Moodring: A Mobile Application for Monitoring Adolescents' Depression
(Technical Paper)

A Priori Assessment of Autonomy of Mobile Health Technologies

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

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Fall 2020

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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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Approved via Qualtrics survey platform due to COVID-19 pandemic

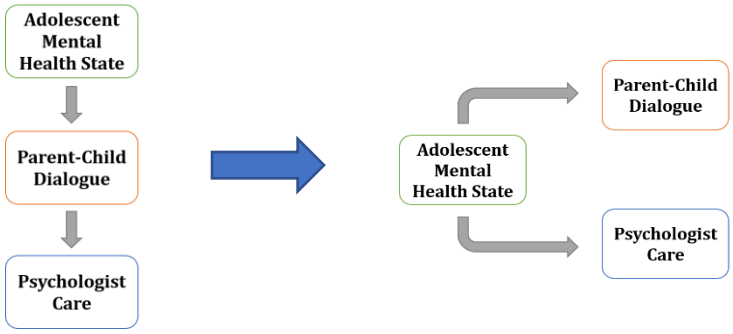
Introduction and Motivation

Depression is a global public health concern. With current events like the Coronavirus pandemic, studies worldwide like Fitzpatrick, Harris, and Drawve (2020) and Huang and Zhao (2020) show mental health assessment from the pandemic via web surveys. The COVID-19 pandemic has also had adverse effects on teenage mental health according to a study from Ellis, Dumas, and Forbes (2020). With or without these exogenous events, depression and mental illness remain concerning. A group that requires special practices for mental health intervention are adolescents, mostly due to being in a unique stage of physical and social development. Current literature provides specialized approaches, including a unique assessment methodology by Reynolds (2010), research on sex differences from Allgood-Merten, Lewinsohn, and Hops (1990) and Petersen, Sarigiani, and Kennedy (1991), along with effects of depression on everyday teenage life in Jaycox et al. (2009).

An influential factor that may exist among teenagers receiving mental health care is the role of independence (Church, 1994). As a result, we may witness a reluctance with children when discussing mental health with their parents (A. Doryab, personal communication, Fall 2020). This can create a dangerous obfuscation in treating an adolescent with depression, as parents will not have knowledge of possible harmful ideations (A. Radovic, personal communication, October 16th, 2020). To visualize this phenomenon, in the left part of Figure 1 , we see that the adolescent mental health state needs to go through the parent before reaching the psychologist. We hope to discuss methods that reduce the inherent information opacity, streamlining information transferal between an adolescent and their provider, as seen on the right of the arrow in Figure 1.

Figure 1

Present Versus Anticipated Information Flow



Note: This shows the parallel phenomenon anticpated through our proposed candidate solution, between major actors in the network

A proposed methodology of streamlining is to integrate two upcoming technologies: passive sensing and mobile applications. Passive sensing from Cornet and Holden (2018) is "the capture of data about a person without extra effort on their part" (p. 120). In healthcare, this is mostly facilitated through portable electronics (i.e. smart watches, fitness watches, and cell phones). Cornet and Holden (2018) also emphasize two major benefits of passive sensing, that is being less user-intensive and allowing for up-to-date feedback (p.121). We will investigate the efficacy of passive sensing in mental health care from both a technical and sociotechnical viewpoint. The technical portion of this project will involve the creation of a mobile application that integrates passive sensing to provide insights to both teens and health care providers on prediction of depressive events. The sociotechnical portion will discuss the current gaps in mental health care for teenagers, specifically with respect to the user and system autonomy provided through each implementation.

Technical Motivation

Since suicide is the second most frequent cause of death in America for the 10-14 age bracket and the 15-24 age bracket (National Institute of Mental Health (n.d.), Table 1), a need for tracking and control of adolescent depression is in strong demand. One method for diagnosing and tracking depression and ideation is self-monitoring, primarily accomplished via survey data. The issue with this method due to some consistently recognized symptoms of depression, fatigue and lack of motivation (Substance Abuse and Mental Health Services Administration, 2016, Table 9). These may decrease the probability that depressed patients would fill out surveys, and patients not actively experiencing symptoms may feel that self-monitoring is not necessary. This issue is further exacerbated for adolescent patients who might be reticent to share survey information with anyone. Our application will address this issue by not requiring active input from patients in order to track and predict emotional states. Mental health problems do not improve alone; diagnosis and monitoring are key for patients, parents, and care-givers to make informed intervention plans and prevent patient harm.

We will use quantitative data from passive sensing to identify depression symptoms and suggest behaviors to alleviate symptoms. Our approach allows for an individualized experience for each adolescent through viewing and understanding their data. Our research also intends to increase communication between adolescents and their parents and care providers. The insights we expect to discover from passive sensing may help increase patient autonomy and improve parents and care providers' understanding of the adolescent's illness.

To balance both autonomy and efficacy of care, we propose a smartphone application named *Moodring*. *Moodring* will integrate the passive sensing approaches, presenting

interpretable and informative mental health predictions. *Moodring* is sponsored by the United States NIH (under Grant Number: 1-R44-MH122067-01), and is a collaboration between: University of Pittsburgh (c/o Ana Radovic), University of Virginia, and a Pittsburgh-area software company, NuRelm (c/o Sam Shabaan). The advisor on this project is Afsaneh Doryab, jointly appointed in Computer Science and Systems Engineering.

This method to monitoring adolescent depression with passive sensing builds on previous methods to combat depression. According to Harari et al. (2016), traditional research methods use self-reported surveys, but patients may forget to pay close attention to their behavior or may succumb to social desirability bias when answering (p. 839). Conversely, approaching depression with passive sensing provides objective data to clinicians without requiring action from the patient. For example, in 2013, Frost et al. used passive sensing in an application called *Monarca* to successfully estimate mood in adults with bipolar disorder using only sensor data (p. 142). We plan to extend this approach to adolescents with depression, who may be even less motivated to take regular surveys to monitor their mental health state.

Our candidate solution will involve a multi-faceted, data-centric approach, with collection, processing, and visualization. We will collect data about our users to use in our machine learning algorithms to then forecast their mental health. This data collection is the core of utilizing the passive sensing principle. We will be using wearable devices along with smart phones to record sensor data. This sensor data will then be processed and forecasted using machine learning techniques. Finally, we will visualize and display our results, and information about the raw signals and possible future mental health states to the users, their parents, and mental health care providers. Patients, caretakers and clinicians will quickly be able to understand the patient's mental state and what factors influence it from the visualizations,

increasing the efficacy of treatment regimens. An overview of this methodology can be found in

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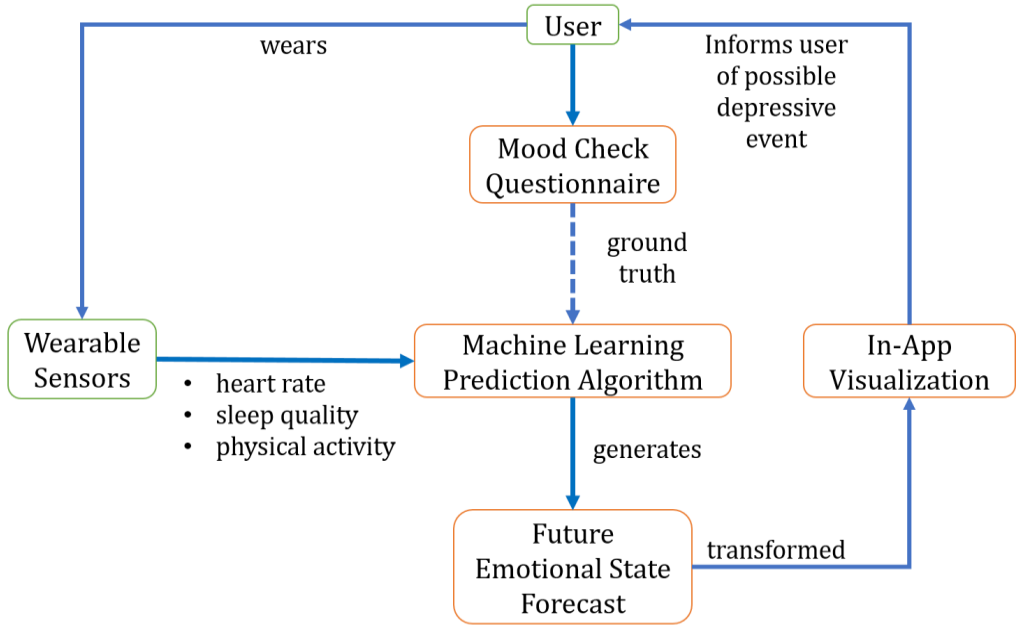
Concept Map for Moodring Implementation



[1]*Note*. This concept map describes how information will flow in the candidate application implementation (reproduced from Bonaquist et al., 2020)

This approach to adolescent mental health care will contribute novelty in three major domains: utilization of passive sensing, quantification and leveraging of machine learning for emotional state prediction, along with a paradigm known as "on-device" modeling, taken from Dhar et al. (2020). Our primary utilization of passive sensing technology is to alleviate the burden of self-monitoring from the adolescent, which may increase adherence to treatment regiments. A secondary benefit of our technique is the quantification of emotions: traditional survey-like approaches to self-monitoring may result in biased answers. Our deliverable will help circumvent this bias by making emotion estimates from mobile tracking. The last concept,

[1] These authors contributed equally to the work, and thus are listed alphabetically in the bibliography.

named “on-device machine learning,” refers to machine learning models being constructed on phones (Dhar et al., 2020). This independent approach to collection, storage, and analysis may increase use of the application due to increased data privacy. If the associated results are strong, this work will be sent to the SIEDS conference at UVa, with possible further opportunities for a top-tier journal or conference in mobile computing.

Sociotechnical Aspects

A major barrier in the treatment of adolescent depression is the willingness of teenagers to discuss their mental health, whether with their practitioner or caretaker. Papers like Stapley, Midgley, and Target (2016) describe difficulties in communication between teenagers with depression and parents (p. 623). A study discussing depressed adolescent autonomy can be found by Pace and Zappulla (2010). We will redefine a concept known as **autonomy**, as the degree of latitude and flexibility the adolescent (or any individual) has in a certain mental health treatment. Example treatments include talk therapy, medication, along with smartphone applications, much like *Moodring*. In order to develop technologies that are efficacious, they must grant a maximal amount of autonomy to the user. In the context of smartphone-based solutions, autonomy can be investigated through three major sources: patient privacy, maintenance and treatment independence. These criteria were developed from project requirements for the *Moodring* project with personal communications with three advisors: A. Doryab, A. Radovic, S. Shabaan, throughout the Fall of 2020.

- **Patient privacy** refers to the ability the user has to control where their information flows. (personal communication, A. Radovic, October 16th, 2020)

- **Maintenance** will describe to the degree of actions needed by the user. An app which requires no input from the user will have less "Maintenance" from a survey application which requires attention every two hours.
- **Treatment independence** will be narrowly defined as the degree of external actors being needed for treatment, that is whether from another human or medication

The current literature revolving the evaluation and progress in mobile health are mostly in the form of survey and concept (conference/journal) papers. Related papers on adolescent mental-health care applications can be found by Grist, Porter, and Stallard (2017). Reconnecting to the technical investigation, papers utilizing passive sensing for mental-health care innovations are discussed in Trifan, Oliveira, and Oliveira (2019). However, a paucity exists on literature that integrates the aforementioned user autonomy paradigm described above. We will create a methodology and survey paper much like the aforementioned, however integrating the autonomy criteria discussed above. With the use of systematic review methods like PRISMA from Moher et al. (2009), the novelty of this paper will come from creating an organized approach (possibly as a methodology or framework) that identifies gaps in current alternatives for mental health care for adolescents as a result of various shortcomings in system autonomies.

The concurrent research on present methods will inform the construction of the technical portion of this project, highlighting an interdependence between the socio-technical and technical aspects. The identification of gaps in research will better inform researchers and industrial leaders on necessary future innovations in applications of adolescent mental health assessment. A feature of technologies would enable differing levels of access to patient data, based on whether accessor is caretaker or clinician (personal communication, A. Radovic, October 16th, 2020). However, this autonomy is not without cost. An example that intersects with the patient

privacy idea is, the withholding of information could obfuscate parent check-ins on teenagers during depressive periods (personal communication, A. Radovic, October 16th, 2020). Another example that affects the maintenance paradigm is that the patient may wish to contribute information they feel may be impactful on the predictions or assessments from the software, but the software does not have a feature to include this information. The inherent safety and practical tradeoffs that generate sources of risk may be integrated into the autonomy assessment.

Conclusions

We present two approaches, one technical and another sociotechnical to contribute to the field of treatment of adolescent depression. Specifically, we are investigating smart-phone implementations for their efficacy and usability in prediction of future emotions by teenagers with depression. The technical portion of this project focuses on the former, attempting to create a product that incorporates the aspects of passive sensing and machine learning, to better inform insights of future emotional states. The sociotechnical portion wishes to emphasize the latter assessment, that is efficacy with respect to current work in the field. This assessment, performed via a methodology paper, will allow for both academics and practitioners to address gaps in this constantly growing field. This will also inform the technical portion through influencing project requirements by identifying frontiers for novelty. Upon conclusion of documentation, if these artifacts are of strong novelty and possess potential to contribute to the field, these will be cross-published in both UVa sponsored venues (like the SIEDS conference and Libra), along with major journals or conferences in the field of mobile computing (like ACM Ubicomp).

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