THE WEARABLE DEVICES REVOLUTION

The general topic covered by this technical project and Science, Technology, and Society (STS) discussion is the impact of mobile computing and sensor systems known as wearable technology has become feasible. The decreasing size of electronic components has enabled the widespread adoption of wearable devices in fitness. Using advanced biometric sensors to track heart rate and step count, these devices can provide rapid feedback about health metrics and can provide detailed information about individual's sleep and physical activity ("The Past, Present and Future of Wearable Technology", 2016). As wearable technology has become more advanced, scientists are attempting to use it to predict increasingly complex biological phenomena. Particular interest has been given to biological rhythms; these rhythms are biological phenomena like the Circadian Rhythms, which influence peoples' alertness, hormone production, and a variety of other biological responses due to the time of day and certain lifestyle factors (Abdullah, 2015). Developing models that would accurately predict these rhythms could have major health benefits for users and can impact quality of life (Haghi, Thurow, Stoll, Habil & Habil, 2017). This idea forms the basis of the technical project to develop a computational model to predict a user's alertness.

With wearable sensors becoming more convenient, powerful, and inexpensive they are capable of analyzing more and more biological phenomena. What started as simple heart rate monitors have now become suites of sensors the size of a wristwatch, that can track physical activity, sleep quality, and even give some recommendations for improving users' health. Between 2014 and 2019, the wearable market has exploded with a growth in units shipped from

22.8 million in 2014 to a project 222.9 million by the end of 2019 as depicted in figure 1. In the data driven information age, these devices have a significant population of users seeking to improve their fitness using quantitative measures of performance. The question is, do these devices actually contribute to users' well being in any meaningful way? This will be the overarching research question for the STS topic of this research which will incorporate Actor Network Theory (ANT) of Bruno Latour and a literature review of current studies on the efficacy of cons[oumer fitness wearables (Latour, 1990). The overall motivation of this research is to help users gain a better understanding of their own bodies. Through both projects, users can be more informed; in the first case, users will be more informed about their own bodies and in the second users can be more informed about the impacts of the devices they buy to help them pursue their health goals. The technical and STS topics are closely linked to one another because even if a successful system for generating individualized predictions of alertness is developed, that may prove inconsequential if users do not find wearable fitness trackers as a whole to be helpful. If users reject the technology and designers cannot prove their usefulness, it may prove to be unethical to continue to sell them under false pretenses.

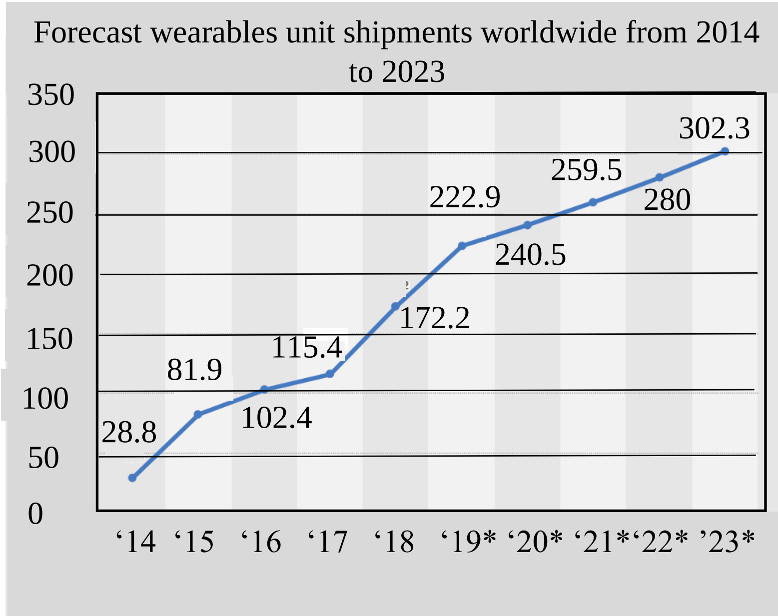

Figure 1. Forecast wearables unit shipments worldwide from 2014 to 2023. The figure shows the growth of the wearable devices market worldwide in terms of millions of units sold; years with '*' markings indicate projected units shipped. (Formatted by Nelson from Statista, 2019)

The technical project is not only the work of the author of this paper. Professor Afanseh Doryab, Associate Professor at the University of Virginia School of Engineering and Applied Science Department of Engineering Systems and Environment (ESE) will oversee the project. Undergraduate systems engineering students in the Department of ESE will also be working on the project, namely: Samantha Miller, Benjamin Carper, Leah Palombi, Kayla Spiegelman, Dillon McGowan, and Lina Romero. The project takes place from late September 2019 to April 2020 culminating in a presentation at the Systems and Information Engineering Design Symposium (SIEDS) conference at U.Va. in late April 2020. A Gantt Chart showing the timetable for both the technical project and the STS investigation is shown below in figure 2.

Both projects are expected to take two full academic semesters to complete. This will prove to be a challenge but given the importance of these projects both are necessary to explore.

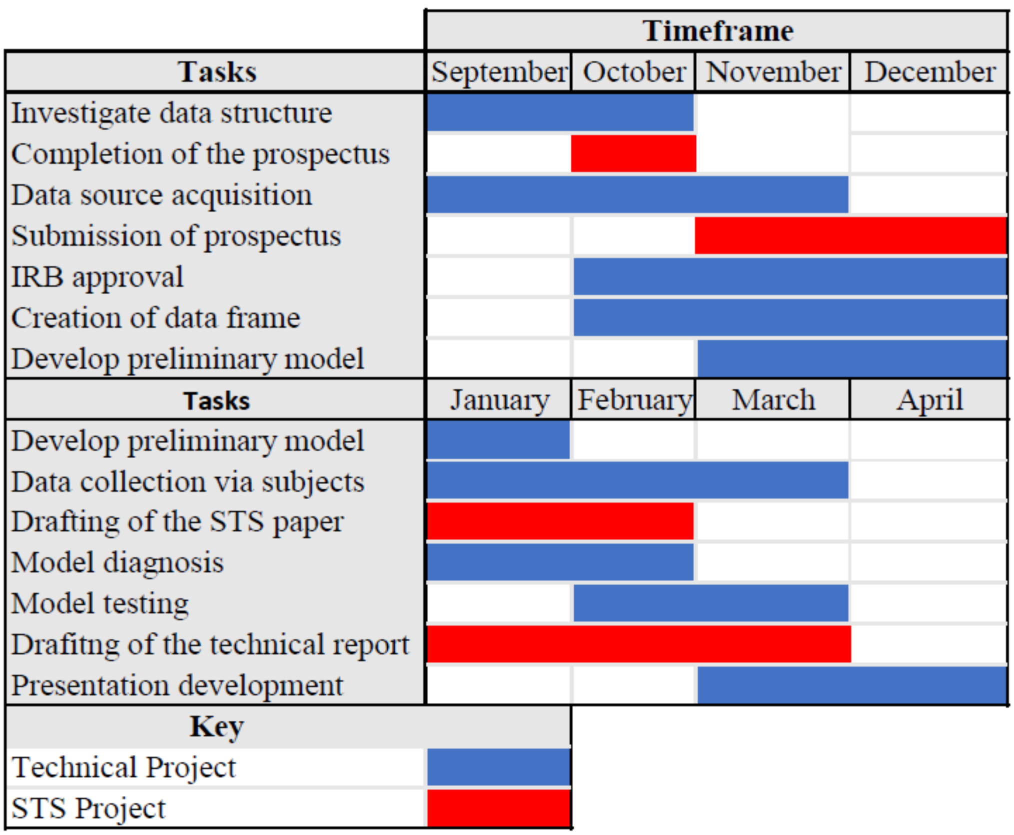

Figure 2. Gantt Chart for the Technical Project and STS Investigation. A Gantt Chart displaying the timetable of necessary steps of the technical and STS components of this work. The chart is separated into semesters, with the top half being “Fall 2019” and bottom half being the “Spring 2020” (Miller & Nelson, 2019).

LEVERAGING WEARABLE SENSORS FOR PREDICTIVE ANALYTICS

While mobile sensors have become more advanced and have become more widely adopted, the analysis they change has not changed drastically. With the last major innovation being the integration of sleep analysis in wearable sensor packages, more analytical capabilities are needed in order to advance the technology (Boger, Wei, & Zhang, 2018). One area in particular wearable sensors can improve is in predictive analytics. Predictive analytics is the use of data to develop computational models and estimates of metrics that give information about future events or behavior (Abdullah, Choudhury, Cosley, Gay, Kay, Kientz, . . ., Murnane 2016). In mobile health sensing, some work is already been done using commercially available wearable sensors, like the popular Fitbit brand devices, to identify and track biological rhythms (Abdullah, 2015). While these efforts have advanced the field, researchers have not been able to effectively predict biological rhythms in a way that is actionable for the user.

The potential of predictive analytics in mobile health sensing cannot be understated. If nuanced phenomena like alertness can be predicted using data from wearables then the possibilities for health improvement may be immense in the future. Prediction will enable users to plan their schedules around personalized health information which can cause major benefits in physical and mental well-being (Haghi, Thurow, Stoll, Habil, & Habil, 2017).

The goal of this research project, led by Professor Afsaneh Doryab, is to accurately predict an individual's biological rhythms and translate these rhythms into useable, beneficial information over the course of the 2019 to 2020 academic year. The project will involve the monitoring of heart rate, step count, galvanic skin responses, skin temperature, and sleep activity of approximately seven to ten individuals over a period of six months; additional data may be gathered from other wearable sensor users in order to obtain a sample outside of university students. The collected data will be used to build and train a model that will generate feedback on stress levels and alertness in an end-user mobile application. The project will conclude with approximately a month of analysis of gathered data and testing of predictive models created.

This research will require several key resources to accomplish. It will be conducted using wearable sensors, machine learning, and predictive analytics to effectively build predictive models to predict alertness. The project will also require the development of a supporting data frame for reading in user data and an end-user application that can effectively communicate alertness predictions to the user. Finally, data from Fitbit wearable sensor users will be collected from mid-November 2019 to the end of March 2020. The collection of this data will require the approval of the project protocol by the University of Virginia Institutional Review Board for the Social and Behavioral Sciences (IRB-SBS). This data will be anonymized and used to provide training data for the awareness model. The models will include features like step count, heart rate, wrist temperature, galvanic skin responses (GSRs), minutes of activity, calories burned, and stages and amount of sleep. It is important to note that minutes of activity, calories burned, and stages and amount of sleep are all features derived from the directly measured features like step count and heart rate. The Department of Engineering Systems and Environment will be supplying the team with two different sensors for eight subjects. The Oura Smart Ring, and the Empatica E4 will be supplied to the subjects for data collection over the next six months. Four research team members will receive the E4; all subjects will receive Oura Smart Rings. These devices will be purchased using a grant from the National Science Foundation for Professor

Doryab's work in mobile health and sensing. There will also be a monthly access fee for all data generated by the Empatica devices covered under the grant.

The ideal outcome of this research project is the development of an effective predictive model that can accurately predict an individual's alertness with the shortest training time possible. An additional goal for the future is to develop a data frame and end user application of sufficient quality and adaptability that future groups can use them as infrastructure to improve the alertness model and develop new models to incorporate into the existing framework. The project will be presented at the SIEDS Conference at U.Va. for undergraduates, graduate students, and faculty of U.Va. and other universities. Therefore, the paper will be written as a conference proceeding. By the actual conference, a working model of awareness should be identified and actionable for an end user.

THE EFFICACY OF WEARABLE FITNESS SENSORS IN SOCIETY

Wearable technology has made it more possible than ever to obtain up to the minute health information for individuals (Ducharme, 2019). This information can be used to improve fitness practices, diet, sleep, and it even has applications in out-patient care in medicine (Doryab, Dey, Kao, & Low, 2019). At present, the majority of commercial wearables for mobile health sensing can track two major aspects of health: activity and sleep quality (Ducharme, 2019). In the United States, health wearable users have jumped from 9% of the population in 2014 and 33% of the population in 2018 (Phaneuf, 2019). Park, Choi, and Kim, researchers writing for The Korea Society of Digital Policy and Management, conclude that the growth of the wearables market greatly increased fitness app use, and that consumer views of efficacy greatly influence the adoption of specific applications (Park, Choi, & Kim, 2015). This indicates that a significant subset of the American population believes that these wearables will help them improve their health over time; if this belief is in fact groundless, it can have major impacts on American consumers. Several studies and experts in fitness have called the effectiveness of fitness tracking into question, and some users report that analyzing their data becomes “an obsessive habit” over time (Ducharme, 2019). There is also a lack of research into the effects of sleep analysis on user health as it is a relatively new advancement in mobile health sensing (Boger, Wei, & Zhang, 2018). Investigation into this branch of analysis could provide useful insights into the hidden benefits or drawbacks of consumer wearable sensors.

THE EFFECTS OF MOBILE HEALTH SENSING ON THE USER

This investigation centers around one question; do users of wearable fitness trackers see significant improvement in their own health? The answer to this question will be pursued using research into a variety of studies done on the subject to evaluate several perspectives on the central question. The question will be broken down to cover the two major services of consumer health wearables: activity tracking and sleep analysis.

The exploration of mobile health sensing called for above will be conducted using two approaches. The first will be the use of Actor Network Theory (ANT) as developed by Bruno Latour in 1990 as an attempt to explain the interactions of different groups in the development of a technology (Latour, 1990). ANT will specifically be applied to model creation and the variety of actors who influence the models created for use in sleep analysis and activity tracking. The second will be a literature review of the scientific community's studies on the benefits and weaknesses of consumer mobile health sensing devices. The goal of literature review is to understand the effects of current and devices from the recent past on individuals and social groups. As suggested by Kathryn Bridges in her undergraduate thesis, actors in model development have competing values of innovation, reliability, timeliness, completeness, and secrecy (Bridges, 2018). The basic network of this discussion is demonstrated graphically in figure three to the right. The literature review and analysis using ANT will synergize to provide a comprehensive and insightful view of the interactions between designers, businesses, social groups, and mobile health sensors.

The anticipated outcome of this investigation is a better understanding of how mobile health sensing impacts users and other relevant social groups. This investigation also aims to uncover the benefits and drawbacks of sleep analysis in order to better inform researchers and the public about their choice in participating in these systems. This paper will take the form of a research paper and exploration of the implications of mobile health sensing using Actor Network Theory. With the help of these two approaches, the true efficacy of wearable sensors in individual mobile health sensing will be identified for the benefit of the public.

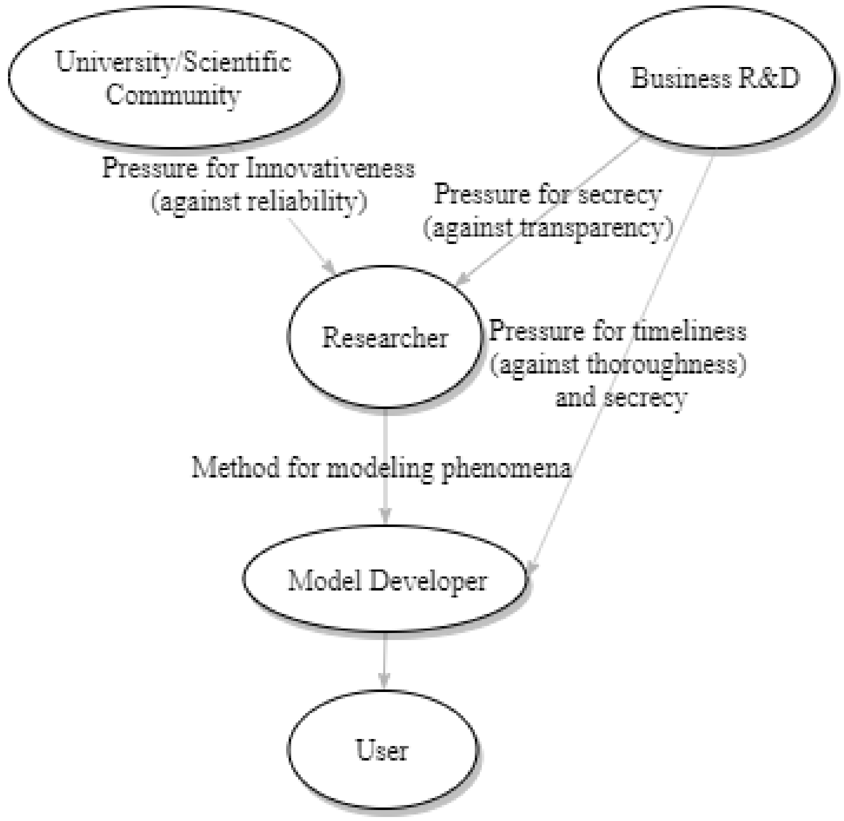

Figure 3. The Network of Actors and Influences in Model Development. This network illustrates the set of actors that influence model development and the pressures they exert on model designers themselves (Adapted by Nelson from Carlson and Barituad, 2019).

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