THE UNIVERSITY OF HONG KONG

DEPARTMENT OF COMPUTER SCIENCE

Final Year Project (2023-2024) Final Report

Project Title:

A Mobile App for

Anxiety Tracking and Management

Student Name: Yeung Wing Pan (UID: 3035691004)

Supervisor: Dr. Choi Yi King

Abstract

This project aims to address the issues of stress and anxiety in society. Daily challenges have contributed to the increased anxiety levels among people. Therefore, the development of effective strategies for reducing stress and anxiety is crucial.

The main motivation is to provide comprehensive, personalized tools that can help users to understand and manage their anxiety effectively. The advanced technologies, such as Heart Rate Variability (HRV) monitoring are used on this project.

Four key functions are outlined, including that Anxiety Recording and Prediction, Data Analysis and Visualization, Learning and Support, and an Anonymous Sharing Community. These functions can ensure users to identify their stress sources, track anxiety triggers, gain insights into their emotional states, and access valuable resources for managing anxiety.

The project has made some progress by successfully accessing basic health data such as HRV (Heart Rate Variability) and RHR (Resting Heart Rate), enabling users to monitor fundamental health trends within the app. The user interface (UI) design has been completed.

Challenges have been encountered, particularly regarding the collection of HRV data due to limitations with the Apple Watch. There is no choice but to shift focus towards understanding the correlation between HRV and emotional states. Based on the situation, the future plan has been updated, aiming to complete the emotional state recording aspect by late November, while the other three functions should be completed within the planned deadline.

Acknowledgements

We thanks to our supervisor, Dr. Choi Yi King, and Prof. Wu Chuan for providing guidance and support. We also thanks to our CAES course Lecturer. Mr. Simon David Boynton, for providing language support and assistance.

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Abbreviations

UI - User Interface

API - Application Programming Interface

IDE - Integrated Development Environment

OS - Operating System

ECG – Electrocardiogram

HRV - Heart Rate Variability

RHR - Resting Heart Rate

SDNN - Standard Deviation of Normal to Normal Interval

rMSSD - Root Mean Square of the Successive Differences (added)

DASS21 - Depression Anxiety and Stress Scale 21

Ch.1 Introduction

1.1 Project Background and Motivation

Stress and anxiety have become significant concerns in the modern world. The daily challenges individuals face have led to heightened levels of anxiety. Addressing this issue is crucial as chronic anxiety can negatively impact both physical and mental health. In a recent survey conducted in Hong Kong (MindHK, 2022), over 40% of the respondents in Hong Kong reported experiencing feelings of anxiousness. Thus, it is essential to develop effective strategies for reducing stress and anxiety to promote better mental health in the modern society.

The application aims to offer comprehensive and personalized solutions to users, empowering them to better understand and manage their anxiety. Additionally, it utilizes cutting-edge technologies like heart rate variability (HRV) monitoring and machine learning algorithms to effectively reduce stress.

Ch.2 Literature Review

Research suggests that with further enhancements, the Apple Watch ECG sensor could potentially be leveraged to develop a stress prediction tool (Velmovitsky et al., 2022). Wearable devices capable of consistently monitoring stress in real-time have the potential to empower individuals in managing their mental health (Velmovitsky et al., 2022). Consequently, the decision to develop the software on the iOS platform, utilizing the Apple Watch for testing and data collection, aligns with this objective.

Neurobiological studies indicate the impact of stress on HRV, underscoring HRV's validity as an objective measure for assessing mental health and stress (Kim, Cheon, Bai, Lee, & Koo, 2018). This project aims to evaluate daily stress levels using HRV

indicators and provide support to users in addressing emotional concerns through stress measurements. Velmovitsky (2023) suggests that the Apple Watch ECG offers a straightforward and cost-effective method for monitoring stress levels. However, findings from Velmovitsky's study (2023) indicate that conventional statistical approaches, such as repeated measures analysis of variance tests, may not be effective in quantifying stress using the Apple Watch ECG. Consequently, HRV should be viewed as a complementary tool for stress assessment.

The central objective of the project is to harness the potential of HRV as a predictive tool for estimating users' daily stress levels. By leveraging HRV data collected from wearable devices, particularly the Apple Watch, the app aims to empower individuals to monitor and manage their stress effectively. Rather than relying solely on HRV, the app integrates various stress management techniques and strategies to provide users with comprehensive support in addressing their emotional well-being. Through daily stress recordings and personalized insights, users can develop a deeper understanding of their stress patterns and discover effective stress management methods tailored to their needs.

Ch.3 Project Objective and Deliverable

This section outlines the four primary functions of the project's mobile application: (1) Track and Record Anxiety, (2) Data Analysis and Visualization, (3) Learning and Support, and (4) Anonymous Sharing Community. Each function serves a distinct purpose in aiding users to identify stress triggers, visualize patterns, access educational resources, and foster a supportive community for anxiety management and emotional well-being.

3.1 Function 1: Track and Record Anxiety

This feature consists of two parts: auto-tracking and manual-tracking. The primary purpose is to record users' anxiety levels and triggers. The auto-tracking part is mainly accomplished by recording the user's HRV to estimate their stress levels based on the HRV values. The manual-tracking part requires users to answer a few simple questions to record their mood and triggers. Additionally, users are encouraged to complete the DASS21 questionnaire every 2-4 weeks to record the severity of their depression, anxiety, and stress levels. All the data collected through Function 1 will be analyzed and visualized into various types of charts for users to reference.

3.2 Function 2: Data Analysis and Visualization

Function 2 aims to analyze and visualize the data collected from Function 1. Its main objective is to calculate the user's Personal Baseline of HRV. Additionally, it provides visualizations such as Line Charts, Point Charts, Heatmaps, and Bar Charts. By analyzing and visualizing the data, this feature can help users better understand the patterns and trends in their anxiety levels, providing a more comprehensive assessment of their mental health status.

3.3 Function 3: Learning and Support

Function 3 serves as a platform for mental health-related organizations to publish valuable health information. Recognizing that we are not mental health professionals ourselves, we aim to collaborate with relevant organizations to allow professionals to provide educational and informative articles on the platform. This enables users to conveniently access information about mental health and learn how to alleviate their stress through professional guidance.

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3.4 Function 4: Anonymous Sharing Community

For the fourth function, the goal is to cultivate a supportive community that allows individuals to connect, empathize, and benefit from shared experiences. This is achieved by creating a secure, anonymous platform where users can freely express their feelings and struggles with anxiety.

Ch.4 Methodology

4.1 Development Environment

The mobile application was developed using Xcode, an integrated development environment (IDE) specifically designed for macOS, which supports the Swift programming language. The user interface was built with SwiftUI, Apple's user interface toolkit, to create a modern and intuitive design. Xcode and Swift were chosen for their native support for iOS development, ensuring optimal performance, seamless integration with Apple's ecosystem, and a wide range of built-in tools and libraries that expedite the development process.

4.2 Programming Paradigm

The application follows the MVVM (Model-View-ViewModel) design pattern. MVVM is a design pattern that helps to separate the business logic and presentation layer in the application, making the codebase more organized, maintainable, and testable.
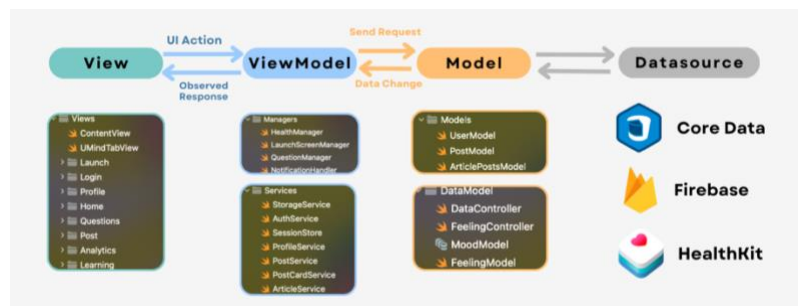

Figure 1. MVVM Structure of Application

4.3 Data Storage

For local data storage and management, CoreData was implemented. CoreData is a framework provided by Apple for managing the model layer in an application, allowing for efficient data handling and manipulation.

4.4 Health Data Integration

HealthKit was utilized to integrate and access the user's health data from various wearable devices. HealthKit is a framework provided by Apple that allows apps to interact with health and fitness data on Apple Watch and iPhone, providing a unified interface for managing health-related data.

4.5 Testing Devices

Apple Watch was used as the primary testing device for the project to ensure the accurate integration and functionality of health-related features.

4.6 Database Management

Firebase was chosen as the database solution for the application. Firebase is a comprehensive app development platform provided by Google, offering various services including real-time database, authentication, and cloud storage. The use of Firebase ensured seamless data synchronization and scalability for the application.

4.7 Technical Implementation Details

The following section details the implementation of four distinct functions: Anxiety Recording and Prediction (Function 1), Data Visualization (Function 2), Learning and Support (Function 3), and Anonymous Sharing Community (Function 4).

4.7.1 Function 1: Track and Record Anxiety

1. HRV and RHR Data Collection

Collecting HRV (Heart Rate Variability) and RHR (Resting Heart Rate) data from wearables such as the Apple Watch is achieved through the HealthKit framework. Simultaneously, data synchronization and routine updates are utilized to acquire the most recent HRV and RHR measurements.

Regarding RHR data, real-time calculations are feasible when users wear the Apple Watch. However, as per Apple Developer Documentation, HRV data on the updated Apple Watch is limited to SDNN (Standard Deviation of Normal to Normal Interval) and doesn't provide raw HRV data. Furthermore, the Apple Watch does not support the real-time collection of HRV SDNN data and does not allow HRV measurement to be triggered programmatically. The Breathe application on the Apple Watch appears to have a higher likelihood of triggering HRV measurements in real-time (Sharp, 2021). Consequently, for HRV data collection, users will be encouraged to initiate the Breathe application before recording their mental states to obtain their latest HRV records.

2. User Emotion and Triggers Collection

The manual tracking feature consists of two distinct forms. The first is the Mood and Triggers Form, which was designed with four simple questions:

1. How is your feeling?
2. What are you doing?
3. Who are you with?
4. Where are you now?

This form allows users to actively participate in monitoring their emotional well-being and provides valuable insights into their stress triggers and emotional patterns. Designed to foster self-awareness, the Mood and Triggers Form prompts

users to reflect on their current emotional state and environmental factors. It facilitates a better understanding and management of stress triggers and encourages proactive engagement in their mental health journey.

The second form is the DASS21 Questionnaire (Lovibond,1995). Users are encouraged to complete this questionnaire every 2-4 weeks to record the severity of their depression, anxiety, and stress levels.

The DASS21 questionnaire includes the following questions:

5. I found it hard to wind down
6. I was aware of dryness of my mouth
7. I couldn't seem to experience any positive feeling at all
8. I experienced breathing difficulty (e.g. excessively rapid breathing, breathlessness in the absence of physical exertion)
9. I found it difficult to work up the initiative to do things
10. I tended to over-react to situations
11. I experienced trembling (e.g. in the hands)
12. I felt that I was using a lot of nervous energy
13. I was worried about situations in which I might panic and make a fool of myself
14. I felt that I had nothing to look forward to
15. I found myself getting agitated
16. I found it difficult to relax
17. I felt down-hearted and blue
18. I was intolerant of anything that kept me from getting on with what I was doing
19. I felt I was close to panic
20. I was unable to become enthusiastic about anything
21. I felt I wasn't worth much as a person
22. I felt that I was rather touchy
23. I was aware of the action of my heart in the absence of physical exertion (e.g. sense of heart rate increase, heart missing a beat)
24. I felt scared without any good reason
25. I felt that life was meaningless

The integration of the DASS21 questionnaire enables a comprehensive assessment of the user's emotional state and enhances the overall effectiveness of the application in anxiety management. Utilizing the DASS21 provides a scientifically validated method for assessing and monitoring the severity of emotional states. Its standardized scoring system offers clear insights into the user's depression, anxiety, and stress levels, aiding in more targeted and effective interventions. The DASS21 is widely recognized and utilized in both clinical and research settings, further attesting to its authority and reliability.

Figure 2a. Interface of Mood and Track Form   Figure 2b. Interface of DASS21 Form
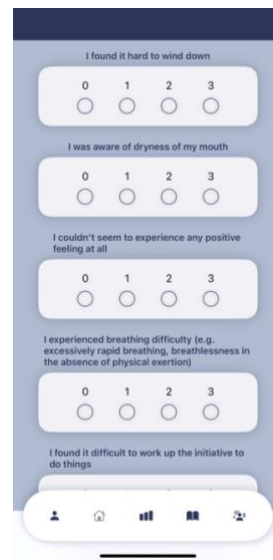
4.7.2 Function 2: Data Visualization

For the implementation of the data visualization features, SwiftCharts, a library provided by SwiftUI for creating charts and graphs, was utilized. This library offers a variety of customizable chart types that are essential for visualizing the collected HRV and RHR data effectively.

1. Calculation of HRV Personal Baseline

The calculation of the HRV Personal Baseline involved several steps:

1. **Data Collection:** The application collected HRV data in each hour from the user's wearable devices over the past two weeks.

2. **Collection of Past Seven Days' Data:** For the current day, the application collects the HRV data from the previous seven days.

3. **Outlier Removal:** Extreme values were removed from the past seven days' data to ensure accuracy.

4. **Grouping Data:** The remaining data was divided into two groups: Max-group and Min-group based on whether they were above or below the seven-day average HRV.

5. **Calculation of Average Max and Min Values:** The application calculated the average maximum and minimum values from each group.

6. **Area Mark Generation:** Finally, the application utilized the daily past seven days' average maximum and minimum values to generate Area Mark for visualization.

7. **Integration with Average HRV Line Chart:** In the HRV Personal Baseline chart, the Area Mark is combined with an Average HRV Line Chart. If the data on the line chart exceeds or approaches the boundaries of the Area Mark, the data for that day will be displayed in red. The following graph is the sample of the HRV Personal Baseline.

Figure 3. Graphs of HRV Personal Baseline

2. Chart Presentation

A key aspect of this feature is the presentation of charts generated by the application. Each chart is designed with a specific purpose, and users are guided on how to interpret the information encapsulated within them. The main charts are used in the application including:

- Line chart: This chart provides a visual representation of the HRV and RHR data collected over time. It allows users to track their heart rate variability and resting heart rate trends, facilitating a deeper understanding of their physiological responses to stress and anxiety.

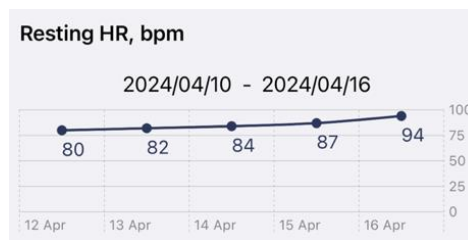Figure 4. Line Chart of Resting Heart Rate

- Scatter Plot: The Scatter Plot displays the HRV recorded every hour throughout the day. The HRV values are color-coded to represent different ranges of HRV. For example, red represents low HRV and blue represents the highest HRV. This visualization allows users to observe the daily range of HRV and patterns of anxiety occurrences.
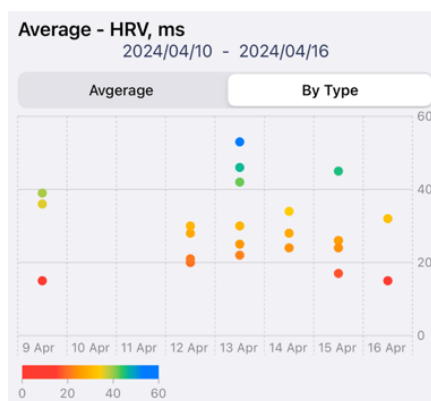

Figure 5. Scatter Plot of HRV

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- Heatmap: The Heatmap illustrates the frequency and intensity of anxiety episodes based on the HRV data collected. The Heatmap is generated by aggregating the HRV values recorded throughout the day and color-coding them to represent different ranges of HRV. This visualization enables users to identify patterns of anxiety occurrences over different periods.

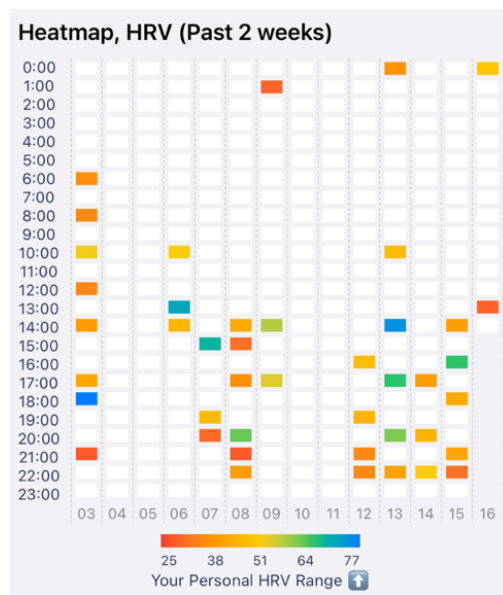Figure 6. Heatmap of HRV

4.7.3 Function 3: Learning and Support

1. Blogging Function for Uploading Contents

The blogging functionality will be extended to professional mental health-related organizations, enabling them to publish information on our platform related to psychology and mental well-being. Invitations will be extended to encourage these organizations to contribute content.

2. User Permissions

To maintain the integrity and quality of the content on the platform, a user authentication and permission system is implemented:

General Users: Upon logging in, general users can access the application's features for anxiety tracking and data visualization. They can view articles and resources published by organizational users but cannot upload or publish content on the platform.

Organizational Users: These users are granted permission to publish and manage articles and resources on the platform. They can create, edit, and delete articles to ensure the content remains relevant and up-to-date. Organizational users play a vital role in providing valuable information and resources to support users in their journey towards better mental health.

4.7.4 Function 4: Anonymous Sharing Community

Anonymous Sharing Community provides users with a platform to share their thoughts, experiences, and insights anonymously, fostering a supportive and empathetic community environment. This function consists of two primary components:

1. Content Posting

This feature integrates text editors and media upload capabilities, empowering users to create and share diverse content.

2. Comments and Interactions

Real-time comment and interaction functionalities are developed to facilitate seamless communication within the community.

Ch.5 Current Results and Difficulties

5.1 Structure and Implementation Details

5.1.1 File Structure

UMind

    |__ Utilities

    |__ Models

    |__ Services

    |__ Managers
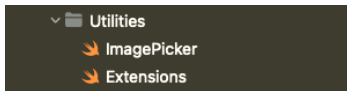
    |__ Views

    |__ DataModel
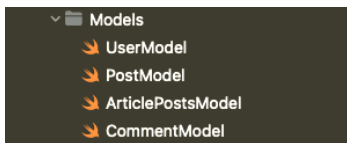

Figure 7a. Structure of Utilities
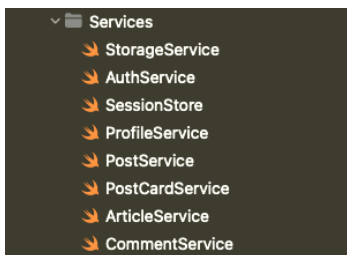

Figure 7b. Structure of Models
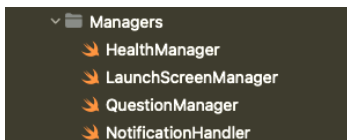

Figure 7c. Structure of Services

Figure 7d. Structure of Managers

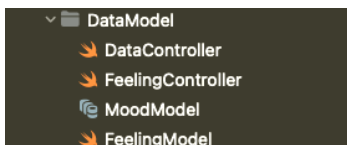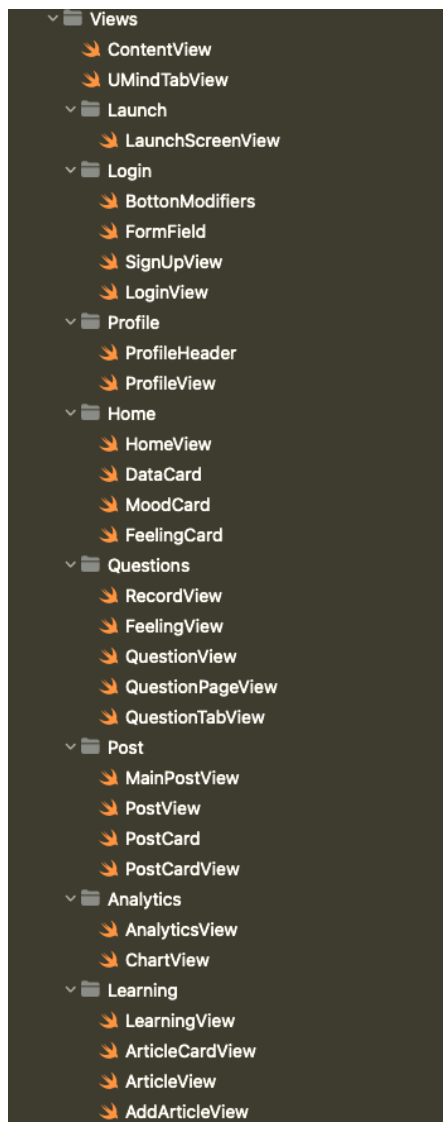
Figure 7e. Structure of DataModel

Figure 7e. Structure of Views

5.1.2 User Model

```
struct User: Encodable, Decodable{
    var uid:String
    var email:String
    var profileImageUrl:String
    var username:String
    var searchName:[String]
    var bio:String
    var isOrganization:Bool

}
```

Figure 8. UserModel

The UserModel is utilized within our application to store pertinent information about users. It encompasses the user's unique identifier (uid), email address (email), URL of the profile image (profileImageUrl), username (username), search names (searchName), biography (bio), and a flag indicating whether the user is an organization (isOrganization). These details are crucial for our application as they allow us to identify and differentiate users, manage their profiles, provide personalized content and features, and appropriately distinguish between regular users and organizations. By storing this information in the UserModel, we can efficiently manage user data, ensuring smooth operation of user experience and application functionality.

5.2 User Interface Design

The current results showcase the successful implementation of the user interface design for key pages within the application. Each page is meticulously crafted to provide users with a seamless and intuitive experience, facilitating efficient navigation and interaction with the app's features.

5.2.1 Profile Page

1. Profile View

The Profile Page serves as a centralized platform for users to check their HRV Personal Baseline and health data. Users can view their body data, including height,

weight, age, and gender, directly on this page. These data are collected from HealthKit, ensuring accuracy and synchronization with the user's health profile. Additionally, users can access their HRV (Heart Rate Variability) Personal Baseline and view their past posts, providing valuable insights into their physiological well-being and previous interactions within the community.
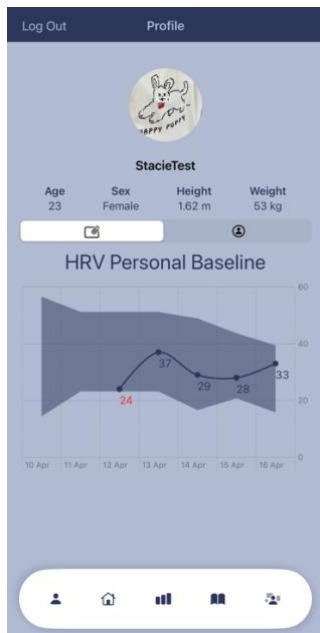
Figure 9a. Interface of Profile Page (Baseline)

Figure 9a. Interface of Profile Page (Past Posts)

2. Implementation Details

To implement the Profile Page functionality, we utilized the HealthKit framework to gather the necessary health data. The following are the key implementation details:

readMostRecentSample() Function: This function is responsible for fetching the most recent height and weight data from HealthKit. It utilizes the HKSampleQuery to retrieve the latest samples for height and weight types. The fetched data is then displayed on the Profile Page interface.

```
func readMostRecentSample(){
    let weightType = HKSampleType.quantityType (forIdentifier: HKQuantityTypeIdentifier.bodyMass)!
    let heightType = HKSampleType.quantityType(forIdentifier: HKQuantityTypeIdentifier.height)!
    let queryWeight = HKSampleQuery(sampleType: weightType, predicate: nil, limit: HKObjectQueryNoLimit, sortDescriptors: nil) { (query, results, error) in

        if let result = results?.last as? HKQuantitySample {
            print(result.quantity)
            self.Weight = "\(result.quantity)"
            print("weight => \(self.Weight)")
        }
    }


    let queryHeight = HKSampleQuery(sampleType: heightType, predicate: nil, limit: HKObjectQueryNoLimit, sortDescriptors: nil) { (query, results, error) in

        if let result = results?.last as? HKQuantitySample {
            print(result.quantity)
            self.Height = "\(result.quantity)"
            print("height => \(self.Height)")
        }
    }
    healthStore.execute(queryWeight)
    healthStore.execute(queryHeight)
}
```

Figure 10b. Source Code of readMostRecentSample()

readData() Function: This function retrieves the user's age and gender
information from HealthKit. It utilizes the dateOfBirthComponents() method to
calculate the user's age based on their birthdate and the biologicalSex() method
to obtain the user's gender. The retrieved data is displayed alongside height and
weight on the Profile Page.

```
func readData(){
    var age : Int?
    var sex : HKBiologicalSex?
    var sexData : String = "N/A"

    do{
        let birthDay = try healthStore.dateOfBirthComponents()
        let calendar = Calendar.current
        let currentYear = calendar.component(.year, from: Date() )
        age = currentYear - birthDay.year!
    }catch{}

    do{
        let getSex = try healthStore.biologicalSex()
        sex = getSex.biologicalSex
        if let data = sex {
            sexData = self.getReadableBiologicalSex(biologicalSex: data)
        }
    }catch{}

    self.Age = age ?? 0
    self.Sex = sexData

    print("Age: \(age ?? 0)")
    print("Sex: \(sexData)")
}
```

Figure 10a. Source Code of readData()

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5.2.2 Home Page

1. Home View

The Home Page is divided into three main sections:

Daily Mood Table: This table displays the user's mood records for the past week. Each mood record is represented by a different colored emoji symbol, providing a quick visual overview of the user's emotional state over time.
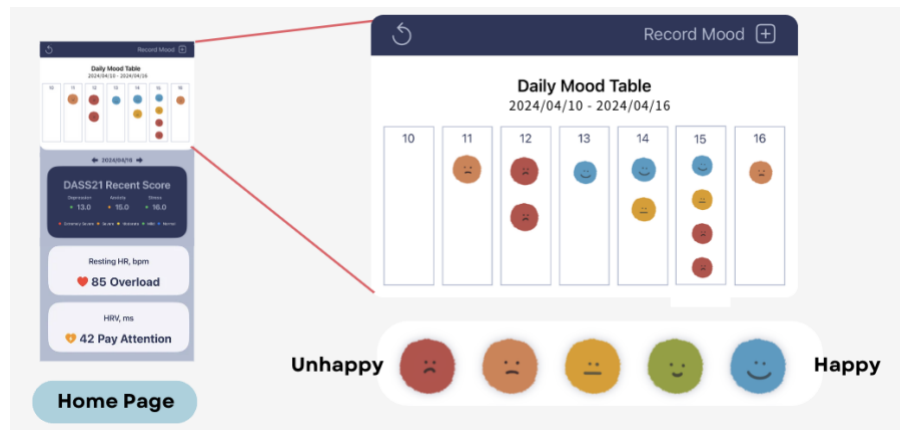
Figure 11a. Interface of Home Page (Daily Mood Table)

DASS21 Records: The DASS21 Records section presents the user's responses to the DASS21 questionnaire, allowing them to track changes in their depression, anxiety, and stress levels over time.
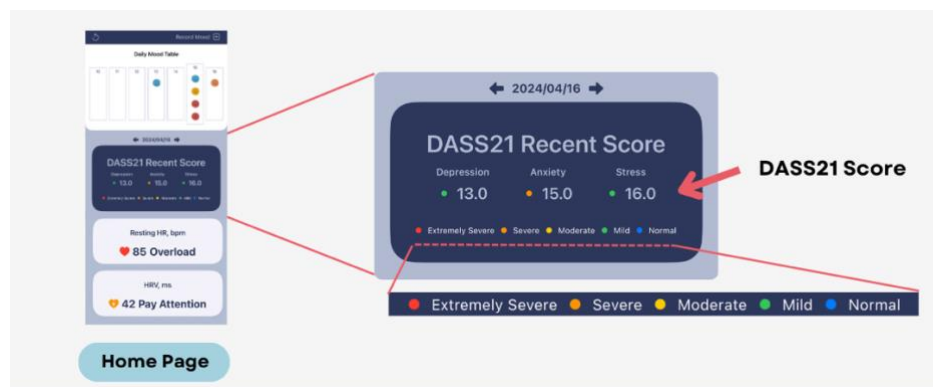
Figure 11b. Interface of Home Page (DASS21)

Heart Rate Monitoring: The Heart Rate Monitoring section displays the user's Resting Heart Rate (RHR) and Heart Rate Variability (HRV) data. If any of these data points fall outside the normal range, a prompt message will appear next to the data, alerting the user to pay attention to their physiological indicators.
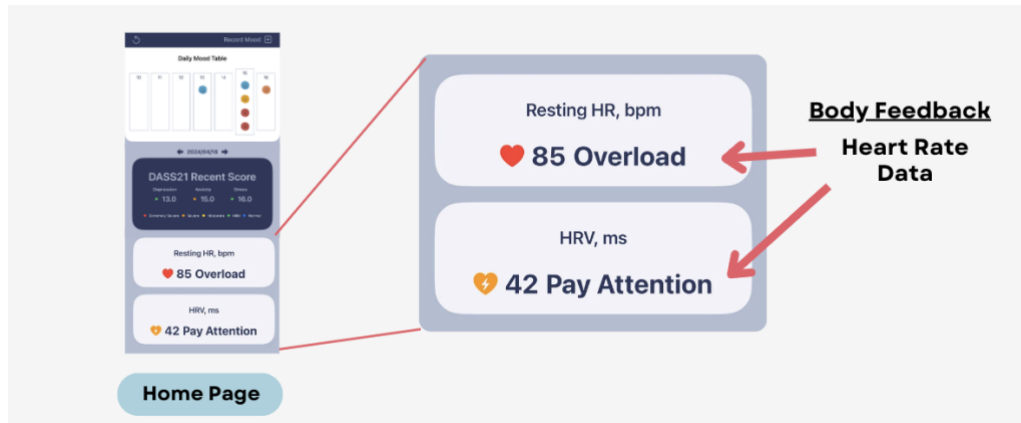
Figure 11c. Interface of Home Page (Body Feedback)

2. Self-Monitoring Record
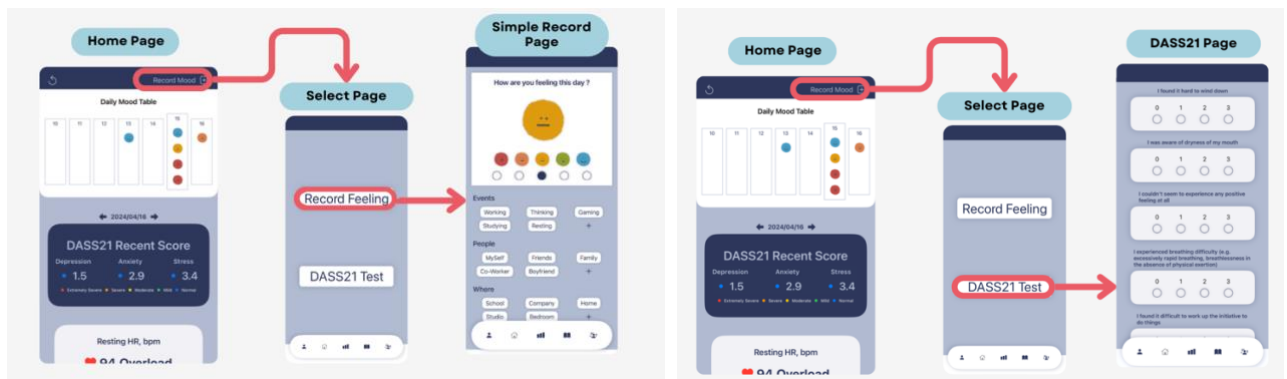
Figure 12. Interface of Home Page (Self-Monitoring Record)

Upon clicking the button located in the upper-right corner, users can choose between two options: "Record Feeling" and "DASS21 Test". Selecting "Record Feeling" directs users to a page where they can input their current mood and related triggers. Here, users can answer questions regarding their emotional state,

activities, company, and location. After submitting their responses, the data is then stored using Core Data, preserving the entries securely within the application.

Alternatively, choosing "DASS21 Test" navigates users to another page specifically designed for completing the DASS21 questionnaire. On this page, users respond to a series of questions aimed at assessing their levels of depression, anxiety, and stress. Once they finish the questionnaire, the results are saved using Core Data, ensuring the confidentiality and accessibility of the recorded data.
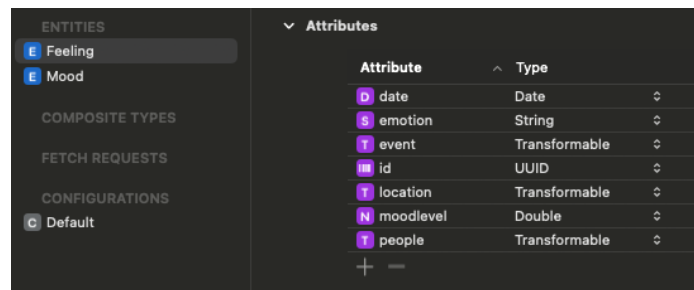
Figure 13. Attributes of Feeling (CoreData)
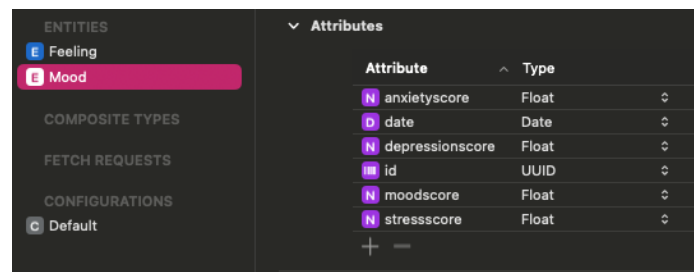
Figure 14. Attributes of Mood (CoreData)

The Self Monitoring Record feature allows users to collect and record their emotional data using Core Data, ensuring secure storage within the application. Both the Mood and Triggers Form responses and the DASS21 Questionnaire results are stored using Core Data, enabling easy access and retrieval of the collected data for future reference and analysis.

Figure 15. Struct of FeelingData   Figure 16. Struct of MoodData

The FeelingData structure captures the user's mood and triggers information, including the current date, mood level, emotional state, events, people involved, and location. Meanwhile, the MoodData structure is utilized to record the results of the DASS21 questionnaire, containing the current date along with scores for anxiety, depression, and stress levels. These data structures facilitate efficient organization and management of user-generated content, empowering individuals to monitor and track their emotional well-being effectively.

5.2.3 Analytics Page

1. Analytics View

The Analytics Page provides users with detailed insights and visualizations of their anxiety data, enabling them to track patterns, identify triggers, and monitor progress over time. It presents data in various formats:

Line Chart of RHR and HRV: This chart displays the user's Resting Heart Rate (RHR) and Heart Rate Variability (HRV) data over a specified period, allowing users to observe trends and fluctuations in their physiological parameters.
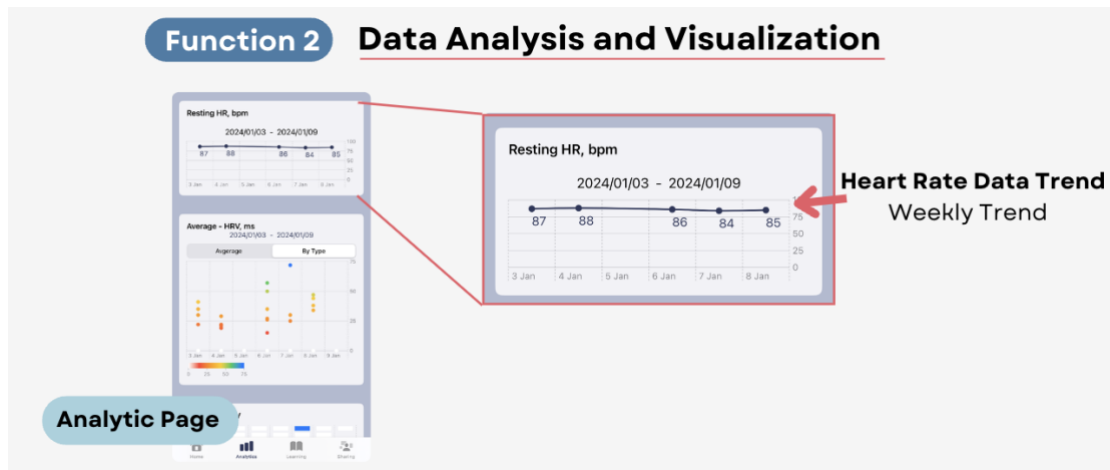
Figure 17. Interface of Analytic Page (Line Chart)

Point Chart of HRV (Scatter Point): The Scatter Point chart visualizes HRV data points over time, with each point representing a specific HRV measurement. The color-coded representation allows users to identify variations in HRV intensity and frequency.
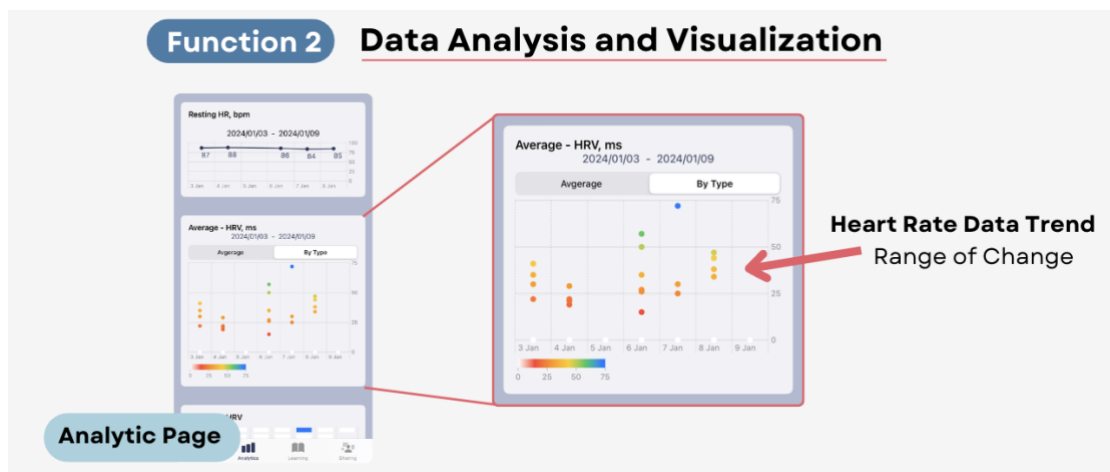
Figure 18. Interface of Analytic Page (Point Chart)

Heatmap of HRV: The Heatmap presents HRV data in a graphical format, with colors indicating the intensity of HRV measurements. This visualization method offers users a comprehensive view of their HRV patterns and trends.
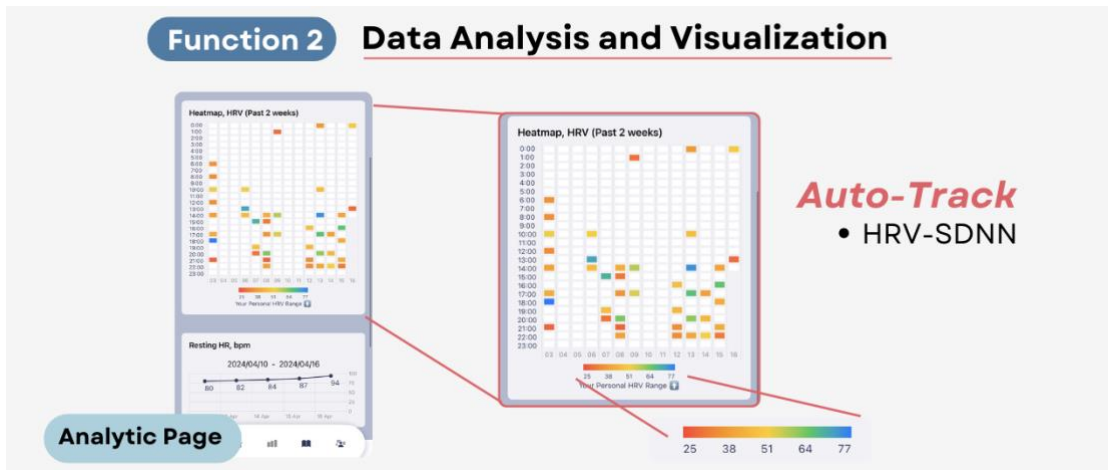
Figure 19. Interface of Analytic Page (Heatmap)

Bar Chart of Triggers: The Bar Chart displays triggers associated with anxiety episodes, providing users with insights into the factors contributing to their stress levels.
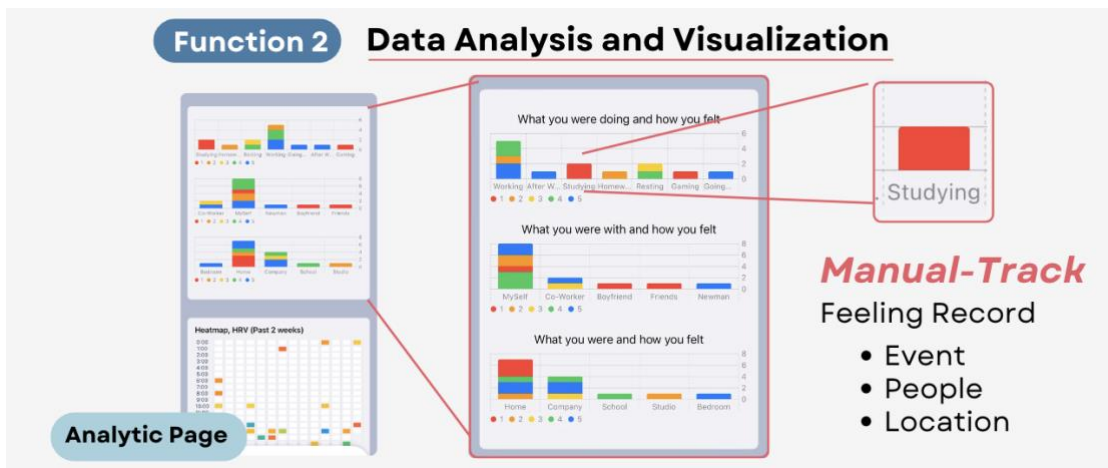
Figure 20. Interface of Analytic Page (Bar Chart)

2. Implementation Details

Real-time RHR Data Retrieval:

The Analytics Page retrieves the user's RHR data for the past week using the fetchPastWeekRestingHRData() function. This function utilizes HealthKit queries to obtain discrete average RHR values for each day within the specified timeframe. However, rather than storing the data in Core Data, it dynamically fetches the latest RHR values each time the app is launched. This approach ensures that users always have access to the most up-to-date cardiovascular information without the need for persistent data storage.

```swift
@Sendable func fetchPastWeekRestingHRData() {
    let calendar = Calendar.current
    let endDate = Date.startofDay // 当前日期
    let startDate = calendar.date(byAdding: .day, value: -6, to: endDate)!

    let heartRateType = HKQuantityType.quantityType(forIdentifier: .restingHeartRate)!

    for day in 0...6 {
        let currentStartDate = calendar.date(byAdding: .day, value: day, to: startDate)!
        let currentEndDate = calendar.date(byAdding: .day, value: 1, to: currentStartDate)!
        let predicate = HKQuery.predicateForSamples(withStart: currentStartDate, end: currentEndDate, options: [.strictStartDate,.strictEndDate])

        let query = HKStatisticsQuery(quantityType: heartRateType, quantitySamplePredicate: predicate, options: .discreteAverage) { _, result, error in

            guard let result = result, error == nil else {
                print("Error fetching resting HR data: \(error?.localizedDescription ?? "Unknown error")")
                return
            }

            if let averageHeartRate = result.averageQuantity() {
                let date = result.startDate
                let heartRateAvg = averageHeartRate.doubleValue(for: HKUnit(from: "count/min"))

                let bodydata = BodyData(
                    id:0,
                    currentdate: date,
                    amount: String(format: "%.0f", heartRateAvg)
                )


                DispatchQueue.main.async {
                    let calendar = Calendar.current

                    self.checkdateRHR.append(date.dateFormattedStringYMD())
                    self.bodydata_list[date.dateFormattedString()] = bodydata
                    self.HR_bodydata_list[date.dateFormattedString()] = bodydata

                }

                print("\(date.dateFormattedString()) 的平均心率：\(String(format: "%.0f", heartRateAvg)) 次/分")
            } else {
                print("没有可用的心率数据")
            }
        }

        healthStore.execute(query)

    }

}
```

Figure 21. Source Code of fetchPastWeekRestingHRData()

Real-time HRV Data Retrieval:

Similarly, HRV data for the past two weeks is obtained through the fetchPastWeekHRVData() function. This function employs HealthKit queries to acquire discrete average HRV values for each day over the designated period. Like the RHR data retrieval process, HRV data is dynamically fetched upon app launch, providing users with instant insights into their autonomic nervous system activity without the need for long-term data retention.

```swift
@Sendable func fetchPastWeekHRVData() {

    let calendar = Calendar.current
    let endDate = Date.startofDay // 当前日期
    let startDate = calendar.date(byAdding: .day, value: -13, to: endDate)!

    let HRVType = HKQuantityType.quantityType(forIdentifier: .heartRateVariabilitySDNN)!

    for day in 0...13 {
        let currentStartDate = calendar.date(byAdding: .day, value: day, to: startDate)!
        let currentEndDate = calendar.date(byAdding: .day, value: 1, to: currentStartDate)!

        let predicate = HKQuery.predicateForSamples(withStart: currentStartDate, end: currentEndDate, options: [.strictStartDate,.strictEndDate])

        let query = HKStatisticsQuery(quantityType: HRVType, quantitySamplePredicate: predicate, options: .discreteAverage) { _, result, error in
            guard let result = result, error == nil else {
                print("Error fetching resting HRV data: \(error?.localizedDescription ?? "Unknown error")")
                return
            }

            if let averageHeartRate = result.averageQuantity() {

                let date = result.startDate
                let heartRateAvg = averageHeartRate.doubleValue(for: .secondUnit(with: .milli))
                let bodydata = BodyData(
                    id:1,
                    currentdate: date,
                    amount: String(format: "%.0f", heartRateAvg)
                )

                DispatchQueue.main.async {

                    self.checkdateHRV.append(date.dateFormattedStringYMD())

                    self.bodydata_list[String(bodydata.id)+date.dateFormattedString()] = bodydata
                    if(day>6){
                        self.HRV_bodydata_list[date.dateFormattedString()] = bodydata
                    }
                    self.HRV_bodydata_list_2week[date.dateFormattedString()] = bodydata
                }

                print("\(date.dateFormattedString()) Average HRV:\(String(format: "%.0f", heartRateAvg)) ms")
                print(self.HRV_bodydata_list)
            } else {
                print("No HRV data")
            }
        }

        healthStore.execute(query)
    }
}
```

Figure 22. Source Code of fetchPastWeekHRVData()

5.2.4 Learning Page

1. Learning View

The Learning Page serves as an educational hub where users can access articles and resources related to psychology, mental health, and stress management. Users can click on the cover image of each article to read the full content. Additionally, professional mental health-related organizations can publish articles on this page to share valuable insights and information with users. This feature aims to empower users with knowledge and strategies for improving their emotional well-being and coping with anxiety.
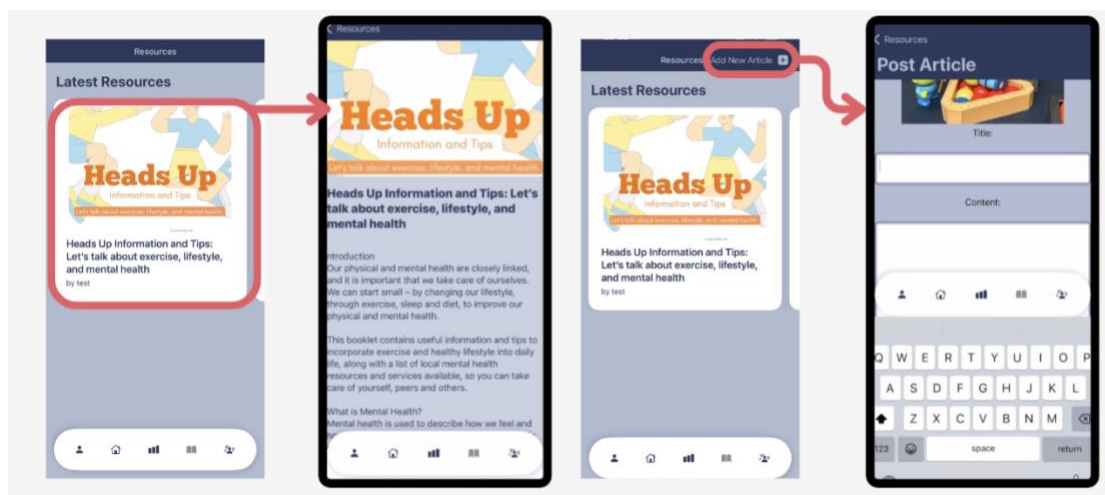
Figure 22. Interface of Learning Page

On the left side of Figure 9, it demonstrates the user experience for a general user. When a general user clicks on the cover image of an article on the Learning Page, the application navigates them to the content page of the selected article. This allows the user to access and read the full content of the article seamlessly within the app interface.

On the right side of Figure 9, it illustrates the interface for organizational users. In the top right corner of the Learning Page, there is a button "Add New Article +" specifically

designed for organizational users. By clicking on this button, organizational users can add new articles to the platform, contributing valuable content for other users to access and benefit from.

2. Implementation Details

The Learning Page harnesses the power of Firebase Firestore to curate and manage articles on psychology, mental health, and stress management. Each article is represented by a document within Firestore, encapsulating essential attributes such as ID, title, content, likes, organization details, media URLs, and publication date. Upon accessing the Learning Page, the application dynamically fetches article data in real-time from Firestore, ensuring that users have access to the latest educational content. When a user interacts with an article by clicking on its cover image, the app seamlessly retrieves the corresponding content from Firestore and presents it within the app interface, facilitating a smooth reading experience. The ArticlePostsModel structure serves as the backbone for modeling article data, providing a standardized format for efficient storage and retrieval of article metadata and content.

```
struct ArticlePostsModel: Hashable, Encodable , Decodable {

    var id: Int
    var title: String
    var content: String
    var likes: [String: Bool]
    var organizationId: String
    var articleId: String
    var organization: String
    var profile: String
    var mediaURL: String
    var date: Double
    var likeCount: Int
    var articleType: [String]
}
```

Figure 23. Struct of ArticlePostsModel

<u>**5.2.5 Sharing Page**</u>

1. Sharing View

The Sharing Page provides users with a platform to engage in open communication, share personal experiences, and offer support within the community. Users can access this page to connect with others who may be facing similar challenges and find solace in shared experiences.

Post Creation: Users can easily create new posts by clicking on the button located in the top right corner of the page. This allows users to share their thoughts, feelings, and insights on anxiety management and emotional well-being with the community.

Engagement Tools: The Sharing Page incorporates engagement tools such as liking and commenting to encourage interaction among users. Users have the option to show appreciation for posts by liking them and engage in meaningful discussions by leaving comments.
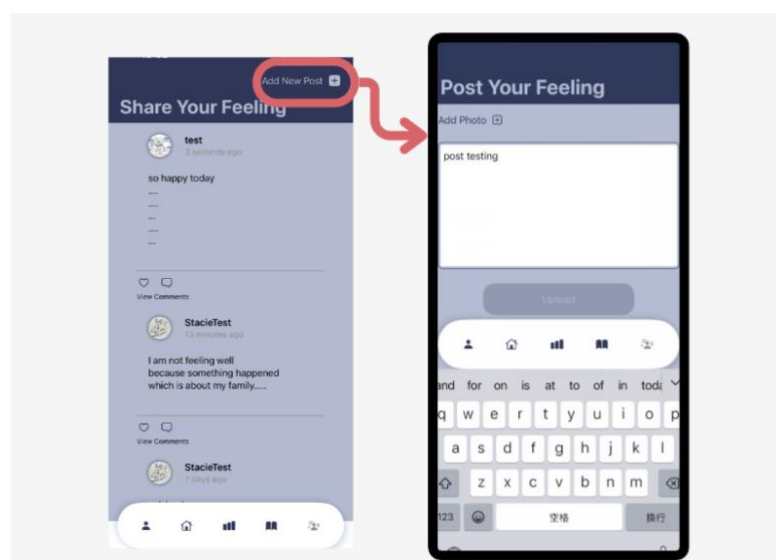
Figure 14. Interface of Learning Page

2. Implementation Details

The Sharing Page empowers users to engage in open communication and community support through the integration of Firebase Firestore for post and message management. User-generated content, including posts and messages, is stored as documents in Firestore, each containing attributes such as content, likes, owner details, post IDs, media URLs, timestamps, and engagement metrics. Firebase Cloud Functions enhance the functionality of the Sharing Page by triggering notifications and updates across the platform in response to user interactions, ensuring a dynamic and responsive user experience. The PostModel structure defines the schema for post data, facilitating the consistent storage and retrieval of post metadata and content. By leveraging Firebase Firestore's real-time data synchronization capabilities, the Sharing Page fosters meaningful connections and discussions within the community while providing users with intuitive engagement tools for liking and commenting on posts.

```swift
struct PostModel: Encodable, Decodable {

    var content: String
    var likes: [String: Bool]
    var ownerId: String
    var postId: String
    var username: String
    var profile: String
    var mediaURL: String
    var haveImage: Bool
    var date: Double
    var likeCount: Int
}
```

Figure 25. Struct of PostsModel

5.3 Difficulties and Adaptations

During the course of development, several technical challenges were encountered, primarily revolving around the limitations in accessing comprehensive HRV data directly from wearable devices like the Apple Watch. Initially, the intention was to leverage HRV data for predictive analytics using machine learning algorithms. However, the constraints posed by the Apple Watch, which provides HRV data only in the SDNN format and lacks support for accessing RR-Interval data, posed a significant obstacle to this approach.

5.3.1 HRV Prediction Challenges

The initial approach to address the HRV data limitations involved exploring the feasibility of accessing raw voltage data from the Electrocardiogram (ECG) to derive RR-Interval data. However, the absence of affordable ECG analysis APIs capable of processing raw voltage data for RR-interval analysis rendered this solution impractical. Consequently, the envisioned HRV prediction functionality, relying on machine learning algorithms, could not be implemented due to the unavailability of requisite data.

5.3.2 Adaptation

In response to these challenges, a pragmatic adaptation was made to the project's focus. Instead of relying on HRV prediction, the emphasis shifted towards providing users with insights into the correlation between their HRV data and emotional states. This adaptation led to the development of the HRV personal baseline feature. The HRV personal baseline feature[1] calculates the user's HRV baseline based on their HRV data

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[1] mentioned in section 4.7.2 Calculation of HRV Personal Baseline

collected over the past 7 days. This baseline serves as a reference range representing the user's typical HRV variation. The calculation method involves statistical analysis to derive the average maximum and minimum HRV values, which are then visualized as a chart for user reference. Importantly, this HRV personal baseline is prominently displayed within the profile page of the application, ensuring easy access and understanding for users.

5.2.3 Significance of HRV Personal Baseline

While the original intention was to provide HRV prediction capabilities, the implementation of the HRV personal baseline offers a valuable alternative. By offering users insights into their HRV trends and variability, the HRV personal baseline empowers users to monitor their physiological well-being and potentially identify patterns associated with their emotional states. Although it deviates from the initial plan, the HRV personal baseline remains a significant contribution to the application's functionality, aligning with the project's overarching goal of promoting emotional well-being and stress management.

5.2.3 Future Directions of HRV Personal Baseline

Despite the initial setback regarding ML implementation, the project continues to evolve towards providing valuable insights into users' emotional well-being. The focus remains on refining HRV assessments and exploring potential associations with emotional states.

Moving forward, efforts will be directed towards further enhancing the accuracy and relevance of HRV analysis, potentially incorporating additional data sources and refining statistical models. Additionally, strategies will be devised to increase data

collection efforts and engage users more actively in contributing to the refinement of the HRV personal baseline.

By addressing these challenges and continuing to innovate, the project aims to empower users with actionable insights for better emotional management and overall well-being.

Ch.6 Phase Progression

6.1 Phase 1: Inception (October 1, 2023 - January 7, 2024)

During the initial phase of the project, primary emphasis should be placed on HRV research and implementing the emotion status recording functions. However, due to the HRV research challenges (referenced in Chapter 5: Current Results and Difficulties), this phase experienced delays in HRV-related components. The deadline for HRV Data Collection and Automatic Recording, initially set for the end of Phase 1, will be postponed to late January as we continue our efforts to comprehend the complexities of HRV analysis. Basic UI design and implementation of HomeView, QuestionTabView and AnalysticsView are finished.

6.2 Phase 2: Elaboration (January 8, 2024 - April 22, 2024)

In this phase, significant progress was made in resolving the challenges related to HRV analysis. Particularly, a solution was developed to calculate the HRV personal baseline, addressing the limitations of the Apple Watch and ensuring the project's adaptability. The successful resolution of the HRV personal baseline issue marked a significant milestone in the project's development, paving the way for the seamless integration of HRV data into the application's functionality. Additionally, during this phase, the development of Functions 3 and 4, namely the learning and support blogging function and the anonymous sharing community, was completed, further enhancing the application's features and user experience.

Ch.7 User Feedbacks and Future Plan

7.1 User Feedback

Throughout the development process, insightful feedback has been gathered from early users, offering valuable perspectives on their experiences and expectations regarding the application's functionality. Notably, two users, UserA and UserB, provided noteworthy insights:

Feedback of User A

User A commended the application's utility as an emotion diary, expressing satisfaction with the ability to record daily experiences and emotional states. However, they suggested that further integration between Heart Rate Variability (HRV) data and mood records would significantly enhance the app's functionality and user experience, facilitating deeper insights into the correlation between physiological metrics and emotional well-being.

Feedback of User B

User B, though not personally grappling with emotional challenges, raised concerns regarding monitoring the health metrics of their family members, particularly their elderly grandmother. They emphasized the importance of a family-oriented version of the application, allowing users to track the HRV and heart rate of their loved ones, thereby fostering peace of mind and facilitating proactive health management within the family unit.

7.2 Future Plans

In response to the feedback received and ongoing development initiatives, several strategic plans have been delineated to augment the application's capabilities and address user needs:

7.2.1 Integration of Personal HRV with Emotional States

Objective: To enhance the understanding of users' emotional well-being by integrating their Heart Rate Variability (HRV) data with their recorded emotional states.

Plan: Building upon user feedback, particularly from User A, who expressed a desire for deeper insights into the connection between physiological and emotional states, we will prioritize the integration of personal HRV data with emotional states within the application. By collecting additional user data and leveraging machine learning techniques, such as linear regression, we aim to develop predictive models that correlate HRV patterns with emotional responses. This integration will provide users with valuable insights into their emotional well-being, empowering them to make informed decisions about their mental health.

7.2.3 Enhanced Database Security and Facilitate Family Health Monitoring

Objective: To ensure the security and privacy of user data while enabling family members to monitor each other's health metrics.

Plan: Responding to concerns raised by User B regarding the desire for family-oriented health monitoring features, we will focus on enhancing database security measures and facilitating family health monitoring within the application. By implementing robust encryption protocols and access controls, we aim to safeguard user data against unauthorized access or breaches. Additionally, the development of a family health monitoring feature will allow users to securely share their health data with trusted

family members, fostering a supportive environment for collaborative health management.

By diligently prioritizing user feedback and aligning future plans with the evolving needs of its user base, the application aspires to transcend as an indispensable tool for emotional well-being management and family health monitoring.

Ch.8 Conclusion

In conclusion, the development of the mobile application aimed at addressing stress and anxiety has progressed significantly, despite encountering various challenges along the way. The project originated from the pressing need to combat the rising levels of stress and anxiety in modern society, as evidenced by surveys indicating the prevalence of these issues, particularly in regions like Hong Kong.

The application's objectives were delineated into four primary functions: tracking and recording anxiety, data analysis and visualization, learning and support, and an anonymous sharing community. Each function was meticulously designed to cater to specific aspects of anxiety management, ranging from self-monitoring to community support.

Throughout the development process, the team encountered technical challenges, particularly concerning the limitations in accessing comprehensive HRV data directly from wearable devices like the Apple Watch. Despite initial plans to implement predictive analytics using machine learning algorithms, constraints in accessing raw HRV data necessitated a pragmatic adaptation. This led to the development of the HRV personal baseline feature, offering users insights into their HRV trends and variability.

User feedback played a pivotal role in shaping the direction of the application, with users expressing a desire for deeper integration between HRV data and emotional states, as well as family-oriented health monitoring features. In response, future plans include enhancing database security measures and facilitating family health monitoring within the application.

In essence, while the project has encountered challenges and necessitated adaptations, it remains committed to its overarching goal of empowering individuals to manage their stress and anxiety effectively. By prioritizing user feedback and continuously innovating, the application aspires to become an indispensable tool for emotional well-being management and family health monitoring, ultimately contributing to a healthier and happier society.

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