

**Designing a Smartphone Application to Predict Depression in Adolescents with Machine Learning**  
(Technical Topic)

**College Mental Health Resources in Response to COVID-19**  
(STS Topic)

**A Thesis Project Prospectus Submitted to the**

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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## Introduction

Depression in adolescents has been increasing over the past 10 years; “in 2018, about 1 in 7 adolescents aged 12 to 17 (14.4 percent) had a past year major depressive episode, or 3.5 million adolescents” (Lipari, 2018, p. 4). Stressful life events, like the COVID-19 pandemic, can be a factor in increased rates of adolescent suicidality (Sj et al., 2020). Adolescents need social interaction, but due to COVID-19 there is lack of direct, face-to-face interaction among adolescents which may lead to behavioral and social impediments triggering more mental health issues later in life (Qi et al., 2020, p. 514). The patient suffering from depression may not know which factors increase likelihood of their depression (Frost et al., 2013, p.133). Many adolescents are not diagnosed with mental health issues because depressive symptoms can be confused with biological and social changes that occur during adolescence (Thapar et al., 2012, p. 1060).

This capstone project will consist of a technical project and research around science, technology, and society (STS). Mental health in adolescents is why the technical portion of this research will attempt to predict the future mental health state of an adolescent using objective data. To develop mental health predictions for adolescents with depression, the technical project will focus on developing a smartphone application that uses machine learning models to analyze environmental, social, behavioral, and biological factors. This predictive machine learning model will be developed to enhance the insights into an adolescent’s level of depression. Identifying key factors in an adolescent’s depression helps individualize the care provided to the adolescent.

The STS research will provide an understanding of colleges’ and universities’ mental health resources available to students. Depressive symptoms are more prevalent during stressful times like a pandemic (Sj et al., 2020). COVID-19 forced many schools to turn to online learning

and limit the amount of in-person interactions on campuses (Baker et al., 2020). Due to the increase in adolescents and college students experiencing mental health issues, colleges need to provide adequate resources to their students. This research will compare colleges' and universities' mental health resources and student satisfaction from these resources in previous years compared to this year.

### **Designing a Smartphone Application to Predict Adolescent Depression with Machine Learning**

According to Harari et al. (2016), “[i]n existing procedures for collecting data on behavior, researchers typically ask participants to estimate the frequency or duration of past or typical behaviors” (p. 839). This approach to patient self-monitoring, accomplished via survey data, serves as a major tool for diagnosing and tracking depression. However, self-monitoring for depressive symptoms presents several shortcomings. Patients with depression may be less likely to fill out surveys, because consistently recognized symptoms have included fatigue and lack of motivation (Substance Abuse and Mental Health Services Administration, 2016, Table 29). Likewise, patients not actively experiencing symptoms may not feel that self-monitoring is necessary. These issues are further exacerbated in adolescent patients who might be reticent to share survey information with parents or healthcare providers.

Due to the various shortcomings of self-monitoring, the current mobile applications for adolescent mental health care do not provide optimal user experience nor accuracy regarding mental state. The mobile application Moodring avoids self-monitoring issues by not requiring active input from patients to track and predict mental health states. This is facilitated by two paradigms known as passive sensing and machine learning. According to Cornet and Holden

(2017), passive sensing describes “...the capture of data about a person without extra effort on their part” (p. 120). Luxton (2016) explains machine learning as “...a core branch of AI [artificial intelligence] that aims to give computers the ability to learn without being explicitly programmed” (p. 3).

The approach to monitoring adolescent depression with passive sensing builds on previous approaches to combat mental health problems. For example, in 2013, Frost, Doryab, Faurholt-Jepsen, Kessing, and Bardram used passive sensing in an application called Monarca to successfully estimate mood in adults with bipolar disorder using only passive sensor data, such as location, calls and messages, and activity levels (p. 142). In 2011, Burns et al. created an application called “Mobilyze!,” which successfully used machine learning models to predict patient mood, emotion, and motivational state based on a variety of sensor values from smartphones (p. 1). Currently, an application called Monsenso also monitors patients with their smartphone sensors and relays the data to both patients and health care providers (Monsenso). Moodring plans to extend these approaches to adolescents with depression, who may be ideal candidates due to their high levels of smartphone use.

The team will use quantitative data from passive sensing coupled with machine learning to identify and forecast depressive symptoms, and provide suggestions to alleviate symptoms. The AWARE framework will be used to conduct passive sensing, collecting sensor data from smartphones with features such as location, screen time, phone calls, and distance travelled. The AWARE framework is an open source programming framework that “...captures hardware, software, and human-based data from smartphones” (<https://awareframework.com>). Using this sensor data, the team will engineer other useful features that may indicate signs of depression

such as amount of sleep, amount of time spent at home, and frequency of communication with peers.

The team will create a machine learning model to provide greater insight into an adolescent patient's mental state based on features most relevant to the patient. The application will relay this prediction, as well as a summary of the relevant features, to the patient in a dashboard. This approach allows for an individualized experience for each adolescent and provides an opportunity to understand how their behaviors contribute to their mental state. If the patient wants to fill out a questionnaire about their mood, they may do so to provide a basis of comparison for the machine learning model, referred to as the ground truth. However, the application will not require any questionnaire data in order to summarize and forecast mental health status for the patient.

The anticipated deliverable for the technical project is a minimum viable product for this smartphone application. Figure 1 shows the flow of information between the application and the patient. The application will continually process sensor data, forecast mental state, and provide visualizations for the patient. Initially, the team will develop the application using sensor data from their own smartphones to provide a proof of concept for a lightweight smartphone application to forecast mental health status and summarize sensor data. The team will test the accuracy of the application's machine learning predictions using de-identified patient data from Afsaneh Doryab's previous studies.

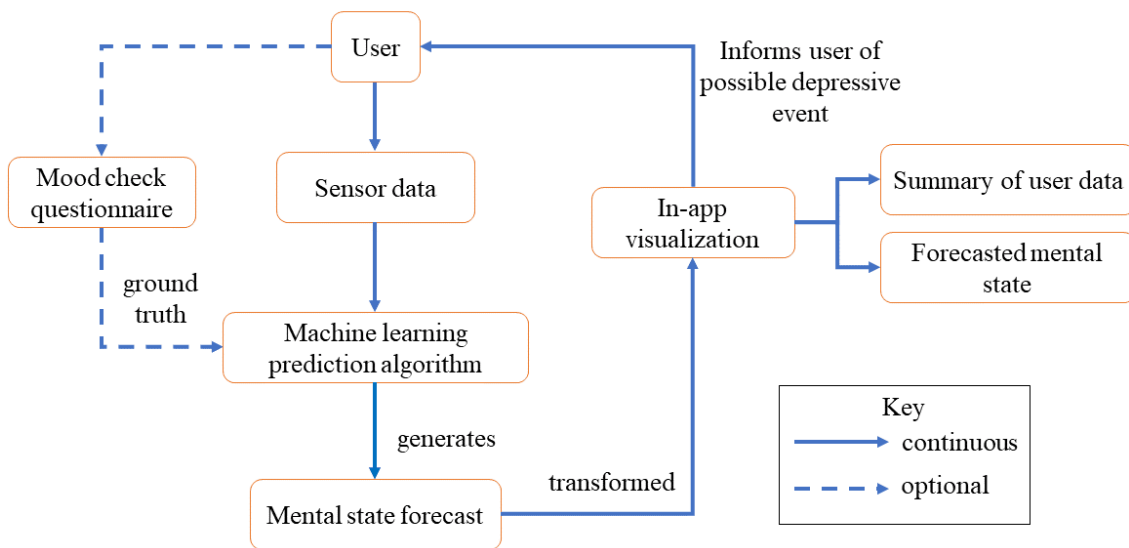


Figure 1. Moodring concept map. This figure lays out how Moodring will collect data and relay information to the user. (Adapted by Meredith Grehan (2020) from Neil Singh, 2020).

This combination of technology will be able to accomplish the goal for several reasons. First, passive sensing alleviates the burden of self-monitoring by the patient due to the ability to derive information from quantitative measurements provided by mobile sensors. Traditional approaches to self-monitoring allow for user bias which decreases the accuracy and integrity of analysis. Second, the deliverable will help circumvent this issue by consistently collecting unbiased, objective data through passively monitoring the adolescent. The forecasting methodology for mental health status under the context of depression in adolescents serves as a novel aspect of the deliverable. Currently, technology that monitors mental health exists, but to the team’s knowledge, no other mobile applications can predict depressive states in adolescents. Third, another novel and major improvement over present work is that this modeling will all occur on the device on which the application is installed. This will allow for greater privacy over existing practices, which use external storage, such as “the cloud.”

The desired outcome of the smartphone application is for patients and their caretakers to gain an understanding of the factors affecting their mental state. Specifically, patients should learn what behaviors, such as reduced sleep or more time spent at home, contribute to their depression. The application also provides an opportunity to facilitate communication between adolescents and their parents and care providers. Adolescents control consent over sharing their data summary and mental health forecast with their parents and care providers. This would help those who care for the adolescent quickly understand the patient's mental state and corresponding influential factors.

The Moodring project is sponsored by the United States National Institute of Health, and is a collaboration between the University of Pittsburgh, the University of Virginia, and a Pittsburgh-area software company called NuReIm. At the University of Virginia, Afsaneh Doryab holds the grant from the National Institute of Health.

### **College Mental Health Resources in Response to COVID-19**

Failure to treat mental health issues has a major impact on one's social and physical development, which will affect the person later in life (Kieling et al., 2011). College is a developmental time for adolescents to become young adults. In 2013, about 41.6% of college students experienced anxiety and 36.4% experienced depression (*College Students' Mental Health Is a Growing Concern, Survey Finds*, n.d.). The number of college students experiencing depression and anxiety will likely be higher in 2020 due to COVID-19. Further, the American College Health Association found that 60% of college students now find it harder to access mental health care during COVID-19 (*New Research Uncovers COVID-19's Impact on College Student Mental Health and Well-Being*, n.d.). Studies have shown that college students

experiencing depression or other mental health issues see a half a letter grade drop in their grade point averages, which could lead to delayed graduation or even dropping out (Bradley et al., 2016). Colleges and universities need to be equipped with the proper mental health care to meet the needs of developing adolescents attending their schools.

COVID-19 (Coronavirus Disease 2019) is an infectious disease spread through droplets of saliva, coughs, or sneezes (*Coronavirus*, n.d.). The first case was confirmed on January 20, 2020 in Washington State; the patient had recently returned from Wuhan, China, where the disease originated (Holshue et al., 2020). Many of the first cases were due to travel, but in March, cases and hospitalizations rapidly increased. COVID-19 ceased normal social interactions; states now have limits and protocols for social gatherings, restaurant capacities, and mask mandates. Studies have shown that during a pandemic, people will have more negative emotions, including increased symptoms of anxiety and depression (Bavel et al., 2020, p. 463).

The University of Washington was the first school to move classes to a virtual environment to limit the spread, and they were followed by most other colleges and universities (Baker et al., 2020). Soon virtual learning became the new normal for much of the country, as most colleges and universities moved classes online for the rest of the spring semester. The conditions of the COVID-19 pandemic did not improve over the summer, so colleges and universities had to decide if students should return to campus in the fall. Some schools are completely locked down and only conducting online classes remotely, and some schools have students back on campus and are conducting online and in-person classes. Students are experiencing a stressful learning environment with the combination of online learning and limited social interaction. With schools trying to limit in-person activities, what does this mean for access to and effectiveness of mental health resources at colleges and universities?



The STS research will be based on the following questions, but will be limited to the University of Virginia. How have colleges and universities changed their mental health resources to combat the increase in anxiety and depression rates among students? Are these changes adequate enough to meet the demand? This research will use Actor Network Theory to determine if colleges and universities are adequately providing mental health resources to their students, a main actor in this network. This will be a comparative case study based on the University of Virginia's mental health resources in previous year to this year. There will be multiple comparisons including: the amount of mental health resources, utilization rates among students, and access, satisfaction, and promotion of these resources. I will conduct interviews with the mental health department at the University of Virginia (UVa) to determine if UVa thinks they are providing adequate resources for students. I will also interview UVa students to obtain their views on the adequacy of mental health resources available to them. If the information from the UVa mental health resources and students is not sufficient, then the research will focus on a different college or university. The main goal will be to determine if the mental health resources provided by colleges and universities, while looking solely at UVa, are keeping up with the likely increase in mental health issues in their students due to COVID-19.

### **Conclusion**

The technical project of this capstone will help personalize mental health care and make the process autonomous. It will develop a minimum viable product of a machine learning model that analyzes data to predict depressive behaviors in adolescent patients. This model will use passive sensing to collect the data to eliminate any need for the patient's input. The results from the model will be shown in a summarized dashboard. Personalized information about mental

health will help the adolescent patient, caretaker, and clinician better understand that adolescent's depression.

The comparative case study of UVa's mental health resources will determine if the University of Virginia has taken the right steps to handle the likely increase in mental health issues in students due to COVID-19. This case study will provide a comprehensive analysis of mental health resources UVa has provided in previous years compared to this year. The case study will provide insights into UVa's provision of mental health resources and highlight any areas in which UVa could improve.

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