Final Year Project (2023-2024)

Project Title:

A Mobile App for

Anxiety Tracking and Management

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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.

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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

Some findings suggest that by incorporating further enhancements and improvements, data from the Apple Watch ECG sensor can be utilized in creating a stress prediction tool (Velmovitsky et al., 2022). Wearable devices capable of consistently and instantly monitoring stress will empower individuals to address their mental health (Velmovitsky et al., 2022). Consequently, the software is chosen to be developed on the iOS platform, utilizing the Apple Watch as the device for testing and data measurement.

Based on existing neurobiological findings, it is evident that stress affects HRV, suggesting that utilizing HRV as an objective measure to evaluate mental health and

stress is reasonable (Kim, Cheon, Bai, Lee, & Koo, 2018). Consequently, this project intends to assess daily stress levels through the HRV indicator and support users in addressing emotional issues using stress measurements. According to Velmovitsky (2023), the Apple Watch ECG could serve as a straightforward, cost-effective, and non-intrusive method to monitor an individual's stress levels. However, Velmovitsky's study (2023) found that the utilization of repeated measures analysis of variance tests did not yield statistically significant results, implying that the Apple Watch ECG might not be suitable for quantifying stress using conventional statistical approaches. Therefore, HRV should be considered a supplementary tool.

The primary focus of the project revolves around users recording their daily stress levels and discovering effective methods to manage stress within the app. HRV is utilized to predict and estimate users' daily stress levels rather than being relied upon as the sole stress indicator.

Ch.3 Project Objective and Deliverable

This section delineates the four key functions of the project's mobile application: (1) Anxiety Recording and Prediction, (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: Anxiety Recording and Prediction

The application can record both automatic and manual input of users' anxiety levels and triggers. Additionally, HRV-based stress prediction will be utilized to alert users in advance of their heightened stress levels. This proactive notification aims to

encourage users to log their emotions and environmental factors within the mobile app, enhancing the efficiency of developing Function 2.

3.2 Function 2: Data Analysis and Visualization

The processed data collected from users' wearable devices will be presented through clear graphs and charts. This presentation aims to provide users with meaningful insights into the patterns and trends of their anxiety, empowering them to make well-informed decisions for more effective anxiety management.

3.3 Function 3: Learning and Support

The platform offers users a curated library of resources covering anxiety and stress management, along with guided relaxation activities available in video and audio formats.

3.4 Function 4: Anonymous Sharing Community

To cultivate a supportive community allowing individuals to connect, empathize, and benefit from shared experiences, it is essential to create a secure, anonymous platform where users can express their feelings and struggles with anxiety.

Ch.4 Methodology

This section delves into the technical aspects required for the project, encompassing Equipment and Platform Setup, System Architecture Design, and Technical Implementation Details of various functions within the mobile application. It covers HRV and RHR Data Collection and Prediction, Data Visualization, Learning and Support resources, and the creation of an Anonymous Sharing Community for user engagement and support.

4.1 Equipment and Platform Set Up

This section covers two areas: the Development Environment used for creating the mobile application and the selection and preparation of Updated Testing Devices.

4.1.1 Development Environment

The mobile application will be created using the Swift programming language and the SwiftUI framework for iOS devices. Xcode, Apple's integrated development environment (IDE), will facilitate coding, testing, and debugging.

4.1.2 Updated Testing Devices

The primary testing devices selected are the iPhone and Apple Watch. To ensure full functionality, it is necessary for all testing devices to update to the latest OS version to access the capabilities of the iPhone and Apple Watch effectively.

4.2 System Architecture Design

This section elaborates on two key areas: Client-Side and Server-Side components of the System Architecture Design.

4.2.1 Client-Side

The iOS-based mobile application functions as the client, managing user interactions, data input, and information display. As health data is collected from the user's device, some basic data analytics are processed on the client-side to enable rapid responses.

4.2.2 Server-Side

The server hosts the database, handles complex data analytics, stores user data, and provides the client with information and strategies for managing stress.

4.3 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).

4.3.1 Function 1: Anxiety Recording and Prediction

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. Recording

A user-friendly data entry interface will be designed that enables users to answer their emotional status and DASS21 questionnaire, which is designed to measure the severity of common mental health conditions.

3. HRV Prediction

A predictive model will be developed by considering relevant factors, user-specific trends, and historical HRV data. Ideally, rather than relying on comparisons with general public's HRV scores, individuals should establish the practice of regularly monitoring their own HRV data.

The implementation involves a systematic process, commencing with the

consistent collection of HRV data from the user over a minimum period of 30 days to ensure a robust sample size.

The calculation involves determining the mean and standard deviation of the 30-day HRV dataset. The mean provides insight into the user's average HRV level, while the standard deviation indicates the variability within the dataset. Employing these statistical metrics allows for the computation of a normal range, typically expressed as the mean plus or minus 1 to 2 standard deviations. Extracting the range's 95%, a common statistical practice, ensures a comprehensive representation of the user's normal variability.

To maintain real-time accuracy, it is imperative to continuously update the user's normal range as new HRV data becomes available. This dynamic adjustment accounts for changes in the user's lifestyle habits over time.

Implementing a notification and recommendation system adds a practical layer to the process. In instances where a user's HRV falls outside the established normal range, the system can promptly notify them and offer relevant, personalized suggestions. These recommendations may include reminders for relaxation exercises, increased physical activity, or improvements in sleep hygiene.

This personalized and dynamic approach not only refines the precision of assessing a user's HRV status but also facilitates tailored health recommendations.

4.3.2 Function 2: Data Visualization

It is planned to choose appropriate SwiftCharts which is a library provided by SwiftUI for creating charts and graphs.

1. 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
- Scatter Plot
- Heatmap

4.3.3 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. Content Recommendations

Subsequently, the curated information will be recommended to the users. Recommendations will be tailored based on the user's age and the level of psychological stress. It is hoped that users will be able to explore suitable organizations on the platform. In times of difficulty, having access to a wealth of information will empower users to seek assistance effectively. This approach aligns with our commitment to fostering a supportive environment for mental health and well-being on the platform.

3. Rating and Reviews

The inclusion of this feature will allow users to assess and provide feedback on the content available. This feature is designed to empower users to selectively recommend high-quality content to others on the platform.

4.3.4 Function 4: Anonymous Sharing Community

1. User Profile Management

The User Profile Management function ensures the privacy of user profiles and all associated personal details. Only the user's self-defined username is made public, maintaining a secure and confidential environment.

2. Content Posting

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

3. 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 Current Results

Access to HRV and RHR data has been successfully implemented at this stage of the project. The UI design of function 1 and function 2 has been completed, and UI coding is now in progress.

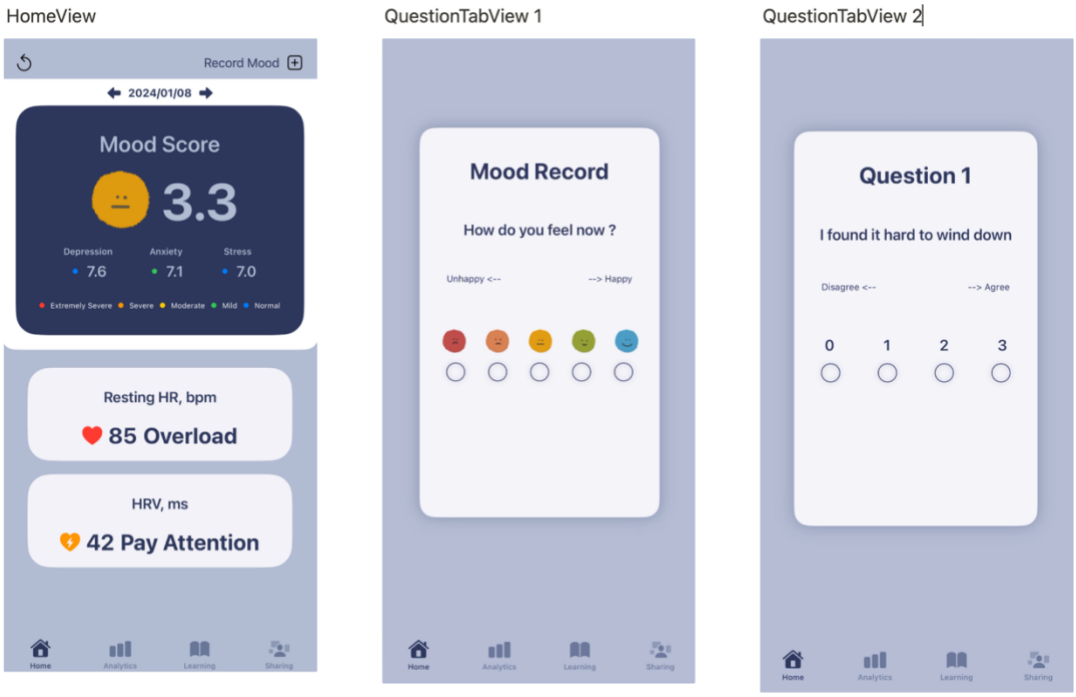

Figure 1. UI design for Function 1(HomeView and QuestionTabView 1 & 2)

Basic heart rate data, encompassing HRV and RHR, can be accessed in the HomeView (Figure 1). There are labels (e.g. “Overload” and “Pay Attention”) aside HRV and RHR data, which represent the severity of the heart rate data. Those labels refer to users’ personal normal range. In addition, DASS21 Score are also shown on HomeView (Figure 1). There are coloring dots aside the score, which represent the severity of their Depression, Anxiety and Stress.

Users can rate their current mood by clicking the "Record Mood" button, where one mark indicates the most unhappy state, while five marks denote the most joyful state. The Daily Mood Score (QuestionTabView 1), calculated as the

mean of mood marks, will be generated after users input a new record. The DASS21 Score (QuestionTabView 2), calculated as the separate score and will be shown on HomeView after finishing the whole questionnaire.

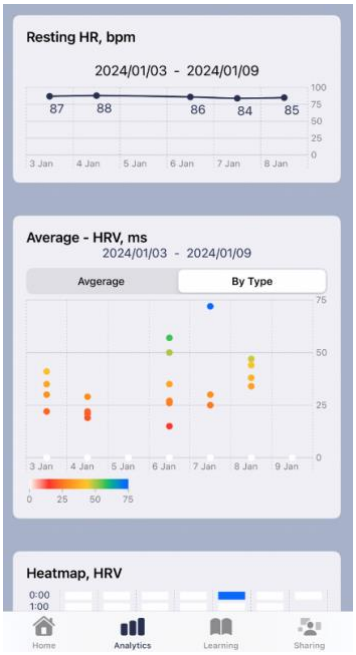

Figure 2. UI design for Function 2 (AnalyticsView)

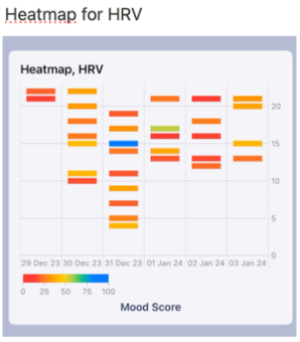

Figure 3. UI design for Function 2 (Heatmap of HRV Data)

Figure 4. UI design for Function 2 (Heatmap of Mood Data)

The AnalyticsView is utilized for data visualization, enabling users to review the trends of their health data and mood (Figure 2). Weekly Mood status and HRV SDNN data are displayed via a Heatmap (Figure 3 and 4), facilitating easy observation of their weekly mood through color representation. Additionally, stress-related HRV data is depicted using Line Charts and Scatter Spot.

5.2 Difficulties

Throughout the development process, several technical challenges have been encountered. The limitations of the Apple Watch restrict the accessibility of HRV data solely in the SDNN format, excluding the RR Interval data essential for calculating rMSSD-formatted HRV. This constraint has necessitated an adaptation in our approach to HRV analysis.

Initially, one of the crucial methods to address the aforementioned problem was to explore the potential of accessing raw voltage data from the Electrocardiogram (ECG) and generating the RR-Interval data from it. However, there are no free or affordable ECG analysis APIs available in the market that can process users' ECG raw voltage data for RR-interval analysis. This limitation implies that calculating HRV in various formats using ECG data is presently an impractical solution.

5.3 Solution

Due to these challenges, the decision has been made to redirect the project's focus toward aiding users in comprehending the correlation between HRV and their daily emotional states.

The final solution involves the collection of long-term HRV data from users, spanning a period of, for instance, 30 to 90 days. Subsequently, statistical methods are applied to eliminate extreme values, and the 95% range of this refined data is extracted to establish the user's normal HRV range. Additionally, efforts are made to explore potential linear relationships between a user's HRV data and their recorded emotional states.

By gathering an extended dataset, outliers and extreme values can be more effectively identified and addressed, contributing to a more accurate representation of the user's HRV baseline. The statistical approach of extracting the 95% range ensures a robust and personalized understanding of normal HRV variability for each user.

Furthermore, the exploration of linear relationships between HRV data and emotional records seeks to uncover potential correlations. The implementation strategy includes utilizing CoreML to explore and establish the linear relationship

between a user's HRV data and their recorded emotional states. CoreML, a machine learning framework for iOS, can be leveraged to develop a model that analyzes the collected data and identifies potential linear correlations.

In summary, this approach combines statistical rigor with a personalized understanding of user data, aiming to refine HRV assessments and uncover potential associations with emotional states.

Ch.6 Future Plan

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)

This phase will focus on developing learning and support blogging function (Function 3) and implementing an anonymous sharing community (Function 4). Meanwhile, HRV and health-related research will continue to ensure the project's adaptability and responsiveness. Finally, the integration testing of Functions 1 to 4 will be completed in this phase.

Ch.7 Conclusion

The primary objective of the application is to provide users with a comprehensive solution for tracking and managing anxiety, leveraging cutting-edge health technology such as heart rate variability (HRV) monitoring.

Outlined through four key functions—Anxiety Recording and Prediction, Data Analysis and Visualization, Learning and Support, and the establishment of an Anonymous Sharing Community—the application aims to assist users in identifying stress sources, tracking anxiety triggers, gaining insights into their emotional states, and accessing valuable resources for anxiety management.

Regarding the current status, successful access to HRV and Resting Heart Rate (RHR) data has enabled users to monitor their basic health data within the application, serving as an initial step in the anxiety tracking process. The completion of the User Interface (UI) design is complemented by ongoing coding efforts aimed at bringing the design to fruition.

However, encountered challenges along the journey include limitations imposed by the Apple Watch, leading to adjustments in our approach to HRV data analysis and a shift towards understanding the correlation between HRV and emotional states. Despite considering the exploration of accessing raw voltage data from ECG, it proved unfeasible due to a lack of suitable analysis APIs.

Regarding the future planning of the project, challenges in HRV research have resulted in the postponement of the HRV Data Collection and Automatic Recording phase to Phase 2.

In conclusion, this project is poised to have a meaningful impact on anxiety management in the digital age. Despite facing challenges, the project persists in its mission to provide users with invaluable insights and support.

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