

Intelligent Depression Detection and Support System: Statistical Analysis, Psychological Review and Design Implication

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Abstract—Depression is a familiar psychological disorder caused by a combination of genetic, biological, environmental, and psychological factors. Untreated depression carries a high cost in terms of relationship problems, family suffering, and loss of work productivity. However diagnosis and treatment of depression is difficult due to varied severity, frequency, and duration of symptoms in depressed individuals. In this study, correlation between depression levels and behavioral trends of individuals has been established through a survey involving around 120 undergraduate students. The survey outcome is analyzed from a psychological viewpoint and finally some design implications on an automated system of depression detection and support system have been proposed.

I. INTRODUCTION

Depression is a common psychological phenomenon, more than just sadness. People with depression may experience a lack of interest and pleasure in daily activities, significant weight loss or gain, insomnia or excessive sleeping, lack of energy, inability to concentrate, feelings of worthlessness or excessive guilt and recurrent thoughts of death or suicide [1]. About 350 million people worldwide suffer from depression, which is approximately 5% of the world's total population. Depression is a leading cause of disability worldwide, and is a major contributor to the overall global burden of disease [2]. Depression causes one death every 40 seconds worldwide; statistically the second leading cause of death among 15-29 year olds globally in 2012 [3]. In addition, it is estimated that 10 to 15 percent of women experience postpartum depression after giving birth, which limits their capacity of childcare, ultimately resulting in poor growth and development of the children [4].

Standard scales are available to detect depression which are used by psychologists to diagnose the depression level of patients appearing before them. But due to the lack of awareness on psychological well-being, a large percentage of population refrain from taking expert assistance. Moreover, depressed

individuals often show an attitude of hiding their psychological state. Recent study reveals that depression is reflected in behavioral fluctuation of certain day-to-day activities. The goal of this study is to design wearable equipment that can detect depression automatically, and take initiative to provide necessary support to the depressed individual. To ensure effectiveness of the system, a survey has been conducted among 120 participants. The survey outcome, reviewed by psychology expert, provided the knowledge base for the system design.

The rest of the paper is organized as follows: depression, its causes, symptoms and remedies have been discussed in section II. Section III presents a brief discussion on related works. The survey outcome has been presented in Section IV. Reason behind behavioral fluctuation, reviewed from the psychological point of view, has been discussed in section V. Design of an automated depression detection and support system as been proposed in Section VI. The paper has been concluded discussing future prospects in Section VII.

II. DEPRESSION

In terms of psychology, **depression** is a mood or emotional state that is marked by feelings of low self-worth or guilt and a reduced ability to enjoy life. On the basis of severity of symptoms, it can be classified into a number of forms [5] including:

Major Depression: Severe symptoms that interfere with person's ability to work, sleep, study, eat, and enjoy life. An episode can occur only once in a person's lifetime, but more often, a person has several episodes.

Persistent Depressive Disorder: A person diagnosed with persistent depressive disorder may have episodes of major depression along with periods of less severe symptoms, but symptoms must last for 2 years.

Psychotic Depression: It occurs when a person has severe depression in addition to some form of psychosis, such as having disturbing false beliefs, or a break with reality (delusions), or hearing or seeing upsetting things that others cannot hear or see (hallucinations).

Postpartum Depression: Many women experience depression after giving birth due to the hormonal and physical changes and the overwhelming responsibility of caring the newborn. It is estimated that about 10 to 15 percent of women experience postpartum depression after giving birth.

Seasonal Affective Disorder (SAD): SAD is characterized by the onset of depression during the winter months, when there is less natural sunlight. The depression generally lifts during spring and summer. SAD may be effectively treated with light therapy. However nearly half of those with SAD do not get better with light therapy alone. Antidepressant medication and psychotherapy can reduce SAD symptoms, either alone or in combination with light therapy.

Bipolar Disorder: Bipolar disorder is characterized by cycling mood changes- from the extreme highs (e.g., mania) to the extreme lows (e.g., depression).

Although the population suffering from depressive disorder can be classified into various categories, they exhibit some common emotional, physical, behavioral, and cognitive symptoms [6]. Depending on the severity of disorder, the range of the symptoms may vary to a large extent.

A. Emotional Symptoms

Constant sadness: This feeling of sadness can occur for no apparent reason (such as a serious event). It can be intense and feel like there is nothing that will make it go away.

Feeling of worthlessness and excessive or inappropriate guilt: A depressed person often experiences negative and unrealistic feelings of guilt.

Loss of interest or pleasure in favorite activities: This loss of interest may affect all aspects of a person's life: from previous hobbies, e.g. going to movies, reading, shopping etc. to everyday activities the person used to enjoy, for example cooking, doing odd jobs, playing with the children.

B. Physical Symptoms

Low energy: People with depression often feel low on energy, even when they have not exerted themselves. This depressive fatigue is characterized by the fact that neither rest nor sleep alleviates it.

Psychomotor impairment: Depression may make one feel as if everything is slowed down. They may undergo lack of promptness in speech, thinking, and body movements. Increased pauses before answering, decrease in volume of speech, inflection, amount or variety of content, or muteness may accompany depression.

Aches and pains: Depression can be accompanied by physical pain including headaches, joint pain, stomach pain, and other pains.

Insomnia or hypersomnia: For a person suffering from depression, sleep is often broken and unrefreshing. The person often wakes up in the early hours and mental anguish prevents him or her from getting back to sleep. Other cases can include excessive sleep.

Change in weight: Often weight loss or weight gain is a significant symptom in diagnosing depression.

C. Behavioral Symptoms

Change in appetite: In case of depression, most commonly, appetite is decreased: food seems tasteless and servings too large. Conversely, people sometimes increase their food consumption (especially sweets) which can result in weight gain.

Impression of restlessness: For some people, depression makes them feel very agitated and almost jumpy (e.g. inability to sit still, pacing, hand-wringing, fiddling with clothes or other items.).

D. Cognitive Symptoms

Difficulty in making decisions or in focusing: Depression can cause one to experience diminished ability to think, concentrate and demonstrate indecisiveness.

Dark or suicidal thoughts: These ideas can occur frequently during depression. They must be taken very seriously and the person must ask for help right away if they are experiencing such emotions.

Various genetic, biological, social and financial factors have been reported as causes of depression. Individuals suffering from depression exhibit symptoms in a varied range of severity, frequency, and duration depending on their particular type of illness. In accordance, their treatments also differ, including combination of medication, psychotherapy and brain stimulations. It is quite alarming that, only about 50% of the population experiencing major depression receive treatment [2]; in many countries, this number is fewer than 10%. That is why support from family, friends and near ones become a necessity. Studies reveal that, isolation from social activities increases risk of depression while social interaction and support helps greatly in fighting out the problem.

Depression Level	Number of participants	Percentage	Depression frequency	Average length of depression episode
Minimum	83	69.17	Once in a month	3 days
Mild	14	11.67	Once a week	2 days
Moderate	8	6.67	Twice a week	2 days
High	7	5.83	Once in a month	17 days

Table 1: Distribution of depression among participants

III. RELATED WORKS

A significant number of research have been conducted to sense psychological state of individuals on the basis of sensor data. Some of these systems involve active participation of users while the others passively collect the data to determine mental state. In [7], the authors presented a smart phone based self-monitoring and assessment system for bipolar patients that can replace the existing paper based system. In this system, users actively participate to update information on their daily activities which assists them to manage their psychological condition and also offer the clinicians an opportunity to remotely track their patients.

The difficulties in correlating natural expression with individual's mental state have been explored by Hoque *et al.* [8]. Their proposed system determines the difference between natural smile and frustrated smile in accordance with the context. In their extended work [9], they measured collective mood of an academic campus by quantitative analysis of the interactions. This study also revealed periodic pattern e.g., more smiles during the weekends and strong correlation with campus events reflecting the emotional responses of a large community.

In [10], the authors suggested that smartphone sensor data from context-aware system can be used to automatically determine need of assistance for a patient suffering from major depressive disorder. Their suggestion paved the way to develop StudentLife [11], a continuous sensing application that assesses the day-to-day and week-by-week impact of workload on stress, sleep, activity, mood, sociability, mental well-being, academic performance, etc. on a group of students. Results from the StudentLife study show a number of significant correlations among the automatic objective sensor data from smart phones, mental health and educational outcomes of the students.

In addition to the existing systems, we propose our smart phone and smart watch based context-aware automated depression detection system, capable of triggering a support system when necessary.

IV. SURVEY

As the initial step we conducted an extensive survey among 120 participants, belonging to different academic departments, social class, age, and gender. The objectives of the survey are:

- To understand behavioral change because of depression in perspective of our country (Bangladesh)
- To identify measurable parameters for depression detection
- To identify the target group requiring support to overcome complexities of depression

106 of our participants are undergraduate students, the rest are graduate students and faculty members. Average age of the participants is 21. 59 of them were male (50%). 101 of them use smart phone. 113 of the participants use social network in regular basis with an average of 241 friends on their profile. The level of depression the participants experienced in previous 7 days of the survey is given in table 1.

Depression level of the participants was measured using an established scale [12]. From Table 1, it is evident that around 30% of the participants suffer from various levels of depression. As level of depression increases from minimum to mild or moderate, frequency of depression also increases. Though participants with high level of depression suffer less frequently, their length of depressive episode is evidently higher, which justifies the underlying assumption of depressive disorders.

In Table 2 we present some observations from the survey, from which we get valuable insight for our proposed system. Among a few noticeable observations, Table 2 shows that the higher percentage of participants with at least mild level of depression prefer talking with friends while depressed (mild: 53%, moderate 50%, high 43%). Individuals suffering from high level of depression use phone more frequently (Once in 6 hours on average) and for longer amount of time (16 minutes per call on average) than others. Their higher need of support justifies this behavior. Though most of the participants avoid sending SMS while depressed, higher percentage of them send longer than usual SMS (moderate 71%, high 43%). A clear deviation is also found in Facebook chatting pattern at depression. Higher percentage of individuals chat less or do not chat at all while depressed, especially individuals with high level of depression show clear aversion to Facebook chatting (86% of individuals with high depression chat less or do not chat at all). Most of our participants prefer staying at home while depressed, but a notable percentage show interest in going out. It is also noticeable that most of the participants prefer classical music while depressed (mild 66.7%, moderate 50%) but in case of high depression, highest percentage of individuals (43%) refrains from listening to music of any kind.

V. PSYCHOLOGIST'S VIEWPOINT

Music, movie, social network, etc. are used as therapeutic tools for depression treatment [13]. Music, reading, talking and sharing feelings with others help people to modify their depressed mood. Depressed people listen to music for getting relief from their painful feelings. Some of them like classical music; some like high bits music. In depression some love to sit alone, read a story book, some like to eat spicy

	Minimum	Mild	Moderate	High
Preferred way of conversation	1. Face to face (39.5%) 2. None (34%)	None (53%)	None (50%)	1. Face to face (43%) 2. Phone (43%)
Preferred company for conversation	1. Friends (54.6%) 2. Family members (21%)	Friends (53%)	Friends (50%)	Friends (43%)
Average interval between phone call	11 hours (39% don't use phone while depressed)	53% don't use phone while depressed	10 hours (37% don't use phone)	6 hours
Average phone call duration	7 minutes	8 minutes	10 minutes	16 minutes
Average interval between SMS	40% avoid messaging over phone	Once in three hours	Once in three hours	43% avoid messaging over phone
Length of SMS	1. 32% send shorter sms 2. 28% send longer sms	1. 60% send shorter sms 2. 33% send longer sms	71% send longer sms	43% send longer sms
Interval between Facebook chatting	1. 30% chat less frequently 2. 11% chat more frequently 3. 28% don't chat at all	1. 33% chat more frequently 2. 33% don't chat at all	1. 37% chat less 2. 25% chat more frequently 3. 25% don't chat at all	86% chat less frequently or don't chat at all
Duration of Facebook chat	1. 26% chat shorter than normal 2. 16% chat longer	40% chat longer	1. 25% chat shorter 2. 25% chat longer 3. 25% don't chat at all	86% chat shorter or don't chat at all
Preferred place to stay while depressed	1. 35% prefers home 2. 35% like to go out 3. 22% prefers to stay with friends	1. 40% prefers home 2. 40% like to go out	1. 37.5% prefers home 2. 50% like to go out	1. 57% prefers home 2. 28.6% likes to go out
Preferred type of music while depressed	1. 20% don't listen to music 2. 45% listen to classical music 3. 14% prefer rock music	66.7% listen to classical music	50% listen to classical music	43% don't listen to music

Table 2: Behavioral fluctuation due to depression

food while some lose their appetite. Some get relief from depression by communicating with friends while some do not take interest to communicate. Generally, in extreme level of depression people lose interest in activities like listening music, reading books, or communicating with others face to face, or any other means. From the survey it was evident that the participants who were suffering from mild and moderate level depression were found to listen to music, especially classical music. The high level depressed participants (43%) did not listen to music at all, moderate level depressed like to listen to music (50%), and mild (66.7%) love to listen classical music.

Depressed people loss motivation to communicate with others. Especially young adult do not feel comfortable to communicate with family and relatives. Depressed people generally love isolation, but sometimes adults like to share their feelings through conversation or messages. This survey also found that high level depressed participants talk more than a minimal level depressed adult over phone. It was evident that average call duration of minimal depressed adult was 7 minutes, 32% of them send comparatively shorter SMS and 28% longer SMS. In case of mild depression average call duration was 8 minutes, in 60% cases they reduce SMS length and in 33% cases they send longer SMS. High level depressed adults' average phone call duration was 16 minutes and 43% of them send longer than usual SMS.

An interesting observation from this survey is that depressed adult avoid Facebook chatting. High level depressed participants do not involve in Facebook chatting (86%). It indicates that online social interaction do not attract highly depressed adults which comply with some previous studies on impact of social media on increasing depression [14].

VI. PROPOSED SYSTEM OUTLINE

Our proposed system comprises of three modules:

- Data collection
- Data analysis
- Support system

A. Module 1: Data collection

In the proposed system, data will be collected from sensors of wearable devices. Users do not need to explicitly participate in data collection. The wearable device periodically collects data on several parameters including user's physical state, behaviour and social interaction. Sensors provided with these devices will provide data on the following:

- **Heart rate:** A study conducted by Harvard Medical School [15] shows that, cardiovascular system is directly affected by mind and mood. Psychological states like anxiety, depression etc. create a state of emergency readiness, which results in hormone levels rise, blood vessels constrict, and heartbeat speed up. If a person is seriously depressed or anxious, the emergency response becomes constant. Eventually it damages the blood

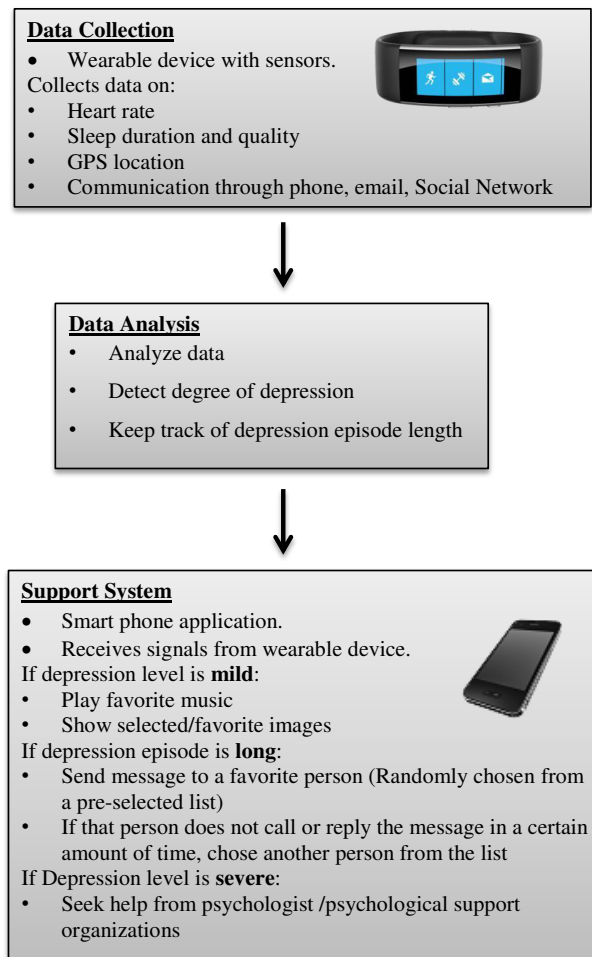


Figure 1: System Outline

vessels and makes the heart less sensitive to signals telling it to slow down or speed up as the body's demands change. Our proposed system will monitor these deviations and try to detect depression from the heart rate sensor data.

- **Sleep duration and quality:** Irregularity in sleep duration and quality is one of the key symptoms of depressive disorder. In [16] authors report that most of the patients suffering from depressive disorder first seek help due to insomnia and hypersomnia. Their study outcome state that 83% of depressed patients had at least one insomnia symptom which imply that we can potentially detect depression by monitoring sleep pattern

of users.

- **GPS location:** Our survey outcome depicts that depression creates a significant change in movement pattern of individuals. Most of our survey participants prefer staying at home while depressed when they were supposed to be at their work place. Our system will be designed to track GPS location with a view to identify the change in movement pattern due to depression.
- **Communication through phone, email, social network:** As we discussed in our survey data analysis, depressed individuals largely deviate from their usual social interaction which can be a potential indicator for depression detection.

B. Module 2: Data Analysis

As the wearable device automatically collects data on several physical parameters and social interaction, these data will be sent to the synchronized smart phone periodically, where it will be analyzed to identify specific patterns indicating depression. Machine learning methodologies will be implemented to provide better personalized service to the user. Once the system detects depression, it will trigger supportive measures. At the same time the system will keep record of the length of depression episode to identify the severity of depression and initiate adaptive support mechanisms.

C. Module 3: Support system

The support system will vary from person to person and might require rigorous calibration. An Android application will be designed to act according to the level of depression.

If depression level is mild:

- Play a music track from a pre-selected list
- Show images of memorable events on phone screen, etc.

If depression episode is long:

- Send message to a person, randomly chosen from a pre-selected list
- If that person does not call or reply the message in a certain amount of time, the next person from the list will be notified

If depression level is severe:

- Alert psychologist or psychological support organizations

VII. CONCLUSION AND FUTURE WORKS

The goal of this study is to direct usage of technological advancements in betterment of humanity. We have conducted a survey that reveals significant correlation between depression level and behavioral changes of individuals. We have assessed the survey outcome under psychological viewpoint and implementing the results, a system design has been proposed that identifies who is in need of psychological support around us and take appropriate action. Currently, implementation of the system is in progress and we look forward to investigate its effectiveness in practical field.

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