BUILDING RHYTHM-AWARE TECHNOLOGY FOR HEALTH AND PRODUCTIVITY

ETHICAL IMPLICATIONS OF WEARABLE TECHNOLOGIES IN MODERN WORK ENVIRONMENTS

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
Samantha Miller

October 31, 2019

Technical Project Team Members
Ben Carper, Dillon McGowan, Joe Nelson, Leah Palombi, Lina Romero, Kayla Spigelman

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: Samantha Miller Date: 10/31/19

Approved: Catherine D. Baritaud Date: Dec. 12, 2019
Catherine D. Baritaud, STS Division, Department of Engineering and Society

Approved: Afsaneh Date: 11/1/2019
Afsaneh Doryab, Department of Computer Science Engineering

In his 1930 essay *Economic Possibilities for Our Grandchildren,* the economist, John Maynard Keynes, predicted that "science and compound interest will have won" humanity the gift of time (1930, p. 358). He proposed that by the twenty-first century society would be functioning in a fifteen-hour work week and that "for the first time since his creation man will be faced with his real, his permanent problem" of, "how to occupy the leisure" (Keynes, 1930, p. 358). Unfortunately, economists of the early 20th century did not foresee that work is no longer a means of buying free-time, but rather a means of identity production (Thompson, 2019). The American identity largely revolves around accumulating more hours at the office despite the fact that a staggering 87 percent of employees are not engaged at their job (Thompson). This suggests that the modern workplace cultivates a culture of productivity rather than efficiency, eliminating the potential for the valuable leisure time Keynes predicted in 1930.

According to research done by Till Roenneberg, author of *Internal Time,* getting to the office by 8 am requires that 69 percent of the population wakes up before their bodies are ready (Vetter, Fischer, Matera, & Roenneberg, 2015). The prevalence of sleep loss raises the question of how can people efficiently perform while exhausted, which is an underlying skill required by most jobs. With the introduction of wearable technology such as Fitbits and smart watches, people can view sleep and fitness data. Furthermore, behavioral change techniques such as feedback and rewards encourage individuals to consistently monitor their health (Sullivan & Lachman, 2017, p. 2). The mobile health market is expected to grow eight-fold, "from $5.1 billion in 2013 to $41.8 billion in 2023," (Brown, 2016) which implies even more data will be stored despite users' minimal knowledge of the data's whereabouts (p. 7). Therefore, collecting and analyzing biometric data does not come without consequences in relation to data safekeeping and privacy concerns.

The technical research for this project will revolve around researching physiological metrics from wearable technology that can be extracted in order to "understand circadian rhythms, sleep-wake cycles or rest-activity patterns and their associations with health outcomes" (Doryab, Dey, Kao, & Low, 2019, p. 3). The goal of the technical project is to make people aware of their unique biological clock, so that they can better manage their time and achieve high performance both at work and in their daily life. To meet the goal, a process known as circadian computing will be used. This method identifies unique biological rhythms of individuals based on human physiology and behavior (Abdullah, Murnane, Matthews, & Choudhury, 2017, p. 35). Data will be acquired from online databases of Fitbit data, as well as novel technology worn by team members. Using this information, the group will create predictive models that detail unique circadian rhythms and provide tailored recommendations based on chronotype, the circadian profile that lies on a spectrum from "proverbial 'early birds' (early types) to 'night owls' (late types)" (Abdullah et al., 2017, p. 36).

Gathering data from health monitoring devices requires an exploration of the risks involved, specifically in regards to privacy. The STS research project particularly focuses on wearable technology in the workplace and the ethical implications that arise from the proliferation of productivity monitoring applications. The Social Construction of Technology framework will be used to acknowledge relevant social groups and the motives driving their adoption of wearable technology. Using this framework will enable an in-depth examination of different stakeholders, such as employees and employers, and will drive research into established and proposed privacy regulations. Overall, the STS research will tightly complement the technical project by providing theories regarding the future ethical implications of circadian aware technology should it make its way into the modern workplace.

THE NEED FOR TECHNOLOGY TO REDUCE MISALIGNMENT OF SOCIAL AND BIOLOGICAL RHYTHMS

According to the U.S. Centers for Disease Control, the sleep disorder epidemic affects 50-70 million people in the U.S. alone (Murnane, Abdullah, Matthews, Choudhury, & Gay, 2015, p. 36). Despite this staggering statistic, people continue to misalign their biological and social clocks, resulting in social jetlag (Murnane et al., p. 36). As described by chronobiologists, Roenneberg, Allebrandt, Merrow, and Vetter (2012), social jetlag quantifies the misalignment between circadian and social clocks, which often results in chronic sleep loss (p. 939). Inadequate sleep and circadian disruption can lead to a number of complications such as obesity, cancer, type-2 diabetes, and psychological disorders (Abdullah, 2015, p. 516). Despite these devastating consequences, a study found that 80 percent of the population lives against their innate biological rhythms (Roenneberg, Allebrandt, Merrow, & Vetter, 2012, p. 939). This means that a majority of society is at risk of reduced cognitive performance and memory consolidation (Kyriacou & Hastings, 2010, p. 260). According to Abdullah et al. (2015), leading researchers in ubiquitous computing and human-centered design, this cycle of circadian misalignment is perpetuated by three factors: an internal circadian oscillator that promotes wakefulness during the day, a homeostatic system that encourages sleep the longer one is awake, and a social clock based on social

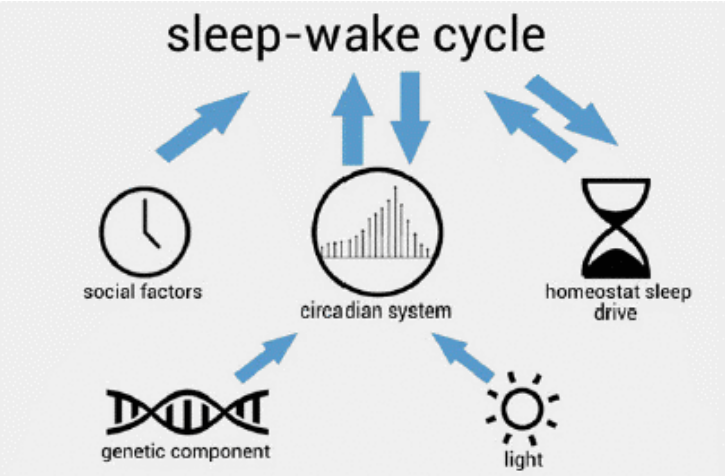

Figure 1: A depiction of the factors contributing to the sleep-wake cycle. Social factors are not influenced by the sleep-wake factor; however, the circadian system and the homeostat sleep drive are affected by when an individual sleeps and how much (Abdullah et al., 2017).

responsibilities (p. 844). The interaction between these three factors, as well as light and genetic components, is illustrated in Figure 1 on page 3 and explains the need for technology or systems to intervene when these factors are being neglected. For example, the technical project will explore whether wearable technology can detect misalignment between factors driving the sleep-wake cycle, and can then provide recommendations on how to adjust an individual's lifestyle accordingly.

The consideration of delaying school start times in order to increase sleep duration has grasped the attention of many scholars interested in circadian disruption. The source of this conversation stems from noticeable sleep deprivation in teenagers because of two driving forces: the circadian regulation of sleep, which delays their sleep onsets, and their academic obligations, which encourage early sleep onset (Dunster et al., 2018, p. 1). In a pre-post research study done by Dunster et al. (2018), they discovered that after delaying secondary school start time by an hour, the median sleep duration increased by 34 minutes and median grades increased by 4.5 percent (p. 5). Direct causality cannot be proven, however this pattern of sleep deprivation affecting cognitive performance extends to workplaces as well. A few years ago, Till Roenneberg, a chronobiologist at Ludwig-Maximilian University in Munich led a real-world experiment at a steel factory in which they assigned a day shift to early risers and a late shift to night owls (Vetter et al., 2015). This chronotype-adjusted shift schedule reduced overall social jetlag by one hour, did not alter stress levels, and increased satisfaction with leisure time. These positive results were a result of synchronization of the clocks shown in Figure 1 on page 3, because it is the mismatch—not the hours themselves—that matter (Laber-Warren, 2018).

The benefits of considering when people have the most energy and when they are peaking mentally are extremely apparent. Economically, the financial burden of not sleeping

properly is estimated toward 1 percent of gross national product, both in the U.S. and Germany (Laber-Warren, 2018). Accident-related incidents may contribute to this estimation, as drowsy drivers cause 16.5 percent of fatal crashes, and 16 percent of workers have experienced at least one safety-related incident because of fatigue (Laber-Warren). These are preventable events that can be remedied with consideration of circadian rhythm.

DESIGNING TECHNOLOGY THAT IDENTIFIES CHRONOTYPE AND PROVIDES RECOMMENDATIONS

The technical project will be led by Afsaneh Doryab, a computer science professor at the University of Virginia, and a leading researcher in ubiquitous computing and circadian rhythms. With Doryab's grant from The National Science Foundation, group members will aim to accomplish their project's goal of using wearable technology to identify individuals' unique chronotypes and provide them with feedback on their peak productivity periods. Using the necessary biometrics, a model will be built that takes into account the internal circadian oscillator that promotes wakefulness during the day, as well as the homeostatic system that encourages sleep as the body and mind becomes exhausted. The outline for the project can be seen in Figure 2 on page 6.

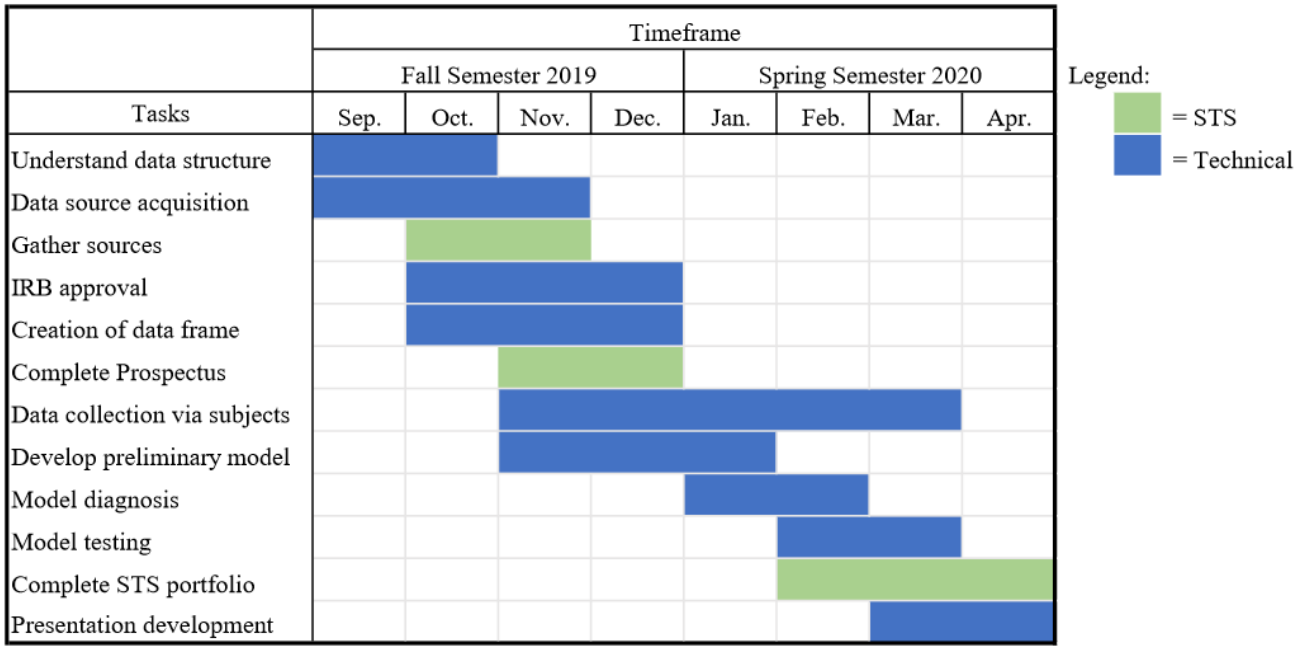

Figure 2: Project Proposal Gantt Chart: This figure lays out the timeline for the technical project and STS project, by month (S. Miller, 2019).

First, the group will develop an understanding of the structure of wearable technology data, specifically that of Fitbits as data exports are already available online. Simultaneously, each group member will wear Oura Rings, a novel multisensory device capable of measuring sleep, activity, and lifestyle data. This data collection cannot be initiated until IRB approval has been obtained, and it is yet to be determined what the data export process will entail. Following data acquisition, the group will develop a preliminary machine-learning model. This model will read in data from the available Fitbit or Oura Ring data, extract the necessary features, and identify a chronotype for the individual. Doryab has identified a Chronomics Analysis Toolkit (CAT) written in the R coding language that provides a baseline for the feature extraction (Gierke, 2013). After diagnosing any potential issues with the model, it will begin providing recommendations on when the user is most alert, most tired, and most productive. Ideally, these interventions may be embedded in wearable technology, office or home equipment, personal calendars, or even light fixtures to indicate when it is optimal sleeping/waking hour. A

conference paper will detail the methods used to obtain the model, including the physiological metrics and the software used to extract them. In April, these findings will be presented at the annual Systems and Information Design Symposium (SIEDS).

INVESTIGATING THE MORAL AND ETHICAL IMPLICATIONS OF WEARABLE TECHNOLOGY IN THE MODERN WORKPLACE

The introduction of wearable technology in the workplace is no longer a hypothetical scenario looming in the future. In fact, a number of companies have required that their employees participate in health data collection, such as CVS Pharmacy who demands that employees using their health plan provide certain biological data, otherwise they must pay a fine of $50 per month (Brown, 2016, p. 5). While it is true that gathering employee data from health monitoring devices can encourage workplace fitness and reduce workplace losses due to illness and absence, it also poses a number of problems in regards to morality and privacy. A number of relevant lawyers and social scientists have expressed their concern over employee wellness programs that seem to be becoming ever-more intrusive and coercive, while also acknowledging the lack of federal law protecting employees' health and fitness data from potential misuse (Moore & Piwek, 2017, p. 8). In order to prevent violations of user's privacy, the STS research project will identify the relevant social groups involved in the adoption of wearable technology in the workplace, and describe the potential ethical issues that may arise from mishandling of the data. The Social Construction of Technology (SCOT) framework will provide a means of interpreting motives, and will effectively describe the forces contributing to the larger network of wearable technology in the workplace.

SOCIAL GROUPS AFFECTED BY WEARABLES IN THE WORKPLACE

Bjiker's concept of The Social Construction of Technology (SCOT) framework is based upon the principle that the developmental process is determined by technical problems resulting from applications of technology by specific social groups (Pinch & Bijker, 1984). These various social groups exercise interpretive flexibility in which the same artifact can be associated with different meanings, thus transforming the technology in different or coexisting directions (Kline & Pinch, 1996). This concept can be applied to wearable devices, as depicted in Figure 3. The various social groups interact with the technology, and sometimes each other, creating a larger network of contributing forces to the development or altering of the device.

Each social group depicted has varying interpretations and motivations regarding wearable technology. According to Brown, a professor of business law at Bentley University, the collection of health-related data sits at the convergence of three trends: The Internet of Things, the Quantified Self Movement, and the rise of the health data platform (Brown, 2016, p. 9). All of these trends affect the common user of wearable technology.

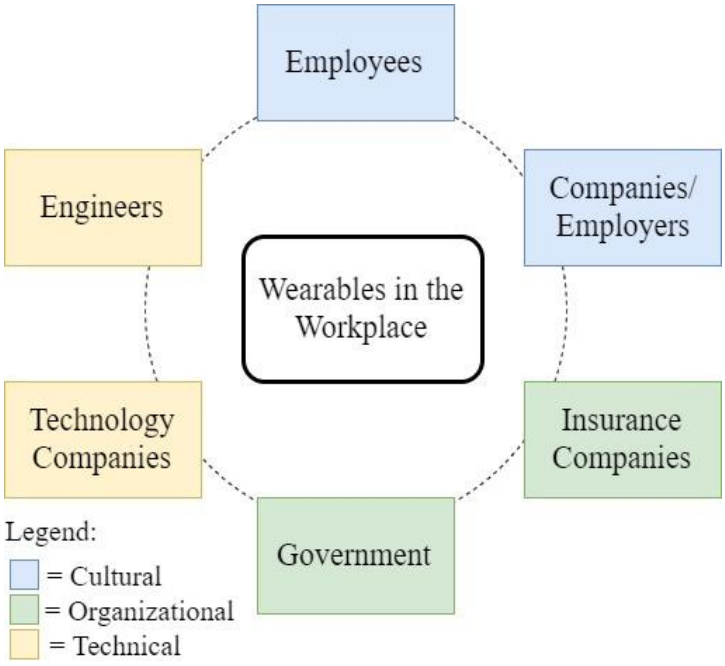

Figure 3: SCOT Framework for Wearable Technology in the Workplace: This depiction of wearable technology demonstrates the various stakeholders that lie on the boundary of the main artefact, wearables (Adapted by Samantha Miller from W. Bjiker, J. Bonig, & E. van Oost, 1984).

The Employee Social Group at Risk

The relationship between the cultural social groups identified in Figure 3 on page 8 is an interesting one, as it raises concerns over coerced consent, and employee stigmatization. When thinking about the workplace, an employee may be tempted to participate in data collection because of perceived benefits outweighing risks, causing users to be incentivized to surrender their privacy for a tangible reward (Gauttier, 2019, p. 353). Furthermore, the hierarchical relationship at play between employees and managers raises the question as to whether opting in or opting out is ever really possible and if the relationship between the two parties is actually consensual (Moore & Piwek, 2017, p. 8). In fact, in their identification of vulnerable subjects, the National Bioethics Advisory Committee included employees under the category of "Institutional Vulnerability" because although these individuals have the cognitive ability to consent, they may not be able to make a truly voluntary choice due to coercion ("Ethical and Policy Issues in Research Involving Human Participants", 2001). Another external factor contributing to an employee's adoption of wearable technology may be fear of being shamed for not participating in a wellness initiative. As employee monitoring becomes normalized, the employee choosing not to measure their productivity, or stress, may be seen as abnormal (Moore & Piwek, 2017, p. 8). Therefore, the rise of health data platforms may ostracize those choosing not to surrender their data to the Internet of Things, and favor those who are extrinsically motivated by the illusion of digital productivity, also known as the Quantified Self.

The Quantified Self Enabling Unethical Decisions

The concept of the Quantified Self is largely encouraged by the employer social group within the cultural category. Using data collected on their employees, companies can adjust employees' health care premiums depending on how much physical activity their wearable devices monitored, forecast absences due to illness, and prevent workplace accidents based upon recorded physical fitness (Brown, 2016, p. 5). This practice reduces employees to strictly data, and productivity is quantified by hours spent sitting at a desk or speaking with a supervisor. Immeasurable or qualitative aspects of the labor process such as taking breaks to encourage creativity, now may be used against employees because they do not translate to efficiency (Moore, 2015, p. 4).

Redirecting the purpose of the introduction of wearable technology in the workplace from one of encouraging physical wellbeing to one of surveillance, opens the door to a number of potential invasions of privacy that must be mitigated by the organizational social groups. Legal scholars are concerned about what limits employers from using the complex insights provided by these devices for discriminatory hiring, promotion, and other related decisions (Ajunwa, 2018, p. 44). For example, if an employer is trying to decide between which of two candidates to promote, they may review each candidate's biometric data for conditions that correlate with lower productivity levels or higher health insurance costs. There are currently no federal anti-discrimination laws to protect employees against decisions made on these bases (Brown, 2016, p. 20). While the Health Insurance Portability and Accountability Act of 1996 (HIPAA) serves traditional health care well, mHealth technologies and health social media are currently outside of the scope of the act ("Examining Oversight of the Privacy & Security of Health Data Collected by Entities Not Regulated by HIPAA", 2016, p. 1). Further research regarding the gaps

in oversight between HIPAA-covered entities and those that are not regulated by HIPAA must be done in order to protect the privacy of participating employees and define limits on what employers may and may not have access to. Figure 4 below illustrates the scope of big data being collected in the workplace, and how the employee as a user is largely isolated from the system. They likely are unaware of where their data goes beyond the office walls, and as a result may fall victim to unfair treatment and decision-making. Because users are outside of the larger network, it will be up to the organizational and technical social groups to consider the interpretive flexibility of wearable technology in order to protect users' rights. Updated rules and regulations, as well as improved code to encrypt users' data can effectively minimize both the barrier in knowledge and abuse of data, respectively.

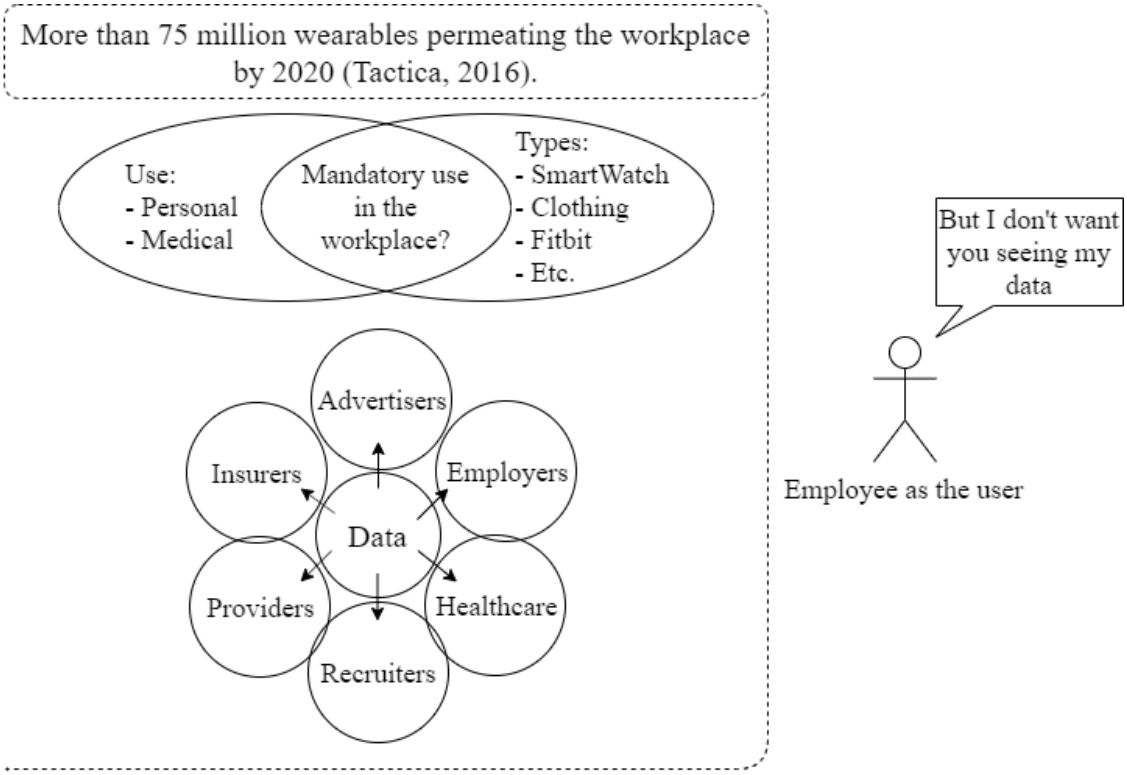

Figure 4: The Isolated User: This figure represents the user on the outside of the barrier of wearable technology, represented by the dotted line. The amount of data can be understood by the 2020 prediction of the number of wearables, their different uses, and the different types. This data may be distributed to a number of different parties without the user's knowing (S. Miller, 2019).

The anticipated outcome of the STS research will be a thorough understanding of the potential biases and discriminatory practices that may come about with employer possession of employee biometric data. For example, according to a three-part study led by a business and ethics researchers, supervisors possess a morning-bias in favor of those who arrive early, which then significantly impacts their performance ratings (Yam, Fehr, & Barnes, 2014). If this is the case, then having data to identify the productivity, or lack-thereof, may encourage employers and supervisors to act on their inherent biases and discriminate against those who do not quantify up to standards in the morning. While these practices may seem obviously unethical to non-lawyers, they are currently legal. The project will compile available research done by legal and sociotechnical scholars in order to provide potential solutions to this gap in law that allows discriminatory actions in the workplace to persist. The Social Construction of Technology framework will be the backbone of this scholarly article in order to encapsulate the magnitude of the issues experienced by the different social groups and the argument made for resolving them.

WORKS CITED

Abdullah, S. (2015). Towards circadian computing: A sensing & intervention framework for BodyClock friendly technology. *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers*, 515–520. doi:10.1145/2800835.2801657

Abdullah, S., Murnane, E. L., Matthews, M., & Choudhury, T. (2017). Circadian computing: sensing, modeling, and maintaining biological rhythms. In J. M. Rehg, S. A. Murphy, & S. Kumar (Eds.), *Mobile Health: Sensors, Analytic Methods, and Applications* (pp. 35–58). doi:10.1007/978-3-319-51394-2_3

Ajunwa, I. (2018). Algorithms at work: Productivity monitoring applications and wearable technology as the new data-centric research agenda for employment and labor law. *St. Louis University Law Jounral*, 63(1), 21-54. Retrieved from https://ssrn.com/abstract=3247286

Brown, E. A. (2016). The Fitbit fault line: Two proposals to protect health and fitness data at work. *Yale Journal of Health Policy, Law and Ethics, 16*(1), 1–50. Retrieved from https://digitalcommons.law.yale.edu/

Doryab, A., Dey, A. K., Kao, G., & Low, C. (2019). Modeling biobehavioral rhythms with passive sensing in the wild: A case study to predict readmission risk after pancreatic surgery. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 3*(1), 1–21. doi:10.1145/3314395

Dunster, G. P., de la Iglesia, L. de la Ben-Hamo, M., Nave, C., Fleischer, J. G., Panda, S., & de la Iglesia, H. O. (2018). Sleepmore in Seattle: Later school start times are associated with more sleep and better performance in high school students. *Science Advances*, *4*(12). doi:10.1126/sciadv.aau6200

National Bioethics Advisory Commission. (2001, August). *Ethical and Policy Issues in Research Involving Human Participants*. Retrieved from https://bioethicsarchive.georgetown.edu/nbac/human/overvol1.html

U.S. Department of Health and Human Services. (2016, July). *Examining oversight of the privacy & security of health data collected by entities not regulated by HIPAA*. Retrieved from https://www.healthit.gov/sites/default/files/non-covered_entities_report_june_17_2016.pdf

Gauttier, S. (2019). Modifying consent procedures to collect better data: The case of stress-monitoring wearables in the workplace. In W. Abramowicz & R. Corchuelo (Eds.), *Business Information Systems* (pp. 350–360). doi:10.1007/978-3-030-20485-3_27

Keynes, J. M. (1930). Economic possibilities for our grandchildren. In *Essays in Persuasion* (pp. 358-373). New York, NY: Harcourt Brace.

Kline, R., & Pinch, T. (1996). Users as agents of technological change: The social construction of the automobile in the rural United States. *Technology and Culture, 37*(4), 763–795. doi:10.2307/3107097

Kyriacou, C. P., & Hastings, M. H. (2010). Circadian clocks: Genes, sleep, and cognition. *Trends in Cognitive Sciences, 14*(6), 259–267. doi:10.1016/j.tics.2010.03.007

Laber-Warren, E. (2018, December 24). New office hours aim for well rested, more productive workers. *The New York Times*. Retrieved from https://www.nytimes.com/

Miller, S. (2019). Project proposal Gantt chart [Figure]. *Prospectus*. (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Miller, S. adapted from W. Bjiker, J. Bonig, & E. van Oost. (2019). SCOT framework for wearable technology in the workplace [Figure]. *Prospectus*. (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Miller, S. (2019). The isolated user [Figure]. *Prospectus.* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, Va.

Moore, P., & Robinson, A. (2016). The quantified self: What counts in the neoliberal workplace. *New Media & Society, 18*(11), 2774–2792. doi:10.1177/1461444815604328

Moore, P., & Piwek, L. (2017). Regulating wellbeing in the brave new quantified workplace. *Employee Relations*. doi:10.1108/ER-06-2016-0126

Murnane, E. L., Abdullah, S., Matthews, M., Choudhury, T., & Gay, G. (2015). Social (media) jet lag: How usage of social technology can modulate and reflect circadian rhythms. *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, 843–854. doi:10.1145/2750858.2807522

Pinch, T., & Bijker, W. (1984). The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science, 14*(3), 399-441. doi: 10.1177/030631284014003004

Roenneberg, T., Allebrandt, K. V., Merrow, M., & Vetter, C. (2012). Social jetlag and obesity. *Current Biology, 22*(10), 939–943. doi:10.1016/j.cub.2012.03.038

Sullivan, A. N., & Lachman, M. E. (2017). Behavior change with fitness technology in sedentary adults: A review of the evidence for increasing physical activity. *Frontiers in Public Health*. doi:10.3389/fpubh.2016.00289

Thompson, D. (2019, February 24). Workism is making Americans miserable. *The Atlantic*. Retrieved from https://theatlantic.com/

Tactica. (2016, April). *Wearable devices for enterprise and industrial markets*. Retrieved from https://www.pwc.com/us/en/industry/entertainment-media/assets/pwc-cis-wearables.pdf

Vetter, C., Fischer, D., Matera, J. L., & Roenneberg, T. (2015). Aligning work and circadian time in shift workers improves sleep and reduces circadian disruption. *Current Biology, 25*(7), 907–911. doi:10.1016/j.cub.2015.01.064

Yam, K. C., Fehr, R., & Barnes, C. M. (2014). Morning employees are perceived as better employees: Employees' start times influence supervisor performance ratings. *Journal of Applied Psychology, 99*(6), 1288-1299. doi:10.1037/a0037109