Personalization in Circadian Rhythm-Based Event Scheduling
(Technical Topic)

Equitable Use of Wearable Technology in Employee Wellness Programs
(STS Topic)

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Systems Engineering

By
Prachi Sadekar

December 2, 2022

Technical Team Members:
Jackson Baitinger, Sean Conway

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.

ADVISORS

Joshua Earle, Department of Engineering and Society

Afsaneh Doryab, Department of Systems Engineering

Introduction

Wearable devices, like smart watches or rings, are a growing technological commodity, most often used for tracking health and activity metrics such as heart rate, steps, sleep quality, calories burned, and exercise types and amounts. More advanced devices are also capable of measuring a user's blood oxygen levels, taking ECGs, tracking ovulation cycles, and are enabled with fall detections systems that can alert authorities if a user is unable to stand up (Apple Press Release, 2022). These advancements in wearable devices allow users to better understand their physical health and make changes to their daily habits. However, the increased integration of wearable devices into employer wellness programs poses a risk of equitability in the workplace. This Prospectus will first introduce the technical project of recommending a daily activity schedule using rhythm aware technology, then detail the research question and methods for the STS thesis paper, and lastly summarize key texts related to the STS topic wellness programs and the equitable use of wearable devices in the workplace.

Employer wellness programs originated in the 1990's and often take the form of insurance deductible reductions or direct financial rewards (Torres and Zhang, 2021). The intent of bettering employee health and encouraging healthy habits is a noble one, but current wearable technology struggles with accurate detection of health metrics for darker-skin and obese users (Ajmal et al., 2021). This creates an inequity within the workplace because the inaccuracy of wearables to capture the true activity levels for certain groups of employees may prevent them from receiving the financial benefits of these programs. There is also a concern for employees with disabilities who are physically unable to perform the activities required for the program benefits. In the STS paper, I aim to understand the current integration of wearable devices in the

workplace, and how these devices can be used in an equitable way while still promoting healthy employee habits.

The goal of the technical project, sponsored by the National Science Foundation as part of the rhythm aware technology lab, is to synthesize previous works on human circadian cycles and data collected through Fitbits and Oura rings to develop an optimal activity calendar for college students. We will deliver our recommendations as "events" on a user's Google Calendar to naturally embed the schedule into their daily routine. Our first calendar iteration will rely on previous works on human chronotypes, whether someone is a "morning" or "evening" person, to develop two generic calendars (one for each chronotype). In our second iteration, we will use a survey to gather activity preferences data and understand how a user prioritizes exercise, sleep, homework, and social activities. The third and last iteration incorporates explicit feedback through bi-weekly surveys of users' mental and physical health and implicit feedback through accepting, rescheduling, or deleting Google Calendar event suggestions. This project is an important advancement in wearable and rhythm aware technology because it enables users to combine personal health information with their activity preferences to develop the optimal work-life schedule and prevent burnout.

Technical Report

Background

The National Science Foundation sponsored the capstone project investigating Rhythm Aware Technology for Health and Wellness. This project is a collaborative effort with two other Systems Engineering students, Jackson Baitinger and Sean Conway, with Professor Afsaneh Doryab as our faculty advisor. The goal of our technical project is to recommend the optimal

times of day to conduct physical/cognitive tasks and sleep based on an individual's fitness data and preferred scheduling habits. Many fitness trackers on the market collect personal health data such as steps, sleep quality, heart rate, and exercise levels, and we will use this information to determine a user's natural circadian rhythm to personalize their recommendations. We will add these personalized recommendations directly to a user's Google Calendar to reduce the travel time needed between applications and increase the chances of the recommendations being naturally implemented into one's daily routine.

Initial Survey and Calendar Iteration One

The recommendations will be split into three categories: sleep timing, cognitive tasks and stress management, and fitness and recovery. Within the sleep management recommendations, we will advise users on the optimal time to wind down, sleep, wake up, and alert users about their low energy time periods (usual afternoon lulls). Because circadian rhythms vary by chronotype, whether someone is generally a "morning" or "evening" person, our first iteration of recommendations will involve building separate calendars for each chronotype with generic time blocks to optimize daily activities. For example, an early chronotype ("morning" person) has increased cognitive function in the morning and early afternoon, so they should prioritize completing homework/work during these hours and workout in the late afternoon or evening instead. The recommended times will be developed from existing literature on daily rhythms and well-being.

Calendar Iterations Two and Three

As we build these initial calendars, we will also send out an anonymized survey to collect data about chronotypes, activity/time preferences, priority of activities, and frequency of

activities to a stratified sample of college students. Using this collected data, in our second iteration we will supplement our initial chronotype calendar with personalized recommendations for the average college student. We will develop a prioritization function/matrix based on our understanding of what activities students value more (a pairwise analysis) from the survey data. In our third and last iteration, we will implement implicit feedback changes by observing whether a user follows a recommendation, reschedules them, or ignores them. We will also implement bi-weekly explicit feedback through a survey to understand if a user's quality of life has actually improved based on our recommendations. As a stretch goal, we will try to use daily Fitbit data to provide live recommendations such as scheduling a nap during the day if a user did not receive enough sleep the previous night.

STS Project

Research Question: How can wearable devices be equitably implemented in the workplace?

Wearable fitness devices continue to enter the office space as a part of employee wellness programs. Hundreds of companies have introduced these programs with the goal of improving employee health and well-being, but for an estimated two million employees, complying with wearable technology will also be a job requirement in coming years (PWC). With the relative ubiquity of wearable devices now in the market, it is necessary to understand how equitable the technology is. Health metrics are useful for wearable devices to measure and evaluate individual wellness, but research shows that wearables are less accurate for people of color and those with a high body mass index (Ajmal et al., 2021). Most smart watches are equipped with a green light sensor because of its cost efficiency and accuracy within testing groups that were predominantly light-skinned (Colvonen et al., 2020). Because companies and insurance providers are increasingly using smart watches to reward healthy, active employees and "personalize"

healthcare options, darker-skinned and/or obese people suffer the consequences of these inaccurate readings and may be left out of a reward system or have to pay higher insurance premiums.

Proposed Frameworks for Analysis

My primary frameworks for analyzing the research question of equitable institution of wearable device-based wellness programs will be the Social Construction of Technology (SCOT), Disability Studies, and Race Critique. The SCOT framework will help to understand how the rise of "datafication" and the quantified self has increased the use of wearable devices in society. The quantified self movement is characterized by a greater ability to track and collect data on oneself and use the information to better inform personal decisions (Giddens, Gonzalez, and Leidner, 2016). As SCOT outlines, human values shape the way technology evolves, and our current values reflect the need for constant access to information to make data-driven decisions. This follows why employers and insurance companies choose to create wellness programs. The more personalized information the company can gather on an employee's physical condition, the less risky an insurance policy becomes. Since I am considering how equitable the implementation of wearable device wellness programs is, I will also use the Disability Studies and Race Critique frameworks to examine how people of color and disabled employees are impacted by the programs. This framework is especially important because technological development and testing has historically left out these groups who are now facing further marginalization (McIlwain, 2020).

Identifying Social Groups

The main social groups involved in the wellness programs and the wearable devices space are: employers who have implemented the programs, wearable device manufacturers that supply the technology, insurance companies, and the employees at companies that institute the programs. The employee category can be further broken down into relevant employee groups: "healthy" employees who benefit from the program, people of color (POC) employees whose activities may be misrepresented in the data, and employees with disabilities who cannot participate in the program. Regulatory agencies and government policies are also a relevant group, especially the Civil Rights Act and Americans with Disabilities Act (ADA) which are enforced by the U.S. Equal Employment Opportunity Commission (EEOC). These social groups either directly contribute to or are impacted by the implementation of wearable device-based wellness programs. I will not be considering companies who have not instituted wellness programs or third parties that have a stake in the data collected by wearable devices. While there are privacy concerns related to wearable devices, particularly because they are not subject to HIPAA when not prescribed by a medical professional, the focus of this project is employee equity in relation to wearable devices in the workplace (Theodos & Sattig, 2020).

Research Methods and Timeline for Completion

My primary methods for research will be reading and synthesizing previous papers within the space of inequities for wearable devices and employee wellness programs. I will first focus on how wearable device usage has grown in over the past decade and investigate the role of the quantified self movement and datafication. Then, I will explore the inception of employee wellness programs and how wearable devices were integrated. After establishing this social

history, I will continue to research the inequities that exist for wearable device technology and how these issues pervade the wellness programs that are dependent on them. The timeline for these three stages will be January/early February, mid-late February, and March and April respectively.

Key Texts

To understand why inequities in wellness program access are necessary to address, it is first important to understand the benefits wellness programs can provide to companies and why they have a financial incentive to implement them. In a 2010 article about workplace wellness programs, Baicker, Cutler, and Song found that medical costs fall by $3.27 for every dollar spent on wellness programs and absenteeism costs fall by $2.73 for every dollar spent (2010). The companies that choose to implement wellness programs tend to provide insurance plans to employees, and by investing in healthy habits, companies can reduce their overall health care costs and premiums. By encouraging and rewarding healthier behavior, employees may also become more productive and miss fewer days of work, benefitting both the employee and employer (Baicker, et al., 2010). Wellness programs are almost always voluntary and can entail health risk assessments, education materials, and counseling, and even intervention methods such as weight loss or quitting smoking (Baicker, et al., 2010).

In a 2018 article, Julie Elman argues that despite Fitbit prominently featuring wheelchair users in its advertising, because wearable devices primarily use steps as a measure of activity, people with physical disabilities are not afforded the same utility from the devices. This problem is exacerbated in the Fitbit wellness programs that reward employees who meet their activity goals. Elman argues that measuring health and wellness through a wearable device brings in

historical and moral values of able-bodied users and is biased in the way exercise is quantified (2018). This article is important to my STS topic because of its argument about inequitable access to wearable devices for disabled users.

Souza et al., use a case study to describe why wearable based wellness programs exist and the benefits they provide. The main goal for employers when opting into a wellness program is reducing their total health insurance and medical clearance costs (Souza et al., 2017). Previous studies also indicate that improving an employee's health and wellness will decrease absenteeism and increase productivity (Souza et al., 2017). In the case study, participants were assigned four daily health goals: walk 6,000 steps, drink two liters of water, perform 30 minutes of exercise, and get at least six hours of sleep. For every fully completed task, the participants received points in a competition with other users as an incentive for participation. At the end of the study, participants indicated they enjoyed the gamification of activity and had identified ways to create healthier habits (Souza et al., 2017). This article lays out why wellness programs are used by employers and what incentive structures exist within the programs. In order to properly argue that certain employee groups are disadvantaged in these programs, it is first important to understand how wellness programs are beneficial.

With the increased demand for wearable devices for fitness and health management over the last decade, Ajmal, Boonya-Ananta, Rodriguez, Le, and Ramella-Roman conducted a study to investigate how accurate these devices (2021). Based on anecdotal and systematic reports, there is a higher rate of error for users with elevated skin tones and high body mass indices (Ajmal et al., 2021). In their study using Monte Carlo modeling of a PPG signal, Ajmal et al. found that higher BMI and skin tones can create a relative loss of signal up to 61.2% for a Fitbit Versa, 32% in a Series 5 Apple Watch, and 32.9% in a Polar M600 (2021). The results of this

study are necessary to understand the equity issues of widespread wearable device-based wellness programs, especially because Fitbit itself sells thousands of devices in bulk to employers for these programs (Forbes, 2014).

Bibliography

Ajmal, Boonya-Ananta, T., Rodriguez, A. J., Du Le, V. N., & Ramella-Roman, J. C. (2021). Monte Carlo analysis of optical heart rate sensors in commercial wearables: the effect of skin tone and obesity on the photoplethysmography (PPG) signal. *Biomedical optics express*, *12*(12), 7445–7457. https://doi.org/10.1364/BOE.439893

Apple Press Release. (2022, October 6). *Apple reveals Apple Watch Series 8 and the new Apple Watch Se*. Apple Newsroom. Retrieved October 12, 2022, from https://www.apple.com/newsroom/2022/09/apple-reveals-apple-watch-series-8-and-the-new-apple-watch-se/

Baicker K, Cutler D, Song Z. Workplace wellness programs can generate savings. Health Aff (Millwood). 2010 Feb;29(2):304-11. doi: 10.1377/hlthaff.2009.0626. Epub 2010 Jan 14. PMID: 20075081.

Edwin N. Torres, Tingting Zhang (2021), The impact of wearable devices on employee wellness programs: A study of hotel industry workers, International Journal of Hospitality Management, Volume 93, 102769, ISSN 0278-4319, https://doi.org/10.1016/j.ijhm.2020.102769.

EEOC. (n.d.). *What laws does EEOC enforce?* US EEOC. Retrieved October 12, 2022, from https://www.eeoc.gov/youth/what-laws-does-eeoc-enforce.

Elman, J. P. (2018). "Find Your Fit": Wearable technology and the cultural politics of disability. New Media & Society, 20(10), 3760–3777. https://doi.org/10.1177/1461444818760312

Giddens, Laurie & Gonzalez, Ester & Leidner, Dorothy. (2016). I Track, Therefore I Am: Exploring the Impact of Wearable Fitness Devices on Employee Identity and Well-being. Americas Conference on Information Systems

McIlwain, C. (2020, June 25). *Of course technology perpetuates racism. it was designed that way*. MIT Technology Review. Retrieved October 12, 2022, from https://www.technologyreview.com/2020/06/03/1002589/technology-perpetuates-racism-by-design-simulmatics-charlton-mcilwain/

Olson, P. (2014, April 28). *The quantified other: Nest and fitbit chase a lucrative side business*. Forbes. Retrieved October 12, 2022, from https://www.forbes.com/sites/parmyolson/2014/04/17/the-quantified-other-nest-and-fitbit-chase-a-lucrative-side-business/?sh=59564efa2c8a

Peter J Colvonen, Pamela N DeYoung, Naa-Oye A Bosompra, Robert L Owens, Limiting racial disparities and bias for wearable devices in health science research, *Sleep*, Volume 43, Issue 10, October 2020, zsaa159, https://doi.org/10.1093/sleep/zsaa159

Souza, M., Miyagawa, T., Melo, P., Maciel, F. (2017). Wellness Programs: Wearable

Technologies Supporting Healthy Habits and Corporate Costs Reduction. In: Stephanidis, C. (eds) HCI International 2017 – Posters' Extended Abstracts. HCI 2017. Communications in Computer and Information Science, vol 714. Springer, Cham. https://doi.org/10.1007/978-3-319-58753-0_44

Theodos, K., & Sittig, S. (2020). Health Information Privacy Laws in the Digital Age: HIPAA Doesn't Apply. *Perspectives in health information management, 18*(Winter), 1l.