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IoT Powered Wearable to Assist Individuals Facing Depression Symptoms

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Abstract - *In this decade mental ailment like depression, anxiety, and stress has become preeminent and has a pertinent impact on society. Irrespective of the age many individuals have gone through this phase of life due to various factors like societal or peer pressure, chronic illness, workload and other similar reasons. The proposed work is intended to identify the abnormal state or attitude and temperament of the individual facing depressive disorder. The existing systems provide the various diagnostic methods or various means for reviewing the intensity of depression endured while they visit the psychiatrist. But in this work, a wearable is designed such that it captures the biological parameters experienced by the clinically depressed person while they undergo stress. IoT plays a role in sensing, analyzing and processing the data in the cloud. The processed statistics can be accessed by the psychiatrist as well as the caretaker. In the case of predominant variations, an alarm system is triggered and notified to the psychiatrist as well as the caretaker. In this proposed solution a mobile application is developed which is automated to play a song or change the ambiance to calm down the individual to reduce their stress to some extent if detected with medium or severe intensity levels.*

***Keywords*----Internet of Things; sensors; mental health; depression; wearable technology; serotonin; EEG; EMG; GSR; MDD.**

1. INTRODUCTION

World Health Organization (WHO) considers depression as a mental disorder. It is estimated that by the year 2030, depression would be one of the top three pandemic diseases [1]. "Without mental health there can be no true physical health" said the first Director-General of the World Health Organization (WHO) in 1954. Depression is believed to be treatable but unfortunately, many depression and anxiety disorder victims keep suffering as they don't get the care and attention as well as support. Moreover, some individuals are not even aware that they are depressed. It is characterized by perpetual depressed mood and loss of interest in daily activities. If this perpetual feeling characterizes to be always in a low mood then it may lead to a range of physical as well as behavioral symptoms. If not treated or diagnosed on time it could last a lifetime and the disorder becomes more wrecking which on severity causes suicidal thoughts which is a life-threatening spin-off. Societal and the social norms followed by an individual will have an impact to some extent.

They are not intentional but unnoticed acts in a day to day life which contribute to depression at a minimal ratio. Depending on the stage the individual is depressed, some get cured, few suffer and many ends up in committing suicide. This disorder forms a risk factor for cardiovascular disease and stroke but on diagnosing at an early stage the individuals will be responding better to early-stage treatments. Decades ago Internet technology has stepped into healthcare and due to its intervention Internet of Things (IoT) plays a major role in the healthcare sector along with embedded technologies.

Personalized and connected health provides a ray of hope to revolutionize the healthcare sector. Wearable technologies have become part and parcel of everyone's life which helps in tracking and monitoring the vital signs on real-time their fitness and health through smart watches, and mobile apps embedded with sensors. Customized and connected healthcare system by continuous monitoring benefits the patients, doctors, caretaker as well medical staffs by holding a database of the patient in Electronic Health Record (EHR) maintained by each and every hospital. This continuous monitoring system eradicates the need for frequent visits to the hospital. Smartphones which embody many health apps and physical tracking system equipped with various sensors makes life easier and automated. Still there are security concerns, data privacy, cost-effectiveness and wireless communication methods for transmission of biosignals from wearable sensors contrived, so a wearable could be designed to track the vital signs of chronic depressive persons and monitoring them continuously and analyzing the data gathered on daily, weekly, and monthly basis on cloud platform providing a statistical analysis report.

This paper is organized as follows. Section-II describes in detail about depression and its effect on an individual. Section-III provides a report on the market study and available technologies. Section-IV elucidates the various methodologies used in the diagnostic and therapeutic approach for treating depression. Section-V profound the proposed architecture for the assisting system with details of sensors that are to be used and the architectural design of the proposed wearable. Section-VI delineates the conclusion got from the study carried on and the future work that could be done.

2. MAJOR DEPRESSIVE DISORDER

Depression and anxiety are two major depressive disorders which emerge by continuous stress and pressure faced by individuals on daily basis. It is impossible to obviate life's knock-back and its effects. Hence the way people react to them is always different. The possible cause of depression and anxiety could be a single or a combination of psychological, biological and social factors. Research says that prolonged symptoms of depression because of changes in brain function such that reoriented activity of certain neural networks in the brain which results in an imbalance of the hormones which are normally secreted in the brain.
The pertinacious feeling of sadness, loss of interest on something on which previously was interested, low appetite, inability to think, changes in sleep pattern, chronic neck pain and headache, trembling hands, jerk while sleeping, low energy level, Insomnia, restlessness which could be noticeable by others and recurring thoughts of death or suicide, or suicidal attempts.

Depression symptoms can last for weeks, months and several years. If diagnosed and treated in early stages it will avoid major consequences in one's life as well as his/her family. Different life aspects will lead an individual into depression phase and unluckily majority of the individuals are not completely aware of it.

Many therapeutic measures and diagnostic methods are available to treat depression. With respect to the stages of depression some get cured, few commit suicide and many continuously suffer. Major Depressive Disorder (MDD) leads to a risk factor of coronary heart disease, stroke, dementia, schizophrenia, memory loss, Alzheimer disease and many more related to cognitive behavior of an individual.

But on the early stage of diagnosis and therapy has proven that the individuals with depressive symptoms respond better. Sinew of depression therapy at initial stages is usually medication, counseling as well a combination of both. These therapies are witnesses to reconcile brain changes associated with depression and anxiety.

3. MARKET STUDY

The most extensively used diagnostic depressive conditions are found in American Psychiatric Association's revised fourth edition of Mental Disorders (DSM-IV-TR) and the WHO's International Statistical Classification of Diseases and related health problems (ICD-10).

The increasing ubiquity of MDD expands the market 2018 to 2016 as per the National Institute of Mental Health which constitutes that depression is prevailing more among female adults and to the population between the ages of 18 to 25 years. Due to this increase, the global depression drug market has found a profound growth in recent years. The market is classified according to the distribution channel, class of drugs and region wise distribution.

The drugs can be rated into atypical antipsychotics, serotonin-norepinephrine reuptake inhibitor, selective serotonin reuptake inhibitor, central nervous system (CNS) stimulant, and others. MDD have accounted for the highest market share as per the analysis of 2017 owing to the highest rate of work stress and nature of job all over the world.

The depression drugs market can be ramified into online pharmacies, hospital pharmacies and the retail pharmacies where retail pharmacies held maximum share in the market due to the rising preference of patients who buy from retail pharmacies. The major companies that operate in manufacturing depression drugs and contour in the market study include Otsuka Pharmaceutical Co.Ltd, Eli Lilly and Company, Pfizer Inc, Allergan USA. Inc, Novartis AG, GlaxoSmithKline, Sebela Pharmaceutical Inc, and Johnson & Johnson. These contenders adopt various growth strategies to expand their production, strengthen their customer base. Thus the increasing potential, as well as decreased side-effects of drugs, drives the growth of anxiety disorders & depression treatment market propitious.

4. LITERATURE SURVEY

Depression is one of the common forms of MDD which not treated on time will lead to fatalities. Many researchers have come up with various speculations related to detection, diagnosing and monitoring depression and anxiety issues in individuals. In [9] the authors have proposed a Watch-Dog system which uses a novel decision selection algorithm based on the random forest by sensing the active versus

dormant state of the user using a tiny accelerometer sensor bound in the wrist to detect self-harming activities with applications in the psychiatric hospital facilities.

In [10] the authors have tried to design a prototype of a wearable device to assist individuals with MDD by identifying the speech recognition for the use of determining their positive and negative phases by an emotional user interface. In [11] the authors demonstrate a fear induction task for 20 seconds using a wearable sensor on young children using machine learning which resulted in a high fraction of accuracy which points to the diagnosing approach for children with internalizing disorders. In [12] the authors present a deep regression network known as DepressNet to assimilate depression representation with a visual explanation which provides a clinical prediction of the depression severity from facial images.

In [13] the authors have proposed a deep spatiotemporal depression analysis framework which predicts the depression levels of an individual with respect to the visual expression data by using Beck Depression Inventory-II values obtained. In [14] the authors have studied and tested for any relevance between emotional stimuli and its gastric response by obtaining a gastric myoelectrical activity response as a result to the study carried out. In [15] the authors have studied about the alternate therapy for depression using low-intensity Transcranial Ultrasound stimulation which is a noninvasive neuromodulation technique and suggest that this technique would be an optimistic therapeutic strategy for depression and its related issues.

5. DIAGNOSTIC AND THERAPEUTIC METHODS

It is estimated that more than 10 million cases as per year need medical attention for MDD which may resolve within months if proper diagnostic methods and concurrent therapy are given. The main methodology initially followed is an oral interview between the expert and the patient. Standardized Questionnaires as framed by the Diagnostic and Statistical Manual of Mental Disorders IV Text Revision [2] such as Hamilton Rating Scale for depression (HRSD) [3], Beck Depression Inventory [4] and Patient Health Questionnaire depression scale (PHQ-8) [5], Zung Self-Rating Depression Scale, Center for Epidemiologic Studies-Depression Scale (CES-D). The questionnaire provides a rating on the intensity of depression in an individual.

5.1 Physical Examination

Some physical examination includes CT Scan, MRI, ECG, EEG, EMG and Blood screening test to measure Serotonin level which is the major hormone which plays a vital role in depression. Higher the levels lower the depression and vice versa. The motor activities can be measured by the amount of dopamine in the blood which also needs to be checked when depression is diagnosed at later stages which have led to reduced motor activity due to neurological damage.

5.2 Non-Verbal Biomarkers

Non-Verbal biomarkers are also used to detect the intensity of depression which includes continuous monitoring of physical signs such as audio signals [8], facial expressions [6], and head movements[7]. This non-verbal biomarkers collected would speed up the assessment and will allow for self-monitoring effectively.

5.3 Depression Screening Tests using Questionnaire

5.3.1 Hamilton Rating Scale for Depression (HRSD):

It is the most widely used clinician-administered depression assessment scale for evaluating antidepressants' effects. This questionnaire, which was designed for adults, is used to rate the severity of patients' depression by probing their mood, feelings of guilt, suicidal ideation, insomnia, agitation or retardation, anxiety, weight loss and somatic symptoms[3]. The original version contains 17 items pertaining to symptoms of depression experienced over the previous week. A score of 0–7 is considered normal, while a score of 20 or higher (indicating at least moderate severity) is usually required for entry into a clinical trial.

5.3.2 Beck's Depression Inventory:

The mental health questionnaires, including Beck's questionnaire [4], the patient is assigned a numerical value between 1 and 63, which indicates the level of depression severity. Researchers have shown that the level of depression in people is associated with structural changes in the brain, therefore, by analyzing brain signals, it is possible to detect depression level. It emerged from the Hamilton Rating Scale for depression.

5.3.3 Patient Health Questionnaire for Depression and Anxiety (PHQ-4):

It is a practical screening tool for measuring depression and anxiety disorder. PHQ4 is the 4 questions screening tool but illustrating in every 2 questions [5]. This screening tool is used by the psychiatrist to detect the symptoms of the patients. According to the score, it is classified as normal,

mild, moderate, and severe conditions. The result will lead to the next assessment using PHQ-9 for depression and GAD-7 for anxiety. Moreover, the sensitivity-specificity or Sense-Spec shows 84% of the total diversity from the analyzed factor confirmation of two separate portions of depression and anxiety based on the four-question patient health questionnaire(PHQ4).

5.3.4 Patient Health Questionnaire-9 (PHQ-9):

This assessment consists of 9 practical questions used for evaluating depression severity. With this screening tool, it is classified into four levels of mild, moderate, pretty severe, and severe depression. The PHQ-9 is a precise assessment of depression severity [8]. The sensitivity and specificity of results are 88%.

5.3.5 Generalized Anxiety Disorder-7 (GAD-7):

Generalized anxiety disorder 7 (GAD-7) is one of the most practical screening tools with high reliability and the sensitivity of this screening tool is around 89% and 82% of the specificity. These percentages were classified by the accurate cut point of GAD-7. In particular, mental health professionals confirm that the outcome of this questionnaire is valid and is able to evaluate generalized anxiety disorder severity.

6. Cognitive Behavioral Therapy

Therapy is one type of psychotherapy discovered by Aaron T. Beck who is American psychiatrist. Cognitive therapy is the therapeutic accessed within the major group of cognitive behavioral therapies (CBT). This therapy established for helping the patient to handle their negative feelings, thoughts, and behaviors by identifying and changing the way they think, their behaviors, and emotional responses. The method includes helping patients improve their skills for modifying beliefs, identifying the proper way of thinking, and changing their behaviors. The result of using cognitive therapy is based on patient and therapist cooperation and beliefs in testing.

7. Neurofeedback

It is the methodology followed as therapeutic means for depression and anxiety especially with children experiencing ADHD is Neurofeedback. It is also known as EEG Biofeedback which is a way to train the human brainwaves and provides information to the human brain in the form of graphics using a video game for instance. It trains the human brain by using the electrochemical process in the brain and sends EEG signals to the brain's cortex which will effectively reduce and manage stress. This modern method can be effectively used and considered to be harmless.

8. Electroconvulsive Therapy

Electroconvulsive Therapy works for patients enduring severe Depression who couldn't respond to other treatments. This involves minor electric shock given to the patient to induce a seizure when the patient is made to sleep by giving sleeping pills. The doctor sends a painless electric current through the scalp to the brain. This therapy is also known as electroshock therapy which is the best option to treat patients suffering from severe depression.

9. Transcranial Magnetic stimulation

Transcranial Magnetic Stimulation is a therapy given to adults for whom antidepressant have failed to work and here there is no need for sedation before the therapy is given. The therapy is given 4-5 times a week up to 6 weeks. Here the doctor will keep an electromagnetic coil over the side of the scalp which creates a magnetic field and sends an electric current to a particular region of the brain especially the prefrontal cortex which is one of the major regions that controls mood.

10. Vagus Nerve Stimulation

Vagus Nerve stimulation is another methodology which is used when the patient is resistive to all available therapies. It is a deep brain stimulation surgery where an implant similar to a pacemaker is placed in the chest which is wired to the left vagus nerve in the neck. The stopwatch-sized device sends pulses at regular intervals which relay the stimuli between the nerve and the brain.

11. Other Methods

Deep learning, Neural Networks, and Machine Learning implied on the wearables designed and defined to diagnose and detect the onset of changes in mood and prevent any fatal occurrence like self-harming by early detection. With the help of the internet, sensors which capture biosignals and wireless communication will provide a statistical report on the individual suffering from the depressive disorder.

6. PROPOSED ARCHITECTURE

The proposed wrist-worn wearable will sense the biosignals like the heart rate, temperature, blood pressure, SPO2 level, and the movement of the patient.

Sensors like accelerometer, gyroscope, and galvanic skin response will be leveraged to identify the desired parameters. The inertial sensor is intended to filter the false alarms due to the physical activity of an individual.

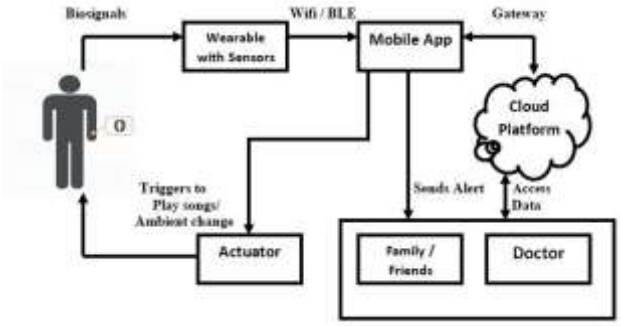

Figure1: Block Diagram of the proposed Solution

The proposed architecture as in Fig. 1, the wearable captures the biosignals from the patient, relays them via Wifi / BLE to the mobile and then transmits them through the gateway to Cloud for processing. The real-time monitored data of daily routine is periodically analyzed and stored in the cloud. It could be accessed by both caretaker as well as the doctor to know the progress of the patient. And on critical variations as well as if an abnormality is sensed in the patient, it then triggers the notification system to send alerts to both the doctor as well as to the caretaker. Simultaneously it activates the actuator to play a song or display pictures or run videos or change the ambient temperature to calm down the patient.

7. CONCLUSION AND FUTURESCOPE

The Proposed architecture would help individuals suffering from depressive disorders and will safeguard them from a serious devastating scenario of suicidal deaths. The system would change the mood and mental state by diverting the individual by automated playback of songs or display of favorite pictures or videos when triggered by the symptoms via the mobile app as well as sends the notification to the psychiatrist or nearby hospital and to the caretaker of the individual on emergency situations. The device would keep updating the database on daily, weekly and monthly basis and generate a statistical report of the individual about the variations in the biosignals captured and relayed by the sensors embedded in the wearable.

The Future scope includes the study and implementation of monitoring the individuals on the intake of prescribed medicines by the psychiatrist with respect to the assessment level of dosage prescribed could be provided reducing side-effects of the drugs. However, the real challenge lies in the type of technology to be applied, selection of sensors, accuracy, and standardization of the wearable to meet up the clinical data as the data generated would be voluminous, using an appropriate communication protocol, data storage and designed with cost-effectiveness. Moreover, the hesitation for the patients to use the technology is a major challenge and barrier to be concerned.

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