MOBILE HEALTHCARE APPLICATION FOR BREATHING TRAINING MONITORING AND GAMIFICATION IN HEART RATE VARIABILITY FOR WELL-BEING

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Hons.) Software Engineering

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May 2018

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"MOBILE HEALTHCARE APPLICATION FOR BREATHING TRAINING MONITORING AND GAMIFICATION IN HEART RATE VARIABILITY FOR WELL-BEING"** was prepared by **VASANTA LIM XIN JING** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Hons.) Software Engineering at Universiti Tunku Abdul Rahman.

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ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Lee Poh Foong and co-supervisor, Miss Chean Swee Ling for their invaluable advice, guidance and his enormous patience throughout the development of the research.

In addition, I would also like to express my gratitude to my loving parents and friends who had helped and given me encouragement and motivation during the whole process of the development of the project.

ABSTRACT

Nowadays, people are under stress due to high workload. These people often ignore their physical health as well as mental health. Some stress-related diseases such as cardiac disease, depression and asthma have all become more and more common in our society. Hence, this project is developed with the objectives: To design a mobile application that allows users to check their well-being level, to provide a mobile application that provides training in deep breathing to reduce stress, and to design a mobile application game that encourages the users to achieve a healthy breathing rate with Heart Rate Variability (HRV) measurement.

To achieve the objectives, the mobile application is designed to provide deep breathing exercise guidance to the users and allow the user to measure their HRV by using phone camera. The mobile application also encourages the users to achieve healthy breathing rate by awarding the users when they achieve a better HRV results.

Prototyping methodology is selected as the system development methodology of this project, while research, questionnaires and prototyping are chosen as the research methodology. A mobile application and a web application are developed successfully and pass all the test cases.

In conclusion, this project is a successful project that has met all the project's objectives. All the users' data and records of using the mobile application are stored in the web application. From the data collected, it is proved that most of the users have positive feeling (happy, calm, and sleepy) after measuring HRV or performing breathing training exercise.

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CHAPTER 1

INTRODUCTION

1.1 Background

Mind-body dualism is a view in the philosophy of mind that mental is two distinct substances. Dualism believes that there is a two ways interaction between mental and physical substances. Mental health and physical health are closely related and affecting each other (Ohrnberger et al., 2017).

Stress is a part of life. Everyone experience stress but not everyone can handle stress well. The sources of stress for every group age are different. People who are 18 to 47 years old have the highest average stress level. Students suffer stress from their studies, and after they graduate, they suffer stress from job stability, financial stress and also stressed by work. Then for those who are over 48 years old will start to feel stress about their health problem (American Psychological Association, 2012).

There are positive benefits of stress such as increase one's efficiency and even boost memory. Stress also brings negative impact on health if people do not handle stress effectively. Constant stress can lead to depression disorder and anxiety disorder (Khan and Khan, 2017). Some stress-related diseases such as cardiac disease, depression and asthma have all become more and more common in our society.

Heart rate variability (HRV) is known as psychological stress indicator (Kaur et al., 2014). It is a new way to track well-being as it can be used to measure how well people can handle stress. Researchers also indicates that higher HRV represents good general health (Jarczok et al., 2015). Therefore, HRV will be used in this project to measure the wellness of a person.

1.2   **Problem statement**

Nowadays, people are under stress and tension. The daily workload can sometimes be unbearable. These people need help to keep track of their wellness and provide ways for them to distress.

Using the traditional heart rate variability device to check for the stress level is very inconvenience as the sensor needs to be wet and worn flat against the skin. Performing daily measurement can be a burden. Besides, these HRV devices are expensive for some people. These people need a low-cost setting method in regulating their mood and check for their well-being level.

1.3   **Objectives of Project**

i.   To design a mobile application that allows users to check their well-being level.

ii.   To provide a mobile application that provides training in deep breathing to reduce stress.

iii.   To design a mobile application game that encourages the users to achieve a healthy breathing rate with Heart Rate Variability (HRV) measurement.

1.4   **Proposed solution**

HRV can be used to measure the well-being level of a person as it was positively associated with cheerfulness and calmness (Geisler et al., 2010). To measure the HRV of the user, the user's pulse is detected from a finger by using the phone camera assist with flashlight beside the camera. This allows us to measure the wellness of the user in a quick way. By using this approach, the user can save extra medical fees and knows his/her well-being level instantly. After the user checks for his/her HRV, it will be recorded as the initial HRV value.

There are some ways for us to reduce stress in life. One of the techniques is deep breathing (Cheng et al., 2017)(Cheng et al., 2018)(Kabat-Zinn et al., 1992)(Dusek et al., 2008)(Cuijpers et al., 2014). Deep breathing is the easiest and cheapest way to make a people calm down. Furthermore, deep breathing helps ones to focus and relax the muscle. Therefore, the deep breathing training will be provided in the application to guide the user to achieve healthy breathing rate.

After the breathing training, the user can choose to measure his/her HRV again. The measurement for HRV is conducted in game based. When the latest user's HRV is better than the initial HRV, the user will be awarded a 'puzzle'. This will encourage the user to achieve a healthy breathing rate with HRV measurement.
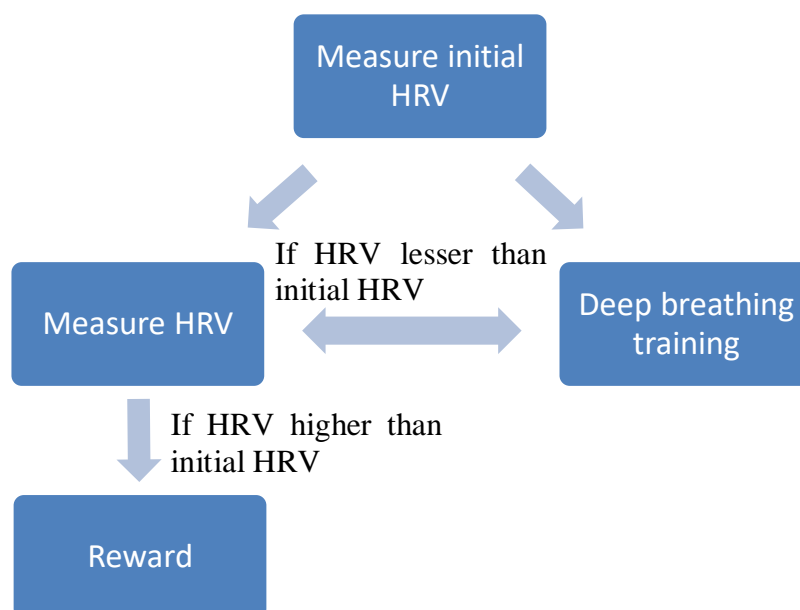
Figure 1.1: Flow Chart of modules

1.4.1 **Technology involved**

Several technologies are involved in a mobile application development in order to achieve some functionality. Technologies involved in this project include the mobile database engine, mobile operating system and also mobile application framework. Besides, a web application also developed to support the mobile application.

1.4.1.1 **Mobile Database Engine**

Mobile database engine is required in this project to store data. SQLite database is used in this project as SQLite's features are very suitable for this project and it is free to use.

SQLite database (SQLite, n.d) needs no server to run. The application can directly communicate with the SQLite database to retrieve and store data. Next, SQLite database is cross-platform and self-contained. This means that SQLite is usable in any environments including the embedded devices such as iPhone and Android devices.

For this project, the SQLite database is used to store the user's HRV records and user's rewards. The HRV records included the date and time the user measures HRV, and also the HRV results. This HRV data is stored in the user's device and viewable by the user.

1.4.1.2 **Mobile Operating System**

There are a lot of mobile operating system such as iPhone OS, Android OS, Windows OS, BlackBerry OS, Symbian, and web OS.

Operating System	4Q16 Units	4Q16 Market Share (%)	4Q15 Units	4Q15 Market Share (%)
Android	352,669.9	81.7	325,394.4	80.7
iOS	77,038.9	17.9	71,525.9	17.7
Windows	1,092.2	0.3	4,395.0	1.1
BlackBerry	207.9	0.0	906.9	0.2
Other OS	530.4	0.1	887.3	0.2
Total	431,539.3	100.0	403,109.4	100.0

Table 1.1: Comparison of the market share between different operating system
(Gartner, 2017)

According to the table above, 80% of the users use Android OS, while approximately 18% of the users use iPhone OS. Android has the greatest amount of users while other operating system has too little amount of users, hence this is major reason that this project is developed for Android operating system.

Another reason for choosing Android operating system is because it is open source and android applications are free to develop. Besides, the price for publishing the application on Google Play Store (Android) is much cheaper than App Store (iOS). Google Play Developer Account only cost $25 (around RM102.08), while Apple iTunes Developer Account costs $99 per year (around RM404.22 per year). It will be a large amount of money for publishing an iOS application compare to Android application.

Therefore, in this project, the mobile application is built for Android platforms.

1.4.1.3 **Mobile Application Framework**

As the mobile application for this project is built for Android OS and future it can be improved to support iOS, the cross-platform mobile application frameworks such as React Native is chosen for the application development.

React Native is a famous cross-platform framework developed by Facebook. React native allows developers to build mobile apps using only JavaScript and it is impossible for the user to differentiate from application built using C or Java as it shares the same UI building blocks as usual iOS and Android Apps (Facebook, 2017).

Besides, using react native can help developers to increase the development time as react native have the feature – hot reloading. The developers do not need to waste time recompiling code after they edited their code, but only reload the apps.

React native provides a better way to develop a mobile application as it can be easily converted between Android and iOS. This makes the application to have more space for development in future.

1.4.1.4 **Cloud Application Platform**

In this project, the web application is deployed on Heroku.

Heroku is a free and flexible cloud application platform. It provides free web hosting and allows developers to spend more time on developing rather than managing servers, deployment, ongoing operations, or scaling.

For this project, all data that are collected from the application will be stored in Heroku and admin can view the data collected from the developed web page.

1.4.1.5 **Web Application Framework**

In this project, a web-based application is created using Laravel framework.

Laravel is a Model-View-Controller framework. This means that it separate the business logic code from presentation code. Therefore, developer can change the appearance of a web page easily without touching the backend code or change the backend code without touching the front end code. This makes Laravel project easier to maintain.

Laravel framework is chosen to develop this web-based application is because Laravel is built with authentication and authorization systems. This makes implementing authentication become simple. Besides, Laravel is integrated with mail services. Functions provided in Laravel were fully utilised in this project.

API is created using Laravel in this project for authentication and authorization purpose. It includes login, register, reset password and send password to user's email address. API also created for storing HRV data and breathing data from the mobile application, and for retrieving the HRV and breathing data to present in web view.
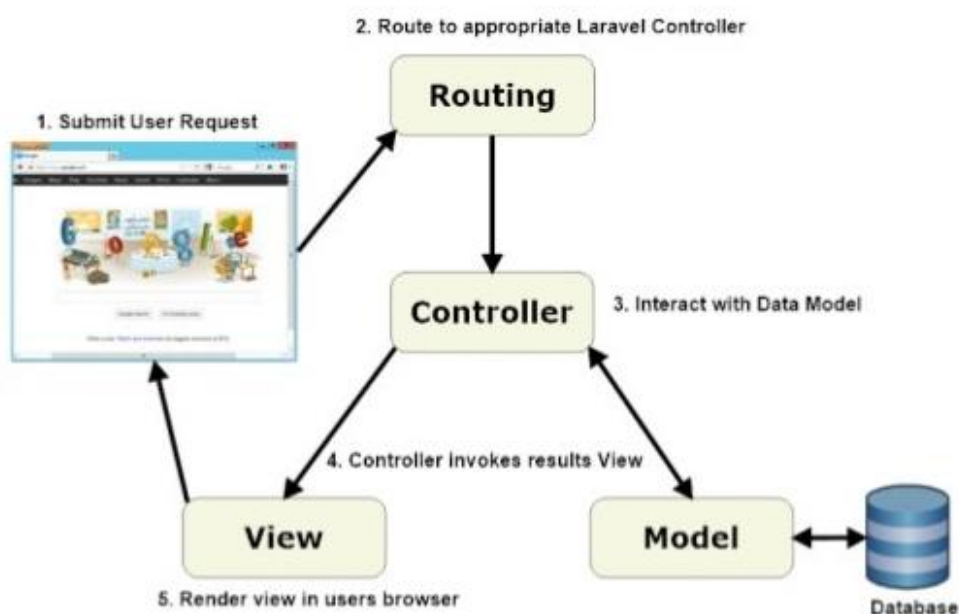
Figure 1.2: Laravel MVC framework

1.4.2 **Development Tools**

There are several tools that I used to develop my project. Following are the tools that I used:-
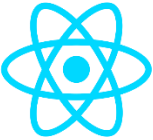
Tools	Description
Figure 1.3: React Native	React Native is used in this project to develop the mobile application.
Figure 1.4: SQLite	The SQLite database is created in the mobile application for storing the apps data on the local devices.
Figure 1.5: Heroku	Heroku is used in this project for the web application. The web application is deployed on Heroku.
Figure 1.6: Laravel	Laravel is used in this project to develop the web application.

Table 1.2: Development Tools

1.5 **Proposed approach**

The proposed methodology for this project is prototyping.
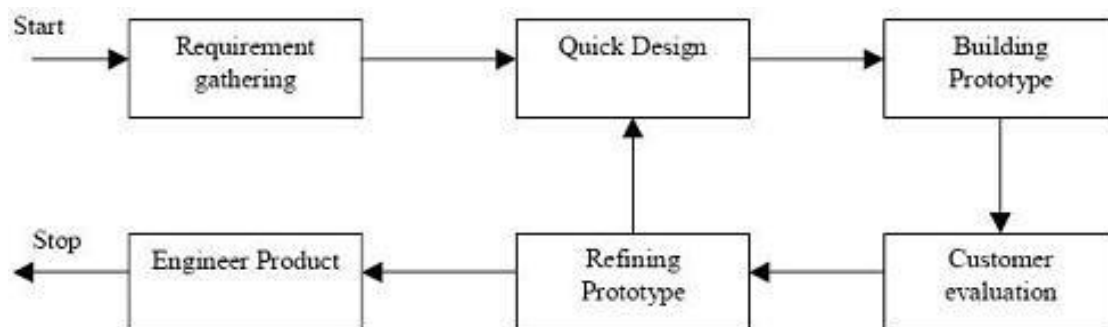
Figure 1.7: Prototyping process

Prototype (Volchko, 2017) is a simple model of the system to be developed. It shows how the actual system looks like with some basic functionalities. This allows the developer to evaluate an idea and also gather the feedback.

The main aim for prototype is to test the product and usually it is used to demonstrate, testing, and communication. It enables developer to understand the requirements at early development stage. In the prototyping process, after the developer understands the requirements, a simulation model will be developed for the user to interact with it.

After showing the prototype to the user, developer is able to get valuable feedback and this helps developer to understand what is expected from the user. This allows the developer to identity the missing functionalities easily. After received feedback from the user, developer will continue improve the model until the user is satisfied with it, and lastly, the developer implements the actual system.

1.6 **Scope**

1.6.1 **Deliverables**

This project is developed a mobile application for breathing training monitoring with heart rate variability (HRV). It is a game-based mobile app for well-being. Therefore, this mobile application should provide breathing training to help users achieve healthy breathing rate. Next, this mobile application is able to connect with phone camera and flashlight to detect the users' pulse from finger. The users' pulse is detected by processing the image captured by the camera. The mobile application also calculates the HRV of the user and save it in the centralised database. This project also includes a web-based application. Admin can check all users breathing data and HRV data from the webpage.

1.6.2 **Modules**

1. Registration and login

    a. Users are required to register if they are the first-time users, and then login in in-order to use the mobile application.

2. HRV Measurement

    a. Use Smartphone Application Frame Processing to process the image of users' finger.

    b. Analyse pulse using the frame of image

    c. Calculate HRV from the frames.

    d. Display stress level based on pulse and heart rate of users.

3. Breathing Training

    a. Provide a breathing training for users to guide them on how to deep breathe in order to achieve healthy breathing rate.

4. History

    a. Users can view the history of their HRV results on particular time and day at history activity.

5. Reward
    a. Users will be awarded a piece of puzzle when the HRV measured is better than the initial HRV value.

6. Web-based application
    a. Admin can view all users' data from the webpage.

1.7   **Justification**

This mobile application brings convenience to those who are eager to know about their HRV value. Users can use this application anywhere, anytime, as long as they have their personal mobile device with them. They can view their history records of HRV records in the application and keep track of their mental healthiness.

Besides, this mobile application provides breathing training to assist the users to achieve a healthy breathing rate. Users will calm down when they focus in the breathing training. This helps users to reduce stress, and keep their mind fresh.

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

There are a lot of methods that can help people to release stress and maintain mental health and well-being. Common ways that people use to handle their stress are exercising, entertainment, talk to someone, and also eating. Some of the people use 'unhealthy' ways such as overeating or smoking to escape from the stress in real life. These ways might help them to reduce pressure, but also cause negative impact to their health. According to the researchers, meditation can encounter stress effectively in a healthy way (Cheng et al., 2017)(Cheng et al., 2018)(Chiesa and Serretti, 2009).

Deep breathing involves contraction of the diaphragm, expansion of the lung, and deepening of inhalation and exhalation, which consequently decreases the respiration frequency and maximises the amount of blood gases. During deep breathing, the neurons will spread signals that can make people calm. Practice deep breathing can improve physical and mental health. Therefore, in this project, the mobile application will provide deep breathing training for the users to help them maintain their well-being-ness.

2.2 **Existing similar mobile application**

2.2.1 **Breathe2Relax**

Breathe2Relax is a free of charge mobile application developed by National Center for Telehealth & Technology in both iOS and Andriod platforms. This mobile application provides the users detailed information on the effects of stress on the body and also provides breathing exercise to help users manage their stress.

This application can capture users' heart rate using Healthkit and Apple Watch throughout the breathing exercise to improve user relaxation experience. Besides, users are allowed shortening or lengthening the exhale time in the application according to their own condition.

Figure 2.1: Screenshot of Breath2Relax breathing exercise

2.2.2   **Welltory**

Welltory is a mobile application developed by Welltory Inc for both iOS and Android devices. This mobile application is free to use and offers In-App Purchases. It has a high rating and high user's amount.

This mobile application will break down the users' HRV result into 3 areas, performance, energy and stress. The application will provide recommendations according to the biofeedback to help users to plan their day.

It tracks the users' heartbeat using photoplethysmography (PPG) technique and then run through the heart rate variability algorithm. PPG is an optical technique used to detect volumetric changes in blood in peripheral circulation (Peng et al., 2015)(Kurylyak et al., 2012). The HRV measurement can be done using phone's camera or external heart rate monitor.
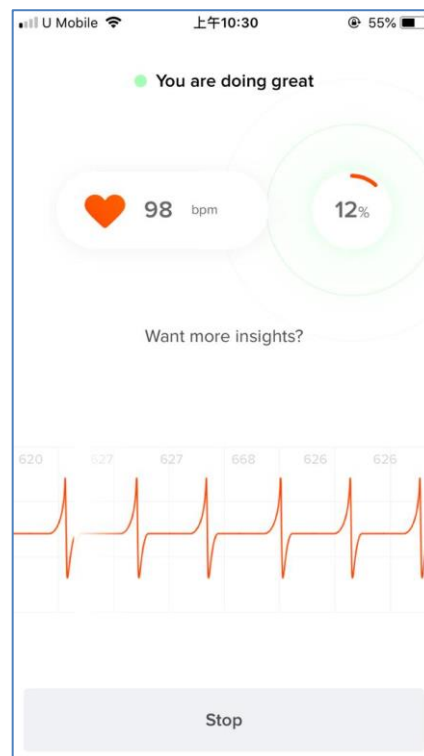
Figure 2.2: Screenshot of Welltory

2.2.3 **Champions of the Shengha**

Champions of the Shengha is a mobile game developed by BfB Labs. The application is free to download and there is no any In-App purchase for this game, but the users need to purchase a wearable device called "Magic Transmitter". The Magic Transmitter costs £39.95 including shipping fee, which is about RM 212.62.

Champions of the Shengha is a real-time card battling game play through a heart-rate monitor. The Magic Transmitter needs to be clipped on the users' ear to track the users' heart rate. This Magic Transmitter will illuminate light to the skin to measure the users' heart rate variability and determine the users' emotional state. Users need to keep calm and focus in order to cast their spell.

Besides, this mobile game provides breathing training to teach the users on how to regulate their emotions. After go through the breathing training, users can learn to stay focus and their magic power in the game will increase.
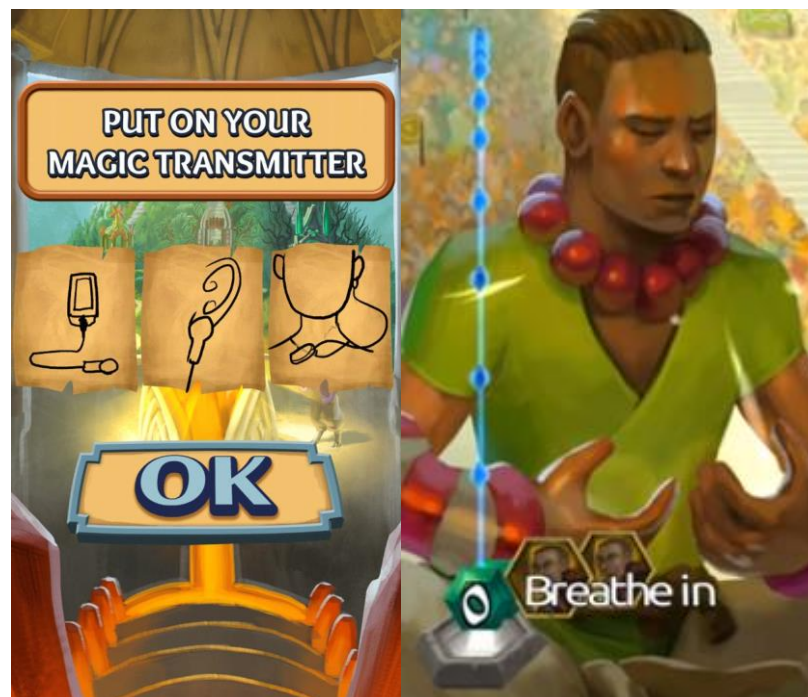
Figure 2.3: Screenshot of Champions of the Shengha

2.3   **Comparison between existing mobile applications**

Breathe2Relax	Welltory	Champions of the Shengha
Multiplatform – iOS and AndroidOS	Multiplatform – iOS and AndroidOS	Multiplatform – iOS and AndroidOS
Measure user's heart rate using Apple Watch or Healthkit. (iOS user only)	Measure user's heart rate using smartphone camera	Measure user's heart rate using sensory device
Provide a lot of information about health and stress to user.	Provide information about user's stress, performance and energy.	Do not provide any information about health and stress to user.
Provide breathing training for user to release stress.	Do not provide any way to counter stress.	Provide breathing training for user to learn how to regulate their emotions.
Allow users to review their stress data.	Allow users to review their stress data.	Users cannot review their stress data.
Activities are not interactive.	Activities are not interactive.	Interactive, able to duel with players all around the world.
Free to download and use.	Free to download, provide In-App purchase.	Free to download, need to purchase external device.
No privacy policy	Privacy policy is applied	High privacy policy
No disclosed information sharing or data gathering functions are included.	May disclosed information sharing or data gathering functions.	No disclosed information sharing, have data gathering functions

Table 2.1: Comparison between existing mobile applications

From the comparison above, it can conclude that a good design of the mobile application should be:

1. Easy to use
2. Interactive
3. Measure heart rate variability accurately in an easy way
4. Provide breathing training to guide users on stress reducing
5. Allow users to review their stress data

2.4   **System Development Methodology**

There are a lot of system development methodology that can be chosen to use in a project. Each methodology is unique and has their advantages and disadvantages. Therefore, there is no best methodology but the most suitable methodology.

2.4.1   **Waterfall**
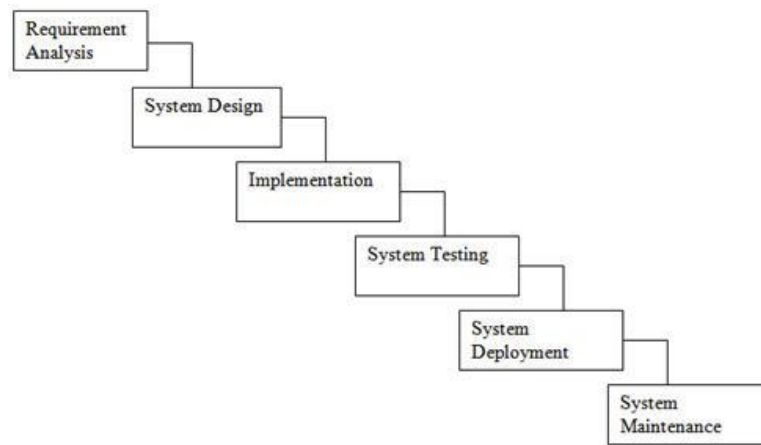
Figure 2.4: Waterfall model

Waterfall model is a classical software development process introduced by Dr. Winston W. Royce in a paper published in 1970. It is named as waterfall because this model has 6 phases and each phase has to be completed before going to the next phase. This type of model is suitable for small projects that have no uncertain requirements. Planning should be done before enter the implementation phase and software testing will only start after the development is completed. Strictly no backward of development allowed.

Advantages of waterfall model

1. Simple and easy to understand and use.
2. Can have tight control throughout the development process.
3. Project can be well documented.
4. Provide predictable end result of time, scope and cost.

Disadvantages of waterfall model

1. High risk if the project requirement is in uncertainty and if the technology is not enough mature.

2. No end users or stakeholders involvement throughout the process.

3. Does not follow the general testing principle as the testing will be carried out after development completed. And this will increase the cost of a bug.

2.4.2 Scrum

Figure 2.5: Scrum model

Scrum is a well-known agile method developed by Ken Schwaber. This framework focuses on gaining experience-based knowledge and the decision is made using the knowledge learned. The team will have meeting very frequently to share their updates, plan for the implementation and decide the duration for each phase.

Advantages of scrum model

1. Easy to cope with any changes on the requirements.

2. Able to change the development at any stages.

3. Spend time and money effectively.

4. Get feedback from stakeholders.

Disadvantages of scrum model

1. Project may fail if less commitment from the team members.

2. Need to have experienced team members in the project to accomplish tasks.

3. High pressure, need to spend a lot of effort on project development.

2.4.3   **Prototyping**
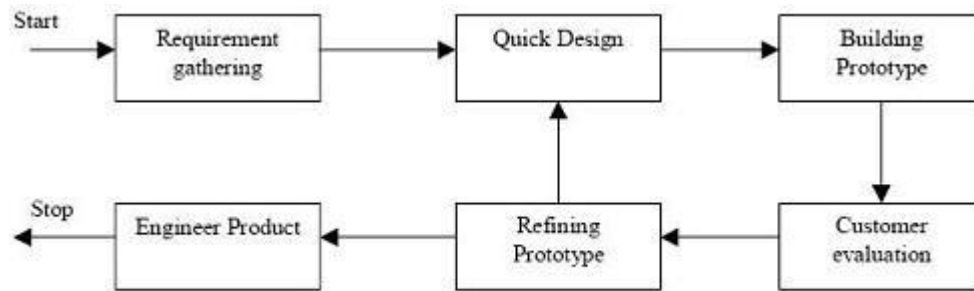
Figure 2.6: Prototyping model

Prototyping is a useful system development methodology that shows how the actual product will be. After gathers the requirement, developer will do a quick design and built the prototype. This simulation prototype will show to the customer. This allows the developer to get a fast feedback from customer. After refining the prototype, the developer will repeat the steps until the developer and customer satisfied with the idea.

Advantages of prototyping
1. High user involvement in the development.
2. Fast user feedback.
3. Enhance communication between user and developer.
4. Helps to identify missing or misunderstood features.

Disadvantages of prototyping
1. May increase the complexity of the project as the scope may expand beyond the original plans.
2. May cause project duration increase.
3. Developer may invest too much effort on building prototypes.
4. User may think prototype is the real product.

2.4.4   **The Verdict**

After compare and contrast the software methodology mentioned above, prototyping methodology is chosen for this project. Prototype model can help the developer to have better understanding on the project. It also can inspire the developer to have better idea on the design of interface. Last but not least, this prototype model can adapt to change of requirements in any phase of development.

2.5   **Research Methodology**

A few methods are used to collect data and gather important information that is related to this project.

2.5.1   **Research**

Nowadays, existing documents in the field that have been studied or solved by other professional researchers can be easily found online. Developers can analyse these existing documents and collect data that is related to the project. This existing document will shorten the research time and provide ideas on the problem solution.

2.5.2   **Questionnaires**

Questionnaire is a common research instrument that consists of a set of questions with a choice of answer. By using questionnaires, developers can gather information from large amount of respondents as questionnaires can be spread easily using some online templates such as Google Form and Survey Monkey. Larger the sample size, higher the accuracy (Marley, 2017). Therefore, 200 respondents from different age groups are found to gather information for this project.

2.5.3   **Prototyping**

Prototyping is a good way for developer to gather information, and it is the pre-design of the project. A prototype is often done by developer to show the stakeholders how the product to be developed will look like and how it will work like. This can foster communication between the stakeholders and the developer. Stakeholders can understand the project well and even pointed out what functionality the developer had missed out.

2.6 Heart Rate Variability Application

Nowadays, people need not buy expensive devices to measure their heart rate. HRV can be measure using a phone application. These Heart Rate Variability (HRV) applications allow users to record and store their R-R intervals on the phone to analyst their HRV. This is definitely good news for users who are unwilling to purchase expensive HRV device and users who are urge to know their HRV value.

2.6.1 Heart Rate Variability
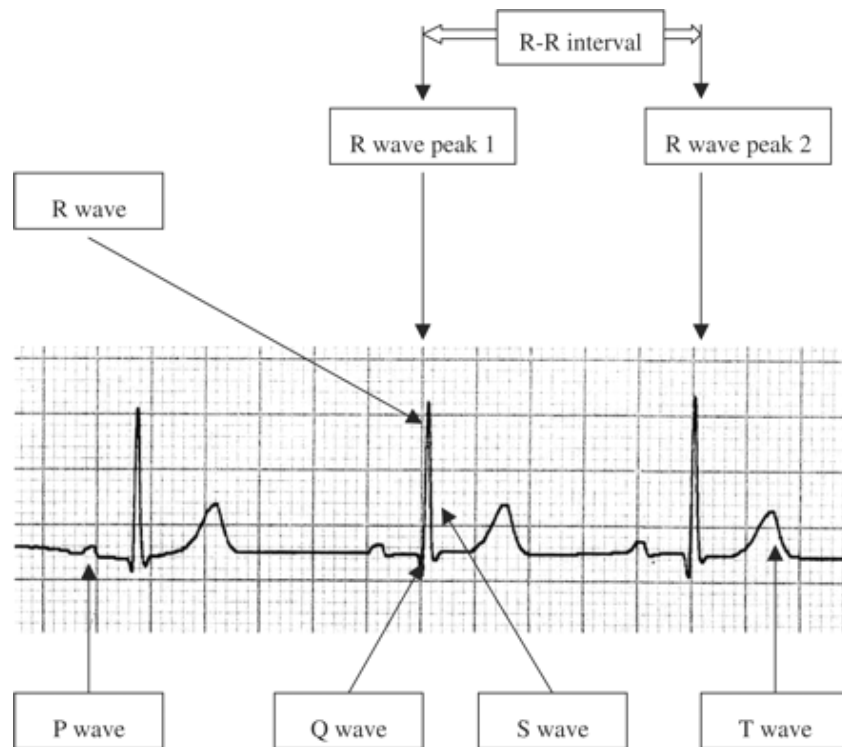
Figure 2.7: Electrocardiogram

(Reed et al., 2012)

HRV is the degree of fluctuation in the length of the intervals between heartbeats (R-R interval / inter-beat interval) and it is measured in millisecond (ms). Measurement of HRV included time domain method and frequency domain method. The time domain analysis such as standard deviation of NN intervals (SDNN) and Root Mean Square of the Successive Differences (RMSSD) reflects the activity of cardiac system while the frequency domain analysis such as Lower Frequency Power (LF) and Higher Frequency Power (HF) reports the sympathovagal balance of the autonomic nervous system (ANS) (Marek Malik *et al.*, 1996) (Wang and Huang, 2012).

SDNN is the most straightforward and useful metric (Wang and Huang, 2012). SDNN is the standard deviation of all normal RR intervals. In our heart, there is a node call atrioventricular node (AV node). This node contributes to the PR intervals in an electrocardiogram. The practice of time domain measures will neglect the presence of fluctuations in PR interval. During calculating the SDNN, any RR interval that begins or ends with premature ventricular contractions (PVCs) and premature atrial contractions (PACs) is simply deleted from the sequence. Below is the formula of SDNN:

$$SDNN = \sqrt{\frac{1}{N-1}\sum_{j=1}^{N}(RR_j - \overline{RR})^2}$$

where

SDNN = Standard deviation of NN intervals

RR = Normal to normal RR intervals

HRV will increase when heart is beating slowing and decrease when heart beats quickly. Therefore, when people feel stressed, HRV value will decreased (Saravanan et al., 2014) (Kim et al., 2018). Decreased in HRV also can be related to cardiac diseases, fatigue and also burnout (Olsson, 2010). While higher HRV represents good general health (Jarczok et al., 2015).

2.6.2 Method to measure HRV using smartphone

Photoplethysmography (PPG) technique can be used to track the user's heartbeats. PPG is an alternate non-invasive technique for the detection of blood volume changes. There are two possible PPG operation modes, reflection mode and transmission mode.
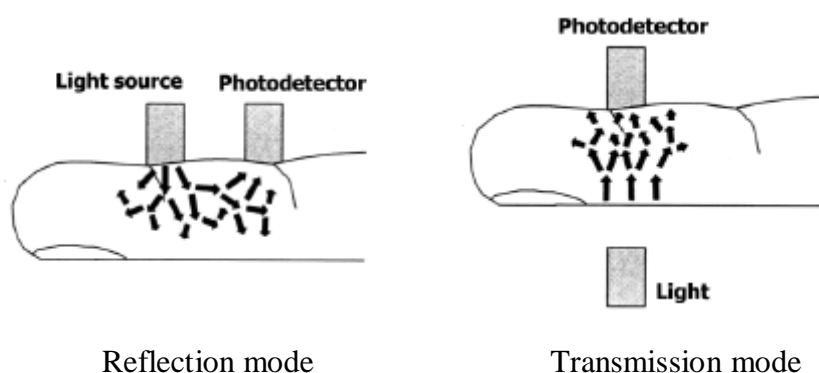
Figure 2.8: Reflection and transmission modes for video acquisition
(Damianou, 1995)

Nowadays, smart phones are equipped with high-resolution camera, processors and LEDs. Therefore PPG technique is able to apply on smartphone to detect heart rate. The light sources will be replaced by smartphone's LEDs, while photo detector will be replaced by smartphone's camera. For smartphone-based photoplethysmogram, reflection mode will be used for video acquisition.

To detect HRV using smartphone, the user needs to cover the smartphone's camera and LEDs with his/her fingertip. The light illuminated by LEDs will be absorbed by blood in the user's fingertip. When the capillaries are rich in blood, more light is absorbed by the blood and this leads to lower reflective index and darker frame intensities (Chandrasekaran, 2010).

A video will be recorded to obtain the pulse wave. From the frame, an analysed region will be selected to analyse the change of intensity of light on the frame. Usually the video frame will be split into 4 quadrants and the first quadrant will be selected as analysed region. This is because this region has most changes and the fluctuations are predominant (Zhang et al., 2011).

2.7 **Deep Breathing Exercise**

Deep breathing is an exercise that helps in mood regulations and it is good for mental and physical wellbeing (Davis et al., 2008).

The article "Stress management techniques: Evidence-based procedures that reduce stress and promote health" by Varvogli and Darviri (2011) talks about various ways that helps in stress reduction. These stress managing techniques are useful techniques that can help people to handle their stress and it is an effective tool for health enhancement.

This article discussed about some evidence-based stress management techniques including deep breathing exercise. Varvogli and Darviri (2011) state that, these stress management techniques are commonly used for health related problems such as cardiovascular disease, high blood pressure, diabetes, obesity, and headaches. However, these stress management techniques not only applicable to people who manifest a disease or disorder but also applicable to healthy people.

Varvogli and Darviri (2011) also argue that there is no any negative side effect from deep breathing exercise. Besides, Varvogli and Darviri (2011) also note down the details that people need to pay attention to when practicing the techniques.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1   Introduction

In this chapter, the methodology of the project and project activities along a timeline will be discussed.

3.2   System Development Methodology

The system development methodology that used for this project is prototyping.

3.2.1   Prototyping
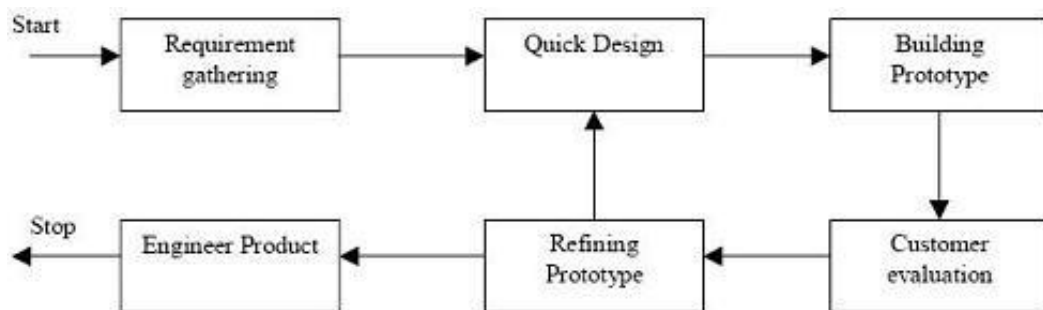
Figure 3.1: Prototyping model

a) Requirement Gathering phase

Studies and analysis are performed at this phase. The fact finding about stress and heart rate variability is done by doing research and collected through questionnaires. Besides, the functional and non-functional requirements are analysed. These requirements will be reviewed and signed-off by the supervisor.

b) Quick design phase

The design phase is performed after requirement gathering phase. Design of the system should fulfilled the requirements gathered. A storyboard will be designed during this phase to show the workflow and the design of user interface. This phase is referred back when there are changes on the requirements or functionalities of the system. Most of the time this phase is referred back after each iteration of evaluation with the stakeholder had been done.

c) Building prototype phase

After the storyboard is signed-off, a prototype is built. The prototype is focused on the user interface interaction and same basic core functionality. It shows how the actual mobile application looks like and how it works.

d) Customer evaluation phase

After the prototype had been developed, it is tested and evaluated by the end user. User's satisfaction and feedback is observed and recorded. This phase helped the developer to develop a better prototype in the next iteration or completed product.

e) Refining prototype phase

After analyse the feedback and evaluation of user on the prototype, the prototype is refined and the functionalities were readjust to meet the user's requirements. The process moved on to the next phase after the prototype is granted and approved by stakeholder.

f) Engineer product phase

This is the final phase of development. The enhanced version of prototype with better user interface design and functionalities is developed. Before deployment, testing was carried out. After all tests passed, the documentation for the project is done for the reference of the future maintenance of the product and the product is released to the customer.

3.3   **Work Flow**

3.3.1   **Work Breakdown System**

1.0 FYP

    1.1 Planning

        1.1.1 Confirm project title

        1.1.2 Problem statements

        1.1.3 Project Objectives

        1.1.4 Project Scope

        1.1.5 Technology Used

        1.1.6 Project Plan

        1.1.7 Requirement gathering

    1.2 Questionnaire

        1.2.1 Design questionnaires

        1.2.2 Distribute questionnaires

        1.2.3 Analyse result

    1.3 Literature Review

        1.3.1 Existing similar mobile application

        1.3.2 Methodologies

        1.3.3 Heart Rate Variabilities (HRV)

    1.4 Interface Design

        1.4.1 Quick Design

        1.4.2 Supervisor Feedback

        1.4.3 Refine design

    1.5 Development Phase

        1.5.1 Prototyping loop

            1.5.1.1 Quick design

            1.5.1.2 Build prototype

            1.5.1.3 Get user feedback

            1.5.1.4 Refine prototype

        1.5.2 Implementation

            1.5.2.1 Create Interface

            1.5.2.2 Create Database

            1.5.2.3 Implement Breathing Training

1.5.2.4 Connection of camera and flashlight

1.5.2.5 HRV Calculation with SDNN

1.5.2.6 Link all the modules

1.6 Testing Phase

1.6.1 Unit Testing

1.6.2 Integration Testing

1.6.3 System Testing

3.3.2   Gantt Chart

3.3.2.1   Planning

Task Name	Duration	Start	Finish	Predece
Planning	**27 days**	**Mon 28/5/18**	**Mon 2/7/18**	
Confirm project title	5 days	Mon 28/5/18	Fri 1/6/18	
Problem Statement	2 days	Mon 4/6/18	Tue 5/6/18	2
Project Objectives	2 days	Wed 6/6/18	Thu 7/6/18	3
Project Scope	2 days	Fri 8/6/18	Sat 9/6/18	4
Technology Used	7 days	Mon 11/6/18	Tue 19/6/18	5
Project Plan	3 days	Wed 20/6/18	Fri 22/6/18	6
Project Requirement	6 days	Mon 25/6/18	Mon 2/7/18	7

Figure 3.2: Gantt Chart Diagram for Planning

3.3.2.2   Fact Finding

Task Name	Duration	Start	Finish	Predece
Fact Finding	**28 days**	**Tue 3/7/18**	**Fri 3/8/18**	**8**
Design Questionnaire	3 days	Tue 3/7/18	Thu 5/7/18	
Distribute Questionnaire	21 days	Fri 6/7/18	Mon 30/7/18	10
Analyse Result	3 days	Tue 31/7/18	Thu 2/8/18	11
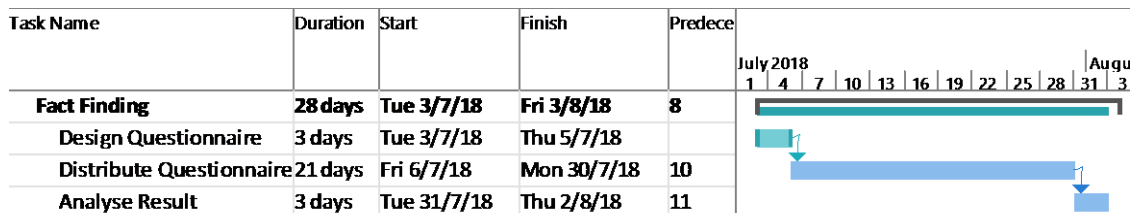
Figure 3.3: Gantt Chart Diagram for Fact Finding

3.3.2.3   Literature Review

Task Name	Duration	Start	Finish	Predece
Literature Review	**25 days**	**Tue 3/7/18**	**Tue 31/7/18**	
Existing mobile application	7 days	Tue 3/7/18	Wed 11/7/18	
Methodologies	4 days	Thu 12/7/18	Mon 16/7/18	14
Heart Rate Variability	14 days	Tue 17/7/18	Tue 31/7/18	15
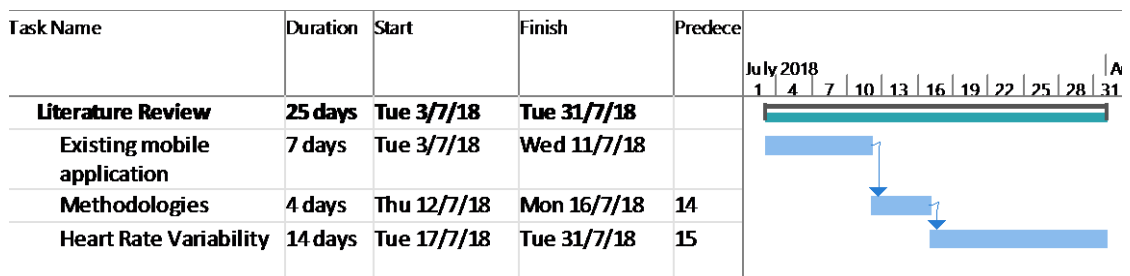
Figure 3.4: Gantt Chart Diagram for Literature Review

3.3.2.4 Interface Design

Task Name	Duration	Start	Finish	Pre
Interface Design	**14 days**	**Tue 24/7/18**	**Thu 9/8/18**	
<First Iteration>	**8 days**	**Tue 24/7/18**	**Wed 1/8/18**	
Quick Design	2 days	Tue 24/7/18	Wed 25/7/18	
Supervisor Feedback	3 days	Thu 26/7/18	Sat 28/7/18	19
Refine design	2 days	Mon 30/7/18	Tue 31/7/18	20
<Second Iteration>	**7 days**	**Wed 1/8/18**	**Thu 9/8/18**	
Quick Design	2 days	Wed 1/8/18	Thu 2/8/18	
Supervisor Feedback	3 days	Fri 3/8/18	Tue 7/8/18	23
Refine Design	2 days	Wed 8/8/18	Thu 9/8/18	24

Figure 3.5: Gantt Chart Diagram for Interface Design

3.3.2.5 Development Phase

Task Name	Duration	Start	Finish	Predece
Development Phase	**54 days**	**Mon 14/1/19**	**Thu 28/3/19**	
Prototyping loop	**54 days**	**Mon 14/1/19**	**Thu 28/3/19**	
<First Iteration>	**13 days**	**Mon 14/1/19**	**Wed 30/1/19**	
Quick Design	1 day	Mon 14/1/19	Mon 14/1/19	
Build Prototype	7 days	Tue 15/1/19	Wed 23/1/19	29
Get Supervisor f	3 days	Thu 24/1/19	Mon 28/1/19	30
Refine Prototype	1 day	Tue 29/1/19	Tue 29/1/19	31
<Second Iteration>	**12 days**	**Wed 30/1/19**	**Thu 14/2/19**	
Quick Design	1 day	Wed 30/1/19	Wed 30/1/19	
Build Prototype	7 days	Thu 31/1/19	Fri 8/2/19	34
Get Supervisor f	3 days	Mon 11/2/19	Wed 13/2/19	35
Refine Prototype	1 day	Thu 14/2/19	Thu 14/2/19	36
Implementation	**30 days**	**Fri 15/2/19**	**Thu 28/3/19**	
Create Interface	1 day	Fri 15/2/19	Fri 15/2/19	
Create Database	1 day	Mon 18/2/19	Mon 18/2/19	39
Implement Breal	2 days	Tue 19/2/19	Wed 20/2/19	40
Connection of ca	3 days	Thu 21/2/19	Mon 25/2/19	41
HRV calculation \	18 days	Tue 26/2/19	Thu 21/3/19	42
Link all the modi	2 days	Fri 22/3/19	Mon 25/3/19	43

Figure 3.6: Gantt Chart Diagram for Development Phase

3.3.2.6 Testing Phase

Task Name	Duration	Start	Finish	Predece	ar '19 M T W T F
Testing Phase	3 days	Tue 26/3/19	Thu 28/3/19		
Unit Testing	1 day	Tue 26/3/19	Tue 26/3/19		
Integration Testing	1 day	Wed 27/3/19	Wed 27/3/19	46	
System Testing	1 day	Thu 28/3/19	Thu 28/3/19	47	

Figure 3.7: Gantt Chart Diagram for Testing Phase

CHAPTER 4

REQUIREMENT GATHERING AND FACT FINDING

4.1   Introduction

This chapter will discuss about the method used for fact finding and the requirement gathered.

4.2   Questionnaire

In this project, questionnaire is used for fact finding. The questionnaires were distributed online using Google Form. A total amount of 200 respondents from different age group have been collected to evaluate the source of stress of people nowadays, and how people handle their stress. From this survey, it also can found that quite a number of respondents are interested with a mobile application that can help them to measure stress level and provide a way for them to release stress.

4.2.1   Respondents' information

Figure 4.1: Respondents' gender

Out of 200 respondents, 56% of the respondents (111 people) are female, while 44% of the respondents (89 people) are male.
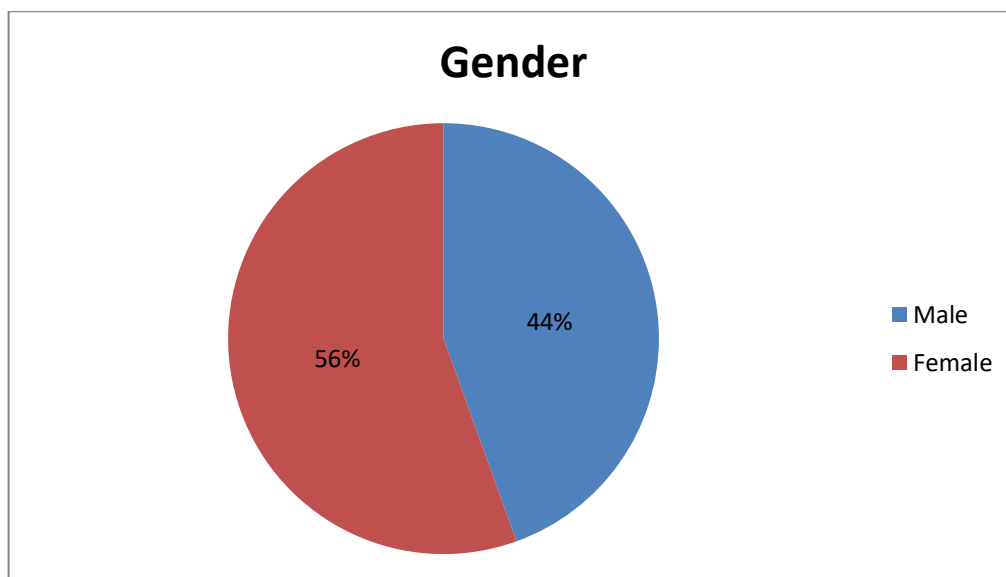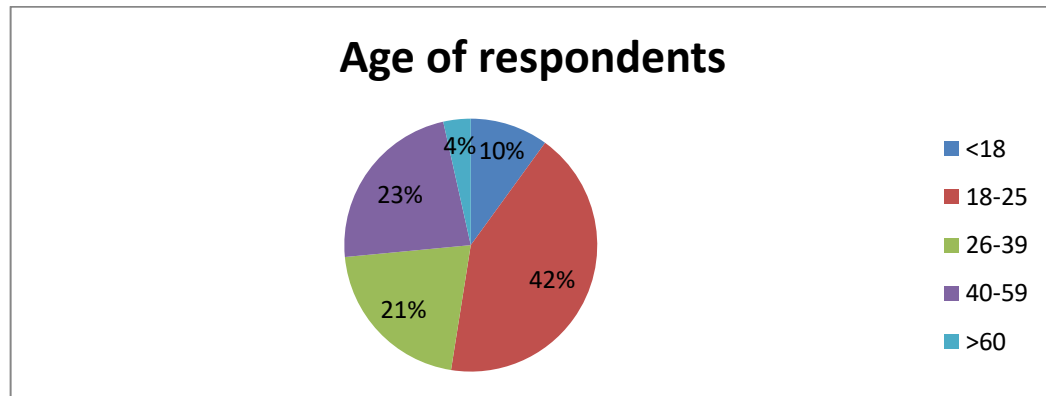
Figure 4.2: Age of respondents

The age of respondents is divided into categories. This survey is more focus on those who are 18 to 59 years old. Out of 200 respondents, 10% of the respondents (20 people) are less than 18 years old. 42% of the respondents (85 people) are from 18-25 years old. 21% of the respondents (42 people) are from 26-39 years old. 23% of the respondents (46 people) are from 40-59 years old. The rest of 42% respondents (7 people) are larger than 60 years old.

4.2.2 Stress of respondents
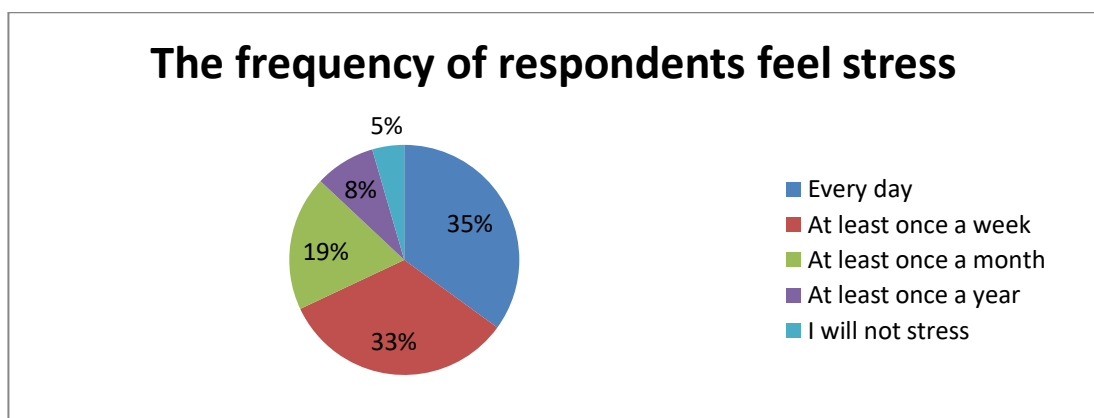
Figure 4.3: Frequency of stress

Out of 200 respondents, 35% of the respondents (70 people) feel stress every day. 33% of the respondents (66 people) feel stress at least once a week. 19% of the respondents (38 people) feel stress at least once a month. 8% of the respondents (17 people) feel stress at least once a year. 5% of the respondents (9 people) claimed that they will not stress. From the result concludes that most of the respondents are experiencing huge stress from their daily life.
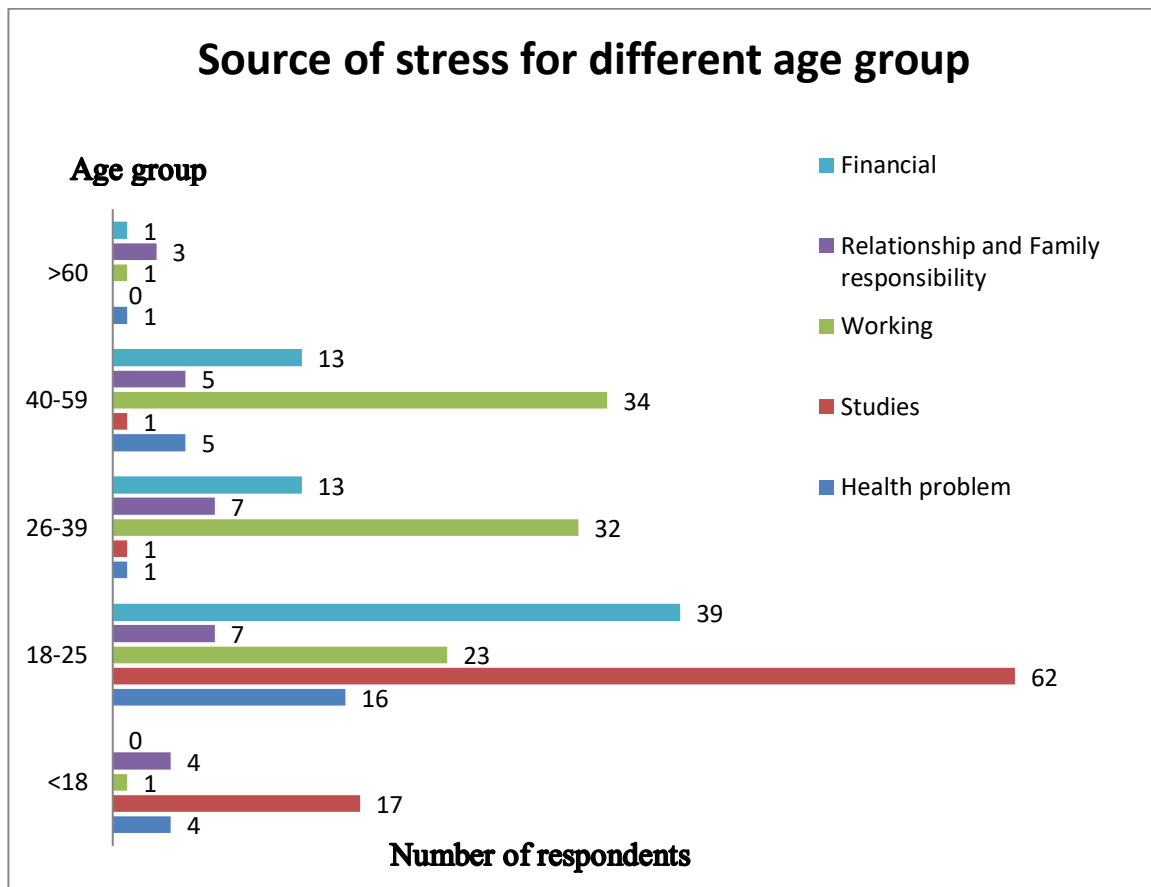
Figure 4.4: Source of stress for different age group

The above chart is generated by analysing from the questions "Respondent's age" and "Source of stress". Most of the respondents have more than one source of stress. 31% of the respondents (91 people) feel stress from working. 28% of the respondents (82 people) stress is come from studies. 22% of the respondents (66 people) having financial stress. 10% of the respondents (30 people) feel stress in theirs' personal relationship of family stress, while the rest of 9% of the respondents (27 people) feel stress with their health problem.

It found that the main source of stress for respondents below 25 years old is studies. This is because most of the respondents who are under 25 years old are students and they are more focused on their academic studies. Besides stress from studies, 39 respondents from the age group 18-25 years old have financial stress. Most of them go for work due to their financial stress and at the same time they experience stress from work. They also feel stress with their health condition as most of them have no sufficient rest for a long time.

While for respondents who are 26 to 59 years old, the main source of stress is stress from working. This portion of respondents already goes for work. Therefore, out of 42 respondents, only one of them having stress from studies, while 76% of them (32 people) having financial stress. This age group of respondents also has family stress and health stress. Lastly, for respondents who are above 60 years old, the main source of their stress is come from family. In conclusion, every age group will have different source of stress.
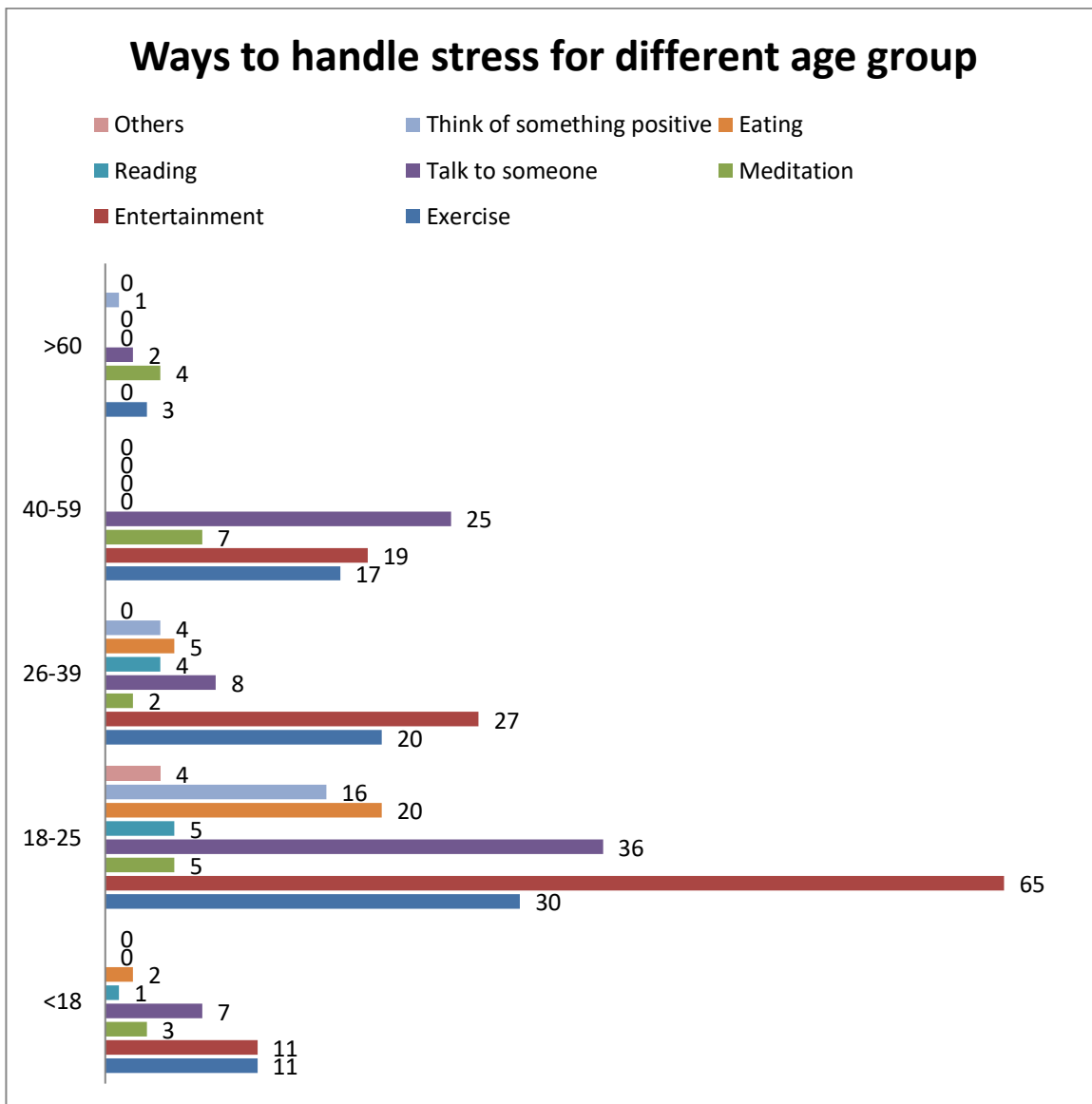
Figure 4.5: Ways to handle stress for different age group

The above chart is generated by analysing the result from questions "Respondent's age" and "Ways to handle stress". Most of the respondent used more than one way to handle their stress. Entertainment is the most popular ways to release stress. Out of 200 respondents, 59.5% (119 people) feel that entertainments such as playing games, watching movie, and listen to music can help them to release their tension.

From the results from respondents under 18 years old, 55% of the respondents (11 people) were found will do exercise and entertain their self to release stress. 7 out of 20 respondents will talk to someone when they feel stress.

For the respondents who are between 18 to 25 years old, 76.5% of them (65 people) will find entertainment when they are stress. 36 of them (42.4%) claimed that they will talk to someone to release stress and 30 of them (35.3%) will go for exercise when they feel stress.

While for the age group "26-39", 64.3% of respondents (27 people) claimed that their way of handle stress is through entertainment while 47.6% of respondents (20 people) states that they will exercise when they are stress.

Next, for those who are in between 40 years old to 59 years old, most of them (54.3%) will choose to talk with someone when they are stress. 41% of them (19 people) will find some entertainment to release stress while 36.9% of them (17 people) will exercise.

Lastly, 4 out of 7 respondents who are above 60 years old states that they will meditate when they are stress. Besides, 3 of them will go for exercise, while 1 will think of something positive.

According to this finding, most of the people handle their stress through entertainment while 10.2% of respondents (21 people) will meditate to release stress. The mobile application that promotes healthy way to handle stress such as breathing training will be a good choice that helps people handles their stress.

4.2.3   HRV application

Respondent who know what is HRV

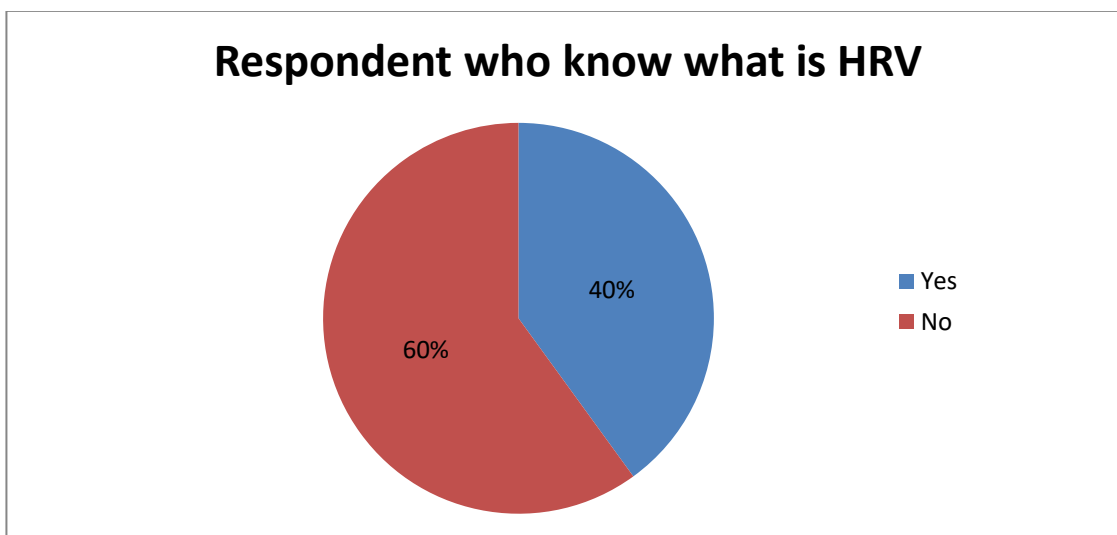Figure 4.6: Respondents who know what is HRV

Out of 200 respondents, only 40% of respondents (80 people) know what Heart Rate Variability (HRV) is.

Have experience using mobile application to measure HRV
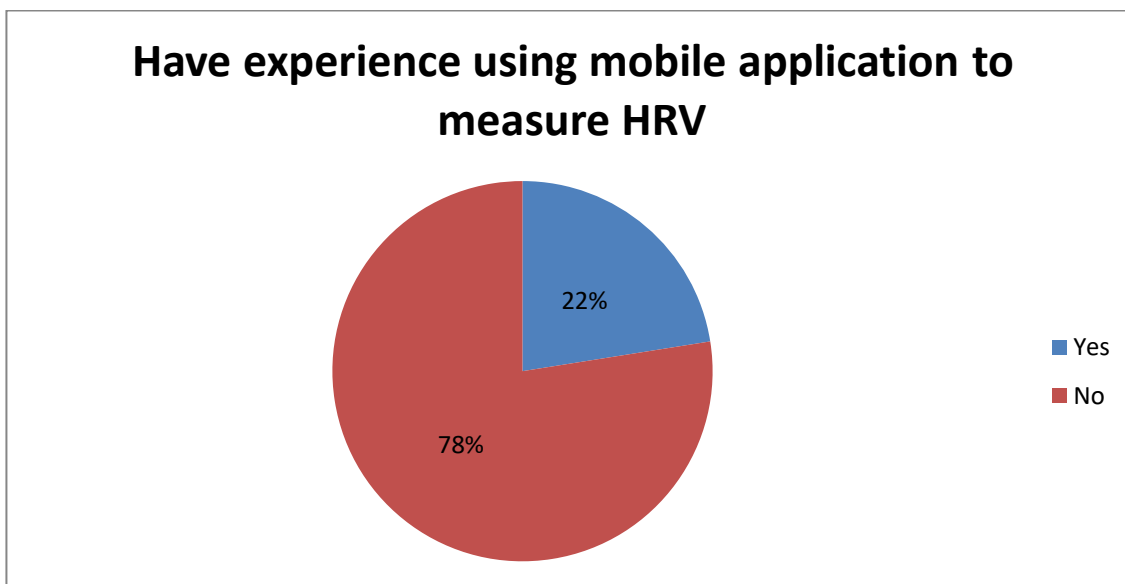
Figure 4.7: Respondents experience in using mobile application to measure HRV

Out of 200 respondents, only 22% of respondents (45 people) have experience using mobile application to measure their HRV.
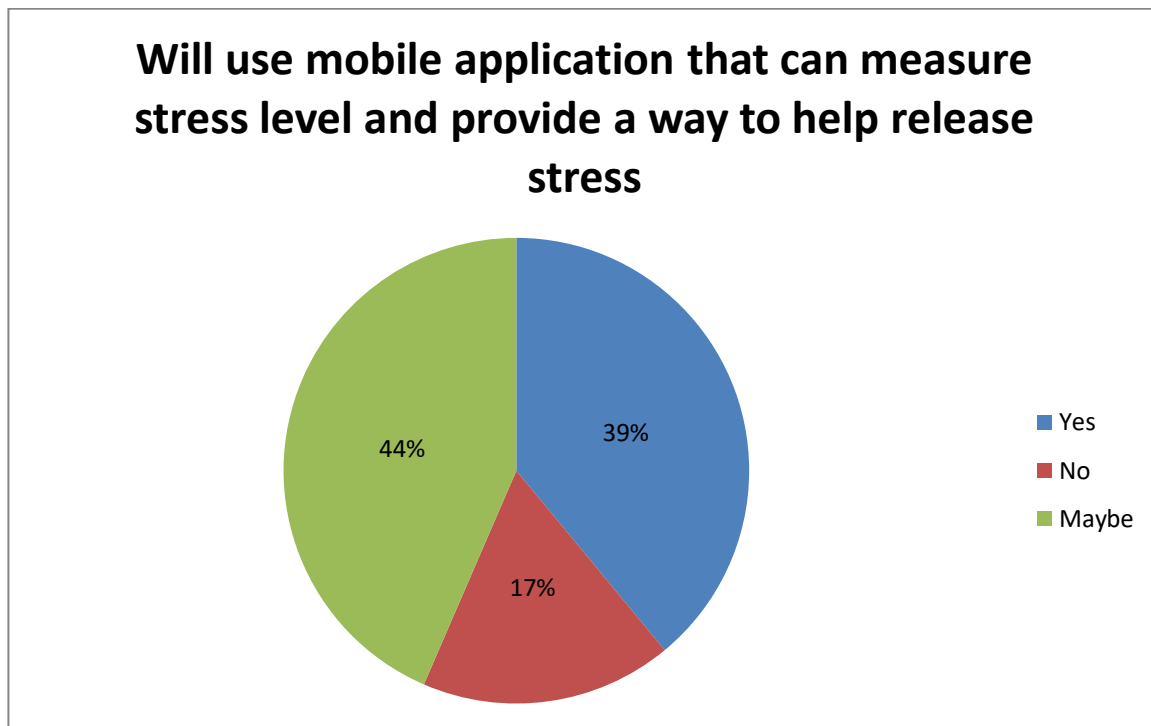
Figure 4.8: Respondents that are interested in the mobile application to be developed

Out of 200 respondents, 39% of respondents (78 people) claimed that they will use mobile application that can measure their stress level and help them to release stress.

4.2.4   Summary

Nowadays people are suffered by stress. Lots of them handle stress with unhealthy ways such as eating. The mobile application that is going to be developed in this project is able to provide them a healthier way of handling stress. From the result, it was found that this mobile application would be a useful application for those who hope to know their stress level and hope to learn healthy way of handling stress.

4.3   **Project Requirement Specification**

4.3.1   **Functional requirements**

Functional requirements will be denotes on the features, functions and also the usage of the mobile application from the perspective of the product and also user. The functional requirements for this mobile application are:-

1. Application shall allow user to login and register for an account.
2. Application shall allow user to reset password.
3. Application shall allow user to retrieve new password from email.
4. Application shall able to store the HRV data and breathing data of different account on the same device.
5. Application shall able to determine the user's HRV value.
6. Application shall able to provide deep breathing training.
7. Application shall able to provide a reward for the user when the user achieve a better HRV value compare to his/her initial value.
8. Application shall able to record the user's HRV data for history display.
9. Application shall able to record the user's rewards collected in the rewards display.
10. Application shall able to return user's HRV data back to the server automatically.

The functional requirements for the web application are:-

1. Application shall authorize the admin to view all users' HRV data and breathing data.
2. Application shall display the HRV data and breathing data in table and chart form.

4.3.2   **Non-functional Requirements**

The non-functional requirements for this mobile application are:-

1. Application shall able to let first time user to register an account for the mobile application.
2. Application shall able to calculate the HRV in around 2 minutes.
3. Application shall able to run on the Android platform version Kit-Kat 4.4 and above.
4. Application shall able to connect with camera and flashlight.
5. Application shall able to connect to any internet connection for the breathing data and HRV raw data to send back to the server.
6. Application shall be user friendly by providing instructions to guide the users.

The non-functional requirements for the web application are:-

1. The application shall be safe and secure to use.

CHAPTER 5

SYSTEM DESIGN

5.1   **Behavioural UML Diagram**
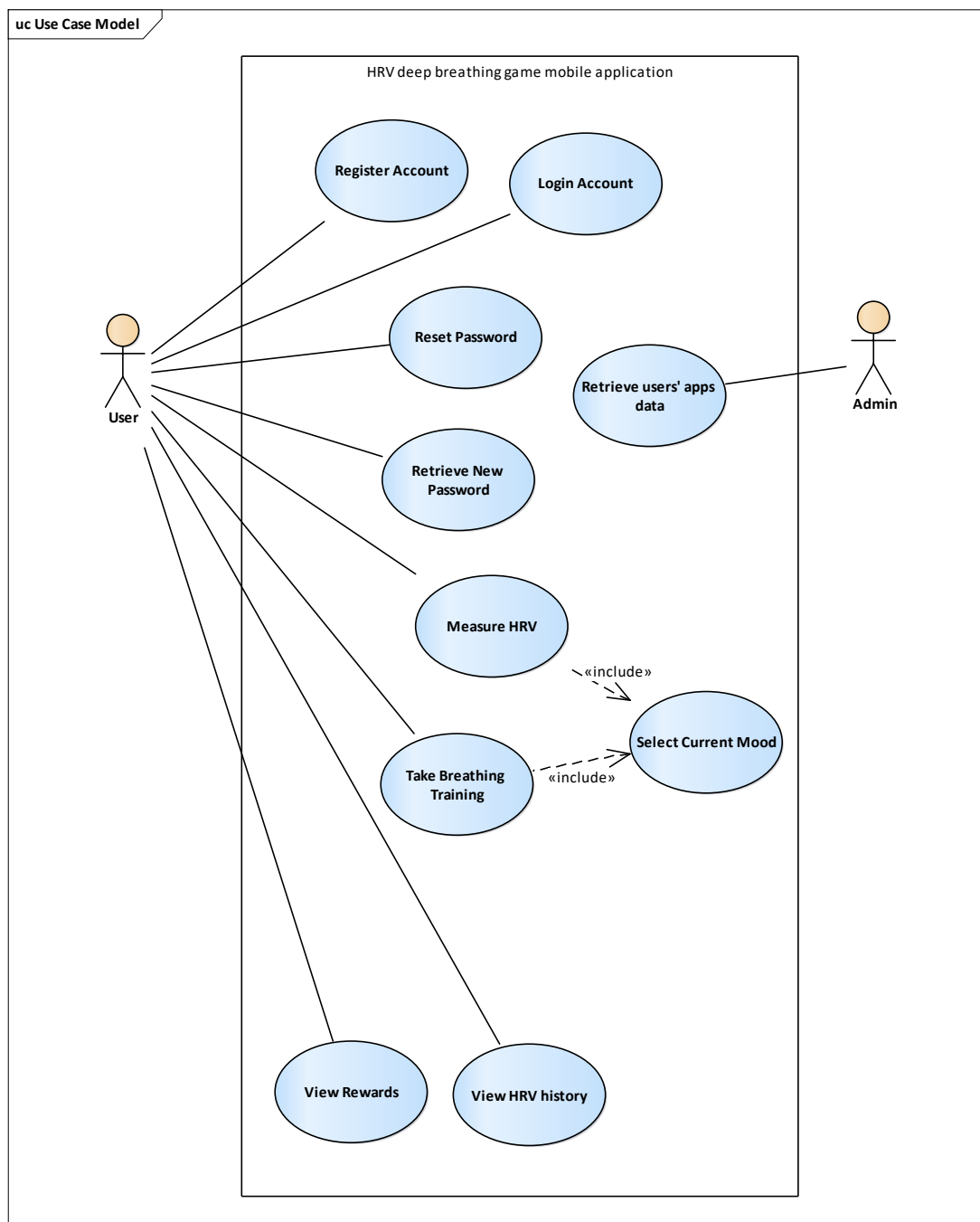
5.1.1   **Use Case Diagram**

Figure 5.1: Use Case Diagram

5.1.1.1 **Use Case Description**

Use Case ID	1
Use Case Name	Register Account
Actors	User
Description	User needs to register an account to use the mobile application.
Pre-condition	User does not have an account.
Post-condition	-
Flow of Events: 1. User chooses to register an account 2. User enters personal information. 3. System stores the new account information.	

Table 5.1: Register Account Use Case

Use Case ID	2
Use Case Name	Login Account
Actors	User
Description	User needs to login before using the mobile application.
Pre-condition	User does not login to his/her account.
Post-condition	-
Flow of Events: 1. User enters username and password. 2. System checks if the username and password are valid. 3. System navigates user to application home screen.	
Alternative Flow of Events: 2.1 Username or password is invalid. 2.1.1 System displays message indicating username or password is invalid.	

Table 5.2: Login Account Use Case

Use Case ID	3
Use Case Name	Reset Password
Actors	User
Description	User can reset password using the mobile application.
Pre-condition	User logged in to his/her account
Post-condition	-

Flow of Events:

1. User enters old password, new password and reconfirm new password.

2. System checks if the old password is correct.

3. User is logged out and system ask user to login with new password.

Alternative Flow of Events:

2.2   Old password is wrong.

   2.2.1   System displays message indicating password is wrong.

Table 5.3: Reset Password Use Case

Use Case ID	4
Use Case Name	Retrieve new password
Actors	User
Description	User can retrieve new password from email.
Pre-condition	User forgot password.
Post-condition	-

Flow of Events:

1. User enters the registered email address.

2. System checks if the email is valid.

3. System sends an email with the auto-generated password to the user's email.

Alternative Flow of Events:

2.3   Email address is invalid.

   2.3.1   System displays message indicating email is invalid.

Table 5.4: Retrieve New Password Use Case

Use Case ID	5
Use Case Name	Select Current Mood
Actors	User
Description	User needs to select an emoji that represents his/her current mood or feeling.
Pre-condition	User login to the mobile application.
Post-condition	-
Flow of Events:	
1. System displays a lists of emoji. 2. User selects the emoji that represents his/her current feeling/mood.	
Alternative Flow of Events:	
2.1 User does not select an emoji. 2.1.1 Use case terminates.	

Table 5.5: Select Current Mood Use Case

Use Case ID	6
Use Case Name	Take Breathing Training
Actors	User
Description	User can practice deep breathing guided by the application
Pre-condition	User login to the mobile application.
Post-condition	-
Flow of Events:	
1. User chooses to have a breathing training. 2. Perform use case Select Current Mood. 3. System guides the user to deep breathing. 4. Perform use case Select Current Mood.	
Alternative Flow of Events:	

2.1 User does not select an emoji.
    2.1.1   Use case terminates.
4.1 User does not select an emoji.
    4.1.1 Use case terminates.	

Table 5.6: Take Breathing Training Use Case

Use Case ID	7
Use Case Name	Measure HRV
Actors	User
Description	User can measure their heart rate by using the smartphone camera.
Pre-condition	User login to the mobile application.
Post-condition	-

Flow of Events:

1. User chooses to measure HRV.
2. Perform use case Select Current Mood.
3. User puts fingertip on the mobile camera.
4. System records a 2 minutes video of user's fingertips and calculates HRV.
5. System calculates and displays user's HRV value.
6. Perform use case Select Current Mood.
7. System compares the user's HRV value with initial HRV value.
8. System rewards the user a puzzle when HRV value is higher than initial HRV value.

Alternative Flow of Events:

7.1 User have no initial HRV

    7.1.1 System rewards the user a puzzle.

    7.1.2 Use case terminates.

8.1 HRV value is smaller than initial HRV

    8.1.1 System displays a message indicates the user needs to go for breathing training.

    8.1.2 Perform use case Take Breathing Training.

    8.1.3 Use case terminates.

Table 5.7: Measure HRV Use Case

Use Case ID	8
Use Case Name	View HRV History
Actors	User
Description	User can view their previous measurement records that have been done.
Pre-condition	User login to the mobile application.
Post-condition	-
Flow of Events:	

Flow of Events:
1. User chooses to view history.
2. System displays all history of user's HRV.

Table 5.8: View HRV History Use Case

Use Case ID	9
Use Case Name	View Reward
Actors	User
Description	User can view the rewards collected
Pre-condition	User login to the mobile application.
Post-condition	-
Flow of Events:	

Flow of Events:
1. User chooses to view rewards.
2. System displays all user's rewards.

Table 5.9: View Reward Use Case

Use Case ID	10
Use Case Name	Retrieve users' apps data
Actors	Admin
Description	User's apps data will be shared with the admin for data analysis.
Pre-condition	User done at least one HRV measurement or breathing training.
Post-condition	-

Flow of Events:

1. The user's HRV records will be sent to server when user's device is connected to internet.

2. Admin retrieves users' apps data (HRV records and breathing training records) for data analysis.

Table 5.10: Retrieve Users' Apps Data Use Case

5.1.2   **Activity Diagram**

5.1.2.1 **Login**
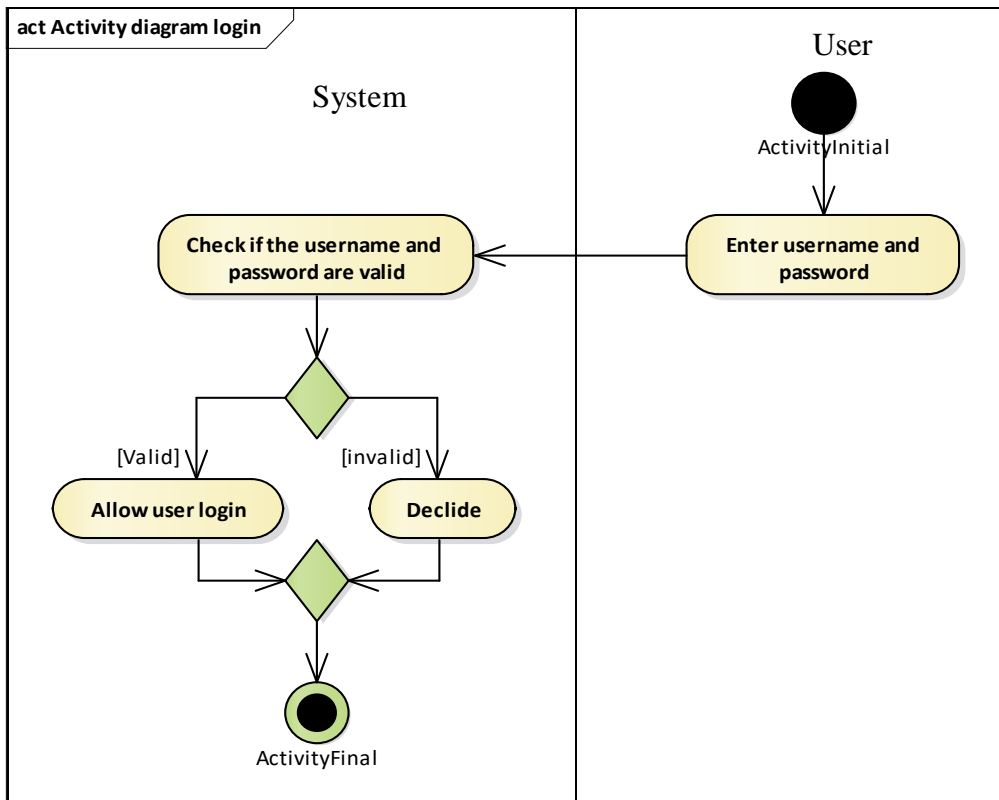
Figure 5.2: Activity Diagram for Login

5.1.2.2 **Register**
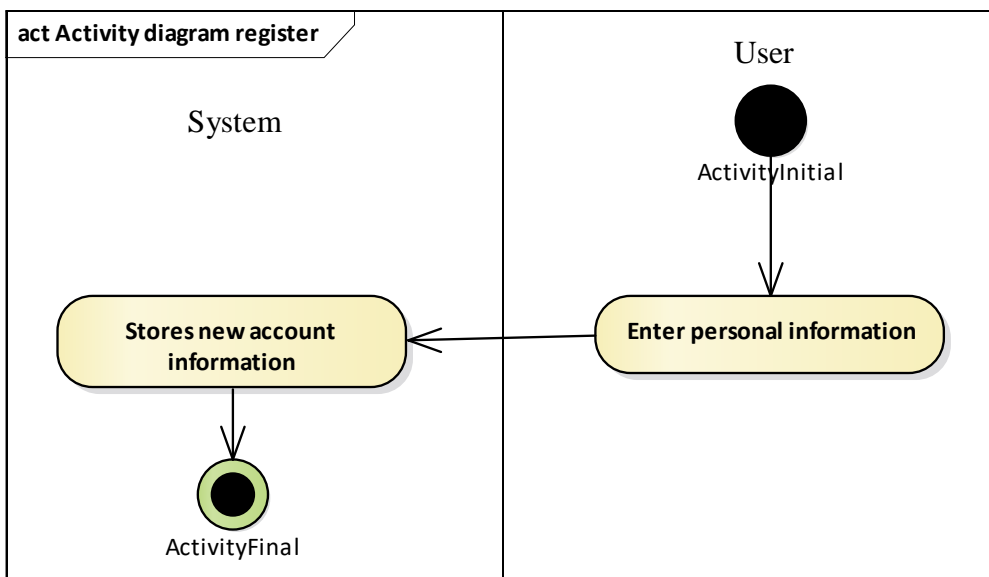
Figure 5.3: Activity Diagram for Register

5.1.2.3 **Take Breathing Training**
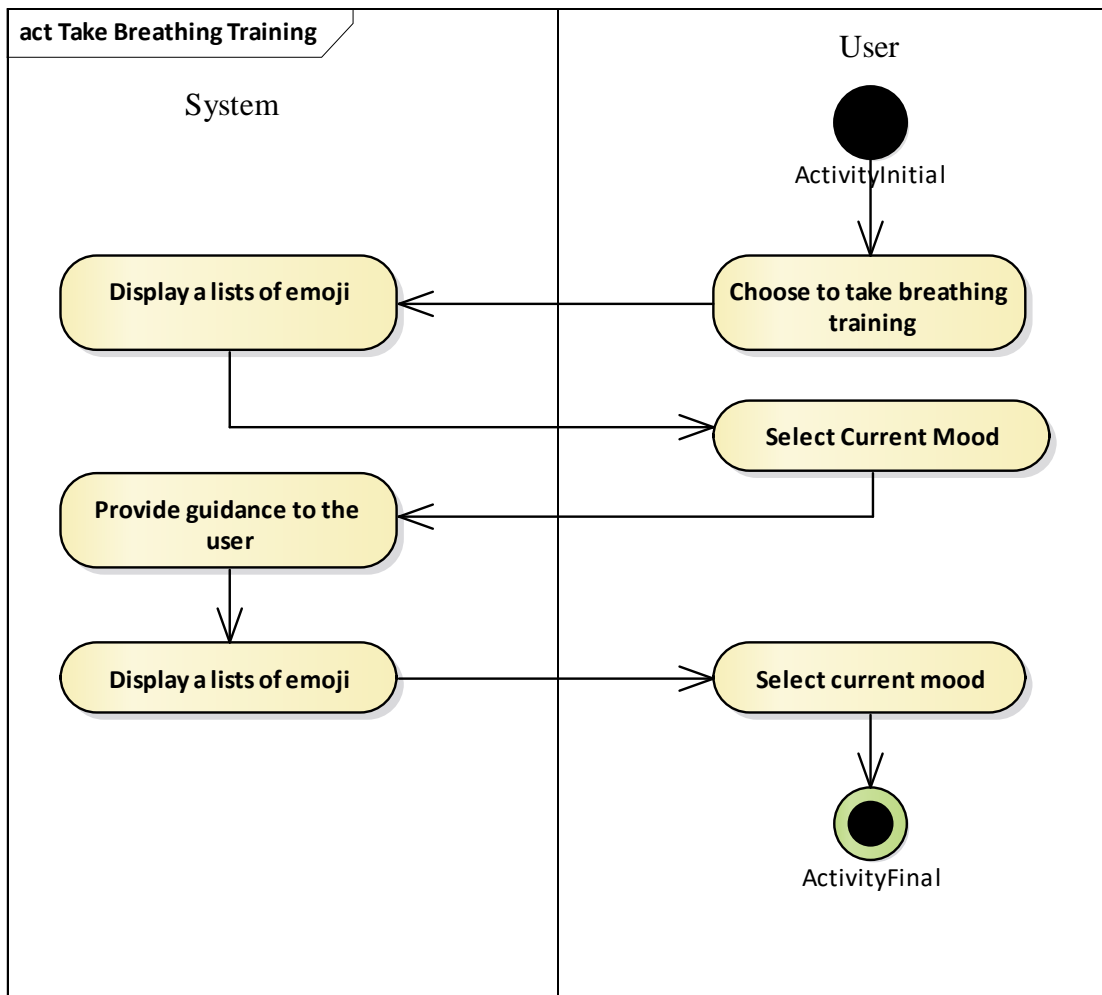
Figure 5.4: Activity Diagram for Breathing Training

5.1.2.4 Measure HRV
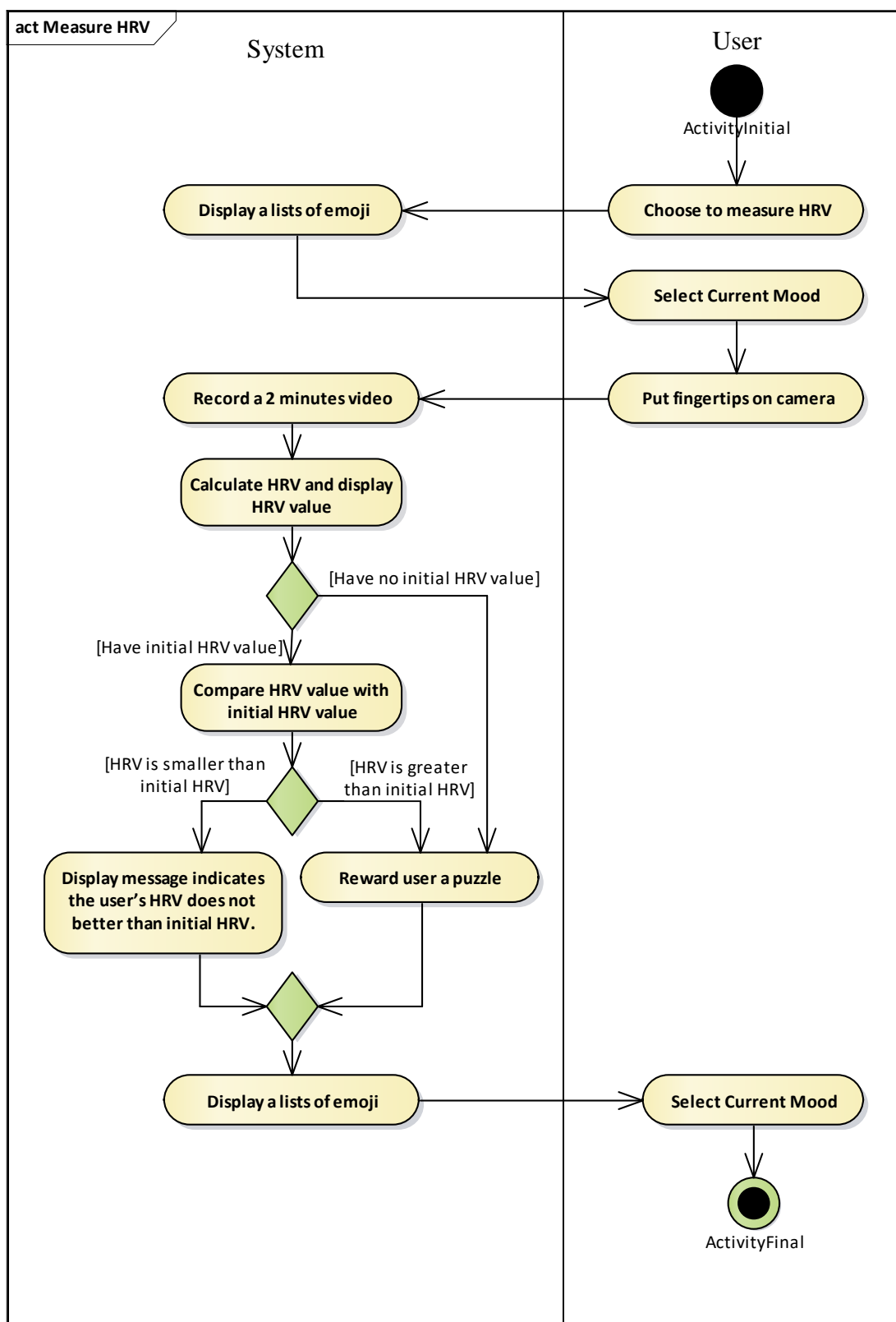
Figure 5.5: Activity Diagram for Measure HRV

5.1.2.5 **View History**
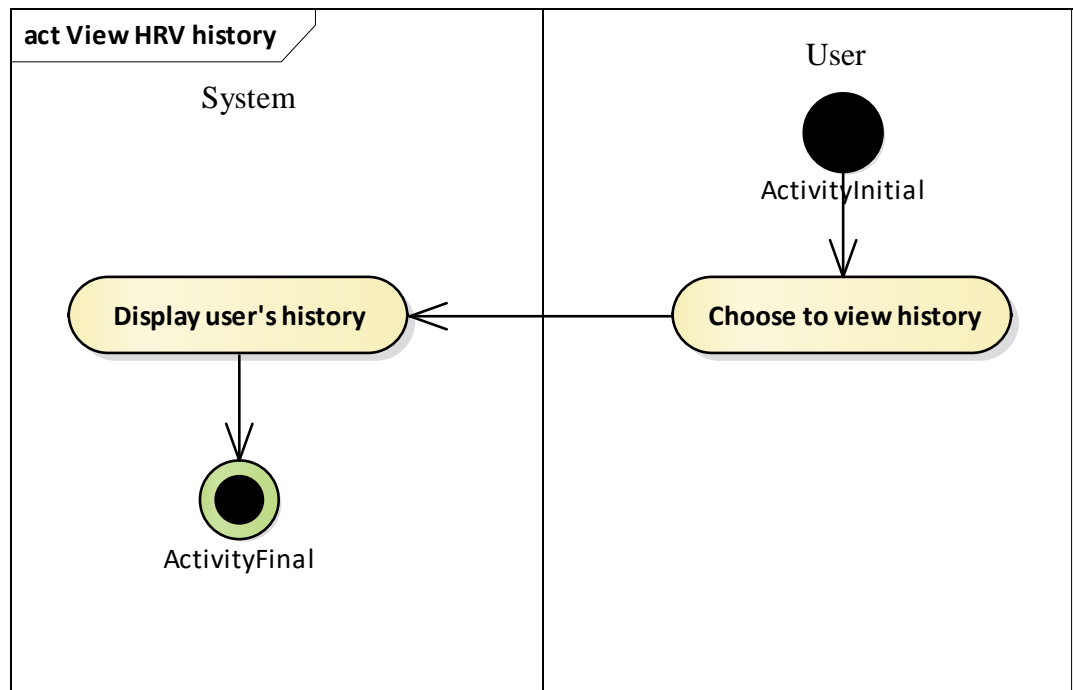
Figure 5.6: Activity Diagram for View History

5.1.2.6 **View Rewards**
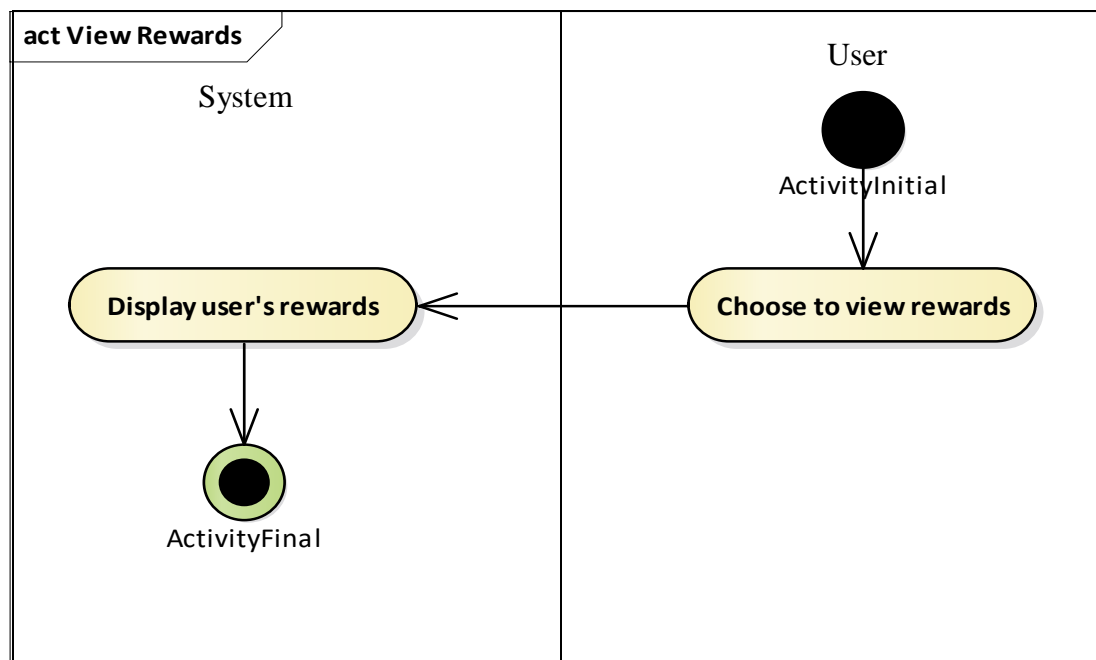
Figure 5.7: Activity Diagram for View Rewards

5.1.2.7 **Generate Users Apps Data**
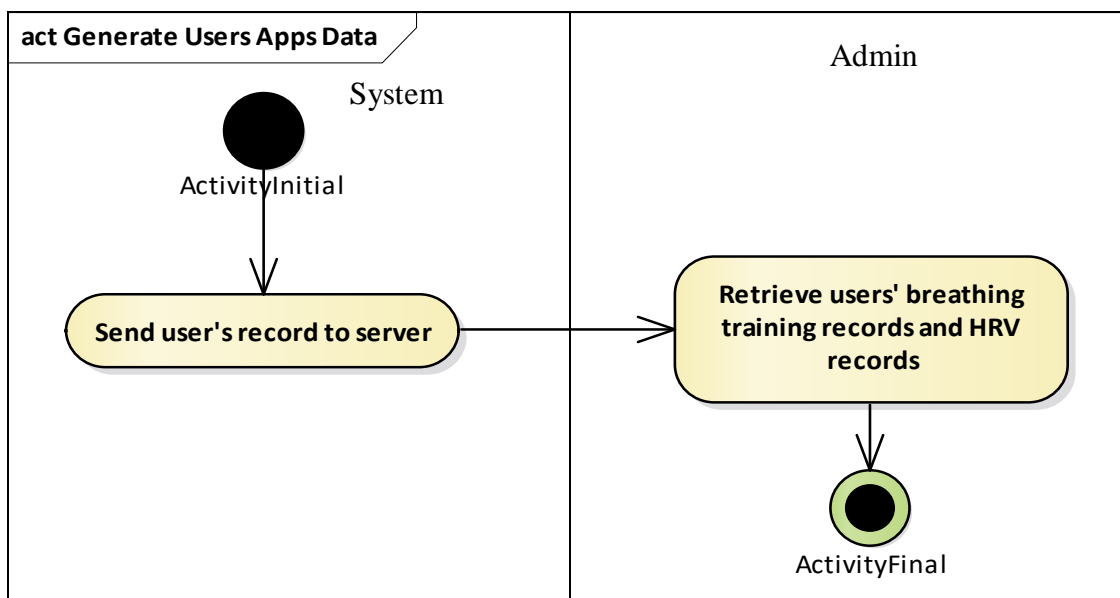
Figure 5.8: Activity Diagram for Generate Users Apps Data

5.2 Structural UML Diagram

5.2.1 Design Class Diagram
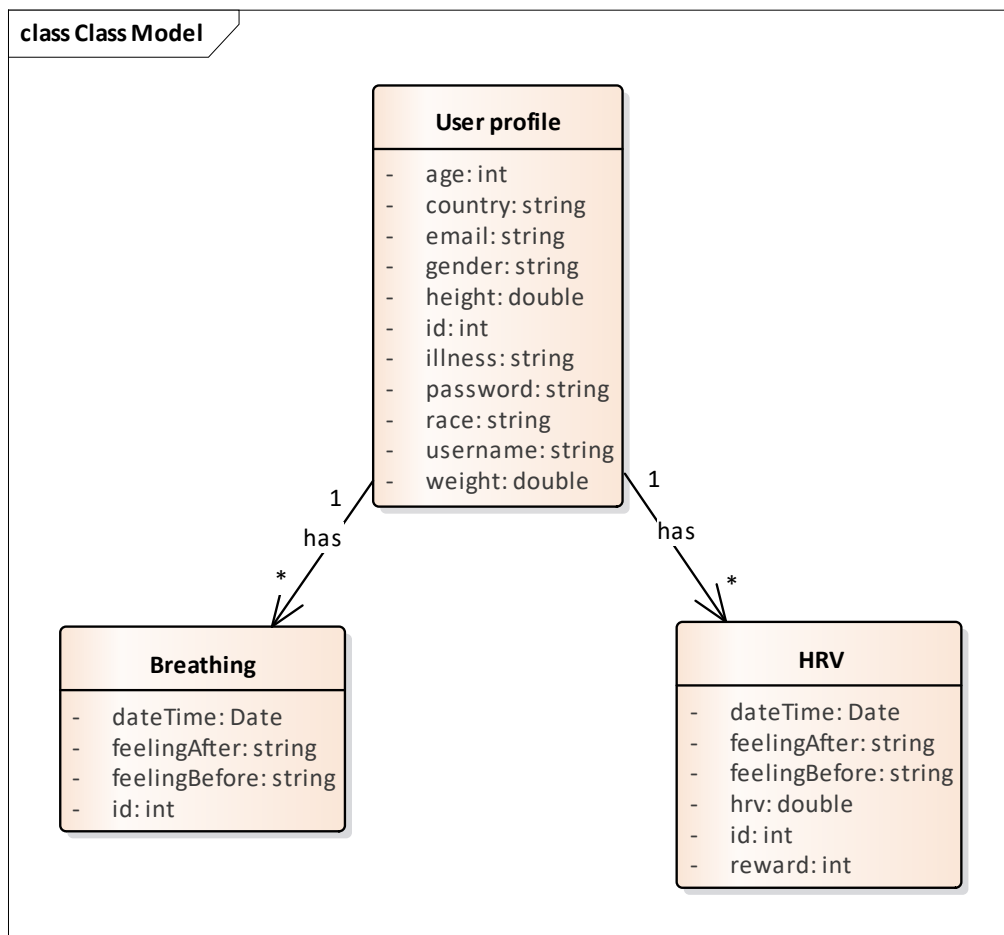
Figure 5.9: Design Class Diagram

5.3 **Database Diagram**

5.3.1 **Data Flow Diagram (DFD)**

5.3.1.1 **Context Diagram**
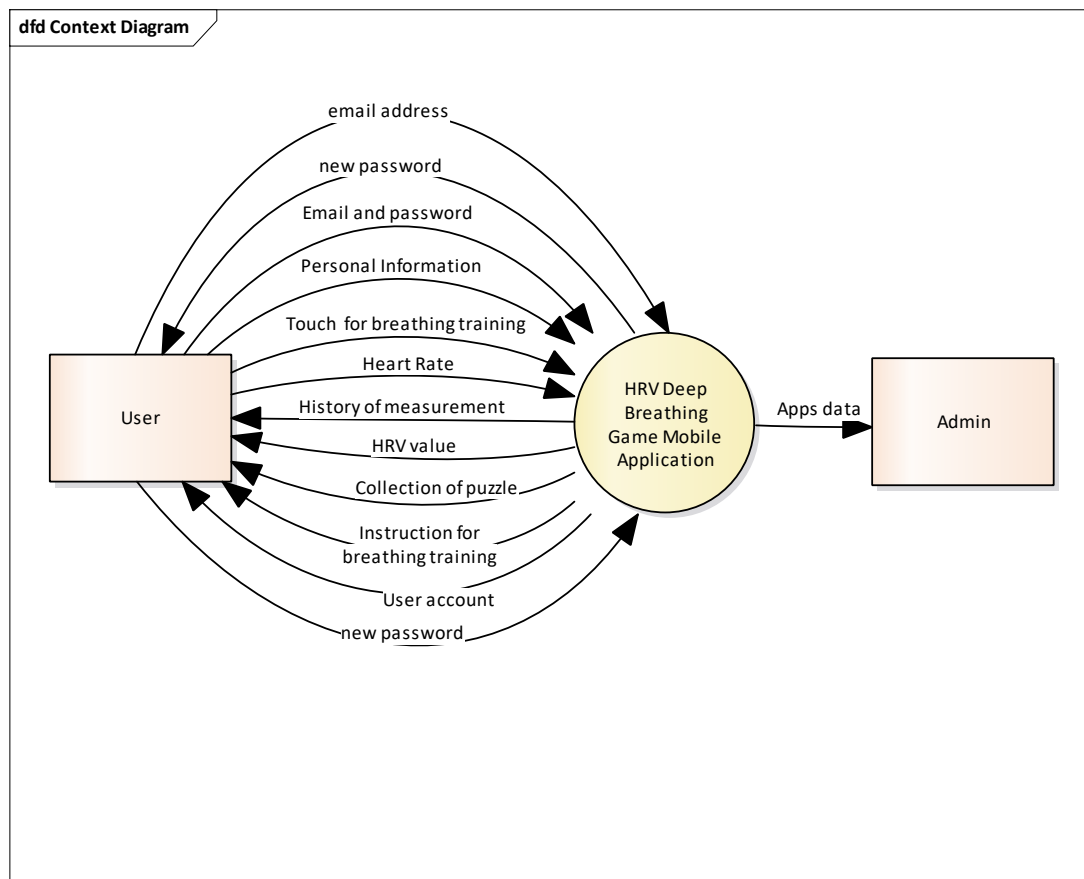
Figure 5.10 Context Diagram

5.3.1.2 **Data Flow Diagram (Level 1)**
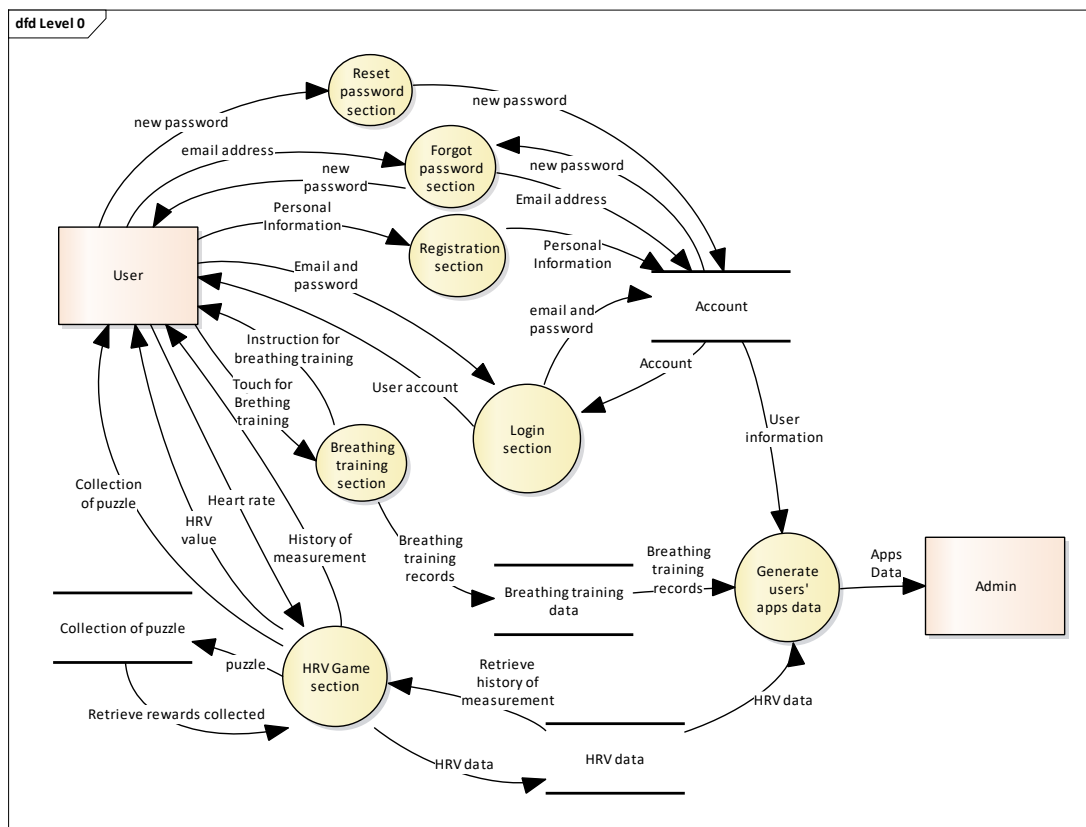
Figure 5.11: DFD Diagram (Level 1)

5.3.2 **Entity Relationship Diagram (ERD)**

class Logical View

user

«column»
*PK id: INT
    username: VARCHAR(50)
    email: VARCHAR(50)
    password: VARCHAR(50)
    gender: VARCHAR(50)
    age: INTEGER
    height: DOUBLE
    weight: DOUBLE
    race: VARCHAR(50)
    country: VARCHAR(50)
    illness: VARCHAR(50)

«PK»
+   PK_user(INT)

deepBreathing

«column»
*PK id: INTEGER
    userId: INTEGER
    dateAndTime: DATETIME
    feelingBefore: VARCHAR(50)
    feelingAfter: VARCHAR(50)

«PK»
+   id(INTEGER)

hrv

«column»
*PK id: INTEGER
    userId: INT
    dateAndTime: DATETIME
    feelingBefore: VARCHAR(50)
    feelingAfter: VARCHAR(50)
    hrvValue: DOUBLE
    reward: INTEGER

«PK»
+   id(INTEGER)

Figure 5.12: Entity Relationship Diagram

5.4   **Mobile Application User Interface**

5.4.1   **Home Screen**

This is the first screen the user will encounter when the application is launched. User can choose to 'Login' by entering his/her email and password. If user does not have account, he/she will need to register a new account. User will be navigated to the register page if he/she presses the 'Register' button in login screen. User is required to enter some personal information in order to create an account. After that, user will be redirected back to the home screen to login to their profile.
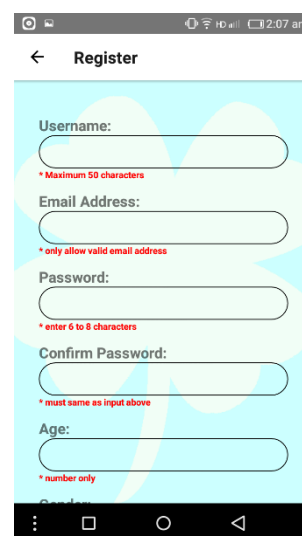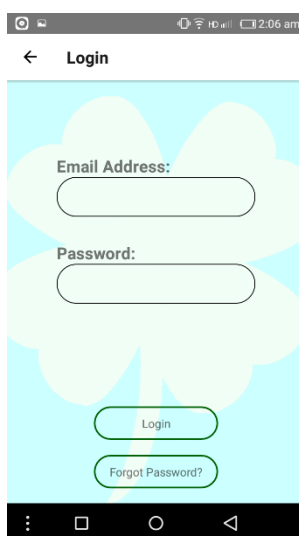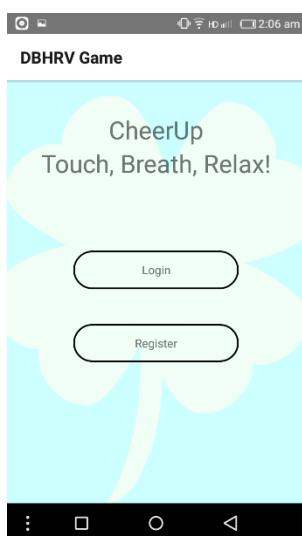
Figure 5.13: Home Screen   Figure 5.14: Login Screen   Figure 5.15: Register Screen

If user forgot the password, he/she can press the 'Forgot Password' button in the login screen to get an auto generated password from email.
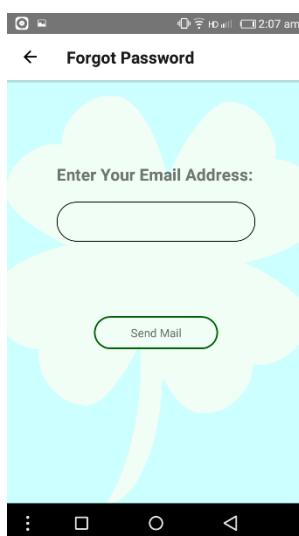
Figure 5.16: Forgot Password Screen

5.4.2 Menu Screen

After login successfully, user will be navigated to the menu screen.
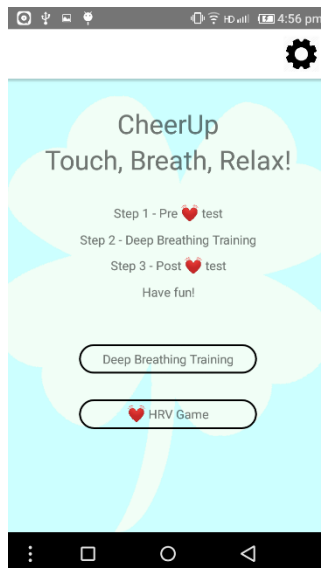
Figure 5.17: Menu Screen

5.4.3 Setting Screen

When user presses the wheel button on the menu screen, the user will be navigated to the setting screen. User can view his/her username and email in this screen. User can also choose to logout or change password in this screen.
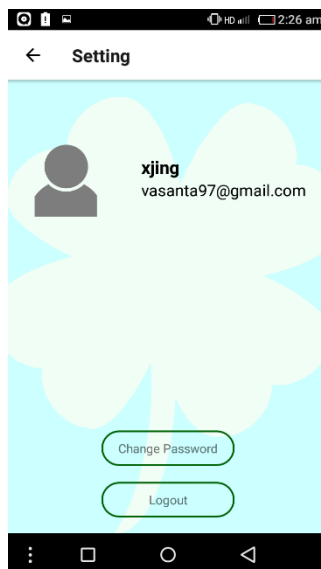
Figure 5.18: Setting Screen

5.4.4   Change Password Screen

When user presses the change password button in the setting screen, the user will be navigate to this screen.
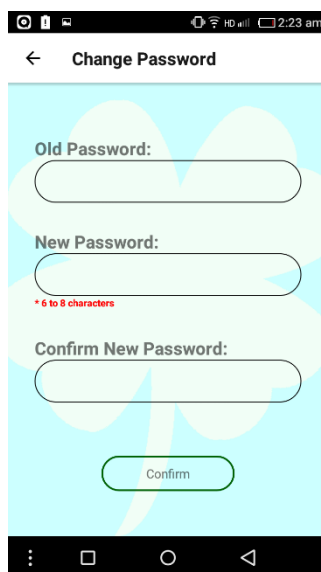
Figure 5.19: Change Password Screen

5.4.5   Feeling Screen

User will be navigated to the Feeling Screen before and after he/she starts the deep breathing training and measuring HRV.
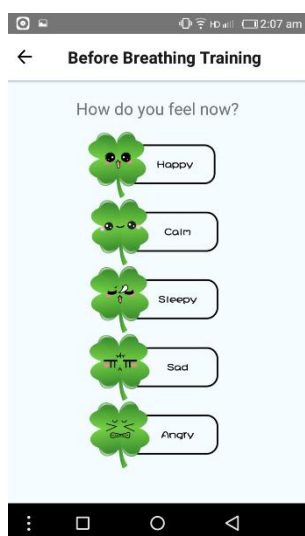
Figure 5.20: Feeling Screen (Before)   Figure 5.21: Feeling Screen (After)
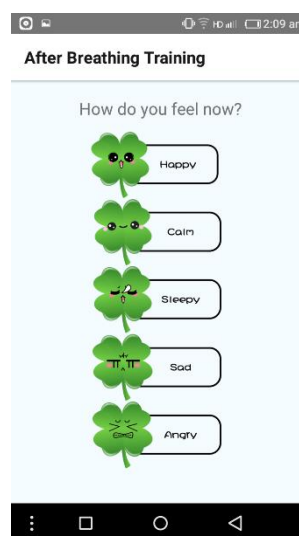
5.4.6   **Breathing Training Screen**

User will be navigated to the Breathing Training Screen after the user chooses an emoji that represents his/her current feeling/mood.

The instruction will ask the user to press the centre button and breathe in. A circle will slowly expand when user touch the centre button. When the circle reached the maximum, the instruction will change and ask the user to release the button and breathe out. Then, the circle will shrink until its original size, and the instruction will change back to "Press and breathe in".

This breathing training takes 2 minutes to complete.
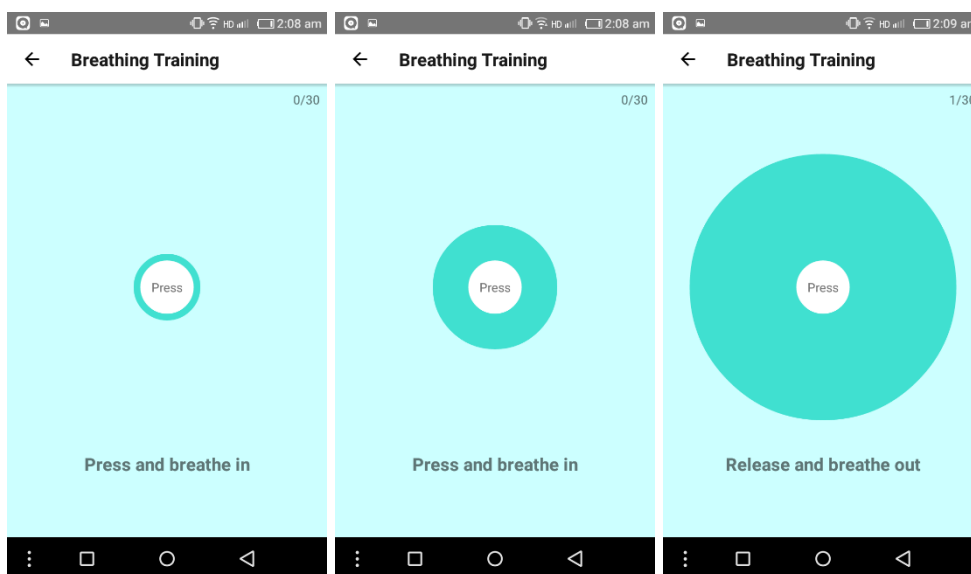
Figure 5.22: Breathing Training Screen

5.4.7 HRV Game Screen

User will be navigated to the HRV Game Screen after the user chooses an emoji that represents his/her current feeling/mood. A puzzle of clover will appear when the user's HRV value is better than initial HRV. After user collected all puzzles (4 puzzles), the puzzles will be cleared and the Reward Screen will be updated.
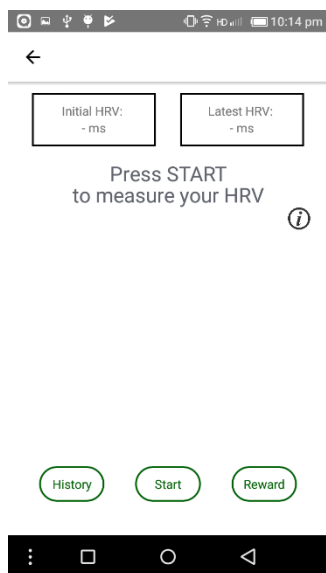
Figure 5.23: HRV Game Screen (Initial)
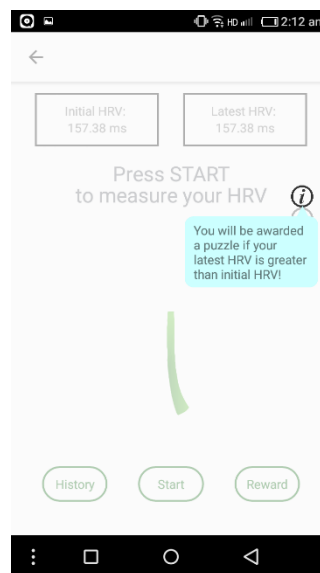
Figure 5.24: HRV Game Screen (After measured initial HRV)
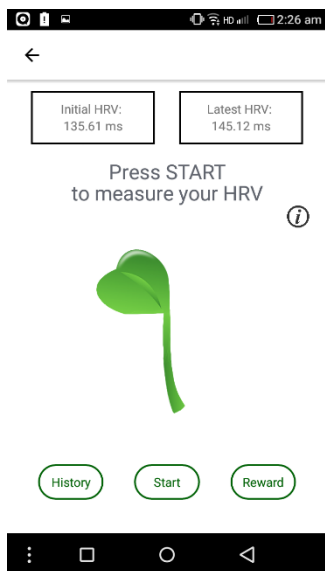
Figure 5.25: HRV Game Screen (After first measurement)
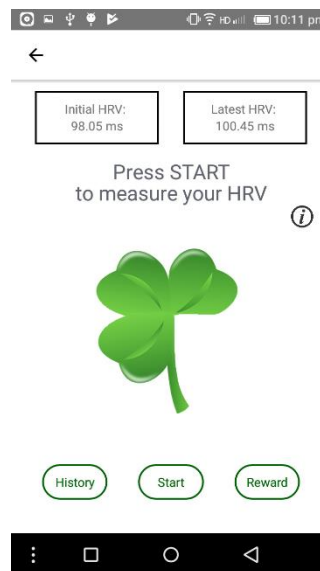
Figure 5.26: HRV Game Screen (After third measurement)
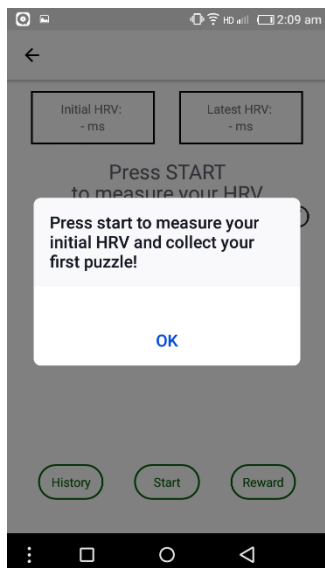
Figure 5.27: Message popup when user haven't done any measurement
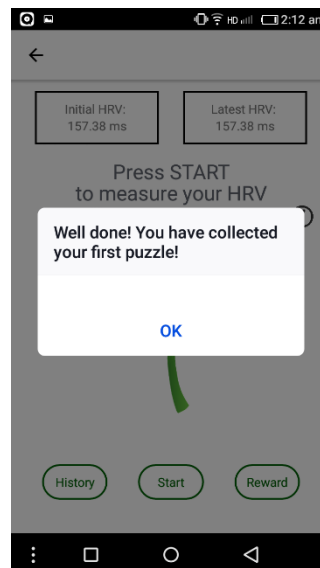
Figure 5.28: Message popup when user done the initial measurement
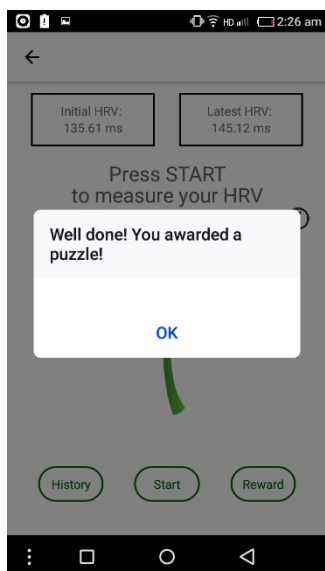
Figure 5.29: Message popup when user's HRV is higher than initial HRV
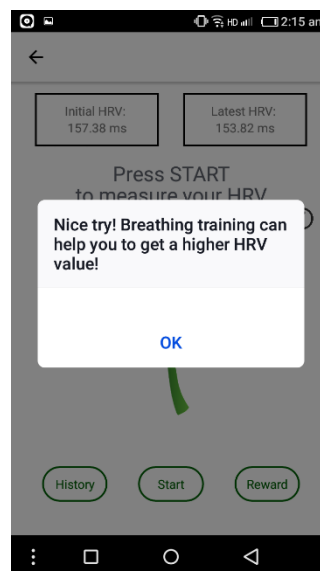
Figure 5.30: Message popup when user's HRV is lower than initial HRV

When user's HRV is lower than initial HRV, the user will be navigated to the breathing training section.

5.4.8 Measure HRV Screen

After the user pressed Start button, user will be navigated to the Measure HRV Screen. After done the measurement, user will be navigated to the Feeling Screen. The measurement takes 2 minutes to complete.
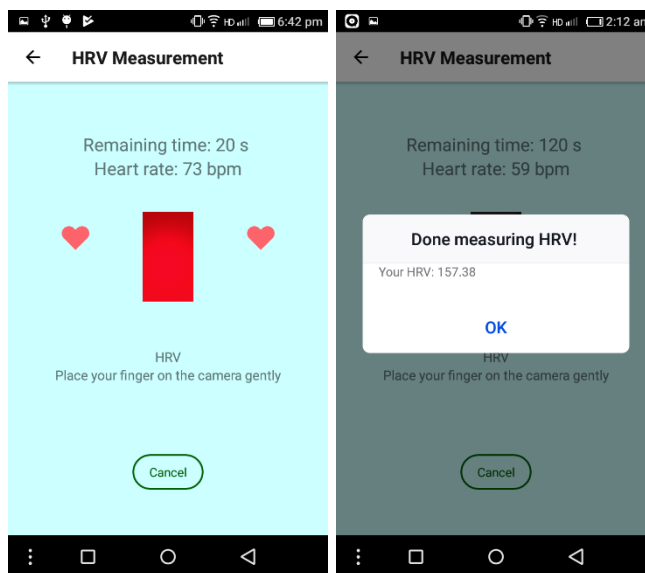
Figure 5.31: Measure HRV Screen

5.4.9 Reward Screen

User will be navigated to the Reward Screen if the user pressed the Reward button in HRV Game Screen. All the puzzles that user collected will display in this screen.

Figure 5.32: Reward Screen

5.4.10 **History Screen**

User will be navigated to the History Screen if the user pressed the History button in HRV Game Screen. All the history of measuring HRV will display in this screen.
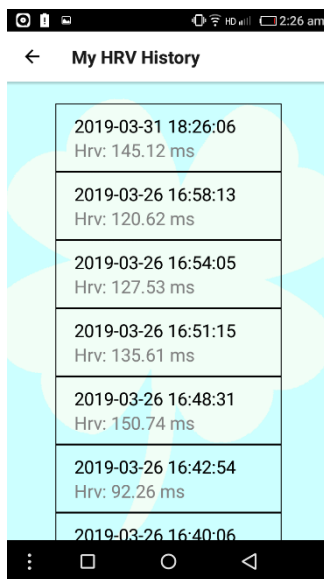
History Screen

5.5   Web Application User Interface

5.5.1   Main page
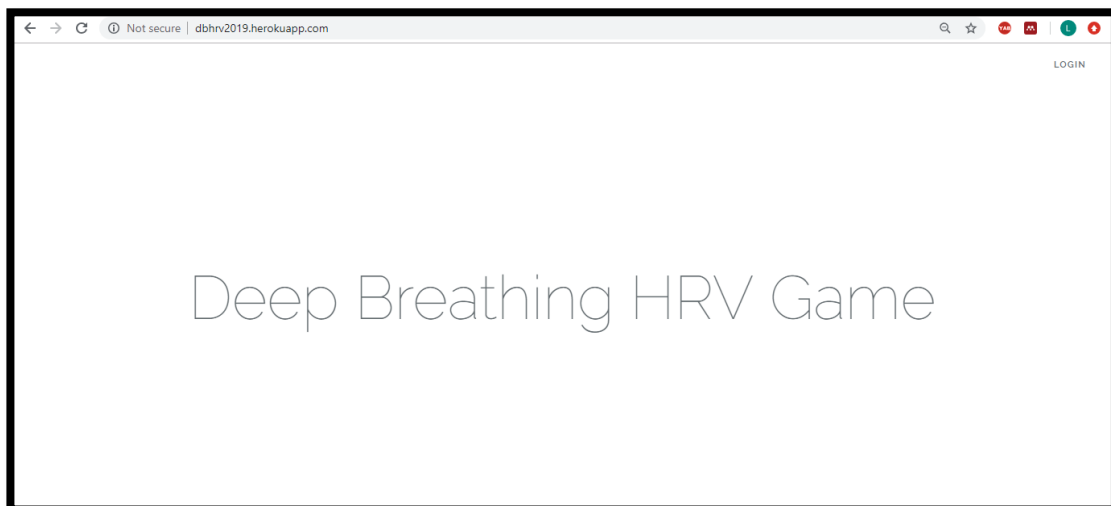
Figure 5.33: Main Page

5.5.2   Login page
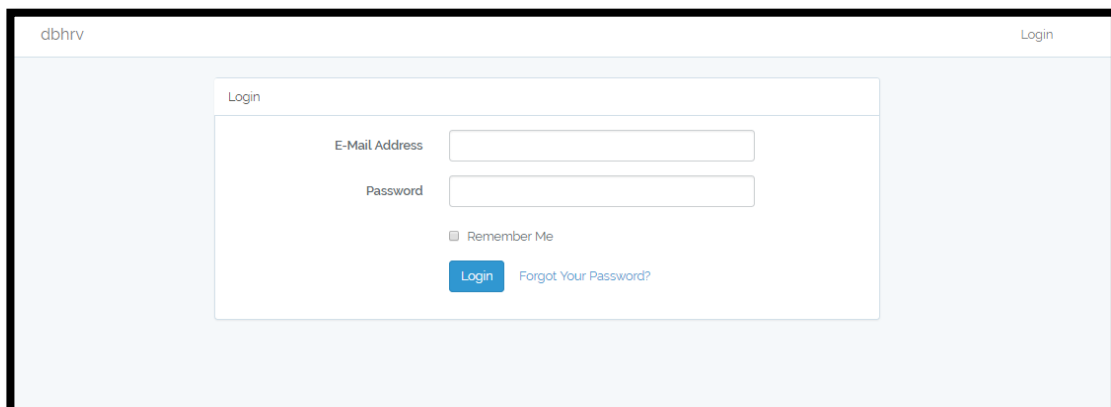
Figure 5.34: Login page

5.5.3　Home page

Only admin is authorized to view the page content.
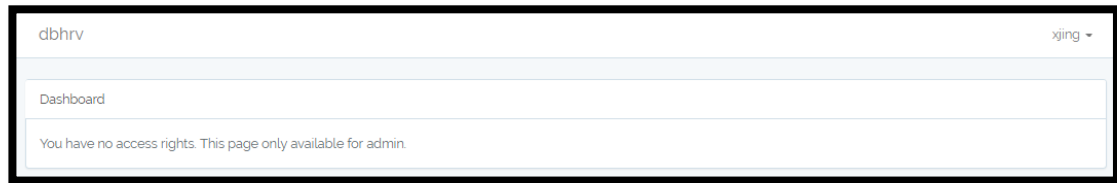
Figure 5.35: Home page when login as normal user
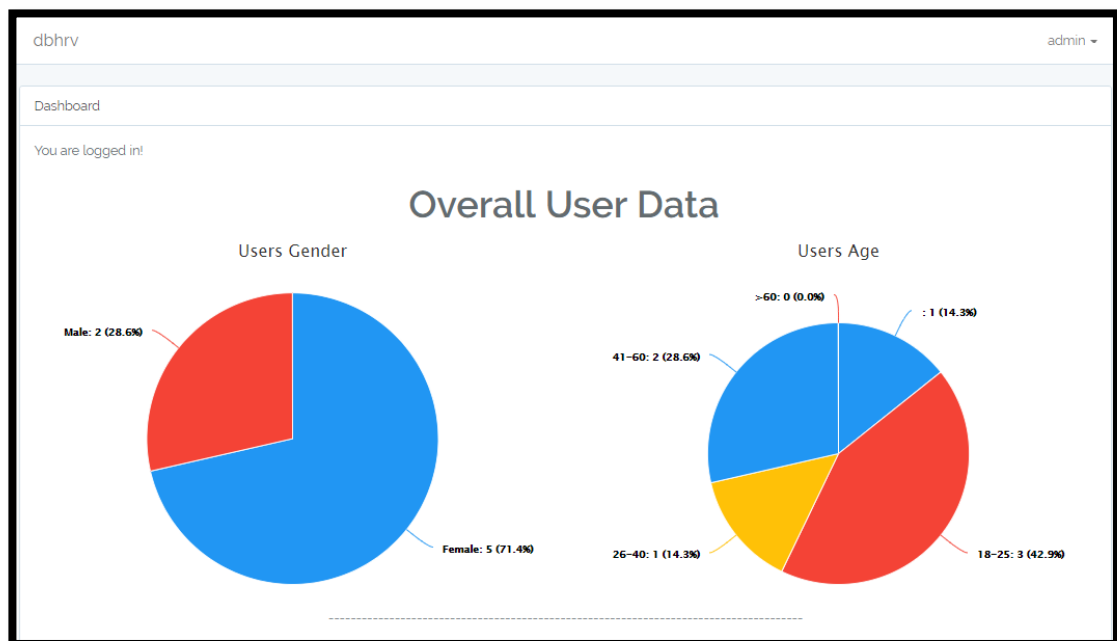
Figure 5.36: Home page when login as admin (Overall user data)

Overall Breathing Training Data

No.	Username	Age	Gender	Weight	Height	Race	Country	Illness	Date Time	Feeling before	Feeling after
1	admin	22	Female	40 kg	150 cm	Chinese	malaysia	no	2019-03-31 18:09:42	sleepy	calm
2	xjing	22	Female	50 kg	150 cm	Chinese	malaysia	no	2019-03-28 08:57:24	sleepy	happy
3	Joyce	40	Female	56 kg	156 cm	Chinese	Malaysia	None	2019-03-26 18:20:04	calm	happy
4	Jimmy	23	Female	68 kg	176 cm	Chinese	Malaysia	No	2019-03-26 16:58:58	calm	sleepy
5	xjing	22	Female	50 kg	150 cm	Chinese	malaysia	no	2019-03-26 16:31:57	sleepy	sleepy
6	xjing	22	Female	50 kg	150 cm	Chinese	malaysia	no	2019-03-26 15:58:39	calm	sleepy
7	Jimmy	23	Female	68 kg	176 cm	Chinese	Malaysia	No	2019-03-26 09:19:58	sad	sleepy
8	xjing	22	Female	50 kg	150 cm	Chinese	malaysia	no	2019-03-26 09:16:49	calm	happy

Breathing Training Feeling Changes

Figure 5.37: Home page when login as admin (Overall breathing training data)

Overall HRV Data

No.	Username	Age	Gender	Weight	Height	Race	Country	Illness	Date Time	Feeling before	HRV (ms)	Feeling after
1	xjing	22	Female	50 kg	150 cm	Chinese	malaysia	no	2019-03-31 19:21:31	sad	145.88	sleepy
2	xjing	22	Female	50 kg	150 cm	Chinese	malaysia	no	2019-03-31 18:26:06	sleepy	145.12	happy
3	admin	22	Female	40 kg	150 cm	Chinese	malaysia	no	2019-03-31 18:22:26	sleepy	145.01	sad
4	admin	22	Female	40 kg	150 cm	Chinese	malaysia	no	2019-03-31 18:18:08	sleepy	156.58	happy
5	admin	22	Female	40 kg	150 cm	Chinese	malaysia	no	2019-03-31 18:15:16	sleepy	153.82	sleepy
6	admin	22	Female	40 kg	150 cm	Chinese	malaysia	no	2019-03-31 18:12:38	sleepy	157.38	calm

Average Age: 23.5

Average Weight: 50

Average Height: 150

Average HRV: 111.4

HRV Feeling Changes

Figure 5.38: Home page when login as admin (Overall HRV data)

CHAPTER 6

IMPLEMENTATION AND TESTING

6.1 Implementation of Mobile Application

The whole application is written in JavaScript except the HRV measurement part. The HRV measurement part is written in Java. This is because of the limitation of React Native. Therefore, the react-native-camera class is extended to allow it to be used to measure user's heartbeats and HRV.

6.1.1 Collection of Inter-beat Interval (IBI)

On every peak of the heartbeat, a milliseconds of time will be collected, and the next peak milliseconds of time will be used to minus with the previous milliseconds time. The difference between the peak and next peak will be the Inter-beat interval (IBI). Then these results will be store in an array to calculate the HRV results.

```java
TYPE newType = currentType;
if (imgAvg < rollingAverage) {
    newType = TYPE.RED;
    if (newType != currentType) {
        //To get the latest beat peak time
        peakNext = System.currentTimeMillis();

        RR[RRIndex] = (peakNext - peakBefore) / 1000d;
        RRIndex++;

        //RR[i-1] = RR[i] which will be use to calculate ibi for sdnn HRV calculation later on
        peakBefore = peakNext;

        //When is RED, then beats will be increase by one;
        beats++;
        time++;
    }
}
```

Figure 6.1: IBI Calculation

6.1.2 **HRV Calculation**

When time reaches 2 minutes, the collection of IBI will be stopped and the calculation of HRV starts. Before the calculation start, the first four IBI collected will be ignore, as there might be some inaccurate result due to the movement of finger. Moreover, there might be some Ectopic beats that might be collected during the IBI calculation. Hence, the removals of Ectopic beats are essential in order to get a better accurate of SDNN HRV result. The SDNN formula is then will be apply to calculate the HRV result.

```java
//stop measure when time reach 2 minutes and calculate HRV
if (stopMeasureTime >= 120){
    camera.setPreviewCallback(null);
    camera.stopPreview();
    camera.release();
    camera = null;

    guide.setVisibility(View.VISIBLE);
    next.setVisibility(View.VISIBLE);
    preview.setVisibility(SurfaceView.GONE);

    //get sum of RR interval
    for (int i = 4; i<RR.length;i++){

        //To remove Ectopic Heartbeat from involve in the calculation
        checkEctopicHeartBeat = Math.abs(RR[i]-RR[i-1]);
        if(checkEctopicHeartBeat<=1.5 && RR[i]!=0 && RR[i] > 0.6 && RR[i] <1.1) {
            sumOfRR += RR[i];
            count++;
        }
    }

    //mean of RR interval
    meanOfRR = sumOfRR / count;
```

```java
    for (int i = 4; i < RR.length; i++){

        checkEctopicHeartBeat = Math.abs(RR[i]-RR[i-1]);
        if(checkEctopicHeartBeat<=1.5 && RR[i]!=0 && RR[i] > 0.6 && RR[i] <1.1) {
        //to get the (sum of square of RR interval) - (Mean of RR interval)
            sumOfSquareOfRRminusMeanRR += pow(RR[i] - meanOfRR, 2);
        }
    }

    //final sdnn HRV result
    sdnnHRVResult = (sqrt(sumOfSquareOfRRminusMeanRR / (count-1)))*1000d;
    sdnnHRVResult = Math.round(sdnnHRVResult*100)/100d;

}
```

Figure 6.2: SDNN Calculation

6.2 Unit Testing

Unit testing is performed during the development phase to make sure that defects are found and solve. Unit testing was carried out by testing on individual program units or methods to ensure that they are functioning as intended.

6.2.1 Register Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Empty Field Validation	1. Click Register with empty fields	Register fail with warning to fill out the empty fields	Pass
Check Email	1. Register using existing email	Register fail with warning email is registered	Pass
Email Validation	1. Register with incorrect email format	Register fail with warning invalid email	Pass
Check Password	1. Register with different password in both password and confirm password	Register fail with warning password not match	Pass
Password Validation	1. Register with password less than 6 characters or more than 8 characters	Register fail with warning length of password must be 6-8 characters	Pass
Register	1. Register with all correct format	Register successfully	Pass

Table 6.1: Register Module Unit Test

6.2.2 Login Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Empty Field Validation	1. Click Login with empty fields	Login fail with warning to fill out the empty fields	Pass
Login validation	1. Login with incorrect email address or incorrect password	Login fail with incorrect email and password	Pass
Login	1. Login with correct email and password	Login successfully	Pass

Table 6.2: Login Module Unit Test

6.2.3 Forgot Password Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Empty Field Validation	1. Click Send Mail button with empty fields	Send mail fail with warning to fill out the email field	Pass
Email Validation	1. Click send mail button with incorrect email format	Send mail fail with warning invalid email	Pass
Send mail	1. Fill in the email address 2. Press the send mail button	Send auto generate password to mail successfully	Pass

Table 6.3: Forgot Password Module Unit Test

6.2.4 Setting Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Logout	1. Click logout button 2. Click Yes when system ask to double confirm the logout action	Logout successfully	Pass

Table 6.4: Setting Module Unit Test

6.2.5 Feeling Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Feeling button	1. Press the feeling button	Show a popup message to confirm	Pass

Table 6.5: Feeling Module Unit Test

6.2.6 Breathing Training Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Breathing training	1. Press the button when the circle is in initial state	The circle expand and system prompt a message "Press and breathe in"	Pass
	2. Hold the button when the circle is at maximum size	The circle maintain at the maximum size and system prompt a message "Release and breathe out"	
	3. Release the button when the circle is at maximum size	The circle starts to shrink and system prompt a message "Release and breathe out" Circle stop shrinking when it reached its initial size, and system prompt a message "Press and breathe in"	

Table 6.6: Breathing Training Module Unit Test

6.2.7   **HRV Game Module**

Test Case	Test Execution Steps	Expected Result	Pass/Fail
First reward	1. Check on initial value, latest value and the image shown	Initial value and latest value should be the same value, the image shown is a stick	Pass
Second reward	1. Check on initial value, latest value and the image shown	Latest value is larger than initial value, the image shown is a stick with a leaf	Pass
Third reward	1. Check on initial value, latest value and the image shown	Latest value is larger than initial value, the image shown is a stick with two leaves	Pass
Forth reward	1. Check on initial value, latest value and the image shown	Latest value is larger than initial value, the image shown is a stick with three leaves	Pass
Fifth reward	1. Check on initial value, latest value and the image shown 2. Press OK on the popup message and check on initial value, latest value and the image shown	Latest value is larger than initial value, the image shown is a stick with four leaves. After press the OK on the popup message, the initial value and latest value will become empty and the image is blank.	Pass

Table 6.7: HRV Game Module Unit Test

6.2.8 HRV Measurement Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Countdown Time	1. Check on countdown time	Count down start with 120 seconds (2 minutes) and a dialog with HRV results is popup after 2 minutes	Pass
Heartbeat display	1. Check on heartbeat display	Average heartbeat should be shown every 10 seconds	Pass
IBI recording	1. Console check the IBI that are recording in the background	0.2-2.5 milliseconds of time recorded in an array	Pass
SDNN calculation	1. Measure heartbeat for 2 minutes 2. After 2 minutes, check on console 3. Check IBI array and length of the array after remove ectopic beats 4. Check mean of IBI 5. Check the SDNN result	IBI collected should be within 0.6 – 1.1 milliseconds, while for SDNN result is 40 milliseconds to 170 milliseconds, depends on the finger put on the camera	Pass

Table 6.8: HRV Measurement Module Unit Test

6.2.9 History Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Show History	1. Check the history screen	Show all HRV history of the user	Pass

Table 6.9: History Module Unit Test

6.2.10 Reward Module

Test Case	Test Execution Steps	Expected Result	Pass/Fail
Show Reward	1. Check the reward screen	Show all rewards of the user	Pass

Table 6.10: Reward Module Unit Test

6.3 Integration Testing

After unit testing is done, integration testing was proceed. Integration testing was used to test is there any error when all the modules tested in the unit testing were integrated.

6.3.1 Register and Login

Test Case	Register account and successfully login
Test Procedure	1. Click Register button 2. Fill all the required fields 3. Submit the details 4. Login in with username and password that just register
Expected Results	Login successfully with the newly registered account
Pass/Fail	Pass

Table 6.11: Register and Login Integration Test

6.3.2 Breathing training with feeling before and after

Test Case	Breathing training with feeling before and after
Test Procedure	1. Select a feeling on feeling screen. 2. Perform breathing training for 30 cycles. 3. Select a feeling on feeling screen. 4. Visit https://dbhrv2019.herokuapp.com (FOR Admin)
Expected Results	Feeling before and after display on the web server (FOR Admin)
Pass/Fail	Pass

Table 6.12: Breathing training with feeling before and after Integration Test

6.3.3 **Measure Initial HRV with feeling before and after**

Test Case	Measure Initial HRV with feeling before and after
Test Procedure	1. Select a feeling on feeling screen. 2. Measure heartbeat and HRV stress for 2 minutes 3. Select a feeling on feeling screen. 4. Check HRV Game Screen. 5. Check HRV result on History. 6. Visit https://dbhrv2019.herokuapp.com. (FOR Admin)
Expected Results	• The feeling before and after and HRV results should be successfully display on the History screen • HRV results, feeling before and feeling after display on the web server (FOR Admin) • The HRV Game Screen should have one stick.
Pass/Fail	Pass

Table 6.13: Measure Initial HRV with feeling before and after Integration Test

6.3.4 **Measure HRV with feeling before and after**

Test Case	Measure HRV with feeling before and after
Test Procedure	1. Select a feeling on feeling screen. 2. Measure heartbeat and HRV stress for 2 minutes 3. Select a feeling on feeling screen. 4. Check HRV Game Screen 5. Check HRV result on History 6. Visit https://dbhrv2019.herokuapp.com (FOR Admin)
Expected Results	• The feeling before and after and HRV results should be successfully display on the History screen • HRV results, feeling before and feeling after display on the web server (FOR Admin) • The number of leaves in HRV Game Screen will be increased based on the number of collected puzzles, in the condition when the HRV is larger than initial HRV.
Pass/Fail	Pass

Table 6.14: Measure HRV with feeling before and after Integration Test

6.4 **System Testing**

System testing is essential after integration testing is done. System testing is to ensure that the system function works perfectly when all the modules and integrated parts were combined together. System testing was done with the device: Huawei Honor 8x.

6.4.1 **Perform Breathing Training**

Test Case	Full process with performing breathing training
Test Procedure	1. Register and login 2. Press Deep Breathing Training button 3. Select a feeling on feeling screen. 4. Perform breathing training for 30 cycles. 5. Select a feeling on feeling screen. 6. Press setting button on menu screen. 7. Press logout.
Expected Results	• Register and successfully login • Breathing data (feeling before and after) submitted to the web server (FOR Admin) • Logout successfully
Pass/Fail	Pass

Table 6.15: Performing Breathing Training System Test

6.4.2   **Measure HRV**

Test Case	Full process with Measure HRV
Test Procedure	1. Register and login 2. Press HRV Game button 3. Press Start button 4. Select a feeling on feeling screen. 5. Measure heartbeat and HRV stress for 2 minutes 6. Select a feeling on feeling screen 7. Press history button and check history.
Expected Results	• Register and successfully login. • System shows the HRV results. • Feeling before and after and the HRV results will be send to server. • If the HRV measured is the first measurement, it will update the initial value and latest value, the system will show a stick (the first puzzle collected) • If the HRV measured is higher than the initial measurement, it will update the latest value and the puzzle collected will increased by 1. • If the HRV measured is lower than the initial measurement, it will update the latest value and ask the user to go for breathing training. • HRV data (HRV results, feeling before and after) submitted to the web server (FOR Admin) • HRV results and the date time are updated in history screen.
Pass/Fail	Pass

Table 6.16: Measure HRV System Test

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1   Contribution of Application

This application would have a great contribution to the community. This application cares about people well-being-ness and provides a way to help people to achieve mental wellness. People who use this mobile application could measure their HRV anywhere, anytime. People could also practice deep breathing exercise provided in the mobile application in order to achieve a healthy breathing rate.

Besides, this project collected the mobile application's data and stores in the server. These data are useful for studies on HRV, such as study on the relationship between different age group and HRV, relationship between different gender and HRV, and also the studies on how well deep breathing can helps in increasing HRV.

7.2   Limitations of Application

There are some limitations of this application. First, when the application starts to measure the user's HRV, there will have some noises that would affect the accuracy of the measurement. These noises might come from the movement of the fingers and phone with low sensitivity camera. Another limitation would be, during measuring the HRV, the application could not stop the measurement when the user leaves his/her finger from the camera.

7.3   Recommendations for Future Improvement

These are some recommendations for future improvement for this project:-

1. Develop iOS version for this project.
2. Allows the application to detect whether the user's finger is moving when measuring HRV and alert the user not to moving the finger.
3. Stops the measuring of HRV when user's finger is not on the camera.
4. Improve the game idea for the application to attract more users.
5. Provide more information on health and mental wellness to users in the application.

7.4   **Conclusion**

In conclusion, the project Mobile Healthcare Application for Breathing Training Monitoring and Gamification in Heart Rate Variability for Well-being is a successful project that has met all of the requirements. This project has been developed for 1 year and all of the processes were done according to the work plan and Gantt Chart.

To achieve the objectives of this project, a mobile application that can act as a HRV measurement tools and encourage users to practice deep breathing has been developed. Before development starts, prototyping is chosen to be the software methodology for this project and all the whole project process was well planned. After that, functional and non-functional requirements were gathered and the system was designed using different types of diagram, such as use case diagram, class diagram and also database design diagram.

Good planning and design of the system helped in the development phase. During development phase, React Native was used to develop the mobile application and a real mobile device was chose to become the emulator. Besides, Laravel was used to develop the web application. The mobile application was written in JavaScript and Java, while the web application is written in JavaScript and PHP. API had been created to allow passing data from mobile application to web application.

After the development phase, unit testing, integration testing and system testing were conducted to ensure that the system works well. Every test was passed and this project had fulfilled all requirements and objectives.

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APPENDICES

APPENDIX A: Questionnaires

Deep Breathing HRV game
* Required

Part A

The following questions are general questions

1. Gender *
Mark only one oval.

- ◯ Male
- ◯ Female

2. Age *
Mark only one oval.

- ◯ <18
- ◯ 18-25
- ◯ 26-35
- ◯ 36-39
- ◯ 40-59
- ◯ >60

3. How frequent you feel stress? *
Mark only one oval.

- ◯ everyday
- ◯ at least once a week
- ◯ at least once a month
- ◯ at least once a year
- ◯ I will not stress

4. What is the source of your stress? *
Check all that apply.

- ☐ Stress from health problem
- ☐ Stress from studies
- ☐ Stress at work
- ☐ Stress in a personal relationship such as marriage
- ☐ Financial stress
- ☐ Other:

5. How do you handle your stress? *
Check all that apply.

- ☐ Exercise
- ☐ Entertainment
- ☐ Meditation
- ☐ Talk to someone
- ☐ Reading
- ☐ Eat
- ☐ Think of something positive
- ☐ Other:

Part B

The following questions are related to the application

6. **Do you know what is heart rate variability (HRV)?** *
   Mark only one oval.

   ◯ Yes

   ◯ No

7. **Have you use mobile application to measure your HRV before?** *
   Mark only one oval.

   ◯ Yes

   ◯ No

8. **Will you use a mobile application that can measure your stress level and provide a way for you to release stress?** *
   Mark only one oval.

   ◯ Yes

   ◯ No

   ◯ Maybe