Undergraduate Thesis Prospectus

Leveraging Smart Devices to Predict Health

(technical research project in Systems Engineering)

Wearable Health Devices: The Unintended Effects of Continuous Health Monitoring

(STS research project)

by

Shalin Shah

December 4, 2019

technical project collaborators:

Erin Barrett
Laura Barnes
Mehdi Boukhechba
Lihua Cai
Cameron Fard
Hannah Katinas
Sanjana Mendu
Charles Moens
Lauren Perry
Blake Ruddy
Ian Tucker
Tucker Wilson

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.

signed: _____ date: _____

approved: _____ date: _____
Peter Norton, Department of Engineering and Society

approved: _____ date: _____
Laura Barnes, Department of Engineering Systems and Environment

word count: 1282

General research problem

How can personal health monitoring be improved? Over the last decade, personal health devices have proliferated. They offer real-time health and fitness feedback that is far more convenient than visits to physicians or trainers (Haghi et al., 2017). Personal health wearables and mobile applications are portable and serve individuals, usually outside of the formal healthcare system. Typically, they have communication functionality (Fox, 2017). The devices have been improving, but problems of connectivity, power consumption, wearability, and risk of data loss persist (Haghi et al., 2017).

Leveraging smart devices to predict health

How can we use personal smart devices to identify disease indicators? Smartphones and other wearable devices can collect millions of data points from each of its users daily, contributing to a significant change in how the healthcare community approaches health monitoring. While the potential impact of this data is unprecedented, predictive models that capture additional value of the data can be improved (Dias and Cunha, 2018).

My capstone team will contribute to the ongoing project's goal of developing a means to predict individuals' health states from their patterns of daily life as measured by signals collected from smart devices. The ultimate goal of the broader research, funded by the Defense Advanced Research Projects Agency (DARPA), is an application to military personnel to provide "actionable pre-clinical indicators of warfighter mission readiness from only a smartphone" (LMATL, 2017). By building predictive health analytics that utilize smartphone sensors, the onset of illnesses, concussions, or even mental health complications can be identified in real

time. The more comprehensive project has already helped the team understand and improve data collection practices.

In the current stage of research, my team will build from this progress by translating raw signal data from smartphone sensors to deduce activities and contexts of interest (e.g., running, coughing, and sleeping) and improving information displays for intelligibility to users. In parallel, my team will assess relative smart device battery consumption of proposed data collection strategies. By gaining a better sense of system limitations, accurate predictive models can be developed to minimize complications of battery-drained devices and noise data.

Mobile sensing data will be collected through the Sensus application. Sensus, developed at the University of Virginia (UVA), uses "event-driven architecture that triggers actions in response to changes to the device or network state" (LMATL, 2017). The app will push surveys as notifications to participants' smartphones to give additional context to the data collected. Surveys will prompt users to report activities, such as location, length of activity, and phone position. This additionally collected data will enable the team to build strong foundational inputs for predictive health models.

My capstone advisors are Laura Barnes and Mehdi Boukhechba of the Department of Engineering Systems and Environment. My graduate team includes Lihua Cai and Sanjana Mendu, and my undergraduate team includes Erin Barrett, Cameron Fard, Hannah Katinas, Charles Moens, Lauren Perry, Blake Ruddy, Ian Tucker, and Tucker Wilson. The size of the team will allow us to divide the team into sub-teams, which may lead to more specialized individual roles throughout the project. Preliminarily, the team has separated to address data collection, data visualization, and data modeling, the latter of which I will help take responsibility for. The research will result in a recommendation for smartphone data collection

using Sensus and for intuitive data visualization for the researchers' web platform, presented at the Systems Information Engineering Design Symposium (SIEDS) in May 2020.

Wearable health devices: the unintended effects of continuous health monitoring

How are patients, physicians, technology companies, insurance companies, and advocacies responding to the implications of wearable health devices? Revenues from wearables are expected to reach $34 million in 2019. Since their introduction, wearables have intended to put "the individual citizen in the center of the healthcare delivery process managing [his or her] own health and interacting with care providers – a concept that is commonly referred to as 'patient empowerment'" (Dias and Cunha, 2018). Besides such health ownership, wearables can save time and medical costs. Networked wearables may be less expensive and improve patient and physician access to personal medical information (Fox, 2017).

A 2014 McKinsey study estimated that, by 2020, about 40% of the Internet of Things (IoT) technology will be health-related. This would represent a $117 billion market, of which wearables will contribute a substantial portion (Bauer et al., 2014). But continuous health monitoring bears complex implications for data privacy, network security, insurance practices, and the patient (Fox, 2017).

Researchers have studied health wearables. Piwek et al. (2016) found no evidence that wearables improve the health of healthy individuals and contend that they do not yet support reliable patient diagnosis. Cheung et al. (2019) attribute low consumer adoption of wearables to companies' "inadequate knowledge in the adoption intention of users of wearable healthcare technology." Although Schukat et al. (2016) assert that large-scale data sharing benefits individuals and researchers, they warn that trust in sensors may leave users' data vulnerable to

compromise. Data security vulnerabilities are ubiquitous. One user of Zoom, a cloud computing communications company, discovered a flaw in Zoom's software that "allowed malicious actors to secretly access the cameras of anyone who'd ever used the popular videoconferencing service"; the firm went public weeks later but failed to remedy the flaw for months (Burt, 2019). With blockchain, developers may reduce risk in a decentralized way (Reyna, 2018).

Patients typically weigh financial costs and time benefits against privacy costs (Blau, 2017). In a French study of patients with chronic conditions, researchers found that most believe wearables could improve their treatment. One patient asserted only wearables can let a physician account for all parameter inputs to diabetes treatment assessment. Patients also identified risks. One commented: "There are risks or drawbacks if some information is disclosed to social networks, banks, insurance or work. It will be necessary for patients to be educated on that" (Thran, 2019). Some physicians doubt monitoring helps them care for patients (Rosenblum, 2015). Proponent physicians note that with wearables, they can monitor outpatients' medical compliance (Loos, 2016). But other doctors warn that non-contextualized patient data, such as step count, are useless in diagnosis and treatment (Rosenblum, 2015).

Insurance companies have welcomed wearables because they may induce customers to make healthier choices. Health insurer UnitedHealthcare and life insurer John Hancock have offered financial incentives for meeting physical health goals, as tracked by wearables (Senior, 2018; UnitedHealthcare, 2017). Nevertheless, though the National Association of Insurance Commissioners (NAIC) acknowledges such benefits, it is cautious about data privacy (NAIC, 2019). The Center for Digital Democracy (CDD) calls for "meaningful, effective, and enforceable safeguards into its foundation" (Montgomery et al., 2017). The American Civil Liberties Union (ACLU) (2019), in a letter to the Senate, asked the body investigate the effects

of gene patenting, an issue analogous to health data privacy. In a letter to Congress, large technology companies urged lawmakers to "act and ensure that consumers are not faced with confusion about their rights and protections" so that the companies can strengthen consumer trust (Stephenson et al., 2019).

References

ACLU (2019). The American Civil Liberties Union [Letter to the Senate]. https://www.aclu.org/sites/default/files/field_document/2019-06-04_aclu_statement_urging_senate_help_committee_to_hold_hearings_re_gene_patenting.pdf.

Bauer, H., Patel, M., Veira, J. (2014). The Internet of Things: Sizing up the opportunity. McKinsey. https://www.mckinsey.com/industries/semiconductors/our-insights/the-internet-of-things-sizing-up-the-opportunity.

Blau, M. (2017). Health wearables raise new privacy concerns. *Boston Globe.* https://www.bostonglobe.com/business/2017/08/09/health-wearables-raise-new-privacy-concerns/0W2X9iNuLttoa7dUTFTzLJ/story.html.

Cheung, L., Lam, M. H. S., Tse, G., Flint, S. W., Broom, D. R., Tso, E. K. H., & Lee, K. Y. (2019). Examining Consumers' Adoption of Wearable Healthcare Technology: The Role of Health Attributes. *International Journal of Environmental Research and Public Health, 16*(13), 2257.

Dias, D. & Cunha, J.P.S. (2018). Wearable Health Devices—Vital Sign Monitoring, Systems and Technologies. *Sensors, 18*(8), E2414.

Fox, N.J. (2017). Personal health technologies, micropolitics and resistance: A new materialist analysis*. Health: An Interdisciplinary Journal for the Social Study of Health, Illness and Medicine, 21* (2), 136-153.

Haghi, M., Thurow, K., Habil, I.,Stoll, R., & Habil, M. (2017). Wearable Devices in Medical Internet of Things: Scientific Research and Commercially Available Devices. *Healthcare Informatics Research, 23*(1), 4-15.

LMATL (2017). Lockheed Martin Advanced Technical Laboratories. *Warfighter Analytics using Smartphones for Health (WASH).* Cherry Hill, NJ.

Loos, J., Davidson, E. (2016). Wearable Health Monitors and Physician-Patient Communication: The Physician's Perspective. *Institute of Electrical and Electronics Engineers.* https://ieeexplore.ieee.org/abstract/document/7427606/authors#authors.

Montgomery, K., Chester, J., Kopp, K. (2017). Health Wearable Devices in the Big Data Era: Ensuring Privacy, Security, and Consumer Protection. *The Center for Digital Democracy.* https://www.democraticmedia.org/sites/default/files/field/public/2016/aucdd_wearablesreport_final121516.pdf.

NAIC (2019). National Association of Insurance Commissioners. Wearables. https://content.naic.org/cipr_topics/topic_wearables.htm.

Piwek, L., Ellis, D. A., Andrews, S., & Joinson, A. (2016, February 2). The Rise of Consumer Health Wearables: Promises and Barriers. *PloS Med, 13*(2), e1001953. https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1001953.

Rosenblum, A. (2015). Your Doctor Doesn't Want to Hear About Your Fitness-Tracker Data. *MIT Technology Review*. https://www.technologyreview.com/s/543716/your-doctor-doesnt-want-to-hear-about-your-fitness-tracker-data/.

Schukat, M., McCaldin, D., Wang, K., Schreier, G., Lovell, N.H., Marschollek, M., & Redmond, S.J. (2016). Unintended Consequences of Wearable Sensor Use in Healthcare. *Yearkbook of Medical Informatics,* (1), 73-86.

Senior, A. (2018, September 19). John Hancock Leaves Traditional Life Insurance Model Behind to Incentivize Longer, Healthier Lives. https://www.johnhancock.com/news/insurance/2018/09/john-hancock-leaves-traditional-life-insurance-model-behind-to-incentivize-longer--healthier-lives.html

Stephenson, R., Sweet, J., Gluski, A., Styslinger, L., Bezos, J., Squeri, S., . . . Rometty, G. [Letter to Congress] (2019). *Business Roundtable*. https://s3.amazonaws.com/brt.org/BRT-CEOLetteronPrivacy-2.pdf.

Thran, V. (2019). Patients' views of wearable devices and AI in healthcare: findings from the ComPaRe e-cohort. *npj Digital Medicine, 2*(53). https://www.nature.com/articles/s41746-019-0132-y.