# Hotei: Wellness Activity Recommendation

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*Abstract*— **The issues of stress and general emotional well being are important in the context of student life where almost 63% suffer from stress, and 27% of all students suffer from a mental problem of some sort. This project aims to help manage a student's stress levels whilst helping them become more aware of their emotional well being. This will be done through the development of a smartphone app, making use of heart rate data from a wearable device to automatically detect moments of stress, a recommendation system to provide tailored activity suggestions to help them relieve such stress, and ultimately improve their over all emotional well being.**

## I. INTRODUCTION

In a market becoming increasingly populated by wearables [2] and apps targeted at improving aspects of physical well being - namely fitness, sleep quality and nutrition, there are in contrast very few solutions targeted at improving consumers' emotional well being. In relation, an increasing concern which can have a strong negative effect on emotional well being is stress. These are important issues for students, where 27% of all students suffer from a mental health problem, and 63% of students report suffering from stress levels that interfere with their day to day lives [1].

Stress is a term used to generalise the human body response to a demand or threat. Such demands can include the pressures of work, a sudden negative change in a persons life, or trauma from a major incident.In the short term, stress can be a motivator however, the survival response activated by stress can cause health problems if prolonged. Continued strain on the body can cause problems such as heart disease, high blood pressure, diabetes and mental health conditions such as anxiety and depression. The later two conditions are, in fact, the most common conditions for students with mental health problems [1].

There are steps one can take to reduce or manage their stress levels so that they can avoid the long term harms of it. As stated by the National Institute of Mental Health [15], such steps can include: recognising the signs of stress, exercising, trying a relaxing activity or staying connected with people who can provide emotional support. However, since each individual deals with stress differently there is currently no definitive activity that can be recommended to them at an instant.

Just as awareness has increased of the importance of fitness, sleep and nutrition with regards to overall physical well being, it is important to address the issues of stress management and provide greater awareness of an individuals emotional well being. This project involves the development of a smartphone app which works in conjunction with a wearable device to detect when a user is stressed based on their heart rate. It will then offer tailored recommendations of activities they can do to help manage such stress. Tailored recommendations are provided to better suit to how a particular individual prefers to deal with stress. It is through such methods to help manage stress and by correlating a users emotions with activities they perform throughout the day, that the project will improve an individuals overall emotional well being.

## II. HYPOTHESIS

The following hypotheses are proposed to test the benefit of the devised solution:

- The use of personalised activity recommendations can help reduce a user's stress levels.
- Reduction in stress can cause an improvement in emotional well being.

## III. BACKGROUND

### A. Stress Detection

Stress can be detected through various physiological indicators. Prior studies in this field target the measurement of such signals related to changes in body functions as a result of stress. This includes the use of heart rate, heart rate variability, electrodermal activity (EDA), muscular tension and blood pressure [4]. Although it has been concluded that EDA is one of the most robust means to detect stress, its use in a wearable device is not practical since it requires electrode placement in both palms of hands [16]. Blood pressure is also impractical considering that the non-invasive methods are cumbersome. Alternatively, the wide usage of heart rate monitors in fitness trackers and smart watches has proven that its detection is suitable in a wearable device.

For this mobile application one of core measurements taken is the users heart rate variation (HRV). Stress detection in this mobile application will rely on the user's heart rate variation (HRV). HRV measures the time gap between each heart beat, recording the variation in the beat-to-beat interval. Methods that can be use to detect heart beats include: electrocardiography (ECG), blood pressure and the signal derived from a photoplethysmograph (PPG).

Research has linked high HRV to overall good health and fitness, while low HRV are associated with fatigue [14], stress [3] [12] and poor health. HRV has been shown to have positive correlations with a persons subjective well-being [9], which was indicated by positive habitual mood and satisfaction with life. All of these factors are applicable to a students well-being.

### B. Quantifying Emotional Well-being

Unlike physical well-being, emotional well-being is hard to quantify using physiological data given that it is largely subjective. Several studies have established emotional well-being as being made up of three components [11]: 1) Life evaluations, 2) Positive affects, and 3) Negative affects.

In a proposed framework to measure happiness [5], data is fused from three sources: social networks, wearables and web sources. It is suggested that social network data can be used to extract positive and negative experiences, wearable data can be used to estimate a user's general health, and web source data can detect the levels of corruption and change in quality of governance - two factors determined to affect national happiness significantly [11]. It has been found that, within a given time period, calculating the ratio of positive affects to negative affects correlates highly to a wide variety of questionnaire measures of emotional well being [7], [6].

Given the conclusive agreement that emotional well being can be quantified using positive and negative affects, this project will make use of the same measures. Through further research, it will be determined how the number of positive and negative affects will be combined into a single well being score.

## IV. Related Work

This section provides a summary of similar attempts to solve the issue of stress management and the use of technology to improve emotional well being.

A study done by Japanese firm, Hitachi, aimed to use wearables to measure happiness. A fundamental rule of $1/T$ is formulated that strongly correlates physical activity to happiness, where $T$ represents the duration of sustained activity. It is concluded that users who's activity habits followed the rule closely, tended to have greater happiness levels determined from separate surveys.[20]

Yano et al. concludes that happiness is determined by a users' habits and activities. As a result it records body movement, speech tone and the number of social interactions to gauge the level of happiness within the work environment.[21]

Ströhle concludes that whilst there is growing evidence for the positive effect that exercise has on managing depression and other mental disorders, there is still very little knowledge regarding alternative activities that can be done when the disorder hinders such activity.[19]

## V. Hardware Platform

The hardware for this system will consist of a wearable heart rate monitor used in conjunction with a Apple iPhone. The heart rate monitor is used to measure the HRV of the user, providing a constant reading for the Hotei application. The heart rate monitors under consideration are as follows:

### A. Apple watch

The Apple watch is a wearable smart watch that can measure the users heart rate, by using photoplethysmography. An advantage of this hardware is its graphical interface which can be used to provide additional information and feedback to the user alongside the main mobile application. An issue with this device is that the accuracy of heart readings is greatly effected by movement.

### B. FitBit

Fitbit is a wrist worn device that can be used to measure the users heart rate and daily steps taken. The heart rate is recorded with a optical heart rate sensor and with more recent models can measure HRV. The data gathered by the device can be synced via Bluetooth to a iOS device in intervals throughout the day, for example every 15 minutes.

### C. ECG

Electrocardiography (ECG) monitors the rate and rhythm of the heart using electrodes placed on the skin, usually in the chest area, to record the electrical activity generated by the hearts muscle depolarization. This is by far the most accurate method for measuring HRV but is very intrusive and cumbersome to the user. Due to the specification of this project, aiming to be used daily to monitor the user, this approach may not be suitable.

## VI. System Design

### A. Overview

Hotei is an application that enables users to record their happiness level at any time and allow them to understand how their emotion fluctuate throughout the day. Then, based on the users data, Hotei would make suggestions to help them maintain a happier life style.

We decided to use iPhone and iOS to implement our application out of several reasons:

1) Single app works on every device: Unlike Android and other platforms, which have the same OS but different hardware, meaning different specification for the app, like DPI, Aspect ration, performance, etc. Whilst on iOS, the app virtually works on every iPhone (assuming updated iOS firmware).
2) Team members' previous experience and future trend. Each one of us owns at least one Apple device and some of us has already had iOS dev experience. Furthermore, Apple's phone and app market is growing constantly and shows a promising user base.
3) Apple's effort on security and Health kit: This allows us, developers, worry less about legality and low-level programming but focusing on the high-level functionality of the application.

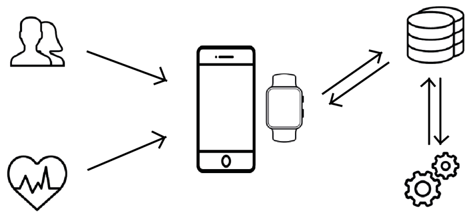

Fig. 1. Architecture of Hotei

As shown in Fig. 1 Users actively input their happiness level in Hotei app on either iPhone or Apple Watch. Heart rate is also collected passively at a certain time interval. These data are then sent to our server for data processing. Detail on the use of these data is discussed in **Back-end**.

### B. Initialisation

Upon the first start-up of Hotei, users would create their own profile. Then, it asks the user to rate a subset of activities that they like from the database. This set of rating will help Hotel to make suggestion by comparing the user with other users.

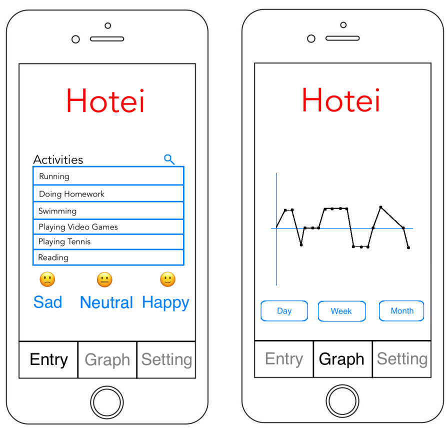


Fig. 2. Mock-up of Entry tab and Graph tab

### C. Features

- Happiness Level Recording: Hotei will ask the user to input their happiness level every few hours. Happiness level is scales as -1, 0, -1; which correspond to positive, neutral and negative feelings as shown in Fig: 2. This rating can be associated with an activity or not, so that we can better learn what the user likes to do. Besides the intervallic prompt, the user can actively input an entry when he feels happy or sad. This helps us to learn more about the user and also, the user can later see his happiness level throughout a time period.
- Activity Recommendation: We monitor user's heart rate and the user's history constantly. If we see an heart rate pattern that indicates that user is in distress, we suggest activities or display encouraging message to cheer up the user. Refer to **Heart Rate Analysis** section.
- Viewing Historical Data: This allows users to better learn about themselves and take control of their emotion. As shown in Fig. 2, user can see their emotion fluctuation in day/week/month view. Furthermore, this data might be able to assist a CESD test and aid doctors to help a (potential or not) depression patient better.

### D. Back-End

*1) Recommendation System:* The recommendation system will be used to generate bespoke activities for each individual user. The user will record the preference for an activity they have recently done through the happiness level as described earlier. Through collaborative filtering[8] we will use the preference of other similar users of an activity to predict the preference of the target user for this activity. Using the k-NN algorithm, a neighbourhood of users will be found that are most similar to the target user.

The similarity between a pair of users $s(u, v)$ will be determined using a similarity metric such as pearsons correlation (1). We can determine a target users preference $p(u, i)$ for an activity $i$ by taking a weighted average of the ratings of $i$ by users in the target user neighbourhood (2). The activity with the highest preference will be recommended, an extension to this could be to assign weights to activities depending on the time of day and the estimated length of the activity.

$$s(u,v) = \frac{\sum_{i \epsilon I_u \cap I_v} (r_{u,i} - \overline{r_u})(r_{v,i} - \overline{v_v})}{\sqrt{\sum_{i \epsilon I_u \cap I_v} (r_{u,i} - \overline{r_u})^2} \sqrt{\sum_{i \epsilon I_u \cap I_v} (r_{v,i} - \overline{r_v})^2}} \tag{1}$$

$$p_{u,i} = \overline{r_u} + \frac{\sum_{v \epsilon N} s(u,v)(r_{v,i} - \overline{r_v})}{\sum_{v \epsilon N} |s(u,v)|} \tag{2}$$

Where $r_{x,i}$ represents a user $x$ rating for item $i$ and $\overline{r_x}$ is the average rating for all items by $x$

Historically collaborative filtering has suffered from two problems; **User Cold Start** [18], a new user will have no recorded activity so finding similar users is impossible. We aim to solve the user cold start problem by asking a user their preference for some activities on sign up. **Sparsity** [10], this occurs when the rating profile for a user is predominantly empty, making it harder to find definite similar users. We aim to solve this problem using dimensionality reduction techniques [17].

*2) Heart Rate Analysis:* The heart rate variability of the user will be monitored using the chosen wearable device, see section V for details. Features will be extracted from the HRV signal and classified. The features can be analysed in either the time domain, calculating the average R-R intervals, or the frequency domain, calculating the power of the normal sinus to normal sinus (NN) interval of the HRV signal.

The classification will be initially done using a support vector machine (SVM) which identifies the input as one of two classes, stressed and not stressed. In the future, this can be extended to multiclass classification, identifying different types of stress or different side-effects of a low HRV, like fatigue. As the project matures and the classifier model becomes more complex the SVM can be replaced by a more flexible machine learning technique, such as artificial neural networks.

*3) GPS:* When each entry is created by the user, GPS data is embedded into the entry for two purposes that might be implement in the future:

- Area-based happiness level analysis for research purposes.
- See if there are correlation between location and happiness level.

*4) Database and Encryption:* The database that will persist the data produced by Hotei will be server based, this choice stems from many design decisions;

- The activity recommendation system is dependent on the information of other users to provide tailored recommendations, having a centralised location for the data makes this analysis more convenient.
- The machine learning that will be performed on heart rate & GPS data will be much more efficient on a server compared to a mobile device.
- Allows a user to access Hotei from any mobile device.

We will aim to build a RESTful API for a database backend. The server will be hosted using either Microsoft Azure or Amazon Web Services, this is because these companies strive for excellence in data protection and privacy, which is a necessity in health applications. To protect out RESTful API from external attacks, no API calls can be made without authentication, this can be achieved using OAuth2 to authenticate each call, every user will have an access token before being able to read or write data. Figure 3 represents the flow of a user entering the system and receiving data from the API.

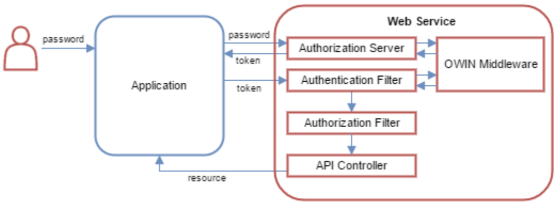


Fig. 3. User API encryption mechanism

## VII. EVALUATION

Generating a method for evaluating the performance of the application is difficult due to the intended long term use case. The testing has been broken down into two sections: assessment of the stress detection and assessment of the application for stress reduction.

### A. Stress Detection

A critical component of the application is the ability to detect when the user is stressed. This feature is important in being able to test the hypotheses fully. In order to test the ability of the application to detect stress a repeatable and controlled experiment needs to be devised.

The basis of this test is using a reliable method to generate stress. In the past options such as a cold pressor test of the Stroop test were popular options for inducing stress in laboratory conditions. The decision of the group was instead to use the *Trier Social Stress Test* [13]. The *Trier Social Stress Test* is broken down into two sections: a 10 minute anticipation stage and a 10 minute test period. In the 10 minute anticipation stage the test subject will be given a pen and paper and told to prepare a 5 minute speech aimed at convincing a mock interview panel why they are the optimal candidate for a job. When the test period begins the test subject will be placed in a room in front of a panel of three people, a video-camera, and a visible microphone. Their notes will be taken away from them and they will be asked to present. The panel will not react to the participants speech, and if the participant finishes before the 5 minutes is over they will be asked to continue speaking til the end of the 5 minutes. Once their presentation is complete the test subject will be asked to serially subtract 13 from 1022 as fast and as accurately as possible, and told that if they make a mistake they will have to start again. Every time the subject makes a mistake an interviewer will say "Stop, 1022". This has been shown in numerous independent studies to induce stress in participants.

The test will be conducted at Imperial College, South Kensington Campus, and will be carried out on volunteers from the student population. At the beginning of the experiment subjects will be asked to wear the smart heart rate monitoring device that is connected to the application. These assumptions are made: the test subjects are not in a stressed state at the beginning of the test, the test subject find the interview and arithmetic components of the test stressful. If the application reports that the user is stressed, the detection engine will be deemed a success.

### B. User Trial

A group of volunteers from Imperial College London will be asked to use the application for a week. They will be given a survey asking them about their experience of using the application as a whole. The survey will cover areas including but not limited to: ease of use, helpfulness of the recommendations, accuracy of the stress detection, and overall utility of the application. The data taken from the survey and the anonymised data from the application will provide enough information to infer whether the use of personalised activity recommendations have helped to reduce user's stress levels, and an improvement in overall well being.

## VIII. CONCLUSION

To conclude, this design report highlights our aim to develop a stress detection platform that offers activity suggestions to ease the user's tension. The aim of the system is to take heart rate, accelerometer readings, and user input to gauge the current stress levels of the user. The system then responds when it believes the user is stressed by recommending activities that it believes will reduce the user's stress. These activities will be recommended based on past preferences as well as a recommendation engine using the preferences of other users. The background reading has found similar applications exist however there is an absence of those that link detection with a personalised resolution. The report includes the current direction of the project as well as considering a clear evaluation plan to test the hypotheses.

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