making information provided by the applications much easier to comprehend. This goes for especially medical domain applications. Prior to the use of the visualization of information, applications consisted of audio-only instructions. However, now, audio instructions are being integrated with and more importantly enriched with visualizations, which are interactive in nature. One common approach for visualization, has been the 'circle-based' approach. Here, a circle is displayed expanding and contracting, which helps the user to relate to the physical expansion and contraction activity of the human lungs. The visual perception of such a graphic during a breathing activity, helps the end user to better enhance their experience of breathing by connecting them more with their bodily sensations of breathing. Considering the example of a basic blue circle animated to encourage the user to deliberately slow down the pace of their breathing. (Morris and Guilak, 2009;Morris et al. 2010). (write about temporal breathing and musical characteristics here

Chapter 4

Design and Implementation

4.1 Overall Design

A web-based server application was decided upon to be utilized for the testing phase of the thesis, especially due to the ongoing COVID-19 situation, which placed restrictions on physical social interaction. As a result, the testing phase had to include only remote testing by the participants, from the comfort and safety of their homes, with the use of their personal equipment. The equipment would have ideally included a 3D printed device similar to the Breathing+ headset[7], which had been created to transmit the acoustic power of exhale breath from a human being's nostril, to the computer to use the output as a controller for games made to reduce instances of anxiety, improve stamina, control asthma symptoms, and enhance recovery after illness or surgery. The testing equipment would have also included a high quality microphone, however due to the ongoing national pandemic restrictions, a voluntary restriction was imposed, to utilize personal microphones.

The Web application has been created, not just to maintain simplicity in terms of usage, but also to ensure that the user does exactly as the application instructs. As a result, this maintains the attention of the user on the application, rather than putting them into a mental state of easy distraction while using the application due to the freedom of choice. This is also ensured if the user's attention and usage is 'hand-held' by the application, thus making sure that they concentrate their attention from the beginning until the end.

4.2 Design specifics : Visual and Sonic

4.2.1 Visual Interaction Design

Phase 1 : Initiation

The application begins by greeting the user, and thanking them for contributing to the experiment. The reason behind the tone of gratitude in the page text, is to form an initial personal connection with the user, in the sense that their agreement for participation is being rewarded with a token of gratitude. Not just from the experiment host, but also from the web application itself. After thanking the user, the application proceeds to encouraging them to relax themselves by first adjusting their physical posture to a much more comfortable one. After-which the user is informed of a short breathing exercise. The purpose of this quick exercise, is to guide the user into the mode of a meditative state of mind, by performing the activity of breathing. The user would have already been doing this even before the activity, however in the current case, the application is only activating and involving the user's mind to be more aware of the breathing they were already doing.
Once the application guides the user to get their mind and body relaxed and at least attentive, it proceeds to the next step, which is the second and final breathing practice exercise. Only this time,with the aid of a visual, which is a 3d sphere, along with a 'formula', which behaves as a textual aid for the user to follow while breathing in reality. This formula is '[inhale-exhale] x 3', which means that the user needs to perform the combination of inhaling and exhaling, for three repetitions. The 'rule of three' is a writing principle that suggests that a trio of events or characters is more humorous, satisfying, or effective than other numbers. This second exercise, in particular, prepares the user for the challenges which await them in the application.Once the first two breathing exercises are completed by the user, they can then proceed to the main page, where they would be presented with a menu of three challenges, each with it's own takeaways.

Phase 2 : Challenges

Here, on the main page, there are three challenges presented to the user. These commonly involve breathing, with different techniques and purposes. However all the challenges revolve around one purpose, which is to reduce the anxiety of the user. Each challenge comprises of a visual component, a sonic component as well as an overall metaphor, or in other words, a take away. The visual component is for the purpose of keeping the user's attention captured throughout the challenge. Since anxiety is usually a mental state of worry or concern directed towards the anticipation of an imaginary situation in the future, the mind can be always brought to the present moment with the method of distraction. Anything visual is known

Figure 4.1: Example of the 4 point scale emotion checklist

to capture attention immediately. Hence, it was considered to involve a visual component. More importantly, the application allows the user to play the challenges in the sequence decided by the application. The user is only shown the challenges in the beginning, however they have to complete the series from the first to the third challenge. This was considered on the assumption that users already having any form and level of anxiety before being involved in the application, would need to be guided and 'hand-held' through the activity-cum-challenges. This would, in theory, void them of any distracting and potentially indecisive mental states, which would of course hinder their performance on the challenges.
Now since the ears and the eyes generally function together in order to make complete sense of any incoming information, it is an ideal amalgamation if the details are of both sonic and visual form. This ensures the capture of the user's attention even more, hence helping them come to the present moment and have the ability to relax themselves much more. Once the user's attention is directed toward the visual and hence the challenge ongoing on the screen, the textual support helps them maintain their breath. In this way, not only is the user paying a good amount of attention, but they are also accomplishing a task, which keeps them in a state of anticipation to make an accomplishment of any kind. This is the point of reward, which results in the release of endorphins. In this phase of challenges, the visual aspects are pivotal around what we consider using to possibly bring the user to attention to the web page activity. For example the waveforms in the first activity, the expanding and contracting sonic box in the second, and a similar circular visual in the third. These were chosen over the sole usage of audio cues as the user would need their eyes focused in order to pay proper attention to the task at hand.

Phase 3 : Reflection

This is the phase, where along with the application, the user is provided with a questionnaire which poses a number of questions to the user, upon completion of all three challenges over the period of 4 days. These questions include both subjective and objective types. The objective types are those which have a 4-point scale attached, on which the user needs to confirm their choice of rating based on their emotional status. This rating specifically refers to the level of association perceived between the metaphor intended to be expressed by the application and the metaphor automatically understood by the user based on their interaction. A

rating scale was considered for usage since the users would have more expressive yet convenient ways to put forward how they felt about their experience, with of course the support of being spontaneous and not overthinking how they felt. The subjective types intend to acquire answers which are completely unique to the user. This has been considered especially because the average user would generally have their own personal and unique thoughts and critique to share.

4.2.2 Sonic Interaction Design

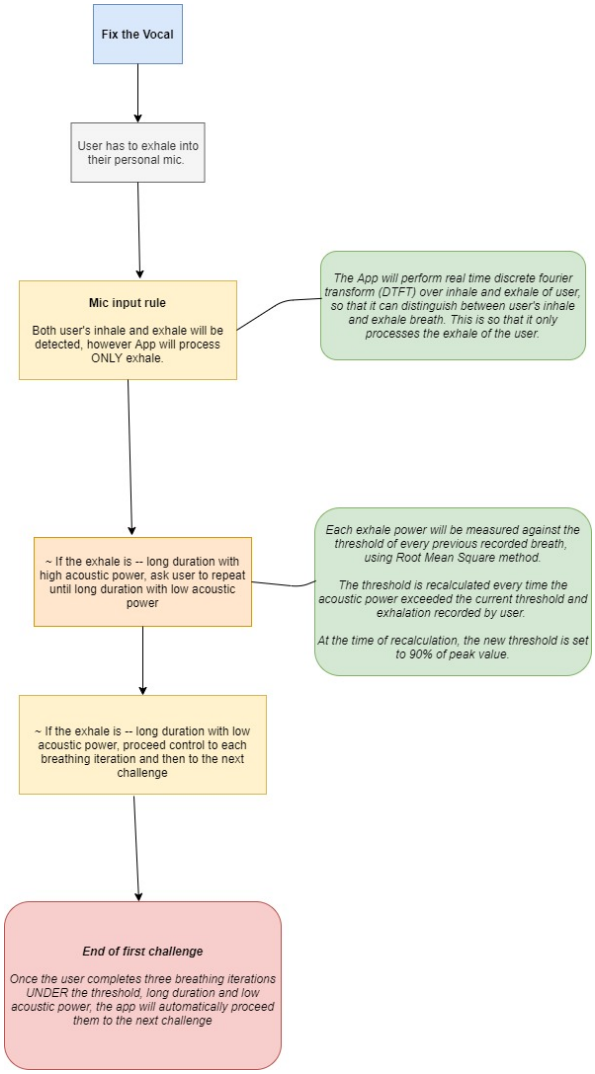

Figure 4.2: Flowchart for Challenge One

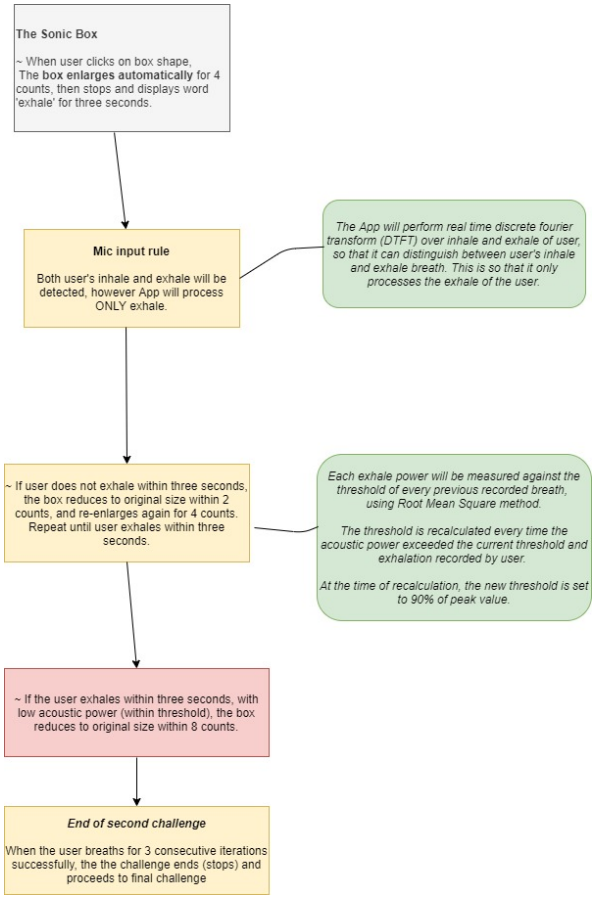

Figure 4.3: Flowchart for Challenge Two

4.3 Web page designs

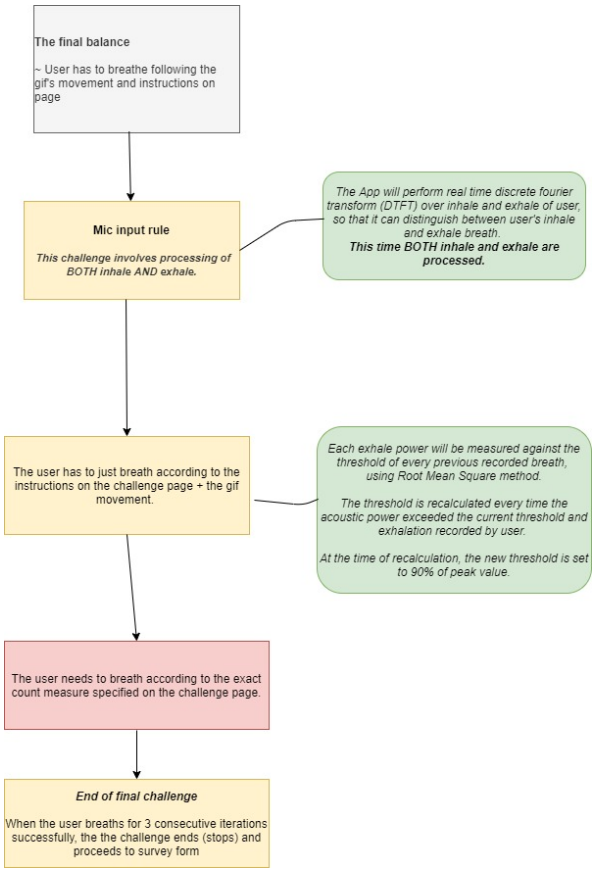

Figure 4.4: Flowchart for Challenge Three

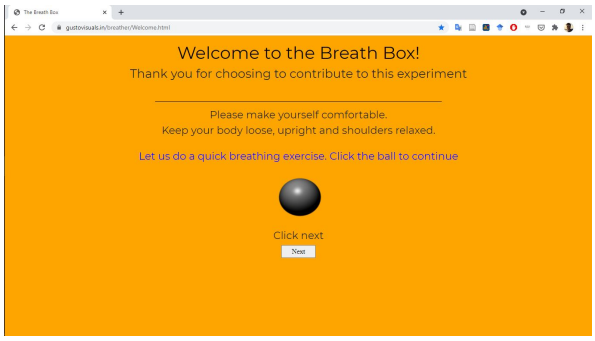

Figure 4.5: Welcome page with Exercise 1

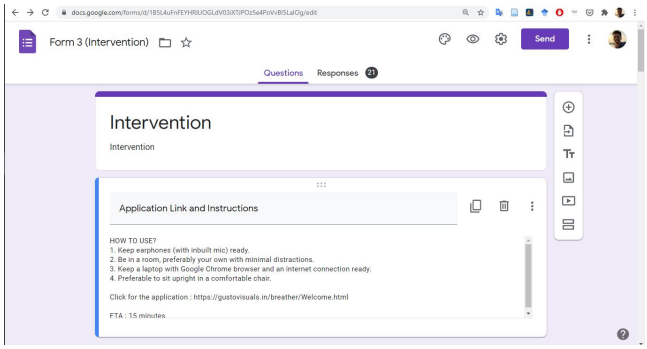

Figure 4.6: Pre and post-experiment intervention form

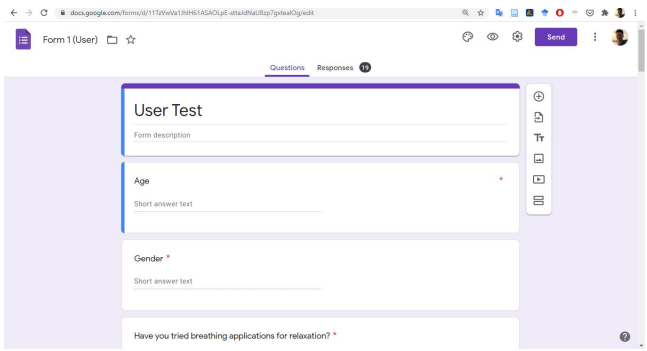

Figure 4.7: Post-experiment user feedback form

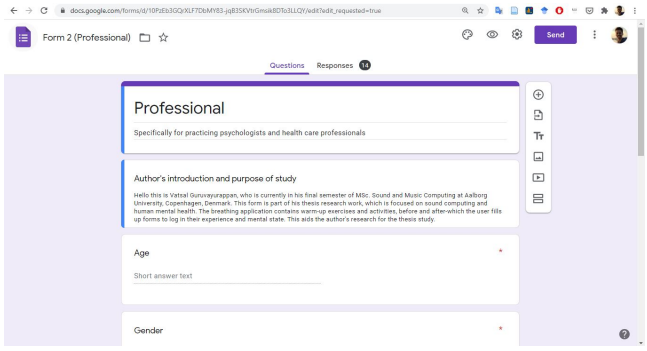

Figure 4.8: Professional user form

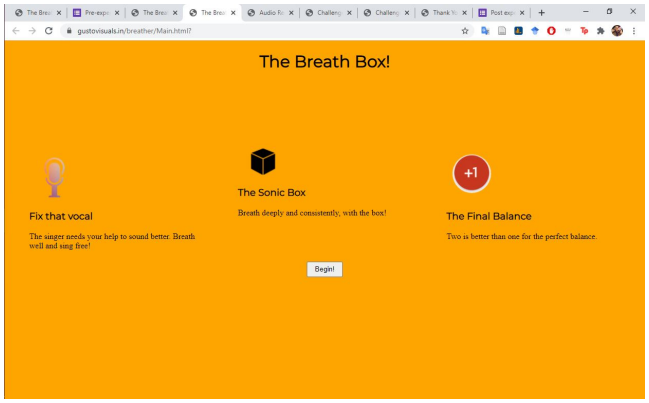

Figure 4.9: Main Menu

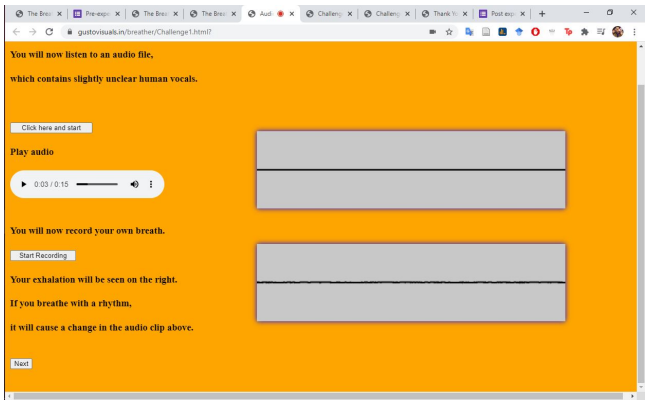

Figure 4.10: First challenge page

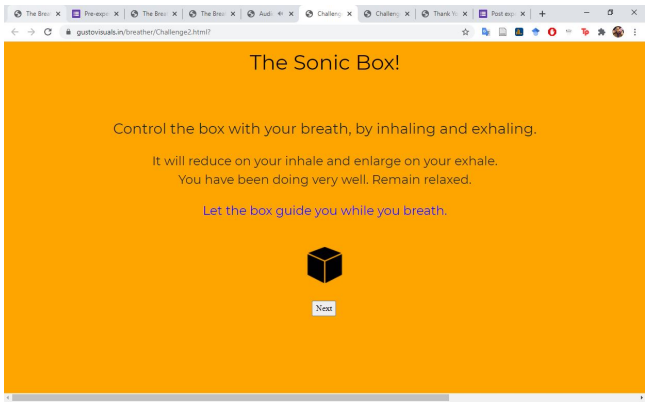

Figure 4.11: Second challenge page

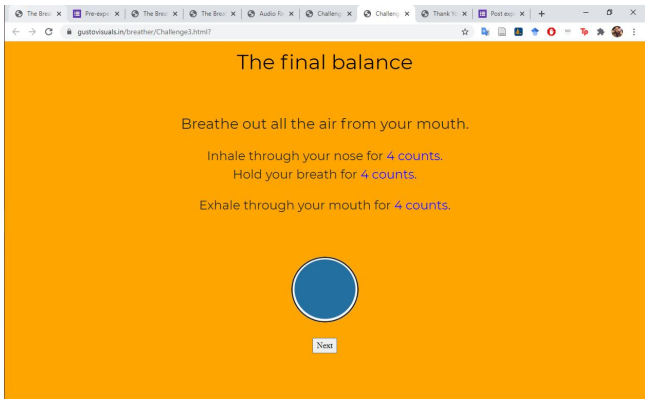

Figure 4.12: Third challenge page

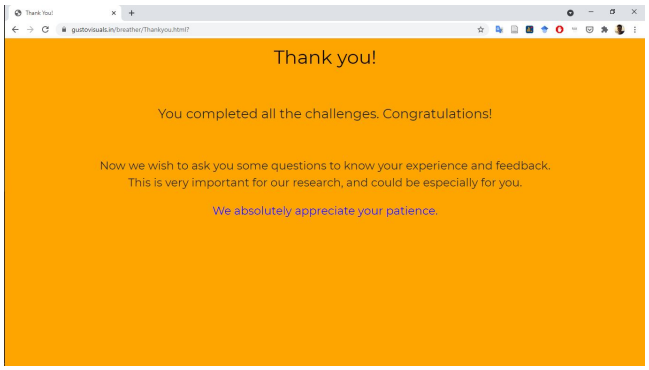

Figure 4.13: Final page

Chapter 5

Testing and Evaluation

5.1 Testing

The subjects would be garnered via web application link broadcasting through social network platforms, email, etc. This is especially due to the ongoing pandemic situation which demands preventive care through social distancing. Hence, the equipment for the experiment would be the subject's personal and the location would be from the subject's comfort space. The web application would be hosted onto a remote server, where the user side browser would be connected to a back-end containing the code as well as storing data collections, results, statistics, etc.

5.2 Evaluation

This phase was be carried out, as specified in Chapter 4 of Design and Implementation, section 4.2.1 : Phase 3 - Reflection. Here, the end user or subject would need to fill out a questionnaire immediately post the experiment period. The data gathered from all the users, would be tabulated and analysed for quantitative as well as qualitative statistics. [5] [13]

5.3 Expert Interview

The interview was conducted by Dr. Vaishali Mardhekar (Research consultant and Visiting faculty, Psychology), from Pune, Maharashtra, India[1]. The purpose of considering her for the interview was to include professional insight and recommendations with specific regard to anxiety and overall mental health in direct association with digital technology. The interview was conducted via email, through a

[1]https://www.linkedin.com/in/vaishali-mardhekar-ab420515

set of 11 questions encompassing the overall application's association with mental well-being, through the medium of sonic and visual elements and feedback.

Below are the interview answers, exactly as received from Ms Vaishali's end :-

5.3.1 The interview

Question 1: How helpful do you think breathing applications are in reducing anxiety?

Answer 1: Being in psychology field for several years, I think breathing exercises are very useful in reducing anxiety. Readily available apps will certainly become popular among people because of the increased awareness among people regarding relation of breathing and psychological states. In my view breathing applications have multipurpose use and will be definitely beneficial for people of any age.

Question 2 :Which digital platform, according to you, is more practical for breathing applications? Smartphone or Desktop/Laptops?

Answer 2: I think smartphone followed by laptop. Because in one of our survey in Pune we found that desktop is used only by few people above age if 50. Majority of them use smartphone or laptop. Most of them use smartphone to see how much km they have walked or similar as it is easy to see while exercising.

Question 3: Would sonic or visual feedback in an application catch the user's attention to reduce anxiety faster?

Answer 3: I think sonic or visual feedback in an application may catch the user's attention but not sure whether it will reduce anxiety faster. As per my knowledge every body has its own clock so let that person take it's time. Surely sonic or visual feedback will motivate the person to use the app.

Question 4: Should smartphone breathing applications be intrusive or non-intrusive in nature? If intrusive, then why? *(Intrusive: When any app intrudes or disturbs the usual functioning of the user's phone. E.g. the app may ask the user if they wish to block and mute background apps and notifications while the app is being actively used)*

Answer 4: Yes I think it should be intrusive because breathing exercise will be beneficial if we concentrate on that task. Any disturbance in between may affect the body for sometime.

Question 5: With respect to question 4, to which extent should the application be intrusive or non-intrusive?

Answer 5: The example which you have given that the app may ask the user if they wish to block and mute background apps and notifications while the app is being actively used. I think the app should see that while doing breathing exercise the person should remain undisturbed due to mobile issues.

Question 6: Which sonic elements work better to calm down a person in a short span of time (minutes)? *(E.g. Sounds from Nature/Instrumentals/Human Vocals/Musical Soundtrack containing both instruments and human vocals/Miscellaneous Sounds)*

Answer 6: I think you can give option of selecting the sound as we have for our mobile ringtones. So that it will have a personalized effect. The sound should be soothing and sound of Nature/Instrumentals/Human Vocals/Musical Soundtrack depends on each individual. I prefer nature whereas my husband prefers instrumental.

Question 7: In your opinion, which age group would this application be ideal for? And why?

Answer 7: This app will be useful for one and all. Even for pregnant women. For ailing patients. There are several benefits and I am myself doing breathing exercise since my childhood. Till date everyday at whatever cost and at least for a few minutes I do breathing exercise.

Question 8: Does gender play a role in how the app is being designed? If yes, How?

Answer 8: I am not very sure about gender but design of app may differ across age. Like older people will prefer easy use with less of aesthetic beauty of the app whereas youngsters will prefer more attractive one.

Question 9: What would you like to improve in this application?

Answer 9: I think basically the whole concept of breathing application is amazing. It will be helpful not only for individuals but also for health and mental health professionals.

Question 10: After your experience of sampling the application, would you recommend it to anyone needful?

Answer 10: Certainly

Question 11: In your opinion, which approach would you prefer and why? *Traditional approach: Professional-to-Patient (in person) Modern approach: Computer-to-Human (virtual)*

Answer 11: In my opinion I would prefer both the approaches and a particular

approach depends on situation. As my student works in remote rural place he would prefer in person. Whereas my friend counselor in Pune may prefer virtual.

Additional comments (as received)
"I, Dr. Vaishali Mardhekar (Research consultant and Visiting faculty, Psychology) really appreciate your efforts in making a user friendly app meant to enhance mental health. I take this opportunity to congratulate you for the innovative contribution as a new entrant in sound engineering field. Best wishes for your project."

5.4 Statistical Analysis

A total of 21 participants took part in this testing phase, between the age group of 20 to 60. The testing was carried out over the period of about one and a half week. This period also included a pre-intervention and post-intervention questionnaire, to be filled separately from the application.

5.4.1 Questionnaires

The questionnaires displayed below, consist of the following types :-

- Intervention : This form is filled by the users, once before testing the application, and once immediately after. The same form was meant to be filled immediately post testing the application, ideally over a period of 4 days.

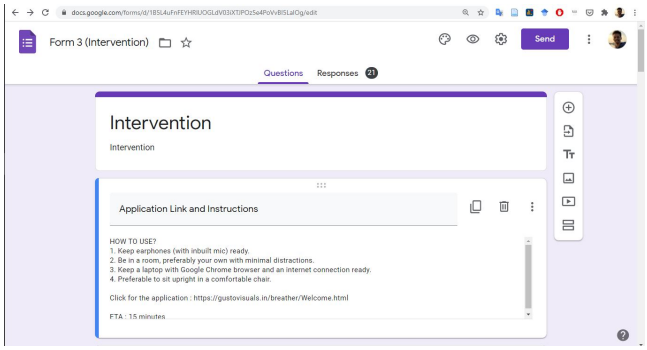

Figure 5.1: Pre-experiment intervention form

- User : This form is the feedback form to be filled by the users once they have successfully completed the application testing and filled the intervention form twice.

- Professional : This form is filled only once by professional experts, which includes practicing psychologists and health care professionals.

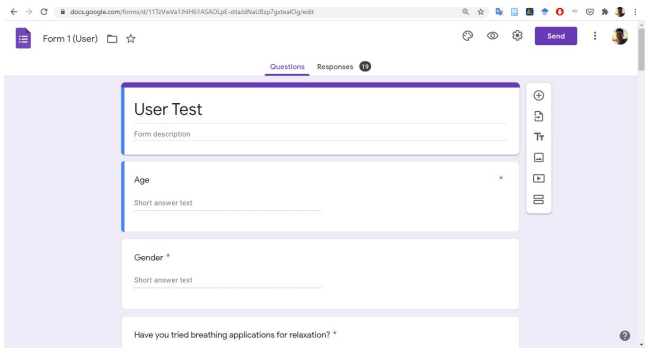

Figure 5.2: Post-experiment User form

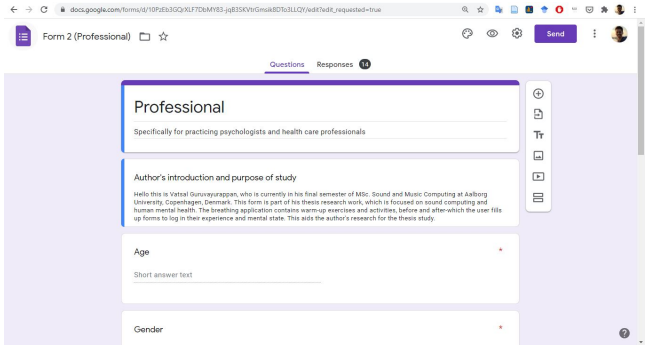

Figure 5.3: Professional expert user form

5.4.2 Results

A. Form 3

Participant age range:-

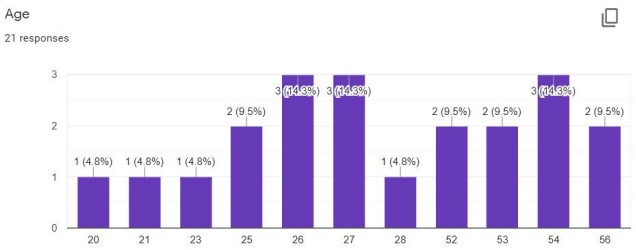

Figure 5.4: Age of participants

Participant gender:-
Intervention emotions : **I. Negative - Angry**
II. Negative - Nervous
III. Negative - Irritated

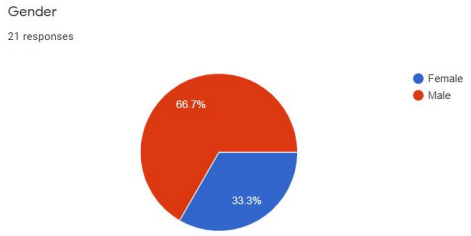

Figure 5.5: Gender of participants

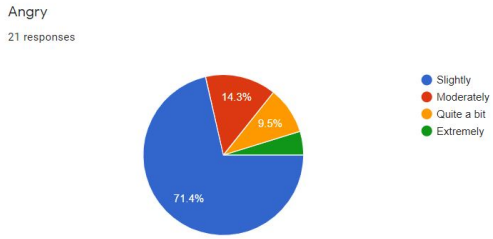

Figure 5.6: Participants' 'Anger' emotion quotient

IV. Negative - Uninterested
V. Negative - Tired
VI. Positive - Attentive
VII. Positive - Energetic
VIII. Positive - Calm
VIV. Positive - Relaxed
VV. Positive - Inspired

B. Form 1

Whether participants' have used any other apps?
Whether instructions were clear?
Navigability of the application
Whether the mic was detected
Whether the user was able to associate the shape movements with their breath
How quickly were you able to focus on your breathing rhythm? (first challenge : 'Fix the Vocal')
How did it feel to listen to the clear vocal audio?
Were you able to associate your breathing activity with the changing box size?
How quickly were you able to focus on your breathing with the box's changing size? (second challenge)

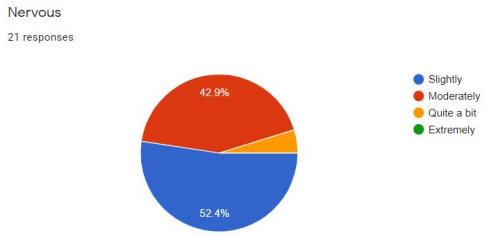

Figure 5.7: Participants' 'Nervous' emotion quotient

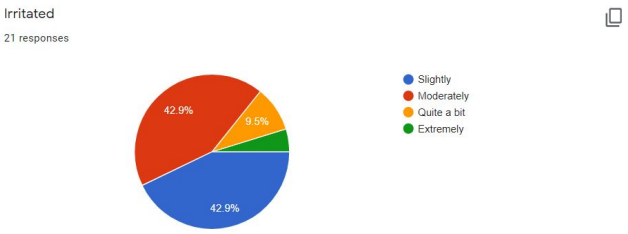

Figure 5.8: Participants' 'Irritated' emotion quotient

Did the combined audio-visual feedback help with your focused breathing? (Second challenge - 'The Sonic Box'))

How quickly were you able to focus on your breathing with the animated circle? (third challenge))

How quickly were you able to focus on your breathing with the animated circle? (third challenge))

App improvement suggestions from the users

Other comments

App recommendation

If user's feel the app keeps them relaxed

If user's knowledge of the app's relaxation purpose will help them become more relaxed

C. Form 2

Profession

App's usefulness in relaxing clients?

Will the professionals use such apps for counselling?

Professional comments

Professional comments

5.4.3 Data Analysis

The data analysis contains the following elements:-

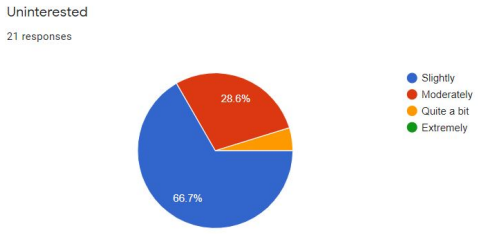

Figure 5.9: Participants' 'Uninterested' emotion quotient

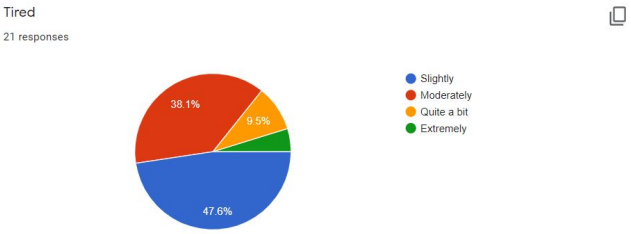

Figure 5.10: Participants' 'Tired' emotion quotient

- Google form statistics
- Microsoft Excel sheet tabulation
- IBM SPSS analysis for significant increase/decrease for Paired samples t-test

The intervention questionnaire involved requiring the participants to log their emotions on a 4 point scale, which contained the options of 'Slightly', 'Moderately', 'Quite a bit' and 'Moderately'. The intervention largely questioned the participants about their emotional status through the week. The emotions consisted of:-

- **Negative emotions :** Angry, Irritated, Uninterested, Nervous, Tired.
- **Positive emotions :** Attentive, Calm, Energetic, Inspired, Relaxed.

The scoring of the intervention data was performed according to the following :-

- **Angry** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Irritated** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Nervous** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Uninterested** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Tired** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4

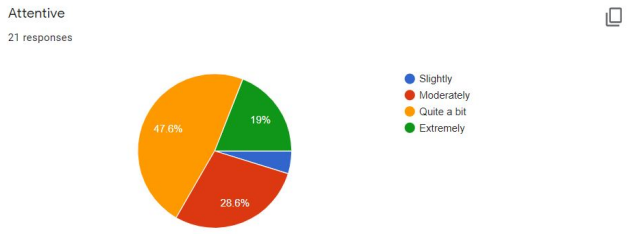

Figure 5.11: Participants' 'Attentive' emotion quotient

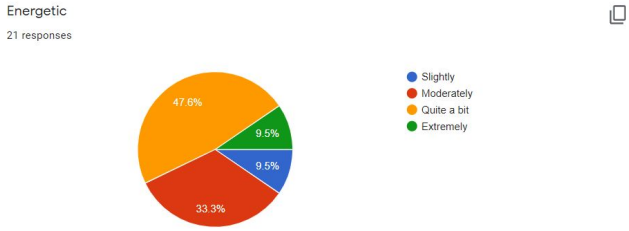

Figure 5.12: Participants' 'Energetic' emotion quotient

- **Attentive** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Calm** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Energetic** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Inspired** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4
- **Relaxed** : Slightly - 1 | Moderately - 2 | Quite a bit - 3 | Extremely - 4

5.4.4 SPSS Analysis

Scored intervention data in Excel

Scored intervention data in SPSS

Paired sample t-test results:-

- Angry output
- Attentive output
- Calm Output
- Energetic Output
- Inspired output
- Irritated output

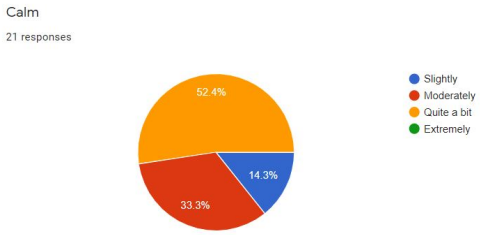

Figure 5.13: Participants' 'Calm' emotion quotient

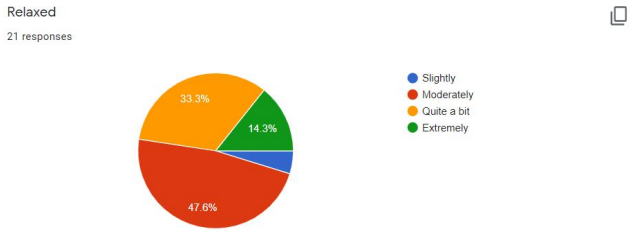

Figure 5.14: Participants' 'Relaxed' emotion quotient

- Nervous output
- Relaxed output
- Tired Output
- Uninterested Output

The statistics illustrate that the participants' self-report on the emotions checklist shows the breathing exercise's impact on the reduction of anxiety, considering the statistically significant increase in positive emotions (figs.5.46, 5.45, 5.44,5.49, 5.43) and decrease in negative (figs. 5.42,5.47, 5.50, 5.48, 5.51) emotions. These findings prove the third hypothesis, which is that the breathing exercise was effective in reducing anxiety.

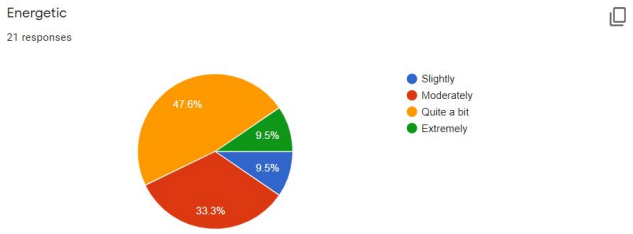

Figure 5.15: Participants' 'Inspired' emotion quotient

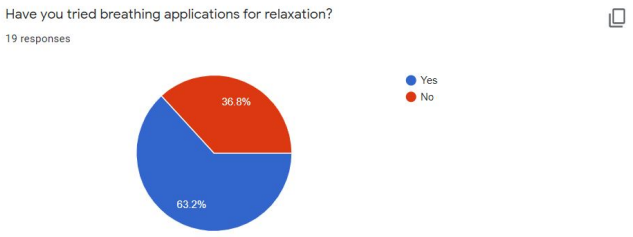

Figure 5.16: Participants' use of other apps

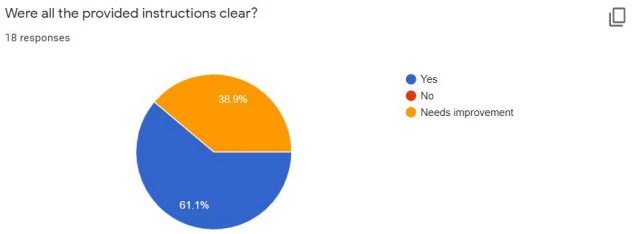

Figure 5.17: Clarity of instructions

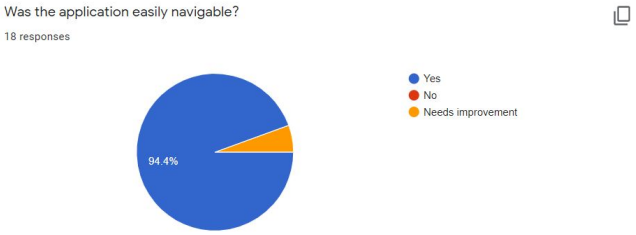

Figure 5.18: Application navigability

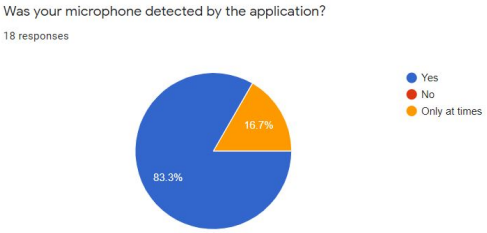

Figure 5.19: Mic detection

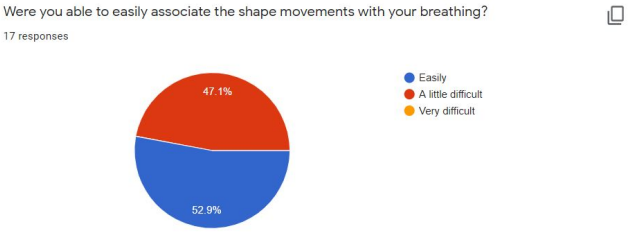

Figure 5.20: Ease of Shape association with breathing

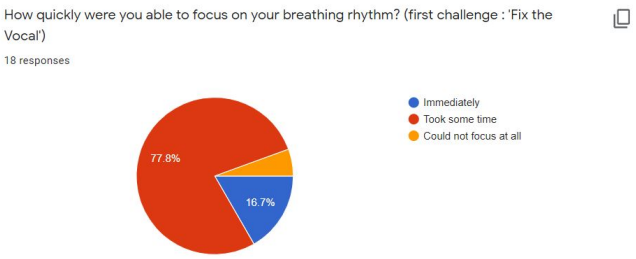

Figure 5.21: Pace of breath focus

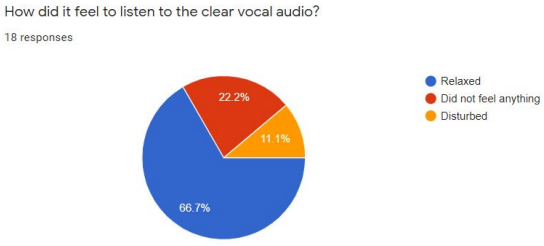

Figure 5.22: User's experience of the clear vocal

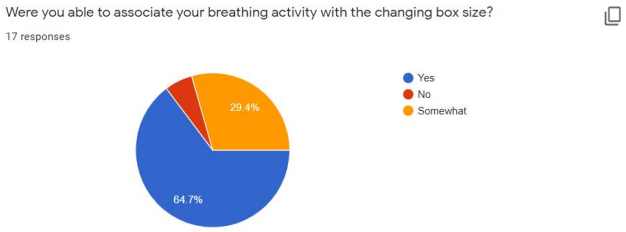

Figure 5.23: User's breath association with the changing box

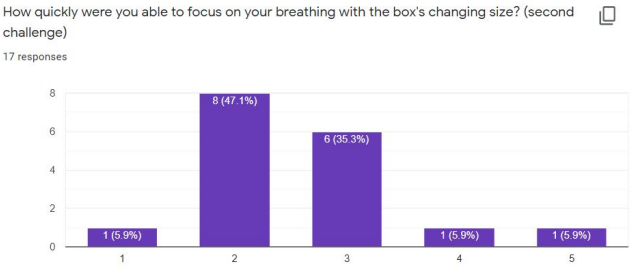

Figure 5.24: Breath focus pace with changing box size

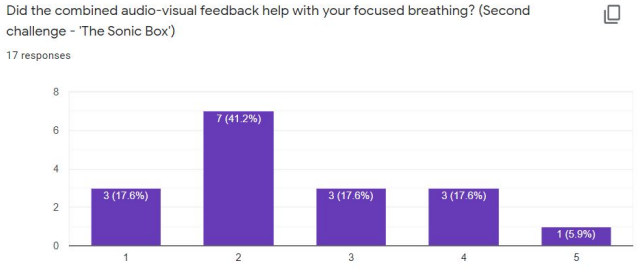

Figure 5.25: Effect of combined audio-visual with breath focus

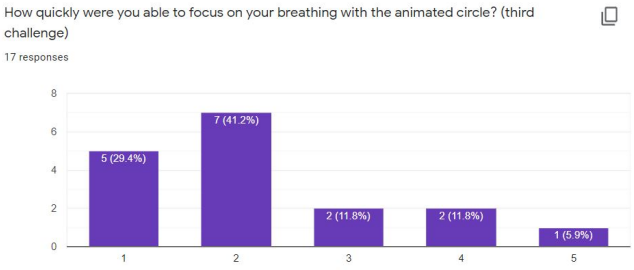

Figure 5.26: Breath focus pace with animated circle

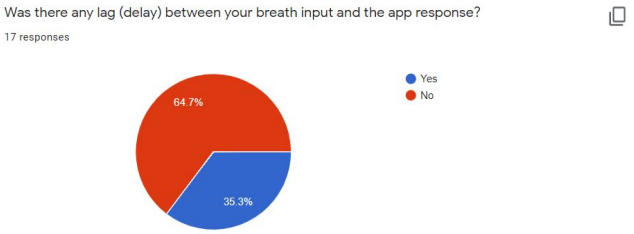

Figure 5.27: Delay between app input and breath response

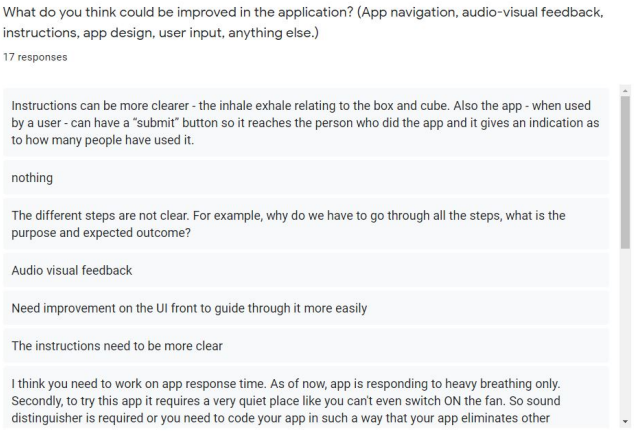

Figure 5.28: Subjective Feedback 1

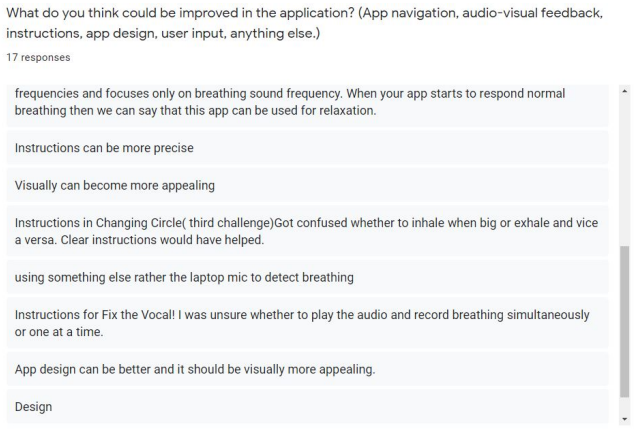

Figure 5.29: Subjective Feedback 2

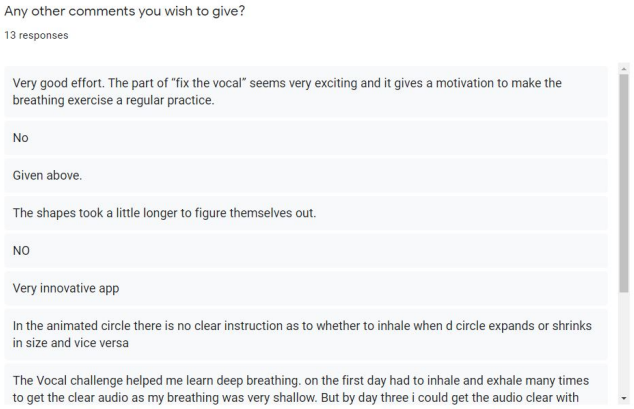

Figure 5.30: Other comments 1

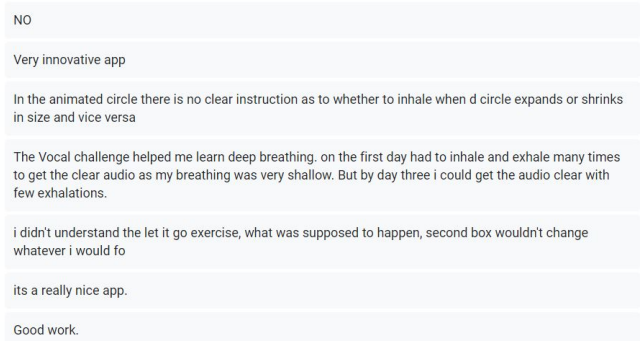

Figure 5.31: Other comments 2

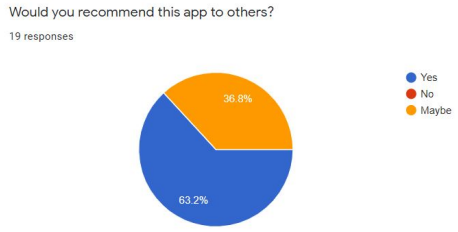

Figure 5.32: Users' app recommendation

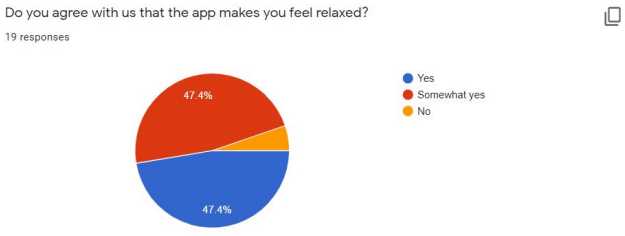

Figure 5.33: Users' app relaxation quotient

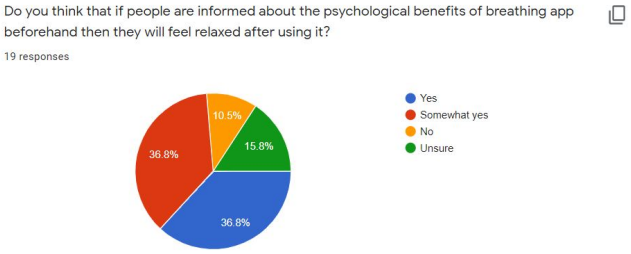

Figure 5.34: Users' app relaxation quotient

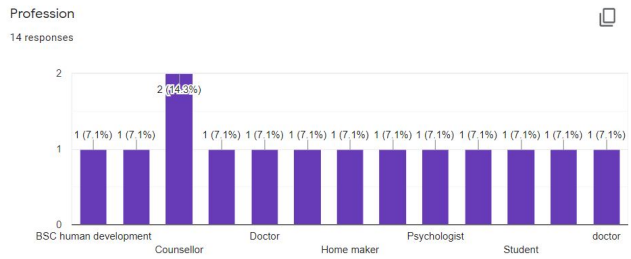

Figure 5.35: Professionals' domains

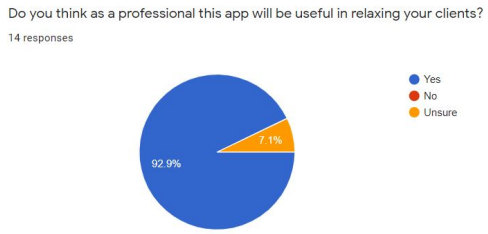

Figure 5.36: App's usefulness in relaxation

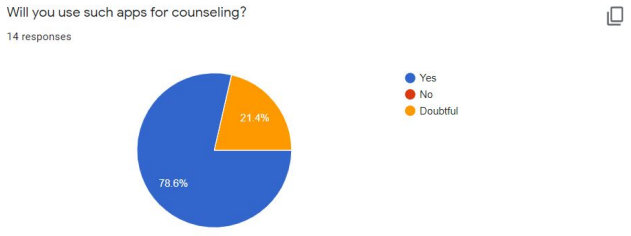

Figure 5.37: Professionals' choice for app in counselling use

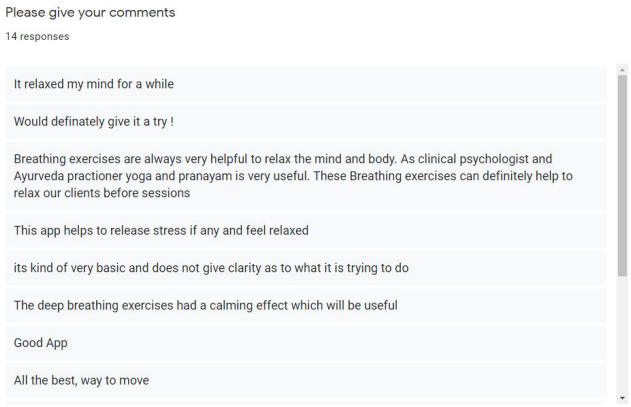

Figure 5.38: Professionals' comments 1

Figure 5.39: Professionals' comments 2

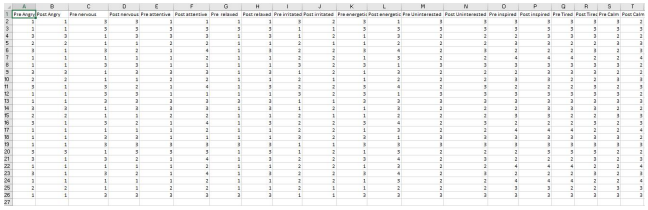

Figure 5.40: Scored intervention data in Excel

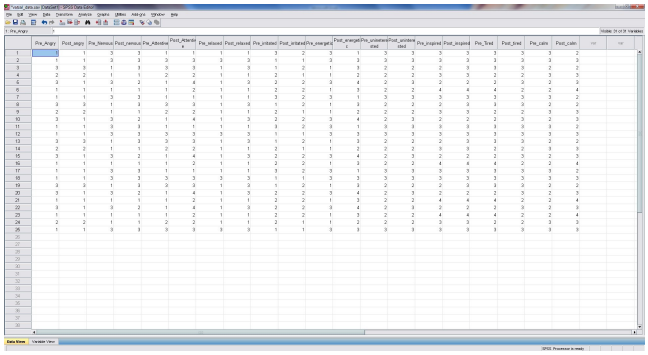

Figure 5.41: Scored intervention data in IBM SPSS

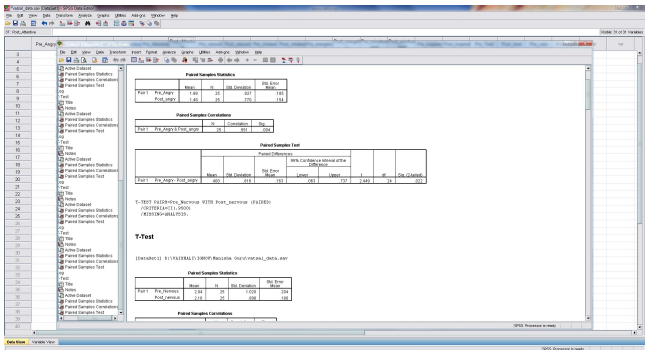

Figure 5.42: Output of Anger emotion

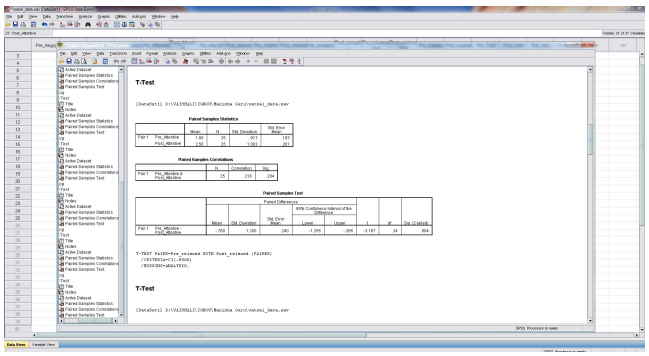

Figure 5.43: Output of Attentive emotion

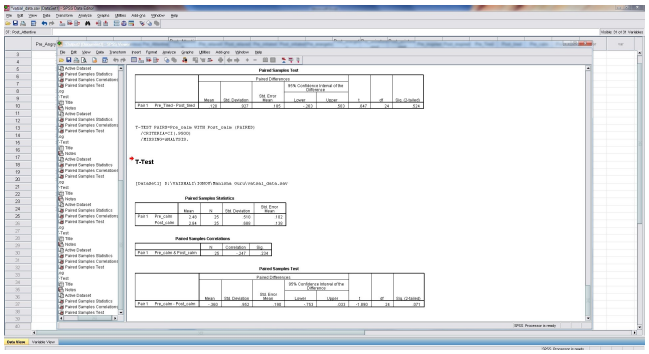

Figure 5.44: Output of Calm emotion

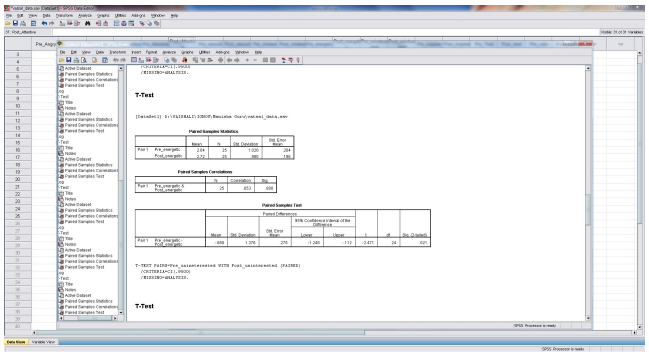

Figure 5.45: Output of energetic emotion

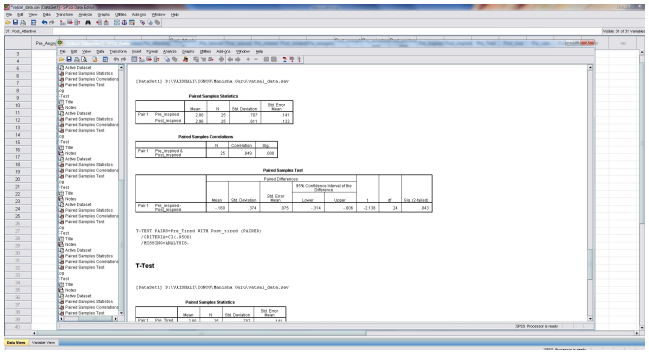

Figure 5.46: Output of Inspired emotion

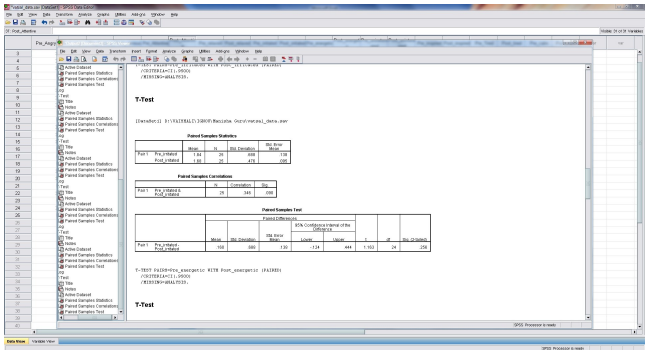

Figure 5.47: Output of irritated emotion

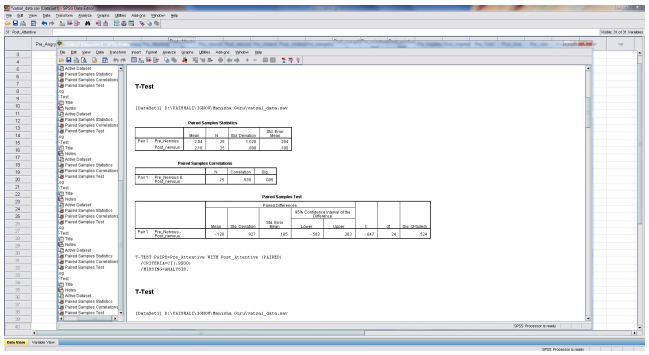

Figure 5.48: Output of nervous emotion

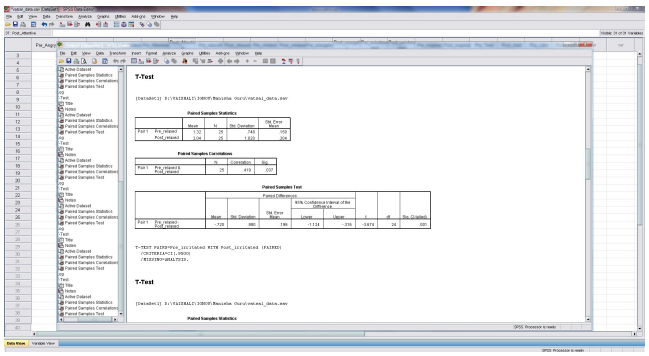

Figure 5.49: Output of relaxed emotion

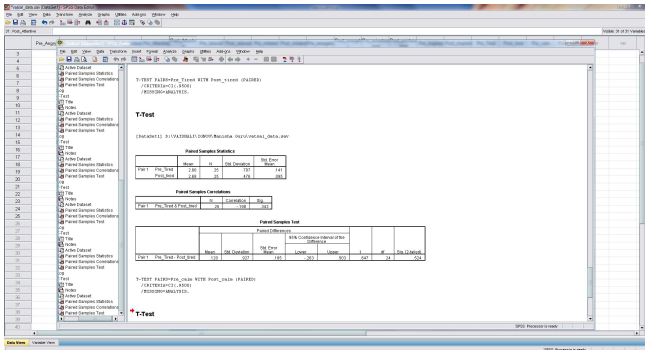

Figure 5.50: Output of Tired emotion

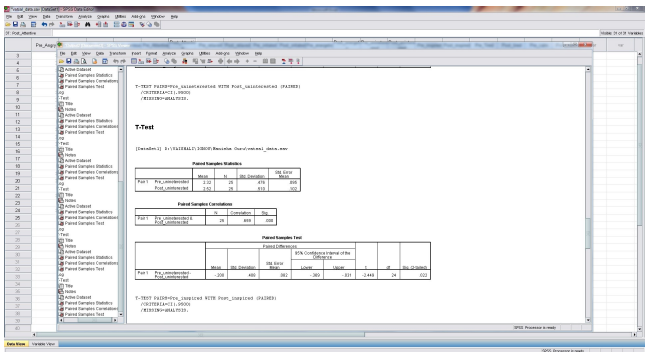

Figure 5.51: Output of Uninterested emotion

Chapter 6

Conclusion

The findings of the experiment suggest that participants did indeed experience self-reported relaxation after using the web based breathing application. This illustrates a high probability that the use of audio-visual feedback in the application, worked in favor of satisfying the second hypothesis. Similar to other works such as 'Breathing+ headset' and 'Life Tree', which intend to induce relaxation in users, 'The Breath Box' results share common ground. One of the major limitations to this testing phase was the sample size as well as in terms of the implementation design of the web interface. An attempt was made of diving into the depths of both audio computing, human mental health and their intersection. Although according to past research, visual modalities have been known to make more of an impact on the end-user's mental state, so as to encourage them and enable a more enhanced and comfortable initiation into the realm of digital, augmented or virtual reality of breathing techniques and relaxation experiences. Research is always ongoing to ensure that sonic elements make as much an impact as visual elements do, so that the phrase 'More than meets the eye' is successfully achieved, as it takes a considerable amount of planning and design in user experience and perception to achieve successful connections through purely sonic methods. It has been plausibly described, that as long as any atmosphere is sufficiently calm and composed for the user, then users can take steps directed toward concentrating their attention without too much analyzing and prevent their dwelling on any form of ruminating thoughts[11].

'The Breath Box' is possibly an attempt at the creation of a very simplistic, minimalist-designed realm which hopes to cross the obstacles toward achieving a healthy balance, slightly inclined toward more sonic elements and modalities.

The web application link can be accessed at **'The Breath Box'**. And the questionnaires can be accessed separately at

1. Pre-experiment: https://forms.gle/F3KsEreSDyGsF9K29

2. Post-experiment : https://forms.gle/nLmmVXAHJXy9XTbDA

list

In case you have questions, comments, suggestions or have found a bug, please do not hesitate to contact me. You can find my contact details below.

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Chapter 7

Future Scope

Maintaining a balance and control over our breathing rhythm, consistency, capacity and power, not only strengthens our body's nervous system, but also makes our mind much more resilient in nature. The paper's focus on reducing instances of anxiety, expands to the potential of the human being becoming a handler of the human mind, rather than otherwise. By practicing a variety of breathing techniques, an individual can maintain a firm hold over their thought processes, resulting in overall well-being and physiological balance (relaxation).

While the thesis is definitely not limited to breathing exercises to reduce anxiety, it extends to countless other possibilities and even realms. For instance, instrument performance, virtual reality, soundscapes and so on. Taking the example of the breath based electronic instrument, where the user's inhale and exhale are individually detected, as well as finger pressures to recreate the acoustic qualities of a harmonica, by Wheaton et. al.[15]. Although this instrument dates back to the late 1990s, it goes to illustrate how breathing based controllers for musical instruments were invented even back then. The possibilities of futuristic technologies involving the human breath, are endless and unlimited. Musical innovations can be produced, where-in musicians and aspiring enthusiasts can not only produce compositions, they can also be much better aware of their physiological balance in tandem with their performance art. Breathing could even be incorporated into visual art performances or installations, along with even futuristic virtual therapy, which could be both personal or professionally practiced.

With regard to the realm of Virtual Reality, breathing applications can be expanded in terms of audio, visual and spatial dimension in order to enhance the experience by making it more immersive for the user. Futuristic applications can resemble and innovate upon past examples like 'Life Tree', a breathing game which helps users breath deeply, slowly and rhythmically by focusing on the in-game visual of a tree which grows and shreds based on the user's inhale and exhale. The microphone used is also specifically created for the application. The application

was designed to involve mainly a visual modality for enhancing the breathing experience[11].

Additionally, Virtual Reality has been long incorporating breathing as wholesome applications which have an added immersive experience for absorbing and learning new ways of exercising balanced breathing techniques. These applications, could very well be extended across majority of educational levels, so children could be well educated regarding mental health and its dis-orders.[8]

The boundaries of dimensions with regard to the human perception of audio could be pushed well enough, to the mind's limit. The potential involves scenarios such as soundscape creation and immersion. Similar to Anil Camci's 'INVISO', which contains a very user friendly system creation, audio input, user pathway creation and user experience. Ambient soundtracks could be inserted at locations of varying heights and distances from one another. And the user's 'head' element in the system, could be put into a user-created pathway by simply drawing it out. 'INVISO' not only provides a high level of convenience in soundscape creation, but it also gives a good amount of positive satisfaction for the user once they listen to their own sonic creation in a three dimensional space[2]. Users could very well experiment with ambient soundtrack inputs at various locations in the space, and play around with dummy head pathways to breath along with. Futuristic versions of 'INVISO' are limited as much as the mind imagines, and hence it invokes high amounts of curiosity as to how an activity like breathing could be connected to technologies like Virtual Reality involving expanded dimensions.

Ongoing research however also considers that Virtual Reality environments may not necessarily play a significant contribution to considerably calming down an individual's mental and physical well-being, as long as the individual is in a sufficiently relaxing overall setting. It is also to be noted that the sample size of any Virtual Reality meditation experiment or program would need to be large enough to achieve significant results in order to make firm conclusions. This helps to acquire insight into the right balance between only auditory guidance and both audio-visual guidance.[1]

Another aspect of human disorders, with respect to mental health, is ADHD, or 'Attention Deficit Hyperactivity Disorder'. This disorder happens to be co-morbid with anxiety disorder. Previous research on relaxation and biofeedback techniques along with the experiment results from 'The Journey to the Wild Divine', shows that there is potential for biofeedback games to produce progress on the symptoms of ADHD and any other disruptive behaviors, with the exception of a few side effects. It is to be especially noted, that since millennial youth are technically advanced, the presence of a video game module as part of therapy would in fact stimulate the interest to maintain practice for breathing techniques.[14].

7.0.1 Suggestions for future testing periods

Further studies should ideally be conducted involving demographic variables like age, sex, occupation, any medication use, etc. In this way, a much more precise and accurate finding could be achieved, being inclusive of more intricate parameters such as the above mentioned. The application could also involve a machine learning model which has breath data-sets trained into it, inclusive of a much wide range of age, gender and occupation.

Chapter 8

Appendix

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Appendix A

Appendix