Applications of Digital Health and Patient Monitoring in Opioid Addiction Recovery

A Technical Report submitted to the Department of Computer Science

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Rishub Handa

Spring, 2022

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

Daniel Graham, Department of Computer Science

Rosanne Vrugtman, Department of Computer Science

Applications of Digital Health and Patient Monitoring in Opioid Addiction Recovery

CS4991 Capstone Report, 2022

Rishub Handa
Computer Science
The University of Virginia
School of Engineering and Applied Science
Charlottesville, Virginia USA
rh4gh@virginia.edu

Abstract
Over 3 million Americans have been diagnosed with Opioid Use Disorder (OUD). 91% of patients relapse at least once due to a lack of continuous oversight in their treatment, which typically consists of withdrawal medication and weekly counseling. To reduce the risk of relapse, I developed a digital health service that monitors when patients consume their withdrawal medication and connects them to appropriate resources at times of high risk via a Digital Therapeutic Chatbot (DTC). The medication tracker was a 3D printed Wi-Fi and cellular enabled dispenser programmed in C++. The patient portal and DTC were developed with the MERN stack. 2 initial pilot studies suggested that this technology is viable in a clinical setting and improves patient demeanor towards their recovery. The combined studies had a Net Promoter Score (NPS) of 92%. Future improvements may entail developing a reliable decentralized network of peer recovery specialists and utilizing Machine Learning techniques to more accurately predict when a patient will relapse.

1 Introduction

In 2020, 93,000 Americans died from drug overdoses, which indicates a 30% increase in drug fatalities from the previous year [1]. Over 70% of these deaths are related to opioid abuse, largely due to increased use in fentanyl and other synthetic opioids [2]. For the 16 million patients worldwide currently suffering from OUD, recovery is incredibly difficult, and 91% of patients relapse at least once. Traditional detox programs are largely ineffective, as 59% of patients relapse within the first week and 80% relapse within the first month of sobriety [3, 4].

Medication Assisted Treatment (MAT) is a form of recovery in which a provider prescribes medication to mitigate withdrawal symptoms (e.g. Suboxone, Methadone, etc.) with weekly/bi-weekly counseling to address the psychosocial impacts of addiction. This treatment program has been found to be the most effective form of outpatient treatment. Patients treated with Suboxone are 4 times less likely to have a positive drug screen and are 23% less likely to visit the emergency room due to lethal overdose [5, 6]. In spite of this, 55% are not retained in treatment after one year [7]. Lower patient disenrollment is crucial, as they are >4 more likely to fatally overdose the first month after stopping treatment due to lower tolerance and higher cravings [8].

From the >200 interviews I conducted with patients and providers, I found that patients discontinue treatment due to a lack of continuity in care. Addiction is a chronic illness that affects patients 24/7, and their living circumstances tend to be discouraging towards recovery; the majority of patients tend to be homeless or from low income backgrounds. When patients are disengaged from treatment outside of the clinic, and return to environments that promote addiction, they are more likely to relapse.

Low engagement in care also leads to decreased medication compliance. While on Suboxone, patients are unable to abuse opioids and feel its euphoric effects for 24-48hrs. Thus, it is critical to ensure patients continue to take their Suboxone as prescribed.

2 Related Works

PositiveLinks is a digital health intervention for patients in managing HIV. Similar to OUD, HIV is a chronic disease that is best managed when the patient is retained in long term care. HIV and OUD also share a similar demographic of patients with low socioeconomic backgrounds with low medical literacy, and HIV is a major risk factor for people who abuse drugs via injection. The PositiveLinks team demonstrated an increase in 12-month retention in care (RIC) from 51% to 81% [9, 10]. Edwards et al. further corroborated the efficacy of a text based digital therapy for substance abusers with HIV [11].

3 MedLock

3.1 System Overview

To improve continuity of care in outpatient MAT, I founded a company called MedLock in October 2018. I developed a medication dispenser for Suboxone strips and a Digital Therapy Chatbot (DTC) that provided patients with coping strategies and connected them to Peer Recovery Specialists (PRS) during times of high risk of relapse based on their medication usage data. PRS are people who have previously recovered from addiction and now volunteer their time to help others. Our platform made this data available to providers and counselors to better inform their medical decisions.

Figure 1: MedLock Suboxone tracker and DTC.

Patients would dispense Suboxone strips as recommended by their prescription and record the intensity of their withdrawal symptoms and cravings via the colored buttons on the device. This data informed the DTC which would alter its communication based on its prediction of the patient's likelihood of relapse. At low probabilities, it would check in on the patient as a friend, providing important educative facts about their recovery and coping strategies. At times of high risk, the DTC would alert a designated peer recovery specialist to reach out to the patient and connect them with time-sensitive resources as needed.

3.2 Technology

The MedLock web application presented data about the patient to the provider and PRS team. It was developed with ReactJS for the frontend, NodeJS for the backend, and MongoDB as the NoSQL database. The application was hosted on an Ubuntu webserver. To comply with the Health Insurance Portability and Accountability Act (HIPAA), I ensured that all patient health information (PHI) was encrypted in transit, encrypted at rest, and redundant across multiple data centers. For further security, I whitelisted the IP addresses of the computers within the clinic network with the NGINX Reverse Proxy.

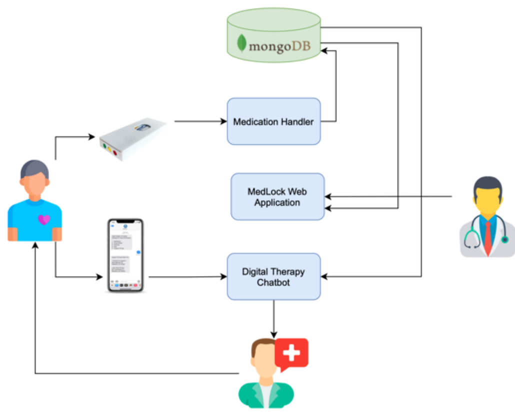

Figure 2: System overview of key stakeholders and technologies.

The DTC was built in NodeJS and utilized the Twilio API for SMS communication with patients. The DTC calculated the patient's relapse risk level based on their average symptom/craving score recorded with the three buttons on the device as well as the time they last took their medication. When the Suboxone medication is past its half-life, for example, patients are more likely to experience cravings, especially during times of high stress. The system was unit tested with the Jest framework.

The medication tracker was the complex aspect of this system. As shown in Figure 3, the Suboxone strip passes through two copper capacitive plates, which detects the dispensing with a high pass filter. The capacitance and resistance values were calculated such that when a 10 kHz wave is passed through the capacitor, the signal is attenuated based on the capacitance of the copper plates. Capacitance is calculated as:

$$C = \frac{\in_0 * A}{d}$$

In this equation, A is the area of the copper plates, $\in_0$ is the permittivity of the dielectric material between the plates, and d is the distance between the plates.

As the strip passed between the plates, the dielectric material changed from only air to air with an aluminum strip. This altered the capacitance and thus the signal from the sensor. However, since the area of the copper plates were >1.5 in^2, the plates were subject to high interference from the environment, thus producing a volatile signal. To correct the signal, I implemented exponential smoothing and additive seasonality decomposition over the data. The Wi-Fi and Cellular enabled microcontroller that implemented this algorithm was programmed in C++.

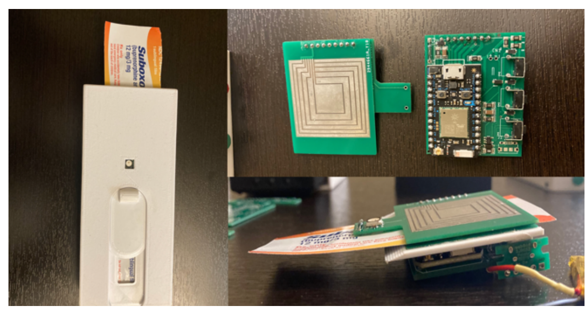

Figure 3: Inner mechanisms of the Suboxone strip tracker.

4 Results

I was able to raise over $90,000 through pitch competitions and grants to fund the development of the technology and to pilot it in a clinical setting. I developed partnerships with 5 clinics, including some of the largest clinic chains in the mid-Atlantic. In spite of multiple delays due to COVID-19, the MedLock team launched 3 pilot studies with 17 patients in the summer and fall of 2020. The first study yielded inconclusive results due to technical and logistical failures associated with building and deploying MedLock with a remote team. The second and third pilots proved to be more successful in demonstrating the feasibility of this technology in the clinic. 92% of patients indicated that they would recommend MedLock to a friend struggling with addiction. Providers described that they were more confident in accurately assessing their patients with this data during consultations.

5 Conclusion

The opioid epidemic impacts millions of Americans with physical and psychological distress. With an incredibly high relapse rate, it is very difficult to recover from addiction, even with assistance prescription medications and psychotherapy. Prior work has shown that digital health can improve RIC for HIV patients and substance abusers. Our initial pilots with the MedLock medication tracker and DTC corroborate the potential applications of digital health in opioid addiction recovery.

6 Future Work

Future improvements on our software could create a more intuitive user experience to decrease onboarding time and improve engagement for the web application. With recent advancements in text transformers, such as GPT-3, the DTC can also be enhanced to provide more human-like conversation. This deeper conversation could be better analyzed with natural language process and sentiment analysis to gain a more accurate prediction of patient's relapse risk.

7 UVA Computer Science Evaluation

Through this invaluable experience, I developed many technical and non-technical skills. As the CEO, my responsibility to was develop client relationships and raise money to keep the company afloat while learning to build the medication tracker and DTC. Managing a team remotely during COVID especially challenged my abilities as a leader and taught me how to navigate difficult circumstances.

While my CS education prepared me with detailed knowledge of how computers operate, I did not gain an adequate systems level understanding of how software is architected in practical applications. I think providing students with a basic survey of webservers, databases, site reliability, and networking early in their CS education would better prepare them for upcoming internships and classes. Such a class would help provide context for their new learnings in subsequent years. However, my perspective may be biased, as I was a student in the first class of the redesigned CS pilot program.

References

[1] Ahmad FB, Rossen LM, Sutton P. 2021. Provisional drug overdose death counts. National Center for Health Statistics. Retrieved from https://www.cdc.gov/nchs/nvss/vsrr/drug-overdose-data.htm.

[2] CDC. 2021. Drug Overdose Deaths. Retrieved from https://www.cdc.gov/drugoverdose/deaths/index.html

[3] Azadfard M, Huecker MR, Leaming JM. 2021. Opioid Addiction. *StatPearls*. DOI: https://www.ncbi.nlm.nih.gov/books/NBK448203/

[4] Smyth P, Barry J, Keenan E, Ducray K. 2010. Lapse and relapse following inpatient treatment of opiate dependence. Irish Medical Journal (Jun. 2010), 176-9. DOI: https://www.lenus.ie/handle/10147/110022

[5] Charmian D. Sittambalam, Radhika Vij & Robert P. Ferguson. 2014. Buprenorphine Outpatient Outcomes Project: can Suboxone be a viable outpatient option for heroin addiction?, Journal of Community Hospital Internal Medicine Perspectives. DOI: 10.3402/jchimp.v4.22902

[6] Velander JR. 2018. Suboxone: Rationale, Science, Misconceptions. Ochsner J., (Spring 2018), 23-29. DOI: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5855417/

[7] Manhapra A, Agbese E, Leslie D, Rosenheck R. 2018. Three-Year Retention in Buprenorphine Treatment for Opioid Use Disorder Among Privately Insured Adults. Psychiatric Services, 768-76. DOI: https://ps.psychiatryonline.org/doi/10.1176/appi.ps.201700363

[8] Davoli M, Bargagli AM, Perucci CA, Schifano P, Belleudi V, Hickman M, Salamina G, Diecidue R, Vigna-Taglianti F, Faggiano F. 2007. Risk of fatal overdose during and after specialist drug treatment. Addiction, (Dec 2007), 1954-9. DOI: 10.1111/j.1360-0443.2007.02025.x.

[9] Rebecca Dillingham. 2018. PositiveLinks: A Mobile Health Intervention for Retention in HIV Care and Clinical Outcomes with 12-Month Follow-Up. AIDS PATIENT CARE and STDs, DOI: 10.1089/apc.2017.0303

[10] Campbell, B.R., Swoger, S., Tabackman, A. et al. 2021. PositiveLinks and the COVID-19 Response: Importance of Low-Barrier Messaging for PLWH in Non-urban Virginia in a Crisis. AIDS Behav. DOI: https://doi.org/10.1007/s10461-021-03294-w

[11] Glasner-Edwards S, Patrick K, Ybarra ML, et al. 2016. A Cognitive Behavioral Therapy-Based Text Messaging Intervention Versus Medical Management for HIV-Infected Substance Users: Study Protocol for a Pilot Randomized Trial. JMIR Res Protoc. DOI:10.2196/resprot.5407