Smart Patch For Stress Relief For Hypertension Patients

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Abstract: Stress is one of the important factors for various health ailments in our body. Chronic stress can increase the risk for heart attack and stroke by up to 50%. This smart patch tracks and optimizes the resilience to stress by increasing natural heart rate variability (HRV), a biomarker of physical and psychological health. A low HRV score is linked with anxiety, distraction and poor performance. This project aims at improving the HRV and allows to train themselves to stay focused and in control throughout the day. The device uses scientifically-validated HRV biofeedback exercises that have been used by doctors, psychologists and coaches. It’s safe, drug-free and has improved stress, mood and focus for thousands of people. The patch measures heart rate variability (HRV) to recognize the stress patterns with clinical-grade accuracy. HRV is the healthy variation in heart rate and it can act as a robust biomarker of stress and psychological health. When the mind and body are relaxed, the heart naturally speeds up on each inhale, and slows down on each exhale. This creates high HRV, and a gentle wave pattern in heart rate known as respiratory sinus arrhythmia. The patch is always attached to the body.

1. INTRODUCTION

Clinical studies have shown time and again that stress is a major cause of a range of diseases from cardiovascular disease to depression to substance abuse. Stress causes 54% of individuals to fight with people close to them. Workplace stress in the each country costs more than $300 billion each year in health care, missed work, employee turnover, legal costs, workers’ compensation, and insurance. Workers who report they are stressed incur health care costs 46% higher than other employees. In the pre-developed model, the human’s stress level is sensed by the HRV of the heart which is measured with the help of ECG and in the existing model the stress level is measured and monitored throughout the day by attaching a patch like structure on the patient or the person who is needed to be monitored.[2]

So it was considered that the best way to tackle the stress by calming down oneself, for which the Haptic vibration is used as a nudge in the process, it gives an indication for the person so that he/she can calm themselves by inducing breathing and meditation. Whenever there is a decrease in the HRV the device generates vibration by the use of Haptic engine present, and this vibration is thus considered as the alarm for the person who is under observation, during the vibration period he/she has to breathe in and breathe out for about 3 long minutes. All the existing features of the model would be used as such in addition to which the innovation made are added to enhance the feasibility and performance of the existing system.

The proposed model measures the position of the patient using desired sensors which gives us the timeframe to measure the HRV of the patient instead of measuring it throughout the day, so that the ECG is measured only during the necessary period, by this method false alarm can be neglected as the HRV decreases during much of the activities such as running, swimming, etc. So in order to avoid such errors the position and movement of the patient is also measured. The database of the complete week would be stored for the future reference and noting the period under which the patients suffers the stress at the most, so as to tackle the stress in the future and by avoiding such situations.

All sorts of things can cause stress, from physical exertion to a bad day at work. There’s “good” stress (like receiving a big promotion), and there’s “bad” stress (like having a traffic accident). For the purposes of this discussion, “stress” means bad stress. Stress is not caused exclusively by what happens to us; sometimes our thoughts and emotions are more culpable in producing stress than anything external. Stress—however it is produced—can cause massive physical changes in the body. Human beings evolved in an environment where failure to respond instantly...
to a threat often resulted in death. When we perceive a threat, the body floods with stress hormones like adrenalin that accelerate the body’s ability to respond rapidly. In the developed world, we are less likely to encounter threats that merit this sort of response—but our bodies don’t know this. When experience a fender-bender or supervisor says something perceive as negative, body tends to flip into Fight or flight mode with all its attendant bodily changes, 5 reacting as though just encountered a hungry cave bear. The problem is that prolonged high rates of stress are hard on the body.

About 25 years of clinical research have shown that one of the most reliable indicators of stress is heart rate variability (HRV). HRV is the variation in the time interval between one heartbeat and the next. When we think of our heart rate, we generally think of a number between 60 and 90 beats per minute. This number represents the range for the average heart rate. In fact, heart rate changes from beat to beat.

2. LITERATURE SURVEY

Wheat, A. L., & Larkin, K. T [5] emphasized that Low heart rate variability (HRV) characterizes several medical and psychological diseases. HRV biofeedback is a newly developed approach that may have some use for treating the array of disorders in which HRV is relatively low. This review critically appraises evidence for the effectiveness of HRV and related biofeedback across 14 studies in improving HRV and baroreflex outcomes and clinical outcomes. Results revealed that HRV biofeedback consistently effectuates acute improvements during biofeedback practice, whereas the presence of short-term and long-term carry-over effects is less clear. Some evidence suggests HRV biofeedback may result in long-term carry-over effects on baroreflex gain, which is an area most promising for future investigations. On the other hand, concerning clinical outcomes, there is ample evidence attesting to efficacy of HRV biofeedback. However, because clinical and psychological outcomes do not improve concurrently in all cases, the mechanism by which HRV biofeedback results in salutary effects in unclear. Considerations for the field in addressing shortcomings of the reviewed studies and advancing understanding of the way in which HRV biofeedback may improve physiological and clinical outcomes are offered in light of the reviewed evidence. Henriques, G., Keffer, S., Abrahamson, C., & Horst, S. J. [1] proposed about the two studies that explored the effectiveness of a computer-based heart rate variability biofeedback program on reducing anxiety and negative mood in college students. A pilot project (n = 9) of highly anxious students revealed sizable decreases in anxiety and negative mood following utilizing the program for 4 weeks. A second study (n = 35) employing an immediate versus delayed treatment design replicated the results, although the magnitude of the impact was not quite as strong. Despite observing decreases in anxiety, the expected changes in psycho physiological coherence were not observed.

3. METHODOLOGY

The main work of the device is done by the software which is programmed inside the microcontroller. Data from both the accelerometer and the Heart Rate monitor is constantly monitored by the microcontroller and HRV of the person is measured instantaneously and continuously. In order to measure HRV, there are multiple methods which can be used. The following methods are the possible methods which can be used. They are Time domain methods, Frequency domain methods and Geometric domain methods.

In the above mentioned methods, since the necessity for accuracy is less in this product, time domain methods are used due to its computational simplicity as it requires only taking the average of the time intervals between the heart beats. There are various measures that are used in time domain measurement and each given information about certain part of the variation between two NN intervals. Here NN intervals refer to the interval between the peaks of the QRS complex.

HRV is a measure of stress which is roughly equal to the variation in the NN intervals of the heart beat. So the time stamps of all the peaks are separately identified and the values are stored in the buffer of the microcontroller. This enables us to continuously keep track of the patient's HRV and when the HRV reaches stressed levels, the output, the Haptic vibration motor is enabled. The motor is made to vibrate at an ambient frequency in order to make the comfortable. [4]

The Cloud part of the project is also a secondary purpose. Although continuous monitoring is done on the user and the data is saved locally in the memory, due to continuous storage of data, it becomes impossible on the long run to make the device to store all the useful data. So data is sent to the cloud via Wifi which is made possible by Intel Edison in a periodic fashion thereby ensuring safe storage of values. These values can also be used for manipulations and can also be used to determine the stress cycle of a patient. Android applications can be used to provide feedback on the stress levels of the patient and can also be used as parameter for doctors to suggest remedies to control the stress levels. The Android application provides a day wise / week wise feedback on the previous cycle's data.
The interfacing of ECG sensor with AD8232 as shown in Fig 3.1 involves five pins namely- Gnd, supply (3.3V), L0-, L0 and analog output pin.

3.1 Interfacing the accelerometer with Intel Edison board:

As the datasheet says, ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

ADXL335 is 3v3 compatible device; it's powered by a 3.3v source and also generates 3.3v peak outputs. It has three outputs for each axis i.e. X, Y & Z.

The accelerometer module has 5 pins, namely

- GND-To be connected to Intel Edison’s GND
- VCC-To be connected to Intel Edison’s 3.3V
- X-To be connected to Analog Pin A5
- Y-To be connected to Analog Pin A4
- Z-To be connected to Analog Pin A3

The interfacing is done as per the pin out provided as shown in Fig 3.2

3.2 Monitoring activity using accelerometer

An accelerometer measures proper acceleration, which is the acceleration it experiences relative to freefall and is the acceleration felt by people and objects. Put another way, at any point in space-time the equivalence principle guarantees the existence of a local inertial frame, and an accelerometer measures the acceleration relative to that frame. Such accelerations are popularly denoted g-force; i.e., in comparison to standard gravity.

An accelerometer at rest relative to the Earth's surface will indicate approximately 1 g upwards, because any point on the Earth's surface is accelerating upwards relative to the local inertial frame (the frame of a freely falling object near the surface). To obtain the acceleration due to motion with respect to the Earth, this "gravity offset" must be subtracted and corrections made for effects caused by the Earth's rotation relative to the inertial frame.

As it is used to measure the acceleration of the person relative to the gravity, the activity performed by the person can be judged. It is necessary so that the ECG and HRV are measured only during stable state of the person when there is least possible movement, as we know that even heavy exercise or momentary activities increases the stress by pumping up the heart beat.

In order to avoid the false detection of the stress during such condition an accelerometer is used.

At static condition : During static condition there is minimal relative acceleration between the person and the gravity as there is not much action.

This state is considered the best to measure the stress in the person, as there is no activity any discomfort caused in the heart rate can be easily detected and monitored.
Reading obtained during static condition is shown above in Fig 3.3

At walking condition: During walking condition there is slight deviation in the relative acceleration between the person and the gravity.

Walking outdoors has also been shown to improve energy levels. Try walking outside for 20-30 minutes several times per week to alleviate stress and give your mind a boost. Like any other cardiovascular exercise, brisk walking boosts endorphins, which can reduce stress hormones and alleviate mild depression. Reading obtained during walking condition is shown below in Fig 3.4

At running condition: Running requires the coordination of all the muscles in your body. Conditioning exercises improve the ability of your leg muscles to push against the ground, increase the frequency of your strides and enhance the endurance of your core and upper body muscles. Such exercises also augment the capacity of your cardiovascular, respiratory and muscular system to transport and utilize energy and oxygen. Include running-specific conditioning exercises to improve your running economy. During such condition the heart beat rate is higher, which can give a false indication of stress in the person even though the person is not in the stress. Reading obtained during running condition is shown below in Fig 3.5

The Haptic vibration motor is interfaced with a help of transistor in order to have the stable 3.3V supply. As shown in the above circuit diagram in Fig 4.9, the positive of the motor is connected to the power supply and negative terminal of the motor is connected to the emitter of the transistor, so that when the base triggering is high the motor starts to vibrate (Only when the base input is high the motor starts to vibrate or else remain stable).

### 3.3 Sensor Pad Locations to Board Input

Although an ECG trace may be obtained with the electrodes attached in a variety of positions, conventionally they are placed in a standard position each time so that abnormalities are easier to detect. Most monitors have 3 leads and they are connected as follows:

- Red - RA - right arm or second intercostal space on the right of the sternum.
- Yellow - LA - left arm or second intercostal space on the left of the sternum.
- Black - RL - right leg or more often in the region of the apex beat, as shown in Fig 3.7
The cables from the electrodes usually terminate in a single cable, which is plugged into the port on the ECG monitor. A good electrical connection between the patient and the electrodes is required to minimize the resistance of the skin. For this reason gel pads are used to connect the electrodes to the patient’s skin. However when the skin is sweaty the electrodes may not stick well, resulting in an unstable trace. When electrodes are in short supply they may be reused after moistening with saline or gel before being taped to the patient’s chest.

4. WORKING

Approaches carried out to detect the stress:

In order to detect the stress in the patient the following approaches were made:

- Obtaining the ECG waveform of the patient.
- Measuring the HRV from the ECG waveform.
- Monitoring Stress through Heart Rate Variability
- Detection of patient’s activities.

4.1 Obtaining ECG of the patient

An electrocardiogram (ECG or EKG) means recording of electrical activity of the heart. Small electrical impulses are created in the heart by so called pacemaker cells. These impulses spread through the heart muscle and make it contract. ECG records these signals as they travel through the heart. To the trained specialists, ECG provides large amount of information about the structure and the function of the heart. [1]. In most cases ECG is measured from the skin surface with ECG electrodes. These electrodes detect very small electrical changes on the skin that comes from the heart as it contracts. ECG is widely used to detect various abnormalities in heart rhythm, size of the heart chambers or possible damage to the heart muscle or its nervous system. In order to obtain the ECG waveform sensor AD8232 was used.

4.2 Initial test made using Arduino UNO board: In order to obtain the sample outputs, the sensor was interfaced with Arduino UNO microcontroller as the functions were much similar to that of Intel Edison board. After interfacing the sensor with the board sample outputs were obtained for the verification of the output obtained to the desired output as shown below in Fig.4.1

![Fig 4.1 Interfacing of the sensor with the Intel Edison board](image1)

4.3 Calibrations made

From the analysis of the sample outputs obtained in the initial stages it was evident that the system was not able to generate proper ECG waveform under the prescribed conditions due to various external elements such as noise and interference. In order to obtain a proper ECG waveform, some of the modification was made in the design. The 3.5mm jack connector was neglected for the interfacing of the leads to the sensor; instead the leads were directly soldered to the sensor circuit board. By eliminating the jack connector the noise in the waveform was reduced to get a proper ECG waveform. Adjustments were also made in the program to get a ripple free ECG waveform. Once the calibrations were made in the system to get desired waveforms, the outputs from the calibrated system were rechecked by obtaining samples as shown in Fig 4.2

![Fig 4.2 Calibrated ECG waveform](image2)

From the above sample it was evident that the calibration made is fetching desired results.
4.4 Measuring the HRV from the ECG waveform

- After obtaining the ECG waveform successfully it was necessary to measure the HRV (Heart Rate Variability) for the detection of the stress in the patient.

- The body reacts to nearly everything happening around you through your emotions, observations, thoughts and activity. Your brain guides the body by regulating heart and other organs through autonomic nervous system. This physiological variation of heart rate, controlled by autonomic nervous system, is called Heart Rate Variability. Measuring heart rate variation reveals wide range of information about your body and health.

4.5 HRV measuring methods

The most widely used methods can be grouped under time-domain and frequency-domain. Other methods have been proposed, such as non-linear methods.

SDNN, the standard deviation of NN intervals. Often calculated over a 24-hour period. SDANN, the standard deviation of the average NN intervals calculated over short periods, usually 5 minutes. SDANN is therefore a measure of changes in heart rate due to cycles longer than 5 minutes. SDNN reflects all the cyclic components responsible for variability in the period of recording, therefore it represents total variability.

4.6 Samples of HRV measured under different conditions: Based on the algorithm obtained the measurement of the HRV was carried out on a person under two different conditions, normal and stressed condition and the results are recorded as shown below in Fig 4.3 and Fig 4.4

Depressed HRV after MI may reflect a decrease in vagal activity directed to the heart. HRV in patients surviving an acute MI reveal a reduction in total and in the individual power of spectral components[3]. In post-MI patients with a very depressed HRV, most of the residual energy is distributed in the VLF frequency range below 0.03 Hz, with only small respiration-related variations.
5. CONCLUSION

This system predicts the onset of heart problems which deals with the heart rate of the patient and tries to avoid any such problems. When the device is placed near the heart of the hypertension patient, the system continuously monitors the heart rate variability and over time if the values are not in the normal range the vibration motor is gradually enabled to assist the patient to restore their regular beat rhythm.

When the patient restores their regular rhythm, the motor is gradually switched off. The turning off and turning on of the motor is made to be as smooth as possible in order to make the patient feel comfortable and also to avoid discomfort of the patient. During application of this product, the development board can be stripped off of the unused features like Bluetooth, USB, Serial protocols etc. in order to reduce the size of the module and can be made to fit in a smaller module. The methodology used here is a simplistic one, but for some applications some other methods maybe used to suit the requirements in a better way.

6. REFERENCES


