Design And Implementation Of An Intelligent Depression Detection And Support System

M.Sc Engineering Thesis

by

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Candidate’s Declaration

It is hereby declared that the whole thesis or part of it has not been taken from other works without reference. It is also declared that this thesis or part of it has not been submitted elsewhere for the award of any degree or diploma.

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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. Psychologists use standard scales to detect depression but for that the depressed person needs to be present before the psychologist. Recent study reveals that, depression is reflected in behavioral fluctuation of certain day-to-day activities and physical parameters. It has also been studied that isolation from social activities increases risk of depression while social interaction and support helps greatly in fighting out the problem. In this thesis, a model of depression detection and support system has been designed using extensive user survey on different symptoms and effects of depression that measures different levels of depression based on individuals’ physical state, behavior, and social interaction. The detection system of the model will detect different levels of depression by periodically collecting following data of users: a) heart rate interval through sensors in the smart-watch, b) sleeping pattern through monitoring activities during night, c) movement pattern through GPS location information, and d) communication pattern through monitoring phone calls, email, and social network usage. The support system will receive the level of depression from the detection system. If the depression level is mild, it will play a music track or show images of memorable events. If the depression episode is long, it will send messages to family and friends from a pre-selected list. If the depression level is severe, it will alert family, psychologist or psychological support organizations. This model has been verified by a psycho-social counsellor. Finally an intelligent wearable system has been developed which consists of an Android application installed in a smart-watch synchronized with the user’s smart-phone. In the developed module Heart Rate Variability data is collected by the sensor of the smart-watch and analyzed in user’s smart-phone. If the data indicates signs of depression, an SMS alert is sent to an emergency contact person to provide necessary support. Thus the system acts as both depression detection and support system.
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Chapter 1

Introduction

Depression is a common psychological phenomenon, more than just sadness. Especially when long-lasting and with moderate or severe intensity, depression may become a serious health condition. 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].

1.1 Background and Present State of Depression

About 350 million people worldwide suffer from depression, which is approximately 5% of the world’s total population. The number of patients diagnosed with depression increases by 20% every year ranking it as the 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. Close to 800,000 people die due to suicide every year; statistically the second leading cause of death among 15-29 year olds globally in 2012 [3].

Though depression imposes severe mental health crisis worldwide, women experience depression at twice the rate of men. This 2:1 ratio exists regardless of racial or ethnic background or economic status. The lifetime prevalence of major depression is 20-26% for women and 8-12% for men. Depression may increase a woman’s risk for broken bones. The hip bone mineral density of women with a history of major depression was found to be 10-15% lower than normal for their age-so low that their risk of hip fracture increased by 40% over 10 years [4]. 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[5].
1.2 Motivation

Depression causes lose in health, productivity and economic prospect worldwide, which, along with reluctance to avail treatment and support, act as motivational factor behind studies on automatic depression detection and development of effective support system.

1.2.1 Effect on Health

There are interrelationships between depression and physical health. It often co-occurs with other illnesses and medical conditions. 25% of cancer patients, 10-27% of post-stroke patients, 1 in 3 heart attack survivors, 1 in 3 HIV patients, 50% of Parkinson’s disease patients and 8.5-27% of persons with diabetes experience depression. Depression is also common in patients suffering eating disorder (50-75%) or substance abuse (27%) [4]. Sometimes, symptoms of depression may follow a recent medical diagnosis, but in other cases, certain medications used to treat the illness may trigger depression. In most cases, depression lifts as patients adjust or as the other condition is treated, but it may persist, even as physical health improves. Research suggests that people who have depression and another medical illness tend to have more severe symptoms of both illnesses. They may have more difficulty adapting to their co-occurring illness and more medical costs than those who do not also have depression [6].

1.2.2 Effect on Economy

Mental health problems constitute the largest single source of world economic burden, with an estimated global cost of US $2.5 trillion – greater than cardiovascular disease, chronic respiratory disease, cancer, or diabetes individually. Depression ranks among the top three workplace issues, following only family crisis and stress. Economic study on US population reveal that on account of medical expenditures, lost productivity and other costs each year depression’s annual toll on businesses amounts to about $70 billion. Depression accounts for nearly $12 billion in terms of lost workdays. Additionally, more than $11 billion in other costs accrue from decreased productivity due to symptoms that sap energy, affect work habits, cause problems with concentration, memory, and decision-making[4].

1.2.3 Treatment of Depression

Though depression cannot be fully prevented, some prevention programs can partially reduce depression [2]. Effective community approaches to prevent depression include
school-based programs to enhance a pattern of positive thinking in children and adolescents. Interventions for parents of children with behavioural problems may reduce parental depressive symptoms and improve outcomes for their children. Exercise programs for the elderly can also be effective in depression prevention.

There are effective treatments for moderate and severe depression. Health-care providers may offer psychological treatments, such as behavioural activation, cognitive behavioural therapy [CBT], and interpersonal psychotherapy [IPT]; or antidepressant medication, such as selective serotonin reuptake inhibitors [SSRIs] and tricyclic antidepressants [TCAs]. Different psychological treatment formats for consideration include individual and/or group face-to-face psychological treatments delivered by professionals and supervised lay therapists. While prescribing antidepressant, health-care providers should keep in mind the possible adverse effects associated with antidepressant medication, the ability to deliver either intervention, and individual preferences. Psycho-social treatments are particularly effective for mild depression, while antidepressants can be considered as an effective form of treatment for moderate-severe depression but are not the first line of treatment for cases of mild depression [2].

Several studies reveal that, social support plays an important role in mental health problems. People coping with depression tend to report fewer supportive friends, less contact with their friends, less satisfaction with their friends and relatives, lower marital satisfaction, and confide less in their partners. It is likely that lack of social support and feelings of loneliness can make people more vulnerable to the onset of mental health problems like depression. Therefore mental health problems are closely correlated to problems with social support and aggravate the feelings of loneliness. For these reasons, reconnecting with others in healthy, supportive ways is often an important component of managing most mental health including depression [7].

Although there are known, effective treatments for depression, fewer than half of those affected in the world (in many countries, fewer than 10%) receive such treatments [2]. Barriers to effective care include a lack of resources, lack of trained health-care providers, and social stigma associated with mental disorders. Another barrier to effective care is inaccurate assessment. In countries of all income levels, people who are depressed are often not correctly diagnosed, and others who do not have the disorder are too often misdiagnosed and prescribed antidepressants.
1.3 Contribution

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[8]. Therefore, the objective of this thesis are:

- To develop a model that can correlate different levels of depression with behavioral fluctuations and lack of different measurable social activities.
- To design an intelligent detection system that may implement our above model to detect different levels of depression.
- To design an intelligent support system that may provide supports to the depressed individuals like playing a music track, showing images of memorable events, sending messages to friends or family etc.

The research has been conducted over the years keeping in mind the objectives, and the contribution of the research can be summarized as follows:

- A model has been designed using extensive user survey on different symptoms and effects of depression that measures different levels of depression based on individuals’ physical state, behavior, and social interaction. This model has been verified by a psycho-social counselor.
- An intelligent wearable system has been developed which consists of our Android application installed in a smart-watch synchronized with the user’s smart-phone. This system acts as both depression detection and support system.

1.4 Organization of the Thesis

The rest of the thesis is organized as follows: Depression, its causes, symptoms and remedies have been discussed in chapter 2. Chapter 3 presents a brief discussion on related works. The survey outcome has been presented in chapter 4. Reason behind behavioral fluctuation, reviewed from the psychological point of view, has also been discussed in this chapter. Design of an automated depression detection and support
system as been proposed in chapter 5. Developed modules and their working procedure have been demonstrated in section 5.2 of chapter 5. The thesis has been concluded discussing future prospects in chapter 6.
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. According to DSM V [9], which is widely considered as the universal authority for psychiatric diagnoses, in terms of treatment and recommendations, depressive disorder can be classified into a number of forms including disruptive mood dis-regulation disorder, major depressive disorder (including major depressive episode), persistent depressive disorder (dysthymia), premenstrual dysphoric disorder, substance/medication-induced depressive disorder, depressive disorder due to another medical condition, other specified depressive disorder, and unspecified depressive disorder; on the basis of variation and severity of symptoms.

Major depressive disorder represents the classic condition in this group of disorders. It is characterized by discrete episodes of at least 2 weeks’ duration (although most episodes last considerably longer) involving clear-cut changes in affect, cognition, and neurovegetative functions and inter-episode remissions. A diagnosis based on a single episode is possible, although the disorder is a recurrent one in the majority of cases. Careful consideration is given to the delineation of normal sadness and grief from a major depressive episode. Bereavement may induce great suffering, but it does not typically induce an episode of major depressive disorder. When they do occur together, the depressive symptoms and functional impairment tend to be more severe and the prognosis is worse compared with bereavement that is not accompanied by major depressive disorder. Bereavement-related depression tends to occur in persons with other vulnerabilities to depressive disorders, and recovery may be facilitated by antidepressant treatment. A more chronic form of depression, persistent depressive disorder (dysthymia), can be diagnosed when the mood disturbance continues for at least 2 years in adults or 1 year in children. This diagnosis, includes both the DSM-IV [10] diagnostic categories of chronic
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major depression and dysthymia.

After careful scientific review of the evidence, premenstrual dysphoric disorder has been categorized in the same class with other depressive disorders. Almost 20 years of additional research on this condition has confirmed a specific and treatment-responsive form of depressive disorder that begins sometime following ovulation and remits within a few days of menses and has a marked impact on functioning.

A large number of substances of abuse, some prescribed medications, and several medical conditions can be associated with depression-like phenomena. This fact is considered in the diagnoses of substance/medication-induced depressive disorder and depressive disorder due to another medical condition.

2.1 Severity Levels of Depressive Disorder

Severity of level in depressive disorder is based on the number of criterion symptoms, the severity of those symptoms, and the degree of functional disability. The levels are marked as:

**Mild:** Few, if any, symptoms in excess of those required to make the diagnosis are present, the intensity of the symptoms is distressing but manageable, and the symptoms result in minor impairment in social or occupational functioning.

**Moderate:** The number of symptoms, intensity of symptoms, and/or functional impairment are between those specified for ‘mild’ and ‘severe.’

**Severe:** The number of symptoms is substantially in excess of that required to make the diagnosis, the intensity of the symptoms is seriously distressing and unmanageable, and the symptoms markedly interfere with social and occupational functioning.

2.2 Specifiers for Depressive Disorders

A number of factors regarding subject’s physiological, psychological and environmental condition may exacerbate symptoms of depression, therefore affects diagnosis and treatment. These specifiers are discussed as follows:

2.2.1 Anxious distress

Anxious distress has been noted as a prominent feature of both bipolar and major depressive disorder in both primary care and specialty mental health settings. High levels of anxiety have been associated with higher suicide risk, longer duration of illness,
and greater likelihood of treatment non-response. Therefore, it is clinically useful to specify accurately the presence and severity levels of anxious distress for treatment planning and monitoring of response to treatment. Anxious distress is defined as the presence of at least two of the following symptoms during the majority of days of a major depressive episode or persistent depressive disorder (dysthymia):

1. Feeling keyed up or tense.
2. Feeling unusually restless.
3. Difficulty concentrating because of worry.
4. Fear that something awful may happen.
5. Feeling that the individual might lose control of himself or herself.

**Severity Level:**

1. **Mild:** Two symptoms.
2. **Moderate:** Three symptoms.
3. **Moderate-severe:** Four or five symptoms.
4. **Severe:** Four or five symptoms and with motor agitation.

### 2.2.2 Mixed features

Mixed features associated with a major depressive episode have been found to be a significant risk factor for the development of bipolar I or bipolar II disorder. As a result, it is clinically useful to note the presence of this specifier for treatment planning and monitoring of response to treatment.

A. At least three of the following manic/hypomanic symptoms are present nearly every day during the majority of days of a major depressive episode:

1. Elevated, expansive mood.
2. Inflated self-esteem or grandiosity.
3. More talkative than usual or pressure to keep talking.
4. Flight of ideas or subjective experience that thoughts are racing.
5. Increase in energy or goal-directed activity (either socially, at work or school, or sexually).
6. Increased or excessive involvement in activities that have a high potential for painful consequences (e.g., engaging in unrestrained buying sprees, sexual indiscretions, foolish business investments).

7. Decreased need for sleep. Feeling rested despite sleeping less than usual; to be contrasted with insomnia.

B. Mixed symptoms are observable by others and represent a change from the person’s usual behavior.

C. For individuals whose symptoms meet full criteria for either mania or hypomania, the diagnosis is specified as bipolar I or bipolar II disorder.

D. The mixed symptoms are not attributable to the physiological effects of a substance (e.g., a drug of abuse, a medication or other treatment).

### 2.2.3 Melancholic Features

This specifier is applied if these features are present at the most severe stage of the episode. There is a near-complete absence of the capacity for pleasure, not merely a diminution. Even highly desired events are not associated with marked brightening of mood. Either mood does not brighten at all, or it brightens only partially (e.g., up to 20%-40% of normal for only minutes at a time). The ‘distinct quality’ of mood that is characteristic of this specifier is experienced as qualitatively different from that during a non-melancholic depressive episode. A depressed mood that is described as merely more severe, longer lasting, or present without a reason is not considered distinct in quality. Psychomotor changes are nearly always present and are observable by others. Melancholic features exhibit only a modest tendency to repeat across episodes in the same individual. They are more frequent in in-patients, as opposed to out-patients; are less likely to occur in milder than in more severe major depressive episodes; and are more likely to occur in those with psychotic features. **Symptoms:**

A. One of the following is present during the most severe period of the current episode:

1. Loss of pleasure in all, or almost all, activities.

2. Lack of reactivity to usually pleasurable stimuli (does not feel much better, even temporarily, when something good happens).

B. Three (or more) of the following:

1. A distinct quality of depressed mood characterized by profound despondency, despair, and/or moroseness or by so-called empty mood.
2. Depression that is regularly worse in the morning.
3. Early-morning awakening (i.e., at least 2 hours before usual awakening).
4. Marked psychomotor agitation or retardation.
5. Significant anorexia or weight loss.
6. Excessive or inappropriate guilt.

2.2.4 Atypical features

Atypical depression has historical significance and today does not connote an uncommon or unusual clinical presentation as the term might imply. Mood reactivity is the capacity to be cheered up when presented with positive events (e.g., a visit from children, compliments from others). Mood may become euthymic (not sad) even for extended periods of time if the external circumstances remain favorable.

Increased appetite may be manifested by an obvious increase in food intake or by weight gain. Hypersomnia may include either an extended period of nighttime sleep or daytime napping that totals at least 10 hours of sleep per day (or at least 2 hours more than when not depressed). Leaden paralysis is defined as feeling heavy, leaden, or weighted down, usually in the arms or legs. This sensation is generally present for at least an hour a day but often lasts for many hours at a time. Unlike the other atypical features, pathological sensitivity to perceived interpersonal rejection is a trait that has an early onset and persists throughout most of adult life. Rejection sensitivity occurs both when the person is and is not depressed, though it may be exacerbated during depressive periods.

This specifier can be applied when these features predominate during the majority of days of the current or most recent major depressive episode or persistent depressive disorder.

A. Mood reactivity (i.e., mood brightens in response to actual or potential positive events).

B. Two (or more) of the following:
   1. Significant weight gain or increase in appetite.
   2. Hypersomnia.
   3. Leaden paralysis (i.e., heavy, leaden feelings in arms or legs).
   4. A long-standing pattern of interpersonal rejection sensitivity (not limited to episodes of mood disturbance) that results in significant social or occupational impairment.
C. Criteria are not met for “with melancholic features” or “with catatonia” during the same episode.

2.2.5 Psychotic features

Delusions and/or hallucinations are present.

With mood-congruent psychotic features: The content of all delusions and hallucinations is consistent with the typical depressive themes of personal inadequacy, guilt, disease, death, nihilism, or deserved punishment.

With mood-incongruent psychotic features: The content of the delusions or hallucinations does not involve typical depressive themes of personal inadequacy, guilt, disease, death, nihilism, or deserved punishment, or the content is a mixture of mood-incongruent and mood-congruent themes.

2.2.6 Peripartum Onset

This specifier can be applied to the current or, if full criteria are not currently met for a major depressive episode, most recent episode of major depression if onset of mood symptoms occurs during pregnancy or in the 4 weeks following delivery. Mood episodes can have their onset either during pregnancy or postpartum. Although the estimates differ according to the period of follow-up after delivery, between 3% and 6% of women will experience the onset of a major depressive episode during pregnancy or in the weeks or months following delivery. Fifty percent of ‘postpartum’ major depressive episodes actually begin prior to delivery. Thus, these episodes are referred to collectively as peripartum episodes.

Women with peripartum major depressive episodes often have severe anxiety and even panic attacks. Prospective studies have demonstrated that mood and anxiety symptoms during pregnancy, as well as the ‘baby blues’, increase the risk for a postpartum major depressive episode.

Peripartum-onset mood episodes can present either with or without psychotic features. Infanticide is most often associated with postpartum psychotic episodes that are characterized by command hallucinations to kill the infant or delusions that the infant is possessed, but psychotic symptoms can also occur in severe postpartum mood episodes without such specific delusions or hallucinations.

Postpartum mood (major depressive or manic) episodes with psychotic features appear to occur in from 1 in 500 to 1 in 1,000 deliveries and may be more common in primiparous
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women. The risk of postpartum episodes with psychotic features is particularly increased for women with prior postpartum mood episodes but is also elevated for those with a prior history of a depressive or bipolar disorder (especially bipolar I disorder) and those with a family history of bipolar disorders.

Once a woman has had a postpartum episode with psychotic features, the risk of recurrence with each subsequent delivery is between 30% and 50%. Postpartum episodes must be differentiated from delirium occurring in the postpartum period, which is distinguished by a fluctuating level of awareness or attention. The postpartum period is unique with respect to the degree of neuroendocrine alterations and psychosocial adjustments, the potential impact of breast-feeding on treatment planning, and the long-term implications of a history of postpartum mood disorder on subsequent family planning.

2.2.7 Seasonal pattern

The specifier ‘with seasonal pattern’ is applied to the pattern of major depressive episodes in major depressive disorder, recurrent. The essential feature is the onset and remission of major depressive episodes at characteristic times of the year. In most cases, the episodes begin in fall or winter and remit in spring. Less commonly, there may be recurrent summer depressive episodes. This pattern of onset and remission of episodes must have occurred during at least a 2-year period, without any nonseasonal episodes occurring during this period. In addition, the seasonal depressive episodes must substantially outnumber any nonseasonal depressive episodes over the individual’s lifetime.

This specifier does not apply to those situations in which the pattern is better explained by seasonally linked psychosocial stressors (e.g., seasonal unemployment or school schedule). Major depressive episodes that occur in a seasonal pattern are often characterized by prominent energy, hypersomnia, overeating, weight gain, and a craving for carbohydrates. It is unclear whether a seasonal pattern is more likely in recurrent major depressive disorder or in bipolar disorders. However, within the bipolar disorders group, a seasonal pattern appears to be more likely in bipolar II disorder than in bipolar I disorder. In some individuals, the onset of manic or hypomanic episodes may also be linked to a particular season.

The prevalence of winter-type seasonal pattern appears to vary with latitude, age, and sex. Prevalence increases with higher latitudes. Age is also a strong predictor of seasonality, with younger persons at higher risk for winter depressive episodes.

This specifier applies to recurrent major depressive disorder.
A. There has been a regular temporal relationship between the onset of major depressive episodes in major depressive disorder and a particular time of the year (e.g., in the fall or winter).

B. Full remissions (or a change from major depression to mania or hypomania) also occur at a characteristic time of the year (e.g., depression disappears in the spring).

C. In the last 2 years, two major depressive episodes have occurred that demonstrate the temporal seasonal relationships defined above and no nonseasonal major depressive episodes have occurred during that same period.

D. Seasonal major depressive episodes (as described above) substantially outnumber the nonseasonal major depressive episodes that may have occurred over the individual’s lifetime.

Symptoms, diagnostic criteria, comorbidity, risk factors of different category of depressive disorder are discussed in detail in the following sections.

2.3 Major Depressive Disorder

The criterion symptoms for major depressive disorder must be present nearly every day to be considered present, with the exception of weight change and suicidal ideation. Depressed mood must be present for most of the day, in addition to being present nearly every day. Often insomnia or fatigue is the presenting complaint, and failure to probe for accompanying depressive symptoms will result in under-diagnosis. Sadness may be denied at first but may be elicited through interview or inferred from facial expression and demeanor. With individuals who focus on a somatic complaint, clinicians should determine whether the distress from that complaint is associated with specific depressive symptoms. Fatigue and sleep disturbance are present in a high proportion of cases; psychomotor disturbances are much less common but are indicative of greater overall severity, as is the presence of delusional or near-delusional guilt.

The essential feature of a major depressive episode is a period of at least 2 weeks [11] during which there is either depressed mood or the loss of interest or pleasure in nearly all activities. In children and adolescents, the mood may be irritable rather than sad. The individual also experiences at least four additional symptoms drawn from a list that includes changes in appetite or weight, sleep, and psychomotor activity; decreased energy; feelings of worthlessness or guilt; difficulty thinking, concentrating, or making decisions; or recurrent thoughts of death or suicidal ideation or suicide plans or attempts. To count toward a major depressive episode, a symptom must either be newly present or must
have clearly worsened compared with the person’s pre-episode status. The symptoms must persist for most of the day, nearly every day, for at least 2 consecutive weeks. The episode must be accompanied by clinically significant distress or impairment in social, occupational, or other important areas of functioning. For some individuals with milder episodes, functioning may appear to be normal but requires markedly increased effort.

The mood in a major depressive episode is described by the person as depressed, sad, hopeless, discouraged, or "down in the dumps". In some cases, sadness may be denied at first but may subsequently be elicited by investigation e.g., by pointing out that the individual looks as if he or she is about to cry. In some individuals who complain having no feelings, or feeling anxious, the presence of a depressed mood can be inferred from the person’s facial expression and demeanor. Some individuals emphasize somatic complaints e.g., bodily aches and pains rather than reporting feelings of sadness. Many individuals report or exhibit increased irritability e.g., persistent anger, a tendency to respond to events with angry outbursts or blaming others, an exaggerated sense of frustration over minor matters. In children and adolescents, an irritable or cranky mood may develop rather than a sad or dejected mood. This presentation is however different from a pattern of irritability when frustrated.

Loss of interest or pleasure is nearly always present, at least to some degree. Individuals may report feeling less interested in hobbies, or not feeling any enjoyment in activities that were previously considered pleasurable. Family members often notice social withdrawal or neglect of pleasurable avocations e.g., a formerly avid golfer no longer plays, a child who used to enjoy soccer finds excuses not to practice. In some individuals, there is a significant reduction from previous levels of sexual interest or desire.

Appetite change may involve either a reduction or increase [12]. Some depressed individuals report that they have to force themselves to eat. Others may eat more and may crave specific foods e.g., sweets or other carbohydrates. When appetite changes are severe in either direction, there may be a significant loss or gain in weight, or, in children, a failure to make expected weight gains may be noted.

Sleep disturbance may take the form of either difficulty sleeping or sleeping excessively [13]. When insomnia is present, it typically takes the form of middle insomnia i.e., waking up during the night and then having difficulty returning to sleep or terminal insomnia i.e., waking too early and being unable to return to sleep. Initial insomnia i.e., difficulty falling asleep may also occur. Individuals who present with oversleeping (hypersonomnia) may experience prolonged sleep episodes at night or increased daytime sleep. Sometimes the reason that the individual seeks treatment is for the disturbed sleep.
Psychomotor changes include agitation e.g., the inability to sit still, pacing, hand-wringing; or pulling or rubbing of the skin, clothing, or other objects or retardation e.g., slowed speech, thinking, and body movements; increased pauses before answering; speech that is decreased in volume, inflection, amount, or variety of content, or muteness. The psychomotor agitation or retardation must be severe enough to be observable by others and not represent merely subjective feelings.

Decreased energy, tiredness, and fatigue are also common. A person may report sustained fatigue without physical exertion. Even the smallest tasks seem to require substantial effort. The efficiency with which tasks are accomplished may be reduced. For example, an individual may complain that washing and dressing in the morning are exhausting and take twice as long as usual.

The sense of worthlessness or guilt associated with a major depressive episode may include unrealistic negative evaluations of one’s worth or guilty preoccupations or ruminations over minor past failings. Such individuals often misinterpret neutral or trivial day-to-day events as evidence of personal defects and have an exaggerated sense of responsibility for untoward events. The sense of worthlessness or guilt may be of delusional proportions e.g., an individual who is convinced that he or she is personally responsible for world poverty. Blaming oneself for being sick and for failing to meet occupational or interpersonal responsibilities as a result of the depression is very common and, unless delusional, is not considered sufficient to meet this criterion.

Many individuals report impaired ability to think, concentrate, or make even minor decisions [9]. They may appear easily distracted or complain of memory difficulties. Those engaged in cognitively demanding pursuits are often unable to function. In children, a precipitous drop in grades may reflect poor concentration. In elderly individuals, memory difficulties may be the chief complaint and may be mistaken for early signs of a dementia ("pseudodementia"). When the major depressive episode is successfully treated, the memory problems often fully abate. However, in some individuals, particularly elderly persons, a major depressive episode may sometimes be the initial presentation of an irreversible dementia.

Thoughts of death, suicidal ideation, or suicide attempts are common in patients of Major Depressive Disorder [14]. They may range from a passive wish not to awaken in the morning or a belief that others would be better off if the individual were dead, to transient but recurrent thoughts of committing suicide, to a specific suicide plan. More severely suicidal individuals may have put their affairs in order e.g., updated wills, settled debts, acquired needed materials e.g., a rope or a gun, and chosen a location and time to accomplish the suicide. Motivations for suicide may include a desire to give up in the face of perceived insurmountable obstacles, an intense wish to end what
is perceived as an unending and excruciatingly painful emotional state, an inability to foresee any enjoyment in life, or the wish to not be a burden to others. The resolution of such thinking may be a more meaningful measure of diminished suicide risk than denial of further plans for suicide. The evaluation of the symptoms of a major depressive episode is especially difficult when they occur in an individual who also has a general medical condition e.g., cancer, stroke, myocardial infarction, diabetes, pregnancy. Some of the criterion signs and symptoms of a major depressive episode are identical to those of general medical conditions e.g., weight loss with untreated diabetes; fatigue with cancer; hypersonnia early in pregnancy; insomnia later in pregnancy or the postpartum. Such symptoms count toward a major depressive diagnosis except when they are clearly and fully attributable to a general medical condition. Non-vegetative symptoms of dysphoria, anhedonia, guilt or worthlessness, impaired concentration or indecision, and suicidal thoughts should be assessed with particular care in such cases. Definitions of major depressive episodes that have been modified to include only these non-vegetative symptoms appear to identify nearly the same individuals as do the full criteria.

Major depressive disorder is associated with high mortality, much of which is accounted for by suicide; however, it is not the only cause. For example, depressed individuals admitted to nursing homes have a markedly increased likelihood of death in the first year. Individuals frequently present with tearfulness, irritability, brooding, obsessive rumination, anxiety, phobias, excessive worry over physical health, and complaints of pain e.g., headaches; joint, abdominal, or other pains. In children, separation anxiety may occur.

Although an extensive literature exists describing neuro-anatomical, neuro-endocrinological, and neuro-physiological correlates of major depressive disorder, no laboratory test has yielded results of sufficient sensitivity and specificity to be used as a diagnostic tool for this disorder. Until recently, hypothalamic-pituitary-adrenal axis hyperactivity had been the most extensively investigated abnormality associated with major depressive episodes, and it appears to be associated with melancholia, psychotic features, and risks for eventual suicide. Molecular studies have also implicated peripheral factors, including genetic variants in neurotrophic factors and pro-inflammatory cytokines. Additionally, functional magnetic resonance imaging studies provide evidence for functional abnormalities in specific neural systems supporting emotion processing, reward seeking, and emotion regulation in adults with major depression.
2.3.1 Prevalence

In the United States, twelve-month prevalence of major depressive disorder is approximately 7%, with marked differences by age group such that the prevalence in 18 to 29 year old individuals is threefold higher than the prevalence in individuals age 60 years or older. Females experience 1.5 to 3-fold higher rates than males beginning in early adolescence.

2.3.2 Development and Course

Major depressive disorder may first appear at any age, but the likelihood of onset increases markedly with puberty; however, first onset in late life is not uncommon. The course of major depressive disorder is quite variable, such that some individuals rarely, if ever, experience remission (a period of 2 or more months with no symptoms, or only one or two symptoms to no more than a mild degree), while others experience many years with few or no symptoms between discrete episodes. It is important to distinguish individuals who present for treatment during an exacerbation of a chronic depressive illness from those whose symptoms developed recently. Chronicity of depressive symptoms substantially increases the likelihood of underlying personality, anxiety, and substance use disorders and decreases the likelihood that treatment will be followed by full symptom resolution. It is therefore useful to ask individuals presenting with depressive symptoms to identify the last period of at least 2 months during which they were entirely free of depressive symptoms.

Recovery typically begins within 3 months of onset for two in five individuals with major depression and within 1 year for four in five individuals. Recency of onset is a strong determinant of the likelihood of near-term recovery, and many individuals who have been depressed only for several months can be expected to recover spontaneously. Features associated with lower recovery rates, other than current episode duration, include psychotic features, prominent anxiety, personality disorders, and symptom severity.

The risk of recurrence becomes progressively lower over time as the duration of remission increases. The risk is higher in individuals whose preceding episode was severe, in younger individuals, and in individuals who have already experienced multiple episodes. The persistence of even mild depressive symptoms during remission is a powerful predictor of recurrence.

Many bipolar illnesses begin with one or more depressive episodes, and a substantial proportion of individuals who initially appear to have major depressive disorder will prove, in time, to instead have a bipolar disorder. This is more likely in individuals
with onset of the illness in adolescence, those with psychotic features, and those with a family history of bipolar illness. The presence of mixed features also increases the risk for future manic or hypomanic diagnosis. Major depressive disorder, particularly with psychotic features, may also transition into schizophrenia, a change that is much more frequent than the reverse.

Despite consistent differences between genders in prevalence rates for depressive disorders, there appear to be no clear differences by gender in phenomenology, course, or treatment response. Similarly, there are no clear effects of current age on the course or treatment response of major depressive disorder. Some symptom differences exist, though, such that hypersomnia and hyperphagia are more likely in younger individuals, and melancholic symptoms, particularly psychomotor disturbances, are more common in older individuals.

The likelihood of suicide attempts lessens in middle and late life, although the risk of completed suicide does not. Depressions with earlier ages at onset are more familial and more likely to involve personality disturbances. The course of major depressive disorder within individuals does not generally change with aging. Mean times to recovery appear to be stable over long periods, and the likelihood of being in an episode does not generally increase or decrease with time.

### 2.3.3 Risk Factors

**Temperamental:** Neuroticism (negative affectivity) is a well-established risk factor for the onset of major depressive disorder, and high levels appear to render individuals more likely to develop depressive episodes in response to stressful life events.

**Environmental:** Adverse childhood experiences, particularly when there are multiple experiences of diverse types, constitute a set of potent risk factors for major depressive disorder. Stressful life events are well recognized as precipitant of major depressive episodes, but the presence or absence of adverse life events near the onset of episodes does not appear to provide a useful guide to prognosis or treatment selection.

**Genetic and physiological:** First-degree family members of individuals with major depressive disorder have a risk for major depressive disorder much higher than that of the general population [11]. Relative risks appear to be higher for early-onset and recurrent forms. Heritability is approximately 40%, and the personality trait neuroticism accounts for a substantial portion of this genetic liability.

**Course modifiers:** Essentially all major non-mood disorders increase the risk of an individual developing depression. Major depressive episodes that develop against the background of another disorder often follow a more refractory course. Substance use,
anxiety, and borderline personality disorders are among the most common of these, and the presenting depressive symptoms may obscure and delay their recognition. However, sustained clinical improvement in depressive symptoms may depend on the appropriate treatment of underlying illnesses. Chronic or disabling medical conditions also increase risks for major depressive episodes. Such prevalent illnesses as diabetes, morbid obesity, and cardiovascular disease are often complicated by depressive episodes, and these episodes are more likely to become chronic than are depressive episodes in medically healthy individuals.

2.3.4 Culture-Related Diagnostic Issues

Surveys of major depressive disorder across diverse cultures have shown sevenfold differences in 12-month prevalence rates but much more consistency in female-to-male ratio, mean ages at onset, and the degree to which presence of the disorder raises the likelihood of comorbid substance abuse. While these findings suggest substantial cultural differences in the expression of major depressive disorder, they do not permit simple linkages between particular cultures and the likelihood of specific symptoms. Rather, clinicians should be aware that in most countries the majority of cases of depression go unrecognized in primary care settings and that in many cultures, somatic symptoms are very likely to constitute the presenting complaint. Among the symptoms, insomnia and loss of energy are the most uniformly reported.

2.3.5 Gender-Related Diagnostic Issues

Although the most reproducible finding in the epidemiology of major depressive disorder has been a higher prevalence in females, there are no clear differences between genders in symptoms, course, treatment response, or functional consequences. In women, the risk for suicide attempts is higher, and the risk for suicide completion is lower. The disparity in suicide rate by gender is not as great among those with depressive disorders as it is in the population as a whole.

2.3.6 Suicide Risk

The possibility of suicidal behavior exists at all times during major depressive episodes [14]. The most consistently described risk factor is a past history of suicide attempts or threats, but it should be remembered that most completed suicides are not preceded by unsuccessful attempts. Other features associated with an increased risk for completed suicide include male sex, being single or living alone, and having prominent feelings of
hopelessness. The presence of borderline personality disorder markedly increases risk for future suicide attempts.

2.3.7 Functional Consequences of Major Depressive Disorder

Many of the functional consequences of major depressive disorder derive from individual symptoms. Impairment can be very mild, such that many of those who interact with the affected individual are unaware of depressive symptoms. Impairment may, however, range to complete incapacity such that the depressed individual is unable to attend to basic self-care needs or is mute or catatonic. Among individuals seen in general medical settings, those with major depressive disorder have more pain and physical illness and greater decreases in physical, social, and role functioning.

2.3.8 Differential Diagnosis

Manic episodes with irritable mood or mixed episodes, mood disorder due to another medical condition, substance/medication-induced depressive or bipolar disorder, attention-deficit hyperactivity disorder, adjustment disorder with depressed mood, sadness etc are occasionally misdiagnosed as Major Depressive Disorder due to overlapping symptoms.

2.3.9 Comorbidity

Other disorders with which major depressive disorder frequently co-occurs are substance-related disorders, panic disorder, obsessive-compulsive disorder, anorexia nervosa, bulimia nervosa, and borderline personality disorder.

2.4 Persistent Depressive Disorder (Dysthymia)

The most evident feature of persistent depressive disorder (dysthymia) is a depressed mood that occurs for most of the day, for more days than not, for at least 2 years, or at least 1 year for children and adolescents [15]. This disorder represents a consolidation of DSM-IV-defined chronic major depressive disorder and dysthymic disorder. Major depression may precede persistent depressive disorder, and major depressive episodes may occur during persistent depressive disorder. Individuals whose symptoms meet major depressive disorder criteria for 2 years should be given a diagnosis of persistent depressive disorder as well as major depressive disorder.
2.4.1 Symptoms

A. Depressed mood for most of the day, for more days than not, as indicated by either subjective account or observation by others, for at least 2 years. In children and adolescents, mood can be irritable and duration must be at least 1 year.

B. Presence, while depressed, of two (or more) of the following [15]:

   (a) Poor appetite or overeating.
   (b) Insomnia or hypersomnia.
   (c) Low energy or fatigue.
   (d) Low self-esteem.
   (e) Poor concentration or difficulty making decisions.
   (f) Feelings of hopelessness.

C. During the 2-year period or 1 year for children or adolescents of the disturbance, the individual has never been without the symptoms in Criteria A and B for more than 2 months at a time.

D. Criteria for a major depressive disorder may be continuously present for 2 years.

E. There has never been a manic episode or a hypomanic episode, and criteria have never been met for cyclothymic disorder.

F. The disturbance is not better explained by a persistent schizoaffective disorder, schizophrenia, delusional disorder, or other specified or unspecified schizophrenia spectrum and other psychotic disorder.

G. The symptoms are not attributable to the physiological effects of a substance (e.g., a drug of abuse, a medication) or another medical condition (e.g. hypothyroidism).

H. The symptoms cause clinically significant distress or impairment in social, occupational, or other important areas of functioning.

Because the criteria for a major depressive episode include four symptoms that are absent from the symptom list for persistent depressive disorder (dysthymia), a very limited number of individuals have depressive symptoms that have persisted longer than 2 years but do not meet criteria for persistent depressive disorder. If full criteria for a major depressive episode is met at some point during the current episode of illness, they should be given a diagnosis of major depressive disorder. Otherwise, a diagnosis of other specified depressive disorder or unspecified depressive disorder is warranted.
Depression

Individuals with persistent depressive disorder describe their mood as sad. During periods of depressed mood, at least two of the six symptoms from Criterion B are present. Because these symptoms have become a part of the individual’s day-to-day experience, particularly in the case of early onset, they may not be reported unless the individual is directly prompted. During the 2-year period (1 year for children or adolescents), any symptom-free intervals last no longer than 2 months (Criterion C).

2.4.2 Development and Course

Persistent depressive disorder often has an early and insidious onset i.e., in childhood, adolescence, or early adult life [15]. By definition, it is a chronic course. Among individuals with both persistent depressive disorder and borderline personality disorder, the covariance of the corresponding features over time suggests the operation of a common mechanism.

Early onset i.e., before age 21 years, is associated with a higher likelihood of comorbid personality disorders and substance use disorders. When symptoms rise to the level of a major depressive episode, they are likely to subsequently revert to a lower level. However, depressive symptoms are much less likely to resolve in a given period of time in the context of persistent depressive disorder than they are in a major depressive episode.

2.4.3 Risk Factors

Temperamental: Factors predictive of poorer long-term outcome include higher levels of neuroticism (negative affectivity), greater symptom severity, poorer global functioning, and presence of anxiety disorders or conduct disorder.

Environmental: Childhood risk factors include parental loss or separation.

Genetic and physiological: There are no clear differences in illness development, course, or family history between DSM-IV dysthymic disorder and chronic major depressive disorder. Earlier findings pertaining to either disorder are therefore likely to apply to persistent depressive disorder. It is thus likely that individuals with persistent depressive disorder will have a higher proportion of first-degree relatives with persistent depressive disorder than do individuals with major depressive disorder, and more depressive disorders in general.

A number of brain regions (e.g., prefrontal cortex, anterior cingulate, amygdala, hippocampus) have been implicated in persistent depressive disorder. Possible poly-somnographic abnormalities exist as well.
2.4.4 Functional Consequences of Persistent Depressive Disorder

The degree to which persistent depressive disorder impacts social and occupational functioning is likely to vary widely, but effects can be as great as or greater than those of major depressive disorder.

2.4.5 Differential Diagnosis

Symptoms of Major Depressive Disorder, psychotic disorders, depressive or bipolar and related disorder due to some other medical condition, substance/medication-induced depressive or bipolar disorder and personality disorders often coexist with persistent depressive disorder.

2.4.6 Comorbidity

In comparison to individuals with major depressive disorder, those with persistent depressive disorder are at higher risk for psychiatric comorbidity in general, and for anxiety disorders and substance use disorders in particular. Early-onset persistent depressive disorder is strongly associated with personality disorders.

2.5 Disruptive Mood Dysregulation Disorder

The core feature of disruptive mood dysregulation disorder is chronic, severe persistent irritability. This severe irritability has two prominent clinical manifestations, the first of which is frequent temper outbursts. These outbursts typically occur in response to frustration and can be verbal or behavioral: the latter in the form of aggression against property, self, or others. They must occur frequently i.e., on average, three or more times per week over at least 1 year in at least two settings, such as in the home and at school, and they must be developmentally inappropriate.

The second manifestation of severe irritability consists of chronic, persistently irritable or angry mood that is present between the severe temper outbursts. This irritable or angry mood must be characteristic of the child, being present most of the day, nearly every day, and noticeable by others in the child’s environment.

Some researchers view severe, non-episodic irritability as characteristic of bipolar disorder in children, although both DSM-IV [10] and DSM-5 [9] require that both children and adults have distinct episodes of mania or hypomania to qualify for the diagnosis of bipolar I disorder. In DSM-5, the term bipolar disorder is explicitly reserved for episodic
presentations of bipolar symptoms. DSM-IV did not include a diagnosis designed to cap-
ture youths whose hallmark symptoms consisted of very severe, non-episodic irritability,
whereas DSM-5, with the inclusion of disruptive mood dysregulation disorder, provides
a distinct category for such presentations.

2.5.1 Diagnostic Criteria

A. Severe recurrent temper outbursts manifested verbally (e.g., verbal rages) and/or
behaviorally (e.g., physical aggression toward people or property) that are grossly
out of proportion in intensity or duration to the situation or provocation.

B. The temper outbursts are inconsistent with developmental level.

C. The temper outbursts occur, on average, three or more times per week.

D. The mood between temper outbursts is persistently irritable or angry most of the
day, nearly every day, and is observable by others (e.g., parents, teachers, peers).

E. Criteria A-D have been present for 12 or more months. Throughout that time, the
individual has not had a period lasting 3 or more consecutive months without all
of the symptoms in Criteria A-D.

F. Criteria A and D are present in at least two of three settings (i.e., at home, at
school, with peers) and are severe in at least one of these.

G. The diagnosis should not be made for the first time before age 6 years or after age
18 years.

H. By history or observation, the age at onset of Criteria A-E is before 10 years.

I. There has never been a distinct period lasting more than 1 day during which the
full symptom criteria, except duration, for a manic or hypo-manic episode have
been met.

J. The behaviors do not occur exclusively during an episode of major depressive disor-
der and are not better explained by another mental disorder (e.g., autism spectrum
disorder, post-traumatic stress disorder, separation anxiety disorder, persistent de-
pressive disorder [dysthymia]).

K. The symptoms are not attributable to the physiological effects of a substance or
to another medical or neurological condition.


2.5.2 Development and Course

Disruptive mood dysregulation disorder is more common than bipolar disorder prior to adolescence, and symptoms of the condition generally become less common as children transition into adulthood [16]. The onset of disruptive mood dysregulation disorder must be before age 10 years, and the diagnosis should not be applied to children with a developmental age of less than 6 years. It is unknown whether the condition presents only in this age-delimited fashion. Because the symptoms of disruptive mood dysregulation disorder are likely to change as children mature, use of the diagnosis should be restricted to age groups similar to those in which validity has been established (7-18 years). Approximately half of children with severe, chronic irritability will have a presentation that continues to meet criteria for the condition 1 year later. Rates of conversion from severe, non-episodic irritability to bipolar disorder are very low. Instead, children with chronic irritability are at risk to develop unipolar depressive and/or anxiety disorders in adulthood. Age-related variations also differentiate classic bipolar disorder and disruptive mood dysregulation disorder. Rates of bipolar disorder generally are very low prior to adolescence (<1%), with a steady increase into early adulthood (1%-2% prevalence).

2.5.3 Risk Factors

**Functional Consequences of Disruptive Mood Dysregulation Disorder:** Chronic, severe irritability, such as is seen in disruptive mood dysregulation disorder, is associated with marked disruption in a child’s family and peer relationships, as well as in school performance. Because of their extremely low frustration tolerance, such children generally have difficulty succeeding in school; they are often unable to participate in the activities typically enjoyed by healthy children; their family life is severely disrupted by their outbursts and irritability; and they have trouble initiating or sustaining friendships. Levels of dysfunction in children with bipolar disorder and disruptive mood dysregulation disorder are generally comparable. Both conditions cause severe disruption in the lives of the affected individual and their families. In both disruptive mood dysregulation disorder and pediatric bipolar disorder, dangerous behavior, suicidal ideation or suicide attempts, severe aggression, and psychiatric hospitalization are common.

**Temperamental:** Children with chronic irritability typically exhibit complicated psychiatric histories. In such children, a relatively extensive history of chronic irritability is common, typically manifesting before full criteria for the syndrome are met. Such prediagnostic presentations may have qualified for a diagnosis of oppositional defiant disorder. Many children with disruptive mood dysregulation disorder have symptoms
that also meet criteria for attention-deficit hyperactivity disorder (ADHD) and for an anxiety disorder, with such diagnoses often being present from a relatively early age. For some children, the criteria for major depressive disorder may also be met.

**Genetic and physiological:** Children presenting with chronic, non-episodic irritability can be differentiated from children with bipolar disorder in their family-based risk. However, these two groups do not differ in familial rates of anxiety disorders, unipolar depressive disorders, or substance abuse. Compared with children with pediatric bipolar disorder or other mental illnesses, those with disruptive mood dysregulation disorder exhibit both commonalities and differences in information-processing deficits. For example, face-emotion labeling deficits, as well as perturbed decision making and cognitive control, are present in children with bipolar disorder and chronically irritable children, as well as in children with some other psychiatric conditions. There is also evidence for disorder-specific dysfunction, such as during tasks assessing attention deployment in response to emotional stimuli, which has demonstrated unique signs of dysfunction in children with chronic irritability.

**Gender-Related Diagnostic issues:** Children presenting to clinics with features of disruptive mood dysregulation disorder are predominantly male. Among community samples, a male preponderance appears to be supported. This difference in prevalence between males and females differentiates disruptive mood dysregulation disorder from bipolar disorder, in which there is an equal gender prevalence.

**Suicide Risk:** In general, evidence documenting suicidal behavior and aggression, as well as other severe functional consequences, in disruptive mood dysregulation disorder should be noted when evaluating children with chronic irritability.

### 2.5.4 Differential Diagnosis

Because chronically irritable children and adolescents typically present with complex histories, the diagnosis of disruptive mood dysregulation disorder are made considering the presence or absence of multiple other conditions. Despite the need to consider many other syndromes, differentiation of disruptive mood dysregulation disorder from bipolar disorder and oppositional defiant disorder requires particularly careful assessment. Attention-deficit hyperactivity disorder, major depressive disorder, anxiety disorders, and autism spectrum disorder also exhibit a number of overlapping symptoms, therefore require careful attention while diagnosis.
2.5.5 Comorbidity

Rates of comorbidity in disruptive mood dysregulation disorder are extremely high. It is rare to find individuals whose symptoms meet criteria for disruptive mood dysregulation disorder alone. Children typically present to the clinic with a wide range of disruptive behavior, mood, anxiety, and even autism spectrum symptoms and diagnoses. However, children with disruptive mood dysregulation disorder should not have symptoms that meet criteria for bipolar disorder. In that context, only the bipolar disorder diagnosis is made. In contrast when children have symptoms that meet criteria for oppositional defiant disorder or intermittent explosive disorder along with disruptive mood dysregulation disorder, only the diagnosis of disruptive mood dysregulation disorder is assigned. Also the diagnosis of disruptive mood dysregulation disorder should not be assigned if the symptoms occur only in an anxiety provoking context, i.e. when the routines of a child with autism spectrum disorder or obsessive-compulsive disorder are disturbed, or in the context of a major depressive episode.

2.6 Premenstrual Dysphoric Disorder

Patients with premenstrual dysphoric disorder exhibit expression of mood lability, irritability, dysphoria, and anxiety symptoms that occur repeatedly during the premenstrual phase of the cycle and remit around the onset of menses or shortly thereafter. These symptoms may be accompanied by behavioral and physical symptoms. Symptoms must have occurred in most of the menstrual cycles during the past year and must have an adverse effect on work or social functioning [17]. The intensity and/or expressivity of the accompanying symptoms may be closely related to social and cultural background characteristics of the affected female, family perspectives, and more specific factors such as religious beliefs, social tolerance, and female gender role issues.

2.6.1 Symptoms

A. In the majority of menstrual cycles, at least five symptoms must be present in the final week before the onset of menses, start to improve within a few days after the onset of menses, and become minimal or absent in the week post-menses.

B. One (or more) of the following symptoms must be present:

(a) Marked affective lability (e.g., mood swings: feeling suddenly sad or tearful, or increased sensitivity to rejection).

(b) Marked irritability or anger or increased interpersonal conflicts.
Depression

(c) Marked depressed mood, feelings of hopelessness, or self-deprecating thoughts.
(d) Marked anxiety, tension, and/or feelings of being keyed up or on edge.

C. One (or more) of the following symptoms must additionally be present, to reach a total of five symptoms when combined with symptoms from Criterion B above:

(a) Decreased interest in usual activities (e.g., work, school, friends, hobbies).
(b) Subjective difficulty in concentration.
(c) Lethargy, easy fatigability, or marked lack of energy.
(d) Marked change in appetite; overeating; or specific food cravings.
(e) Hypersomnia or insomnia.
(f) A sense of being overwhelmed or out of control.
(g) Physical symptoms such as breast tenderness or swelling, joint or muscle pain, a sensation of “bloating,” or weight gain.

The symptoms in Criteria A-C must have been met for most menstrual cycles that occurred in the preceding year.

D. The symptoms are associated with clinically significant distress or interference with work, school, usual social activities, or relationships with others e.g., avoidance of social activities; decreased productivity and efficiency at work, school, or home.

E. The disturbance is not merely an exacerbation of the symptoms of another disorder, such as major depressive disorder, panic disorder, persistent depressive disorder (dysthymia), or a personality disorder; although it may co-occur with any of these disorders.

F. Criterion A is confirmed by prospective daily ratings during at least two symptomatic cycles.

G. The symptoms are not attributable to the physiological effects of a substance (e.g., a drug of abuse, a medication, other treatment) or another medical condition (e.g., hyperthyroidism).

Typically, symptoms peak around the time of the onset of menses. Although it is not uncommon for symptoms to linger into the first few days of menses, the individual has a symptom-free period in the follicular phase after the menstrual period begins. While the core symptoms include mood and anxiety symptoms, behavioral and somatic symptoms commonly also occur. Symptoms are of comparable severity (but not duration) to those of another mental disorder, such as a major depressive episode or generalized anxiety disorder.
2.6.2 Associated Features

Delusions and hallucinations are rarely reported in the late luteal phase of the menstrual cycle. The premenstrual phase has been considered by some to be a risk period for suicide.

2.6.3 Prevalence

Twelve-month prevalence of premenstrual dysphoric disorder is between 1.8% to 5.8% of menstruating women. The most rigorous estimate of premenstrual dysphoric disorder is 1.8% for women whose symptoms meet the full criteria without functional impairment and 1.3% for women whose symptoms meet the current criteria with functional impairment and without co-occurring symptoms from another mental disorder.

2.6.4 Risk Factors

**Environmental:** Environmental factors associated with the expression of premenstrual dysphoric disorder include stress, history of interpersonal trauma, seasonal changes, and sociocultural aspects in general, and female gender role in particular.

**Genetic and physiological:** Heritability of premenstrual dysphoric disorder is unknown. However, for premenstrual symptoms, estimates for heritability range between 30% and 80%, with the most stable component of premenstrual symptoms estimated to be about 50% heritable.

**Course modifiers:** Women who use oral contraceptives may have fewer premenstrual complaints than do women who do not use oral contraceptives.

2.6.5 Culture-Related Diagnostic Issues

Premenstrual dysphoric disorder is not a culture-bound syndrome and has been observed in individuals in the United States, Europe, India, and Asia. It is unclear as to whether rates differ by race. Nevertheless, frequency, intensity, and expressivity of symptoms and help-seeking patterns may be significantly influenced by cultural factors.

2.6.6 Functional Consequences of Premenstrual Dysphoric Disorder

Symptoms must be associated with clinically meaningful distress and/or an obvious and marked impairment in the ability to function socially or occupationally in the week
prior to menses. Impairment in social functioning may be manifested by marital discord and problems with children, other family members, or friends. Chronic marital or job problems should not be confused with dysfunction that occurs only in association with premenstrual dysphoric disorder.

2.6.7 Comorbidity

A major depressive episode is the most frequently reported previous disorder in individuals presenting with premenstrual dysphoric disorder. A wide range of medical (e.g., migraine, asthma, allergies, seizure disorders) or other mental disorders (e.g., depressive and bipolar disorders, anxiety disorders, bulimia nervosa, substance use disorders) may worsen in the premenstrual phase; however, the absence of a symptom-free period during the postmenstrual interval obviates a diagnosis of premenstrual dysphoric disorder. These conditions are better considered premenstrual exacerbation of a current mental or medical disorder. Although the diagnosis of premenstrual dysphoric disorder is assigned in situations in which an individual only experiences a premenstrual exacerbation of another mental or physical disorder, it can be considered in addition to the diagnosis of another mental or physical disorder if the individual experiences symptoms and changes in level of functioning that are characteristic of premenstrual dysphoric disorder and markedly different from the symptoms experienced as part of the ongoing disorder.

2.7 Substance/Medication-Induced Depressive Disorder

The notable features of substance/medication-induced depressive disorder include the symptoms of a depressive disorder, such as major depressive disorder; however, the depressive symptoms are associated with the ingestion, injection, or inhalation of a substance (e.g., drug of abuse, toxin, psychotropic medication, other medication [18]), and the depressive symptoms persist beyond the expected length of physiological effects, intoxication, or withdrawal period. As evidenced by clinical history, physical examination, or laboratory findings, the relevant depressive disorder should have developed during or within 1 month after use of a substance that is capable of producing the depressive disorder. In addition, the diagnosis is not better explained by an independent depressive disorder. Evidence of an independent depressive disorder includes the depressive disorder preceded the onset of ingestion or withdrawal from the substance; the depressive disorder persists beyond a substantial period of time after the cessation of substance use; or other evidence suggests the existence of an independent non-substance/medication-induced depressive disorder. This diagnosis should not be made when symptoms occur exclusively during the course of a delirium. The depressive disorder associated with the
Depression

substance use, intoxication, or withdrawal must cause clinically significant distress or impairment in social, occupational, or other important areas of functioning to qualify for this diagnosis.

Some medications (e.g., stimulants, steroids, L-dopa, antibiotics, central nervous system drugs, dermatological agents, chemotherapeutic drugs, immunological agents) can induce depressive mood disturbances. Clinical judgment is essential to determine whether the medication is truly associated with inducing the depressive disorder or whether a primary depressive disorder happened to have its onset while the person was receiving the treatment. For example, a depressive episode that developed within the first several weeks of beginning alpha-methyldopa (an antihypertensive agent) in an individual with no history of major depressive disorder would qualify for the diagnosis of medication-induced depressive disorder. In some cases, a previously established condition (e.g., major depressive disorder, recurrent) can recur while the individual is coincidentally taking a medication that has the capacity to cause depressive symptoms (e.g., L-dopa, oral contraceptives). In such cases, the clinician must make a judgment as to whether the medication is causative in this particular situation.

A substance/medication-induced depressive disorder is distinguished from a primary depressive disorder by considering the onset, course, and other factors associated with the substance use. There must be evidence from the history, physical examination, or laboratory findings of substance use, abuse, intoxication, or withdrawal prior to the onset of the depressive disorder. The withdrawal state for some substances can be relatively protracted, and thus intense depressive symptoms can last for a long period after the cessation of substance use.

2.7.1 Symptoms

A. A prominent and persistent disturbance in mood that predominates in the clinical picture and is characterized by depressed mood or markedly diminished interest or pleasure in all, or almost all, activities.

B. There is evidence from the history, physical examination, or laboratory findings of both (1) and (2):

   (a) The symptoms in Criterion A developed during or soon after substance intoxication or withdrawal or after exposure to a medication.

   (b) The involved substance/medication is capable of producing the symptoms in Criterion A.
C. The disturbance is not better explained by a depressive disorder that is not substance/medication-induced. Such evidence of an independent depressive disorder could include the following:

- The symptoms preceded the onset of the substance/medication use
- The symptoms persist for a substantial period of time (e.g., about 1 month) after the cessation of acute withdrawal or severe intoxication; or there is other evidence suggesting the existence of an independent non-substance/medication-induced depressive disorder (e.g., a history of recurrent non-substance/medication-related episodes).

D. The disturbance does not occur exclusively during the course of a delirium.

E. The disturbance causes clinically significant distress or impairment in social, occupational, or other important areas of functioning.

2.7.2 Development and Course

A depressive disorder associated with the use of substance (i.e., alcohol, illicit drugs, or a prescribed treatment for a mental disorder or another medical condition) must have its onset while the individual is using the substance [18] or during withdrawal, if there is a withdrawal syndrome associated with the substance. Most often, the depressive disorder has its onset within the first few weeks or 1 month of use of the substance. Once the substance is discontinued, the depressive symptoms usually remit within days to several weeks, depending on the half-life of the substance/medication and the presence of a withdrawal syndrome. If symptoms persist 4 weeks beyond the expected time course of withdrawal of a particular substance/medication, other causes for the depressive mood symptoms should be considered.

Although there are a few prospective controlled trials examining the association of depressive symptoms with use of a medication, most reports are from post-marketing surveillance studies, retrospective observational studies, or case reports, making evidence of causality difficult to determine. Substances implicated in medication-induced depressive disorder, with varying degrees of evidence, include antiviral agents (efavirenz), cardiovascular agents (clonidine, guanethidine, methyldopa, reserpine), retinoic acid derivatives (isotretinoin), antidepressants, anticonvulsants, anti-migraine agents (triptans), antipsychotics, hormonal agents (corticosteroids, oral contraceptives, gonadotropin-releasing hormone agonists, tamoxifen), smoking cessation agents (varenicline), and immunological agents (interferon) [18]. However, other potential substances continue to emerge as new compounds are synthesized. A history of such substance use may help increase diagnostic certainty.
2.7.3 Risk Factors

Temperamental: Factors that appear to increase the risk of substance/medication-induced depressive disorder can be conceptualized as pertaining to the specific type of drug or to a group of individuals with underlying alcohol or drug use disorders. Risk factors common to all drugs include history of major depressive disorder, history of drug-induced depression, and psychosocial stressors.

Environmental: There are also risks factors pertaining to a specific type of medication (e.g., increased immune activation prior to treatment for hepatitis C associated with interferon-alfa-induced depression); high doses (greater than 80 mg/day prednisone-equivalents) of corticosteroids or high plasma concentrations of efavirenz; and high estrogen/progesterone content in oral contraceptives.

Course modifiers: In a representative U.S. adult population, compared with individuals with major depressive disorder who did not have a substance use disorder, individuals with substance-induced depressive disorder were more likely to be male, to be black, to have at most a high school diploma, to lack insurance, and to have lower family income. They were also more likely to report higher family history of substance use disorders and antisocial behavior, higher 12-month history of stressful life events, and a greater number of major depressive disorder criteria. They were more likely to report feelings of worthlessness, insomnia/hypersomnia, and thoughts of death and suicide attempts, but less likely to report depressed mood and parental loss by death before age 18 years.

Determination of the substance of use can sometimes be made through laboratory assays of the suspected substance in the blood or urine to corroborate the diagnosis.

2.7.4 Suicide Risk

Drug-induced or treatment-emergent suicidality represents a marked change in thoughts and behavior from the person’s baseline, is usually temporally associated with initiation of a substance, and must be distinguished from the underlying primary mental disorders.

In regard to the treatment-emergent suicidality associated with antidepressants, a U.S. Food and Drug Administration (FDA) advisory committee considered meta-analyses of 99,839 participants enrolled in 372 randomized clinical trials of antidepressants in trials for mental disorders. The analyses reveal an absolute risk of suicide in patients taking investigational antidepressants of 0.01%. In conclusion, suicide is clearly an extremely rare treatment-emergent phenomenon.
2.7.5 Differential Diagnosis

A substance/medication-induced depressive disorder is occasionally misinterpreted as substance intoxication and withdrawal, primary depressive disorder, depressive disorder due to another medical condition etc.

2.7.6 Comorbidity

Compared with individuals with major depressive disorder and no comorbid substance use disorder, those with substance/medication-induced depressive disorder have higher rates of comorbidity with any DSM-IV mental disorder; are more likely to have specific DSM-IV disorders of pathological gambling and paranoid, histrionic, and antisocial personality disorders; and are less likely to have persistent depressive disorder (dysthymia). Compared with individuals with major depressive disorder and a comorbid substance use disorder, individuals with substance/medication-induced depressive disorder are more likely to have alcohol use disorder, any other substance use disorder, and histrionic personality disorder; however, they are less likely to have persistent depressive disorder.

2.8 Depressive Disorder Due to Another Medical Condition

The prominent feature of depressive disorder due to another medical condition is a prominent and persistent period of depressed mood or markedly diminished interest or pleasure in all, or almost all, activities that predominates in the clinical picture and that is thought to be related to the direct physiological effects of another medical condition. In determining whether the mood disturbance is due to a general medical condition, the clinician must first establish the presence of a general medical condition. Further, the mood disturbance is etiologically related to the general medical condition through a physiological mechanism. A careful and comprehensive assessment of multiple factors is necessary to make this judgment. Although there are no infallible guidelines for determining whether the relationship between the mood disturbance and the general medical condition is etiological, several considerations provide some guidance in this area. One consideration is the presence of a temporal association between the onset, exacerbation, or remission of the general medical condition and that of the mood disturbance. A second consideration is the presence of features that are atypical of primary Mood Disorders (e.g., atypical age at onset or course or absence of family history).
2.8.1 Symptoms

A. A prominent and persistent period of depressed mood or markedly diminished interest or pleasure in all, or almost all, activities that predominates in the clinical picture.

B. There is evidence from the history, physical examination, or laboratory findings that the disturbance is the direct patho-physiological consequence of another medical condition.

C. The disturbance is not better explained by another mental disorder (e.g., adjustment disorder, with depressed mood, in which the stressor is a serious medical condition).

D. The disturbance does not occur exclusively during the course of a delirium.

E. The disturbance causes clinically significant distress or impairment in social, occupational, or other important areas of functioning.

2.8.2 Associated Features

Etiology i.e., a causal relationship to another medical condition based on best clinical evidence, is the key variable in depressive disorder due to another medical condition. The listing of the medical conditions that are said to be able to induce major depression is never complete, and the clinician’s best judgment is the essence of this diagnosis. There are clear associations, as well as some neuro-anatomical correlates, of depression with stroke, Huntington’s disease, Parkinson’s disease, and traumatic brain injury [19]. Among the neuroendocrine conditions most closely associated with depression are Cushing’s disease and hypothyroidism. There are numerous other conditions thought to be associated with depression, such as multiple sclerosis. However, the literature’s support for a causal association is greater with some conditions, such as Parkinson’s disease and Huntington’s disease, than with others, for which the differential diagnosis may be adjustment disorder, with depressed mood.

2.8.3 Development and Course

Following stroke, the onset of depression appears to be very acute, occurring within 1 day or a few days of the cerebrovascular accident (CVA) in the largest case series. However, in some cases, onset of the depression is weeks to months following the CVA. In the largest series, the duration of the major depressive episode following stroke was
9-11 months on average.
Similarly, in Huntington’s disease the depressive state comes quite early in the course of the illness. With Parkinson’s disease and Huntington’s disease, it often precedes the major motor impairments and cognitive impairments associated with each condition. This is more prominently the case for Huntington’s disease, in which depression is considered to be the first neuropsychiatric symptom. There is some observational evidence that depression is less common as the dementia of Huntington’s disease progresses.

2.8.4 Risk Factors

The risk of acute onset of a major depressive disorder following a CVA (within 1 day to a week of the event) appears to be strongly correlated with lesion location, with greatest risk associated with left frontal strokes and least risk apparently associated with right frontal lesions in those individuals who present within days of the stroke. The association with frontal regions and laterality is not observed in depressive states that occur in the 2-6 months following stroke.

Gender differences pertain to those associated with the medical condition (e.g., systemic lupus erythematosus is more common in females; stroke is somewhat more common in middle-age males compared with females).

2.8.5 Suicide Risk

There is a clear association between serious medical illnesses and suicide, particularly shortly after onset or diagnosis of the illness. Thus, it would be prudent to assume that the risk of suicide for major depressive episodes associated with medical conditions is not less than that for other forms of major depressive episode, and might even be greater.

2.8.6 Functional Consequences of Depressive Disorder Due to Another Medical Condition

In general, it is believed, but not established, that a major depressive episode induced by Cushing’s disease will not recur if the Cushing’s disease is cured or arrested. However, it is also suggested, but not established, that mood syndromes, including depressive and manic/hypomanic ones, may be episodic (i.e., recurring) in some individuals with static brain injuries and other central nervous system diseases.
2.8.7 Differential Diagnosis

Number of symptoms of depressive disorder due to other medical conditions assimilate with symptoms of depressive disorders not due to other medical conditions, medication-induced depressive disorder, adjustment disorders etc [20]. It is important to note that, the onset of the medical condition is itself a life stressor that could bring on either an adjustment disorder or an episode of major depression. The major differentiating elements are the pervasiveness the depressive picture and the number and quality of the depressive symptoms that the patient reports or demonstrates on the mental status examination.

2.8.8 Comorbidity

Conditions comorbid with depressive disorder due to another medical condition are those associated with the medical conditions of etiological relevance. It has been noted that delirium can occur before or along with depressive symptoms in individuals with a variety of medical conditions, such as Cushing’s disease. The association of anxiety symptoms, usually generalized symptoms, is common in depressive disorders, regardless of cause.

2.9 Other Specified Depressive Disorder

This category applies to presentations in which symptoms characteristic of a depressive disorder that cause clinically significant distress or impairment in social, occupational, or other important areas of functioning predominate but do not meet the full criteria for any of the disorders in the depressive disorders diagnostic class. The other specified depressive disorder category is mentioned in situations in which the clinician chooses to communicate the specific reason that the presentation does not meet the criteria for any specific depressive disorder.

Examples of presentations that can be specified using the ‘other specified’ designation include the following:

- **Recurrent brief depression**: Concurrent presence of depressed mood and at least four other symptoms of depression for 2-13 days at least once per month (not associated with the menstrual cycle) for at least 12 consecutive months in an individual whose presentation has never met criteria for any other depressive or bipolar disorder and does not currently meet active or residual criteria for any psychotic disorder.
• **Short-duration depressive episode (4-13 days):** Depressed affect and at least four of the other eight symptoms of a major depressive episode associated with clinically significant distress or impairment that persists for more than 4 days, but less than 14 days, in an individual whose presentation has never met criteria for any other depressive or bipolar disorder, does not currently meet active or residual criteria for any psychotic disorder, and does not meet criteria for recurrent brief depression.

• **Depressive episode with insufficient symptoms:** Depressed affect and at least one of the other eight symptoms of a major depressive episode associated with clinically significant distress or impairment that persist for at least 2 weeks in an individual whose presentation has never met criteria for any other depressive or bipolar disorder, does not currently meet active or residual criteria for any psychotic disorder, and does not meet criteria for mixed anxiety and depressive disorder symptoms.

2.10 Unspecified Depressive Disorder

This category applies to presentations in which symptoms characteristic of a depressive disorder that cause clinically significant distress or impairment in social, occupational, or other important areas of functioning predominate but do not meet the full criteria for any of the disorders in the depressive disorders diagnostic class. The unspecified depressive disorder category is used in situations in which the clinician chooses not to specify the reason that the criteria are not met for a specific depressive disorder, and includes presentations for which there is insufficient information to make a more specific diagnosis (e.g., in emergency room settings).

2.11 Remission

Remission of depressive disorder is categorized as:

**Partial remission:** Symptoms of the immediately previous major depressive episode are present, but full criteria are not met, or there is a period lasting less than 2 months without any significant symptoms of a major depressive episode following the end of such an episode.

**Full remission:** During the past 2 months, no significant signs or symptoms of the disturbance were present.
Chapter 3

Related Works

Considering the discussion in chapter 2, it can be deduced that patients with depression suffer a great deal of psychological as well as physical hardship. Therefore these patients require close observation and immediate support at the moment of requirement. Traditionally, psychotherapy in combination with medication is prescribed as treatment course, but patients exhibit a tendency to get forgetful of appointment with psychologist or taking medicine in time. Moreover, specially in eastern culture, psychological disorders are not treated with equal importance as physical ailment. In particular, patients with depression has a tendency to stay aloof from regular activities and hide their psychological state. To address these issues and find a way out, a significant number of research have been conducted to sense psychological state of individuals. Some of these systems involve active participation of users while the others passively collect the data to determine mental state.

The difficulties in correlating natural expression with individual’s mental state have been explored by Hoque et al. [21]. Their proposed system determines the difference between natural smile and frustrated smile in accordance with the context. In their extended work [22], 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 [23], 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.

Necessity of identifying universal features to classify psychological state was perceived by Sung et al. [24]. They organized a controlled study on a group of subjects diagnosed
with major depressive disorder. During their stay at health centre for taking treatment, sensor reading of heart rate, skin conductance, physical movement, amount of vocal activity and the characteristics of speech, sedentary state, sleep, and restlessness were collected. The data was plotted against self reported psychological state. The authors found two features most strongly correlated with depression such as: pitch variation in the voice as well as motion energy. While discussing the findings the authors surmised that the controlled environment at health centre affected activities of the subjects, therefore longitudinal studies comprising of larger patient group in different context will bring about more comprehensive detection and monitoring systems.

A data mining model for detecting depressed users in social network based on sentiment analysis is proposed in [25]. Although the depression detection model is proposed based on Chinese vocabulary, the authors claim that basic idea of the frame, especially the sentence structure pattern mining and principle micro-blog features related to depression could be explicitly extended to other language scenarios. In [26], the authors suggested that smart phone 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 [8], a continuous sensing app 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.

A similar study was performed in-home by [27]. Assuming single-person home, they attached sensors to stove, freezer, refrigerator, kitchen sink, microwave, spice cabinet, plate cabinet, glasses and cups cabinet, front door, cleaning closet, medicinal closet, bathroom sink, trash can, wardrobe closet, and shower in order to monitor sleep, movement, speech and body-weight of the subject. Besides a CES-D scale was set to self report the subject’s mood. The two week long monitoring resulted in establishment of strong co-relation between reduction in sleep duration and onset of a depressive episode. Although results of this study did not exhibit any significant relation between depression and the other parameters, the authors suggested that weight indexes of the parameters vary from person to person and are also context dependent, therefore needs rigorous calibration.

With a view to assist psychiatric professionals in making diagnosis and treatment decisions about patients with bipolar disorder authors in [28] introduced a smart phone based mood tracking and analysis system, called SmartMood. In this system statistics are generated for each behavioral factor to quantitatively describe the user’s mood status by analyzing voice data captured from a smart phone while the user is having a conversation to identify a new manic episode. They propose an adaptive running range
method to estimate the normal mood range for each behavioral factor of the user to avoid false alarm. When pitch and amplitude of the voice data obtained from a call session falls out of the estimation of normal mood, the possibility of onset of a manic episode is indicated.

From the above discussion, it is evident that several physical and behavioral symptoms are correlated to individual’s psychological state. Among these heart rate is considered as a reliable parameter due to several reasons. Firstly, heart rate data can be collected by external sensors without active participation of the individual. Moreover, different physiological and psychological fluctuations are instantly reflected in person’s heart rate. Nirjon et. al. have exploited these feature of heart rate to assist people in achieving certain goals of physical activities by selecting a suitable music play-list. However, rather than heart rate, Heart Rate Variability (HRV) is considered as a more reliable psychophysiological marker of mental and physical well-being [29]. Variability in heart rate is mediated by the parasympathetic (vagus) nerves, which slow heart rate, and the sympathetic nerves, which accelerate it. Healthy cardiac activity involves a high degree of beat-to-beat variability, which provides a protective effect against myocardial infarction and heart failure. High parasympathetic tone helps to maintain heart stability and protect against possible adverse cardiac events [30]. Reductions in HRV, as measured by high-frequency (HF) measures reflecting reductions of parasympathetic activity at respiratory frequencies [31], have been reported in patients with Major Depressive Disorder in comparison with healthy control subjects [32], [33].

A number of studies have been conducted to establish correlation between HRV and Major Depression. Some of these studies considered time domain methods to determine HRV ([34], [33], [35], [36]), while others used frequency domain methods ([37]) or combination of both ([38], [39], [32]). A brief discussion on these to measurement techniques is presented in section 5.2.

To determine whether older primary care patients with a Major Depressive Disorder (MDD) have lower heart rate variability (HRV) compared to non-depressed patients, Van der Kooy et al. performed a cross-sectional comparison of 136 elderly persons with MDD and 136 non-depressed controls of matched for age and gender [33]. Depression was determined according to the DSM–IV criteria. HRV of the subjects was measured with an electrocardiogram (ECG) during a 5-minute supine rest. The result of the study indicates statistically significant decrease in HRV in MDD patients compared with controls.

Agelink et al. also performed a similar study over 35 patients with Major Depression fulfilling criteria of DSM-III-R [38]. HRV of these patients were compared with a healthy control group of 64 students, hospital stuffs, office employees and workers. They performed both time domain and frequency domain measurement of HRV obtained from ECG. According to their results, the logRMSSD value in the patients with MDD were
significantly lower in comparison to healthy controls (Rest: $1.36 \pm 0.24$, Deep respiration: $1.49 \pm 0.25$) in both at rest and during deep respiration. Moreover this score also varied according to severity (measured using Hamilton Depression Scale (HAM-D)); i.e. patients with higher severity were recorded with lower logRMSSD value (Rest: $1.15 \pm 0.26$, Deep respiration: $1.22 \pm 0.34$) in comparison to patient group with moderately severe depression (Rest: $1.30 \pm 0.24$, Deep respiration: $1.43 \pm 0.35$).

Both of these studies indicate that logRMSSD of HRV can be a useful indicator of depression and can also provide insight of the severity of the disorder. Therefore, in addition to the existing systems, we propose our HRV based automated depression detection system, capable of triggering a support system when necessary.
Chapter 4

Survey

As discussed in chapter 2, symptoms, development, help-seeking attitude, response to treatment etc. vary from region to region. Therefore design of a depression detection and support system needs to be context aware and adaptable. As the initial step of the research, 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

To obtain the above mentioned objectives, we conducted the survey on randomly chosen 120 participants. 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.

4.1 Depression Scale

Depression level of the participants was measured using an established scale [40]. The scale was developed keeping in mind the socio-economic and cultural context of Bangladesh. The authors followed a structured procedure consisting of three standard
steps while developing the scale: (1) Construction of items, (2) Experimental tryout (3) Validation

- **Construction of items:** The initial version of the scale consisted of 48 item. Later on the basis of consent of a judge panel consisting of 16 members including experienced psychiatrists and psychologists the first experimental version was developed consisting of 61 items.

- **Experimental tryout:** After development, the scale was applied on 72 clinically diagnosed patients with depressive disorders along with a control group of 72 non-depressed individuals. Applying one way ANOVA [41] on the outputs a revised version of 30 items 5 points scale was constructed. The response options are (1) Not at all applicable, (2) Not applicable, (3) Uncertain, (4) A bit applicable and (5) Totally applicable. All items are scored in positive direction, i.e. higher score indicates higher level of depression.

- **Validation:** The scale was validated on the basis of experimental tryout on 263 participants including 124 diagnosed depressed patients and 139 non-depressed individuals. The experimental results exhibit strong positive correlation between the newly developed scale with internationally established scales, i.e. DSM IV [10], the hospital anxiety and depression scale (HADS) [42] and client’s self reported depression. According to the statistical analysis of the experimental results, the scale is applicable for both screening and indicating severity level of an individual.

According to the scale, the depressed subjects are decided to be categorized in four levels: minimal, mild, moderate and high. Possible range of scores is 30 to 150; range 30-100 indicates minimal level of depression, 101-114 indicates mild level, 115-123 indicates moderate level and higher than 124 indicates severe level of depression. The scale is presented in table 4.1.
## Depression Scale

Below is a list of the ways you might have felt or behaved. Please select in what extent you have felt this way during the past week. Please indicate your answer by putting tick mark to one of the possible five answers given at the right side of the statements. Please make sure to answer all the questions:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Statement</th>
<th>Not at all applicable</th>
<th>Not applicable</th>
<th>Uncertain</th>
<th>Somewhat applicable</th>
<th>Totally applicable</th>
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<tbody>
<tr>
<td>1.</td>
<td>I feel lack of peace in my mind.</td>
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<td>2.</td>
<td>Recently I experience low mood.</td>
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<td>3.</td>
<td>My future is dark.</td>
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<td>4.</td>
<td>My condition will deteriorate in future.</td>
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<td>5.</td>
<td>I am finished.</td>
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<td>6.</td>
<td>I think, life is very painful.</td>
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<td>7.</td>
<td>Currently I feel I am a complete failure.</td>
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<td>8.</td>
<td>I find no pleasure anywhere.</td>
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<td>9.</td>
<td>I feel myself very inferior.</td>
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<td>10.</td>
<td>My self esteem has been reduced in every aspect.</td>
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<td>11.</td>
<td>I feel like, people feel pity on me.</td>
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<td>12.</td>
<td>Life is meaningless.</td>
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<td>13.</td>
<td>Often I feel like crying.</td>
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<td>14.</td>
<td>Often I feel irritated.</td>
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<td>15.</td>
<td>I find no interest in anything.</td>
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<td><strong>16.</strong></td>
<td>Recently I cannot think and take decision.</td>
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<td><strong>17.</strong></td>
<td>Recently I cannot concentrate to anything.</td>
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<td><strong>18.</strong></td>
<td>I cannot remember as before.</td>
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<td><strong>19.</strong></td>
<td>I feel weak and become exhausted easily.</td>
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<td><strong>20.</strong></td>
<td>I sleep less than before.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>21.</strong></td>
<td>I sleep more than before.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>22.</strong></td>
<td>My temper has turned irritable.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>23.</strong></td>
<td>My appetite has been reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>24.</strong></td>
<td>My appetite has been increased.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>25.</strong></td>
<td>I have lost weight (Not because of intentional dieting).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>26.</strong></td>
<td>I think speed of my work has reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>27.</strong></td>
<td>I cannot laugh in response to a funny event.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>28.</strong></td>
<td>My sexual desire has been reduced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>29.</strong></td>
<td>I cannot participate in social activities as before.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>30.</strong></td>
<td>Recently I cannot perform academic and professional activities as before.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.2 Distribution of Depression Among Participants

Applying the standard scale discussed in section 4.1 the level of depression the participants experienced in previous 7 days of the survey was determined. Distribution of depression among participants is given in table 4.2.

<table>
<thead>
<tr>
<th>Depression Level</th>
<th>Number of Participants</th>
<th>Percentage</th>
<th>Depression Frequency</th>
<th>Average Length of Depression Episode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>83</td>
<td>69.17</td>
<td>Once in a month</td>
<td>3 days</td>
</tr>
<tr>
<td>Mild</td>
<td>14</td>
<td>11.67</td>
<td>Once a week</td>
<td>2 days</td>
</tr>
<tr>
<td>Moderate</td>
<td>8</td>
<td>6.67</td>
<td>Twice a week</td>
<td>2 days</td>
</tr>
<tr>
<td>Severe</td>
<td>7</td>
<td>5.83</td>
<td>Once in a month</td>
<td>17 days</td>
</tr>
</tbody>
</table>

From Table 4.2 and figure 4.1, 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.
4.3 Questionnaire Design and Verification

The second part of the survey aimed to determine behavioral traits of the participants belonging to different level of depression. The questionnaire was developed keeping in mind that the automated system will be developed using devices of regular use in daily life, i.e. smart-phone, smart-watch etc. Therefore standard range of the parameters available from these devices include smart-phone usage for conversation, SMS; usage of social network; preference of music genre etc. were included in the questionnaire. The questionnaire has been reviewed by Ms Nowshin Nahar, Senior psycho-social counsellor at Eastern University, Dhaka. It is presented below:

Survey on behavioral fluctuation because of depression

1. Identify your age group:
   (a) Below 15
   (b) 15-20 years
   (c) 21-25 years
   (d) 25-30 years
   (e) 30-40 years
   (f) Above 40

2. Identify your gender:
   (a) Male
   (b) Female

3. Which level of education have you completed?
   (a) Primary School
   (b) S.S.C
   (c) H.S.C
   (d) Graduation
   (e) Post-Graduation
   (f) Higher

4. What is your occupation?
   (a) Student
(b) Service
(c) Business
(d) Teaching
(e) Others

5. Do you use smart phone?
   (a) Yes
   (b) No

6. How often do you feel depressed?
   (a) Once or twice a week
   (b) Once or twice in a month
   (c) Several months later
   (d) Rarely

7. How long does your depressed state continue?
   (a) Several hours
   (b) Several days
   (c) Several weeks
   (d) Several months
   (e) Longer

8. Which type of conversation do you prefer during depression?
   (a) No conversation at all
   (b) Face to face
   (c) Phone call
   (d) SMS
   (e) Facebook chat

9. Whom do you feel comfortable to talk during depression?
   (a) Friends
   (b) Family members
   (c) Cousins
   (d) Relatives
   (e) Others (Please mention whom:_______)
10. How frequently do you make a phone call during depression?
   (a) Once in 30 minutes
   (b) Once in an hour
   (c) Once in 2-3 hours
   (d) Once after 6 hours
   (e) No calls at all

11. How long do you continue your telephone conversation during depression?
   (a) 0 minutes (I don’t answer calls)
   (b) less than 5 minutes
   (c) 5-10 minutes
   (d) 10-30 minutes
   (e) longer (How long:______)

12. How frequently do you send SMS during depression?
   (a) I don’t send or reply to SMS when depressed
   (b) Once in 5-10 minutes
   (c) Once in 30 minutes
   (d) Once in an hour
   (e) Rarely

13. How is the length of your SMS during depression?
   (a) As usual
   (b) Longer than usual
   (c) Shorter than usual

14. How many Facebook friends do you have?
   (a) less than 100
   (b) 100-200
   (c) 200-500
   (d) More than 500

15. How frequently do you chat with your Facebook friends during depression?
   (a) As usual
   (b) More frequently than usual
16. How long do you chat on Facebook (or in other Social Networking sites) during depression?
   (a) As usual
   (b) Longer than usual
   (c) Less than usual
   (d) I don’t chat while depressed

17. Where do you prefer to stay while depressed?
   (a) At home
   (b) Among friends
   (c) At workplace
   (d) To go out

18. What type of music do you prefer while depressed?
   (a) Classical
   (b) Pop music
   (c) Rock music
   (d) Country music
   (e) Religious
   (f) I don’t listen to music at depression

In Table 4.3 we present some observations on behavioral traits of the participants with different levels of depression from the survey, from which we get valuable insight for the detection system.
Table 4.3: Distribution of depression among participants

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>**Preferred way of   **</td>
<td>39.5% face to face and 34% none</td>
<td>None (53%)</td>
<td>None (50%)</td>
<td>43% face to face and 43% phone</td>
</tr>
<tr>
<td><strong>conversation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Preferred company</strong></td>
<td>54% friends and 21% family members</td>
<td>Friends (53%)</td>
<td>Friends (50%)</td>
<td>Friends (43%)</td>
</tr>
<tr>
<td><strong>for conversation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average interval</strong></td>
<td>11 hours (39% don’t use phone while depressed)</td>
<td>53% don’t use phone while depressed</td>
<td>10 hours (37% don’t use phone while depressed)</td>
<td>6 hours</td>
</tr>
<tr>
<td><strong>between phone call</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average phone call</strong></td>
<td>7 minutes</td>
<td>8 minutes</td>
<td>10 minutes</td>
<td>16 minutes</td>
</tr>
<tr>
<td><strong>duration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average interval</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>between SMS</strong></td>
<td>40% avoid messaging over phone</td>
<td>Once in three hours</td>
<td>Once in three hours</td>
<td>43% avoid messaging over phone</td>
</tr>
<tr>
<td><strong>Length of SMS</strong></td>
<td>32% send shorter sms and 28% send longer sms</td>
<td>60% send shorter sms and 33% send longer sms</td>
<td>71% send longer sms</td>
<td>43% send longer sms</td>
</tr>
<tr>
<td><strong>Interval between</strong></td>
<td>30% chat less frequently, 11% chat more frequently and 28% don’t chat at all</td>
<td>33% chat more frequently and 33% don’t chat at all</td>
<td>37% chat less frequently, 25% chat more frequently and 25% don’t chat at all</td>
<td>86% chat less frequently or don’t chat at all</td>
</tr>
<tr>
<td><strong>Facebook chatting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Duration of Facebook</strong></td>
<td>26% chat shorter than usual, 16% chat longer</td>
<td>40% chat longer</td>
<td>25% chat shorter, 25% chat longer and 25% don’t chat at all</td>
<td>86% chat less frequently or don’t chat at all</td>
</tr>
<tr>
<td><strong>chat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Among a few noticeable observations, Table 4.3 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). These behaviour have been graphically represented in figure 4.2 and 4.3.

**Table 4.3:**

<table>
<thead>
<tr>
<th>Preferred place to stay while depressed</th>
<th>35% prefers home, 35% like to go out and 22% prefers to stay with friends</th>
<th>40% prefers home, 40% like to go out</th>
<th>37.5% prefers home, 50% like to go out</th>
<th>57% prefers home, 28.6% like to go out</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Preferred type of music while depressed</th>
<th>20% don’t listen to music, 45% listen to classical music and 14% prefer rock music</th>
<th>66.7% listen to classical music</th>
<th>50% listen to classical music</th>
<th>43% don’t listen to music</th>
</tr>
</thead>
</table>

**Figure 4.2:** Preferred company for conversation
Most of our participants prefer staying at home while depressed, but a notable percentage show interest in going out. It is also noticeable in figure 4.4 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.

4.4 Psychologist’s Viewpoint

We consulted our survey outcome with psychologist Ms. Nowshin Nahar to establish the rationale between the behavioral trends reflected by our survey participants and the facts already established. The psychologist’s review goes as follows:

"Music, movie, social network, etc. are used as therapeutic tools for depression treatment [43]. 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 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 [44].
Chapter 5

System Design and Implementation

5.1 System Design

From the survey outcome, it is evident that psychological state of an individual is reflected in several day-to-day behaviour and activities, including phone call interval and duration, pattern of test messaging through SMS and social network, preferred company and place etc. In the light of our survey data analysis and study of some previous research we have designed a depression detection and support system comprising of three modules:

- Data collection
- Data analysis
- Support system

5.1.1 Module 1: Data collection

In the 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 can provide data on the following:

- **Heart rate**: A study conducted by Harvard Medical School [45] shows that, cardiovascular system is directly affected by mind and mood. Psychological states
Data Collection
- Wearable device with sensors.
  Collects data on:
  - Heart rate
  - Sleep duration and quality
  - GPS location
  - Communication through phone, email, Social Network

Data Analysis
- Analyze data
- Detect degree of depression
- Keep track of depression episode length

Support System
- Smart phone application.
- Receives signals from wearable device.
If depression level is **mild**:
  - Play favorite music
  - Show selected/favorite images
If depression episode is **long**:
  - Send message to a favorite person (Randomly chosen from a pre-selected list)
  - If that person does not call or reply the message in a certain amount of time, chose another person from the list
If Depression level is **severe**:
  - Seek help from psychologist/psychological support organizations

**Figure 5.1:** Proposed System Outline

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 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 [46] 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.

### 5.1.2 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.

### 5.1.3 Module 3: Support system

The support system will vary from person to person and might require rigorous calibra-
tion. 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

5.2 HRV Based Depression Detection and Support System

In this section we present our experimental prototype of depression detection and support system. From previous studies and our survey outcome it is evident that, psychological state of an individual can be determined by various measurable parameters like conversation patterns, movement, social interaction, sleep, heart-rate etc. which are easily obtained from sensors available in smart-phones and smart-watches of everyday use. Among these parameters we have considered Heart Rate Variability to develop our experimental detection system because of its reliability and generality.

5.2.1 Heart Rate Variability (HRV)

HRV refers to the variations in the beat intervals or correspondingly in the instantaneous HR. Heart Rate Variability (HRV) is also familiar as 'cycle length variability', 'RR variability' (where R is a point corresponding to the peak of the QRS complex of the ECG wave; and RR is the interval between successive Rs), and 'heart period variability'. It is the physiological phenomenon of variation in the time interval between heart beats. The degree of variability in the HR provides information about the functioning of the nervous control on the HR and the heart’s ability to respond [47].

Heart Rate Variability is measured by the variation in the beat-to-beat interval. Methods used to detect beats include: ECG, blood pressure, ballistocardiograms, and the pulse wave signal derived from a photoplethysmograph (PPG). ECG is considered superior because it provides a clear waveform, which makes it easier to exclude heartbeats not originating in the sinoatrial node. The term "NN" is used in place of RR to emphasize the fact that the processed beats are "normal" beats. Figure 5.2 illustrates the measurement of HRV.

HRV can be evaluated by a number of methods which can be categorized in two major types: Time Domain Methods and Frequency Domain Methods. Also some other methods have been proposed, such as non-linear methods, geometric methods etc.
Time Domain Methods

In time domain methods, either the heart rate at any point in time or the intervals between successive normal complexes are determined. In a continuous ECG record, each QRS complex (Figure 5.3) is detected, and the normal-to-normal (NN) intervals of the instantaneous heart rate is determined. Time Domain Methods are analysed to calculate variables such as:

- **SDNN**: The standard deviation of NN intervals. SDNN is 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. Equation 5.1 gives the formula to calculate SDNN.

\[
SDNN = \sqrt{\frac{1}{N-1} \sum_{n=2}^{N} [I(n) - \bar{I}]^2}
\]  

(5.1)

Here \(N\) is the Total number of heart beats over the time period and \(\bar{I}\) is the mean of RR intervals; calculated as:

\[
\bar{I} = \frac{1}{N-1} \sum_{n=2}^{N} I(n)
\]  

(5.2)

- **RMSSD**: Root mean square of successive differences. RMSSD is the square root of the mean of the squares of the successive differences between adjacent NNs. It gives estimate of short-term components of HRV. RMSSD is determined as:

\[
RMSSD = \sqrt{\frac{1}{N-2} \sum_{n=3}^{N} [I(n) - I(n-1)]^2}
\]  

(5.3)

- **SDSD**: Standard deviation of successive differences. SDSD provides the standard deviation of the successive differences between adjacent NNs.

- **NN50**: The number of pairs of successive NNs that differ by more than 50 ms.

- **pNN50**: The proportion of NN50 divided by total number of NNs.

- **NN20**: The number of pairs of successive NNs that differ by more than 20 ms.

- **pNN20**: The proportion of NN20 divided by total number of NNs.

- **EBC**: Estimated breath cycle. EBC is often provided in data acquisition scenarios where HRV feedback in real time is a primary goal. EBC is the range (max-min) within a moving window of a given time duration within the study period. The windows can move in a self-overlapping way or be strictly distinct (sequential) windows. EBC derived from over 10-second and 16-second sequential and overlapping windows has been shown to correlate highly with SDNN.

While SDANN and SDNN estimates long term components and overall HRV respectively, for estimation of short term components RMSSD is treated as a useful measure [48].

**Frequency Domain Methods**

Frequency domain HRV metrics are based on the estimated power spectral density (PSD)
of the NN (normal to normal RR) intervals. These methods assign bands of frequency and then count the number of NN intervals that match each band. The common definition of bands \cite{49} are as follows:

<table>
<thead>
<tr>
<th>Total HRV power</th>
<th>0 - 0.5 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-low frequency (ULF) power</td>
<td>0 - 0.0033 Hz</td>
</tr>
<tr>
<td>Very low frequency (VLF) power</td>
<td>0.0033 - 0.04 Hz</td>
</tr>
<tr>
<td>Low frequency (LF) power</td>
<td>0.04 - 0.15 Hz</td>
</tr>
<tr>
<td>High frequency (HF) power</td>
<td>0.15 - 0.4 Hz</td>
</tr>
<tr>
<td>Very high frequency (VHF) power</td>
<td>0.4 - 0.5 Hz</td>
</tr>
</tbody>
</table>

In addition, the LF/HF ratio is commonly cited as a parameter of interest. In healthy adults, the LF/HF ratio is typically between 1.5 and 4.5.

Several methods of frequency domain analysis are in practice. Power spectral density (PSD), using parametric or nonparametric methods, provides basic information on the power distribution across frequencies. One of the most commonly used PSD methods is the discrete Fourier transform. Methods for the calculation of PSD may be generally classified as nonparametric and parametric. In most instances, both methods provide comparable results.

The advantages of the non-parametric methods are:

1. In most cases Fast Fourier Transform [FFT] is adapted. The simplicity of the algorithm is one of the advantages of this method.

2. The high processing speed.

On the other hand the advantages of parametric methods are:

1. Smoother spectral components that can be distinguished independent of preselected frequency bands

2. Easy post processing of the spectrum with an automatic calculation of low- and high-frequency power components with an easy identification of the central frequency of each component

3. Accurate estimation of PSD even on a small number of samples on which the signal is supposed to maintain stationarity.
The basic disadvantage of parametric methods is the need of verification of the suitability of the chosen model and of its complexity (that is, the order of the model).

In addition to classical FFT-based methods used for the calculation of frequency parameters, a more appropriate PSD estimation method is the Lomb–Scargle (LS) periodogram [49]. Analysis has shown that the LS periodogram can produce a more accurate estimate of the PSD than FFT methods for typical RR data. Since the RR data is an unevenly sampled data, another advantage of the LS method is that in contrast to FFT-based methods it is able to be used without the need to resample and detrend the RR data [50].

5.2.2 An HRV Based Depression Detection System

Several studies indicate that HRV can be a useful indicator to understand psychological state of an individual. In our study we have considered the experimental results provided by Agelink et al. as base values to detect depression. The HRV is measured using sensor data provided by smart watch. As a sample we have used Microsoft Band 2 [51] which reads Heart Rate Interval as long as the user is wearing the band. To receive the RR interval, an Android application has been developed. Initially after informing the user about some basic privacy policy (Figure 5.4.(a)) the application asks to provide a few demographic information of the user, i.e. name, age, email address etc. Particulars of an emergency contact person is also recorded by the user (name, email address, phone no.). The UI of the profile creation is illustrated in Figure 5.4.(b). Once the profile is created, the user is asked for Heart Rate Interval subscription consent by the application. Once the user grants permission, the application continues reading RR interval data in background. logRMSSD is calculated over 50 RR interval readings, and this gives one depression reading according to the experimental result of Agelink et al. [38]. After taking 50 such readings, if the user is found with more than 10% readings indicating depression, an SMS and/or email notification is sent to the emergency contact person. For experimental purpose an UI is created to view the reading, which is illustrated in Figure 5.4.(c).

This application automatically detects depression without any active participation of the user. Privacy of the user’s personal information is fully protected, as the system does not upload any data to any remote server. Therefore it does not require internet connection either. Such automated systems can be of use in monitoring patients with depression who are forgetful of their personal well-being, therefore requires timely support from their friend and family. The notification system is designed as automatic, because background studies and our survey (Chapter 4) imply that there is a tendency
Figure 5.4: Depression detection application screen shots

(a) Privacy policy
(b) User profile
(c) HRV data
(d) Depression Log
of self-withdrawal from social activities among depressed individuals. There is a provision to store depression history in the application database (Figure 5.4.(d)), which can be helpful for the patients under supervision of psychologist to monitor effectiveness of the treatment and improvement of the patient. Again, this history can be viewed only with consent of the account possessor.

At present the system considers only HRV as indicator of depression and detects depression according to reference logRMSSD value of HRV. We have future plan to add more indicators according to our survey outcome, and we also plan to make the system context adaptive incorporating machine learning methodologies.

### 5.2.3 Experimental Results

To evaluate correctness of the system we designed an experimental setup. We experimented the system on 20 volunteers and at the same time assessed their psychological condition with an established scale [40]. Finally we compared outcome of our system with the scale output to measure accuracy of our system.

**Participants:** We randomly selected 20 volunteers and took their consent to conduct the experiment. This volunteer group is a combination of graduate students, faculty members and executives of different departments of Eastern University. We approached all of them in person and assured them that the experiment will be completely anonymous and none of their personal information will be shared with anyone. All of them verbally consented to co-operate with us. Age range of the participants is 25-35. 7 of them are male and 13 are female. All of the participants possess sound physique and not consuming any anti-depressant medication.

**Methodology:** The experiment was run on each participants for around 20 minutes. For these 20 minutes the put on the smart-watch which is synchronized with an android phone. The smart-watch collected Heart Rate Interval of the participant and sent the data to the smart phone via Bluetooth. The Log RMSSD HRV is calculated taking 50 consecutive Heart Rate Interval readings. We considered 20 consecutive HRV values to determine psychological state of the participants without relaxing quality of performance of the system. If the system detects more than 20% of the readings in the range below the standard value (according to [38]. ) participant is considered depressed by the system.

**Validation:** For validation of the result we have used the standard scale provided by [40]. During the 20 minutes experiment the participants were asked to fill up the 5 point 30 items scale. After the experiment, the result obtained by the system was compared with the outcome of the scale. Unlike the scale our system only differentiate between depressed and non-depressed individuals. Minimal level of the depression scale
is considered as non-depressed, while mild, moderate and severe levels are categorized as depressed. The result of the experiment is presented in Table 5.1 and summarized in Figure 5.5.

Table 5.1: Experimental Result.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>System Output</th>
<th>Scale Output</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant 1</td>
<td>Depressed</td>
<td>Mild depression</td>
<td>True positive</td>
</tr>
<tr>
<td>Participant 2</td>
<td>Depressed</td>
<td>Mild depression</td>
<td>True positive</td>
</tr>
<tr>
<td>Participant 3</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 4</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 5</td>
<td>Depressed</td>
<td>Minimal Depression</td>
<td>False positive</td>
</tr>
<tr>
<td>Participant 6</td>
<td>Depressed</td>
<td>Mild Depression</td>
<td>True positive</td>
</tr>
<tr>
<td>Participant 7</td>
<td>Depressed</td>
<td>Minimal Depression</td>
<td>False positive</td>
</tr>
<tr>
<td>Participant 8</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 9</td>
<td>Depressed</td>
<td>Minimal Depression</td>
<td>False positive</td>
</tr>
<tr>
<td>Participant 10</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 11</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 12</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 13</td>
<td>Depressed</td>
<td>Mild Depression</td>
<td>True positive</td>
</tr>
<tr>
<td>Participant 14</td>
<td>Depressed</td>
<td>Mild Depression</td>
<td>True positive</td>
</tr>
<tr>
<td>Participant 15</td>
<td>Depressed</td>
<td>Minimal Depression</td>
<td>False positive</td>
</tr>
<tr>
<td>Participant 16</td>
<td>Depressed</td>
<td>Minimal Depression</td>
<td>False positive</td>
</tr>
<tr>
<td>Participant 17</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 18</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 19</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
<tr>
<td>Participant 20</td>
<td>Not depressed</td>
<td>Minimal Depression</td>
<td>True negative</td>
</tr>
</tbody>
</table>
**Results:** The experimental result shows that in 80% of cases, the system has correctly determined the psychological state of the participants. 20% cases are determined as false positive. Several reasons can be considered responsible behind this phenomenon. The scale used to validate the system requires conscious response regarding one’s psychological state. Depressed individuals are often found to hide their emotional condition. Momentary stress at workplace or personal life can also be a reason to generate low HRV denoting depression. It is also evident that false negative reading is 0% of the experimental cases, which indicates that this system can be reliable to monitor and support depressed individuals.

**End Users’ Feedback:** While designing the system, we have considered two types of end user: depressed individuals and psychologists. When we asked their opinion about our project, all of our survey and field test participants responded positively regarding necessity of such system. Mainly they appreciated data collection system without active participation of users and the automatic support system. We have talked to psychologists at Department of Educational and Counseling Psychology, University of Dhaka and Psycho-social Counselling Unit, Eastern University. They gave very enthusiastic feedback. Particularly they liked continuous monitoring, support system and storing data log of user’s psychological state. They emphasized that it will help them to monitor their patients.
Chapter 6

Conclusion and Future Direction

The goal of this thesis is to direct usage of technological advancements in betterment of humanity. We have addressed the psychological disorder depression that causes social, economic and health burden all around the globe. We have discussed its variations, symptoms, severity and potential risk factors in detail. With proper understanding of the problem, developing a system which is capable of detecting depression automatically and providing necessary support was determined as the objective of the research.

At start-up we conducted a survey that reveals significant correlation between depression level and behavioral changes of individuals. We developed our model to detect depression based on individuals’ physical state, behavior, and social interaction according to the outcome of the survey. We have assessed the survey outcome and the system design under psychologist’s viewpoint. Then a module of the intelligent wearable system based on our developed model has been implemented. Our intelligent wearable system is an integrated system involving an Android application and a wearable smart-watch connected with a smart-phone. It consist of depression detection and support system. The detection system detects signs of depression by periodically collecting log RMSSD of Heart Rate Variability of the user. The support system receives the signs of depression from the detection system. If depression is detected, an automatic SMS alert is sent to an emergency contact requesting to provide necessary support. In experimental setup, the system performed with high accuracy rate, which establishes its reliability for monitoring depressed individuals and providing them support when necessity arises.

We are analyzing the possibility of measuring several other parameters that we found useful in detecting depression from our survey, which include sleep, movement and communication pattern of the user. Making the system context aware and user adaptive
by introducing machine learning methodology is also considered as future work. Implementation of the complete system is in progress and we look forward to investigate its effectiveness in practical field.
Bibliography


