Building Rhythm-Aware Technology for Health and Productivity

(Technical Paper)

How Interpretive Flexibility of Data Creates Controversy in the

Realm of Data Privacy and Security

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree
Bachelor of Science, School of Engineering

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Spring, 2020

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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

In today's society, people feel pressured to be in a constant state of "busyness" where productivity takes precedence over restfulness. Many people believe that hours of work equate to productivity and therefore try to maximize their hours, while consequently diminishing their utilization. According to Sarah Green Carmichael, a Harvard Business Review author and contributor, "you'll progressively work more stupidly on tasks that are increasingly meaningless" (Carmichael, 2015, para. 11). Brian Lassiter, president of the Performance Excellence Network, explains that this concept of overworking causes humans to work even longer hours to correct their mistakes which leads to a spiraling effect (Lassiter, 2018). What if we could come up with a way to increase our productivity by listening to our bodies' natural rhythms to optimize our working hours. With the rise of mobile and wearable devices, people can now track their health status through sleep metrics, step counts, and calorie consumption. The topics in this paper explain how humans' circadian rhythms can be detected through wearable devices and be used to recommend optimal schedules based on the user's energy and performance levels over time.

Both the technical and STS research topics introduced in this paper center around leveraging mobile devices to gather data and information. The technical project focuses on how technology can be leveraged to detect information about a person's circadian rhythms to make recommendations that will optimize the user's schedule and ultimately boost productivity. The problem at hand surrounds the idea that most people fail to optimize productivity because they do not act in accordance with their biobehavioral rhythms. A group of professors at Cornell University as well as the University of Washington have explored this topic through their joint research and found that "technological solutions often focus on treating the symptoms of a misaligned biological clock rather than having awareness to work in tune with a user's underlying circadian rhythms in the first place" (Abdullah, Choudhury, Gay, Matthews, &

Murnane, 2015, p. 844). The technical thesis proposes a solution that will enable users to live in harmony with their physiological demands.

The STS topic focuses on how the advent of mobile devices has sparked controversy, particularly in the realm of data privacy and security. Interpretive flexibility of data causes this controversy. Users want their data to be private while companies want control in order to drive profit. Because of the numerous data breaches that have occurred, consumers lack trust in the companies and business that own or support their technology to keep their data safe. Spurred by that lack of trust, the engineer holds the responsibility to make ethical decisions to keep technological devices safe and secure by limiting exposure of security vulnerabilities to hackers or other third parties that want access to the data.

Using the Social Construction of Technology (SCOT) framework, the STS topic will delve into the various stakeholder groups that are involved in the controversy and specifically explore the role of the engineer. SCOT, developed by Trevor Pinch and Wiebe Bijker, best models the controversy at hand by analyzing the user groups that influence technological change and policy regulation. Tightly coupled, the technical and STS topics shed light on a rapidly growing industry with opportunities for advancement and conflict.

Building Rhythm-Aware Technology for Health and Productivity

Our internal biological clocks influence performance levels over time; these levels naturally rise and fall throughout the day according to our routines and rhythms. (Abdullah, et al., 2016, p. 465). When people complete tasks at times that do not align with their optimal energy levels, they may not actually be as productive as intended. “Circadian misalignment results when any behavior — including sleeping, waking, or doing cognitive tasks — occurs at the wrong phase with respect to one’s underlying circadian rhythms” (Abdullah, et al., 2016, p. 465). Even slight circadian misalignment leads to sleep deprivation as well as negative impacts on our minds, our bodies, and our behavior toward others. Saeed Abdullah, Ph.D. candidate in Information Science at Cornell University, defined the scope of this problem. Abdullah noted that “around 80% of the population live against their innate rhythms, mostly by adhering to work schedules that demand waking up earlier than our internal clock dictates” (Abdullah, 2015, p. 516). The question that researchers have currently been working to answer is how can we boost human health and productivity in a way that reduces stress and acts in accordance with our physiological rhythms?

The technical project seeks to use circadian rhythms to recommend an optimal schedule for a user that will boost productivity and efficiency in daily life. Under the guidance of Professor Afsaneh Doryab, a team of seven systems engineering students, including Ben Carper, Dillon McGowan, Samantha Miller, Joseph Nelson, Leah Palombi and Lina Romeo, will be working over the course of a year to build a system that tracks and models physiological and behavioral data collected from wearable devices to create optimal schedule recommendations based on machine learning algorithms. The algorithms will understand a person’s natural circadian rhythms to provide data-driven recommendations for the best time to exercise, sleep, or

do work. Since the scheduling will be done in advance for the user, these calendar suggestions will allow the user to feel at ease and consequently, more motivated to do good work at the times that benefit him or her.

The project has been broken down into three sub-projects that will be tackled simultaneously. The first project involves collecting the data from the wearable devices and feeding it into our recommendation algorithms. In completing this task, team members will have to follow the extract, transform, and load general guidelines to move the data from multiple databases into one consolidated database system. Team members will clean the data using a method called feature extraction to pull only the necessary data and remove any extraneous metrics. Additionally, the data will need to be transformed to meet the needs of the system before being loaded. Team members will write stored procedures, scripts that can be stored and rerun at any point in time, to get the data in the proper format. The data will then be spliced in the appropriate way and only the necessary columns will go through the data transformation. All of the other columns will be dropped during the transformation. Finally, the transformation piece involves the physical relocation of this data from one database to another. The stored procedures will handle that movement between databases with the proper code that tells the data where to go. The team members will gather this data from a few devices: the Epatica E4, the Oura ring, as well as the Empatica Embrace. The data stored locally on each device will be gathered and consolidated into one centrally-housed database that will be accessible to the team. To ensure compliance with data regulations and ethics, the team members will complete an Institutional Review Board (IRB) training online to learn and strictly follow the appropriate procedures concerning data collection. The team members will be collecting the data from a small sample of seven to ten participants who will be instructed to wear these devices for 6 to 8 months. This

sample serves as a starting point for this research topic and does not constitute a representative sample, due to its small size.

In the second sub-project, team members will build the machine learning models that will read in the data and output a recommendation. We plan to download anonymized data from our wearable technologies' Application Programming Interfaces (APIs) and begin to build a data model based off that data. Due to the time restrictions of this project, the team members will develop a preliminary data model based on data that comes from sources other than the Epatica E4, the Oura ring, as well as the Empatica Embrace. Publicly available Fitbit data will comprise the bulk of the preliminary model. Fitbit currently does not track galvanic skin response which serves as a strong indicator of mood. Bryn Farnsworth, Ph.D. graduate of Uppsala University in Sweden wrote in his research that "the galvanic skin response refers to changes in sweat gland activity that are reflective of the intensity of our emotional state, otherwise known as emotional arousal" (Farnsworth, 2018, para. 1). As a result, the group will gather data from sources other than Fitbit in the final model. Once the data collection from the other devices begins, the team will write custom code that will align and synchronize the columns that contain the same metrics in the dataframe to create one common, workable framework. This methodology will allow team members to build a model without the time delays involved in waiting for at least six months' worth of data to be collected from the participants' devices. Using the finished framework, the group members will train the computer to understand circadian rhythms based on the data inputs. Running machine-learning algorithms will enable the computer to learn the trends in a person's energy levels which can then be used for scheduling recommendations. The group will test the computer's accuracy using test sets of data that will be set aside to create an unbiased model.

Coding the user interface that will relay the recommendations will be the third sub-project. The user interface will be accessed online via mobile devices or desktop computers. Team members will first develop a storyboard or prototype using Figma that will convey the design and visualizations of the interface. After the prototype has been established, the team will use front-end programming languages to physically code the interface to create a final product which will output optimal scheduling results based on our machine-learning models.

To get a better understanding of the timeline of this project, the Gantt chart in Figure 1 depicts approximate completion times for the tasks in this project.

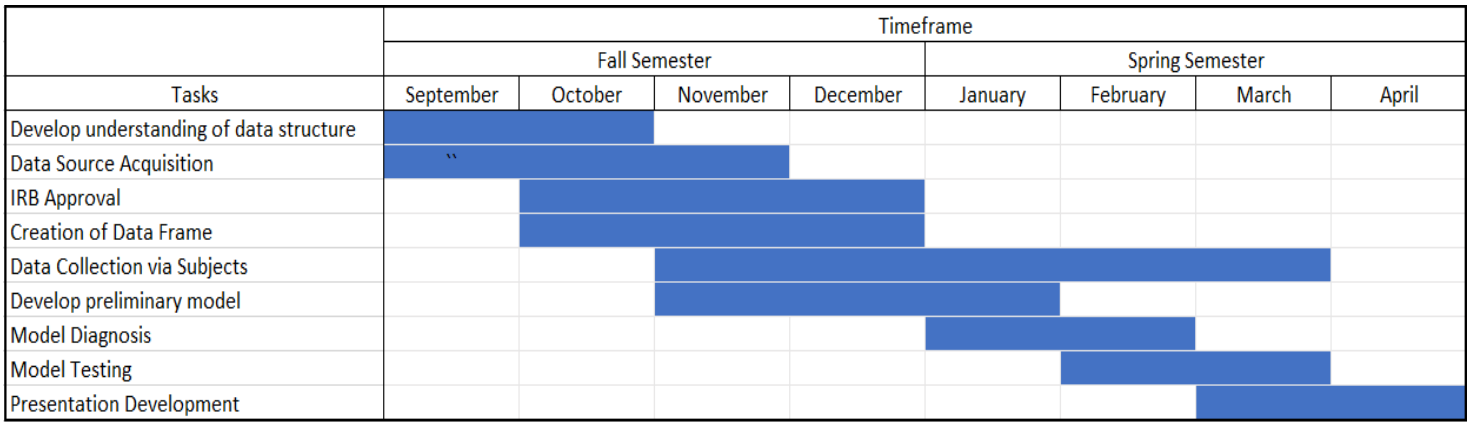

Figure 1: Gantt Chart: This figure depicts the relative timelines for the technical project over the course of two semesters (Nelson, 2019).

The results of this study will be published in a conference paper and will be presented at the Systems and Information Engineering Design Symposium (SIEDS) in April 2020. The conference highlights the work of student research and design projects in Systems and Information Engineering. The project this team worked on falls under the data modeling and decision analysis methodologies as well as the health application.

How Interpretive Flexibility of Data Creates Controversy in the Realm of Data Privacy and Security

With the advent of big data, the collection of data has sparked controversy within the realm of privacy and security. Concerns about data privacy and security have surfaced from consumers, researchers, and scholars. Experts in data security and cloud computing Ke Wan Ching and Manmeet Mahinderjit Singh reported that security vulnerabilities exist in data transmission between local devices, data storage in the Cloud, lack of authentication and authorization, as well as a lack of physical security controls (Ching & Singh, 2015, p.24). These security vulnerabilities have led users to feel skeptical about the trustworthiness of their devices and who has access to their data. Douglas Bonderud, a researcher and writer of security intelligence topics, wrote of a study conducted by IBM which showed that 60 percent of respondents to a cybersecurity and privacy research survey said "they're more worried about cybersecurity than war" (Bonderud, 2018, para. 1). Released in 2018, figure 2 shows statistics of consumer trust in the new digital age. One can see from this graphic that consumers lack trust in organizations to keep their data private and that the emphasis for companies lies more in driving

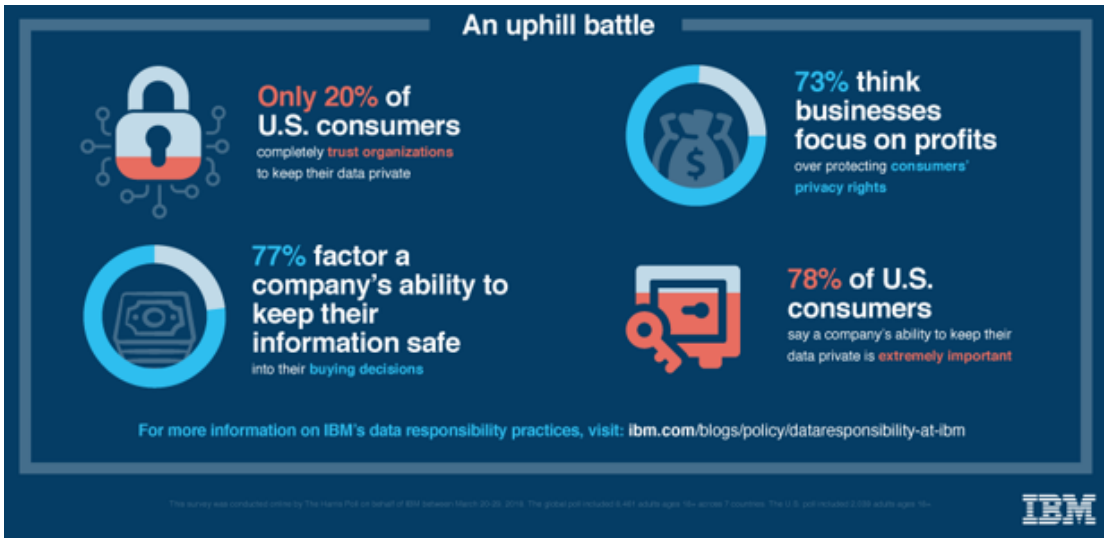

Figure 2: The Significant Gap Between Data Privacy and Consumer Trust: This graphic displaying the results from the IBM Cybersecurity and Privacy Research Survey depicts the miniscule confidence of consumers in businesses to keep their information safe (Bonderud, 2018).

profits and growth than looking after consumers.

Technology today has the capability to track and store your location, biometric data, as well as your purchasing habits. Consumers want their data to stay private while companies want access to this data in order to drive insights that will bring in more revenue. It seems logical that businesses want to outcompete their rivals, but at what cost? The STS topic explores the nature of the controversy surrounding data privacy and security that comes with these new data collection capabilities. Using the Social Construction of Technology framework, developed by Trevor Pinch and Wiebe Bijker, the research gathered will highlight the roles of various stakeholders involved in this dilemma and their own motivations for gathering data to either secure access for users or obtain data for personal profit.

A Word on Interpretive Flexibility

Interpretive flexibility, as defined by Ronald Kline and Trevor Pinch, encompasses the idea that "the same artifact can mean different things to different social groups of users" (Kline & Pinch, 1996, p.776). Kline and Pinch, scholars in the area of science, technology, and society, explain this phenomenon in the context of a bicycle. Kline and Pinch note that a bicycle can be used for transportation purposes or can be solely seen as a machine that looks cool and manly. These meanings can also change over time. With the addition of new features, bicycles can improve their image or amplify their speed, while keeping the same general look and feel. The new features could therefore change users' perspectives on the bicycle. Interpretive flexibility dwindles when closure and stabilization occur. This means that "artifacts appear to have fewer problems and become increasingly the dominant form of the technology" (Kline & Pinch, 1996, p. 766).

In the context of data collection, data can be interpreted in different ways. Users of technologies that collect and store data interpret that data as their own and believe that data should remain private. Gilad Rosner, researcher at the Horizon Digital Economy Research Institute defined ownership. He wrote "owning something confers the exclusive rights to possess, use, and manage that which is owned, and to derive income from it," (Rosner, 2014, p. 625). At the same time, "some scholars believe that an asymmetry exists between individuals and the companies who seek to obtain their data; in other words, people may be at a disadvantage when contracting with businesses with respect to their bargaining power and ability to understand the potential uses of their personal information" (Rosner, 2014, p. 626). When using devices that collect personal data, users are typically required to agree to terms and conditions. The issue lies in ownership language being difficult for users to decipher and understand. Consequently, the data controllers get access to the data and use it for their own personal benefit, with misinformed user permission of course. There are two opposing interpretations within this controversy; the users believe they own the rights to their own data while the data controllers who gain access to the data assert their position that the data now belongs to them.

Third Party Access to Data

Companies have been collecting statistics about their customers' habits in order to personalize experiences for the user and increase sales for the company. This data collection can either be used for good or for bad. Some individuals feel that if companies provide a service which benefits them personally, allowing those companies access to their data would be worthwhile. However, as soon as the data starts to be used to benefit someone else or another third party, the line would be drawn. The controversy about data ethics and data privacy most prominently begins at this stage.

Sarah Shemkus, a notable journalist in the business and technology world, warns her readers about the growing number of insurance companies that have obtained access to customer health data through access to data from wearable devices (Shemkus, 2015). One of Shemkus's articles about fitness trackers featured in *The Guardian* discusses how some insurance companies, motivated to lower the risk profiles of their customer base, make deals with companies to offer discounts or incentives for employees using these wearable devices. As a result, insurance companies expect lower claims payments and can charge lower premiums to employers, making a higher profit themselves (Shemkus, 2015). Shemkus sheds light on the hidden controversies and data privacy concerns that surface as a result of these insurance companies obtaining access to this health data. The more publicly available data that circulates, the larger the risk of a data breach. Greg Dracon, head of the security practice at .406 Ventures, a capital market investment company, stated "as soon as insurers are incentivizing you to wear something because it's going to save money, it becomes a bigger target for the attackers" (as cited in Shemkus, 2015, para. 16).

The involvement of third parties in the examination of individuals' private data for personal profit triggers uneasiness in consumers who are aware of the issue. Due to these rising ethical concerns, research ethics committees such as Institutional Review Boards (IRBs) have sprung up to oversee research done on humans. Danah Boyd and Kate Crawford, scholars in the field of data science and technology and professors at New York University, discuss the ethical concerns that have sparked questions with the advent of big data in their journal article titled "Critical Questions for Big Data". Boyd and Crawford highlight the role IRBs play in upholding moral standards by stating "the goal of IRBs is to provide a framework for evaluating the ethics

of a particular line of research inquiry and to make certain that checks and balances are put into place to protect subjects" (Boyd & Crawford, 2012, p. 672).

The Role of the Engineer

In the greater societal context of data privacy and security, the engineer plays a huge role. Engineers design the blueprints and eventually build technologies that heavily impact human lives. The engineer interacts with businesses, governments, individuals, entrepreneurs and society to develop innovative and ethical products. Many times, the engineer faces dilemmas where he or she may need to make decisions that directly impact users' security. To draw an analogy, let us examine the construction of a bridge. Various stakeholder groups design the blueprints, provide the materials and pay the bills; however, the engineer tests the model and eventually builds the bridge when enough tangible proof has been gathered to assert that the bridge will be safe. Since the engineers are the final link in the chain, if the bridge collapses, the engineers are blamed. In the context of data privacy and security, businesses building products provide their engineers with the resources needed for development, whether physically or monetarily. However, the engineer ultimately decides how to build the features that protect against hackers or other third parties seeking access and remains liable for any faults in the system.

Figure 3 displays the Social Construction of Technology model with the engineer at the center of the various stakeholder groups. This model depicts how stakeholders influence the engineer's work as well as the underlying motivations for using the data collected. With new legislation from government being proposed and demands for increased privacy surfacing from users, the engineer must create the privacy and security features that best protect users from

hackers and other third parties looking to obtain access to personal data. They must act as a shield to keep unwanted parties from compromising security for the innocent.

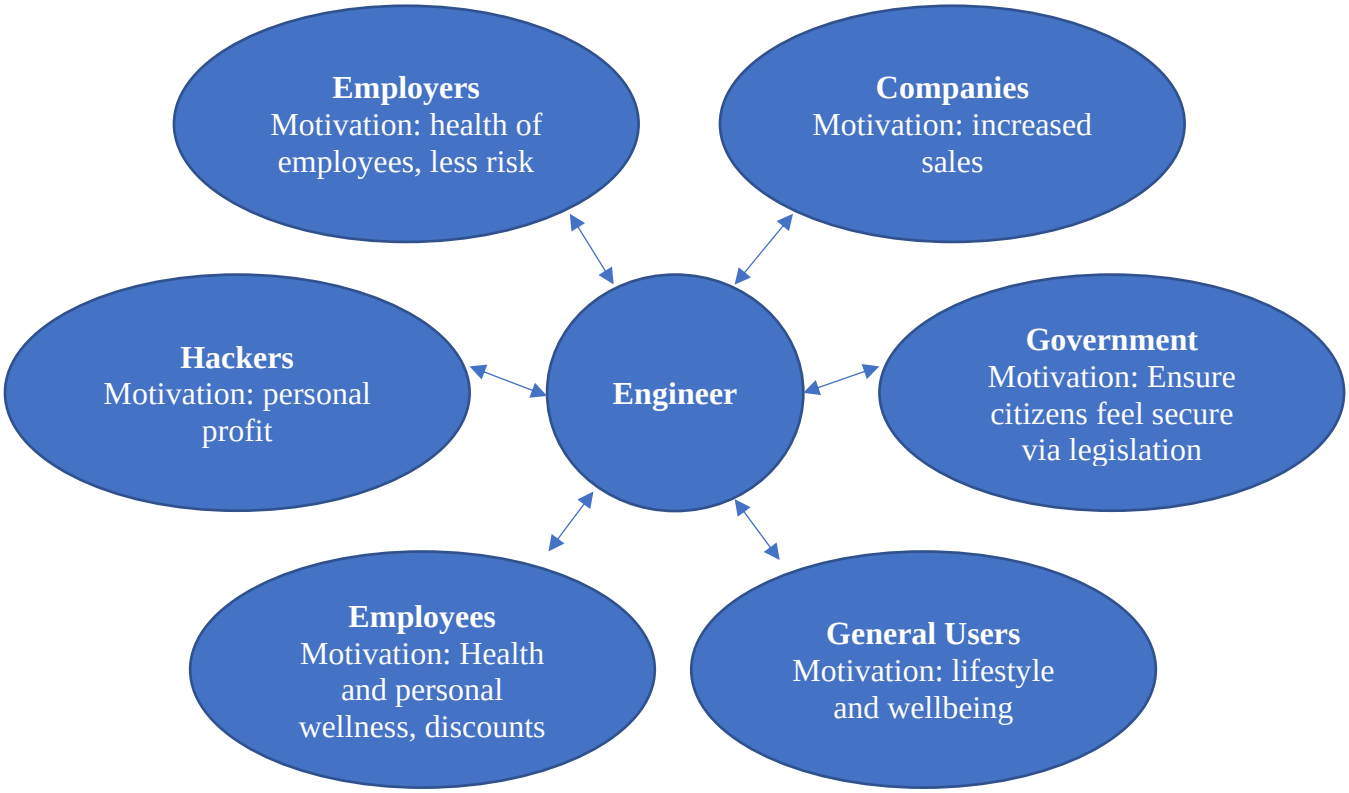

Figure 3: Social Construction of Technology Model: The figure depicts the engineer at the center of the model with the stakeholders around the perimeter and arrows demonstrating the interactions. (Adapted by Kayla Spigelman from B. Carlson & C. Baritaud, 2019).

Is there Common Ground?

In order for there to be standards that can be agreed on, all of the stakeholders involved must converge on their values. Furthermore, the proper legislation needs to be put in place to protect the rights of consumers in maintaining privacy. An article written by Nuala O'Connor, president and CEO of the Center for Democracy and Technology, highlighted that citizens of the United States called on Congress to write a Consumer Privacy Bill of Rights. (O'Connor, 2018).

In 2012, the Office of the Press Secretary released a statement asserting that this bill of rights would "improve consumers' privacy protections and ensure that the Internet remains an engine for innovation and economic growth" (The White House, Office of the Press Secretary, 2012, para. 1). In order for businesses to be successful on the internet, they need loyalty from their customers. Security directly impacts customer loyalty. When the Consumer Privacy Bill of Rights was established, President Obama affirmed "as the Internet evolves, consumer trust is essential for the continued growth of the digital economy" (The White House, Office of the Press Secretary, 2012, para. 3).

The year 2012 simply began the movement toward showcasing and fully recognizing the need for a common data ethic within the United States. The Internet and technology as a whole have come a long way in the past seven years and consumers must continue to push the government for the standards they wholeheartedly demand. Already, California has passed the California Consumer Protection Act which "will allow consumers to force companies to tell them what personal information they have collected" (Roberts, 2019, para. 5). Additionally, the act gives consumers the right to demand that companies delete their personal data or forbid them from sharing the data with third parties. Companies will also have to be more explicit and upfront about the data they collect (Roberts, 2019). The act will go into effect on January 1st, 2020. Even though this act applies to companies that do business in California, other vendors who sell products to California will have to comply as well. Paramount to users' data privacy and security rights, this act will commence the necessary cultural shift based upon transparency for the world of big data. In order to initiate change, a need must be demonstrated and our values must be aligned. California has proved to the world exactly that by setting the standard for the rest of the country to follow.

Conclusion

Big data creates many complications regarding the ethics and privacy rights of individuals. The technical topic explores leveraging mobile devices to detect human circadian rhythms and outputting optimal schedules to help users boost productivity. The STS topic uses the Social Construction of Technology framework to analyze and interpret the influences of various stakeholders as well as the role of the engineer in the fight for data privacy and data security. While the technical project involves the physical collection of data, the tightly coupled STS topic discusses the controversy that occurs as a result. In conclusion, the exploration of the technical and STS topics presented will underscore the importance of leveraging data in an ethical way to hopefully boost consumer trust in the future.

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