Interactive Wearable Healthy Habits Monitor

Devansh Patel
Department of Computer Science
University of Illinois at Chicago
Chicago, IL, USA
dpate336@uic.edu

Huihan Hu
Department of Computer Science
University of Illinois at Chicago
Chicago, IL, USA
hhu25@uic.edu

Aditi Wadhwa
Department of Biomedical Engineering
University of Illinois at Chicago
Chicago, IL, USA
awadhw2@uic.edu

Nur Abdelhalim
Department of Computer Science
University of Illinois at Chicago
Chicago, IL, USA
nabde2@uic.edu

***Abstract*— The purpose of this project was to create a fully wearable device that aimed to encourage the development of healthy habits through the use of gamification in an android application and biological signal monitoring. The purpose for the gamification was to implement a reward system by allowing users to "increase" their overall well-being score by engaging in healthy habits such as exercise and self-soothing while receiving encouraging messages in return. The device monitors the user's survey inputs, heart rate, spO2, positional information, and touching of the palm pressure point as part of its calculation of the well-being score. Preliminary results seen from the device is that it accurately decreases the well-being score when the user's biological or inputted signals are deemed to be in the range of an unhealthy practice. Conversely, the application increases score and rewards the user with positive messages for engaging in a healthy habit.**

Keywords—Healthy habits, wearable technology, gamification, android applications

I. Introduction

A. Concept Development/Justification

The concept for this device arose because there is a strong need for individuals to have an easy yet rewarding method to build healthy habits because these habits can play a major role in disease prevention [1]. Additionally, healthy habits have been linked to an improved overall physical and mental wellbeing [1]. Healthy habits are a broad category, but two of the most studied practices that are linked to improve mental health as well as overall well-being include exercise and mindful relaxation [1,2]. Since these two habits were the most studied, the development of the healthy habits monitor was dictated by incorporating the ability to track these habits. At this stage, it was also determined that it would be the most user-friendly and easiest integration with daily life if the device was compatible with a smartphone application. This allows users to track their habits easily from their phone and does not require the device to remain connected to a computer.

For developing the habit of exercising, the goal was to monitor relevant biological signals such as heart rate and blood oxygen levels. These signals would help detect intensity of any exercise performed as well as the duration that this level of activity was done. Thus, the goal was to develop a range of healthy intervals for both heart rate and exercise intervals to increase the well-being score accordingly. Subsequently, using position data from sensors would also allow the application to be more robust by detecting the type of exercise being performed and increment the wellbeing score based on the activity it detects.

The incorporation of a touch capacitive sensor at a pressure point was also part of the concept development process for the device because a major self-soothing strategy is applying pressure at the Hegu acupoint [3]. The Hegu acupoint can be found at the base of the thumb on the palm for any individual [3]. This practice has been proven to lower one's anxiety levels, and for the purposes of the constructed device, it will be considered a healthy habit. Thus, mindfully pressing on the Hegu acupoint, which will be detected be a touch capacitive sensor, will produce the more the wellbeing score is aimed to increase.

Additionally, the data from the sensors can be displayed for the user in the fitness dashboard so they have additional visuals of the data similar to devices such as smartwatches and fitness trackers.

As a whole, the concept of this device was centered around a reward-system approach to the development of healthy habits with implementation as an android application.

B. Well-Being Score Gamification

Gamification of the overall experience when the device is being used was important for a reward-based approach to developing healthy habits. One reason that gamification was utilized was so the user knows intuitively that the higher their displayed wellbeing score, the better they are performing in developing healthy habits and progressing towards overall wellbeing. However, the current limitation in this approach is that there is not a set incrementation for the overall wellbeing score because scientific studies have not been conducted to develop a "wellbeing score" or anything similar. This is why a gamification approach is also appropriate because it is not claiming that the device is outputting a score based on a scientific study's wellbeing score establishment. There is still scientific basis to the device however because it tracks habits that are known to improve overall wellbeing, it is only the score that is not directly linked to a study.

C. Background on Sensors Used

The healthy habits monitor incorporates a multitude of sensors that were essential to the device's functionality.

One of the primary sensors was the Sparkfun Pulse Oximeter and Heart Rate sensor. With this sensor, it features a MAX32664 Biometric Sensor Hub and MAX30101 Pulse

Oximetry and Heart Module which allow the sensor to report blood oxygen saturation levels (SpO2) and heart rate [4]. The MAX32664 performs the signal processing while the MAX30101 functions as the sensing component.

The MPU-6050 (GY-521) Accelerometer is also another key sensor featured in this device, and its primary functionality includes providing position data across 3 axes (X,Y,Z). This is used in the device to detect movement in the user for the fitness modes in the application that contribute to the increase in wellbeing score.

The final sensor featured in this design is the capacitive touch sensor made using the MPR 121 Breakout board. With this board, the device can detect touch in the appropriate acupoint location with the implementation of a touchpad.

Using a combination of the data from these three sensors, the device is able to perform its function by monitoring healthy habits and in-turn adjusting the displayed wellbeing score accordingly.

II. Hardware Methods

A. Hardware Development

When developing the hardware of this device, the main design considerations included making it compact and comfortable to wear for the user. A limitation to this was that the device had to be housed near the Hegu pressure point because locations on the body that were far away from this would cause excess wiring and defeat the desired wearable design. With this in mind, the following hardware components were chosen for use in the final iteration of the device: Sparkfun Pulse Oximeter and Heart Rate sensor, MPR 121 Breakout board, MPU-6050 (GY-521) Accelerometer, Copper tape, Vinyl, Rechargeable Lithium Battery, FireBeetle Board-328P with BLE4.1x2, Velcro strap, 3D Printed casing, and a Google Pixel 4a.

The FireBeetle Board-328P with BLE4.1x2 is included in our hardware because it was utilized as a controller for Bluetooth communication to the Google Pixel 4a device (although any updated android device is compatible with the monitor). The sensors as aforementioned were incorporated to obtain biological and positional data from the user.

To address the concern that the touchpad at the Hegu point should be close to the housing of the vital hardware components, it was decided that the location of the FireBeetle Board-328P with BLE4.1x2, Lithium Battery, MPR 121 Breakout board, and MPU-6050 (GY-521) Accelerometer were decided to be housed on the user's wrist. This is because the wrist is close enough to both the Hegu acupoint and the user's fingers where the Sparkfun Pulse Oximeter and Heart Rate sensor must attach. This eliminates any excess wiring in the hardware design while maintaining functionality.

In order to house the designated hardware components, it was decided that a casing will be 3D printed because this method allowed us to customize the design of the case. Additionally, PLA material was used to print the casing because this provides the required protection for the hardware so that the user is less likely to damage the device while performing activities-of-daily-living. The final 3D-printed casing featured 3 compartments for the hardware components, and the reason these separate areas were constructed within the casing is to prevent sensors shorting one another since all pin connections were made using a wire-wrapping technique. The case also features a key-slot hole that allows the insulated wiring to pass from the case to the desired Hegu point and the Sparkfun Pulse Oximeter and Heart Rate sensor on the individual's finger. Additionally, to protect the user, there is a lid that attaches to the top of the casing to cover all hardware components from touching the skin. Finally, the last main feature of the 3D-printed casing includes slits on either side of the walls that allow a Velcro strap to pass through so that the case can remain fixed to the user's wrist. Figure 1 displays the 3D-printed casing (without the lid).

Fig. 1: (Left) 3D-printed casing for heart rate and pulse oximeter sensor (Right) 3D-printed casing showing 3 compartments for hardware components. One component houses the FireBeetle board and Lithium battery, the second houses the accelerometer, and the final compartment contains the MPR 121 Breakout board.

There was also casing that was 3D printed for the user's finger to protect the pulse oximeter and heart rate sensor which is pictured in Figure 1 on the left. The design for this includes a flat surface to provide reinforcement for the sensor as well as a slot hole for the user's finger to be inserted for reading. This design was partially inspired by Janais Peace, Francisco Ocegueda, Alberto Carboneri, Robert Finedore.

B. Pin Connections & Hardware Assembly

Assembling the touchpad sensor on the Hegu point was also a crucial part of the device's hardware. To construct the touchpad, the first step was to cut two layers of vinyl and stick them to one another, so they act as insulation for the touchpad sensor itself. A length of wire was then exposed and placed atop the vinyl pieces. Then, a piece of copper tape was cut to fit the size of the Hegu acupoint and placed on top of the exposed wire and vinyl. The remaining length of exposed wire was folded back on top of the copper component, and an identically sized copper piece was placed on top of this layer. Finally, this touchpad was connected to the MPR 121 Breakout board.

In terms of the wiring of the device, all connections were wired using a wire-wrapping method. The device was powered entirely by the Lithium Battery which is connected to the FireBeetle board.

For the accelerometer, its the accelerometer's VCC pin, GND pin, SDA pin, and SCL pin to the 3.3V pin, ground pin, SDA pin, and SCL pin respectively on the FireBeetle board.

The Sparkfun Pulse Oximeter and Heart Rate sensor was wired by connecting the 3.3V, GND, SCL, SDA, RESET, and MFIO pins on the sensor to the 3.3V pin, GND pin, SCL pin, SDA pin, Digital Pin 4, and Digital Pin 5 on the FireBeetle board.

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For the wiring of the MPR 121 Breakout board, the VIN pin, GND pin, SDA pin, and SCL pin on this board were connected to the 3.3V pin, ground pin, SDA pin, and SCL pin respectively on the FireBeetle board. With this, the wiring of the device was completed, and the final device is seen in the images below.

Fig. 2: Final hardware of device featuring 3D-printed casing.

III. Software Methods

For the software, there were two main aspects to design and deliver. The UI and the communication between the Android device and the board.

For establishing communication, we had a baseline to go off of; from the documentation of the FireBeetle board. There were three modules for communication. The base Bluetooth service, the abstract class and the main class to implement the methods from the abstract class which leveraged the underlying Bluetooth service. The main Libraries used for the basic Bluetooth Service were, Bluetooth Manager to maintain the state of the Adapter and the device. The BluetoothGattCharacteristic library to access the Serial channel, for receiving the data. There were several other supporting libraries used. The abstract class on top of this Service was not a pure abstract class, it implements certain methods to leverage the service. Other abstract methods part this class were implemented where in a main class. We also quickly realized, for reliable data transfer and assurance, we had to create a separate thread for the communication and Bluetooth Service running in the background. Once we had gone through this module, the next agenda was to parse the data. This was done in a Utility class written separately with a public access modifier for all its data members and methods. The methods were mainly to parse the input data from the board. This class was instantiated, and methods were used whenever parsing of data was necessary. Its class members were representative of global data points captured from the sensors.

Moving on to the UI, first we had to upgrade the base code we found in the documentation for the board. This code was almost ten years old, outdated and unable to run on the current generation of smartphones. We had to update the SDK, Gradle build, the Java compiler, encoded strings, the Bluetooth protocol and minor grammar changes as the versions went on. Once we overhauled everything, we built a decentralized structure with Activities supported by Fragments. Three main pages were designed. First off, the dashboard, which showed quick information about the user and then some helpful links for articles pertaining to exercise and mental health. Then, the exercise page, the user can select which exercise they are performing, and the Application will track the activity. E.g., It would track duration for runs and reps for squats. The user can also put in a custom workout. For the final page, we built a UI around our pressure point system. It would track the amount of time the user presses the pressure point day by day.

The main pillars for the UI were learnability, efficiency, and safety. To keep in mind learnability, we kept the UI consistent i.e., consistent font, industrial design and coherent theme. For efficiency we followed the fits law wherein the shorter the distance you travel, the fewer mistakes made. The UI elements were sized properly and were tight together to reduce pointing distance. For safety we made sure the user can always undo unintended actions and the main program does not load before the device is paired and calibrated. Figure 3 shows a visualization of the final UI of the device.

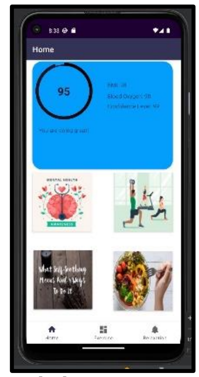

Fig. 3: Final UI design showcasing the home page, exercise mode, and relaxation mode.

IV. Results

After completion of the device, it was tested to determine whether the functionality was implemented as desired. First, the fitness mode was tested to see whether fitness activity positively impacted the overall wellbeing score displayed to the user. This was done for all of the exercise modes in the UI and using the data from the accelerometer and heart rate and pulse oximeter sensor, it was observed that the score incremented positively and successfully displayed a positive message. The same result was seen for the relaxation mode which took in data from the capacitive sensor and the more the sensor was engaged, the higher the score displayed was. Thus, the gamification method was successful for both of the major parts of the device which means that the device is helping to reinforce healthy habits.

V. Conclusions

The development of this healthy habits monitor was meant to address issues some individuals have with developing and maintaining healthy habits because these habits have proven scientific benefits to one's overall wellbeing. Another major goal of the device was to have implementation in an android application. In the application, the data from the sensors was utilized to create a wellbeing score that was displayed to users and the entire application was meant to feel game-like because this provides intuitive visuals to the user on their progress in developing healthy habits while utilizing a reward system through displaying of encouraging messages for good habits.

In terms of future directions for this device, the implementation of a calendar-style system is desirable so that the user can see their wellbeing score over a period of time as opposed to only when they are using the application. Additionally, the hardware of the device could be refined by utilizing more compact sensors in the future so that the device overall is not as bulky as present.

REFERENCES

[1] E. Chacko, “Healthy Habits to reverse cardiovascular risk,” *The American Journal of Medicine*, 16-Dec-2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0002934321002874?via%3Dihub. [Accessed: 02-Dec-2022].

[2] Y. Y. Tang, B. Holzel, and M. Posner, “The Neuroscience of Mindfulness Meditation,” *Nature reviews. Neuroscience*. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/25783612/. [Accessed: 02-Dec-2022].

[3] E. Ister and Y. Altinbas, “The effect of acupressure on anxiety and pain among patients undergoing coronary angiography: A randomized controlled trial,” *Holistic nursing practice*, Nov-2022. [Online]. Available:https://pubmed.ncbi.nlm.nih.gov/36255344/#:~:text=Acupressure%20is%20an%20effective%20technique,among%20patients%20undergoing%20coronary%20angiography. [Accessed: 02-Dec-2022].

[4] “Sparkfun Pulse Oximeter and heart rate sensor - max30101 & max32664 (,” *SEN-15219 - SparkFun Electronics*. [Online]. Available: https://www.sparkfun.com/products/15219. [Accessed: 02-Dec-2022].