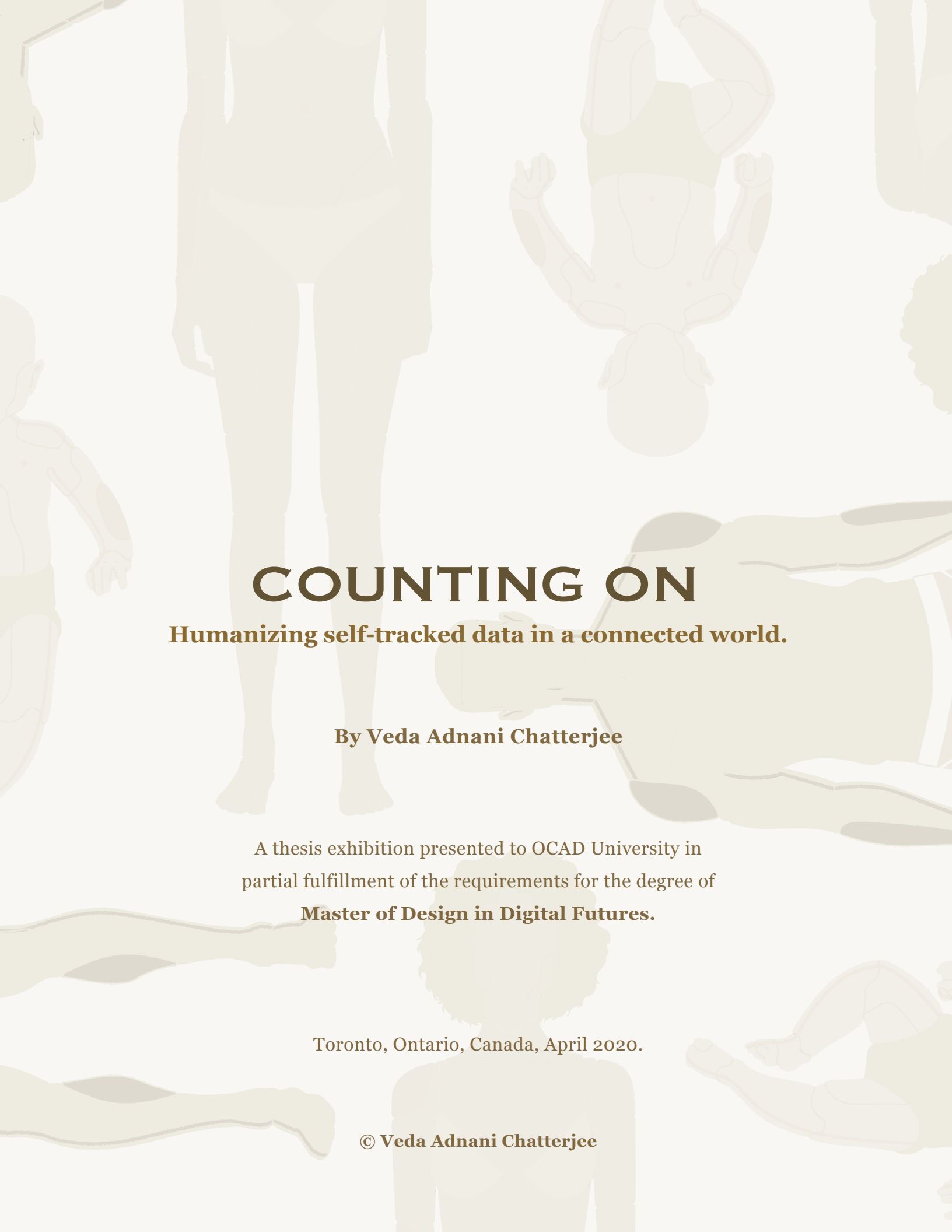

COUNTING ON

Humanizing self-tracked data in a connected world.

By Veda Adnani Chatterjee

A thesis exhibition presented to OCAD University in
partial fulfillment of the requirements for the degree of
Master of Design in Digital Futures.

Toronto, Ontario, Canada, April 2020.

ABSTRACT

This thesis explores the evolving role of the Quantified Self and self-tracking culture within personalized healthcare. Health and fitness wearables are proliferating globally. However, wearable device abandonment rates are also surging. Wearables can sometimes be authoritative or punitive when presenting wearers with their biological data. In the past, some devices have even triggered adverse health-related conditions. This thesis proposes an approach to visualizing biological data from wearables, in ways that are coherent, contextual, and humane. It critiques normative data visualizations in commercial wearables and speculates alternate futures for self-tracking to empower individuals to manage their health and well-being autonomously. Through an iterative development process to prototype creation, the author gathers biological data using a consumer wearable device and uses it to propose an information architecture that categorizes the data coherently. The architecture is applied in hand-drawn, domestic, embedded visualization prototypes that present the author's biological data. Lastly, user interviews are conducted to acquire responses to the prototypes and plan possibilities for future iterations. The purpose of this research is to advocate empathy and compassion in the emerging culture of living with data while considering the intricacies of everyday life, the imperfections of being human, and the need for autonomy in personal data management.

Keywords: Quantified Self, Personal Informatics, Lived Informatics, Self-tracking, Lifelogging, Data Visualization, Data Humanism, Ambient Design, Iterative Development.

ACKNOWLEDGEMENTS

This thesis has come to fruition with the contribution and support of talented individuals that I am grateful for. I would like to express my gratitude to all of them.

To my advisors Kate Hartman and Marcus Gordon, thank you for your commitment to my research.

To Dr. Kate Sellen, Dr. Michael Prokopow, Dr. Bill Leeming, Ala Roushan, Dr. Adam Tindale, Dr. David McIntosh, Dr. Emma Westecott, and Jessica Wyman at OCAD U, thank you for your guidance along my journey.

To my classmates, April and Omid, thank you for you unwavering encouragement, honesty, and more importantly, unending humour.

To Yadnyee Shingre, Andrii Bondarenko, thank you for creating beautiful illustrations that brought my research to life.

The lovely Angie Fleming, thank you for your crash course on all things data.

To all my user testers, thank you for authenticity and optimism. They have been both inspiring and invigorating

And lastly, to my Digital Futures Community at OCAD University – thank you for being a part of this experience.

Thank you all, from the bottom of my heart.

TO MY ETERNALLY YOUNG GRANDPARENTS, MURLI & LATA.

TO MY PARENTS POOJA, BALDEV, ANITA & SUBIR.

TO MY AUNT DURU.

AND TO RAHUL, MY WORLD.

TABLE OF CONTENTS

LIST OF FIGURES

AUTHOR'S NOTE

When I chose to write this thesis on building empathy in self-tracking, I was unaware of just how meaningful the process would end up being. Writing this thesis has been an enriching, invigorating journey of self-discovery. This thesis has given me a deep understanding into just how connected my mind and body are, and what factors affect my physical and mental health and well-being.

Born a millennial, I am part of a generation that seeks purpose in their work with their professional and personal aspirations deeply intertwined. The concept of "hustling harder" and pushing beyond the conventional 9:00 am to 5:00 pm job to expedite growth became somewhat normative. Our profession has become the most significant aspect of our identity, and this tendency is becoming addictive for some. I am no stranger to this trend. My unwavering devotion to my job led to me neglect my health and well-being. My daily struggle to excel inadvertently became my biggest motivation. Sitting at a desk job for close to twelve hours a day, six days a week took its toll on me, and my health began to suffer. In 2014, I was unexpectedly diagnosed with a slipped disc in my lower spine. I went through an array of tests to uncover the details of the problem and sat anxiously with stacks of reports filled with data that came from my body, of which I understood nothing. My dependency on my doctors for answers was frustrating. To make things worse, I was bed-ridden and left with nothing to do for three months, which caused my mind to waver frequently.

In retrospect, being forced to lie down led to me developing a heightened sense of awareness of my body. I focused on getting to know myself better. I looked for physical and psychological patterns, such as being able to pre-empt a cold with the kind of headache I had. I was making mental notes all along. Subconsciously, I was lifelogging to keep track of changes in my body, and I continued to do so even after I had healed. I began to practice Yoga and soon found myself tracking my progress. I was more cognizant about how it was helping to reduce the pain in my back, increasing my flexibility, and making me happier. The opportunity to get to know myself better through increased awareness of my body, made me feel noticeably better about myself, and this knowledge has been life-changing

During that time, the only tracking tools I had were my memory and the rare mobile entry in my Notes application, causing my lifelogging practice to be inconsistent and short-lived. Also, the data I captured was qualitative and personal, with no standard data points or guidelines in place to be able to draw insights in the form of comparisons or set goals. However, somehow it all made sense

to me because I was the one creating the data. I always longed for the right tools to help me capture aspects of my health, on the condition that they would not require my constant attention or extreme effort.

When I discovered the Quantified Self community and learned about the rapid growth of biological sensors, I was enthralled. It felt like discovering a hidden treasure on a remote island. I was keen to explore what the world of self-tracking devices had to offer for improved physical and mental well-being. However, I was soon disappointed when I discovered that one-third of the devices sold globally were abandoned within the first six months of use (Gartner, 2018). I had to investigate why these devices that had the potential to truly transform our health and foster a culture of equitable care were being abandoned so quickly and in significant numbers. One of the most compelling reasons that came to light was gaps in how data extracted from the body and mind were being presented to the wearer. I found that the usual diagrams that inhabit business presentations and medical reports were being used to convey raw biological data to the average wearer. As a designer, I was bothered by this trend, and I viewed this and opportunity to reimagine the way health data is presented to those outside the medical community.

I couldn't help but wonder if we relate to our bodies the same way we relate to numbers at the workplace? Do we scrutinize ourselves the same way we examine statistics in business meetings? Has this ideology stemmed from the millennial intertwining of work and play? And if so, what culture is this trend advocating for the future of self-tracking This thesis is an attempt to move away from this utilitarian approach towards an empathetic and compassionate one. As designers, we must find ways to harness the potential of wearable technology to enhance our well-being that is both science-backed and keeps the wearer at the heart of the design process.

Technology has begun to take care of us in ways that we thought were uniquely human.

chris dancy, the mindful cyborg

INTRODUCTION

This thesis presents a humane approach to visualizing data from the human body within the realm of health and well-being wearables. It employs an iterative development process to critique current industrial practices. By doing so, my research speculates alternate futures for a more empathetic and compassionate approach towards visualizing biological data from wearable, self-tracking devices. I investigate various theoretical concepts within health and well-being theory, Personal Informatics Tools and the Quantified Self. I also scan the industry and study tracking reports of Quantified Self. Simultaneously, I collect data from my body using a Fitbit, and the Flo menstrual tracker. I use this body of data and research to create an information architecture that categorizes different data points from the body. I then utilize this architecture to prototype a design system of embedded, ambient, hand-drawn, domestic visualizations. The visualizations have been created with the intent to contextualize biological data to the wearer's lifestyle and routine and to present siloed data points coherently. I conduct user testing on the visualizations to gain insight into other wearer's preferences and criticisms with approval from the Research Ethics Board at OCAD University. My prototype is one of many possible alternative ways to approach visualizing data from the human body and by no means the only right way to do so. The broader purpose of my thesis is to cultivate a more empathetic mindset within the design community when it comes to the design and development of personal informatics tools for health and well-being.

Research Question:

How might we design systems of data visualizations for health and fitness wearables that present gathered data in ways that are *coherent, contextual, and humane*?

RESEARCH RATIONALE

2.1 Thesis Document Outline

I employ this thesis to create awareness around critical concepts, issues and opportunities within self-tracking for health and well-being. This thesis document begins with a review of relevant theory, Quantified Self practitioner's reports, and a horizon scan of commercial wearable devices. The review is followed by a detailed explanation of the methodologies and methods employed within this thesis. Thereafter, the research is synthesized, and the prototype creation process is elucidated. Also included are results from the Research Ethics Board (REB) approved user testing of the visualization prototypes created within this thesis. The document concludes with a reflection of my journey and the lessons learned.

In this document, the term self-tracking is used several times. Depending on the argument at hand, it may be articulated as self-measurement, self-regulation, self-modulation or self-enhancement. Also, the term active tracking is used when referring to manual logging, and the term passive tracking is used for sensor-based automated tracking. The term wearable also appears several times within this document. In my opinion, a wearable is a technological device designed to be placed on or within the body. Its purpose is to extract data from the body for improved health and well-being.

The words *coherent, contextual, and humane* also appear a number of times in this document, including in my research question. These terms have motivated my research-creation process and served as guiding principles throughout my exploration. While I discuss the meaning of each term concerning this thesis in the Prototyping Motivations Section (5.1), I would like to introduce the three terms briefly to give the reader initial insight into their significance. The term *coherent* in my thesis refers to my attempt to correlate data points currently presented in silos in commercial wearable devices, in an attempt to better place the data within the everyday lived experience. The word *contextual* is pertinent to my research for various reasons. I attempt to contextualize the data I collect in order to present it in a way that can allow it to effortlessly integrate within a user's lifestyle. I also attempt to add context to where the data is presented to the user by attempting to embed my prototypes within domestic spaces. The word *humane* reinforces my user-centered approach and stands for the consideration of factors such as privacy, transparency, and compassion within the development of my research.

2.2 Research Creation Process

This thesis employs an iterative development process that comprises three predominant stages: *examination, definition, and creation*. *Examination* entails problem definition through a detailed research exercise, which involved an analysis of theory, Quantified Self practitioner's reports, as well as a horizon scan of commercially available wearable devices. The objective of this phase was to gain insight into data types can be extracted from different bodies across different genders and life-stages. All of the research conducted during the *examination* stage was applied in the *definition* stage. The *definition* stage began with the creation of a set of diagrams that showcase various data points, based on their location on the human body. I then created a datasheet to capture missing aspects of data points in current wearable devices, in context to lived experiences. I also identified possible links between different data points that have not yet been established. I then created a User Persona based on myself to guide the prototype creation process. In the *creation* stage, I carried forward work done in both the examination and definition stage. I collected data from my body with a Fitbit Alta HR, which is a wearable wristband that tracks activity, sleep and heart data. I used this device along with various mobile applications to track my health. Later, I created an information architecture for categorizing various biological data points, which I followed with the creation of visualization wireframes. I collaborated with an illustrator who created space renders to showcase where my visualizations will reside within domestic settings. Finally, I used the data collected through my Fitbit to populate my visualizations and digitally painted them . Because the iterative development process is cyclical, this thesis turns back to the *examination* stage where the visualizations are used as cultural probes with users that fit the persona generated in the *definition* stage to understand their perspective, preferences and dislikes and evoke discussion on their experiences with self-tracking. Most steps within my iterative development process were iterative within themselves. Ideally, I would have gone back to the *examination* stage to rework my prototypes after using them as cultural probes. However, due to the time constraints within this thesis, I was unable to do so. A detailed diagram of this thesis prototype development process is shown in Figure 1.

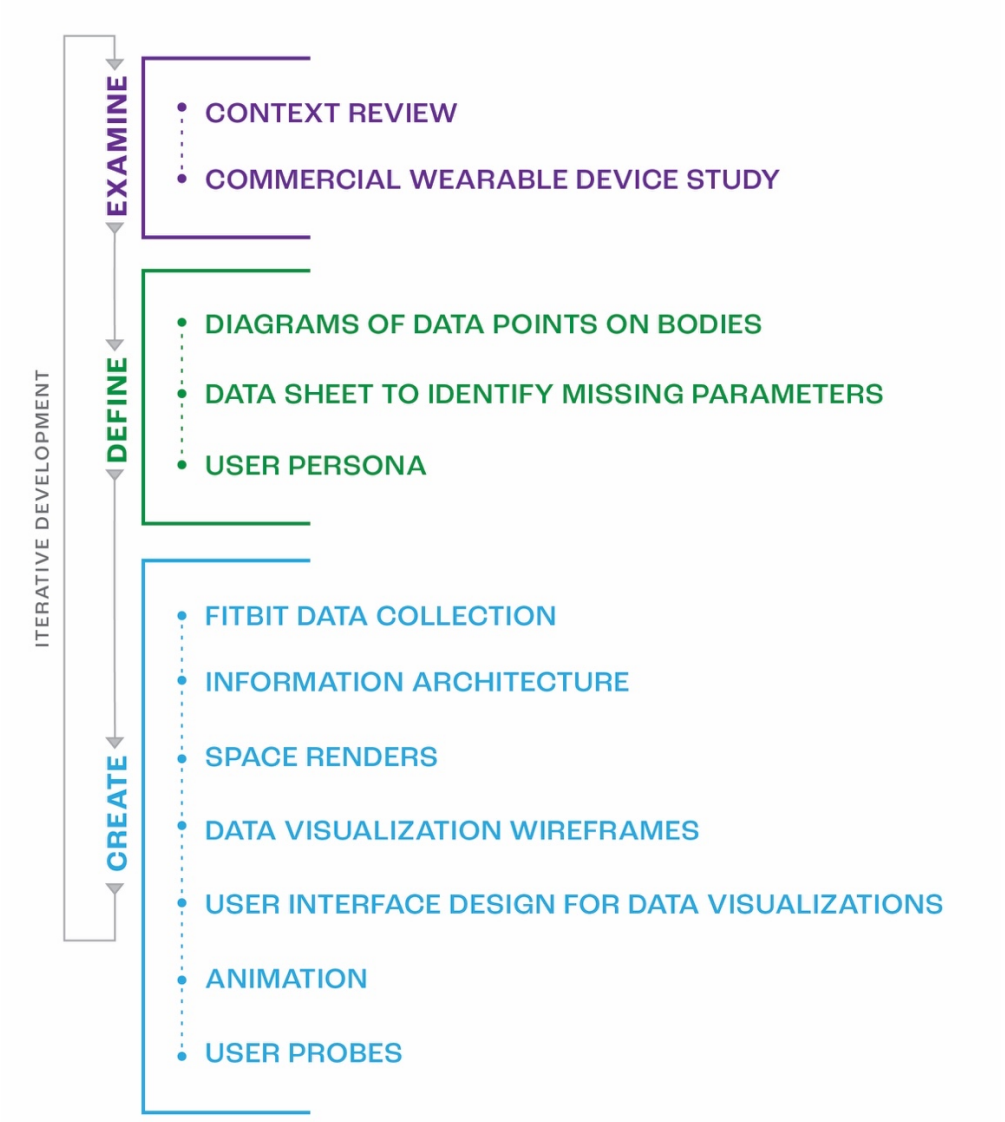

Figure 1: My iterative development process to prototype creation.

2.3 Choice to Work with my Data

A number of creative practitioners that undertake data-based projects in relation to the human body choose to work with their data. Practitioners like Laurie Frick and Giorgia Lupi chose to collect and analyze their own data to create exhibits and publications. Roxolyana (Sana) Shepko-Hamilton, as part of her Graduate Thesis, compounded eight years of social media conversations between her sister and herself and visualized them in order to understand human relationships in the time of the internet (Shepko-Hamilton, 2019)

I favoured working with my data because it gave me the opportunity to control the data collection process. Through my data analysis, I was able to uncover hidden values, beliefs, and assumptions that were embedded within my lifestyle and behaviors. This insight contributed to my reflection and visualization process, and the depth and quality of the insight would not have been the same with another individual's data, or an application. I personally believe that self-tracking is an intimate, private practice, and I did not feel comfortable putting another individual or group of individuals through the intense surveillance that I underwent. I used my personal findings to validate the concept of personalizing data visualization for the body within my prototypes, which was integral to my research-creation process.

Lastly, the reason I was inspired to undertake this research was to find sustainable, personal and accessible ways to look after my health and well-being. Using my own data, not only gave me critical insight into my research but also led me to make changes to my lifestyle and habits.

2.4 Scope and Limitations

The aim of this thesis is not to prescribe a new fool-proof system for biological data visualization, but to propose a shift in mindset, priorities, values, motivations, and behaviors for the design and development of biological data visualizations from health and fitness wearables. While there are multiple causes for device abandonment mentioned briefly within the context review, the focus here lies in visualizing the data in ways that are more contextual, coherent and humane. Listed below are the limitations of this thesis:

- The number of visualizations created within the time allotted for this research. Given the array of data points that can be extracted from the body and categories than can be visualized, this thesis focusses on two key categories due to the constraints in time. In addition, due to the limited time the number of body types that the research is adapted to is limited to the author for this iteration of the research.

- Feedback from user testing on the visualizations is reflected upon, however, not implemented into the prototypes created in this thesis, due to the time constraints.

- Due to the speculative nature of this thesis, the visualizations have not been created with the sole intent of going to market. While they have been developed as prototypes, there is a

significant amount of development required in terms of strategy, insight and testing prior to being commercialized.

- This thesis aims to decode the implications of visualizing biological data as per current industrial norms and addresses front end privacy issues with the visualization of biological data. Privacy concerns with the backend of the technology speculated in this thesis are discussed briefly in the Reflection Chapter (7.0). However, this aspect is not essential to and within the scope of this research and therefore not discussed in detail.

Context Review

3.1 A Short History of Self-Tracking

Wearable self-tracking devices have been described as triggering 'a new culture of personal data' and as representative of a revolution in how individuals understand their own bodies.

- Wolf, 2009

Finding ways to measure things has been an area of interest for humankind for a long time, as measuring things perhaps meant being able to master or control them. Measuring the human body is no exception to this desire. Foucault, in his essay on "Technologies of the self" (1988), elucidates humankind's history of developing self-knowledge through fields such as "economics, biology, psychiatry, medicine, and penology" (p.18). He describes technologies of the self as those that allow individuals to change or transform themselves autonomously, or with the help of others by performing actions to attain "a certain state of happiness, purity, wisdom, perfection or immortality (p. 18)." But as self-tracking has evolved, the level of empathy within the practice has gradually declined. I believe that as technology developed, mankind has simultaneously begun to consider themselves to be machine-like. They have often subjected themselves to the same level of analysis as the devices of their creation. This chapter provides insight into the evolution of self-tracking to understand how the principles of empathy, that were once at the nexus of self-tracking, is no longer a priority.

The human body is a sophisticated, beautiful system of systems that self-regulates. Its eleven systems comprise seventy-eight organs that work tirelessly to maintain a biological balance through what we call homeostasis (Lanese, 2019). In my opinion, self-regulation for the average person has typically been subjective in the past, and the need for effective self-regulation has been a critical driver in the development of self-tracking practices. While self-tracking once depended on natural cues from the body to indicate an imbalance, such as feeling hungry when nutrition is required and perspiring in warm environments. It requires a certain kind of awareness of the body to decipher cues and action a rebalance. In my opinion, traditional practices in the east, such as Yoga, emphasized developing this mind-body relationship to maintain adequate homeostasis

(Iyengar, 2002, p. 4). There were no quantified figures, tables or incentivized tracking contests. Teachers, who had devoted their lives to the practice helped individuals increase their bodily awareness in ways that worked for them. I believe that at the time, empathy formed an integral part of the teacher-pupil relationship, which also encompassed a deep sense of respect and reverence for the human body in all its manifestations.

In the west, a new dialogue around the idea of the self, prompted self-tracking. Self-measurement was practiced by recording and reflecting. Foucault (1988) says that during the Hellenistic age (323-31 BC), "Taking care of oneself became linked to a constant writing activity" (p. 27). Self-tracking was undertaken through diaries, journals and other manual methods. The purpose of self-tracking was to pay attention to the "nuances of life, mood, and reading, and the experience of oneself," or what we might now call the lived human experience. There was no critique on the form or performance of the body. It was merely a qualitative account of what the individual was experiencing. I believe that self-empathy was vital to this practice, and that is evident through the lack of criticism involved, as reflecting encompassed both the good and the bad.

During the Renaissance, the ideology of the self and existence emerged as popular topics for writers. Some of the most prolific writings about the self, came from Husserl, Heidegger, Sartre and other philosophers. Amongst them was Rene Descartes, who wrote "A Discourse on Method" (1637). He said, "cogito, ergo sum," better known as, "I think; therefore, I am" (p. 30). With this statement, Descartes established what is commonly called the Cartesian Split, which led to a mind-body dichotomy that has persisted ever since its inception. Self-regulation of the mind gradually disconnected from the regulation of one's physical body. The development of science and allopathic medicine accentuated this dichotomy, and the treatment of bodily disease with standardized chemical compounds became the norm for effective regulation.

Additionally, as medicine exploded in the 1900s, individuals relegated control of bodily regulation to healthcare professionals, thereby causing a shift in the practice of care, from preventive to corrective (Winter, 2009). It is my position that during this time, the development of ambulatory devices (such as the electrocardiogram machine) in professional healthcare environments gradually quantified the process of reading signals from the body. However, deciphering and acting on the data was reserved for healthcare professionals. By setting benchmarks for good health and normal and abnormal ranges for readings, the medical community allowed the human body to be critiqued with absolute precision. Thus, caring turned to cure, and curing the human became transactional, causing empathy in care to slowly diminish.

As numbers became indicators of good and bad health, they made the process of self-tracking more robotic. The weight scale was the first quantified self-measuring device introduced over a century ago, in the early 1900s (Crawford, Lingel, & Karrpi, 2015, p. 495). It progressed rapidly from healthcare spaces into the public and eventually made its way into domestic households. For the first time, users were able to track an aspect of their body with precision, as often as they wanted, in the privacy of their homes. They could use this data to control their lifestyles, identify weight patterns, make changes to their diet and reflect upon the numbers objectively. Some older scales even came with quotes on them like "He who often weighs himself knows himself well. He who knows himself well lives well". Therefore, it is plausible to believe that the history of the weight scale reminds us that "tracking devices are agents in shifting the process of knowing and controlling bodies, individually and collectively, as they normalize (and sometimes antagonize) human bodies" (Crawford et al., 2015, p. 483-484). Sadly, empathy continued to diminish as the number on the scale became an indicator of self-worth, especially for women, and not much has changed since. The authors also claim that weighing scales have offered the same promise over the last century, that wearable devices provide today, which I believe is enhanced self-knowledge through self-measurement.

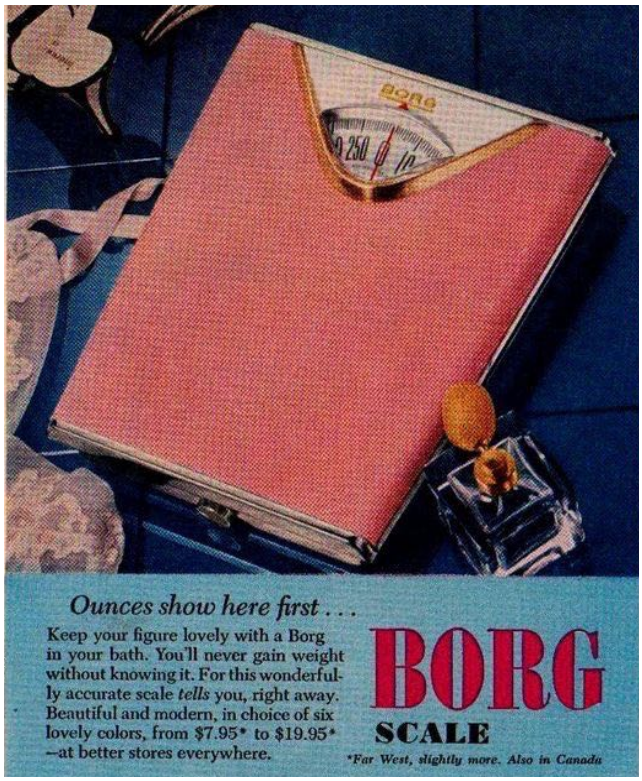

Figure 2: An advertisement for a weight scale in the 1900's. (Source Unknown)

3.2 Self Tracking in 2020

Today, self-tracking or self-measuring is becoming a precision-based, collaborative process between humans and machines. From smart thermometers and smart scales in every home to non-invasive glucose monitors, and seizure detecting skin sensors. Measuring various aspects of the body has become a precursor to any assessment of health and well-being. In her essay "Cyborg Manifesto" (2014), Donna Haraway states that the sharp contrast between human and machine is decreasing incrementally and that eventually, humans could turn into "theorized and fabricated hybrids of machine and organism" (p.150). N. Katherine Hayles, in her book "How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics" (2001), says that "although 'posthuman' differs in its articulations, a common theme is the union of the human with the intelligent machine" (p. 2).

Currently, tracking devices are on our bodies, around us, and even inside us. We refer to them as wearables, implantables, ingestibles, and tattooables. Some of the most popular devices are the Apple Watch and Fitbit Versa, but there are also other devices focused on chronic disease management such as the ingestible sensor from Proteus health for diabetics ("Proteus Digital Health," n.d.). The stark contrast between self-trackers who need the data to survive, and those who adopt it purely out of interest for trending gadgets are discussed in Section 3.6 of this thesis, titled "Motivations."

Wearables are moving beyond wristwatches into other wearable forms for the body. Smart clothing is making its way into consumer markets. Pivot Yoga, dubbed "World's Smartest Yoga Wear" by Business Wire, comprises clothing with invisible sensors that claim to be able to tell your body's yoga position accuracy down to the inch ("Pivot Yoga," n.d.). Myant Inc., a Toronto based enterprise, is also developing smart clothes to read heart health (Fung, 2020). Wearables are unparalleled in their extreme proximity to the body, and their ability to gather data from it 24/7. Some wearables are even disappearing from our consciousness, because of how seamlessly they integrate with the human body (Dunne & Smyth, 2007, p. 3). Crawford et al. state that "By continuously recording a range of variables, these devices become an intimate part of everyday life, silently recording data 24/7, detecting patterns and inferring habits of users' daily (and nightly) lives" (2015, p. 485).

The surge of global wearable shipments in the coming years can be attributed to the rise of sensor-based technology (Gartner, 2018). Sensors are becoming cheaper, smaller, smarter, more

connected and more intuitive, and therefore, wearables are becoming more wearable. Clint Zeagler, a wearable technology designer, states that "devices have become smaller while also being able to sense and measure more. More wearable devices are now used as body sensors, and more devices now take advantage of the human body's ability to sense" (2017, p. 1). For the first time, users can access unprecedented amounts of data collected from their bodies. However, their ability to analyze and apply the insights from the data remains limited. This pertinent challenge is what I address within this thesis.

Wearables serve our desires for longevity, self-optimization, enhancement and perhaps even perfection (Foucault, 1988, p. 4), by allowing us to self-regulate and self-modulate objectively through self-measurement. In the media, these aspirational forms of human beings have appeared in Bladerunner's "Replicants" and Gattaca's "Valids." Steven Brown, in his book "Tokyo Cyberpunk," refers to the Posthuman's "achievement-orientated ideology" as a significant aspect of their personalities, for which wearables are befitting (2010, p. 6). Humans now track their steps, weight, heart rate, sleep patterns, eating habits, and fitness regimes. More specifically, women track their menstrual cycles, parents even track their babies swallowing patterns ("MomSense: The Smart Breastfeeding Monitor," 2019), and pet owners track their pet's activities. The benefits of wearables are plausible. They are empowering us to control our destinies, by giving us the unique opportunity to manage aspects of our health autonomously, with the intent of stimulating behavioral change.

The fields of the Internet of Things, Cloud Computing, Big Data and Artificial Intelligence are also developing rapidly to provide supporting infrastructure to store, analyze, and interpret large sets of big data, collected through wearables across the globe. David Rose in his book "Enchanted Objects" states that the cost of processing (concerning sensors, computers, and displays) has reduced 128 times in the last decade" (2014, p. 118). As wearables are adopted rapidly, the culture of living with personal data could slowly normalize. In 2007, a community of self-trackers that call themselves the Quantified Self Movement emerged across the globe. They organize meetups where users present their journeys with self-tracking using various analogous and digital tools. Wolf, a co-founder of the Quantified Self movement, says that "Numbers are making their way into the smallest crevices of our lives (2009)."

In my opinion, the health and fitness industries stand at the forefront of the wearables movement. The power of care is moving back to the individual as we enter a new area of participatory preventive health. Melanie Swan says that "The individual has become the central focal point in

health, which is now seen as a systemic complexity of wellness and prevention, as opposed to an isolated condition or pathology" (2012, p. 113). In her paper on the "Quantified Self", she adds that the most critical challenge for contemporary medicine is prevention. Technologies that can detect early warning signs before the clinical diagnosis of disease are still in nascent stages. They require large volumes of unobstructed personal health data (about 1 billion points per person) to detect abnormalities or changes in patterns accurately (Swan, 2013, p. 87). Wearables pose a unique opportunity to address this prerequisite, with the ability to intimately and continually extract data from the wearer's body. However, like most things, wearables come with their share of risks and issues.

In my opinion, one challenge is the trend for commercial wearables is to communicate data in an objective, quantified approach that is sometimes punitive. This can often trigger adverse psychological reactions, such as self-doubt and anxiety for wearers. Arwa Mahdawi (2014), a writer for *The Guardian*, says, "There are already accounts of fitness trackers being used by people who suffer from eating disorders, a grim example of self- tracking and internalized surveillance taken to an extreme." I think that authoritative wearables may also continually remind wearers of their incapacities and limitations. Natasha Singer (2015) quotes Natasha Dow Schull, author and professor, says that currently, most wearables cannot promise sustainable behavioral change and might be prodding users to make temporary alterations in their behavior, which only lasts until the user tires and abandons the device altogether. Incidentally, the Gartner report also states that approximately 30% of wearable devices that are purchased are usually abandoned within the first six months of use. Challenges with device adoption are discussed in Section 3.7, titled "Device Abandonment."

3.3 The Wearables Industry

In some way, all of the Big Nine companies have ambitious health strategies that we will see unfold in the coming years.

- Amy Webb, 2019, p. 279

According to Deloitte's 2019 "Global Healthcare Outlook", global healthcare spending records in 2018 were over $7 Trillion, and are slated to rise in the future (2018, p. 7). The need for high-quality healthcare is only increasing with a steadily ageing population, growing numbers of chronic disease cases, increasing obesity rates and sedentary lifestyles. When it comes to the

digital healthcare innovation market, the Big Nine currently own it (Google, Amazon, Microsoft, Apple, IBM, Facebook in the USA, Alibaba, Tencent and Baidu in China). Amy Webb (2019) highlights the keen interest that these entities are taking in driving healthcare innovation, particularly in building wearables with advanced biometric sensors, recognition technologies, ubiquitous devices (IoT), AI frameworks and cloud servers. They are also making sizable acquisitions in the field (to build their respective health ecosystems), as well as setting up dedicated healthcare innovation teams within their organizations. It is evident that healthcare innovation is at the heart of the future agendas of these organizations, and wearables are at the heart of healthcare in the future. In a recent interview with CNBC Apple CEO, Tim Cook said, "If you zoom out into the future, and you look back, and you ask the question: 'What was Apple's greatest contribution to mankind?', it will be about health, we are democratizing it. We are taking what has been with the institutions and empowering the individual to manage their health ("Apple CEO Tim Cook On China, Wall Street And Innovation," 2019)."

Apple has showcased its capabilities in consumer-centric healthcare technology with the new ECG feature on the Apple Watch, and its multiple research health research collaborations with leading healthcare institutions across North America. They also filed a patent for universal ear-pods with inbuilt biosensors (Patent No. US 10,149,041 B2, 2017), not to mention their open-source CareKit, ResearchKit and their foray into direct to consumer healthcare services. Google is not far behind with its WearOS, Deepmind and "big investments in genomics, healthcare application research and HIPAA compliance in the cloud" (Webb, 2019, p. 279). Amazon is catching up with its partnership with Berkshire Hathaway and J.P. Morgan to reimagine insurance and healthcare and its acquisition of PillPack ("Pillpack: by Amazon Pharmacy," 2020) an online pharmacy that dispenses medication based on schedules. Amazon plans to integrate PillPack with Alexa to provide reminders and track individual healthcare needs more closely. More recently, Amazon forayed into creating their own wearables with Alexa powered eyeglasses, rings and EarPods.

Apart from the Big Nine, numerous digital healthcare start-ups have made their mark across the globe in recent years and are contributing significantly to the advancing course of healthcare innovation. Proteus Health ("Proteus Digital Health," n.d.) is one such example, with a digital medicine offering that includes a set of ingestible sensors, a wearable patch and a mobile application to support the hardware. The start-up promises efficiency and measurement in the management of chronic diseases, particularly diabetes and hypertension. Another start-up, Withme, has created a wearable for babies that can continuously monitor their vitals and movements and gives parents the data they need to safeguard their child's health (*Withme Baby*

Monitor, n.d.).

In an interview with *Knowledge@Wharton*, Martin Lindstrom discusses his book titled "Small Data: The Tiny Clues That Uncover Huge Trends" (2014). He talks about how small data reveals the "why" behind the big data, and that is where actual value and insight around consumers lies. The wearables industry must uncover the "why" to overcome current challenges with abandonment. He claims that the biggest issue is "that the corporate world has become completely blinded by Big Data. However, it's very, very hard to describe emotions using data." He also talks about how big data is all about analyzing the past, but small data has the power to uncover the future by giving us insight into how consumers live, and how they relate to the things around them (Knowledge@Wharton, 2016). I believe that for wearables to be successful, they need to uncover the hidden details in their consumer's lifestyles, routines, values, beliefs and behaviors. The essence of this thesis lies in substantiating the role of small data in the individual's health and well-being.

3.4 The Quantified Self and Personal Informatics

Swan defines the Quantified Self as "any individual engaged in the self-tracking of any kind of biological, physical, behavioral, or environmental information" What she also proceeds to state is that labels such as the Quantified Self are natural progressions in the human tendency to measure, calculate and prove things to bring control to the world (2013, p. 85-86). The emergent Quantified Self Community defines themselves as "an international community of users and makers of self-tracking tools who share an interest in "self-knowledge through numbers" through "everyday science" (Quantified Self, n.d.). There are multiple social media groups for communities in different locations across the globe, such as on Facebook (Figure 3).

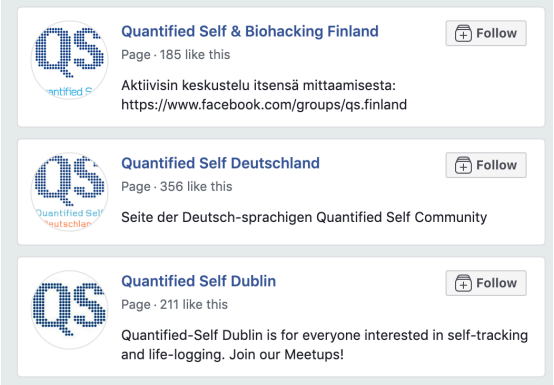

Figure 3: Facebook search result for Quantified Self Groups.

While the name Quantified Self gained popularity across the globe through its global community, the term Personal Informatics is most commonly associated with the design and development of systems and tools that enhance self-knowledge within the realm of Human-Computer Interaction. Li, Dey, & Forlizzi (2010), define Personal Informatics as the process of collecting of reflecting upon data about oneself that informs people about themselves (p. 557). They also state that it "helps people by facilitating collection and storage of personal information, and by providing a means of exploring and reflecting on the information" (p. 558). According to Rooksby, Rost, Morrison, & Chalmers (2014), Personal Informatics can go beyond health and well-being (p. 1164). However, for the purpose of this thesis, I focus on Personal Informatics tools within this domain.

3.5 Self-Tracking Motivations

If you are tracking for any reason — to answer a health question, achieve a goal, explore an idea, or simply because you are curious — you can find help and support here.

- Quantified Self, n.d.

Before discussing motivations, it is essential to understand the desired outcomes for self-tracking. Swan, in her "Health 2050 Model" (Figure 4), highlights the various health outcomes for both physical and mental well-being. Her proposed outcomes range from essential desires such as cure and improvement, to more complex desires such as self-expression and longevity, both of which shed light upon how interconnected the mind and the body is (2012, p. 95).

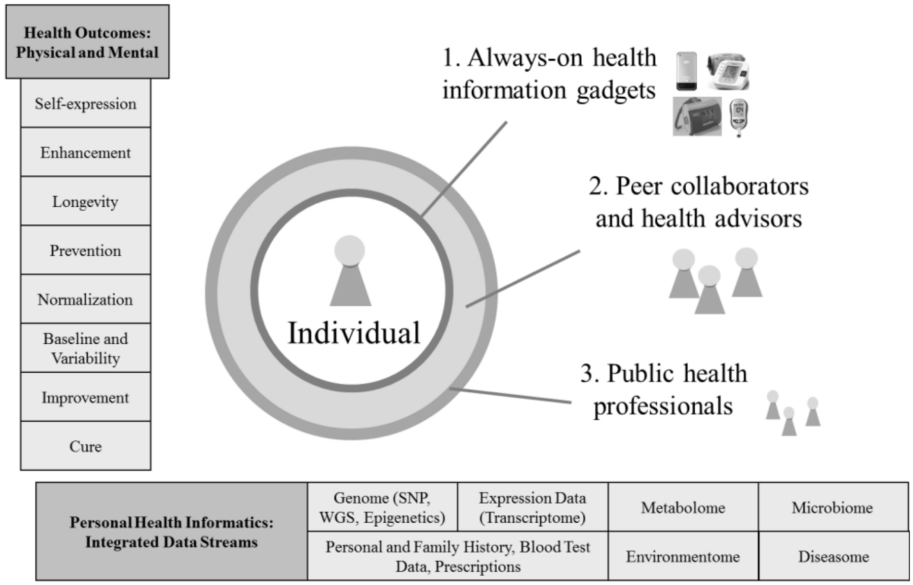

Figure 4: Health 2050: An expanded concept of health and health care (Swan, 2012. p. 95).

The five types of self-tracking, as defined by Rooksby et al. (2014, p. 1167-1169) are:

- **Directive tracking** involves goal-driven tracking. Goals are either set by the user, the product they are using, or a coach that is guiding the process. Individuals generally self-track with an end goal in mind, usually triggered by a desired lifestyle change. For example, to get to a certain weight or muscle mass, optimize a particular aspect of their health, or to manage a long-term disease. Directive tracking usually continues over a prolonged period until the set goals are met, for which progress is usually mapped.

- **Documentary tracking** entails documenting habits and behaviors, and not necessarily changing them. Individuals who track with this approach tend to look at the practice as a way to introspect, reflect or remember. Both pleasant experiences or bad experiences tare logged for their nuances, and the practice is usually inconsistent, as there is no real goal to meet that requires consistent effort.

- **Diagnostic tracking** comprises tracking to look for connections, variances or abnormalities in the body. Extracted data may be logged to be shared either with a relevant professional or a peer. However, there are no set standards for recording with this practice. Tracking of this kind continues until a solution or an answer is found and is not typically

long term. It is generally employed by individuals who are managing a condition, or those looking for symptoms to an undiagnosed issue.

- **Collecting Rewards (Gamified tracking)** encompasses incentive focused tracking. This form of tracking is emerging as a trend within the wearable industry with employers, insurers, and healthcare providers using this strategy to lure individuals into becoming more active, destress, or meeting specific goals set by their respective organizations. One application called Carrot Rewards, a mobile application for residents of three Canadian provinces and one territory, allowed users to complete health questionnaires and track steps in exchange for rewards points with real incentives such as coupons and gift cards ("Carrot Rewards," n.d.)

- **Fetishized tracking** is for trackers fascinated by technology. Trackers are in it merely to experiment with the gadgets they acquire. This type of tracking is short-lived, inconsistent, and only lasts while devices are trendy and desirable.

It is clear from the motivations stated by Rooksby et al. that no one size fits all when it comes to self-tracking. The need for personalization within preventive healthcare is imminent. In my opinion, an individual wearing a device might even assume that the device understands their body, as opposed to a generic version of a person. For example, individuals tracking their nutrition through a documentary-based practice will probably not be inclined towards a device's weight-loss driven proposition to counting calories. The industry is yet to consider these differences. Also, I think that the individual's mental and emotional well-being must play a significant role in the assessment of their overall health. Swan claims that as the new paradigm of participatory preventive health emerges, "mental health and mental performance optimization may become increasingly important as an outcome in the near future" (2012, p. 96). Though the industry is skill skewed towards physical data points, a new wave of devices tracking readings of the mind, such as cognitive load, activity, performance, mood and emotions, are emerging. The GoBe2 band tracks emotions using Galvanic Skin Responses and Stress using Heart Rate Variability, both critical aspects of overall well-being (*HEALBE GoBe3*, n.d.). While I did not use a device to gather my mental well-being data, I use my research and experience with self-tracking in this thesis to establish correlations between physical, mental, and social factors for well-being, that can "enmesh into our everyday life" (Rooksby et al., 2014).

My initial foray into self-tracking was documentary based to gain awareness into my lifestyle. I began tracking with the assumption that I was healthy, and that I needed to change nothing about myself. Through the exercise, I was able to gain an in-depth understanding of my habits, tendencies, and irregularities. I have learned that my caffeine binges and unbalanced sleep timings were affecting my productivity. I wanted to change this habit, which inadvertently converted my documentary-based practice into a directive one. As I began to track with a purpose, I have learned over time how to correlate different data points that were presented to me in silos and use my combined findings to derive insight in order to make sustainable changes to my sleep and caffeine consumption routine. This experience lasted two months and shaped my research-creation process significantly.

3.6 Device Abandonment

Wearables are proliferating owing to individuals across the globe who procure the devices as a form of self-investment (Schüll, 2016). The excitement of the purchase, however, is short-lived, and some devices end up being abandoned sooner than later. Charles Arthur (2014), states that fitness trackers are currently no stickier than new year's resolutions. He expresses his concern for the future of wearables, given the current rates of device abandonment. He quotes research by the Endeavour Partners based in the United States of America, which states that "one-third of American consumers who have owned a wearable product stopped using it within six months.

What is more, while one in ten American adults own some form of an activity tracker, half of them no longer use it." This is an alarming number, given that almost 245 million wearable devices were sold across the globe in 2019 (Figure 7), according to a report by CCS Insight (n.d.). Arthur goes on to discuss where current challenges within the wearable industry might lie. He mentions the possibility of wearables being in nascent stages of development and, therefore, limited in the value they can provide. He also sheds light upon operational challenges such as the need for various device charging, poor device ergonomics, and ambiguous data visualization (2014).

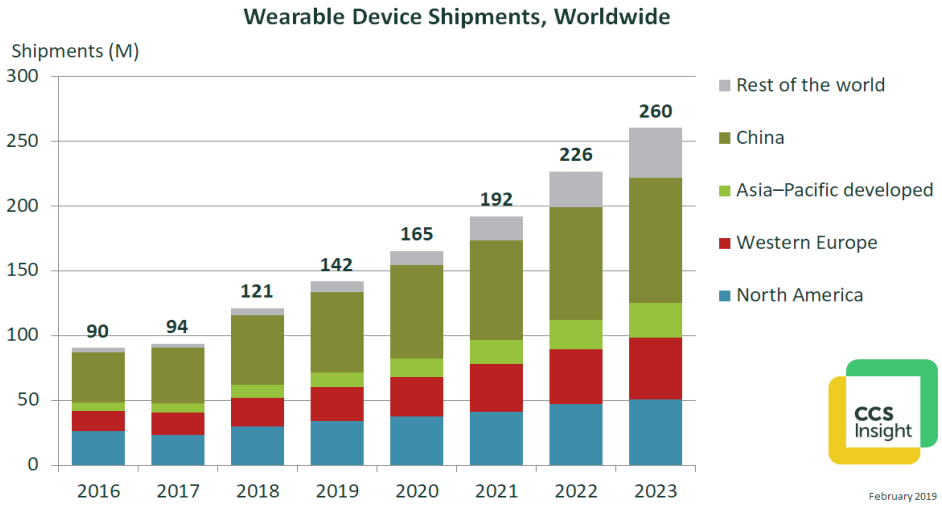

Figure 5: CCS Insights summary on wearable shipments worldwide between 2016-2023 (n.d.).

In this section, I discuss numerous potential causes for wearable device abandonment in alignment with the Stage Based Model of Personal Informatics (Li et al., 2010, p. 561). The model (Figure 8) was created to pave the way for Personal Informatics tools of the future to be designed holistically, and to allow a balance between user-control versus automated technology in tools for self-tracking. The authors state that these tools should also account for multiple facets of their user's lives, which grounds this thesis exploration. Once I have detailed each of the potential abandonment causes, I conclude this section by summarizing the issues that I have attempted to address in my prototype creation process.

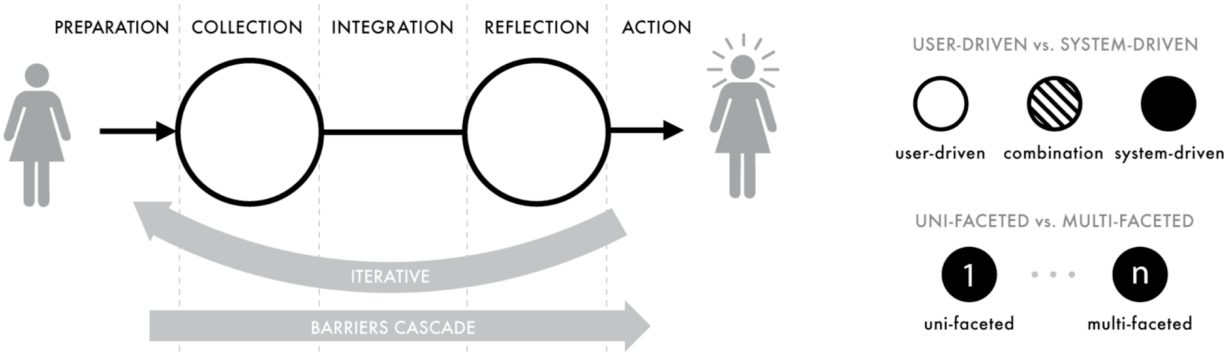

Figure 6: Stage Based Model of Personal Informatics Systems (Li et al., 2010, p. 561).

Stage 1: Preparation

During the preparation stage, the initial challenge for individuals lies in establishing motivation for tracking, which inadvertently influences their search for the appropriate device. It is at this stage that individuals are coerced by various advertisements and beautiful websites by wearable companies. The platforms comprise compelling testimonials (which cannot easily be verified) promising to transform an individual's life quality (Figure 9). Orazi & Nyilasy (2019), state that "Advertisers have been aware of the need to temporally match advertisement delivery to consumers' ever-changing moods, particularly, at a macro level (i.e., as a generally understood principle or matching based on larger chunks of consumer time)" (p. 138). However, wearers tend to be left disappointed in some cases, as their expectations of the device's ability to help them transform (based on advertising promises), versus their everyday experience with the device daily can differ significantly. The phenomenon of overpromising and under-delivering is a cause for device abandonment.

Another potential cause is the social acceptance of the device in the mind of the wearer. Dunne et al. (2014), state that self-tracking is no longer a selfish activity, but a sociable, shared practice (p. 1). The socialization of self-tracking may be making wearers more critical about the aesthetics of the wearable devices they procure. The authors also state that wearables are no longer perceived merely as personal electronics or gadgets. However, because they are attached to the wearer's bodies, they are viewed as a reflection of the wearer's identity, value system, beliefs, and choices. The intimate relationship between the device and its wearer is what the authors refer to as the "apparel-body construct". It suggests how the device might affect its wearer and vice versa (p. 4159). Wearers are often subject to societal judgements based on their choice of device. For example, an individual wearing an Apple Watch might be perceived as a person who is trendy, and particular about their fitness habits and heart rate, as opposed to someone with an everyday wristwatch who might come across as more modest and simplistic. This argument compels me question if the practice of self-tracking is to be flaunted publicly, or intended to be intimate, private, and inconspicuous? In my opinion, wearables should seamlessly integrate within, on, or around our bodies in ways that allow them to become an inherent part of our physical bodies.

Figure 7: Headspace's website promises a "happier life" with daily meditations (Left) (Headspace, n.d.). Fitbit advertisement promises more than your "regular self" (Center) (Fitbit Inc, n.d.).

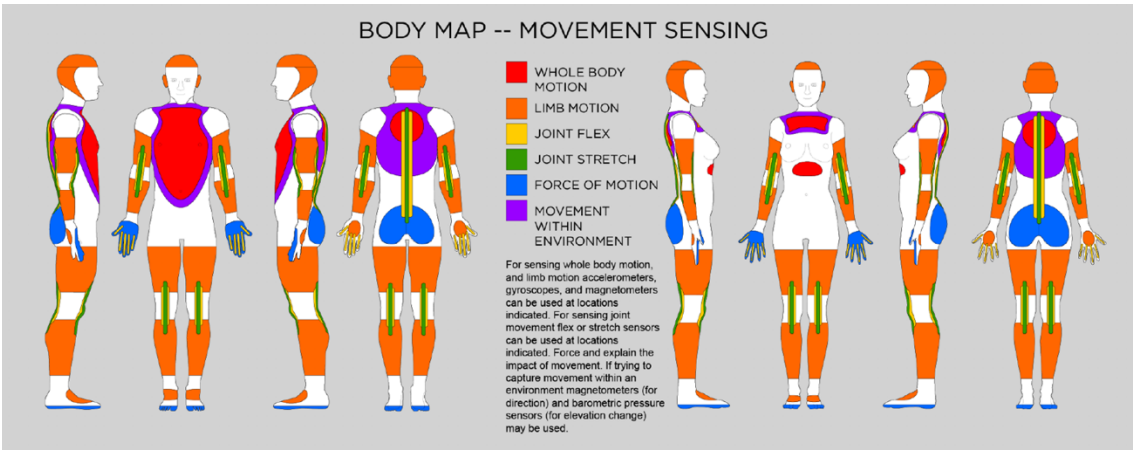

Figure 8: Movement Sensor Placement Body Map for ideal device placement (Zeagler, 2017).

Stage 2: Collection

One of the biggest challenges at the collection stage lies with the comfort of a wearable device on the wearer's body. Dunne & Smyth (2007), define wearability as "the degree of comfort afforded by a body-mounted object or device." In contrast, unwearability entails discomfort or unattractiveness, which can be attributed to devices that continuously demand the user's conscious attention, often causing frustration (p. 1). It is my belief that physical challenges with wearable devices can be categorized into technological, ergonomic, and material. Technological challenges can come from poor battery life and the need for constant charging that can lead to

inconsistent data collection. Rooksby et al. (2014), state that the physicality or ergonomics of the device are vital to its adoption or abandonment (Figure 8). When it comes to the position of the device, wearers prefer wristwatches because they are least obstructive and not as expensive as smartphones (p. 1167).

Wearables that seamlessly integrate with our 'body schema' tend to disappear from our consciousness, exist within our reach in our 'peripersonal space,' and therefore are easier to adopt (Dunne & Smyth, 2007, p. 3). However, in some cases, this desire is pushed too far. The La Roche Posay UV Tracker is too small to keep track of and often misplaced by wearers because of its tiny size (*La Roche-Posay: My Skin Track UV Sensor*, n.d.) (Figure 9).

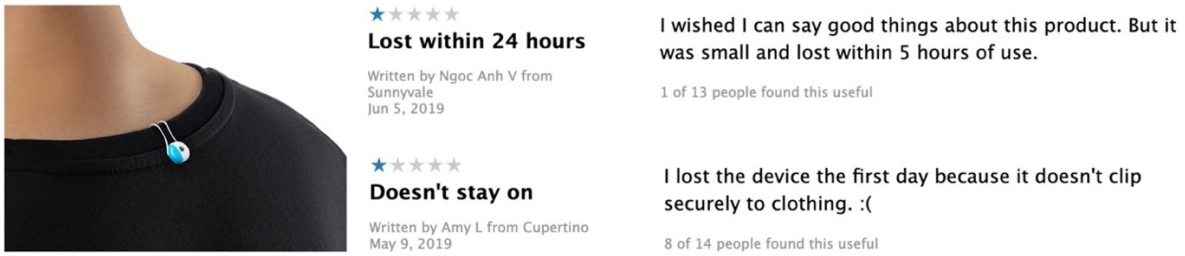

Figure 9: La Roche Posay UV Tracker (Left). Reviews on apple.com for the La Roche Posay UV Tracker (Right) (La Roche-Posay: My Skin Track UV Sensor, n.d.).

Authors Dunne and Smyth (2007), also state that wearable devices currently contain substantially higher concentrations of metallic or plastic elements as compared to clothing (p. 2). This material distinction can lead to an unfamiliar tactility, making wearables feeling unintuitive, stiffer heavier, and, therefore, uncomfortable. In my experience, I often removed my Fitbit and wiped it down because it was causing my skin to perspire more than usual. That being said, there are companies like Myant (Figure 10) that are working to overcome this material barrier by embedding knitted sensors and actuators within everyday clothing (Fung, 2020).

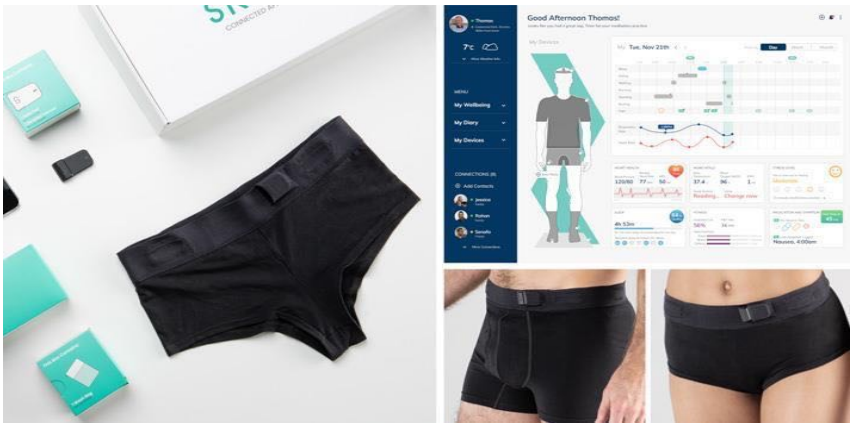

Figure 10: Myant's SKIIN range with smart underwear to monitor heart health (Fung, 2020).

User effort is also a significant challenge for wearable adoption with data collection. The arduous process of continuously inputting data to trace patterns and find anomalies can get tiring for users. In my opinion, manual user input can lead to data sets that are incomplete, inconsistent and inaccurate and, therefore, difficult to act on. This explains why the industry is skewing towards passive data collection for wearable technology in the future. Wolf (2010), in his piece for the New York Times, states that "when familiar pen-and-paper methods of self-analysis are enhanced by sensors that monitor our behavior automatically, the process of self-tracking becomes both more alluring and more meaningful." At CES 2020, passive health and fitness wearables took center-stage with devices like the GoBe3 which counts calories and hydration levels automatically (*HEALBE GoBe3*, n.d.), and the WELT Smart Belt Pro that uses a group of embedded sensors to let users know if they are over-eating (*WELT: Smart Belt*, n.d.). Swan (2013) states that from a perspective of practicality, self-tracking could become more mainstream if it were "automated, easy, inexpensive, and comfortable." However, for now, manual data collection remains one of the biggest challenges for device adoption.

Stage 3: Integration

Data processing during the integration stage can either be effortless, passive, and automated or manual, repetitive, and cumbersome for the wearer. While data input is a challenge for users in the collection phase, in the integration phase, the onus of finding connections across different data points and organizing the data is usually occasionally on the user (Rooksby et al., 2014, p. 1169). While some wearable device applications present extracted data in siloed categories, I think that the essence of the practice lies in establishing correlations between different data points that can

indicate certain conditions when presented cohesively. Rooksby et al. (2014), conducted user research which led to the discovery that individuals were not using a single tracking device at a time, but a combination of devices, applications and exergames. The authors state that just as systems within the human body are deeply interconnected, it only makes sense for biological data points to be deeply integrated as well (p. 1172). The concept of "sensor fusion" is gaining momentum in the field of robotics and autonomous vehicles. It involves the merging of data from multiple sensors to reduce uncertainty within task performance, or motion navigation, a similar structure can be applied to data for health and well-being ("Sensor Fusion," 2014).

There is merit in developing devices in collaboration with the medical community that can provide invaluable insight into our health and well-being by integrating various data points. The AVA Bracelet for women ("AVA: Ovulation Tracking Bracelet," n.d.) uses five distinctive readings from the female body to predict ovulation dates. The Embrace 2 by Empatica, helps patients with epilepsy detect oncoming seizures early, with a combined four readings from the body ("Embrace Watch: Smarter Epilepsy Management," n.d.). With their open-source frameworks such as the CareKit by Apple, and Wear OS by Google, organizations are allowing developers and designers to create custom health sensors, that can integrate with their data-aggregating software. In this scenario, it is unrealistic to expect users to want to input manual data repeatedly, over prolonged periods. For my prototype, I have integrated data that I collected passively from various sources, or in proxy, into one cohesive dataset and then presented it through data visualizations. My objective was to showcase the potential of correlating different data points from my body to communicate its state of well-being, in the context of my everyday life.

Stage 4: Reflection

At the reflection stage, users explore and interact with the data presented to them. The challenge at this stage lies in the practice of short and long-term reflection for the individual. While short term reflection is vital for current updates on a day-to-day basis, long term reflection is undertaken occasionally, when patterns, trends, abnormalities, or progress need to derive actionable insight. Both types of reflection are equally important; however, as stated above, the frequency of accessing each type of reflection usually varies.

In my opinion, current wearables do not provide enough value to users in long-term scenarios. In order for the user to be able to reflect and act on the data provided with ease; they need a plan of action. In my position, users of wearables might not want authoritative orders but are still looking

for qualitative insight in the form of advice, that they can choose to act on at their free will. Joseph F. Coughlin (2014), a contributor for *The Huffington Post*, wrote that while health companies continue to build devices to extract biological data, they must focus on the translation of the devices into real innovation to engage users. Coughlin states that the data collected from various devices can be visualized, but is the meaning of the data understood? And is it understood in a way that it empowers the user or unnerves the user? Currently, most applications come with disclaimers about health advice, and the lack of equivalency to medical diagnoses (McGrath, 2019). I ask that if wearable organizations do not take accountability for their products, then are they worth the investment? I believe that the current process of reflection is a cause of abandonment. Users are left to analyze their data by themselves, and in some cases, this leads to an incorrect self-diagnosis.

With short-term reflection, the challenge lies in the fact that the smallest variation in data, can cause paranoia and increased doctor visits. Schull states that permanent behavioral changes to habits cannot be made simply by displaying numerical information (Singer, 2015). However, on the other side of the spectrum, systems that are too punitive or prescriptive can also backfire, causing users undue anxiety and perhaps leading to device abandonment. Schull also says that some wearable trends have led to the creation of devices whose "primary function is less to enlighten users with information than to prod them to change." She states that this trend has led to the creation of a new category called "nudging technology (Singer, 2015)." The HAPIfork is a classic example of a nudging device. Created by Jacques Lepine, the device promises weight loss, better digestion, and reduced gastric reflux with slow eating through a fork that vibrates in a motion they call "fork serving" if the user eats too quick ("HAPIfork: Eat slowly, lose weight, feel great!," n.d.)(Figure 11). This constant reminder of a poor eating pattern can cause anxiety, stress, and even a loss of appetite for some individuals. I ask if this is the relationship we want to foster with our consumption? My information architecture proposes a switch to nutrients from counting calories and eating patterns, with a focus on nourishing the body.

Another challenge faced during the reflection stage is the lack of data personalization. Body type, age (life-stage), gender, cultural background (lineage), lifestyle, routine, habits, geography, and several other factors can affect data readings from an individual's body. Generic baselines and benchmarks may not resonate with users who want to feel like their investment in themselves have been worth the effort. These considerations need to be factored in when communicating data, especially for long-term reflection. For example, the Reddit channel for Fitbit has a post of a user having issues with collecting accurate data from steps (or glides) taken during skating. (Figure X)

("Fitbit Charge HR data while ice skating," n.d.). Perhaps, setting up custom baselines and benchmarks after developing a detailed understanding of the individual could tackle this issue.

The final challenge in the reflection stage is contextualizing data. Context needs to be considered when presenting data to a user. For example, when would a workout summary feel most valuable or relevant? Or when would insight into a meal seem most useful? Li et al. (2010), state that we must "Recognize that data can be meaningful in the context it is produced but may lose meaning when it is removed from that context" (p. 1172).

Figure 11: Reddit post on Fitbit data collection for ice-skating (Left) ("Fitbit Charge HR data while ice skating," n.d.). HAPIfork Website Banner (Right) ("HAPIfork: Eat slowly, lose weight, feel great!" n.d.).

Stage 5: Action

The Action State is the point at which individuals act upon their reflections. At this stage, some companies coerce people to act upon their findings. They use techniques like gamification and incentivization to get individuals to meet set targets. In some cases, such as with step counts, I think that these targets tend to be arbitrary, and do not prove scientifically beneficial (Cox, 2018). Swan (2013), states that "The presence of financial incentives could also produce greater adoption in self-tracking" (p. 93).

Nevertheless, it can also have adverse effects, such as intense surveillance for when insurers offer discounts on premiums to individuals who meet their daily step goals. Employers are also catching on to this trend. Fitbit's "Health Solutions" arm works towards improving employee health for "better outcomes, and positive returns for your organization" ("One Easy Health Solution for All Your Employees," n.d.). Their offering gives employers unrestricted access to employee health data and brings up questions about privacy and integrity within work cultures.

It is my position that the main challenge with most wearables is that they do not suggest how to

act on data, which is a significant setback for device adoption. The inability to act due to lack of knowledge or confidence in the plan of action based on data can leave users feeling helpless, anxious, frustrated, and perhaps cause abandonment.

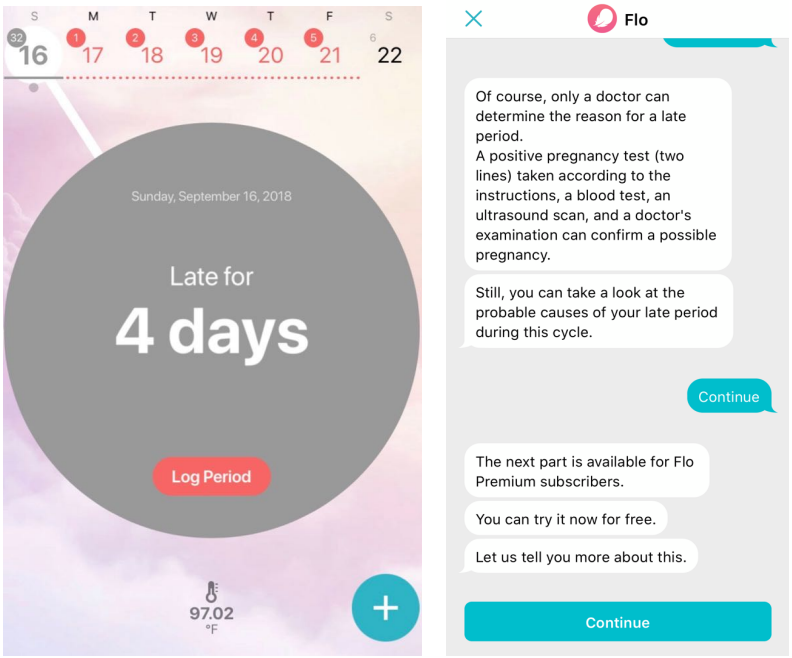

Figure 12: Flo application screenshots: Flo application screen home screen for late period (Left). My experience with taking their in-application chatbot test to investigate why my period was late (Right) (FLO, n.d.)

Data presentation is also a challenge in the action stage. As mentioned in the reflection stage, ambiguous data presentation can lead to anxiety, discomfort and possible abandonment, as no one wants to be reminded of their limitations or mistakes. My recent experience with the Flo menstrual tracker application (Figure 12) was upsetting ("Flo - ovulation calendar, period tracker, and pregnancy app," n.d.). When my period was four days late, the application gave me no reassurance that a delay of up to a week is sometimes possible with travel, a changing routine or increased stress. The application's insight section indicated that I take a pregnancy test. When I wanted to investigate other possible causes of a delayed period (because I knew this was not the cause), I was asked to buy the Premium subscription. Is it best to request an individual to pay for a subscription when they are emotionally vulnerable and in need of genuine advice?

Summary

Li et al. (2010), state that problems in each stage of their model affects the next, in what they call "cascading barriers" (p. 563). Poor data collection affects the integration and, therefore, the reflection stage, leaving the individual unable to act. The authors claim that a holistic approach to the design of all stages for Personal Informatics tools of the future is critical. Each stage of the model needs to be considered both individually and holistically in order for the system to be effective (Figure 6). Below, I have briefly summarized and categorized the issues with device adoption that are discussed in this section:

Issues not addressed in my prototype:

- Misleading advertisements with false promises
- Social acceptance of the device
- Physical comfort afforded by technology, form and material
- Inadequate/Insufficient data to act on
- Short- and long-term reflection

Issues addressed in my prototype:

- Privacy in self-tracking
- User effort in the form of manual input
- Data interpretation and analysis
- Authoritative devices and interfaces
- Need for personalization
- Setting context for data visualization

3.7 Humanizing Biological Data

Over the last few years, I have witnessed the digital product industry skewing towards humanized user interfaces, with some organizations using human attributes as inspiration for their design processes. They use this process to build empathy in user experiences and to make their products more relatable. When Airbnb launched the signature "Belo" identity system in 2014, its design philosophy embodied the idea that its customers should be able to feel like they belong anywhere

(AirBnb, n.d.). Google's Material Design (Google, 2020) aims to humanize interface design across all devices, by bridging the gap between the physical and virtual world by creating the illusion of depth to flat screens. The design team at Apple even titled their design system for best practices as "Human Interface Guidelines" (Apple Inc., n.d.).

As we enter a new information revolution (Lupi, n.d.)l, I believe that data visualization needs to embody similar values to user experience design. Since we can remember, data has mostly been visualized in a professional context. This trend has caused the industry to skew towards design systems that focus on efficiency and optimization. The need to visualize data beyond business is an emerging area. As data sets get bigger and more complex, the need to visualize them without dumbing them down is becoming imperative. Alberto Cairo (2013) says, "The problem arises when the act of reduction—in this case rendering data into an aesthetically elegant graphic—actually begins to oversimplify unintentionally, obscure, or warp the author's intended narrative, instead of bringing it into focus" (p. 266). The adoption of a human-first approach, within data visualization, is vital.

Giorgia Lupi's (n.d.) 'Data Humanism Manifesto' (Figure 13) calls for a paradigm shift in the way information is represented visually. Giorgia asks practitioners to reconsider the way data is visualized. She asks them to move beyond adding numbers to charts into creating visual systems that could be more insightful, personal and thereby more relatable. She asks for data to be embraced in all its complexity and for designers to use the art of data visualization to connect numbers to rich concepts, perspectives, behaviors, cultures and experiences.

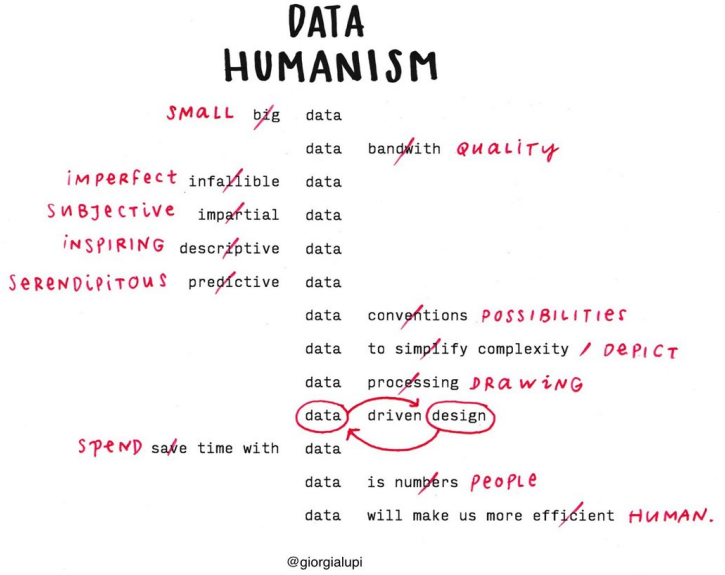

Figure 13: Giorgia Lupi's Data Humanism Manifesto (Lupi, n.d.).

In my opinion, when it comes to our health and well-being, our approach to visualizing data needs to change. Associating the human body with bar charts, pie charts and other precise visualizations can have adverse effects on the user's state of mind. Cairo discusses the concepts of sight, perception, and cognition in his book "the functional art" (2013, p. 180). By taking inspiration from his writing, I argue that perceiving these precise visualizations for data from our bodies as normative, can lead to us subjecting our bodies to the same scrutiny and criticism as we do when number crunching for businesses. This scrutiny may lead to setting unrealistic goals or targets, causing the user to feel increasingly depressed or anxious.

Within the emerging field of data humanism, we are also witnessing the advent of Data Physicalization as a way to humanize our interaction with data. According to the Data Physical Wikipedia, "Data Physicalizing aims to help people explore, understand, and communicate data using computer-supported physical data representations" (Data Phys Wiki, n.d.). Artist Laurie Frick uses materials like felt, acrylic sheets, and paper to visualize her sleep, mood, and personality (Figure 14) (Frick, n.d.). I believe that her practice is a critique of the simplification of complex biological data by commercial wearable devices, and an urge for humans to maintain their spatial understanding of the physical world.

Figure 14: Laurie Frick's felt personality visualization (Left). Sleep, mood and personal data visualization created using colored paper (Right) (Frick, n.d.).

It is my position that the fundamental principles of design communication apply to the design of data visualizations. Authors Isabel Meirelles and Cairo both refer to Gestalt's Principles within their books (Figure 15) (2013, p. 23) (2013, p. 208). The word Gestalt means patterns, and the concept is built based on the brain's ability to "follow certain principles of perceptual organization" (Cairo, 2013). Meirelles quotes Wertheimer (1959), who says that "the Gestalt principles are effective not only in enhancing perceptual inferences but also in facilitating problem- solving and thinking processes" (2013, p. 23). Cairo says that "the visual brain is a device that evolved to detect patterns" (2-13, p. 208). I take inspiration from Gestalt's principles while creating my visualization prototypes to ensure that they are legible and easy to decode while being engaging and visually appealing.

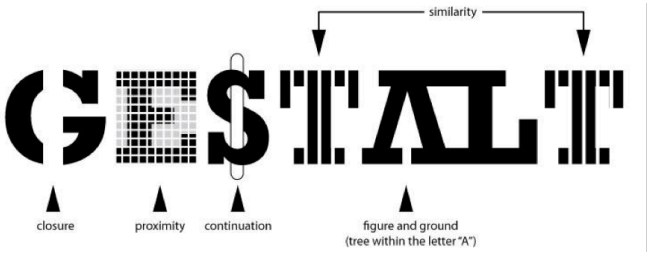

Figure 15: Gestalt's Principles ("Gestalt Principles for Information Design," 2018).

Another essential piece of writing I apply within this thesis is the Ten Perceptual Tasks model by Cleveland and McGill (Figure 16) (Cairo, 2013, p. 216-218). Their paper recommends guidelines for choosing apt graphical forms to visualize data, depending on the purpose of the visualization. The model is based on how easily the human brain can detect differences across various graphical forms. The higher the form is on the scale, the more accurate the viewer's judgement.

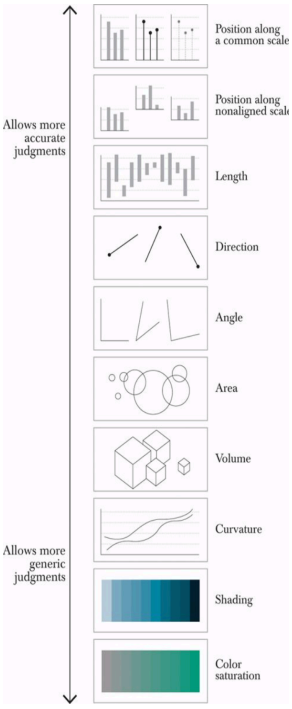

Figure 16: Cleveland and McGill's Ten Perceptual Tasks Model (Cairo, 2013, p. 218)

I also take inspiration from Bill Shander's "4X4 model of Knowledge Content" (2016) (Figure 17). His model comprises four gradual steps to presenting knowledge to engage audiences. He recommends helping the audience to step into the right level of content based on their needs, thereby improving the outcomes of the visualization at hand. His model begins at the water cooler, where concepts are presented to the user. After that, it progresses to the cafe, where data is perceived, and storytelling conveys its' complexity. He then moves to the research library, where the user begins to gain proficiency over the data and prepares to act on it. Lastly, he moves to the Lab, where users begin to interact with and act on the data in a way that best suits them individually. At this stage, users may draw correlations, identify anomalies, or even choose to share the data with others (Shander, 2016). Shander's model helped me understand the user journey to tackle complexity within my data visualizations.

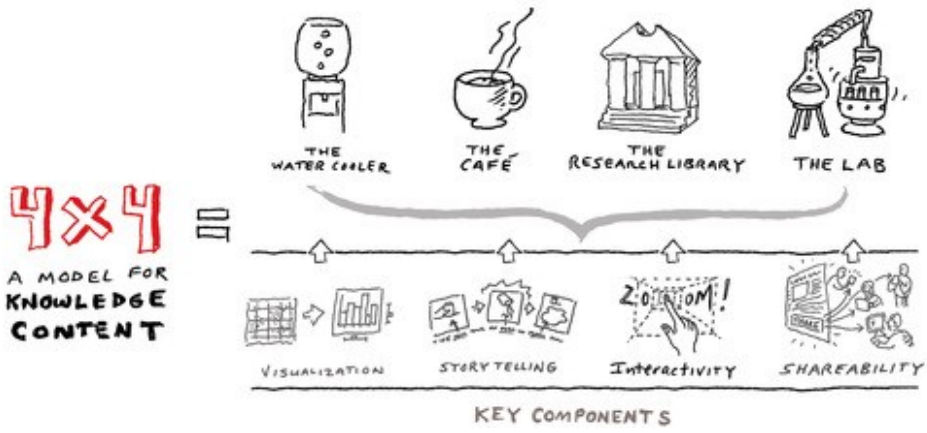

Figure 17: Bill Shander's 4x4 Model of Knowledge Content (2016).

3.8 Quantified Self Reports

In this section, I investigate two Quantified Self practitioners' reports to gain insight into the nature of data they collect, how it is interpreted and presented to their audiences. In my opinion, typical tracking devices currently display essential data points such as steps and weight but sometimes miss the mark on counting or tracking what their users need. There are also gaps in establishing patterns between different data points and presenting the data in an engaging way. I take inspiration from both the self-trackers whose work is showcased below, to organize my datasets and my information architecture prototype.

3.8.1 Chris Dancy

Chris Dancy calls himself "Mindful Cyborg" (2016) and is touted as the "most connected man of Earth." At one point, he was using close to 700 sensors, devices, applications and services to track, analyze and optimize his life from his calorie intake to his spiritual well-being. Chris' Data Book 2016 (Figure 18) consists of an analysis of his favourite memories from the year, his travels, time affluence, computer usage patterns, favorite food, coffee shop and movie theatre visits. Upon analyzing Chris's data more closely, I found that world events that were of matter to him, were also captured in his data book, and that travel took up a significant chunk of his time. Interestingly, his rate of computer usage was inversely proportionate to his travel schedule, and though he had captured the two in different places, the connection was clear. His data collection process is deeply intertwined with his day-to-day routine and tightly integrated with not only his habits and

behaviors but also his values and beliefs. This thesis considers how our values and beliefs affect our biological data and its visualization.

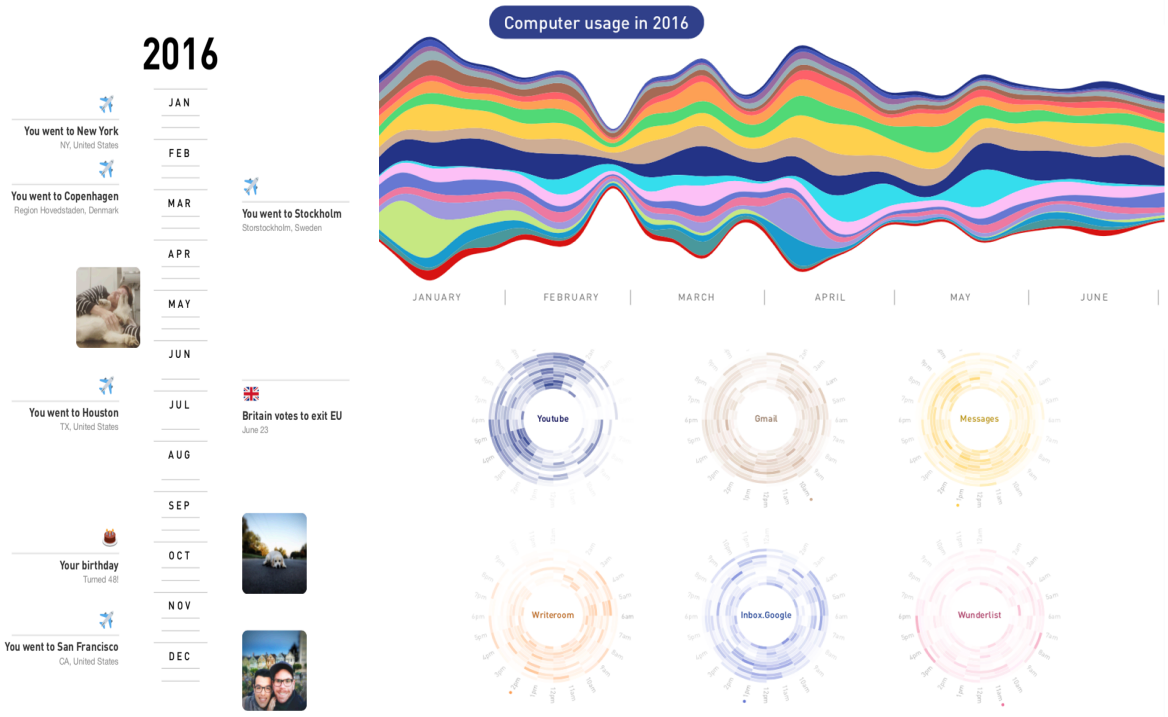

Figure 18: Snippets from Chris Dancy's 2016 Data Book (2016).

3.8.2 Nicholas Felton

Felton's (2014) practice is centred around "translating quotidian data into meaningful objects and experiences." His annual reports went viral when they launched, and though he discontinued them in 2014, they hold some hidden gems of insight. While Felton's data captures his annual summary of an array of points such as his visited locations, weight, heart rate, sleep, computer usage, and alcohol consumption, the most alluring part of his report lies in his page on correlations (Figure 19). It is here that Felton links points that might typically appear separately together, to derive self-knowledge through them. For example, he was able to calculate that the more time he spent at his computer, the more music he listened to and that his weight was inversely proportionate to his heart rate. Felton's ability to co-relate data points that might not typically be found together but affect each other has motivated my prototyping process. His approach to self-tracking is practical and in tune with his everyday life. Felton's knack to capture the complexity of life in a digestible way without dumbing it down or reducing it to a limited number of points for the sake of doing so is inspiring.

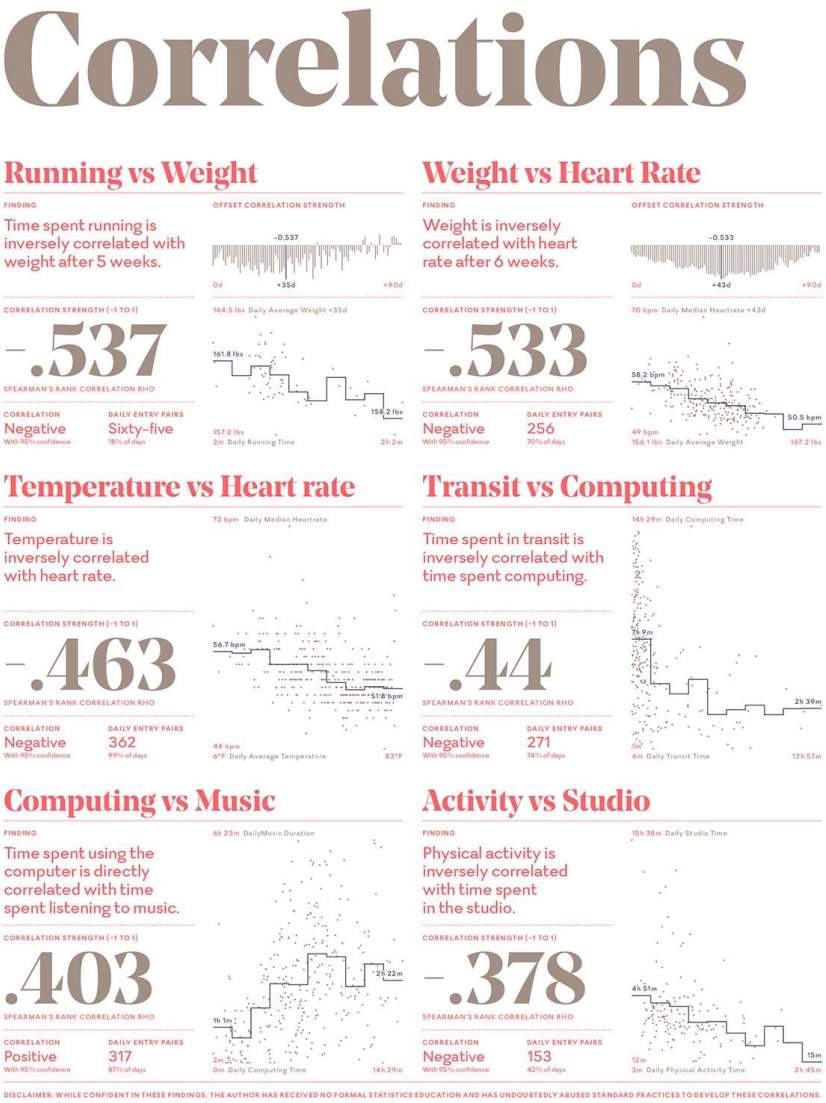

Figure 19: Nicholas Felton's 2014 Annual Report, Correlations (n.d.).

RESEARCH METHODOLOGY

This thesis can be summarized as a critical investigation into the visualization of data from wearables for improved health and well-being. I intend to introduce empathy and compassion to data visualized from the body through the creation of an information architecture, which is then brought to life with two data visualization prototypes. The prototype creation process is iterative. It includes a series of steps of development that lead to the creation of speculative, ambient data visualizations embedded within domestic spaces. Insights into the methodologies and methods used within this thesis are provided in this chapter.

4.1 Speculative Critical Design

The most important question to ask about modern societies is, therefore, what understanding of human life is embodied in the prevailing technical arrangements.

- Feenberg, 1999

While machines are usually predictable, uniform, and disciplined (because we design them to be that way), humans are radically different. I consider that being human comes with the innate ability to be irrational, impulsive, emotional and spontaneous. Current wearable technology is still nascent in its understanding of human nature. The way data is presented on most wearable mobile applications often resembles infographics that frequent business presentations. Using a Speculative Critical Design Methodology, I challenge current approaches for the design of wearable applications, by re-evaluating how wearers want to feel when they interact with a technological entity that is telling of their very being. I also consider how these applications affect wearers on a deep, fundamental level and what the repercussions of their current commercialized approaches might be.

According to Johannessen (2017), “Speculative Critical Design (SCD) explores the societal ramifications following the domestication of technology” to spur social debate on what kind of development is preferred for the future (p. 1). Speculative Critical Design also emphasizes ethical design practices that, in most cases, propose alternate trajectories of value systems (away from commercial ones) for products of the future. My chosen methodological combination suits my

research-creation process for the following reasons. While the critical lens allows me to question normative practices and challenges conventional values (Johannessen, 2017, p. 3), I use a speculative lens to propose alternate value systems for future scenarios that allow for humane data visualization with the user at the nexus of the design and development process. I aim to use the narrative qualities of science fiction that come from Speculative Design (Dunne & Raby, 2013, p. 73), to envision the future of biological data visualization, which must seamlessly integrate into our life scenarios.

A	B
Affirmative	Critical
Problem solving	Problem finding
Provides answers	Asks questions
For how the world is	For how the world could be
Makes us buy	Makes us think

Figure 20: A/B Manifesto Excerpt by Dunne and Raby (Johannessen, 2017, p. 4).

Currently, traditional and affirmative design practices in the wearables industry are skewed in similar directions and are narrowing in terms of possibilities for preferred futures (Dunne & Raby, 2013, p. 34). Designers often conform to building products that generate revenue, in line with the expectations of organizations, economies and society. Success is measured based on commercial viability. Currently, there are some concerns with affirmative practices within the wearables industry, which validates the telling rates of device abandonment across the globe. Using Dunne and Raby's A/B Manifesto to create speculative artifacts (Figure 20), this thesis aims to widen the horizon of design for data visualization from wearables (Johannessen, 2017, p. 4). Listed below are some normative practices within the industry that I critique in this thesis:

- **Authoritarian approach:** I critique the strict, disciplinarian approach that most commercially available wearables are adopting. The concept of "nudging technology" (Schüll, 2016), creates frustration for users, which may stem from a place of the user being unable to keep up with the technology, when in actuality it is the technology that should adjust to the user (p. 12).

- **Lack of personalization:** I critique the use of generic baselines and benchmarks, as discussed in detail in Device Abandonment (Section 3.6). Also, some applications set

unrealistic goals and targets for their users by using arbitrary figures and do not consider the nuances of the user's lifestyle. This choice can disillusion a user who is unable to meet the required targets.

- **Gamification:** While providing tangible incentives to users might be a smart way to get them to be more active (if that is what the user wants), this thesis critiques ambiguous scoring systems on wearable applications. The Fitbit sleep and cardio fitness score are examples or arbitrary numbers that can leave users feeling perplexed and unable to act.

- **Lack of actionable qualitative insight:** Some wearable applications fail to provide actionable insight to their users. They present raw data on different charts but leave users in the dark when it comes to a guide to acting on data. Some applications provide "tips" with lengthy disclaimers to keep themselves safe, which also alarms users who might be anxious when confronted with an abnormality in their data patterns. For example, some menstrual tracking applications assume that a delayed cycle is due to a possible pregnancy. In the healthcare of the future within the home, "Providers of these future objects are ever more concerned with our health and safety, nudging us into behavior change but fearful of litigation" (Chamberlain & Craig, 2017, p. 125).

- **Context and Integration:** Some wearable applications fail to consider the user's lived experience with their biological data. The way the applications categorize data points does not align with the way the user lives through them. Data presented to the user can get challenging to decode, and act on. Further, applications do not consider the context in which the data might be of most value to the user. For example, when might a user be most inclined to view their sleep data?

- **The user's psychological and emotional well-being:** This thesis prototype critiques current practices of extracting data from the body that focuses on the physical form, and do not consider the user's state of mind in presenting a picture of their overall health and well-being.

- **Competitive approach:** This thesis critiques current competitive approaches within social self-tracking to advocate more community-driven tracking practices with the intent of mutual growth at the forefront of the tracking exercise.

As a critical response to the concerns mentioned above, I use my biological data to create prototypes of Critical Speculative Artefacts in the form of domestic, embedded, ambient visualizations that intend to elicit empathy and compassion from users. The artifact prototypes function as design solutions and not art installations. According to Johannessen (2017), the semantic and social values of products are beginning to outweigh their utilitarian values (p. 1). Because data from our bodies can feel like a part of us, we feel a strong sense of ownership and responsibility towards it. This thesis aims to steer interface design for biological data in a more humane direction to pave the way for the design of future Personal Informatics tools.

	Traditional design	SCD
Attitude	**Normative**	**Critical**
Foundation	**Information**	**Speculation**
Mindset	**Pragmatic** Productive	**Idealistic** Dreaming
Purpose	**Commercial** Satisfy industry's need to make money	**Discursive** Spur debate on the development of society
Goal	**Develop solutions** Provide answers by solving problems	**Explore ideas** Find problems by asking questions
Intent	**Serve a user** In seriousness provide clarity	**Provoke an audience** Use ambiguity to make satire

Figure 21: Traditional and Speculative Critical Design Comparison (Johannessen, 2017, p. 7).

According to Johannessen's Traditional and Speculative Critical Design Comparison (Figure 21), this thesis employs a critical attitude towards industrial practices by speculating an idealistic future where data from our bodies can seamlessly enmesh itself into our daily routines and lifestyles (p. 7). My prototypes intend to act like companions as opposed to disciplinarians, in order to cultivate positive self-tracking practices.

I use the principles of Discursive Design by Tharp and Tharp to generate knowledge and "encourage discourse" within the design and development of Personal Informatics tools for health

and well-being (Johannessen, 2017, p. 3). This thesis is catered towards both design experts and users of wearable devices. It resides within the Instrumental External Quadrant in Tharp and Tharp's model on "Types of Discursive Products", (Figure 22) for prototypes aimed at generating knowledge and encouraging discourse (Johannessen, 2017, p. 3). The visualization prototypes I create intend to serve as critical tools to not only spur debate within the wearable design community, but also serve as tools for critical reflection and discourse for self-trackers. My objective is to provoke new ways of thinking about the how we relate our biological data, to learn to be kinder to our bodies, and feel empowered to take control of our well-being. In the next section I shed light upon the iterative development method I undertook to build my prototype.

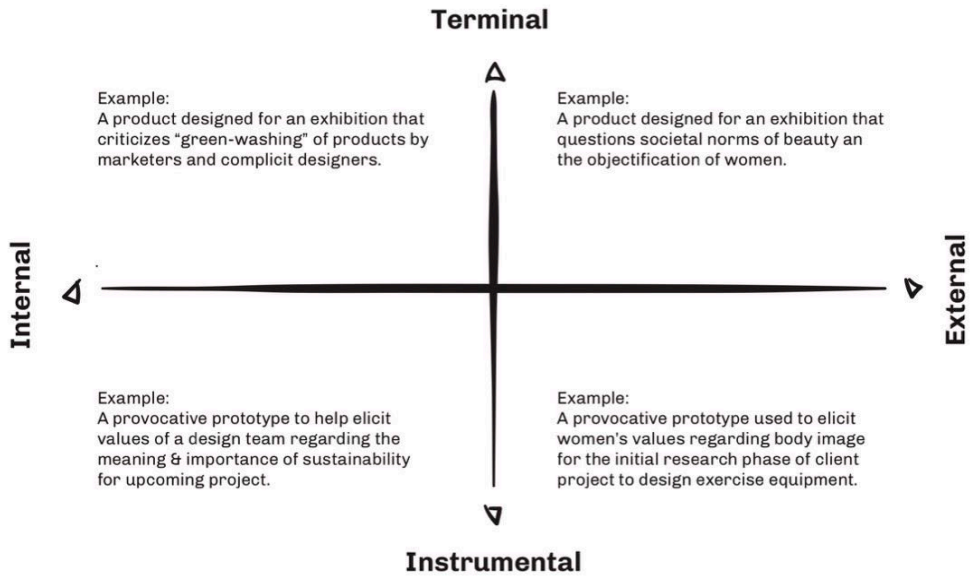

Figure 22: Types of Discursive Products by Tharp & Tharp ((Johannessen, 2017, p. 3)

4.2 Iterative Development

This thesis employs an iterative development process that resides within a Speculative Critical Design methodology. Goodman, E., Kuniavsky, M., & Moed (2012), define iterative development as a "systematic way of integrating the process of finding the problems and creating solutions, focusing on individual elements without losing sight of the whole" (p. 29). The process is evidence-based as opposed to being based on assumptions and calls for "continual refinement through trial and error" (p. 30). This call entails repetitive improvement across different steps of the development process until the prototype has met its set goals. Every cycle is "infusing the process with richer information" (p. 30). Iterative development is most synonymous within the digital

product development industry. I consider that the process is applicable across any domain with human-centred problem-solving at its heart. It is also called rapid development, iterative prototyping, and is gaining favor as a method over conventional ones such as Corporate edict and the Waterfall. As a User Experience Designer, this method has resonated strongly with my professional practice over the last seven years. Therefore, I chose to carry it forward into this thesis exploration.

My prototype creation comprised a process of "progressive refinement through cyclical data-driven development" (Goodman et al., 2012, p. 32). In this thesis, I have created the first version of a visualization prototype that can go through numerous further cycles of development to reach its potential and perhaps become marketable one day. Speaking from my personal experience with iterative development, the lack of a set outcome can make the process feel uncertain, which can also be frustrating for creators. However, I can say from experience that the iterative development process has several benefits. For one, it allows the designer to work with substantial evidence and not on assumptions. This factor was especially crucial for this thesis research since I am dealing with the health and well-being industry, which is normatively science and evidence backed. I wanted to ensure that my prototype is treated as a design prototype and not an art installation. I gathered evidence from extensive contextual research, as well as aligned with current practices within the wearables industry before creating my prototypes.

Secondly, iterative design is a flexible working method and allows progressive refinement across any step of the process. Because this thesis is a new exploration into visualizing biological data, it was difficult to envision the end prototype without rounds of trial and error. Lastly, as I progressed through the various steps of my iterative development cycle (Figure 1), I was able to gain confidence and clarity into my vision for the high-fidelity prototype I would create as part of my research. Working in a structured, progressive manner through the development process was exhilarating.

The three stages within my Iterative Development process, based on research by Goodman et al. (2012), are listed below:

- **Examine:** According to Goodman et al. (2012), "This step attempts to define the problems and whom they affect"(p. 32). I began my research process by studying other Quantified Self practitioners (Section 3.8) to gain insight into their self-tracking exercises, as well as theory from the Quantified Self, personal informatics, and a horizon scan of commercially available

devices. I found that each Quantified Self tracker had a unique approach to self-modulating that was deeply connected to their reason for tracking in the first place.

- **Define:** The *definition* stage was about honing all the research from the examination stage into defining an essential set of issues that need to be addressed within the *creation* stage. In my opinion, the *definition* stage is the most critical and challenging piece of the iterative development process. I used all the research I gathered during the *examination* phase to first create a set of diagrams that showcase various data points based on their location on human bodies. This exercise was critical in establishing an understanding of various data points in different body types, across genders, and life stages. After that, I created a data sheet that captured missing features of biological data points with context to lived experiences, as well as identified possible links between different data points that have not yet been established. I then created a User Persona based on myself to help me focus on who the user that I am prototyping user is. All of the steps mentioned above formed the basis for my *creation* stage. In the *definition* stage, the aspects of the industry that I wanted to critique in my prototype became apparent, and I was to create confidently with evidence to back my design decisions in the *creation* phase.

- **Create:** Creating visualization prototypes was a culmination of progress from both the *examination* and *definition* stages. While I began this part of the exercise, I simultaneously collecting the data I had been tracking with a Fitbit Alta HR, and some mobile applications. Next, I created an Information Architecture to categorize the various biological data points I had studied previously. The goal of this architecture was to challenge normative practices within the industry and correlate data points that are usually presented in silos. I followed this step by creating wireframes for the visualizations. Then, I created space renders to showcase where the visualizations will reside within the domestic setting, and finally, I executed the digital painting and included the data I had collected within it.

Due to the time constraint, it was challenging to go through the entire process repeatedly. Therefore, in some parts, there are multiple iterations within each step. Once the high-fidelity prototypes for the visualizations were created, I turned back to the *examination* stage. At this point, I tested the visualizations with various female users that fit my User Persona to gain an understanding of how they perceived it if they would use it, and how it made them feel.

4.3 The Role of my Prototype

A primary strength of a prototype is in its incompleteness. It is the incompleteness that makes it possible to examine an idea's qualities without building a copy of the final design. Prototypes are helpful as much in what they do not include as in what they do.

- Stolterman, Tenenberg, & Lim, 2008, p. 7

Traditionally, prototypes in Human-Computer Interaction have been judged based on their fidelity. Lim et al. (2008), propose a new mindset for prototyping that is more relevant to current practices within the domain (Figure 23). They define prototyping as "an activity with the purpose of creating a manifestation that, in its simplest form, filters the qualities in which designers are interested, without distorting the understanding of the whole. The best prototype is one that, most simply and efficiently, makes the possibilities and limitations of a design idea visible and measurable" (p. 4). They categorize prototypes as filters, and as manifestations of design ideas. In this thesis, I apply a mixed-fidelity approach to prototyping using an iterative development process. The fidelity across each step depends on its significance in correlation to my overall prototype.

Prototypes as filters imply that designers must filter and focus on qualities that are of interest to them in their process. Because I spent the majority of my time on research, analysis, strategy, ideation, information architecture creation, and design, I decided to collaborate with a developer on the implementation of my visualization prototypes. I did this in order to be able to "extract knowledge about specific aspects of the design more precisely and effectively" (Stolterman et al., 2008, p. 3). The essence of my research lies in uncovering the meaning and the implications of biological data. I was also dealing with several data points in tandem and had to understand each of them in detail.

When it comes to prototypes as manifestations, it is stated that "designs are constituted through iterated interaction with external design manifestations" (Stolterman et al., 2008, p. 9). I view my prototype as a manifestation of my quest for better health. Each decision I made around its material, resolution, and scope was based on my broader objectives for answering my research

question in the most effective way possible. Therefore, I consider this thesis prototype, which is still a work in progress, as a manifestation of my needs, motivations, and goals.

Table II. Example Variables of Each Filtering Dimension

Filtering Dimension	Example Variables
Appearance	size; color; shape; margin; form; weight; texture; proportion; hardness; transparency; gradation; haptic; sound
Data	data size; data type (e.g., number; string; media); data use; privacy type; hierarchy; organization
Functionality	system function; users' functionality need
Interactivity	input behavior; output behavior; feedback behavior; information behavior
Spatial structure	arrangement of interface or information elements; relationship among interface or information elements—which can be either two- or three-dimensional, intangible or tangible, or mixed

Table III. The Definition and Variables of Each Manifestation Dimension

Manifestation Dimension	Definition	Example Variables
Material	Medium (either visible or invisible) used to form a prototype	Physical media, e.g., paper, wood, and plastic; tools for manipulating physical matters, e.g., knife, scissors, pen, and sandpaper; computational prototyping tools, e.g., Macromedia Flash and Visual Basic; physical computing tools, e.g., Phidgets and Basic Stamps; available existing artifacts, e.g., a beeper to simulate an heart attack
Resolution	Level of detail or sophistication of what is manifested (corresponding to fidelity)	Accuracy of performance, e.g., feedback time responding to an input by a user—giving user feedback in a paper prototype is slower than in a computer-based one); appearance details; interactivity details; realistic versus faked data
Scope	Range of what is covered to be manifested	Level of contextualization, e.g., website color scheme testing with only color scheme charts or color schemes placed in a website layout structure; book search navigation usability testing with only the book search related interface or the whole navigation interface

Figure 23: Table of variables for filtering and manifestation dimensions for prototypes (Stolterman et al., 2008, p. 11).

4.4 Prototypes as cultural probes

We often act as provocateurs through our designs, trying to shift current perceptions of technology functionally, aesthetically, culturally, and even politically.

- Gaver, Dunne, & Pacenti, 1999

According to Gaver et al. (1999), cultural probes are intended to "provoke inspirational responses." For the purpose of my research, I wanted to be able to gain insight on user preferences for my visualization prototypes without dominating the conversation or making it about my personal experience with self-tracking. This step was critical in validating my research. In addition, I used the probes to gain insight into other user's data collection and sorting priorities when tracking their menstrual cycles and rest in order for me to be able to contrast them to my own. The probes would trigger dialogue around the user's experiences, attitudes, behaviors and recall of self-tracking and open up possibilities to discuss ideas for new data parameters, visualization styles and environments. Gaver et al. (1999), state that the intent of a cultural probe is not to commercialize products but to develop "new understandings of technology," and therefore through speculation my thesis aims to provide opportunities for the design of biological data visualizations outside of current norms. The author's also state that it is important to work on the aesthetics of the probes as it forms an integral part of the probe's function as pleasure and delight are as critical as efficiency and usability. This aligns with my vision for the prototypes created through this research, and I developed my prototypes to a high fidelity, and ensured that they were interactive in order to gain authentic responses from users. Details on the use of the cultural probes, findings and reflections can be found in Section 6 of this document.

Prototype Creation

My discovery process began around February 2019, in a graduate seminar class at OCAD University called "Digital Theory" taught by Professor Ala Roushan. This class allowed me to build a strong foundational understanding of the ownership, access, distribution, exchange, and use of digital healthcare data and its implications across the globe. On investigating further, I discovered that there was a lack of autonomy that individuals have over their health data. It inspired me to write about the urgent need to empower them with a mode of governance that fosters trust, promotes transparency and calls for accountability in the use of health data.

During this time, I also took a graduate studio class named "Body Centric Technologies," which was taught by my primary advisor Kate Hartman and Lee Jones. It was in this class that I learnt about the intimate relationship that individuals are beginning to share with sensor-based, wearable technological devices, and the science behind medical and pseudo-medical biological sensors, and the cultural implications of self-tracking. I dug deeper and discovered several flaws within the wearables industry, such as a lack of consideration for the user's state of mind, emotions and lifestyle, as well as challenges with interfacing with wearable devices and their applications.

I felt that although wearable hardware was developing rapidly, the software was not up to par with it. While I found a significant amount of literature on the adoption and abandonment of wearables in context to their hardware, very few academics were touching upon software issues and even fewer on the design of biological data visualization. This emerging gap was an opportunity for me to propose a novel approach to improving the user experience for wearables by addressing issues with user experiences and, more specifically, user interfaces.

5.1 Prototyping Motivations

Most wearable devices come with an interface that serves to display the data extracted from them. The interface itself might reside on the wearable device, or a networked personal device such as a smartphone, tablet, or computer. Webb (2019), says that though these applications are currently key to seeing and reporting data, adjusting settings, and archiving information, she goes on to say that this will soon change as smartphones gradually lose their popularity (p. 284). In this thesis, I propose that though smartphone applications may gradually disappear, the need for a wearable device to be supported by an interface that presents extracted data will not. As invisible and

intimate sensors for the body proliferate rapidly, the need to integrate the data they collect into a cohesive interpretation of well-being will be critical to the sustainable adoption of wearable technology. The following design principles motivated my prototype creation process:

Fundamental Principles:

- **Empathic:** The user is at the helm of my prototyping process. Considering the user's lifestyle, routine, and state of mind have shaped each stage of my prototype. I use empathy to understand my user's mental models, which gives me insight into how they organize and structure their data. Then, I use my learnings to create my information architecture and visualization with the hope of improving the relationship the user has with their biological data.

- **Coherent:** Rooksby et al. (2014), suggest that Personal Informatics must be conducted over a range of lived activities and propose a branch of personal informatics as lived informatics, which signifies that people self-track to find meaning in their day to day lives (p. 1171). Additionally, Li et al. (2010), state that individuals might gather personal data for reasons beyond personal informatics (or self-knowledge through numbers). Some of these can be reasons can be reminiscing, aiding memory, and personal information management (p. 558). I strive to find connections between data points that are currently presented in silos in commercial wearables, to give the user a richer understanding of their data and its significance, and for them to be able to act upon it with ease.

- **Humane:** I consider the unpredictable nature of everyday life and human imperfections. My prototype adopts a strategy that is not punitive towards users who have a cheat meal or a bad day, and it does not advocate perfectionism or precision as a practice. The user's psychological and emotional well-being is as valuable as their physical well-being. My prototype will display the data transparently. However, it will be compassionate not only in the visualization of the data but also the actionable insights it provides.

- **Contextual:** In this thesis, I emphasize the importance of context. The meaning and value of the data presented to the user is most likely dependent on the context it is presented in. In his paper Gardner (2000), stresses the need to develop sensitivity to the home as a sanctuary with multiple social and emotional functions that play a significant role in the health and

well-being of its residents. The role of the home as a safe space is what inspired me to integrate biological data using ambient visualizations across space seamlessly (p. 15).

Supporting Principles:

While the fundamental principles have served as drivers for my creative process, the supporting principles served to complement them, and inspire different aspects of my prototype.

- **Flexible:** I have designed my prototype to be flexible enough to adapt to changing user types, needs, behaviors, beliefs, as well as changing devices and tracking motivations.

- **Effortless:** I have attempted to minimize the effort required by the user to integrate and collect data from self-tracking by attempting to find data from proxy sources that are passive. The intent was to allow users to focus on the process of reflecting and acting on the data.

- **Realistic:** I acknowledge that there might be gaps in data collected depending on the nature and use of the tracking devices and that individuals may choose to discontinue use or change trackers. It is unlikely that individuals will wear more than one to two trackers. My prototype considers collecting data from multiple sources.

- **Trustworthy:** The individual that uses my prototype will remain in control of their data, whom they choose to share it with, and what they decide to do with it. They will be given complete knowledge of the system before using it.

- **Meaningful:** I have presented data beyond numbers, in an attempt to move away from conventional representations of numerical data. I aim to provide an approximate, qualitative, sophisticated, insight-driven approach to presenting data to positively transform the way individuals can relate to their data, and therefore themselves.

- **Engaging:** My purpose was to move beyond the convention of quick, easy, and minimal interface design to engage users in ways that are delightful, affable, and intriguing. I wanted to stimulate the users and propose a shift in the way they interact with their biological data.

- **Inclusive:** I advocate socializing tracking, not through a competitive but communal

approach that is supportive and mutually beneficial. This practice is especially pertinent with mental well-being, as well as in health emergencies.

5.2 Data Collection

I began self-tracking using a Fitbit Alta HR device in June 2019 (Fitbit Inc., n.d.) (Figure 24). I procured the device as part of the examination phase in my iterative development process (Figure 1), with the premise of collecting data as the raw material for my visualizations. Using this device was my first experience with a wearable and it was revelatory. My experience with self-tracking was intended as an exploration and not a scientific analysis, and the process of reflecting and learning about myself was a by-product of tracking that I had not anticipated or planned for. Therefore, it has not been stated as a method within this research.

This particular device comes with an accelerometer as well as an infrared heart rate sensor. From a hardware perspective, the device was compact, but the thick rubber-based strap was suffocating. The battery life of the device was average. It had to be charged every three to four days, which led to weekly gaps in my sleep data collection.

Figure 24: (Left) Fitbit Alta HR device ("Fitbit Alta HR," n.d.). (Right) Me wearing the device.

From a software perspective, the device was straight forward. Figure 25 shows two screenshots I captured of the Fitbit iOS application home screen on July 12, 2019. The application captured my daily step count, resting heart rate, and sleep quality passively and expected me to log my period,

daily weight, daily food consumption and water intake manually. The only logging, I willingly undertook through the application was for my menstrual cycle. Not once did I feel inclined to stand on a weighing scale and manually log my weight. I did not log my diet on the application, primarily because I did not see tangible benefits for doing so. Over time, however, I developed a keen interest in monitoring my heart rate and my sleep patterns closely.

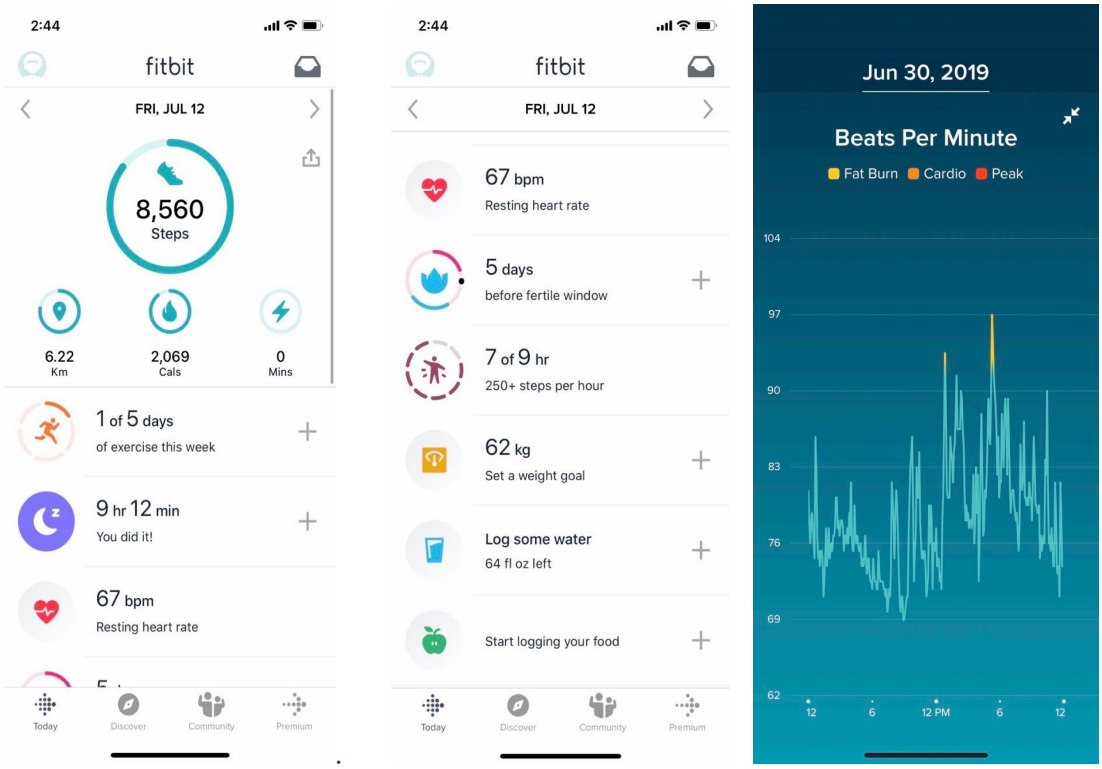

Figure 25: Fitbit home screen for my data on July 12, 2019 (Left, Centre). Fitbit daily heart rate summary screen (Right) (Fitbit Inc, n.d.).

The Fitbit captures a pulse through its infrared sensor, which is used to derive a daily average for a resting heart rate. An individual's resting heart rate offers insight into their stress levels and heart health. My addiction to checking my resting heart rate can be attributed to the stress I felt during this thesis development. Initially, I needed a week with the device to learn how to calibrate the digital reading with my physical awareness of stress. Soon, I found myself checking my heart rate more when I was anxious, which usually caused it to rise further. Also, the line graph that Fitbit used to display daily heart rate variations (Figure 25 was impossible to decipher and came with no insight into what measures I could take to feel less anxious. The graph was not interactive and only showed variances across different ranges of heart rate without context. There was no way

to correlate my heart rate to my life. I could not recollect where, when, or why my heart rate was high, and therefore, I never referred to this chart to reflect, as I derived no value in doing so.

While the Fitbit application does not provide insight into the significance of resting heart rate readings and how to improve them, over time, I learnt to derive these insights on my own. For example, on days that I woke up tired due to a bad night's rest, I noticed that my resting heart rate was high, which was a clear indicator of my body being under more stress than usual. Interestingly, the reading would also rise around a day or two before I got my period. However, the application never told me that my resting heart rate could be affected by my hormones, even though I was using the application to track my cycle.

On days with cardiovascular exercise, my resting heart rate would drop a few bears, indicating that the exercise was reducing the stress on my body, but once again, this was insight I derived on my own. The Fitbit application does provide insight into overall Cardio Fitness. However, I found that the baselines were too generic, and the derivation of the score was unclear. This reading made me anxious as the application was drawing comparisons between a professional athlete (Figure 26) and me. It also claimed that I only had a 20% scope for improvement if I lost 3 kilograms (when weight loss was not on my agenda - because I do not think I need it).

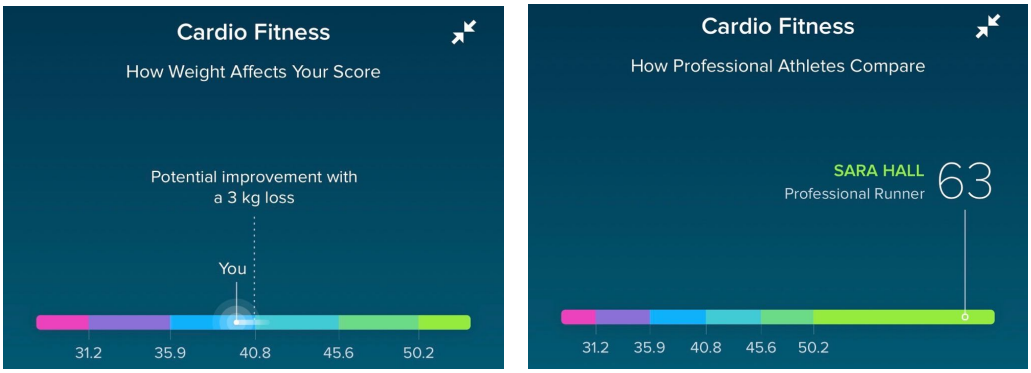

Figure 26: Cardio Fitness comparison on Fitbit application. Potential improvement with suggested weight loss (Left). Comparison Drawn with Female Athlete (Right) (Fitbit Inc, n.d.).

I also experimented with the Premium Fitbit Coach, using their guided workout programs as part of my exercise routine (Figure 27). The programs themselves were very well structured and engaging. I enjoyed the experience of working out with a virtual instructor. While the application could register walking or running as activities (apart from their preset workout regimes with

automated calorie counts), it could not register fairly common workouts such as running on a treadmill, Pilates or yoga.

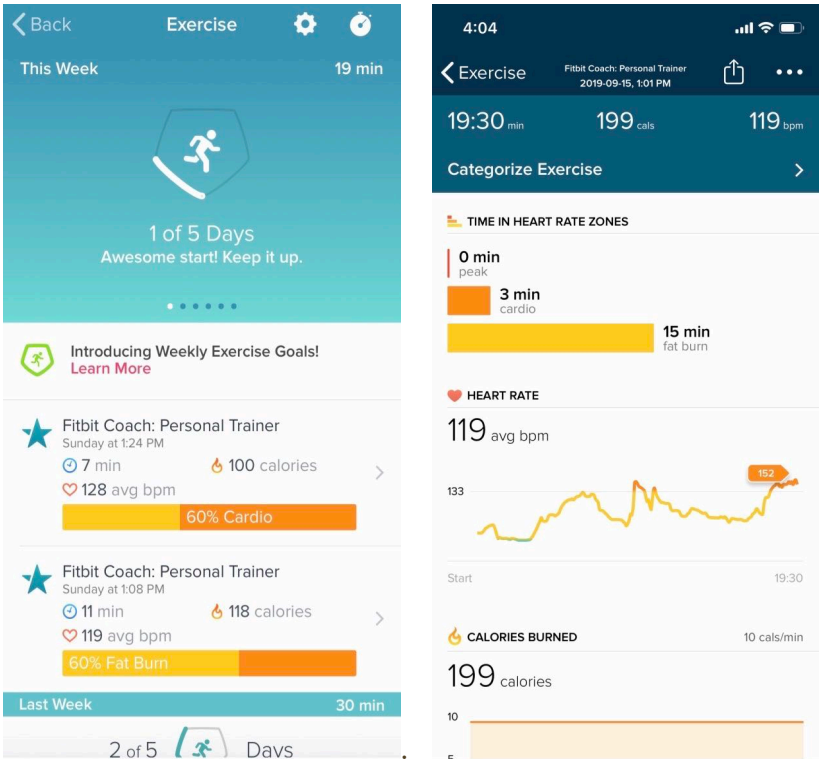

Figure 27: Fitbit Coach data on the Exercise section of the application (Fitbit Inc, n.d.). Summary screen (Left). Detail screen for each workout (Right).

In my opinion, the application's sleep module was one of the most poorly designed for a few reasons. Firstly, their sleep score derivation process was ambiguous, and the application failed to provide actionable insight on how to sleep better (Figure 28, Left and Center). While information about the sleep phases was useful, it was generic. Secondly, insight into my sleeping heart rate, restlessness, and snoring, which are valuable in the context of sleep scenarios, was reserved for premium subscribers. The third setback was that Fitbit provided "typical ranges" for women my age and drew comparisons without contextualizing the group's varied lifestyles, stress levels, routines or cultural backgrounds (Figure 28, Right). Overall, I think that crucial insights in my experience with sleep, such as napping, having bad dreams, menstruating, or consuming too much caffeine too late, were missing from this module.

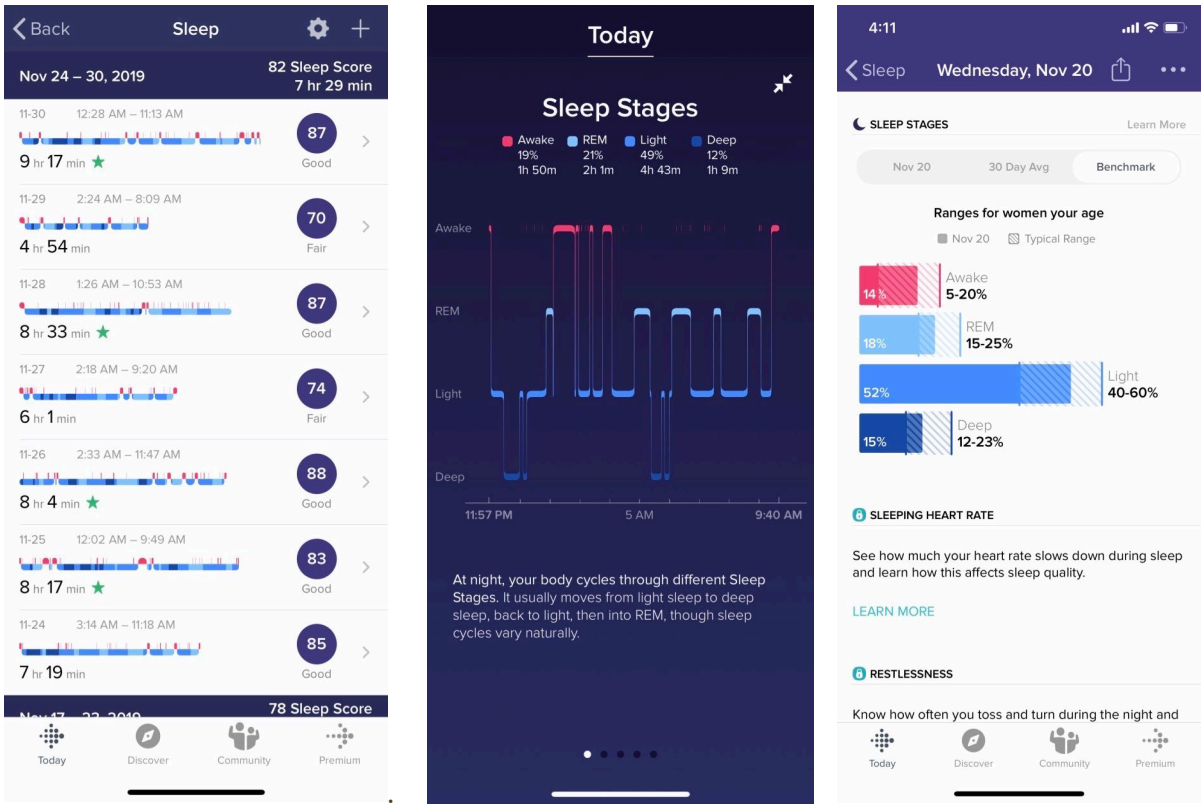

Figure 28: Sleep summary screen and sleep phases screen on Fitbit Application (Fitbit Inc, n.d.). Summary screen (Left). Detail screen visualization (Center). Detail screen benchmarks and premium offers (Right).

After using the Fitbit application to track my period for a few months (Figure 29, Left), I switched over to Flo (Figure 29, Right), because I stumbled upon some great reviews about it online. Upon using it, however, I was disappointed to find that the experience was strikingly similar to the Fitbit menstrual tracker. One, I had to manually enter the first day of my period when it arrived each month, which I occasionally forgot to do. Two, if the application's predictions were incorrect, it would indicate that my period was late, and not that their algorithm was still learning about my cycle. Eventually, I sensed that the application was inclined to assuming that a possible pregnancy was the default cause for a late period. When I tried using the application's Chatbot feature to discuss other causes for my delay, the application prompted me to subscribe to their premium application, before giving me any insight based on the data, they had just collected from me. This experience was agitating. I couldn't help but wonder why an application that was intended to make me feel better about tracking myself was manipulating me. Neither Fitbit nor Flo took my lifestyle, stress levels, travel patterns or exercise regime into consideration when predicting my cycle dates,

and their predictions were incorrect most months. Also, neither could help me plan my work and life schedule more efficiently so that I could have more restful days to cope with the pain when menstruating. Overall, my tracking experience with menstrual data was far from satisfying, and I had to address the pertinent issues mentioned above, within my prototype.

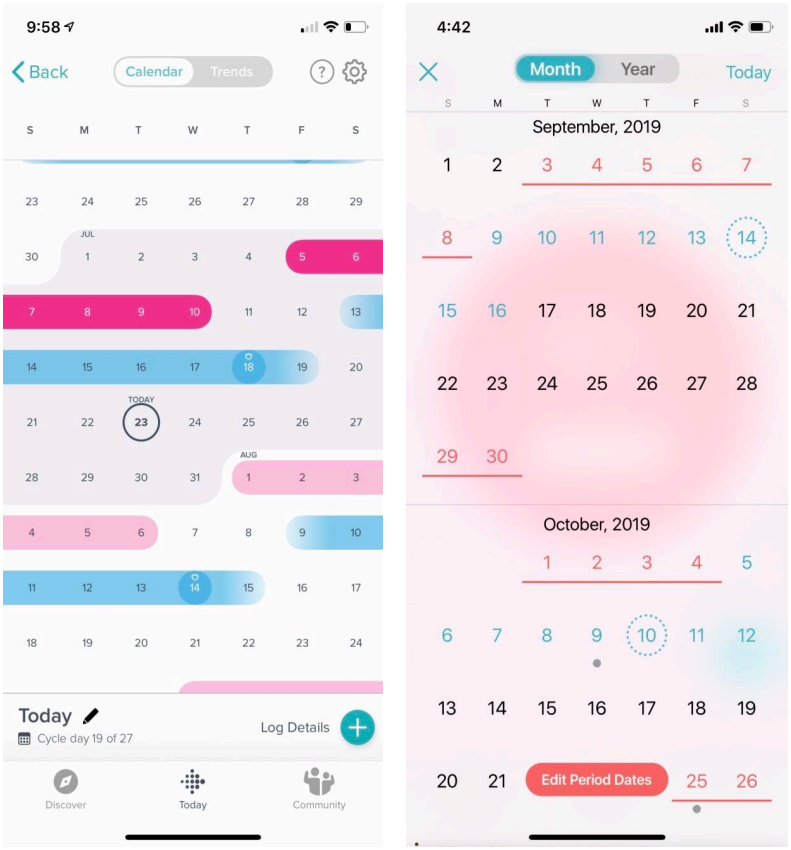

Figure 29: Fitbit menstrual calendar (Left) (Fitbit Inc, n.d.). Flo menstrual calendar (Right) ("Flo ovulation calendar, period tracker, and pregnancy app," n.d.).

Detailed datasets from my Fitbit device can be found in Appendix B of this thesis. The way I have used my Fitbit data in the visualizations I create within this prototype, is deeply interwoven with other forms of tracking through applications like Flo (FLO, n.d.), iCal, my credit card bills, and manual reflective logging. Occasionally, I would also utilize my phone's photo gallery to recollect memories from specific days to make sense of my Fitbit data.

5.3 Prototype One

During the summer of 2019, I had the opportunity to partake in an intensive three-day workshop at the Canadian Film Centre to test the first version of my prototype. The experience was insightful as it allowed me to receive feedback on my hypothesis of the need to humanize the visualization of biological data. Giorgia Lupi's approach approaching data more insightful, complex, and relatable, inspired me to create my first data visualization prototypes. I began developing them iteratively, in a process that comprised five stages shown in Figure 30. I began each of the three prototypes by gathering the data I needed from my Fitbit, which was followed by developing mood boards off Pinterest to inspire the design. I hand-drew the visualizations on my iPad Pro using Procreate and added simple animations to the visualizations in Photoshop to make them feel alive. Lastly, I tested the visualizations with prospective users at the workshop (REB Approval number: 2019-44).

Figure 30: Iterative Development process for Prototype One.

Each visualization was inspired by a different design principle. The three visualizations developed for this workshop are discussed below and accompanied by images that comprise the original Fitbit screen on the left, the design inspiration mood board in the center, and the visualization prototype that I created on the right. I animated the visualizations with static data for this first round. My purpose was to gain insight into the aesthetic and affective preferences of prospective users, before deep diving into a deeper prototype exploration.

5.3.1 Sleep Phase Visualization

I wanted to bring alive a whimsical, dreamy narrative through my sleep phase visualization (Figure 31). I was inspired by galactic bodies like planets and the stars in the night sky. The elements were animated to twinkle in this visualization. I used a line graph to plot my sleep journey during a night and used stars in different colors to connect the sleep phases to the journey. I wanted to build empathy and personalize the content on the screen. I added an action button to integrate a meditation feature into the visualization, for those who might have trouble getting to bed as I do.

Figure 31: Sleep detail screen on Fitbit (Left). Sleep mood board (Center Top) (Richter, 2015), (Center Bottom) (Strautniekas, 2017). Sleep visualization prototype (Right).

5.3.2 Resting Heart Rate Visualization

For the resting heart rate visualization, ambiguity was my driving principle (Figure 32). Giorgia Lupi's (n.d.), philosophy on small, qualitative data that slows users down as opposed to making them more efficient inspired me. When it came to my experience with heart rate data, I found that the live pulse reading made me more anxious. Therefore, I wanted to add a level of complexity and ambiguity to my resting heart visualization to advocate calmness through the approximation of leaf sizes, as opposed to displaying a precise number for a healthy or unhealthy heart rate, which changes from person to person and depends on several factors (Kremer, 2017). Metaphorically, I turned to leaves because leaves and humans are both systems of nature and have veins that allow life to flow through them. For the animations, I added subtle beating movements to the leaves to resemble those of a heartbeat. Positive affirmations were used in the content.

Figure 32: Daily heart rate screen on Fitbit (Left). Heart rate mood board (Center Top) ("Studio Cocorrina," n.d.) (Center Center), (Central Illustration Agency, n.d.) (Center Bottom). Heart rate visualization prototype (Right).

5.3.3 Menstrual Cycle Visualization

I firmly believe that most menstrual cycle tracking applications do not consider the emotional or psychological well-being of their female users when presenting them with a utilitarian tracking calendar as a regularly used interface. As a biological female, I can say that before and during the first day or two of my menstrual cycle, I feel extremely low, off-balance, anxious, and stressed. It is at this time that I seek comfort, support, and encouragement from my loved ones the most.

Upon researching further, I found that most menstrual tracking applications were skewed towards pregnancy and comprised substantially of the color pink. I wanted to change my approach and designed my visualization with the principle of inclusivity at its core. I wanted to present my female trackers with an interface that felt non-judgmental, natural, and more relatable. I intended to design a visualization that was not overtly feminine but conveyed a sense of warmth, support,

and comfort (Figure 33). I took inspiration from a dandelion chart and created monthly flowers, with colour-coded petals to showcase different menstrual phases. I also wanted to give the user a glimpse into the prior and next months without interfering with the visualization in focus. The animated version comprised of subtly motioned flowers in the wind. Because I did not have enough insight into tracking objectives at this stage, I refrained from adding data

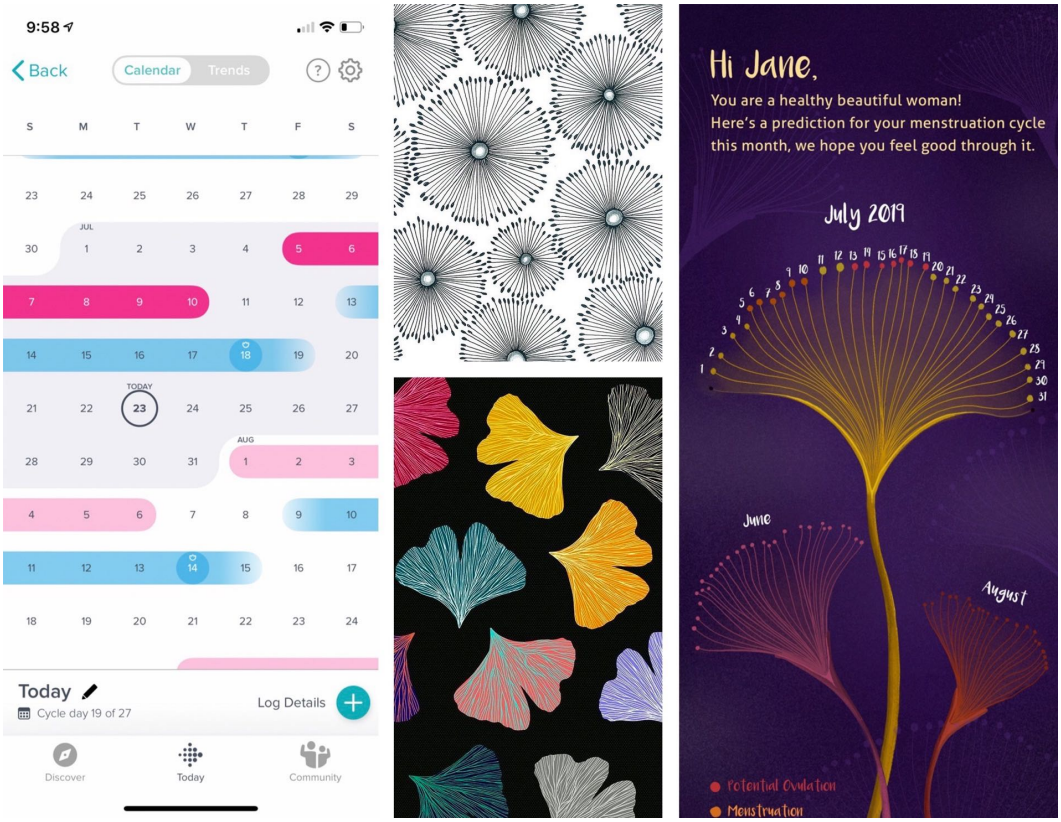

Figure 33: Menstrual calendar screen on Fitbit (Left). Menstrual mood board (Center Top) (James, n.d.), (KRAJACEC, 2015) (Center Bottom). Menstrual visualization prototype (Right).

5.3.4 Summary

At the workshop, I had the opportunity to receive feedback on my visualizations with approximately twenty users. The Research Ethics Board at OCAD University approved the workshop (Approval number: 2019-44). They stated that the visualization prototypes were friendlier, calming, soothing, less robotic, more playful and gave them joy. Some said that the visualizations made them feel like the experience was personalized, as numbers and statistics can feel impersonal. Others even responded to the text stating that the positive language made the

experience more motivating and uplifting. One user claimed, “the interface makes me feel better about the data overall.”

In addition to the positive feedback, there was also constructive criticism that I wanted to apply in the next stage of my prototype development process. Some individuals wanted assurance that the ambiguity of the visualization did not compromise the integrity of the data. One user said that the data should be “something that you can grasp right away.” Some users wanted more interactivity and animation in the visualizations. There was secondary feedback about allocating real estate to the data versus other supporting components on a small smartphone screen. While the menstrual cycle and sleep phase visualizations were well received, the heart rate visualization was too ambiguous for most individuals. Its data was too hard to decode, and the leaf metaphor was not clear enough. Some individuals wanted to add personalized benchmarks and goals to help them improve plausibly. They also felt like there was a layer of depth in lived data missing that they would have liked to see in the visualizations, such as the effect of a nightmare on a good night’s rest. I considered all the feedback stated above, in future prototype iterations.

This experience made the need to incorporate more qualitative, personalized, and actionable visualizations into the next version of my prototype evident. I also had to attempt to make the learning process between the user and their visualized data effortless. I designed this prototype for mobile screens, but my research findings compelled me to look at a ubiquitous integration of the data in the individual’s life.

5.4 Prototype Two

The feedback I received from Prototype One was enlightening. However, the experience also made me feel like I had to gain an in-depth understanding of the types of biological data, their values, units of measurement, and importance. I also wanted to study how the points might vary across body types and life stages, before embarking on another round of making. I needed to build confidence in my understanding of data from the human body, in order to be able to identify gaps in data extraction and visualization, to propose alternate approaches.

5.4.1 Data Mapping on Human Bodies

Deborah Lupton (2016) discusses how digital devices are employed to collect numbers on body functions, emotional states, sexual and social encounters, work productivity, physical activities

and geo-location, to name just some variables (p. 3). Swan (2013), references a table by K. Augemberg, that categorizes various data points from the body (Figure 34) (p. 86). I began data mapping by categorizing and listing biological data points that I discovered through my experience with my Fitbit, my contextual review, and a horizon scan of devices available for sale within the global wearables industry (Appendix C). It is worth noting that more devices with combinations of sensors are gaining popularity, as they can provide more rounded insight into an individual's health and well-being.

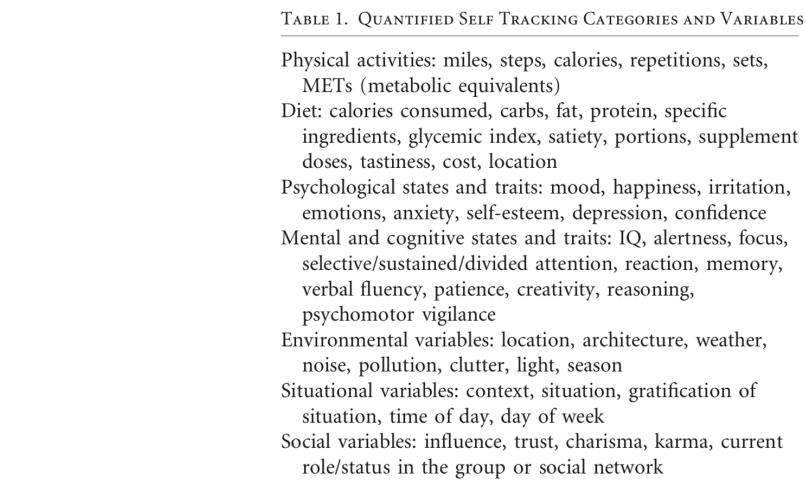

Table 1. Quantified Self Tracking Categories and Variables

Physical activities: miles, steps, calories, repetitions, sets, METs (metabolic equivalents)
Diet: calories consumed, carbs, fat, protein, specific ingredients, glycemic index, satiety, portions, supplement doses, tastiness, cost, location
Psychological states and traits: mood, happiness, irritation, emotions, anxiety, self-esteem, depression, confidence
Mental and cognitive states and traits: IQ, alertness, focus, selective/sustained/divided attention, reaction, memory, verbal fluency, patience, creativity, reasoning, psychomotor vigilance
Environmental variables: location, architecture, weather, noise, pollution, clutter, light, season
Situational variables: context, situation, gratification of situation, time of day, day of week
Social variables: influence, trust, charisma, karma, current role/status in the group or social network

Figure 34: Quantified Self Tracking Categories and Variables, by K. Augemberg (Swan, 2013, p. 86).

During this process, I learnt that there were three broad categories of types of biological data. The first, *electrophysiology*, is concerned with reading electric signals (Carter & C.Shieh, 2010). The second, *biomechanics*, is concerned with the movement of the body (Rogers, 2019). The third, *biochemical*, is concerned with liquid or chemical readings (Dhruv R. Seshadri et al., 2019). It is my position, that while *electrophysical* and *biomechanical* sensors are popular, the promising field of *biochemical* sensing is still in its nascent stages of development. For this thesis, I mapped a male and female adult body, within the age bracket of 25-45 years (Appendix D). I limited my search to this group because data requirements and readings for older adults vary. For example, women in menopause have differing data needs for their reproductive system, and readings like heart rate and blood pressure also differ for most older adults. I was limited to exploring a few body types due to the time allocated. However, I have also mapped an infant's body to elucidate the contrast in readings across life stages from birth to adulthood (Appendix D).

With its' innate ability to reproduce, I learnt that the female body comprised more data points

around the abdomen as compared to a male reproductive system, for which there are currently no devices available. Some applications have begun to accommodate male fertility as a feature. However, the data collected pertains to their lifestyle choices and not readings from their body (Alba, 2015). Additionally, some of the points on the female body overlap with the male body could also signal more data within themselves. Pregnant women also have many dual functioning data points that can provide critical insight into both the mother and babies' health simultaneously. However, I was constrained by time and could not deep dive into this body type.

Another lesson through this process was based on priorities with data types that change across varying life stages. For example, gaining insight into an infant's swallowing patterns is vital to understanding if they are getting the nutrition they need since they cannot communicate ("MomSense: The Smart Breastfeeding Monitor," 2019). On the other end, for some senior citizens, especially those that live alone, a fall detector is critical for emergencies (Apple, n.d.-c). I also discovered that infants were more closely and intensely surveilled by their primary caregivers (especially first-time parents) than individuals who were self-tracking (Wang, O'Kane, Newhouse, Sethu-Jones, & De Barbaro, 2017, p. 3).

I created my diagrams in two iterations, while the first was intended as a wireframe to map data points (Appendix D), for the second I focused on streamlining the labels into types of readings as opposed to types of sensors. I also collaborated with an illustrator Yadnyee Shingre, who created beautiful illustrations for my human bodies. I wanted to invest time in creating these diagrams because I believe they would be useful for future researchers within the fields of the Quantified Self and Healthcare (Appendix E).

5.4.2 Lived Data Points

Post data mapping, I wanted to reflect upon the data points, to identify data collection gaps, and to establish connections across different data points that may be more valuable when presented coherently. With this list, I would gain the clarity I needed to create my information architecture. I studied each data point individually, by listing the old method of data collection (manual), a new method (device or application), sensors used to extract data, and details on readings currently presented from the sensors (Appendix A).

Once I had completed this process, I reflected upon each data point to examine how it is situated within my everyday life, and how I prioritize data collection. I connected various points based on my tracking motivations and referenced the Quantified Self practitioners I had studied to uncover

their sense-making processes (Section 3.8). Interestingly, Felton (2014), learnt through self-tracking that his increasing heart rate was directly proportional to his body temperature and that the more time he spent in his studio, the less physically active he was. I took inspiration from Felton's ability to capture and present complex data in a digestible way without dumbing it down or reducing the number of points to make the data easy to present.

At this point in my exploration, I was already using my Fitbit to self-track. I studied the Fitbit iOS application and reflected upon gaps in my experience, to add to my sheet. The most significant gap, in my opinion, was with the emphasis given to step counting. I never saw value in knowing how many steps I took or how much distance I covered in a day. My step count aggregate never influenced my assessment of my fitness. Over a month, I continued evaluating my Fitbit and went through two iterations of capturing gaps in the data points I had tabulated, based on my lived experience. One unique connection was identifying that my resting heart rate would rise significantly on windier days to fight the cold, and the increase would leave me feeling tired faster. It is worth noting at this stage that I was not tracking data manually at any point in time.

It became apparent that my goals and motivations deeply influenced my experience with self-tracking. My practice was reflective, as I was consciously looking for links and anomalies within the data to make sense of what my body was telling me. One evening, at a meal with my friends, I found myself checking my heart rate every couple of minutes because of the discomfort I was experiencing from an extra cup of coffee that I had earlier in the day. However, I wasn't anxious because I knew what caused the increase and why. That was the moment that I realized I was getting hooked to my device. Whenever I was even the slightest bit uncomfortable, I would robotically turn to my wrist and check my heart rate. The satisfaction of knowing that my heart rate was high at my convenience was cathartic.

5.4.3 User Persona

Swan (2012), says that tools like wearables will have to cater to a "subjective dimension of concerns such as mindset, experience, emotion, ethics, values, and culture at the levels of the individual, family, community, and society that is outside of the realm of reason, science, a system, or some other form of objective truth" (p. 108). As a User Experience designer, I have always created a User Persona before prototyping. It served as a compass to navigate my prototype's design direction and drove my decision-making process. The first iteration of my User Persona (Appendix F) was based on a hypothetical female user, as I had not firmly decided to position myself as the User of

my prototype just yet. For the second iteration (Appendix F), I decided to posit myself as the prototype user. Strangely, while I had no problem crafting personas professionally, undertaking this exercise as a reflective practice was challenging. Our values, beliefs, desires and challenges shape us and influence our behaviors, personality, and lifestyles. However, we rarely articulate these fundamentals. This experience was eye-opening and shed light on my tracking behaviors, indicating that I prioritized my menstrual cycle and sleep schedule in my practice.

5.4.4 Information Architecture

Upon completing my User Persona, I realized that while the data points that sensors can capture will likely not change drastically in the near future, the way the data is categorized and presented is where the potential to transform the experience lies. I revisited the Fitbit (Fitbit Inc, n.d.) and Apple Health (Apple, n.d.-a) iOS applications, where the disconnected in the presentation of data points became apparent. Both applications had siloed categories to present data that they were capturing (Figure 39), but neither were considering how intertwined these data points are within our everyday life.

Swan (2013), says “The aggregation of multiple data streams could be a preliminary step toward two-way communication in big data Quantified Self applications that offer real-time interventional suggestions based on insights from multifactor sensor input processing. This functionality could be extended to the development of flexible services that respond in real-time to demand at not just the individual level but also the community level” (p. 89). (I set out to brainstorm and create an information architecture that presents biological data collected from various sources cohesively.

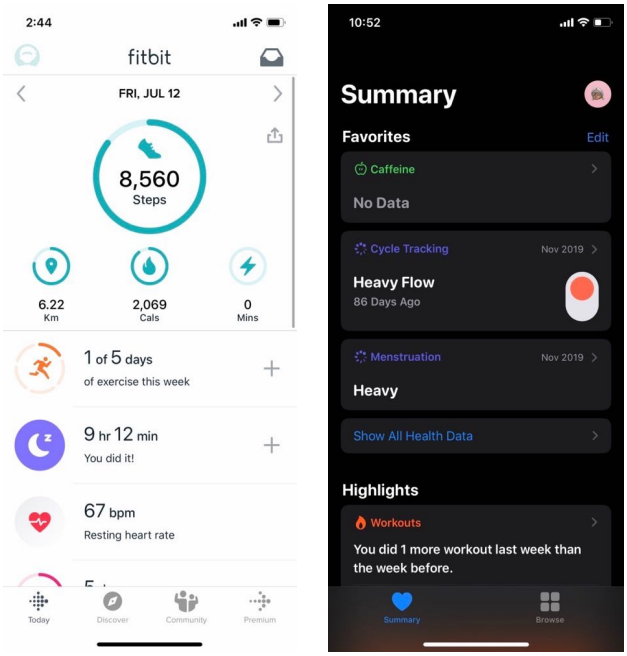

Figure 35: Fitbit (Fitbit Inc, n.d.) and Apple Health iOS ("Health," n.d.) application home screens.

During the first iteration (Figure 36), I categorized the data sets based on how I traverse through my daily life. When it came to sleep, I was more interested in how rested I was feeling. With energy, I longed for insight into my nutrition levels over calorie counting. When it came to activity, I wanted to encompass my daily experiences into a timeline, or a journey, with a focus beyond fitness. I also wanted to be able to know if my loved ones are well. When I conceptualized the four categories for this iteration, I articulated my process as "How we restore affects how we energize, how we energize affects the way we experience life and connect with our loved ones."

Figure 36: First iteration of information architecture.

5.4.5 Visualization Wireframes

I began sketching visualizations for a web-based application, that was inspired by nature (Figure 37). Throughout the wireframing process, I attempted to create a level of abstraction and avoid showing precise numerical data, since I had feedback about numbers triggering anxiety. While digitizing my wireframes, I was drawn to working with radial forms because they were versatile enough to expand to an entire visual system (Appendix J lists tools used).

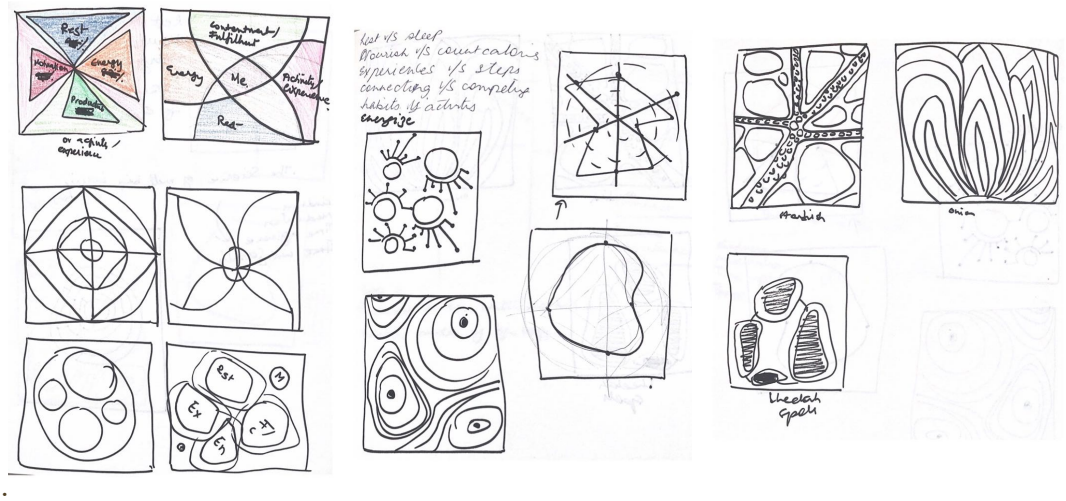

Figure 37: Data Sketches for overall well-being visualizations.

Appendix G shows both iterations of my overall health and well-being wireframe. The visualizations provide an overarching view of the four categories in my information architecture, to present them cohesively. The first visualization did not give the user a clear understanding of varying levels of completion within each category. Therefore, I came up with a second iteration. With the second iteration, I was able to establish more clarity with the levels of completion, without providing precise numbers. There were subtle rings to indicate a minimum, ideal and maximum capacity for each category. I designed the layout so each category could house its insight.

After that, I moved on to creating a wireframe for the energize category (Appendix G). Most nutrition applications I had referred to during my context review were so focused on calorie counting that they hadn't considered other factors internal (within the body) or external (outside the body) that might affect our energy levels. I wanted to combine both types of factors to give the user an overall perspective into data points that might affect their energy levels. For the internal points, I showcase food, water, alcohol (including hangovers) and caffeine consumption levels. For external factors, I showcased humidity (because too much of it triggers nausea for me and also affects the kind of food I want to eat), pollution levels, allergen levels, and sunlight intensity. Having lived in a large pollution city (Mumbai, India) most of my life, I find that pollution can kill appetite and cause extreme fatigue. I also have severe pollen allergies that tend to block my sinuses frequently and inadvertently affect my appetite. Lastly, too much sunlight can cause a heat stroke and calls for cooling foods. Back home, my family would consume more yogurt and buttermilk when it was too hot outside. I took inspiration from all of the above to create this cohesive wireframe.

The next visualization I tackled was for nourishment within the energize category (Appendix G). As discussed previously, I wanted to move focus away from the calorie counting culture and try to visualize nutrition-based data. I looked up government-recommended food plans (Canada, n.d.) and reflected upon my experience shopping at grocery stores. I realized that we sort and shop for food based on food groups, and therefore why can't we present data that aligns with this pattern? Government health plans recommend daily intakes for each food group based on age, sex and lifestyle. I applied insights from these plans into my visualization. Each category within the central grey circle represents a particular food group (Appendix G). The amount recommended for an individual over a day is displayed through outlined circles. Filled circles represent how much the individual has already consumed during that day. I have also visualized a family's nutrition (Figure 45), for caregivers that take charge of their diets. I wanted to contextualize the visualization not

only to the experience of consuming food but also to obtain it.

5.4.6 Summary

The second round of prototyping gave me confidence in my progress for the examination phase. I wanted to continue iterating through the definition and creation phase. While I had clarity in my wireframes, I was not satisfied with the decision to create a web-based application to house them. I revisited my contextual research and realized that the "nudging technology" smartphone applications were inundated with, constituted the direction I was headed in. I was also reminded of Rooksby et al. 's (2014) call to develop Personal Informatics tools that can seamlessly integrate within our everyday life, and it became clear to me that a web-based application was not the right medium for my prototype.

5.5 Prototype Three

Before embarking on my third prototype iteration, I revisited my research question to evaluate if I was meeting the three criteria that I had set for my research - *coherent, contextual and humane*. My attempt to create more coherent visualizations was being realized through the re-categorization of data points in my information architecture and the wireframes I was creating. I was addressing the need for a humane approach, with the abstraction of data and the qualitative insight-based approach in my wireframes. However, I had not addressed the need for *context*.

This gap made me asked myself, when and where does my data matter to me? I reflected upon the time and place that I was thinking about my wellness. When I woke up, the first thing I was used to checking was my sleep data and heart rate on my Fitbit. For my nutrition data, I was mentally processing most information when I was opening my refrigerator, making grocery lists, and shopping. For my menstrual data, I was usually reflecting as a reflex to physical symptoms when I was alone.

If I was on the move, or engrossed in my work at school, I was not thinking about my body. This behavior made me wonder why health applications nudge users when they are preoccupied and unlikely to process the information presented to them. I realized that most of my detailed interactions with my data were within the comfort of my home, at ease. This was my eureka moment. I wanted to find ways to integrate biological data into everyday life in ways that are ambient, passive, unobtrusive and intuitive.

“There is evidence that the home environment is therapeutically advantageous”

- Liaschenko, Breier (Gardner, 2000, p. 15).

I also came across a paper by Glenn Gardner, titled “Hospital and home. Strange bed fellows of new partners?” (2000, where he talks about the home as a private space, “a haven from the demands of the world”. He discusses how the word ‘home’ itself, evokes a sense of belonging, comfort, security and calm, and how being surrounded by familiar things and routines can have a positive impact on our health and well-being. Gardner also discusses how the space of the home can give us control and safety (p. 14). In my opinion, this feeling of control is especially pertinent when it comes to managing our health and safeguarding our data. Perhaps being within the safe space of their homes makes individuals feel confident, like the expert, therefore empowering them to manage their health.

5.5.1 Space Renders

In the next part of my process, I envisioned where my visualizations would be situated within the home. I collaborated with illustrator Andrii Bondarenko (Bondarenko, n.d.)who brought life to the spaces and depicted where my visualizations would reside (Figure 38). The visualizations are embedded within the space, without taking the wearer out of their environment or task, where the data would be of most value to them (Kremer, 2017). The visualizations would reside in the periphery of the user’s attention and be informative without nudging the user repeatedly. I intended for the user to develop a relationship with the visualizations over time and that the visualizations fuse seamlessly to their lived experience. While menstrual data is displayed in the private, intimate space of the kitchen, the dining area is where nourishment is displayed. The bedroom is employed to showcase rest data and the living area to showcase experience data (Figure 38). After this step, I reiterated upon my information architecture and wireframes to further contextualize the visualizations to the spaces they belonged in.

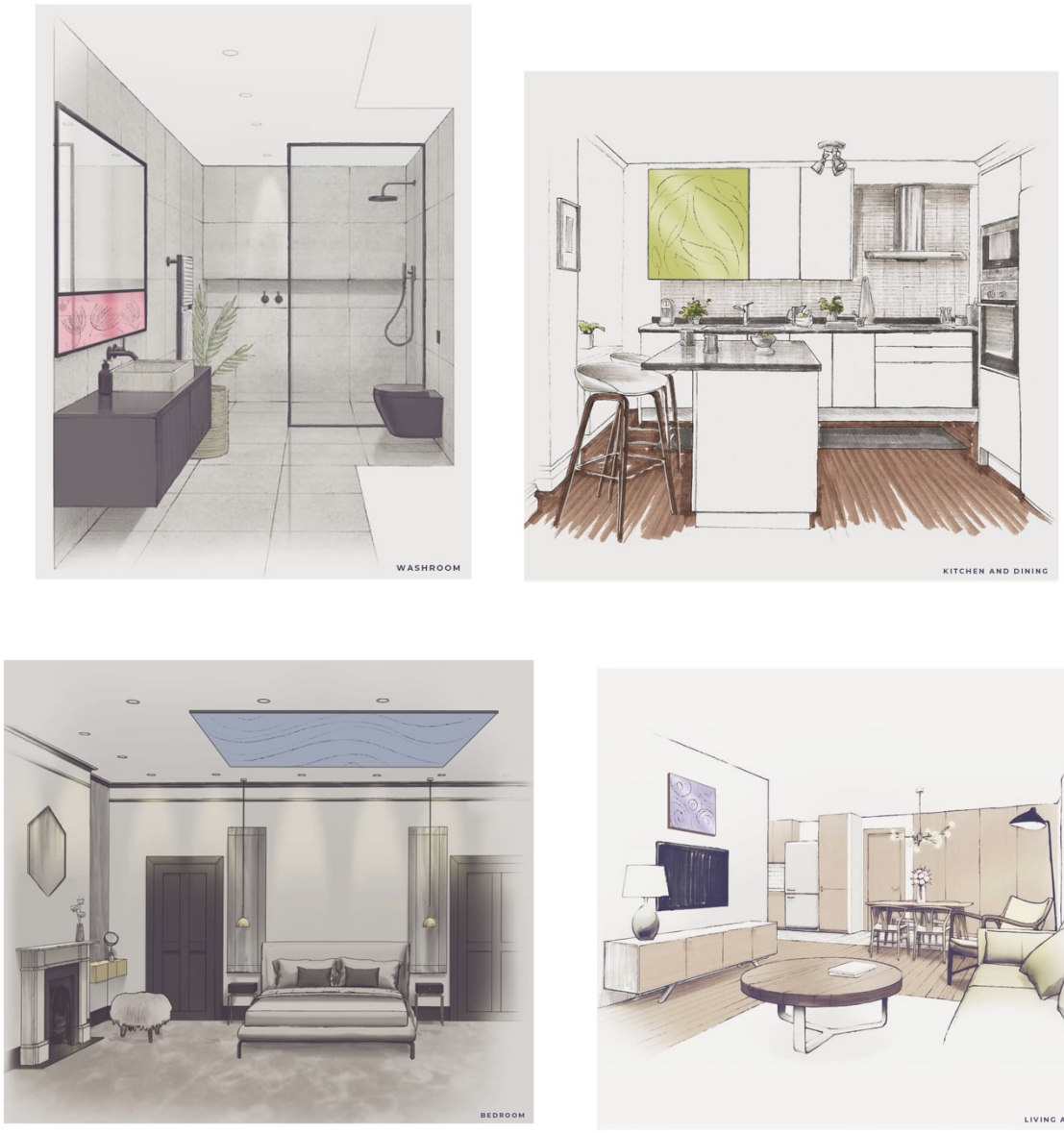

Figure 38: Space renders with subtle graphics as placeholders for my visualizations (Bondarenko, n.d.). Washroom for menstrual visualization (Top Left). Kitchen for nourishment visualization (Top Right). Bedroom for restoration visualization (Bottom Left). Living Room (Bottom Right).

5.5.2 Information Architecture and Wireframe

I developed the second iteration of my wireframes and information architecture in parallel. For the revised information architecture (Figure 39), I was inspired by professor Laurie Santos (n.d.) at Yale, who teaches one of their most popular courses titled “The Science of Well-Being.” She says

that human being's assessment of their well-being is dependent on how they spend their time (time affluence), how much they socialize, help others, and how kind they are. These points are closely linked to the lived human experience and added rigor to my prototype creation process.

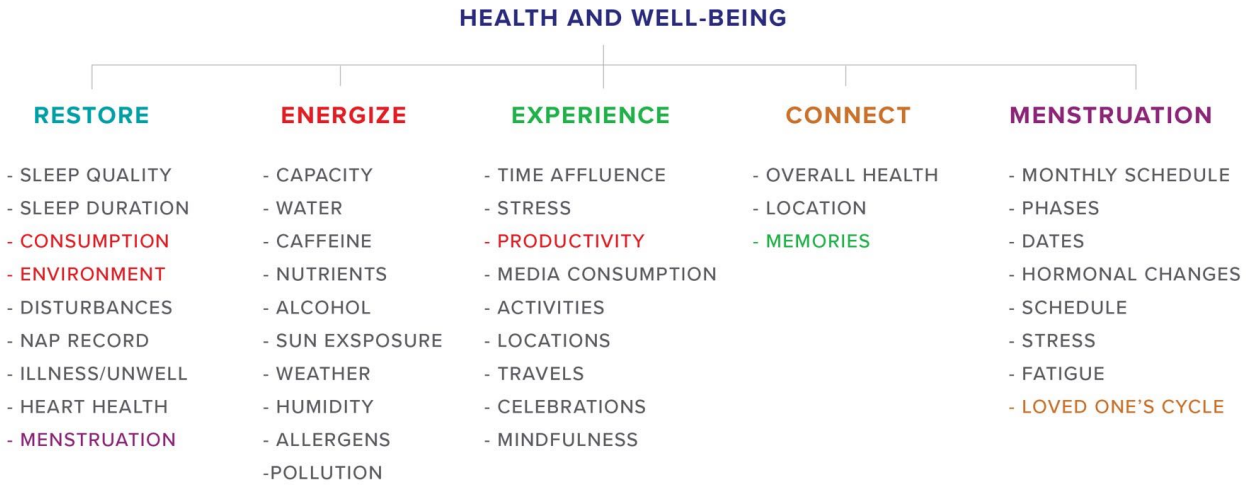

Figure 39: Sitemap Iteration Two.

I developed wireframes with higher fidelity for this round. My effort was devoted to honing best practices from information visualization, conveying the depth and complexity of the data to the user, without overcomplicating the visualizations. I created wireframes for ambient versions of the data visualization as well as for interactive versions, to aid in decoding them. I was aware of the learning curve that the user would undergo with the visualizations and how the users would relate to them in both the ambient and explanatory context.

For the restoration visualization, I displayed sleep phases and sleep influencers like caffeine, food, alcohol and media consumption, which is known to affect sleep quality according to research (Caitlyn Fuller, Lehman, Hicks, & Novick, 2017). I also subtly connected the menstrual visualization to this one because I find that menstrual symptoms affect my sleep quality (Appendix G).

For the menstrual visualization, I connected my schedule to my cycle. I visualized my experience with physical and mental exertion, in correspondence to symptoms like cramps and mood swings (Appendix G). I applied my learnings from using the Fitbit and Flo menstrual trackers. I was inspired by the paper on "Examining Menstrual Tracking to Inform the Design of Personal Informatics Tools" by Epstein et al., (2017). The authors claim that existing applications fail to

consider the changing female body across life stages such as youth, adulthood, pregnancy, and menopause (p. 1). They elucidate findings from user interviews, where one respondent says, “so I know I am not crazy when I start to PMS and so I can up my dosage of my anxiety meds” (p. 4) to counter her mood swings. Another respondent says, “I can literally plan my vacations and excursions around my time” (p. 4), because a period can really dampen holiday plans. A third respondent says, “I suffer from debilitating cramps that cause me to stay home from work, so I track my period to plan in advance as best I can” (p. 4). A fourth respondent says that menstrual tracking applications are a “constant reminder of trying to conceive and not succeeding”(p. 9), as tracking applications can be overtly feminine, and too inclined towards pregnancy, inadvertently upsetting and even hurting those struggling to conceive, or those who have faced a miscarriage (Epstein et al., 2017).

The examples stated above clearly indicate that menstrual tracking is central to the lives of some female trackers. Knowing that I shared my challenges gave me the reassurance I needed to develop this visualization as authentically as I could. Due to time limitations, I could not develop detailed wireframes for the connect and experience categories of my information architecture and had to proceed to designing interfaces for my existing prototypes.

5.5.3 Restoration Visualization Design

For this iteration of my restoration visualization (Appendix H), I used data from my Fitbit to depict my sleep phases through the night. For consumption data (food, caffeine, media), I depicted hypothetical instances. I was inspired by Studio Coccorina (Cocorrina, n.d.), for the aesthetic direction of this visualization. I wanted to carry forward the dreamy scene I had depicted in my first prototype iteration, for which I received positive feedback. I created planets, stars, and other galactic bodies in this visualization, and used lines to show my journey across sleep phases over time.

I was not satisfied with this exploration. Though it was aesthetically pleasing, I found several gaps from a data visualization perspective. Firstly, there was a weak hierarchy in depicting which aspects of the interface were data points, and which were purely aesthetic. Secondly, some of the most striking elements in the design were not related to the data at all but could be misconstrued as depictions of data. Thirdly, the design was too intricate and hard to comprehend at a glance, thereby increasing the cognitive load on the user, which went against my prototyping motivations. Lastly, I believe that the hand-drawn visualizations from my initial prototypes afforded a sense of

warmth and relatability that the geometric forms and deep colors in this visualization were unable to offer. I decided not to proceed in this direction.

5.5.4 Summary

This round of prototyping gave me confidence through each step up to my *creation* stage. For the next prototype iteration, I had to focus on sorting, integrating, analyzing my data, in order to be able to visualize it. After that, I would develop the interface design for the visualizations in high fidelity.

5.6 Prototype Four

For the last iteration of my prototype for this thesis, I first devoted my effort to sorting through all my Fitbit data, cleaning it up, and organizing it. Next, I searched for proxy data sources to integrate into my dataset, to be able to populate some of the parameters I had envisioned in my information architecture and wireframes. Since manual logging was not a feasible option for me, finding proxies was necessary in order to create my visualizations with real and not hypothetical data. This step was most challenging, but also the most educational. It is my position that since user effort is a cause for device abandonment, other self-trackers also face this challenge, and therefore I wanted to work around it. Once my datasets were ready, I shifted focus to designing the menstrual and restoration visualizations and their interactions. I collaborated with developer Vladimir Kuchinov, who built my visualizations in d3.js, using the data and design files provided to him. Once the visualizations were interactive, I user tested them with peers who matched my User Persona. Lastly, I planned the user experience for the thesis exhibit and created a floor plan for my installation (Section 5.7).

5.6.1 Menstrual Visualization

For my menstruation prototype, I already had my wireframe in place, and I was clear on the visual direction I wanted to take. Therefore, I spent most time sorting and categorizing my data (Appendix I). To connect my fatigue levels to my cycle, I correlated the data from my iCal to my Fitbit and Flo cycle datasets. I gathered data for two months of my cycle, which is September and October 2019. From my iCal schedule, I was able to gauge how tired I was and how long I was working. I also gauged the days I cancelled meetings or working from school, which also happened to align with my cycle. I created a column to note a theme for the day, which I noted as a reflection,

in correlation to my schedule, to derive insight on dipping energy and mood levels around the date of my period (Appendix I). I also added a column for reflection to summarize my analysis of each day while organizing the data.

Before I began designing my visualization, I experimented with my data in Tableau to analyze the correlation I had established in my dataset. I had to convert some of my qualitative parameters into a quantitative set to be able to visualize my data in Tableau (Figure 40, 41). I replaced my Theme column with fatigue levels, which I scored from 1-10 based on my schedule for the day (Appendix I). Below are some of the experiments I conducted. Seeing the data visualized in Tableau was helpful in reinforcing my hypothesis about correlating my fatigue to my cycle. I then proceeded to design the visualization on my iPad using Procreate.

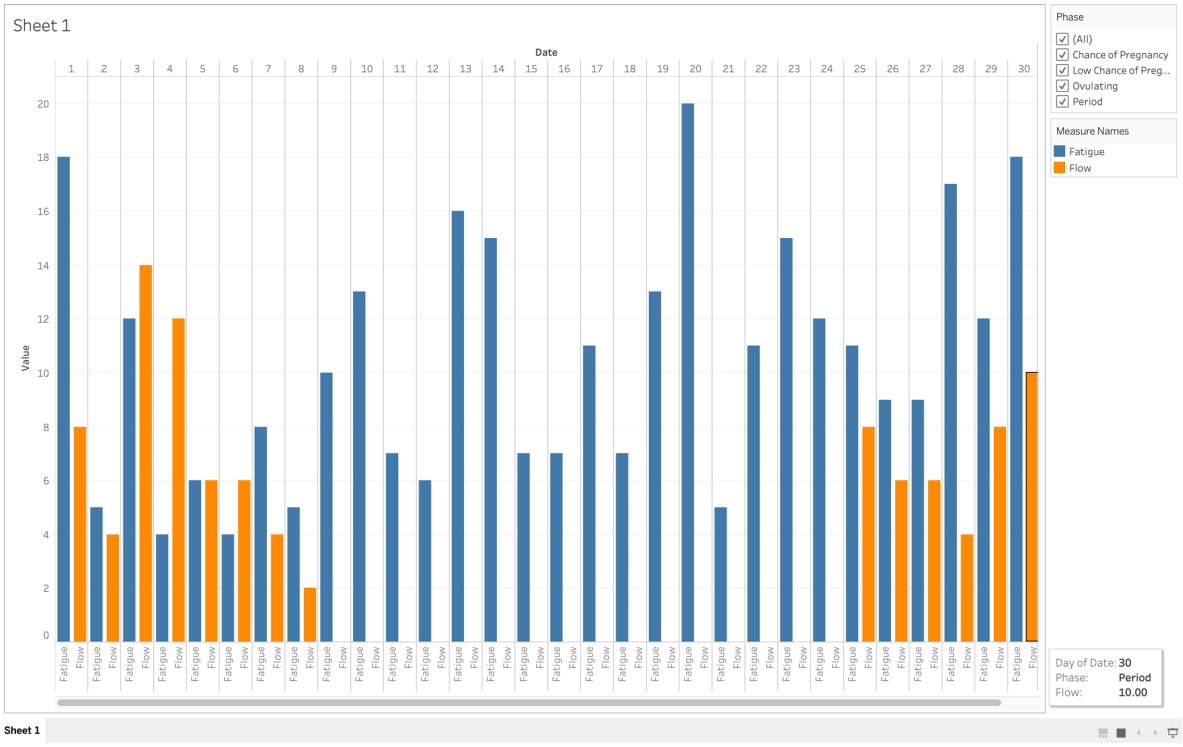

Figure 40: Bar chart that shows correlation between flow and fatigue levels.

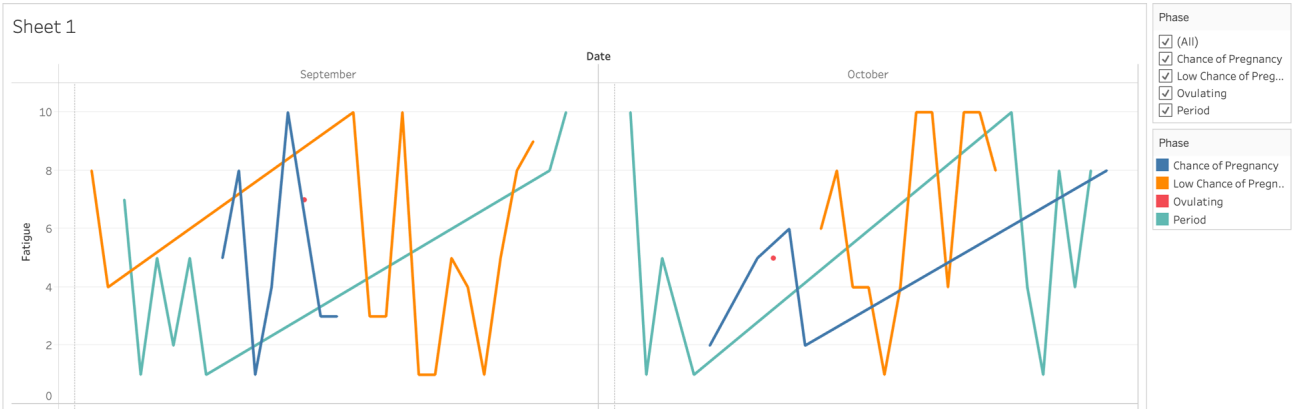

Figure 41: Line chart that shows correlation between fatigue levels, and menstrual phases.

Appendix I, represents the menstrual visualization in both its ambient and interactive form. The flower at the center of the screen represents the current monthly cycle. Each petal represents a day of the month (September 2019 in this image). The color red represents days I had my period, the bigger the dot, the heavier the flow. Ovulation is represented with the color pink, orange signifies high chances of pregnancy, and yellow signifies low chances. The length of the petals is adjusted to the phases as well. Period and ovulation dates are most significant, and therefore those petals are longer. The thin blue line attached to each petal signifies the exertion or fatigue on that day. The small blue flower on top represents the previous month, and the flower at the bottom represents the next month. Appendix I comprises enlarged version of these visualizations. This visualization will reside on a washroom mirror or wall as shown in the space renders (Section 5.5.1). Once I had created the visualization in Procreate, I moved it to Photoshop to design the interactive pieces with the typography. In its interactive version, each petal of the flower is clickable and gives me insight into my reflection for the day as well as well as my fatigue levels. The visualization would also move subtly, with the flowers gently blowing in the wind. Setup details for this visualization are explained in detail in the Exhibit Design Section (5.7).

Once my design files were ready, I handed then over to Vladimir Kuchinov, along with my dataset. After a detailed conversation about the dataset, its translation to the visualization, the animations, and the interactions, he began implementing the visualization. He employed d3.js to develop the visualization, using an HTML design framework called PixiJS (Goodboy, n.d.). After a few rounds of iterating, and brainstorming, we were able to swipe between months, and even display data on the flowers for previous and next months. I then moved onto the restoration visualization.

Live visualization: https://vedaadnani.com/floraldiagram/

5.6.2 Restoration Visualization

Like the menstrual visualization, I began work on the restoration visualization with sorting my dataset. I had data on total time spent in sleep phases from my wearable device, but it was not time sensitive. While Fitbit accounts for four phases of sleep – awake, light sleep, REM (Rapid Eye Movement) sleep, and deep sleep, it does not allow the user to download data on how they transitioned across sleep phases through the night. This data is crucial to understanding quality of rest. For example, on nights that I was in the awake phase at an odd hour, I knew I would wake up tired but the way the data was presented to me was in the format of total awake minutes, which was not valuable. The Fitbit sleep quality score was also ambiguous, and I could not derive any actionable data from it either. Secondly, I needed proxy data sources on my food, alcohol, and caffeine. While I could use my credit card to track meals I had outside, it was impossible to track my consumption patterns at home, which led to some gaps in my data collection. Also, I was not tracking my screen time using an application, and the default tracker on my iPhone only captured data for a week. Therefore, I had no input into this critical data point. Thirdly, my analysis for restoration was more complex and layered than the menstrual visualization. Therefore, I could not use Tableau to experiment with this dataset as it was hard to quantify how much alcohol or food I had consumed on a scale. Lastly, because I had to charge my Fitbit once a week, I had regular data gaps that I could not replace manually (Appendix J).

For the visualization itself, I was also challenged with rethinking my wireframe and design, since it was not successful during my exploration in Prototype Three (Section 5.5). While I was thematically committed to the night sky, I had to reconceptualize the details of each visual structure before I could proceed to the design stage.

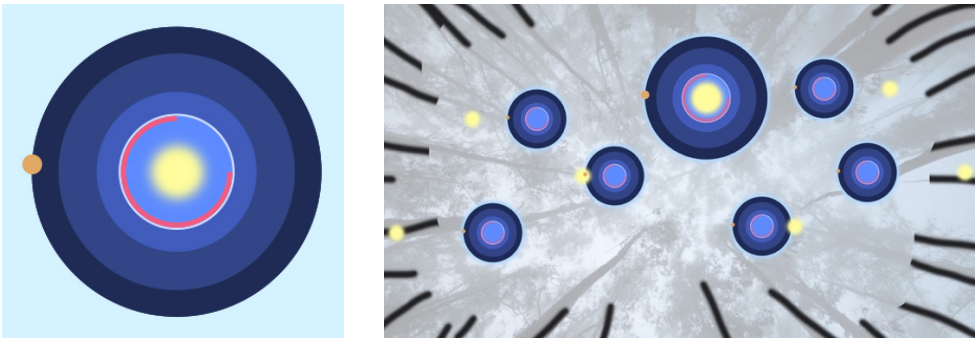

Figure 42: Restoration visualization wireframe. Wireframe for a day (Left). Wireframe for a week (Right).

I began by using my dataset to create a visual system for each night of sleep. I used concentering rings to represent time spent in different sleep phases (awake, light, REM, deep sleep), with gradually darkening shades of blue. I then depicted caffeine consumption post 5:00 pm with a brown dot on the last orbit, and fatigue level as a pink ring. Depicting caffeine and fatigue was necessary, as both affected my quality of deep sleep adversely (Figure 54). There were some data points I was debating. The first was being explicit about a good versus a bad night's rest. While I had initially wireframed the glowing yellow circle to depict a good night's rest and glowing blue for bad, I opted out of this hierarchy because of my own negative experience with the Fitbit sleep score (lack of clarity on good and poor rest). Next, I was deliberating the display of menstrual data, as for some female users it can affect their sleep, however, because of its sensitivity, I was not convinced about displaying it in a bedroom. Upon reflecting, I decided to display the data as another moon (Appendix J), which matched the colors on the menstrual visualization because I believe that partners should be attuned to our menstrual cycles. While including naps was part of my initial concept, I am not a napper, and therefore I had no data on sleeping during the day on my device to apply in this visualization.

Figure 54 (Right), shows a wireframe for a week of restoration. The seven visual circles each represent a night of rest. The biggest one represents the last night, emphasized the next morning. Next, I moved into designing this visualization. I had envisaged this visualization displayed on my ceiling over my bed. I would view it first thing in the morning, at a glance as part of my morning routine, and then proceed with my day. Because of its unique position, I designed the visualization to feel like I was looking through the trees into the universe (Appendix J). I maintained consistency with the cool, dreamy color palette I had used in my first prototype iteration.

For restoration insight (Figure 55, Below), I tried to use qualitative sentences as opposed to numbers, to try and convey the data as meaningfully as possible. For the implementation, I followed the same process with the developer, as for the Menstrual Visualization. The only difference was in converting some numerical data into a basic semantics to make it easier for the user to decode. For example, Fatigue from 1 to 3 can be considered low, and 7 to 10 can be considered high. It can be communicated qualitatively, using these interpretations.

Live Visualization: https://vedaadnani.com/stardomediagram/

5.7 Exhibit Design

As mentioned previously, Gardner (2000), discusses the role of the home as one with multiple social and emotional functions that can profoundly influence an individual's health and well-being (p. 15). In this thesis, I propose contextualizing my biological data visualizations to the spaces in which they are most beneficial. I envisioned these prototypes as ambient, embedded displays within the home that can belong to the spaces they are most useful in. It is my position that by displaying data in this manner, it eases the process of decoding the data for the user. It also allows the user to interact with the data when they need it and empowers them to act upon the data at their free will. I critique nudging technology, by applying the principles of Calm Design (Kremer, 2017), to allow users to perceive their data in their periphery, only interacting with it if need be, and maintaining their spatial awareness throughout the experience.

For the purpose of my exhibit, I chose to showcase my visualizations in the domestic spaces they are intended for. Figure 43 shows a floor plan of my proposed exhibit setup. As users walk into the exhibition space, they are first shown a brief video that explains my research process. Thereafter, they can first look at the menstrual visualization prototype setup within a washroom (sink and mirror), and the sleep visualization which will be projected onto the ceiling using a projector, with a bed to lay upon and view the visualization. I chose to showcase the menstrual visualization first because data from it is carried forward into the sleep visualization. By designing my exhibit this way, I believe that visitors will be able to evaluate the visualizations with an added layer of depth, by building spatial context. To me, this setup is key to realising my research.

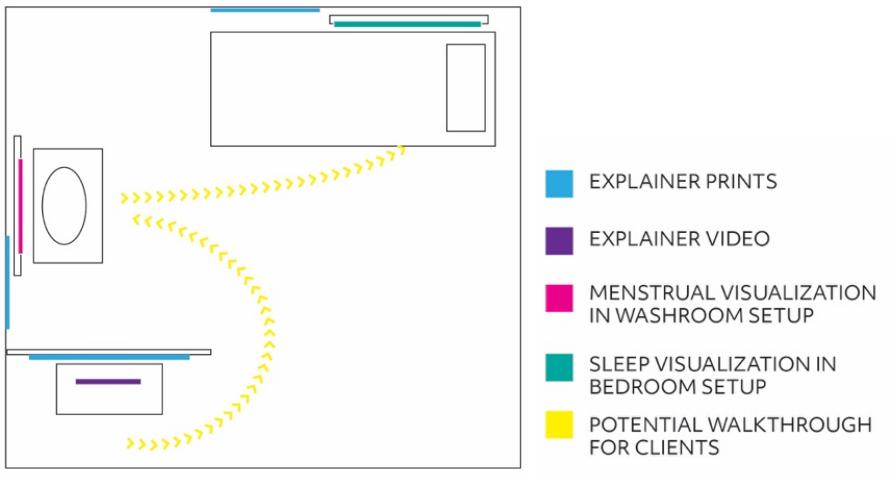

Figure 43: Exhibition setup floor plan design.

Cultural Probes

Once my visualization prototypes were developed to a high-fidelity, I wanted to use them as probes to validate my proposed research question and provoke dialogue around self-tracking. This step was imperative, as I had spent most of my prototyping process independently. By using cultural probes, I could assess if my personal need for humanizing visualizations resonated with other users. Although I had plenty of secondary research available online, engaging with potential users contributed an authentic, real-world perspective and offered dialogue to create new opportunities, ideas to validate my research. Further, I initiated this thesis wanting to change what is considered as normative for wearable device data visualization, and using the cultural probes and tools for dialogue warranted that I was heading in the right direction.

I began the process with approval from the Research Ethics Board at OCAD (Approval number: 101714). Thereafter, I sent out emails to potential users to invite them to experience my visualizations. The objective of this exercise was not to collect self-tracked data from my users but share my experience with tracking to better understand theirs. I wanted to evoke a dialogue with my users on their experiences with tracking. I also wanted them to identify similarities and differences in their data priorities when assessing my visualizations. I also wanted to understand their aesthetic preferences when it came to the visualizations as I had created the prototypes based on my distinct taste and preferences. For each of the five sessions, I ran the user through each of the two visualizations, articulated my own experience with tracking and then asked for their feedback. We discussed data sources, methods for tracking and organizing data and context for the ambient visualizations to give them clarity on the ideology behind the prototypes.

Because the cultural probes involved personal and sensitive information being disclosed, I have opted to not mention any demographic details of my users in this section to respect their privacy. The only demographic aspect I choose to disclose is that all my interviewees were female. Because the visualizations I created were based on my data (I identify as female), I needed users who could assess both the menstrual and restoration visualization from experience. In this section, I share a brief overview of each user session and then summarize the key insights learned through this exercise.

6.1 Session Overviews

Manual logging can come with a bias, while automatic tracking is perceived as more authentic.

- User One

My first user had never used a tracking device but used an application to track her menstrual cycle. She also used a sleep tracking application, but only used its alarm clock feature, since she felt like she was a good sleeper. Her menstrual tracking revolved around being aware of her mood during the time. However, she did not feel the need to log the data in her application, since she already knew what to expect from her period. She believes that manual logging can come with a bias and states the advantage of automatic tracking is in its authenticity and the reassurance it provides. She didn't care for her current menstrual tracking application. She thought that the visualization prototypes were visually pleasing, felt intrigued, and more inclined to engage with them. She thought the visualizations were easy to comprehend after a short brief. The privacy of her data was most vital to her, especially when placed in an ambient context. She wanted complete control and autonomy over her data because it was inherently hers.

The visualization makes the whole process and the idea of menstruating look pretty, feel natural, and it makes me feel like I am going to be ok. Everything you see nowadays is about data, looks boring and medical. Menstruation is not treated as a natural process even though it's the most natural thing there is.

- User Two

My second user wore an Apple Watch, but the only feature she used was the exercise tracker. She used a different application to track her menstrual cycle, on which her focus was on her mood and occasionally her sleep and hair texture. She felt like she wasn't getting returns in the form of insights or advice from her investment of inputting data into the application, and therefore stopped logging. Upon seeing the visualization prototypes, the idea of planning her schedule and holidays around her cycle, having the ability to look at them cohesively, and mentally prepare herself for the next day, excited her. The ambiguity in the visualizations made her feel less anxious about the data. She said that always measuring makes her feel paranoid and like nothing is natural. The visualizations she said, were visually appealing and resonated with her. She felt like necessary advice on lifestyle improvements should be mandated for health and fitness applications and was

intrigued by the idea of time-sensitive ambient visualizations.

It's not pretty, I don't like wearing it, and it makes me feel bad about myself, so I took it off.

- User Three

While the third user was a self-tracker in the past, failing to meet arbitrary and generic goals set for her, made her discontinue. The application made her feel stressed and less than the numbers projected on it. She doesn't see value in tracking menstrual cycles via applications, unless they are intended for pregnancy. Upon looking at the visualizations, she preferred their non-numerical approach. Her most crucial need to want to start tracking again, was for individual baselines and targets to be applied rather than generic ones. She saw the value of linking fatigue with menstruation. Though she was comfortable with displaying her data ambiently, she was averse to interacting with it in the space itself, as it would allow other people to gain access to her data. She was drawn to inherent nature of displaying disturbed sleep, to allow the user to start their day on the right note.

The visualization feels less machinist, less robotic. Flowers feel personal; they feel more relatable; everyone relates to them differently. By relating it to menstruation, you are personalizing it.

- User Four

My fourth user was only tracking her menstrual cycle and not her sleep. She was not logging any data manually and longed for more insight into what to expect with each new cycle. She felt like the visualizations were less mechanical, machinist, and said that they felt more relatable and personal. We discussed the possibility of customizing the visualizations in the future, to add a layer of personalization to the experience. With the sleep visualization, the user wanted more clarity into the hierarchy of the stages and wanted to see what a good night's rest might look like. We also discussed how abrupt sleep disturbances and long day naps might appear in the rest visualizations.

A critical part of humanizing this experience is about how do we balance this creative tension between the human and the device? Advice should not always feel like a bitch slap.

- User Five

My final user was a manual logger. While she has self-tracked using technology in the past, she felt like she was in a one-way relationship with the applications, so she moved to pen and paper. She was tracking to be an advocate of her health, looking to learn about her body. Tracking on paper, she said, has given her deep, complex insight into her body, something no application could deliver. She thought the visualizations were stunning, and a refreshing change from blood applications that are usually red, and female applications that are very pink. She appreciated the dynamism, and biomimicry of the visualizations, and felt like they were alive. The depth and movement of the visualizations were refreshing to her. She saw the potential to layer the visualizations further, by adding points like exercise, self-care, stressors, outliers, diet anomalies, travel schedules to them. The deep correlation of varied points to match her day would be the most valuable part of tracking for her. The need to layer and compare several types of data, and to watch the visualizations evolve made her most curious. One of the most striking aspects of our conversation was about designing for balance. The biological process of homeostasis inspired the context for balance in self-tracking. We discussed the potential for self-tracking applications to reinforce balance with compassion and not in a punitive way.

6.2 Knowledge Gained

Key insights from my cultural probes are listed below:

- All of my users had firm opinions about the menstrual prototype but were reasonably neutral when it came to the sleep prototype. All of them found it easy to interact with the menstrual visualization once explained briefly. The sleep visualization was static, as it was still in development.

- All of them were visually attracted to both visualizations. Some were more intrigued by them, and more enticed to engage with them. I would create customizable visualizations in the future, to personalize the experience.

- Each of my users had unique data needs within both the menstrual and sleep visualization. This pattern made me think about a parameter list, from which users can pick what matters to them, instead of being subjected to seeing and decoding several data points that might not be relevant to them.

- All of my users wanted actionable, qualitative insight as a return on investing in the device emotionally. Some used words such as companion, mother, kind, humorous, joyful, and voluntary to describe the nature of advice they wanted.

- All of my users were seeking a more personalized experience with self-tracking with individualized baselines, goals and targets if set for them.

- Not all users were comfortable with interacting with the ambient visualizations outside of their devices.

- Most users could identify the menstrual data being used in the sleep visualization independently and correlate it to the menstrual visualization.

- Not all users were inclined to manual logging; most picked automatic sensing over it when given the option.

- Privacy was crucial, most of my users felt a strong sense of ownership over their data. They wanted to protect it at all costs and have complete autonomy over it.

To summarize, the cultural probe sessions were invaluable. They gave me direction for a future trajectory for my prototypes, which in order to pursue, require a deeper understanding of the role of menstrual health in the overall health and well-being of females.

REFLECTION

How do we reassess and imagine new algorithmic paradigms that encompass imperfection, accident and messiness?

- McCrae, n.d.

When I reflect upon the year-long journey of my thesis exploration, I feel optimistic about the future of wearable technology. If we can harness its potential to manage our well-being by approaching the design and development process with empathy and compassion. In doing so, we can move away from the overly critical relationship we have begun to form with our bodies, towards one that is humane.

This thesis is an initial exploration into visualizing biological data from wearables in engaging, meaningful, and personalized ways, and therefore seeks to identify opportunities rather than present conclusions. Using an iterative development process, I have applied research from the industry, academia, and Quantified Self practitioners to offer a multi-layered perspective on the implications of self-tracking, to propose an alternate trajectory for its future. I mapped biological data points on different body types, captured missing data points in context to my lived experiences. I self-tracked for six months to be able to use my data in the creation of my prototype. I created an information architecture to categorize the data points coherently, then wireframed, designed and developed biological data visualizations to elucidate my conceptual proposition.

In this thesis, I have documented each step within my research and prototype creation process in detail. This has been done to provide sufficient evidence for my proposition of an alternate approach to the future of biological data visualization that is coherent, contextual and humane. Because these three terms were vital to the realization of my research question, I discuss how I strived to address each of them. In order to achieve coherence, I have developed my information architecture prototypes to align with my everyday experiences in life. Within the architecture, I categorize data points based on the various stages of my day as a critique of generic categorization based on the data type. I have added context in three aspects of my prototype creation process, first, by contextualizing the data points to how they are experienced in real life. Second, by embedding my visualizations in a home, as a component of the ambience, to maximize value and natural-ness to the user. Third, I contextualize the visualizations to the devices they are embedded in, by creating contrasts between the ambient and interactive states. I used multiple digital and physical tools in the creation of my prototype (Appendix K).

Besides addressing the criteria in my research question, I have also addressed issues with device abandonment. Through the creation of my prototype, I minimize user effort by sourcing proxy data sources to passively track data and advocate privacy in self-tracking by presenting the data within the safe space of the home. I also simplify the process of data analysis for the user and propose a more humane, personalized, forgiving and qualitative approach to providing the user with insight and visualizing their data, to make the process of self-tracking more engaging.

From the creation of this research, I gained a newfound appreciation for my body, and the lessons I have learned, have made me feel more empowered in managing my health and well-being. This thesis emphasized the premise of Data Humanism, which revolves around the ideas of small, qualitative, imperfect, complex, and inspiring data, part of which inspired me to look for data from unconventional sources. I embraced my biological data in all its complexity to build a narrative that presented it in ways that felt more humane, natural, and relatable.

I have learned from both my visualization prototypes and using them as cultural probes, that each individual is affected by the data presented to them uniquely. Hence, personalization within biological data visualization is imperative. In my opinion, this need opens up a lot of possibilities in the future for the customization of data points, insights and visualizations for groups of users. With the menstrual visualization, I have learned how central menstrual tracking is in a female's life, and how it can form the nexus of several layers of insight into other aspects of their health and well-being. With the restoration visualization, I have learned that are several occurrences during the day that affect rest quality that users need to reflect upon to assess the quality of their rest.

By using cultural probes, I could also validate my decision to group data points based on how they are lived through, and to add a layer of abstraction to reduce anxiety and ease the process of interacting with the data. All my users found the visualizations easy to understand. They were able to recall data points within both visualizations with ease when asked to do so. This exercise triggered healthy dialogue around different biological data parameters based on how they are lived through, how they should be grouped and prioritized. I learnt about new parameters that I hadn't considered before and this inspired me to chart new trajectories for future iterations of my prototypes. Further, the exercise also gave rise to conversations around aesthetic preferences and the opportunity to customize visualizations in the future. There was also discussion around infusing personality into the interfaces themselves as well as the tone of the insights provided to users. All of the above shed light upon the need for personalization in

futuristic iterations of biological data visualization.

This thesis exploration also came with challenges. While I was advocating passive tracking throughout my research, finding reliable proxies as data sources were, and cleaning up and organizing the data I found was challenging. To add, learning how to work with numerical data and interpret it as semantics was also a new experience. I also consider the influence of the application I had envisioned creating initially on the role of my prototype, but due to being pressed for time, I did not have the opportunity to develop it.

Within this thesis, strategies for privacy in the front-end are explored in substantial detail but strategies for privacy in the backend were not part of my scope and therefore, only discussed briefly. However, I believe that it is important to acknowledge how my research might embed into an ethic of data privacy into the broader vision of society for which I believe decentralization is the answer. The future I speculated through my research is one where wearable and ambient devices that capture various aspects of our health and well-being and exist as self-sufficient systems within the domestic setting. These systems should be designed to receive data automatically, but only send data with the explicit consent of the residents at their ease. I also imagined one networked interface as the control centre for all devices and visualizations with both the front and backend of the technology remaining embedded within the home. This proposed system design increases opportunities for personalizing user experiences by allowing algorithms to adapt to individuals, as well as families or co-residents collectively. It also allows users to customize their visualizations and data parameters based on their nuanced needs and preferences. Lastly, through this system I envisioned that every house over time will possess unique algorithms and self-tracking behaviours that best reflects who they are as individuals and families.

Though I undertook this thesis as a personal exploration, I chose to share my data and my experience with others. My decision was based on my belief in allowing others to see an alternative approach to visualizing their data so that they can make perhaps be more mindful and kinder towards themselves.
This thesis puts forth the idea that an individual's biological data is deeply impressionable. It affects not only our states of physical well-being but also our values, beliefs, identity and our culture in the long term. This thesis is intended to benefit individuals who are currently self-tracking or plan to do so in the future. While the long-term repercussions of authoritative and punitive wearables are yet to be seen, I believe that if people become more aware of how these

systems of wearables work, they can form healthier relationships with the data and manage certain aspects of their health autonomously. Additionally, since employers and healthcare professionals are beginning to hand out tracking devices, average users must understand the repercussions of being surveilled continuously. Users must be empowered and able to control the data from their bodies and have full ownership over it, but for that to be true, they need to know what this world of biological data comprises off in the first place.

7.1 Future Work

I believe that my research delivers a strong message to the industry in an effort to reconsider what interfaces for biological data visualization are considered normative. Second, my research appeals to designers of personal informatics tools to reconsider their approach to designing them, for which I attempt to emphasize the significance of a deep, qualitative understanding of the user's values, lifestyle and behaviours. Third, my research is intended for individuals currently engaged in self-tracking to help them understand the fundamentals of biological data, its purpose and its implications.

Having had the opportunity to reflect upon my literary and contextual research, my iterative development process, and the lessons learned through creating my prototype, I feel confident in continuing my research into biological data visualization in the future, by pursuing a deeper exploration into the role of menstrual health, in the overall health and well-being of females. I strongly believe that digital female health needs innovation urgently and is an underdeveloped sector. From my experience, I can say being a woman is hard. On one hand, we are critical about ourselves and often feel like we need to conform to societal requirements. We look after our loved ones and tend to forget to look after ourselves in the process. Through the cultural probes, I discovered that most of my interviewees believed that female health was underrepresented and sometimes treated as taboo. Even in 2020, menstrual health is stigmatized around the world.

Initially, I had envisioned continuing my research by possibly building a digital product for female health and well-being to change the industry. Coming from a product design background myself, I felt like mobile applications possess the farthest reach in terms of user volume, have utilitarian value and are easy to use for most smartphone users. Upon reflection and consulting with my committee however, I was reminded of the endless mobile applications for women's health (that have been disappointing to say the least) I had researched over the last two years

and felt like I was only adding to the problem by walking down this path.

Though a precise outcome for the future of my research is unclear at this point, I have strategized a possible direction for continuing to develop it. First, I plan to live with my visualizations and update the data regularly as part of an autoethnographic exercise. During this time, I would like to make minor adjustments to the system in order to fix any glitches and make it easy to use for my next round of development. For the second round I would like to share the visualizations with a small group of users, have them live with them and reflect upon their experiences. The idea behind this exercise is to test if the concept of making biological data visualizations ambient is valid and adoptable in the long run.

In parallel to this research I have envision building a tool, toolkit or a workshop with the purpose of uplifting and empowering women to manage their physical, mental, emotional and social health and well-being. The essence of this outcome will lie in promoting body literacy as well as data literacy for female biological data. As part of this outcome I would like to create tools to enable women to imagine their daily routines and find hidden data parameters that matter to them. Thereafter I would aid them using their own mental models to categorize the parameters into groups of their choice, find possible sources for each of the parameters and eventually ideate on how they would imagine their visualizations looking and talking to them. Though I am still unclear on whether this possible outcome should be executed virtually or in the physical world, my hope in either of the two scenarios is that women learn to take better care of themselves and feel good about it.

We have one life. We want to self-optimize and milk the shit out of it.

- Paltrow, 2020

To conclude this iteration of my research, and in the hope for a better future for female health and well-being across the globe, I would like to state that the larger purpose of this thesis exploration has been about re-evaluating the significance what self-tracking. While the term is often associated with synonyms like self-transformation, self-modulation, self-measurement, self-enhancement, and self-regulation amongst others, I have begun to view self-tracking as self-

love, self-care, self-kindness and self-acceptance. I have been lucky to find ways to use my data to uplift and empower me, and I hope to create this opportunity for other individuals who want to take control of managing their health and well-being.

BIBLIOGRAPHY

Fitbit Alta HR. (n.d.). Retrieved from https://www.amazon.ca/Fitbit-Alta-Monitor-Black-Large/dp/B06XDLMTF9/ref=sr_1_5?gclid=CjwKCAiAzJLzBRAZEiwAmZb0at4_8JxiN5sLzyecU6DMAE2UH7CKEf7nowa82le2xoTjhY0cPZGNDhoCiVUQAvD_BwE&hvadid=324826255659&hvdev=c&hvlocphy=9061009&hvnetw=g&hvqmt=e&hvrand=134175359

Airbnb. (n.d.). Design. Retrieved from https://airbnb.design/

Alba, D. (2015). An App for Hacking Fertility Now Also Works for Men. Retrieved from Wired website: https://www.wired.com/2015/04/glow/

Amazon Pharmacy. (2020). Pillpack. Retrieved from https://www.pillpack.com/

Apple. (n.d.). *La Roche-Posay: My Skin Track UV Sensor*. Retrieved from https://www.apple.com/us-hed/shop/product/HML02ZM/A/la-roche-posay-my-skin-trackuv-%0Dsensor

Apple. (n.d.). Health. Retrieved from https://www.apple.com/ca/ios/health/

Apple. (n.d.). Use fall detection with Apple Watch. Retrieved from https://support.apple.com/en-ca/HT208944

Apple. (n.d.). Human Interface Guidelines. Retrieved from https://developer.apple.com/design/human-interface-guidelines/

Arthur, C. (2014). Wearables: one-third of consumers abandoning devices. Retrieved from The Guardian website: https://www.theguardian.com/technology/2014/apr/01/wearables-consumers-abandoning-devices-galaxy-gear

AVA: (n.d.). Ovulation Tracking Bracelet.

Basu, P. (2013). 済無No Title No Title. In *Journal of Chemical Information and Modeling* (Vol. 53). https://doi.org/10.1017/CBO9781107415324.004

Bondarenko, A. (n.d.). No Title. Retrieved from Behance website: https://www.behance.net/we_draw

Brown, S. (2010). *Tokyo Cyberpunk: Posthumanism in Japanese Visual Culture*. Palgrave Macmillan.

Cairo, A. (2013). *the functional art: an introduction to information graphics and visualization*. Berkeley, CA: New Riders.

Caitlyn Fuller, Lehman, E., Hicks, S., & Novick, M. B. (2017). Bedtime Use of Technology and Associated Sleep Problems in Children. *Glob Pediatr Health*. https://doi.org/10.1177/2333794X17736972

Canada, G. of. (n.d.). Canada's food guide. Retrieved from https://food-guide.canada.ca/en/

Carter, M., & C.Shieh, J. (2010). Chapter 4: Electrophysiology. Retrieved from Guide to Research Techniques in Neuroscience website: https://www.sciencedirect.com/topics/neuroscience/electrophysiology

CCS Insight. (n.d.). *OPTIMISTIC OUTLOOK FOR WEARABLES 260 Million Unit Sales in 2023*. Retrieved from https://www.ccsinsight.com/press/company-news/optimistic-outlook-for-wearables/

Central Illustration Agency. (n.d.). Work. Retrieved from

https://centralillustration.com/illustration/aitch#portfolio-9

Chamberlain, P., & Craig, C. (2017). HOSPITAbLe – critical design and the domestication of healthcare. *Proceedings of the 3rd Biennial Research Through Design Conference*, (March), 114–130. https://doi.org/10.6084/m9.figshare.4746952.Image

Chris Dancy. (2016). The Mindful Cyborg. Retrieved from https://www.chrisdancy.com/

CNBC. (2019). Apple CEO Tim Cook On China, Wall Street And Innovation.

Cocorrina, S. (n.d.). Work. Retrieved from https://cocorrina.com/

Coughlin, J. (2014). What Health and Finance Can Learn From the Quantified Self Movement and Each Other.

Cox, D. (2018). Watch your step: why the 10,000 daily goal is built on bad science. Retrieved from The Guardian website: https://www.theguardian.com/lifeandstyle/2018/sep/03/watch-your-step-why-the-10000-daily-goal-is-built-on-bad-science

Crawford, K., Lingel, J., & Karrpi, T. (2015). Our metrics, ourselves: A hundred years of self-tracking from the weight scale to the wrist wearable device. *European Journal of Cultural Studies*, *18(4-5)*, 479– 496.

Data Phys Wiki. (n.d.). Data Physicalization. Retrieved from http://dataphys.org/

Deloitte. (201AD). 2019 Global health care outlook Shaping the future. In *Design Issues* (Vol. 5). https://doi.org/10.1016/j.bios.2017.03.018

Dhruv R. Seshadri, Li, R. T., Voos, J. E., Rowbottom, J. R., Alfes, C. M., Zorman, C. A., & Drummond, C. K. (2019). Wearable sensors for monitoring the physiological and biochemical profile of the athlete. *Npj Digital Medicine*, *2*.

Dunne, A., & Raby, F. (2013). *Speculative Everything: Design, Fiction, and Social Dreaming*.

Dunne, L. E., Profita, H., Zeagler, C., Clawson, J., Gilliland, S., Do, E. Y. L., & Budd, J. (2014). The social comfort of wearable technology and gestural interaction. *2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBC 2014*, 4159–4162. https://doi.org/10.1109/EMBC.2014.6944540

Dunne, L. E., & Smyth, B. (2007). Psychophysical elements of wearability. *Conference on Human Factors in Computing Systems - Proceedings*, 299–302. https://doi.org/10.1145/1240624.1240674

EICA. (2018). Gestalt Principles for Information Design. Retrieved from https://eica.tech/gestalt-principles-for-information-design/

Empatica. (n.d.). Embrace Watch: Smarter Epilepsy Management. Retrieved from https://www.empatica.com/en-int/#

Epstein, D., Lee, N. B., Kang, J. H., Agapie, E., Schroeder, J., Pina, L., … Munson, S. A. (2017). Examining Menstrual Tracking to Inform the Design of Personal Informatics Tools. *CHI*. https://doi.org

Feenberg, A. (1999). Questioning Technology. *Routledge*.

Felton, N. (2014). Annual Report 2014. Retrieved from http://feltron.com/FAR14.html

Fitbit Inc. (n.d.). Fitbit. Retrieved from App Store website:

https://apps.apple.com/ca/app/fitbit/id462638897

Fitbit Inc. (n.d.). One Easy Health Solution for All Your Employees. Retrieved from https://healthsolutions.fitbit.com/

Fitbit Inc. (n.d.). Fitbit Alta HR. Retrieved from https://www.fitbit.com/gb/shop/altahr

FLO. (n.d.). Ovulation calendar, period tracker, and pregnancy app. Retrieved from https://flo.health

Foucault, M. (1988). *Technologies of the self: a seminar with Michel Foucault* (L. Martin, H. Gutman, & H. Patrick, Eds.).

Frick, L. (n.d.). Works. Retrieved from https://www.lauriefrick.com/works

Fung, B. (2020). Myant to Showcase Line-up of Heart Health Management Apparel and Textiles at CES 2020 to Democratize Access to Electrocardiography for All People Across Society. Retrieved from Myant website: https://myant.ca/myant-to-showcase-line-up-of-heart-health-management-apparel-and-textilesat-%0Dces-2020-to-democratize-access-to-electrocardiography-for-people-across-society/

Gardner, G. (2000). Hospital and home. Strange bed fellows of new partners? *Collegian*, *7*(1), 9–15.

Gartner. (2018). Gartner Says Worldwide Wearable Device Sales to Grow 26 Percent in 2019. In *Garnter*.

Gaver, B., Dunne, T., & Pacenti, E. (1999). Cultural Probes. Interactions..., (January + February), 21–29. https://doi.org/10.1016/B978-0-12-801851-4.00006-9

Goodboy. (n.d.). PixiJS: The HTML5 Creation Engine. Retrieved from https://www.pixijs.com/

Goodman, E., Kuniavsky, M., & Moed, A. (2012). Balancing Needs through Iterative Development. *Observing the User Experience*, 21–44. https://doi.org/0.1016/b978-0-12-384869-7.00003-6

Google. (2020). Material Design. Retrieved from https://material.io/design/

HAPIfork. (n.d.). Eat slowly, lose weight, feel great! Retrieved from https://www.hapilabs.com/product/hapifork

Haraway, D. (2014). A manifesto for cyborgs: Science, technology, and socialist feminism in the 1980s. *Feminist Social Thought: A Reader*, 502–531. https://doi.org/10.4324/9780203705841-39

HEALBE. (n.d.). *GoBe3*. Retrieved from https://healbe.com/eu/

Hermiyanty, Wandira Ayu Bertin, D. S. (2017). 済無No Title No Title. *Journal of Chemical Information and Modeling*, *8*(9), 1–58. https://doi.org/10.1017/CBO9781107415324.004

Insights, C. (n.d.). Carrot Rewards. Retrieved from https://en.wikipedia.org/wiki/Carrot_Rewards

Iyengar, B. (2002). *Light on the Yoga Sutras of Patanjali*. Thorsons.

James, A. (n.d.). No Title.

Johannessen, L. K. (2017). The Young Designer's Guide to Speculative and Critical Design. *X*, *x*(x), 1–10.

Knowledge@Wharton. (2016). Why Small Data Is the New Big Data. Retrieved from

https://knowledge.wharton.upenn.edu/article/small-data-new-big-data/

Krajacec, N. (2015). Circles of Life. Retrieved from flickr website: https://www.flickr.com/photos/131948743@N04/18166673610%0A

Kremer, K. (2017). Anticipative Interfaces for Emergency Situations. *Information+*. Retrieved from https://vimeo.com/180945245

Lanese, N. (2019). What Is Homeostasis? Retrieved from Livescience website: https://www.livescience.com/65938-homeostasis.html

Li, I., Dey, A., & Forlizzi, J. (2010). A stage-based model of personal informatics systems. *Conference on Human Factors in Computing Systems - Proceedings*, *1*, 557–566. https://doi.org/10.1145/1753326.1753409

Lindstrom, M. (2017). *Small Data: the tiny clues that uncover huge trends*. Picador.

Lupi, G. (n.d.). Data Humanism, The Revolution will be Visualized. Retrieved from giorgialupi.com website: http://giorgialupi.com/data-humanism-my-manifesto-for-a-new-data-wold

Lupton, D. (2016). You are Your Data: Self-Tracking Practices and Concepts of Data. *Lifelogging*, 61–79. https://doi.org/10.1007/978-3-658-13137-1_4

Mahdawi, A. (2014). The unhealthy side of wearable fitness devices. Retrieved from The Guardian website: https://www.theguardian.com/commentisfree/2014/jan/03/unhealthy-wearable-fitness-devices-calories-eating-disorders-nike-fuelband

McGrath, J. (2019). Lack of regulation means wearables aren't held accountable for health claims. Retrieved from Digital Trends website: https://www.digitaltrends.com/wearables/wearable-

devices-leading-to-over-diagnosis/

Meirelles, I. (2013). *Design for Information*. Rockport.

MomSense. (2019). The Smart Breastfeeding Monitor. Retrieved from https://mymomsense.com/

N. Katherine Hayles. (2001). How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics. *The Library Quarterly*, Vol. 71, pp. 292–293. https://doi.org/10.1086/603278

Orazi, D. C., & Nyilasy, G. (2019). Straight to the Heart Of Your Target Audience: Personalized Advertising Systems Based On Wearable Technology and Heart-Rate Variability. *Journal of Advertising Research*.

Paltrow, G., Doerr, N. D., Ellis, L., Fried, A., Loehnen, E., Lillegard, D., … Walsh, M. (2020). *The Goop Lab, Episode 1*.

Pivot Yoga. (n.d.). Pivot Yoga. Retrieved from https://pivot.yoga/

Proteus Digital Health. (n.d.). How it works. Retrieved from www.proteus.com/how-it-works

Qian, P., Siahaan, E., Wang, E., Stringer, C., Dean Rohrbach, M., Strongwater, D., & LeBlanc, J. (2017). *Patent No. US 10,149,041 B2*. Retrieved from https://pdfpiw.uspto.gov/.piw?PageNum=0&docid=10149041&IDKey=32DD29826078%0D%0A&

Quantified Self. (n.d.). What is the Quantified Self? Retrieved from https://quantifiedself.com/about/what-is-quantified-self/

Reddit. (n.d.). Fitbit Charge HR data while ice skating. Retrieved from https://www.reddit.com/r/fitbit/comments/2vb8p0/fitbit_charge_hr_data_while_ice_skating/

Rev, S. C. L. (2002). *Electronic copy available at : http://ssrn.com/abstract=984509 Electronic copy available at : http://ssrn.com/abstract=984509*. 211–248.

Richter, R. (2015). Among teens, sleep deprivation an epidemic. Retrieved from Stanford Medicine website: https://med.stanford.edu/news/all-news/2015/10/among-teens-sleep-deprivation-an-epidemic.html

Rogers, P. (2019). Biomechanics and Body Movement. Retrieved from Very Well Fit website: https://www.verywellfit.com/understanding-biomechanics-3498389

Rooksby, J., Rost, M., Morrison, A., & Chalmers, M. (2014). Personal Tracking as Lived Informatics. *CHI*.

Rose, D. (2014). *Enchanted Objects: Design, Human Desire, and the Internet of Things*. Retrieved from http://www.amazon.co.uk/Enchanted-Objects-Design-Desire-Internet/dp/1476725632

Santos, L. (n.d.). The Science of Well-Being.

Schüll, N. D. (2016). Data for life: Wearable technology and the design of self-care. *BioSocieties*, *11*(3), 317–333. https://doi.org/10.1057/biosoc.2015.47

Science Direct. (2014). Sensor Fusion. Retrieved from https://www.sciencedirect.com/topics/engineering/sensor-fusion

Shander, B. (2016). 4X4 Model for Knowledge Content. Retrieved from Medium website: https://medium.com/@billshander/4x4-model-for-knowledge-content-575cc7f24601

Shepko-Hamilton, R. S. (2019). *My Sister in Data: Visualizing an online relationship*. (April).

Singer, N. (2015). Technology That Prods You to Take Action, Not Just Collect Data. Retrieved from The New York Times website: https://www.nytimes.com/2015/04/19/technology/technology-that-prods-you-to-take-action-not-just-collect-data.html

Stolterman, E., Tenenberg, J., & Lim, Y. (2008). The Anatomy of Prototypes: Prototypes as Filters, Prototypes as Manifestations of Design Ideas. *ACM Transactions on Computer_Human Interaction*, *15*(2). https://doi.org/10.1145/1375761.1375762

Strautniekas, K. (2017). Looking back '16. Retrieved from Behance website: https://www.behance.net/strautniekas

Swan, M. (2013). The quantified self: Fundamental disruption in big data science and biological discovery. *Big Data*, Vol. 1, pp. 85–99. https://doi.org/10.1089/big.2012.0002

Swan, M. (2012). Health 2050: The realization of personalized medicine through crowdsourcing, the quantified self, and the participatory bio citizen. *Journal of Personalized Medicine*, *2*(3), 93–118. https://doi.org/10.3390/jpm2030093

Tharp, B., & Tharp, S. (2013). Discursive design basics: Mode and audience. *Nordic Design Research Conference*.

Unknown. (n.d.). *None*. Retrieved from https://i.pinimg.com/originals/4f/80/9f/4f809fd55881b9a93281ad6bdbae30d3.png

Wang, J., O'Kane, A. A., Newhouse, N., Sethu-Jones, G. R., & De Barbaro, K. (2017). Quantified baby: Parenting and the use of a baby wearable in the wild. *Proceedings of the ACM on Human-Computer Interaction*, *1*(CSCW), 1–19. https://doi.org/10.1145/3134743

Webb, A. (2019). Tech Trends Report. *Future Today Institute*.

WELT. (n.d.). *Smart Belt*. Retrieved from https://www.weltcorp.com/

Winter, R. (2009). The History of Physicians / Doctors. Retrieved from Soliant website: https://blog.soliant.com/careers-in-healthcare/the-history-of-physicians-doctors/

Withme. (n.d.). *Baby Monitor*. Retrieved from https://www.getinterwoven.com/our-work/withme-baby-monitor/

Wolf, G. (2009). Know thyself: Tracking every facet of life, from sleep to mood to pain, 24/7/365. Retrieved from Wired website: http://archive.wired.com/medtech/health/magazine/17-07/lbnp_%0Dknowthyself

Wolf, G. (2010). The Data-Driven Life. Retrieved from The New York Times website: https://www.nytimes.com/2010/05/02/magazine/02self-measurement-t.html

Zeagler, C. (2017). Where to wear it: Functional, technical, and social considerations in on-body location for wearable technology 20 years of designing for wearability. *Proceedings - International Symposium on Wearable Computers, ISWC*, *Part F1305*, 150–157. https://doi.org/10.1145/3123021.3123042

APPENDICES

APPENDIX A: LIVED DATA SHEET

Reading Name	Old Method	New Method	Sensor/s	Reading info (Range etc.)	Lived data points
Activity	Intensity, Perspiration,	Tracking Movement	Gyroscope, Accelerometer, Heart sensors,	Activity Type, Intensity, Time of activity, Duration, Sedentary time	Sports, Other forms of Fitness - Activities oriented towards increasing the heart rate but with different kids of movement are not tracked accurately. But also Yoga, Tai Chi and other such activities aimed at other heart health factors. What about adventure sports? What about other forms of recreational activities? What about when we are active on holiday or the opposite? What about sexual activity? How tired is the person? How does their sleep quality affect their activity? What is their emotional state? How does that affect their performance? Do they have a workout buddy? What if someone is skating/figure skating? What acitivities cannot be detected? How is the walking surface affecting reading? Can exercise trigger stress/ How do you sleep if you exercise before bed? How tired is the person? How does their sleep quality affect their activity? What is their emotional state? How does that affect their performance? Do they have a workout buddy? What if someone is skating/figure skating? What acitivities cannot be detected? How is the walking surface affecting reading? Can exercise trigger stress/ How do you sleep if you exercise before bed?Cannot detect skating or gliding, cannot detect treadmill incline or stairmaster, cannot detect soft steps, and steps on soft materials.
Steps	Percieved distance, time taken to travel, fatigue	Steps calculated	Pedometer + Altimeter (For height)	No of Steps, Time steps were taken, heart rate during the time	Walking, Running, Cycling? Strolling? Duration? Walking speed not factored. What about stationery activity? What about walking with a friend? Walking your dog? Walking on holiday? How does walking affect our state of mind or emotional well-being.Feeling better walking with people v/s walking alone. Also the motivation for walking - walking for exercise v/s walking as a mode of travel.
Commuting	Time of travel, mode of travel, Memory	Google Maps/ Map based tracking apps	Accelerometer + GPS	Distance, Time, Mode, Destination, Source	Most frequented places. What is our state of mind based on the place we are at? E.g. doctor's clinic v/s a movie theatre. Motivation to travel. Events occuring during the commute affect our well-being, like seeing an accident or an altercation. Weather conditions during travel, pollution and allergens as well. Bumping into friends or acquanitances and travelling together might make us feel better. How do we keep busy while we travel? Do we make memories when we travel?
Sleep	Alarm Clock, Sun	Sleep App, Device	Piezo force, Humidity, Temperature, Capacitive touch, Heart Rate, HRV, Pulse Oximetry,	Sleep Patterns, Sleep Time, Time to fall asleep, Time awake in bed, Sleep Phases (restless, deep sleep, REM, light sleep), Weather affect, Mood Affect, Snoring, Napping	Interruptions, Nightmares, Sleep Aids, Caffeince and alcohol consumption Sleeping next to someone v/s alone? How does stress affect sleep?How does weather affect sleep? Dream Diary? How hectic was the wearers day? How much the wearer have to do the next day? Did the wearer travel? Nap v/s sleep? Healthy v/s unhealthy naps?
Food	Diary/Journal	Camera, Manual Input	Bioimpedence Sensor	Calories, Nutrition, BMI, Food groups, Frequency, Allergies, Weight, Basal Metabolic Rate	Quality or Experience of the meal ?Alcohol? Meal timing? Nature of meal? Caffeine? Eating with friends? Celebrating? Preferences? Dietary restrictions? Meal patterns? What is our relationship with food? Stress-eating? Eating before bed? Midnight snacks? Binge eating? Sugar craving? Snacking with TV > Corelated to media consumption?
Alcohol Consumption	Light-headedness?	Breathalyzer	Fuel Cell Sensor	Blood Alcohol Content	Volume of Alcohol? Nature of Alcohol (mixing)? Acitivities during / before / after consumption? How does alcohol affect your mood?State on mind? How might a hangover affect your physical and mental well-being.
Caffeine	Heart Rate/ENERGY	Manual Input	Nil	Time of consumption, Volume of Consumption,Frquency, Type of beverage	Effect on Heart Rate, Blood Pressure, Productivty, Duration of effect. How does the caffeine affect the drinker long term? What could be its benefits? Can we measure how it stimulates the mind? Its effects change from person to person

Reading Name	Old Method	New Method	Sensor/s	Reading info (Range etc.)	Lived data points
Water Intake	Mental notes	Connected Water Bottle/ Manual Input	Gyroscope, Proximity Sensor inside bottle	Sips Taken/ Glasses consumed Frequency, Daily goal requirement,	Long term benefits of regular water consumption? Bowel movement? Dry throat? Water consumption through other beverages ro foods? Weather? Activity? Female considerations, Nearby restrooms?
Weight	Weighing Scale, in a medical environment	Connected Weighing Scale	Load Cell	Weight, Body Composition - (Fat, Bone and Muscle Content)	HOW DOES KNOWING YOUR WEIGHT MAKE YOU FEEL?How does Stress/Anxiety/Depression or any form of emotional distress affect your weight. Muscle weight is heavier than fat weight. For people who want to lost weight, what about measurements? Manual measuring but also what are the setbacks of each. What are benchmarks based off? What is weight across different genders, body types? Heriditary patterns? Why must this be done daily? Why do smart scales recommend daily measurement? Female Considerations (Water Retention, Pregnant, Ovulating, Travel, Occasion) What are the negative effects of continuous weight monitoring? Consitpation? Diarrhoea/? Illness?
Menstruation	Bleeding into clothing, missed periods, mental notes, journals, pregnancy bulge	Birth Control Medication,Tracking applications, Ovulation bands	Manual Input for most trackers	Calendar, Symptoms, Mood, Disharge, Sexual Activity, Basal Body Temperature, HRV, Resting Pulse Rate, Respiratory Rate, WST	Symptoms outside the typical, emotional changes? Hormonal changes and their affects? How do we want our loved ones to behave if we are going through the PMS and ovulation? How do you contextualize these physiological changes across lifestages? What about other stages in the menstrual cycle? How do hormonal changes affect other aspects of our life? How do we better plan around our period? SCHEDULING. How do we better prepare for our period? Forums, Communities, What is normal? Mother daughter relationships? Birth Control? Sensitivity PCOD? Sexuality? Co-logging couples? How should physical activity be controlled during menstruation? Cultural Stigma, JUDGEMENTS, Sensitivity towards those with fertility issues? Privacy concerns, discretion. tracking beyond pregnancy.
Heart Health	Stethescope	Wearables with infrared, phone flashlight apps	Pulse Oximetry, HRV, RHR, PPG, ECG	Trends, Sinus Rhythm, Afib, Pulse Rate, Calories, RHR, Stress	How does skin colour affect the accuracy of readings?(Fitzpatrick Skin scale).How do readings differ between genders? ages? Do heart rate readings induce further anxiety or help it subside? What if we mistake gas for heart pain? What about when our heart rate rises for stress v/s excitement? adrenalin v/s cortisol v/s endorphins. Hwo does heart rate change depending on the LIVED Activity? Establishing individual baselines? Linking heart rate ot productivty and stress levels?
Environment/ Weather	TV Channel/Radio	iPhone Apps	Insight provided by local departments?	Temperature, Humidity, Chance of Precipitation, Kind of Precipitation, POLLUTION, POLLEN / ALLERGENS	How does the weather affect mood/state of mind? Behaviour? How does it affect activity levels? How does it affect productivity? How does air quality/pollution affect all of the above? How might people with conditions be further affected by weather patterns? How might we use this as an opportunity to get more attention from our loved ones? How might we modify our environment to reduce the adverse affects the weather might have on our mood?
UVA / UVB Exposure	Skin Sensation/Heat	iPhone App, Device		UV Index, UV Exposure - duration and intensity, (A and B), Vitamin D levels	How do we know when to avoid the sun? How do we know how much time we're allowed to be in the sun for? Can we pre-empt our exposure based on our schedule for the day? How is skin type bias affecting these readings? How to best look after/protect my skin? What about those with various skin coditions? What about various reasons for skin tracking? Beauty yes, but health? Cancer patients? Special cases. Geographical location. how does it know when we are indoors/outdoors?
Body Temperature	Hand on neck/forehead underarms	Thermometer (Ear, Forehead, Underarm)	Thermometer	Degree, Range, Long term range, Abnormalities	How does temprature measurement evolve with age? Life stage? Temperature monitoring for children and infants is more frequent and intensive? What about temperature changes during menstruation and ovulation?? Can we gain insight into those phases, and pre-empt them? What is the cause of the temperture spike? Medicines or hormones or other causes? Fatigue? Exertion? Alcohol use? Underlying conditions? (Diabetes or thyroid) HOw does activity affect body temperature? How does the environment affect body temperate? How does sleep affect body temperature?Do certain foods affect body temperature? How do we know when we are about to fall sick? How do we know when we need rest?

APPENDIX B: FITBIT DATA LOG

Sleep Data, July 17 – December 9, 2019

Sleep (reverse)

Start Time	End Time	Minutes Asleep	Minutes Awake	Number of Awakening	Time in Bed	Minutes REM Sleep	Minutes Light Sleep	Minutes Deep Sleep
2019-12-09 10:23PM	2019-12-10 7:35AM	488	63	29	551	108	307	73
2019-12-09 12:00AM	2019-12-09 8:56AM	448	88	29	536	101	281	66
2019-12-08 8:46AM	2019-12-08 12:50PM	216	28	15	244	28	154	34
2019-12-08 2:29AM	2019-12-08 5:50AM	175	26	14	201	23	109	43
2019-12-07 2:57AM	2019-12-07 9:23AM	340	45	19	385	55	242	43
2019-12-06 1:04AM	2019-12-06 7:56AM	356	55	20	411	80	214	62
2019-12-05 12:31AM	2019-12-05 7:56AM	404	41	26	445	99	238	67
2019-12-04 1:28AM	2019-12-04 9:29AM	415	66	22	481	68	285	62
2019-12-03 1:50AM	2019-12-03 8:49AM	373	46	20	419	112	191	70
2019-12-02 1:58AM	2019-12-02 9:59AM	424	57	26	481	125	258	41
2019-12-01 12:24PM	2019-12-01 1:25PM	55	6	0	61	N/A	N/A	N/A
2019-12-01 3:22AM	2019-12-01 11:14AM	395	77	30	472	96	217	82
2019-11-30 12:28AM	2019-11-30 11:13AM	557	88	32	645	154	315	88
2019-11-29 2:24AM	2019-11-29 8:10AM	294	51	13	345	79	175	40
2019-11-28 1:26AM	2019-11-28 10:53AM	513	54	34	567	181	261	71
2019-11-27 2:18AM	2019-11-27 9:20AM	361	61	21	422	92	223	46
2019-11-26 2:33AM	2019-11-26 11:48AM	484	70	24	554	142	264	78
2019-11-25 12:02AM	2019-11-25 9:49AM	497	90	29	587	95	297	105
2019-11-24 3:14AM	2019-11-24 11:18AM	439	45	24	484	133	237	69
2019-11-23 2:24AM	2019-11-23 9:39AM	374	61	15	435	99	215	60
2019-11-22 1:59AM	2019-11-22 8:58AM	366	53	19	419	88	205	73
2019-11-21 1:24AM	2019-11-21 9:19AM	407	68	25	475	114	216	77
2019-11-20 1:46AM	2019-11-20 10:58AM	474	78	22	552	102	287	85
2019-11-19 1:14AM	2019-11-19 8:46AM	390	61	24	451	88	235	67
2019-11-18 1:07AM	2019-11-18 9:20AM	419	73	23	492	113	224	82
2019-11-17 2:56AM	2019-11-17 10:02AM	367	58	22	425	61	288	18
2019-11-16 1:33AM	2019-11-16 10:29AM	462	73	32	535	95	272	95
2019-11-15 1:54AM	2019-11-15 8:49AM	364	51	21	415	67	234	63
2019-11-14 3:08AM	2019-11-14 11:37AM	449	60	26	509	117	263	69
2019-11-13 11:26PM	2019-11-14 1:10AM	92	3	2	104	N/A	N/A	N/A
2019-11-13 1:55AM	2019-11-13 9:45AM	415	55	17	470	115	192	108
2019-11-12 1:05AM	2019-11-12 8:58AM	399	74	17	473	111	209	79
2019-11-11 12:46AM	2019-11-11 9:59AM	485	67	26	552	106	289	90
2019-11-10 2:06AM	2019-11-10 9:55AM	407	62	18	469	109	200	98
2019-11-09 1:11AM	2019-11-09 11:30AM	528	91	24	619	153	254	121
2019-11-08 2:19AM	2019-11-08 8:43AM	350	34	18	384	84	182	84
2019-11-07 10:03AM	2019-11-07 11:09AM	63	2	0	65	N/A	N/A	N/A
2019-11-07 1:10AM	2019-11-07 8:28AM	370	68	19	438	67	223	80
2019-11-05 7:34PM	2019-11-05 11:39PM	240	4	1	245	N/A	N/A	N/A
2019-11-05 12:56AM	2019-11-05 9:25AM	439	69	16	508	131	216	92
2019-11-04 12:35AM	2019-11-04 9:36AM	468	72	27	540	86	317	65
2019-11-03 12:31AM	2019-11-03 8:42AM	389	102	22	491	101	223	65
2019-11-01 11:43PM	2019-11-02 9:43AM	499	101	34	600	135	289	75
2019-11-01 2:07AM	2019-11-01 10:28AM	437	64	21	501	113	246	78
2019-10-31 12:50AM	2019-10-31 8:17AM	388	59	20	447	82	212	94
2019-10-30 12:36AM	2019-10-30 8:21AM	371	94	15	465	80	222	69
2019-10-28 10:24PM	2019-10-29 9:52AM	578	110	31	688	150	319	109
2019-10-28 12:48AM	2019-10-28 9:36AM	448	80	23	528	112	253	83
2019-10-24 12:28AM	2019-10-24 10:04AM	554	21	0	575	N/A	N/A	N/A
2019-10-23 12:37AM	2019-10-23 8:10AM	389	63	19	452	93	213	83
2019-10-22 1:50AM	2019-10-22 8:21AM	352	38	10	390	100	197	55
2019-10-21 1:58AM	2019-10-21 10:08AM	407	83	21	490	110	224	73
2019-10-20 2:36AM	2019-10-20 9:37AM	359	62	19	421	101	224	34
2019-10-19 3:20AM	2019-10-19 11:01AM	422	39	17	461	136	203	83
2019-10-18 12:31AM	2019-10-18 9:14AM	466	56	28	522	122	250	94
2019-10-17 11:41AM	2019-10-17 1:48PM	120	7	0	127	N/A	N/A	N/A
2019-10-17 12:38AM	2019-10-17 5:50AM	290	22	18	312	85	158	47
2019-10-16 1:21AM	2019-10-16 8:14AM	380	33	17	413	80	220	80
2019-10-14 12:58AM	2019-10-14 10:18AM	457	103	14	560	60	313	84
2019-10-12 1:59AM	2019-10-12 10:55AM	484	52	21	536	139	261	84
2019-10-11 12:39AM	2019-10-11 9:52AM	477	76	18	553	127	293	57
2019-10-10 12:41AM	2019-10-10 10:16AM	492	83	24	575	107	282	103
2019-10-08 1:23AM	2019-10-08 9:47AM	431	72	20	503	106	240	85
2019-10-06 10:58PM	2019-10-07 9:00AM	516	86	31	602	76	360	80
2019-10-06 4:07AM	2019-10-06 12:15PM	425	63	18	488	112	263	50
2019-10-05 2:56AM	2019-10-05 7:52AM	278	18	10	296	45	205	28
2019-10-04 12:18AM	2019-10-04 9:29AM	463	88	26	551	97	251	115
2019-10-03 12:18AM	2019-10-03 7:27AM	392	37	20	429	81	261	50
2019-10-02 1:55AM	2019-10-02 11:34AM	485	94	28	579	115	261	109
2019-10-01 1:55AM	2019-10-01 8:15AM	326	54	13	380	97	158	71
2019-09-30 12:01AM	2019-09-30 8:21AM	446	54	29	500	125	273	48
2019-09-29 2:02AM	2019-09-29 11:13AM	483	68	19	551	131	263	89
2019-09-28 2:04AM	2019-09-28 11:01AM	451	86	22	537	141	232	78
2019-09-27 1:24AM	2019-09-27 10:35AM	482	68	25	550	131	264	87
2019-09-25 11:41PM	2019-09-26 9:32AM	506	85	39	591	76	365	65
2019-09-24 11:56PM	2019-09-25 7:43AM	427	40	30	467	125	226	76
2019-09-23 11:37PM	2019-09-24 6:54AM	364	72	18	436	73	202	89
2019-09-22 11:07PM	2019-09-23 8:05AM	437	101	18	538	112	266	59
2019-09-21 2:50AM	2019-09-21 11:13AM	441	62	23	503	114	210	117
2019-09-20 12:10AM	2019-09-20 9:00AM	477	53	21	530	98	289	90

2019-09-19 12:52AM	2019-09-19 10:07AM	498	56	29	554	109	316	73
2019-09-18 1:07AM	2019-09-18 10:17AM	498	52	31	550	123	290	85
2019-09-17 12:12AM	2019-09-17 8:16AM	438	45	19	483	130	209	99
2019-09-16 1:11AM	2019-09-16 6:55AM	299	45	14	344	54	218	27
2019-09-15 1:08AM	2019-09-15 11:17AM	551	58	36	609	136	327	88
2019-09-14 12:35AM	2019-09-14 11:02AM	507	120	27	627	125	290	92
2019-09-13 2:01AM	2019-09-13 9:25AM	403	41	18	444	105	210	88
2019-09-13 2:01AM	2019-09-13 9:25AM	403	41	18	444	105	210	88
2019-09-11 11:41PM	2019-09-12 9:59AM	545	73	33	618	167	269	109
2019-09-10 11:33PM	2019-09-11 9:18AM	529	56	29	585	137	305	87
2019-09-09 11:58PM	2019-09-10 7:59AM	426	55	17	481	118	245	63
2019-09-08 10:53PM	2019-09-09 9:27AM	562	71	30	633	169	260	133
2019-09-08 2:12AM	2019-09-08 11:11AM	462	76	22	538	115	279	68
2019-09-07 3:33AM	2019-09-07 10:15AM	359	43	14	402	80	207	72
2019-09-05 11:04PM	2019-09-06 8:29AM	549	16	2	565	N/A	N/A	N/A
2019-09-04 11:38PM	2019-09-05 7:25AM	424	43	17	467	115	234	75
2019-09-03 9:47PM	2019-09-04 7:49AM	539	63	26	602	155	248	136
2019-09-02 10:13PM	2019-09-03 8:09AM	558	38	2	596	N/A	N/A	N/A
2019-09-02 5:00AM	2019-09-02 2:25PM	496	69	36	565	84	321	91
2019-09-01 1:32AM	2019-09-01 10:38AM	482	64	37	546	109	296	77
2019-08-31 12:37AM	2019-08-31 9:41AM	473	71	29	544	137	263	73
2019-08-30 12:09AM	2019-08-30 10:09AM	483	117	24	600	79	384	20
2019-08-29 12:50AM	2019-08-29 9:08AM	445	53	27	498	146	209	90
2019-08-27 12:02AM	2019-08-27 10:14AM	524	88	37	612	91	350	83
2019-08-26 12:14AM	2019-08-26 4:25AM	233	18	0	251	N/A	N/A	N/A
2019-08-24 11:51PM	2019-08-25 5:47AM	303	52	20	355	65	196	42
2019-08-24 2:06AM	2019-08-24 10:40AM	457	57	27	514	150	200	107
2019-08-23 12:29AM	2019-08-23 11:03AM	536	98	29	634	126	306	104
2019-08-21 10:55PM	2019-08-22 11:20AM	652	92	43	744	197	394	61
2019-08-20 10:02PM	2019-08-21 9:03AM	580	81	32	661	137	362	81
2019-08-20 12:52AM	2019-08-20 2:46AM	113	0	0	113	N/A	N/A	N/A
2019-08-18 10:49PM	2019-08-19 10:04AM	601	74	32	675	214	286	101
2019-08-18 12:43AM	2019-08-18 10:20AM	474	103	30	577	126	282	66
2019-08-17 12:47AM	2019-08-17 9:40AM	463	70	26	533	132	262	69
2019-08-16 12:31AM	2019-08-16 9:24AM	464	69	30	533	140	237	87
2019-08-15 12:26AM	2019-08-15 10:13AM	499	87	35	586	104	303	92
2019-08-13 11:58PM	2019-08-14 8:42AM	456	68	27	524	105	276	75
2019-08-13 11:58PM	2019-08-14 8:42AM	456	68	27	524	105	276	75
2019-08-12 11:02PM	2019-08-13 8:44AM	512	70	27	582	117	319	76
2019-08-12 3:15AM	2019-08-12 10:58AM	391	72	29	463	54	287	50
2019-08-11 11:26PM	2019-08-12 12:40AM	56	18	0	74	N/A	N/A	N/A
2019-08-11 1:49AM	2019-08-11 11:30AM	519	62	25	581	157	296	66
2019-08-10 2:18AM	2019-08-10 11:19AM	457	84	24	541	117	241	99
2019-08-09 12:42AM	2019-08-09 8:57AM	432	62	26	494	98	269	65
2019-08-08 3:19AM	2019-08-08 12:47PM	466	101	23	567	104	283	79
2019-08-06 11:59PM	2019-08-07 9:10AM	460	91	22	551	117	209	134
2019-08-05 12:26AM	2019-08-05 9:19AM	509	23	1	532	N/A	N/A	N/A
2019-08-04 12:02AM	2019-08-04 10:47AM	511	134	29	645	108	311	92
2019-08-03 12:19AM	2019-08-03 9:20AM	518	23	0	541	N/A	N/A	N/A
2019-08-01 11:34PM	2019-08-02 5:30AM	332	24	0	356	N/A	N/A	N/A
2019-08-01 12:40AM	2019-08-01 8:54AM	424	70	18	494	128	203	93
2019-07-31 1:04AM	2019-07-31 9:40AM	491	24	1	515	N/A	N/A	N/A
2019-07-29 10:19PM	2019-07-30 8:55AM	588	48	3	636	N/A	N/A	N/A
2019-07-29 12:58AM	2019-07-29 10:33AM	501	74	31	575	138	272	91
2019-07-25 11:10PM	2019-07-26 8:49AM	514	65	33	579	134	262	118
2019-07-24 11:29PM	2019-07-25 8:36AM	467	80	27	547	81	337	49
2019-07-24 12:39AM	2019-07-24 9:23AM	462	62	17	524	92	299	71
2019-07-23 3:40AM	2019-07-23 7:32AM	231	0	0	231	N/A	N/A	N/A
2019-07-22 11:29PM	2019-07-23 1:25AM	102	14	0	116	N/A	N/A	N/A
2019-07-21 1:56AM	2019-07-21 9:46AM	429	41	24	470	144	206	79
2019-07-20 1:17AM	2019-07-20 9:11AM	414	60	19	474	132	238	44
2019-07-18 11:57PM	2019-07-19 9:40AM	473	110	26	583	121	283	69
2019-07-18 1:48PM	2019-07-18 2:58PM	67	3	0	70	N/A	N/A	N/A
2019-07-17 9:40PM	2019-07-18 7:09AM	497	71	28	568	127	312	58

Activity Data, July 17 – December 9, 2019

Activities

Date	Calories Burned	Steps	Distance	Floors	Minutes Sedentary	Minutes Lightly Active	Minutes Fairly Active	Minutes Very Active	Activity Calories
2019-07-15	1,415	0	0	0	1,440	0	0	0	0
2019-07-16	1,415	0	0	0	1,440	0	0	0	0
2019-07-17	1,432	90	0.07	0	1,433	7	0	0	17
2019-07-18	1,923	5,080	3.69	0	610	179	4	6	630
2019-07-19	1,662	2,787	2.03	0	759	98	0	0	309
2019-07-20	1,870	4,582	3.33	0	809	157	0	0	535
2019-07-21	1,601	1,122	0.82	0	899	71	0	0	203
2019-07-22	1,698	3,332	2.42	0	1,303	107	0	0	353
2019-07-23	1,876	5,464	4.05	0	970	154	0	0	537
2019-07-24	1,866	2,825	2.05	0	697	188	0	0	551
2019-07-25	1,833	2,502	1.82	0	689	154	0	0	483
2019-07-26	2,064	6,064	4.41	0	639	202	17	3	759
2019-07-27	1,857	3,839	2.79	0	1,316	67	41	16	545
2019-07-28	1,428	146	0.11	0	1,435	5	0	0	15
2019-07-29	1,544	572	0.42	0	709	55	0	0	148
2019-07-30	1,981	7,727	5.74	0	87	155	18	9	681
2019-07-31	1,865	5,530	4.11	0	270	107	12	21	522
2019-08-01	2,218	10,514	7.89	0	662	213	27	18	977
2019-08-02	1,821	5,978	4.39	0	603	130	15	6	522
2019-08-03	1,752	4,483	3.3	0	239	108	7	4	413
2019-08-04	1,573	626	0.46	0	737	58	0	0	156
2019-08-05	1,534	559	0.41	0	328	48	0	0	124
2019-08-06	1,509	690	0.5	0	1,398	42	0	0	113
2019-08-07	2,576	12,929	9.4	0	540	237	67	45	1,444
2019-08-08	1,703	1,476	1.07	0	765	108	0	0	312
2019-08-09	1,709	3,306	2.4	0	832	114	0	0	353
2019-08-10	1,788	3,512	2.55	0	784	105	7	3	420
2019-08-11	2,593	9,997	7.37	0	478	277	41	30	1,448
2019-08-12	1,776	977	0.71	0	803	53	0	23	357
2019-08-13	2,032	10,015	7.28	0	681	110	43	22	731
2019-08-14	2,115	7,244	5.27	0	694	167	43	12	847
2019-08-14	2,115	7,244	5.27	0	694	167	43	12	847
2019-08-15	1,898	2,531	1.84	0	716	108	0	30	556
2019-08-16	2,202	12,497	9.34	0	695	135	30	47	935
2019-08-17	2,513	17,793	12.98	0	565	258	58	26	1,382
2019-08-18	1,826	3,101	2.25	0	628	164	0	0	495
2019-08-19	1,918	3,378	2.51	0	637	90	3	35	584
2019-08-20	2,123	10,561	7.68	0	990	170	22	27	862
2019-08-21	2,185	12,475	9.07	0	484	174	38	19	929
2019-08-22	1,953	7,305	5.43	0	522	155	8	11	634
2019-08-23	1,989	6,892	5.01	0	630	147	28	1	641
2019-08-24	2,490	17,821	12.96	0	579	267	70	2	1,328
2019-08-25	2,040	8,623	6.27	0	871	193	17	4	762
2019-08-26	2,205	14,029	10.2	0	966	155	52	16	959
2019-08-27	2,165	10,841	7.88	0	583	231	11	3	909
2019-08-28	2,127	11,947	8.73	0	1,237	175	17	11	849
2019-08-29	2,367	14,160	10.29	0	639	246	32	25	1,167
2019-08-30	2,155	12,706	9.24	0	615	188	23	14	907
2019-08-31	1,925	6,594	4.79	0	721	151	9	15	605
2019-09-01	1,793	4,743	3.49	0	764	130	0	0	452
2019-09-02	1,737	2,789	2.02	0	640	128	0	0	401
2019-09-03	1,884	5,695	4.31	0	643	163	4	9	578
2019-09-04	1,709	3,166	2.34	0	703	113	0	0	351
2019-09-05	1,869	5,641	4.1	0	775	131	7	5	534
2019-09-06	2,039	8,757	6.49	0	701	230	0	0	798
2019-09-07	2,320	13,105	9.95	0	761	201	58	18	1,092
2019-09-08	1,678	2,126	1.55	0	715	121	0	0	333
2019-09-09	1,688	2,610	1.9	0	711	95	0	0	320
2019-09-10	2,074	9,791	7.45	0	727	181	7	18	803
2019-09-11	1,912	5,962	4.38	0	691	133	4	8	585
2019-09-12	1,735	3,026	2.24	0	702	120	0	0	369
2019-09-13	1,840	5,216	3.79	0	854	124	16	2	515
2019-09-14	1,618	1,298	0.94	0	737	76	0	0	220
2019-09-15	1,791	1,434	1.04	0	734	75	1	21	425
2019-09-16	2,067	9,167	6.85	0	879	172	26	19	806
2019-09-17	2,124	6,281	4.78	0	715	242	0	0	825
2019-09-18	1,832	4,631	3.45	0	739	144	4	3	495
2019-09-19	1,809	4,941	3.8	0	759	117	2	8	477
2019-09-20	1,960	6,191	4.54	0	699	200	4	7	674
2019-09-21	1,936	4,437	3.23	0	745	160	23	9	638
2019-09-22	1,878	5,804	4.22	0	1,276	151	5	8	562
2019-09-23	1,920	6,484	5.22	0	705	165	2	8	624
2019-09-24	2,058	5,806	4.22	0	735	266	0	0	806
2019-09-25	1,916	7,395	5.62	0	800	127	8	19	596

2019-09-26	1,765	3,638	2.77	0	720	129	0	0	423
2019-09-27	2,059	5,741	4.47	0	655	224	2	9	816
2019-09-28	1,790	2,160	1.57	0	759	144	0	0	426
2019-09-29	1,630	1,472	1.07	0	808	81	0	0	237
2019-09-30	1,867	6,585	5.29	0	805	135	0	0	547
2019-10-01	1,927	6,151	4.72	0	858	202	0	0	657
2019-10-02	1,547	714	0.52	0	811	50	0	0	131
2019-10-03	1,967	7,642	6.1	0	827	164	6	14	683
2019-10-04	1,917	4,637	3.37	0	688	201	0	0	644
2019-10-05	1,962	4,278	3.11	0	954	172	15	3	665
2019-10-06	2,213	10,970	7.98	0	628	207	47	8	998
2019-10-07	1,849	5,526	4.02	0	702	106	12	18	512
2019-10-08	1,779	2,623	1.91	0	787	150	0	0	440
2019-10-09	1,867	6,187	4.54	0	1,301	125	4	10	536
2019-10-10	1,534	435	0.32	0	830	35	0	0	103
2019-10-11	2,154	7,833	5.78	0	649	225	9	4	883
2019-10-12	1,611	2,098	1.57	0	837	67	0	0	227
2019-10-13	1,703	1,871	1.36	0	1,319	121	0	0	362
2019-10-14	1,713	1,988	1.45	0	757	123	0	0	348
2019-10-15	1,742	3,417	2.53	0	1,316	124	0	0	416
2019-10-16	1,983	8,318	6.52	0	847	170	2	8	693
2019-10-17	1,947	5,583	4.06	0	815	176	10	0	642
2019-10-18	1,645	2,291	1.67	0	833	85	0	0	268
2019-10-19	1,849	4,515	3.36	0	820	149	3	7	532
2019-10-20	1,641	2,130	1.63	0	938	72	3	6	257
2019-10-21	1,767	3,858	2.8	0	820	130	0	0	426
2019-10-22	1,920	5,407	3.93	0	852	198	0	0	637
2019-10-23	1,866	5,395	4.05	0	835	142	2	9	533
2019-10-24	1,506	331	0.24	0	833	32	0	0	82
2019-10-25	1,415	0	0	0	1,440	0	0	0	0
2019-10-26	1,415	0	0	0	1,440	0	0	0	0
2019-10-27	1,461	173	0.13	0	1,423	17	0	0	51
2019-10-28	1,923	5,725	4.16	0	630	164	14	8	646
2019-10-29	1,857	5,996	4.36	0	602	150	0	0	543
2019-10-30	1,928	4,550	3.56	0	799	163	5	8	604
2019-10-31	2,074	8,359	6.24	0	777	185	17	14	799
2019-11-01	1,566	641	0.47	0	869	53	0	0	145
2019-11-02	1,785	3,309	2.53	0	717	123	0	0	425
2019-11-03	1,841	2,696	2.05	0	816	133	0	0	428
2019-11-04	2,018	6,603	4.8	0	710	167	14	9	705
2019-11-05	1,943	6,375	4.72	0	505	172	5	5	661
2019-11-06	1,850	6,062	4.45	0	1,300	130	2	8	529
2019-11-07	1,706	2,415	1.76	0	835	102	0	0	323
2019-11-08	1,840	3,428	2.49	0	888	168	0	0	505
2019-11-09	1,800	2,982	2.17	0	686	124	11	0	449
2019-11-10	1,955	4,678	3.44	0	782	171	6	12	649
2019-11-11	1,782	4,578	3.33	0	760	128	0	0	450
2019-11-12	1,780	3,651	2.65	0	838	129	0	0	426
2019-11-13	1,887	5,056	3.68	0	775	152	9	0	558
2019-11-14	1,681	1,702	1.24	0	758	103	0	0	313
2019-11-15	1,620	1,711	1.24	0	943	82	0	0	239
2019-11-16	1,720	3,005	2.18	0	788	117	0	0	357
2019-11-17	1,667	2,472	1.88	0	914	101	0	0	302
2019-11-18	1,753	2,343	1.7	0	828	120	0	0	393
2019-11-19	2,031	7,835	5.78	0	801	158	8	22	708
2019-11-20	1,753	3,446	2.55	0	774	114	0	0	394
2019-11-21	2,211	9,203	6.73	0	706	230	10	19	978
2019-11-22	1,922	4,763	3.46	0	856	165	0	0	558
2019-11-23	1,791	3,157	2.3	0	855	150	0	0	452
2019-11-24	1,551	756	0.55	0	899	57	0	0	158
2019-11-25	1,889	4,747	3.49	0	680	173	0	0	580
2019-11-26	1,711	1,872	1.36	0	765	121	0	0	359
2019-11-27	1,927	5,293	3.85	0	840	156	5	17	603
2019-11-28	1,692	1,908	1.39	0	772	101	0	0	318
2019-11-29	1,839	3,257	2.37	0	946	149	0	0	467
2019-11-30	1,816	4,027	3.05	0	672	102	6	15	436
2019-12-01	1,586	1,052	0.76	0	840	67	0	0	193
2019-12-02	1,763	4,125	3	0	834	125	0	0	421
2019-12-03	2,099	5,131	3.73	0	773	248	0	0	837
2019-12-04	1,926	3,694	2.69	0	775	174	6	4	611
2019-12-05	1,816	3,268	2.38	0	836	159	0	0	490
2019-12-06	1,877	3,508	2.55	0	852	177	0	0	556
2019-12-07	1,647	2,143	1.55	0	980	75	0	0	264
2019-12-08	1,803	3,143	2.28	0	846	149	0	0	441
2019-12-09	1,685	2,195	1.6	0	799	105	0	0	317
2019-12-10	1,696	2,944	2.14	0	785	98	0	0	320

APPENDIX C: COMMERCIAL WEARABLE DEVICES

Device Name	Summary	URL
Hapi Fork	Fork that controls your eating speed to help you lose weight	https://www.hapilabs.com/product/hapifork
Ava Bracelet	Fertility wristband for women	https://www.avawomen.com/
Withings Smart Scales	Weighing scales with insight into body composition and cardiovascular	https://www.withings.com/ca/en/scales
Seismic	Tailored biomechanical apparel	https://www.myseismic.com/
Bella Beat	Tracking activity, sleep, stress, menstrual health and meditation for wo	https://www.bellabeat.com/
Muse Headband	EEG reading headband to assist with meditation	https://choosemuse.com/muse-app/
Qsun UV Expsoure Tracker	Insight on UV intensity and Vitamin D levels	https://qsun.co/
BACtrack	Blood Alcohol Content reader	breathalyzer
MomSense	Breastfeeding monitor to track swallong patterns	https://mymomsense.com/
KARDIAMOBILE	Portable ECG recorder	https://www.alivecor.com/
Owlet	Oxygen level, heart rate and sleep monitoring for babies	https://owletcare.com/
Beddit	Sleep Monitor	https://www.beddit.com/
Dreem	Headband for sleep monitoring	https://dreem.com/en/understand
Wearable X	Smart clothing for improved Yoga	https://www.wearablex.com/
Smart Breath	Smart clothing for improved Yoga and Pilates	http://www.smartbreath.it/
Empatica	Wearable wrist band to for individuals with epilepsy	https://www.empatica.com/en-int/index.html
MLI Elbow	EMG sensor to reduce muscle strain on elbow	https://www.kickstarter.com/projects/finnbechandersen/mlitm-elbow-helps-people-with-pain-in-their-elbow
Jiobit	Location tracking for loved ones	https://www.jiobit.com/
Livongo	Platform for chronic disease management	https://www2.livongo.com/
Feel	Emotion sensor and mental health advisor	https://www.myfeel.co/
Moodbeam	Moodtracking bracelet	https://www.moodbeam.co.uk/
Cyrcadia	Breast Wellness monitoring	http://cyrcadiahealth.com/core-technology/
Plume Flow	Air Pollution sensor	https://plumelabs.com/en/flow/
Cosinuss	Ear plug for heart rate and body temperature monitoring	https://www.cosinuss.com/products/one/
Sen.se mother (discontinued	Sensors for various domestic activities	System/dp/B0117S7EZW
LA Roche Posay - UV Track	Clip on tracker for sun exposure	https://www.laroche-posay.ca/
GoBe2	Calorie and hydration tracking wearable band	https://healbe.com/eu/
Welt Belt	Fall prevention, activity, waist size tracker, eating tracker belt	https://www.weltcorp.com/
Narrative Clip 2	Wearable life logging camers	http://getnarrative.com/
RescueTime	Application to track time affluence	https://www.rescuetime.com/
Drinkup	Hydration tracking water bottle	https://drinkupbottle.com/
Apple Watch 5	Activity, sleep, heart rate, menstrual monitoring	https://www.apple.com/ca/watch/
Fitbit Alta HR	Activity, sleep, heart rate, menstrual monitoring	https://www.fitbit.com/en-ca/home?utm_source=google&utm_medium=paidsearch&ds_rl=1256838&ds_rl=1256838&gclid=Cj0KCQiAs67yBRC7ARIsAF49CdUPfoJQN1di1m2RuykEPhaPgGAsyQkvqee5Y9zahwQdb3kERy9dK0caAtdeEALw_wcB&gclsrc=aw.ds

APPENDIX D: DATA MAPPED ON BODIES, ITERATION ONE

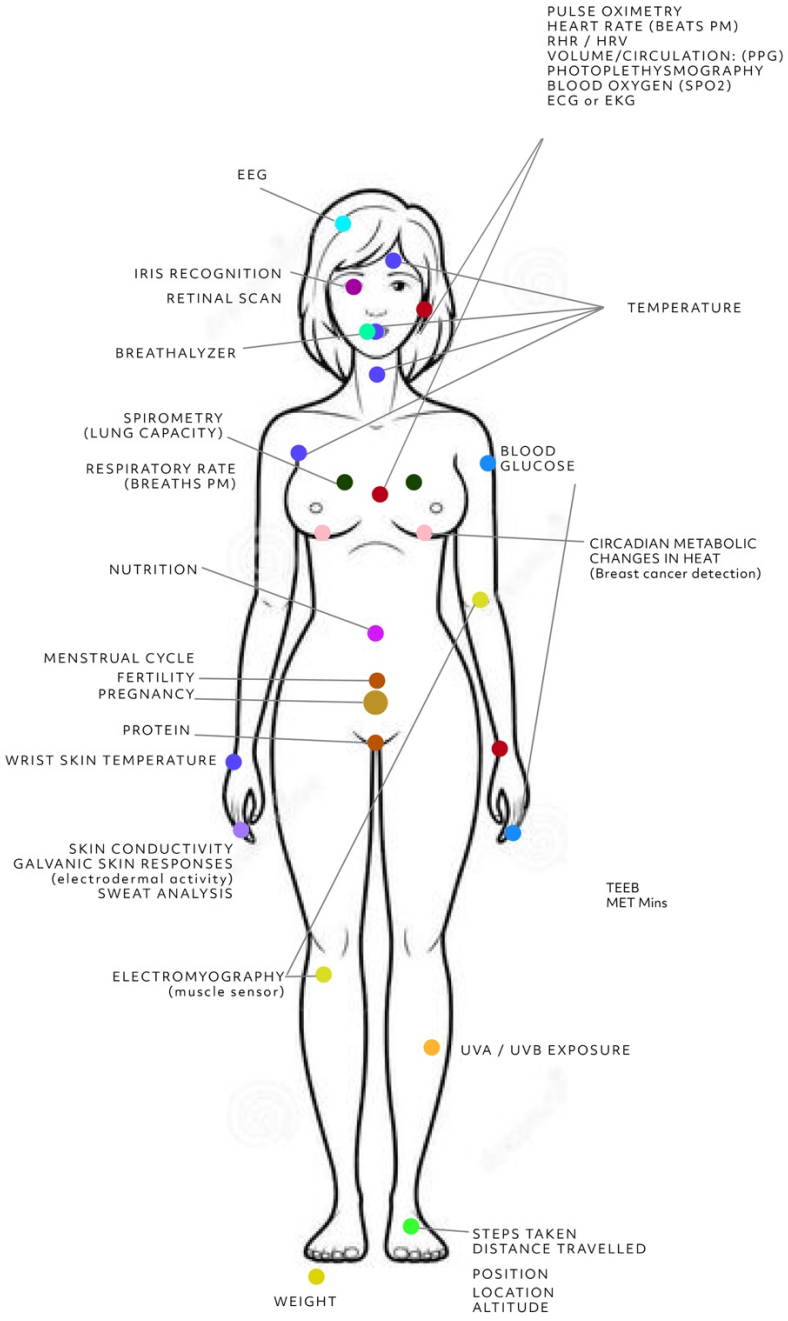

Figure 44: Female body data mapping, iteration one.

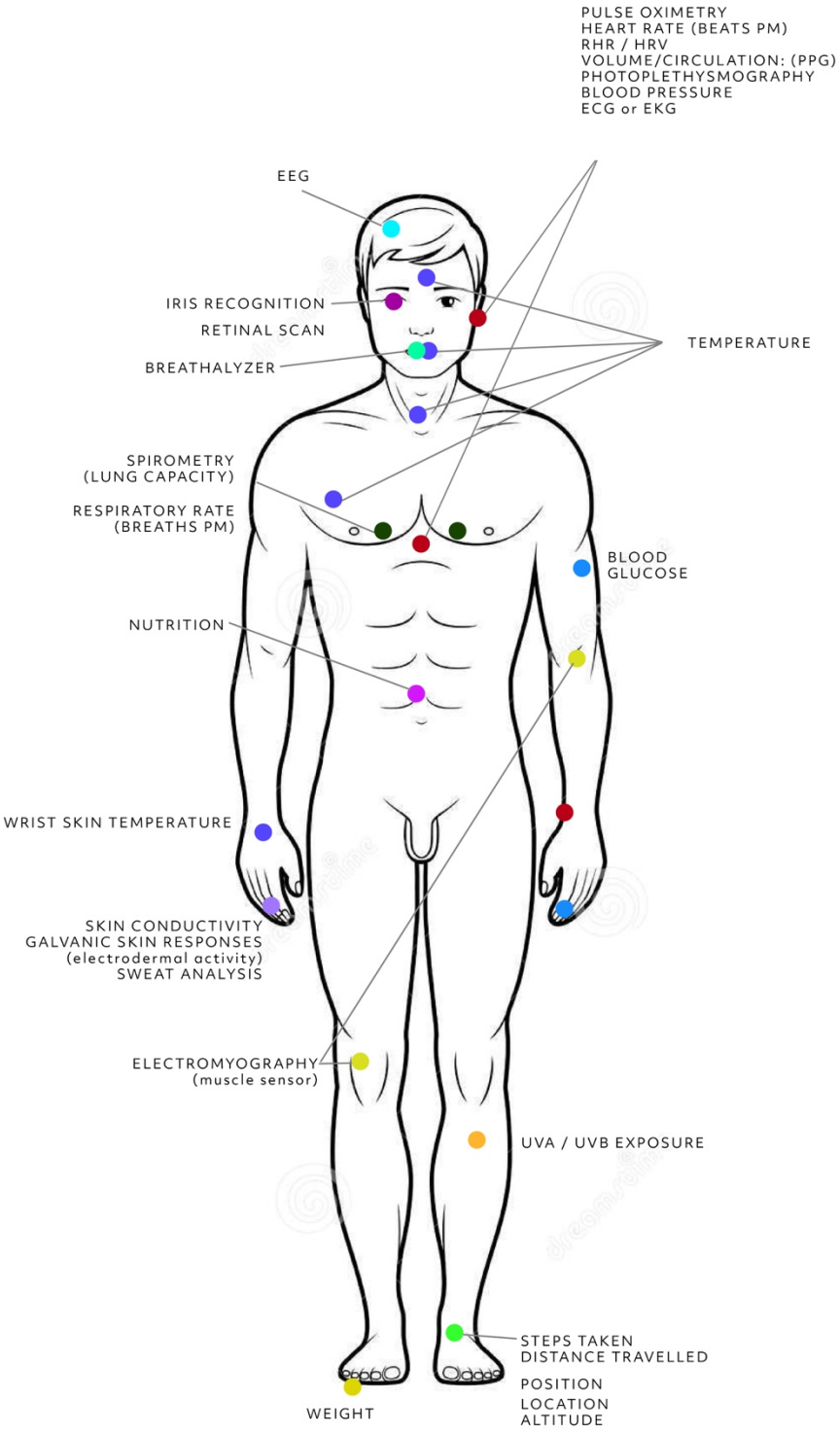

Figure 45: Male body data mapping, iteration one.

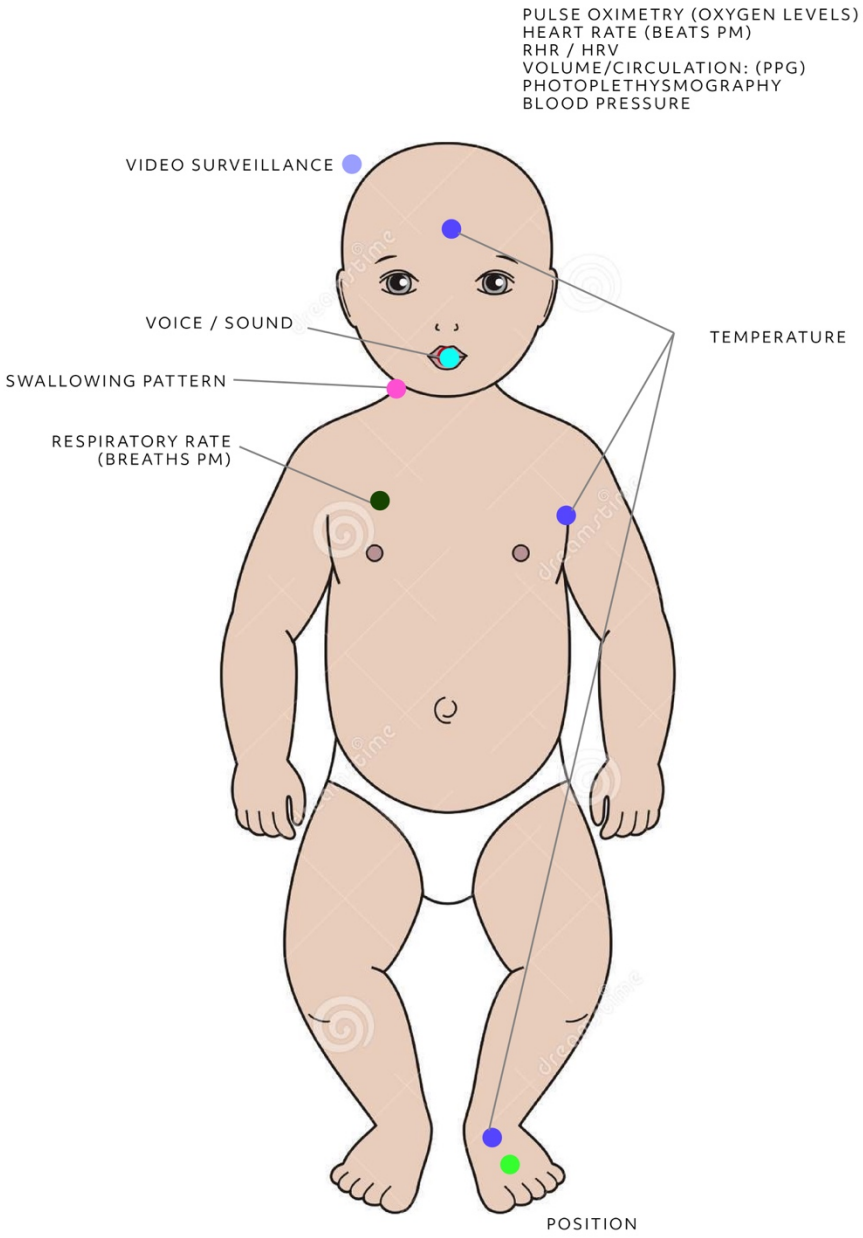

Figure 46: Infant body data mapping, iteration one.

APPENDIX E: DATA MAPPED ON BODIES, ITERATION TWO

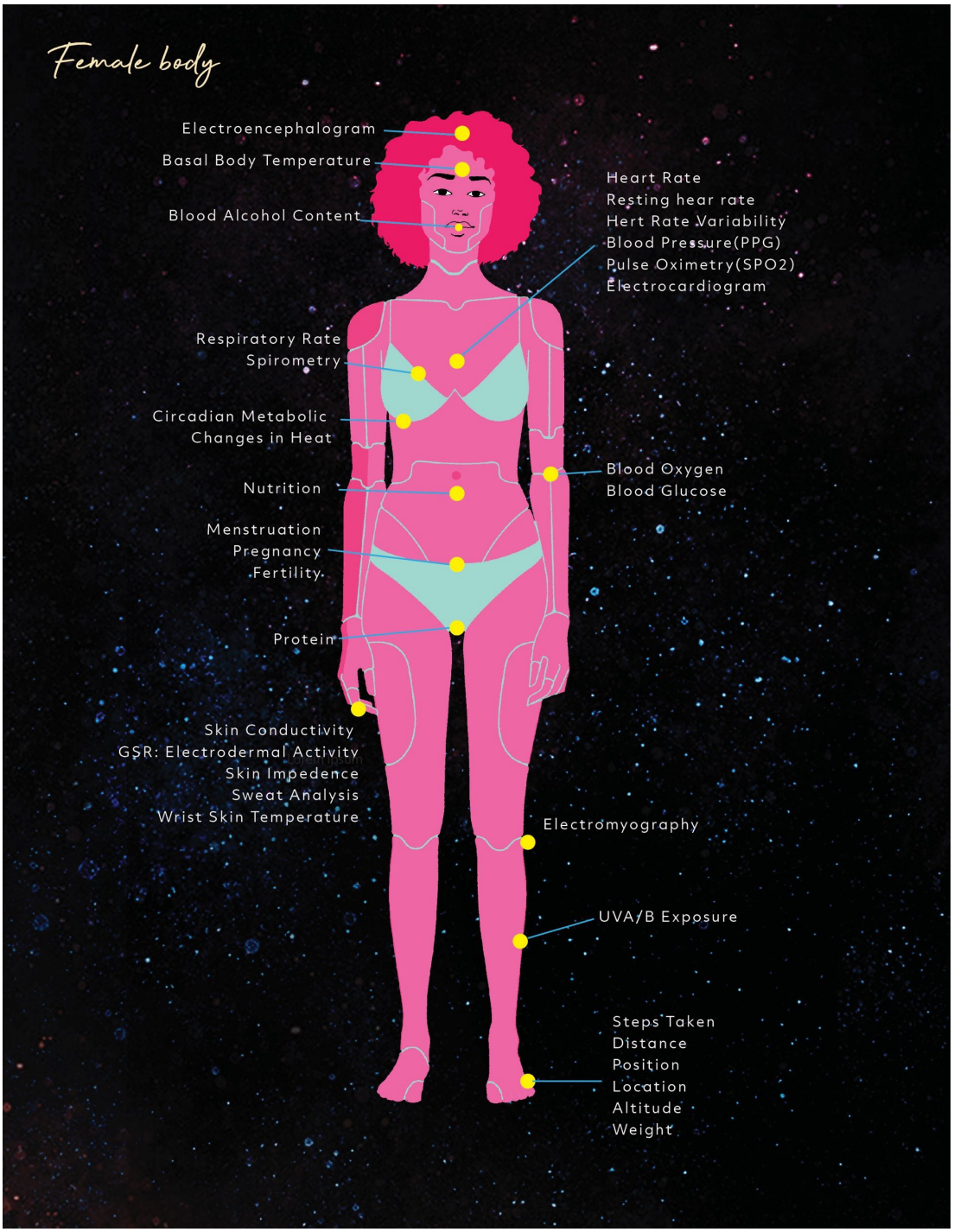

Figure 47: Female body data mapping, iteration two.

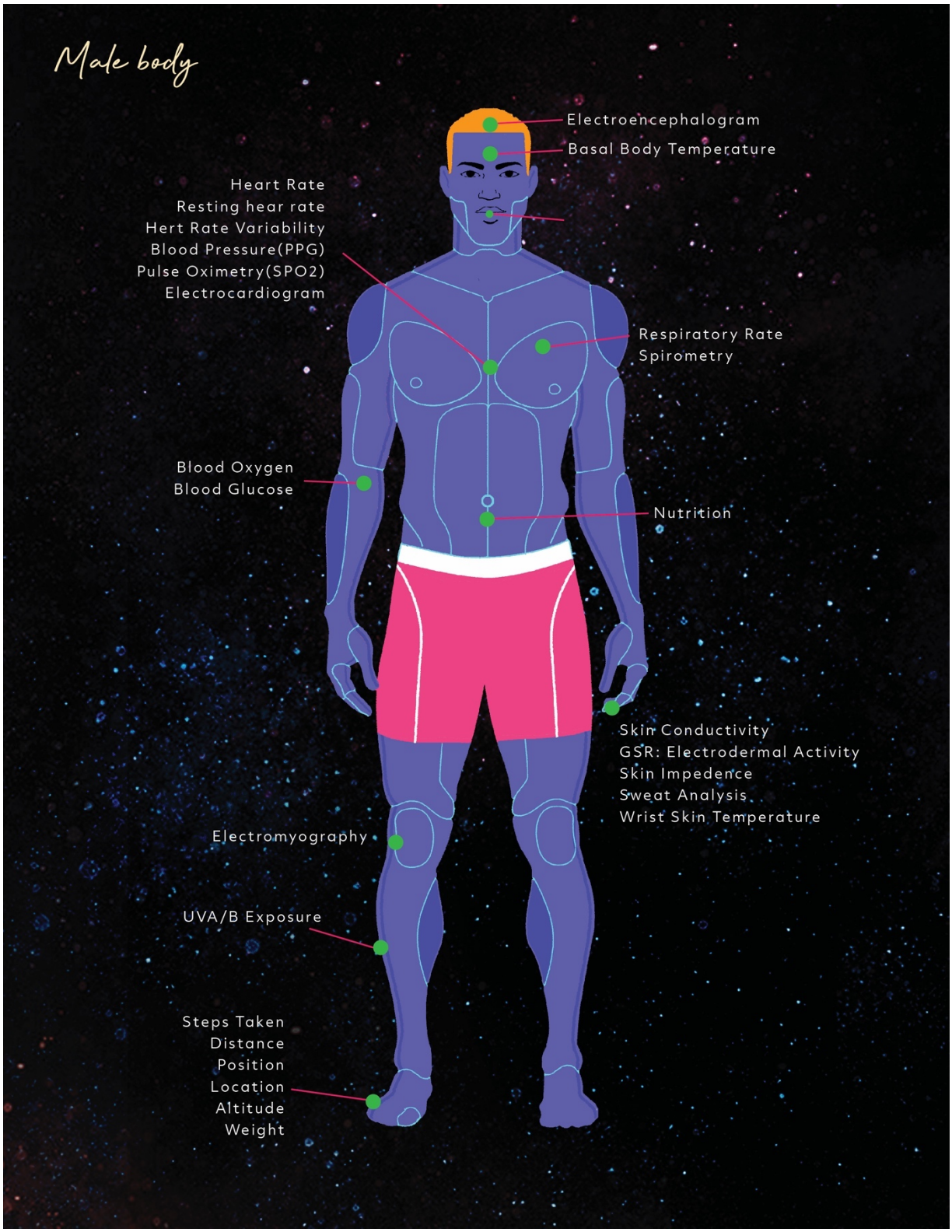

Figure 48: Male body data mapping, iteration two.

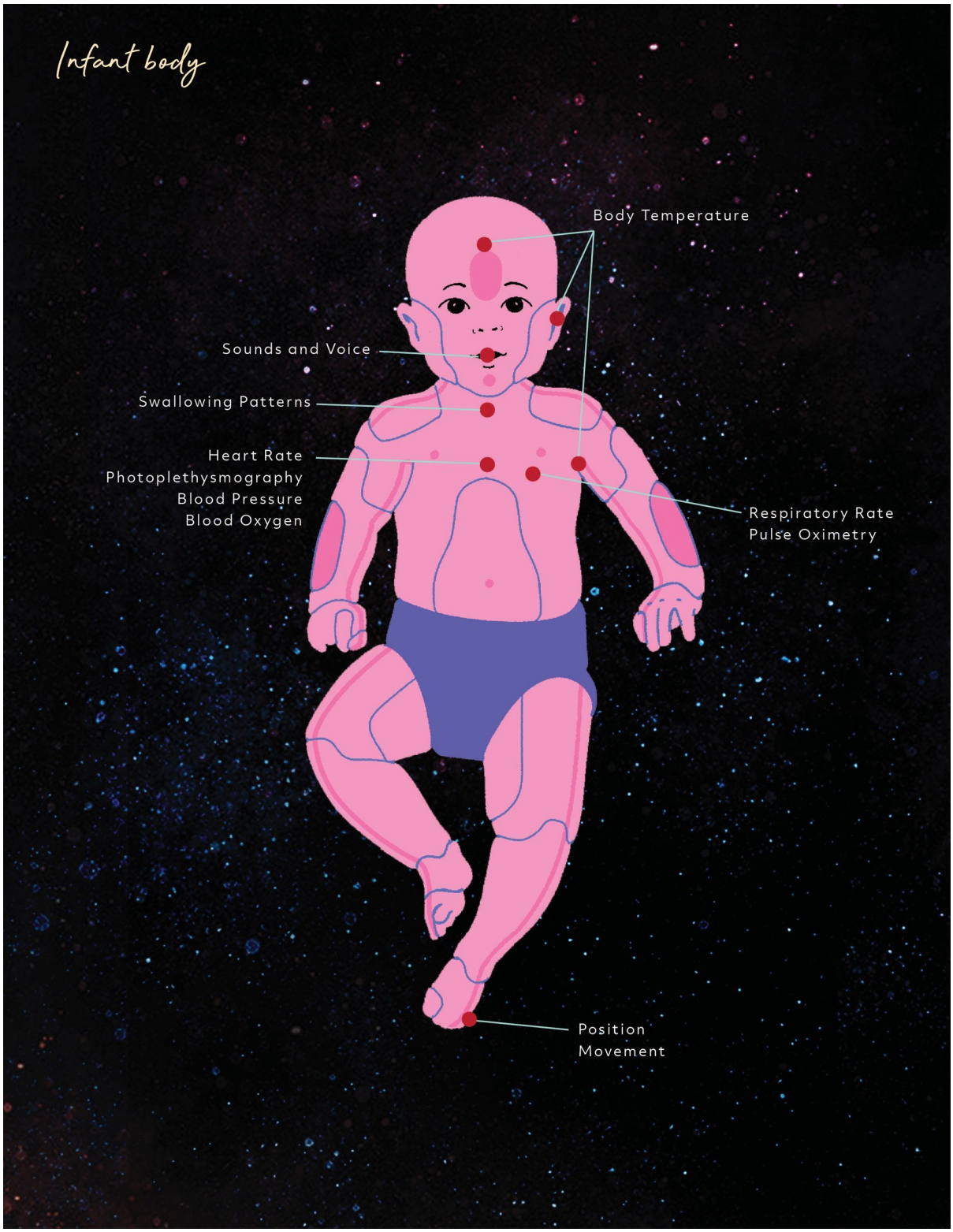

Figure 49: Infant body data mapping, iteration two.

APPENDIX F: USER PERSONA

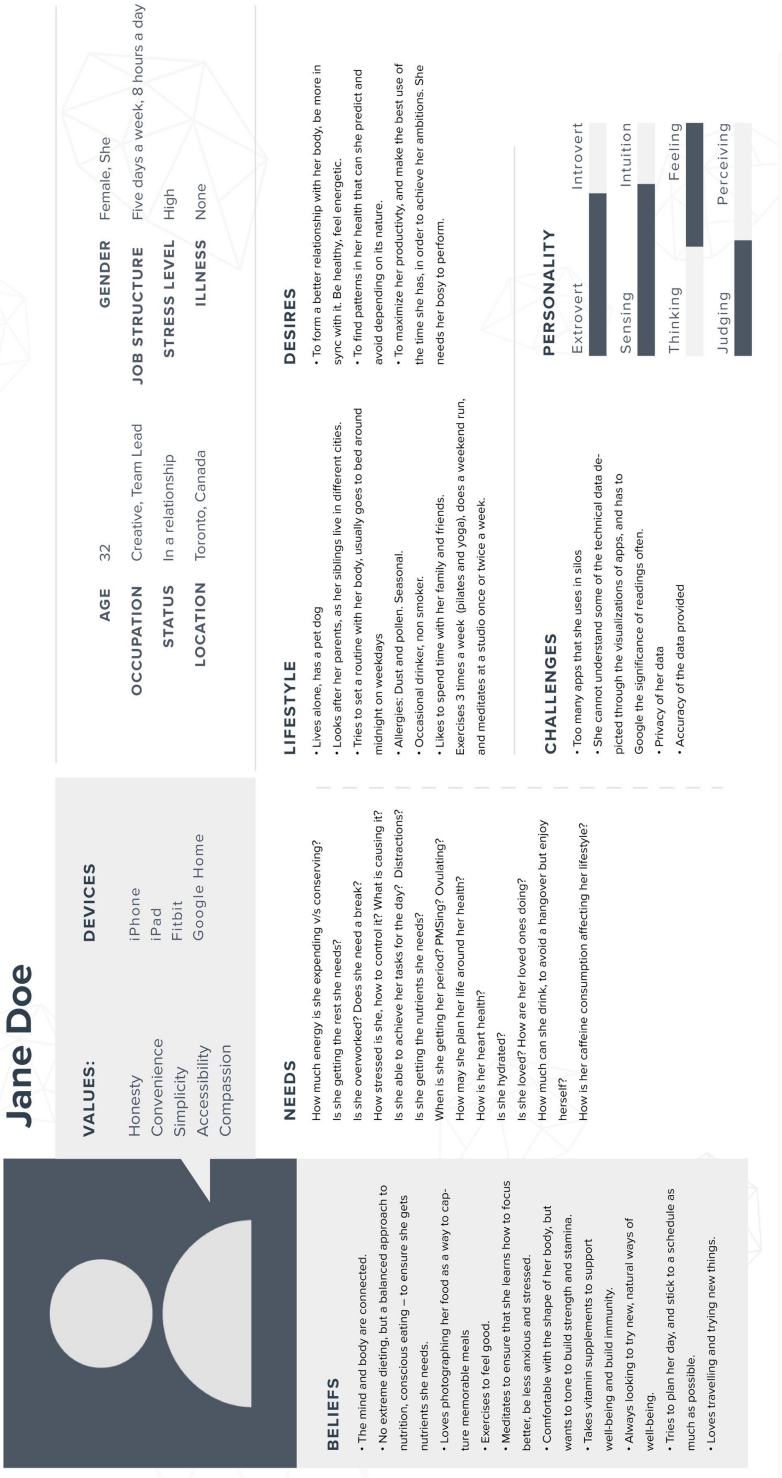

Figure 50: User Persona, iteration one.

Veda Adnani Chatterjee

VALUES:

Empathy
Honesty
Loyalty
Authenticity
Hardwork

DEVICES

iPhone
iPad
Fitbit
Macbook Pro
Flo
iCal

AGE	29	GENDER	Female, She
OCCUPATION	Student, Teacher, Research Assistant	JOB STRUCTURE	Flexible
STATUS	Married	STRESS LEVEL	Medium High
LOCATION	Toronto, Canada	ILLNESS	Allergies

BELIEFS

• The mind and body are connected.
• A balanced approach to nutrition, conscious eating to get the nutrients I need.
• I love food, I love eating and cooking, and photographing my food as a way to capture meals I want to remember.
• I try to exercise 3-5 times a week. It makes me feel great. I usually do pilates as well as cardio. I want to tone my body to build strength and stamina.
• I am an irregular meditator, but I believe in its benefits
• I take vitamin supplements to support my well-being and build immunity.
• I strongly prefer natural, organic over synthetic or artificial methods for my well-being any day.

NEEDS

I need to understand where I am expending all my energy?
How much energy am I expending v/s conserving?
How much energy do I need to get through my day?
Am I getting the quality rest I need? What is affecting it?
What stresses me out? Why? How do I control it?
Am i doing the right things for my body like I think I am?
How can I plan my life around my health? especially with menstruating every month.
Is my heart healthy?
Am i eating healthy?
Am i hydrated?
Am i loved?
Am i drinking too much alcohol or coffee?
Am I too sedentary? Is it affecting my health?

LIFESTYLE

• I live with my aunt and cousin, so space is limited.
• I cannot plan my meals as well as I would like to, but I try to eat healthy.
• Why I try to set a routine I usually go to bed around 1am on most days.
• Allergies: Dust and pollen. Seasonal.
• Occasional drinker, non smoker.
• I love to spend time with my family and friends.
• Exercises 3 times a week (pilates and cardio).
• I love sleeping, though I somehow wake up around 4am on most nights and it usually leaves me feeling tired the next day.
• I love cooking my own meals.

DESIRES

SELF-ACCEPTANCE
• I want to feel better about myself, and be reassured that I am doing the right thing for my health.
• I want to know if I am OK overall or not.
• I want to be realistic with my tracking practice and embrace my bad and good days
• I want to maximise my productivity and achieve all the goals I have set for myself.
• I want a health and well-being companion to guide me through my day to day choices with my health.

CHALLENGES

• I struggle with deciphering my heart data on most applications.
• I Google health conditions too often
• I can't afford premium subscriptions for fitness apps at this point, but I still want ot know more about my body
• I do not trust most applications with my data
• I hate using menstrual trackers that make me think I am pregnant every time I am late.

PERSONALITY

Extrovert — Introvert
Sensing — Intuition
Thinking — Feeling
Judging — Perceiving

Figure 51: User Persona, iteration two.

APPENDIX G: VISUALIZATION WIREFRAMES

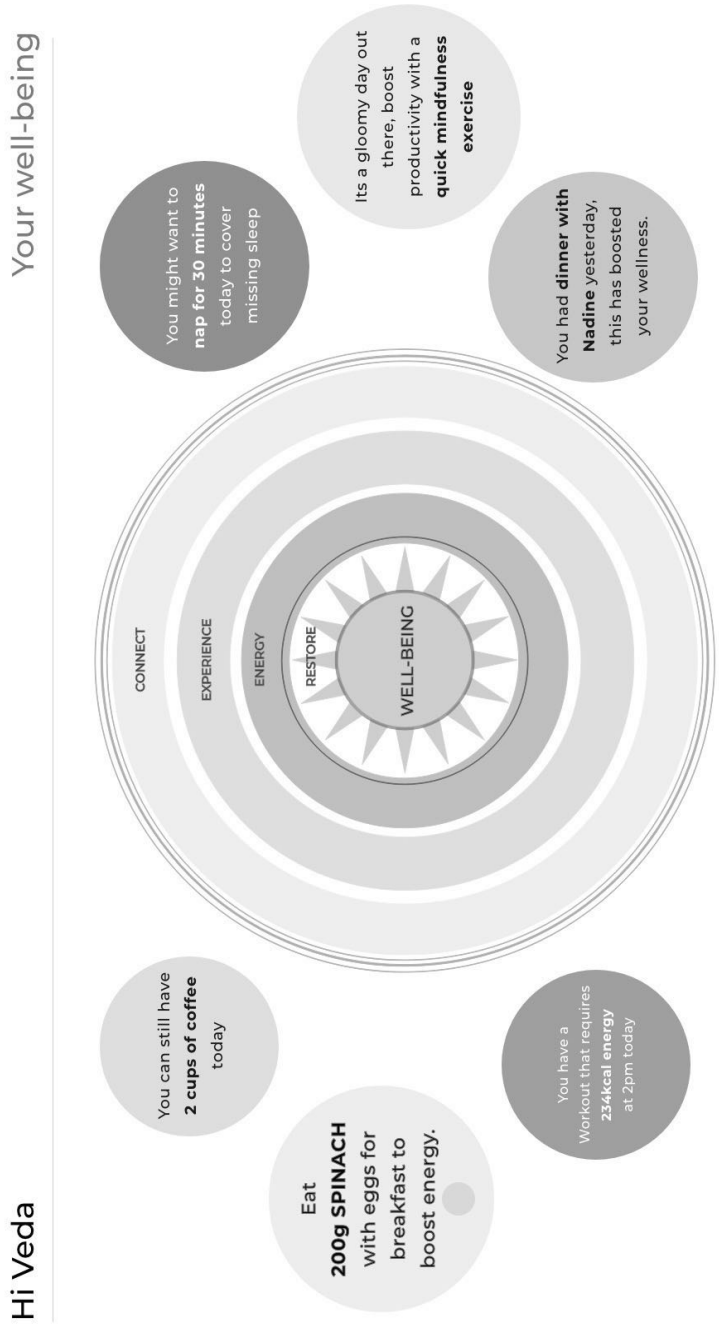

Figure 52: Overall well-being wireframe iteration one, prototype two.

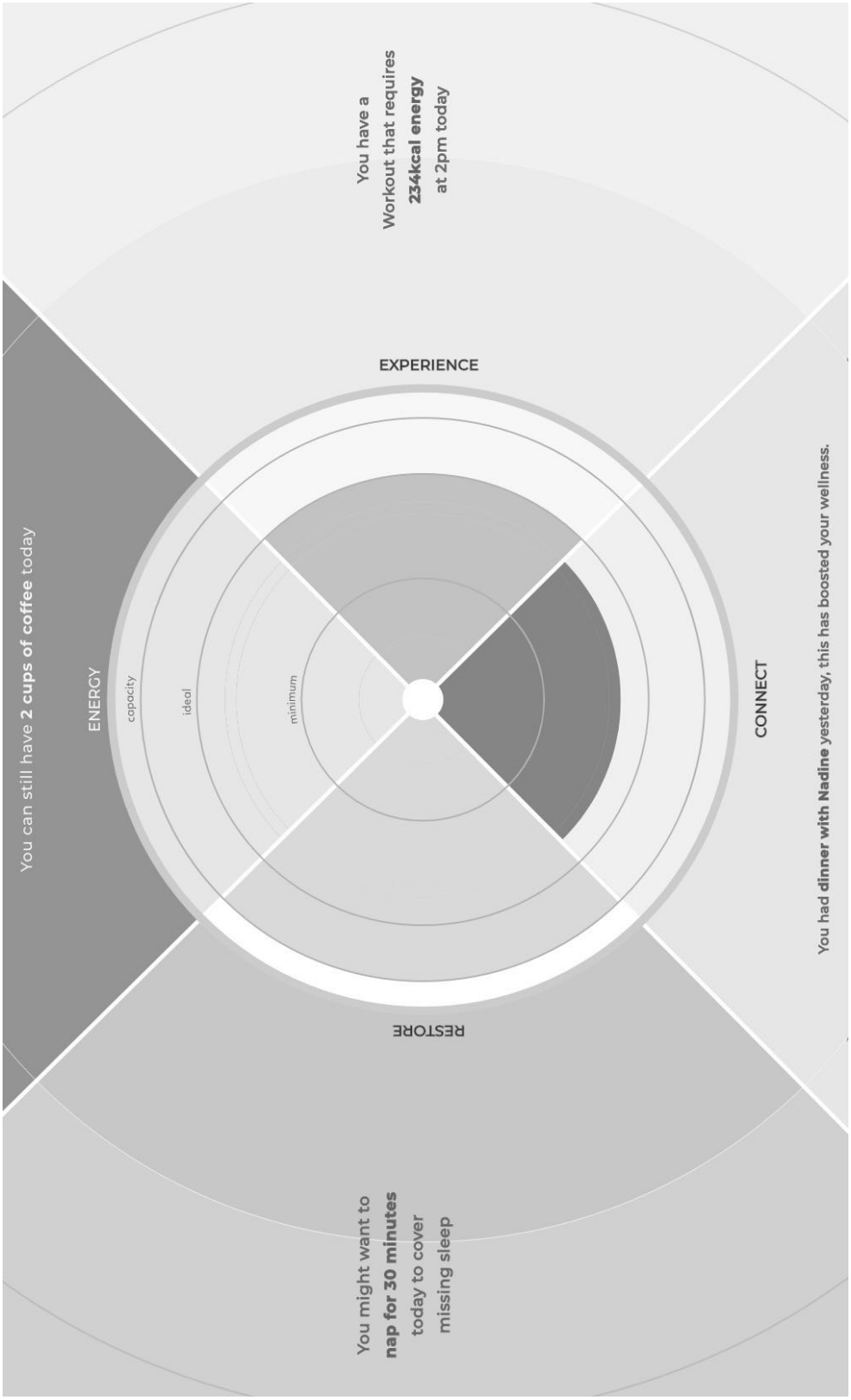

Figure 53: Overall well-being wireframe iteration two, prototype two.

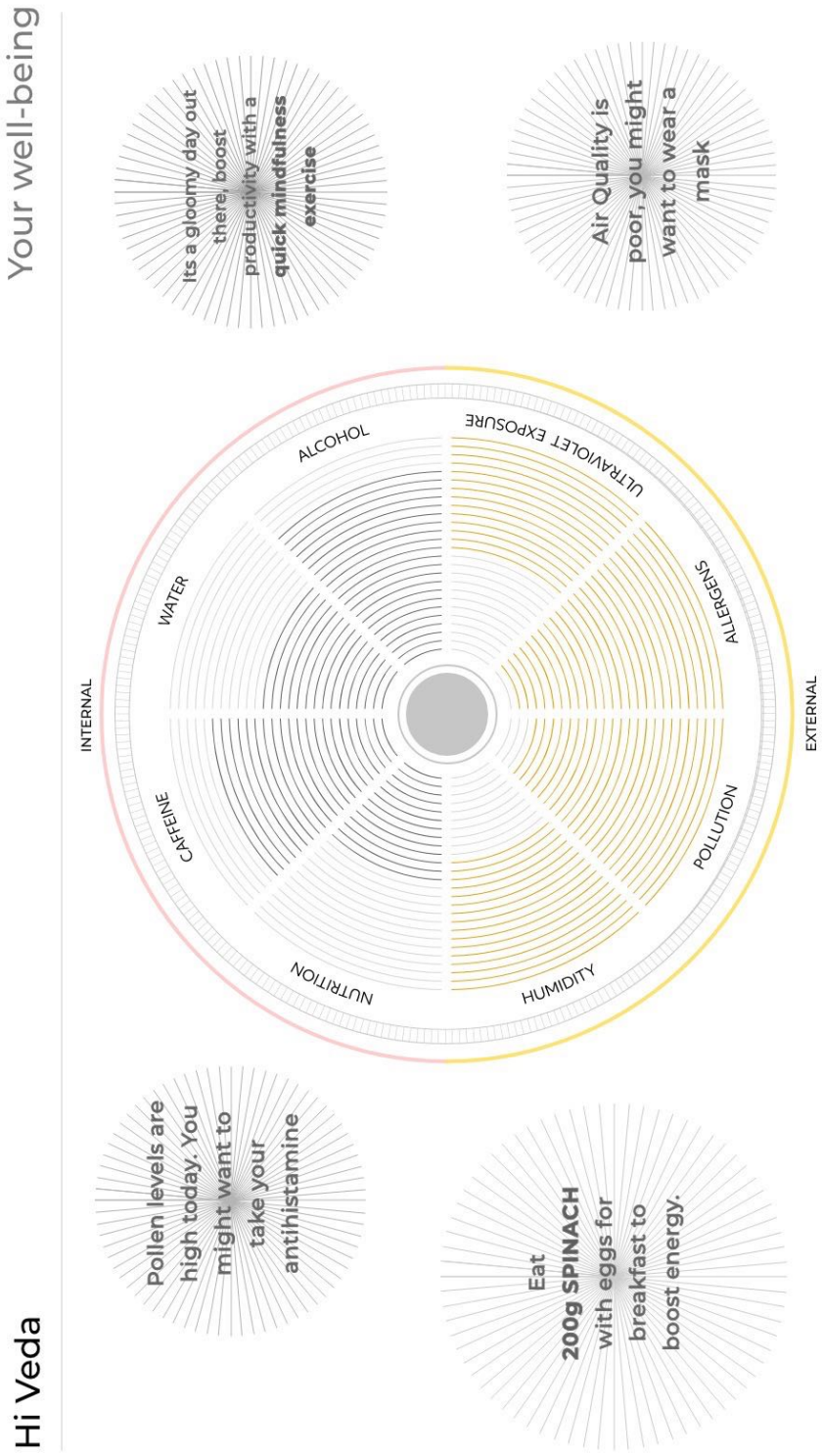

Figure 54: Energize wireframe, prototype two.

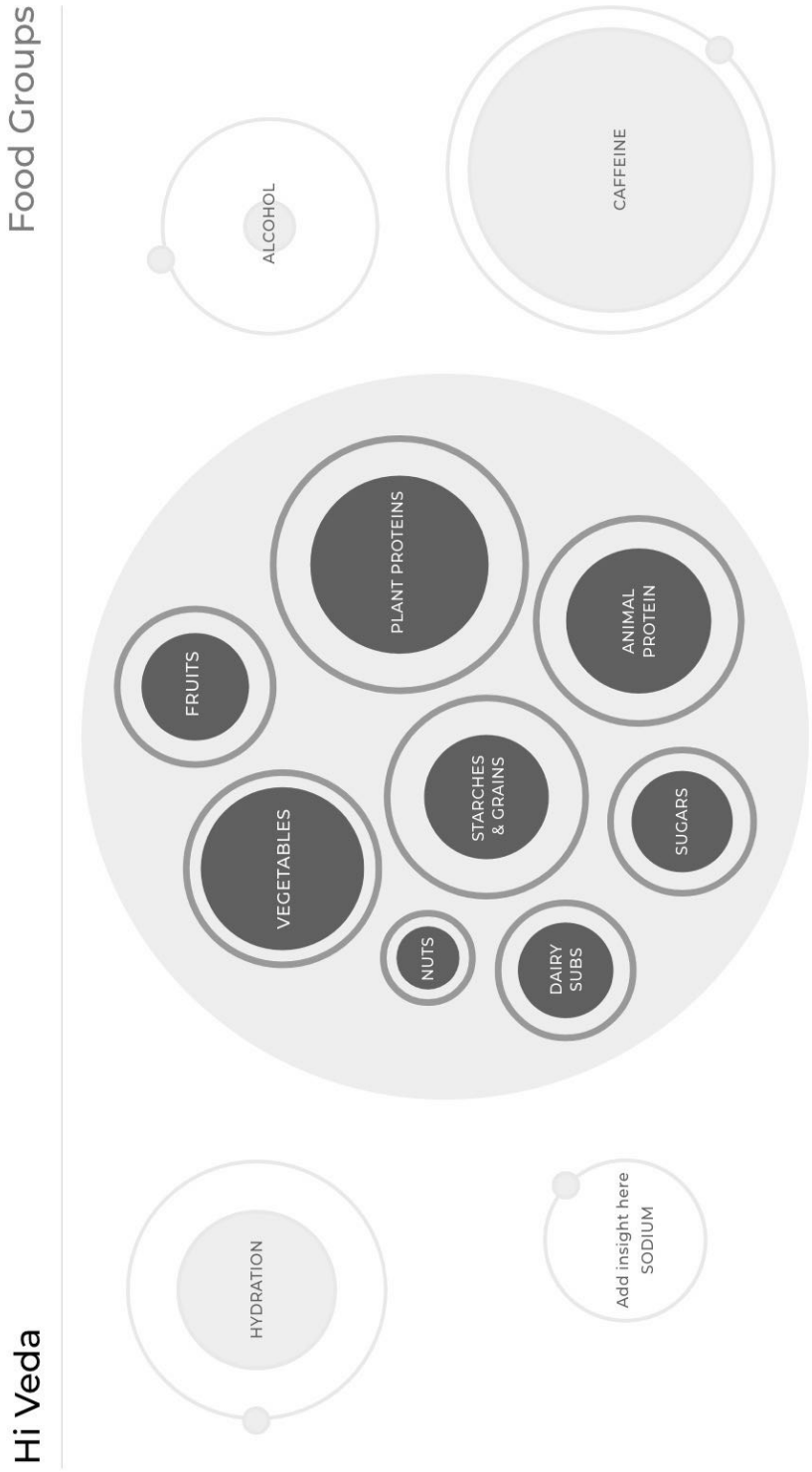

Figure 55: Individual nourishment wireframe, prototype two.

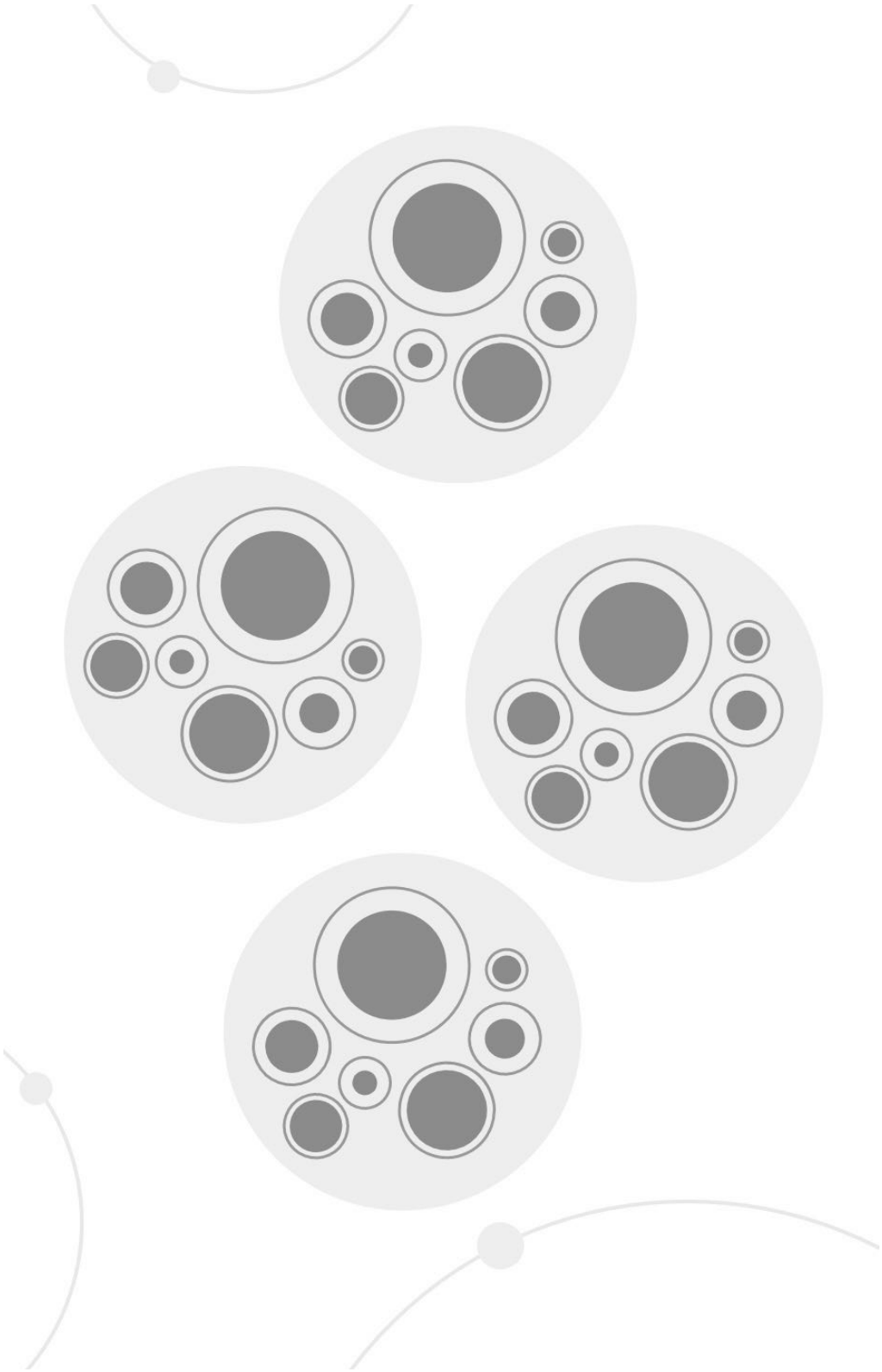

Figure 56: Family nourishment wireframe, prototype two.

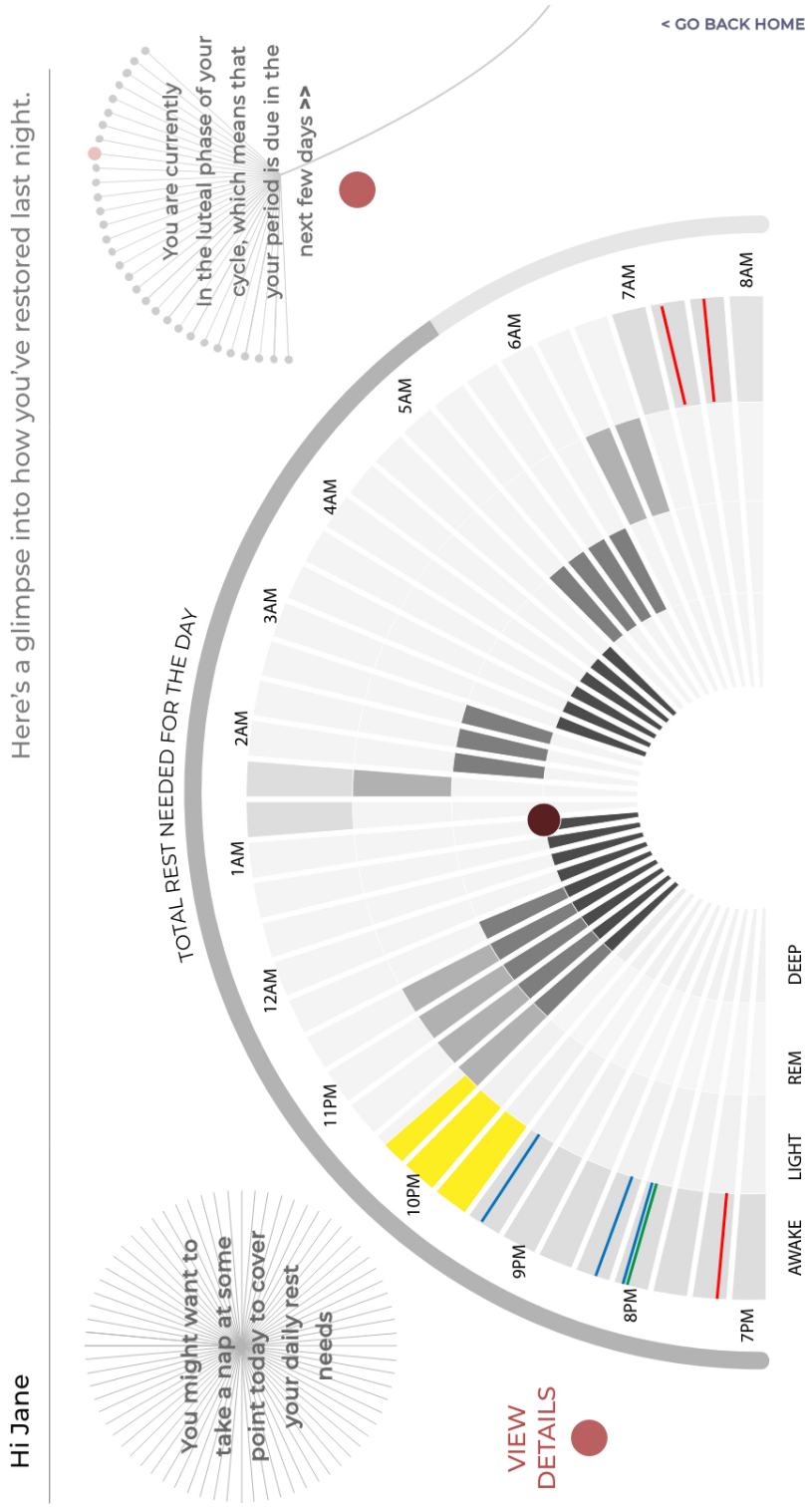

Figure 57: Restoration wireframe ambient state, prototype three.

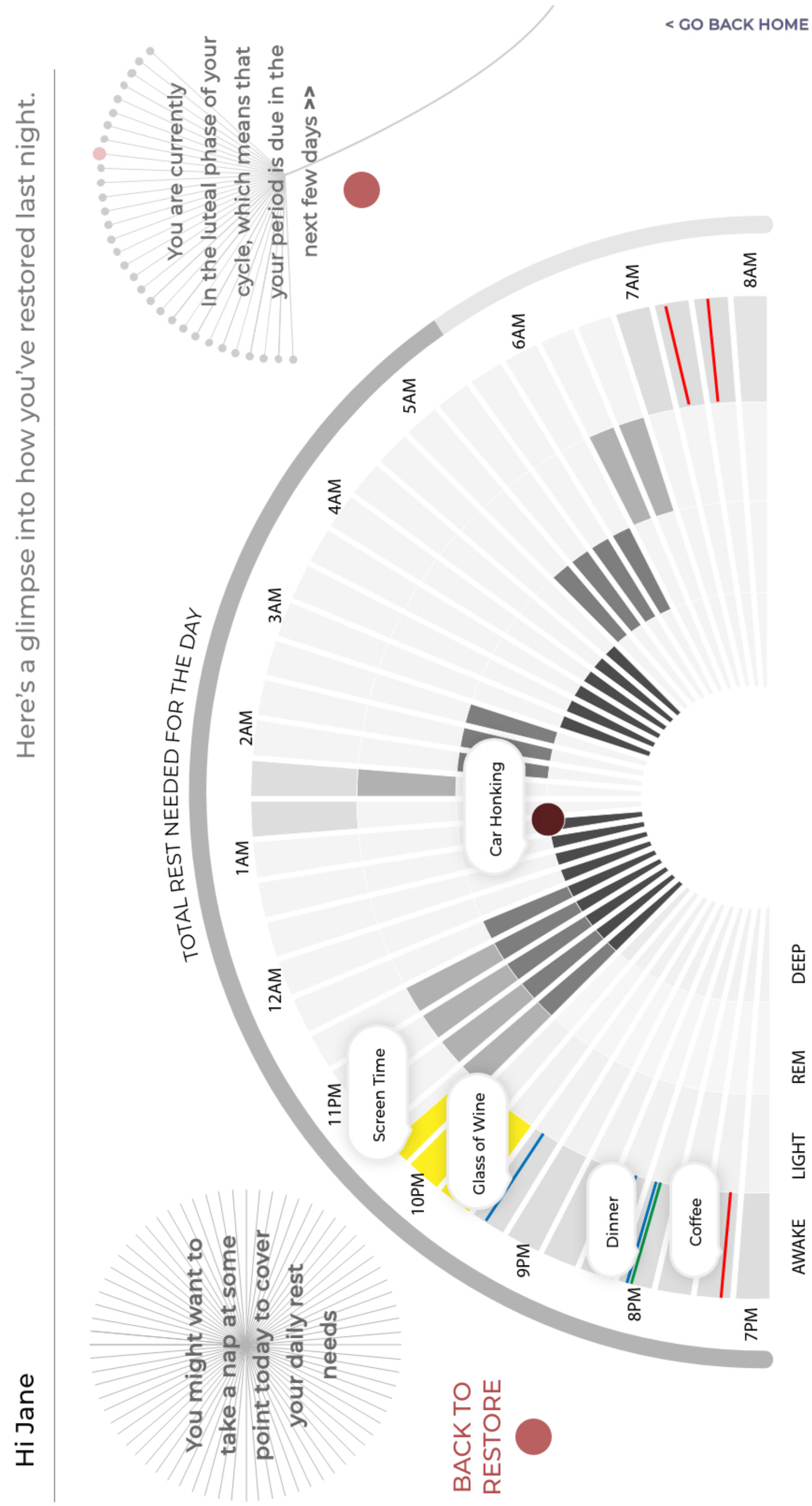

Figure 58: Restoration wireframe interactive state, prototype three.

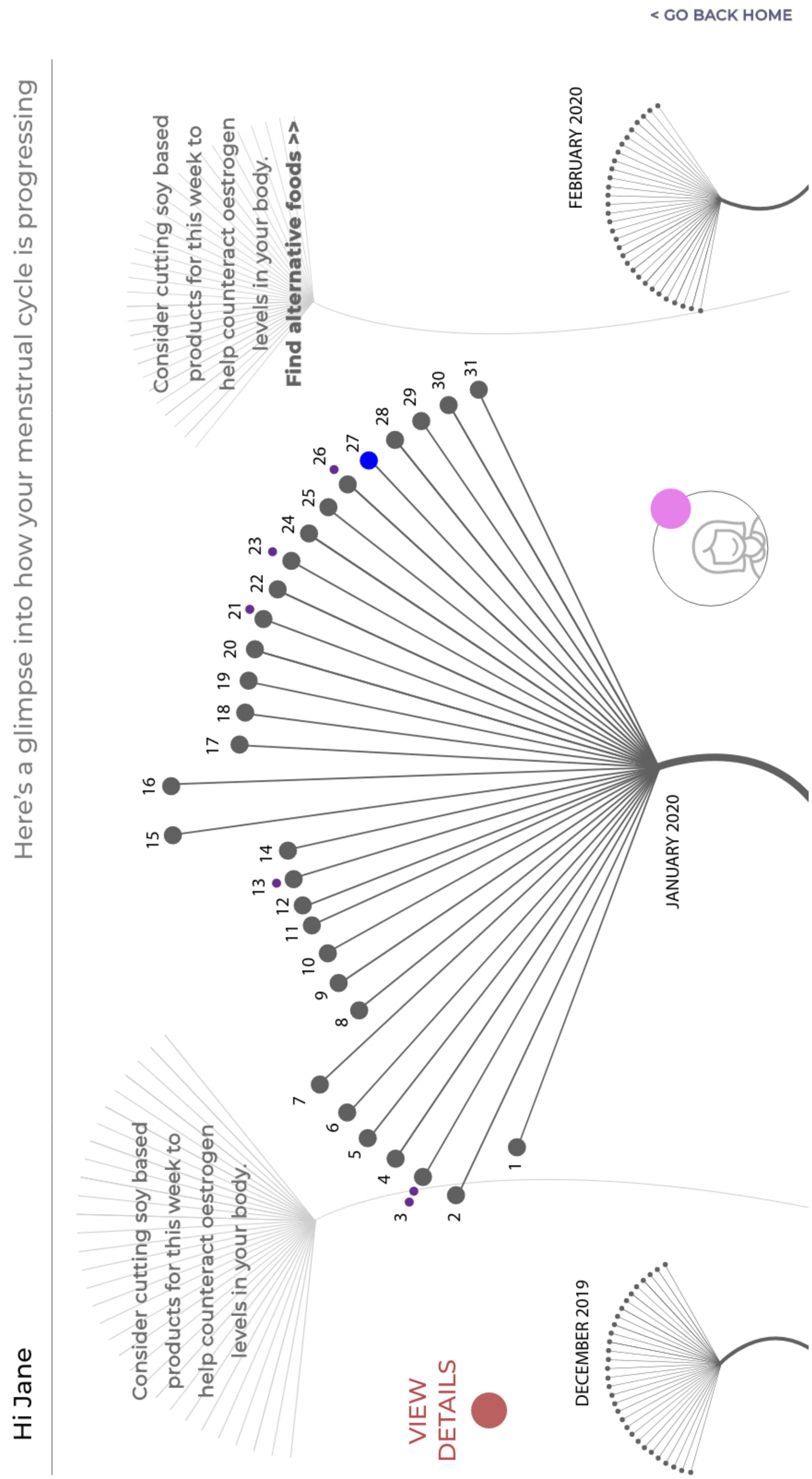

Figure 59: Menstrual wireframe ambient state, prototype three.

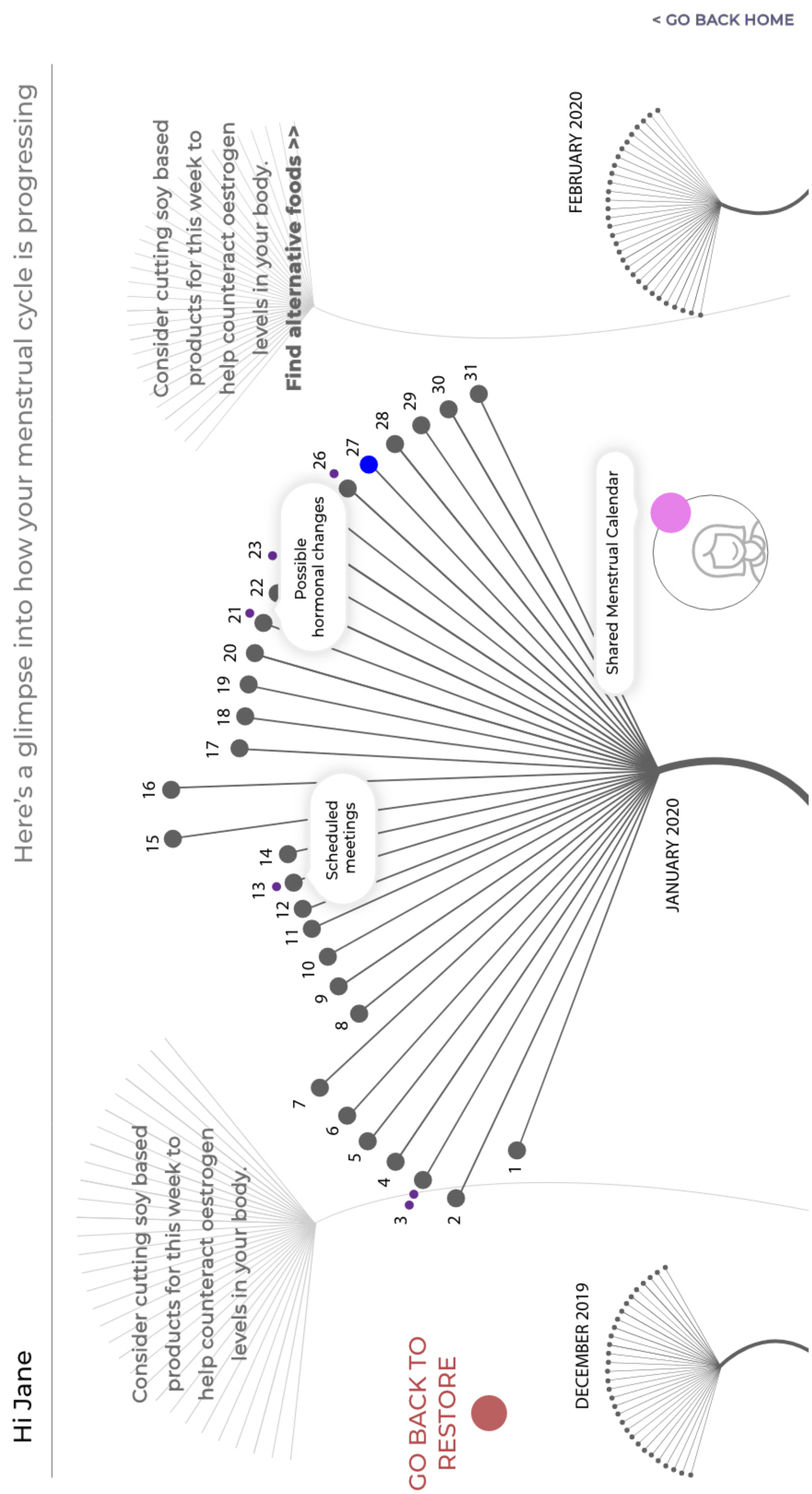

Figure 60: Menstrual wireframe interactive state, prototype three.

APPENDIX H: RESTORATION VISUALIZATION DESIGN

Figure 61: Restoration visualization design, prototype three.

APPENDIX I: MENSTRUAL VISUALIZATION

Date	Day	Phase	Flow	Sexual Activity	Schedule	Start Time	End Time	Fatigue	Reflection
1-9-20	Sunday	Low Chance of Pregnancy	0	Nil	Flight to Toronto from London	10:00:00 AM	9:00:00 PM	8	Was sad to leave my husband
2-9-20	Monday	Low Chance of Pregnancy	0	Nil	Rest	11:00:00 AM	11:00:00 PM	4	Mild Jetlag, recovering from the flight
3-9-20	Tuesday	Period	8	Nil	Doctor's Appointment in Missisauga	11:00:00 AM	4:00:00 PM	7	Overall fatigue throughout hte day. Intense
4-9-20	Wednesday	Period	8	Nil	Rest	11:00:00 AM	11:00:00 PM	1	Recovering from mensutral symptoms
5-9-20	Thursday	Period	4	Nil	Research Meeting at UofT	2:00:00 PM	4:00:00 PM	5	Routine day
6-9-20	Friday	Period	6	Nil	Bar with friends	9:00:00 PM	3:00:00 AM	2	to enjoyment. Alcohol consumed, and eating
7-9-20	Saturday	Period	4	Nil	Dinner with a friend	7:00:00 PM	9:00:00 PM	5	Routine day
8-9-20	Sunday	Period	2	Nil	Dinner with a friend	7:00:00 PM	10:30:00 PM	1	Spent the day reading in bed, resting
9-9-20	Monday	Chance of Pregnancy	0	Nil	Work from home	11:00:00 AM	11:00:00 PM	5	Routine day
10-9-20	Tuesday	Chance of Pregnancy	0	Nil	Class, and advisor meeting	8:00:00 AM	4:00:00 PM	8	Preparing for Colloquium
11-9-20	Wednesday	Chance of Pregnancy	0	Nil	Meditation session at Hoame Studio	5:00:00 PM	7:00:00 PM	1	Restful, decluttering, and re-energizing
12-9-20	Thursday	Chance of Pregnancy	0	Nil	School	11:00:00 AM	6:00:00 PM	4	Routine day
13-9-20	Friday	Chance of Pregnancy	0	Nil	Colloquium @OCAD	9:00:00 AM	5:00:00 PM	10	simultaneously thinking about mine
14-9-20	Saturday	Ovulating	0	Nil	Work from home	11:00:00 AM	7:00:00 PM	7	Preparing for Colloquium
15-9-20	Sunday	Chance of Pregnancy	0	Nil	Indian Lunch in Missisauga	12:00:00 PM	3:00:00 PM	3	Lunch with friend, Preparing for Colloquium
16-9-20	Monday	Chance of Pregnancy	0	Nil	Doctors Appointment, Meditation	1:00:00 PM	7:00:00 PM	3	Preparing for ColloquiumFollowing up
17-9-20	Tuesday	Low Chance of Pregnancy	0	Nil	Class, Teaching	8:00:00 AM	10:00:00 PM	10	Preparing for Colloquium, Teaching at OCAD
18-9-20	Wednesday	Low Chance of Pregnancy	0	Nil	Work from home	11:00:00 AM	7:00:00 PM	3	comfort of home is helpful
19-9-20	Thursday	Low Chance of Pregnancy	0	Nil	Work from home	11:00:00 AM	9:00:00 PM	3	comfort of home is helpful, rehearsing
20-9-20	Friday	Low Chance of Pregnancy	0	Nil	Colloquium @OCAD	9:00:00 AM	5:00:00 PM	10	Presenting at Colloquium
21-9-20	Saturday	Low Chance of Pregnancy	0	Nil	Rest	11:00:00 AM	7:00:00 PM	1	Recovering from Colloquium
22-9-20	Sunday	Low Chance of Pregnancy	0	Nil	Rest	11:00:00 AM	7:00:00 PM	1	Recovering from Colloquium
23-9-20	Monday	Low Chance of Pregnancy	0	Nil	Meeting with Thesis Advisor	12:00:00 PM	2:00:00 PM	5	Routine day
24-9-20	Tuesday	Low Chance of Pregnancy	0	Nil	Class, Meditation, Teaching	10:30:00 AM	10:00:00 PM	4	to recuperate from Colloquium, Teaching at
25-9-20	Wednesday	Low Chance of Pregnancy	0	Nil	Working in school, Meditation	11:00:00 AM	6:00:00 PM	1	recover and progress to next step of thesis
26-9-20	Thursday	Low Chance of Pregnancy	0	Nil	Work from home	11:00:00 AM	7:00:00 PM	5	Routine day
27-9-20	Friday	Low Chance of Pregnancy	0	Nil	family	10:00:00 AM	12:00:00 AM	8	food consumed, enjoyable evening with
28-9-20	Saturday	Low Chance of Pregnancy	0	Nil	Night out with friends	8:00:00 PM	1:00:00 AM	9	Menstrual symptoms commence, however
29-9-20	Sunday	Period	6	Nil	Rest	10:00:00 AM	10:00:00 PM	8	pain, sadness experienced, feeling low.
30-9-20	Monday	Period	8	Nil	Meeting with Thesis Advisor, Work in school	12:00:00 PM	6:00:00 PM	10	Menstrual symtpoms continued
1-10-20	Tuesday	Period	8	Nil	Class, Teaching	10:30:00 AM	10:00:00 PM	10	long day in class and then teaching at OCAd
2-10-20	Wednesday	Period	4	Nil	Work from home	11:00:00 AM	7:00:00 PM	1	Recovering from Tuesday
3-10-20	Thursday	Period	6	Nil	Hoame Studio	12:00:00 PM	7:00:00 PM	5	Decluttering mind, destessing, self-care.
4-10-20	Friday	Period	4	Nil	Research, Work at home	11:00:00 AM	7:00:00 PM	3	Research work deadlines
5-10-20	Saturday	Period	2	Nil	Rest	11:00:00 AM	11:00:00 PM	1	Rest Day
6-10-20	Sunday	Chance of Pregnancy	0	Nil	Lunch with a friend	12:30:00 PM	5:00:00 PM	2	Catching up over lunch and coffee
7-10-20	Monday	Chance of Pregnancy	0	Nil	Hoame Studio	10:00:00 AM	7:00:00 PM	3	Working on writing thesis
8-10-20	Tuesday	Chance of Pregnancy	0	Nil	Class, Teaching	10:30:00 AM	2:00:00 PM	4	Long hours of class.
9-10-20	Wednesday	Chance of Pregnancy	0	Nil	Hoame Studio	11:30:00 AM	7:00:00 AM	5	Routine day
10-10-20	Thursday	Ovulating	0	Nil	Work from home	11:00:00 AM	7:00:00 PM	5	Routine day
11-10-20	Friday	Chance of Pregnancy	0	Nil	Travel to Etobicoke, stay in Etobicoke	12:00:00 PM	12:00:00 AM	6	Stay over at friends house, play with her kids
12-10-20	Saturday	Chance of Pregnancy	0	Nil	house	12:00:00 AM	12:00:00 AM	2	friends and kids
13-10-20	Sunday	Low Chance of Pregnancy	0	Nil	Thanksgiving dinner with April's family	6:00:00 PM	10:00:00 PM	6	Great food, game of pool, overeating!
14-10-20	Monday	Low Chance of Pregnancy	0	Nil	Rest	1:00:00 PM	3:00:00 PM	8	Long journey home, two trains and a bus.
15-10-20	Tuesday	Low Chance of Pregnancy	0	Nil	Study week, work from home, teaching	11:00:00 AM	10:00:00 PM	4	Continuous work on writing, Teaching at OCAD
16-10-20	Wednesday	Low Chance of Pregnancy	0	Nil	Work in school, Meditation session at Hoame Studio	12:30:00 AM	7:00:00 PM	4	Routine day, recovering from Tuesday
17-10-20	Thursday	Low Chance of Pregnancy	0	Nil	Work from home	11:00:00 AM	4:00:00 PM	1	Routine day
18-10-20	Friday	Low Chance of Pregnancy	0	Nil	Work from home	11:00:00 AM	6:00:00 PM	4	Routine day
19-10-20	Saturday	Low Chance of Pregnancy	0	Nil	Family Day	8:00:00 PM	11:00:00 PM	10	Planning wedding remotwly with mother
20-10-20	Sunday	Low Chance of Pregnancy	0	Nil	Family Day	9:00:00 AM	11:00:00 AM	10	Planning wedding remotwly with mother
21-10-20	Monday	Low Chance of Pregnancy	0	Nil	Meeting with Thesis Advisor, Work in school	10:00:00 AM	4:00:00 PM	4	Routine day
22-10-20	Tuesday	Low Chance of Pregnancy	0	Nil	Class, catching up on assignments, teaching	10:00:00 AM	6:00:00 PM	10	Routine day, Teaching at OCAD
23-10-20	Wednesday	Low Chance of Pregnancy	0	Nil	Meditation session at Hoame Studio			10	Feeling Depressed, needed a meditation to pick me up. Wedding stress, assignments, no chance to recover from Tuesday.
24-10-20	Thursday	Low Chance of Pregnancy	0	Nil	Work from home	11:00:00 AM	6:00:00 PM	8	Moody, tired, frustrated.
25-10-20	Friday	Period	8	Nil	Work from home	11:00:00 AM	6:00:00 PM	10	Routine Day, however sharp pain in lower abdomen and legs due to menstruation
26-10-20	Saturday	Period	6	Nil	Work from home, Research	11:00:00 AM	4:00:00 PM	4	Routine Day
27-10-20	Sunday	Period	6	Nil	Rest	11:00:00 AM	7:00:00 PM	1	Routine Rest, Self-care
28-10-20	Monday	Period	4	Nil	Meeting with Thesis Advisor, Work from school, Pilates	10:00:00 AM	6:00:00 PM	8	Alot of moving around, difficult ot exercise with Menstrual cycle ongoing.
29-10-20	Tuesday	Period	2	Nil	Class	10:30:00 AM	2:00:00 PM	4	Routine Day, Mild pain in abdomen but diminshing
30-10-20	Wednesday	Period	2	Nil	Work from school, Meditation session at Hoa	10:00:00 AM	7:00:00 PM	8	Routine Day
31-10-20	Thursday	Chance of Pregnancy	0	Nil	Work from School, Pilates	11:00:00 AM	6:30:00 PM	8	Routine Day, Exercise exhausting

Figure 62: Menstrual visualization design ambient state, prototype four.

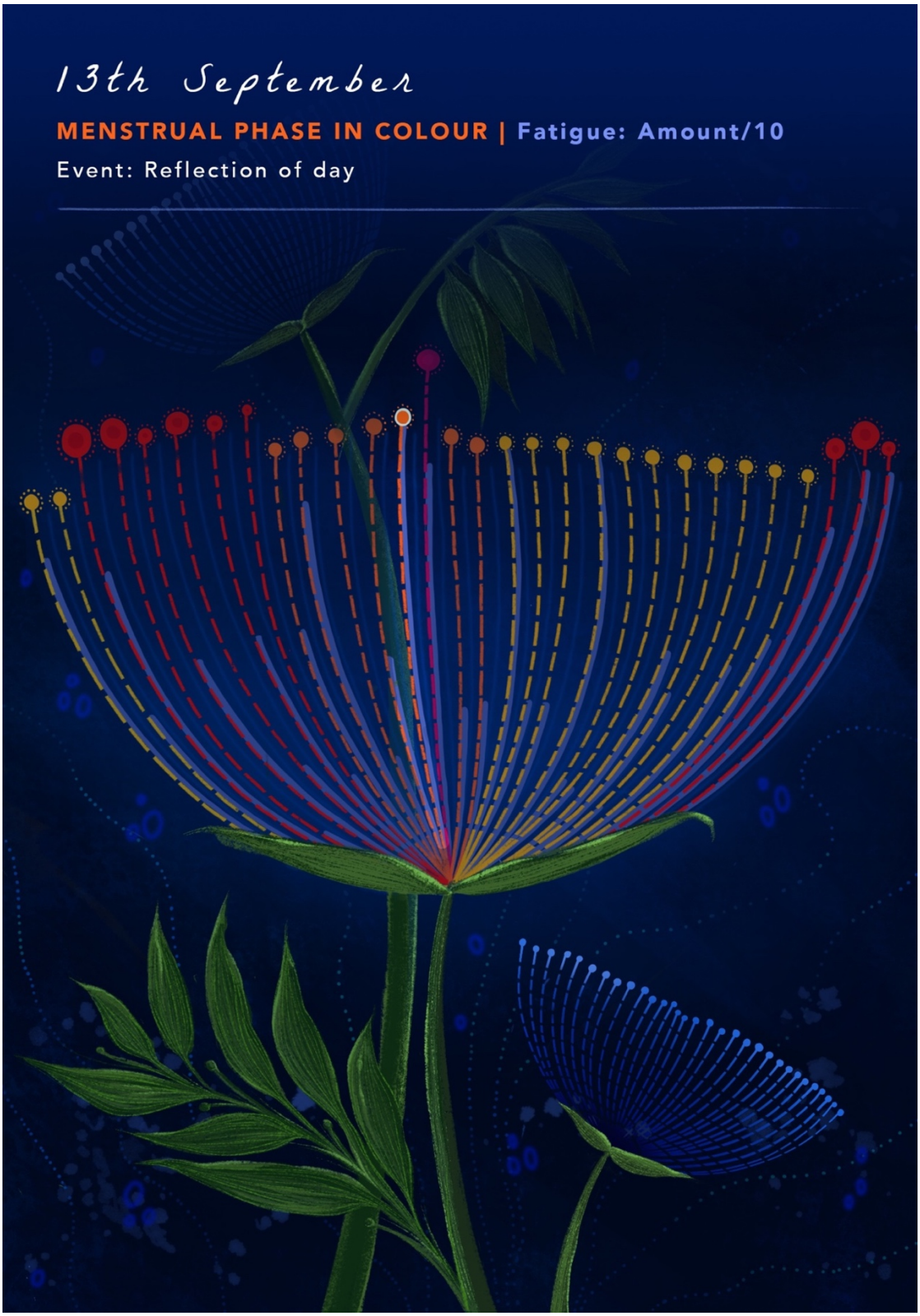

Figure 63: Menstrual visualization design interactive state, prototype four.

APPENDIX J: RESTORATION VISUALIZATION, ITERATION TWO

From Date	From Time	To Date	To Time	Resting Heart Rate	Time in Bed	Minutes Awake	Minutes Asleep	Number of Awakenings	Minutes Light Sleep	Minutes REM Sleep	Minutes Deep Sleep
1-9-19	1:32am	1-9-20	10:38am	77	546	64	482	37	296	109	77
2-9-19	5:00am	2-9-20	2:25pm	77	565	69	496	36	321	84	91
2-9-20	10:13pm	3-9-20	8:09am	77	596	38	558	2	N/A	N/A	N/A
3-9-20	9:47pm	4-9-20	7:49am	76	602	63	539	26	248	155	136
4-9-20	11:38pm	5-9-20	7:25am	75	467	43	424	17	234	115	75
5-9-20	11:04pm	6-9-20	8:29am	74	565	16	549	2	N/A	N/A	N/A
7-9-20	3:33am	7-9-20	10:15am	76	402	43	359	14	207	80	72
8-9-20	2:12am	8-9-20	11:11am	74	538	76	462	22	279	115	68
8-9-20	10:53pm	9-9-20	9:27am	72	633	71	562	30	260	169	133
9-9-20	11:58pm	10-9-20	7:59am	70	481	55	426	17	245	118	63
10-9-20	11:33pm	11-9-20	9:18am	69	585	56	529	29	305	137	87
11-9-20	11:41pm	12-9-20	9:59am	69	618	73	545	33	269	167	109
13-9-20	2:01am	13-9-20	9:25am	70	444	41	403	18	210	105	88
14-9-20	12:35am	14-9-20	11:02am	70	627	120	507	27	290	125	92
15-9-20	1:08am	15-9-20	11:17am	70	609	58	551	36	327	136	88
16-9-20	1:11am	16-9-20	6:55am	71	344	45	299	14	218	54	27
17-9-20	12:12am	17-9-20	8:16am	72	483	45	438	19	209	130	99
18-9-20	1:07am	18-9-20	10:17am	75	550	52	498	31	290	123	85
19-9-20	12:52am	19-9-20	10:07am	75	554	56	498	29	316	109	73
20-9-20	12:10am	20-9-20	9:00am	75	530	53	477	21	289	98	90
21-9-20	2:50am	21-9-20	11:13am	77	503	62	441	23	210	114	117
22-9-20	11:07pm	23-9-20	8:05am	76	538	101	437	18	266	112	59
23-9-20	11:37pm	24-9-20	6:54am	75	436	72	364	18	202	73	89
24-9-20	11:56pm	25-9-20	7:43am	76	467	40	427	30	226	125	76
25-9-20	11:41pm	26-9-20	9:32am	74	591	85	506	39	365	76	65
27-9-20	1:24am	27-9-20	10:35am	74	550	68	482	25	264	131	87
28-9-20	2:04am	28-9-20	11:01am	76	537	86	451	22	232	141	78
29-9-20	2:02am	29-9-20	11:13am	75	551	68	483	19	263	131	89
30-9-20	12:01am	20-9-30	8:21am	73	500	54	446	29	273	125	48

From Date	From Time	Sleep Quality	8 hrsof Sleep?	Event of the day before	Fatigue Level	Caffeine post 5pm?	Menstrual	Alcohol
1-9-19	1:32am	87	yes	Flight to Toronto from London	8	No	Low Chance of Pregnancy	No
2-9-19	5:00am	83	yes	Rest	4	No	Period	No
2-9-20	10:13pm		yes	Rest	4	No	Period	No
3-9-20	9:47pm	90		Doctor's Appointment in Missisauga	7	No	Period	No
4-9-20	11:38pm	87	no	Rest	1	No	Period	No
5-9-20	11:04pm			Research Meeting at UofT	5	No	Period	No
7-9-20	3:33am	71	no	Bar with friends	2	Yes	Period	No
8-9-20	2:12am	81	no	Dinner with a friend	5	No	Chance of Pregnancy	No
8-9-20	10:53pm	91		Dinner with a friend	1	No	Chance of Pregnancy	No
9-9-20	11:58pm	84	no	Work from home	5	No	Chance of Pregnancy	Yes
10-9-20	11:33pm	88		Class, and advisor meeting	8	No	Chance of Pregnancy	No
11-9-20	11:41pm	89		Meditation session at Hoame Studio	1	No	Chance of Pregnancy	No
13-9-20	2:01am	82	no	Meeting with Thesis Advisor, Day in School	4	No	Ovulating	No
14-9-20	12:35am	82		Colloquium @OCAD	10	No	Chance of Pregnancy	No
15-9-20	1:08am	89		Work from home	7	No	Chance of Pregnancy	No
16-9-20	1:11am	68	no	Indian Lunch in Missisauga	3	No	Low Chance of Pregnancy	No
17-9-20	12:12am	83	no	Doctors Appointment, Meditation	3	No	Low Chance of Pregnancy	No
18-9-20	1:07am	85		Class, Teaching	10	No	Low Chance of Pregnancy	No
19-9-20	12:52am	89		Work from home	3	No	Low Chance of Pregnancy	No
20-9-20	12:10am	83	no	Work from home	3	No	Low Chance of Pregnancy	Yes
21-9-20	2:50am	81	no	Colloquium @OCAD	10	No	Low Chance of Pregnancy	No
22-9-20	11:07pm	79		Rest	1	No	Low Chance of Pregnancy	No
23-9-20	11:37pm	70	no	Meeting with Thesis Advisor	5	No	Low Chance of Pregnancy	No
24-9-20	11:56pm	85	no	Class, Meditation, Teaching	4	No	Low Chance of Pregnancy	No
25-9-20	11:41pm	82	no	Working in school, Meditation	1	Yes	Low Chance of Pregnancy	Yes
27-9-20	1:24am	85		Work from home	5	No	Low Chance of Pregnancy	No
28-9-20	2:04am	77	no	Working in school, Meditation, Outing with family	8	No	Period	Yes
29-9-20	2:02am	87		Night out with friends	9	No	Period	No
30-9-20	12:01am	87		Rest	8			

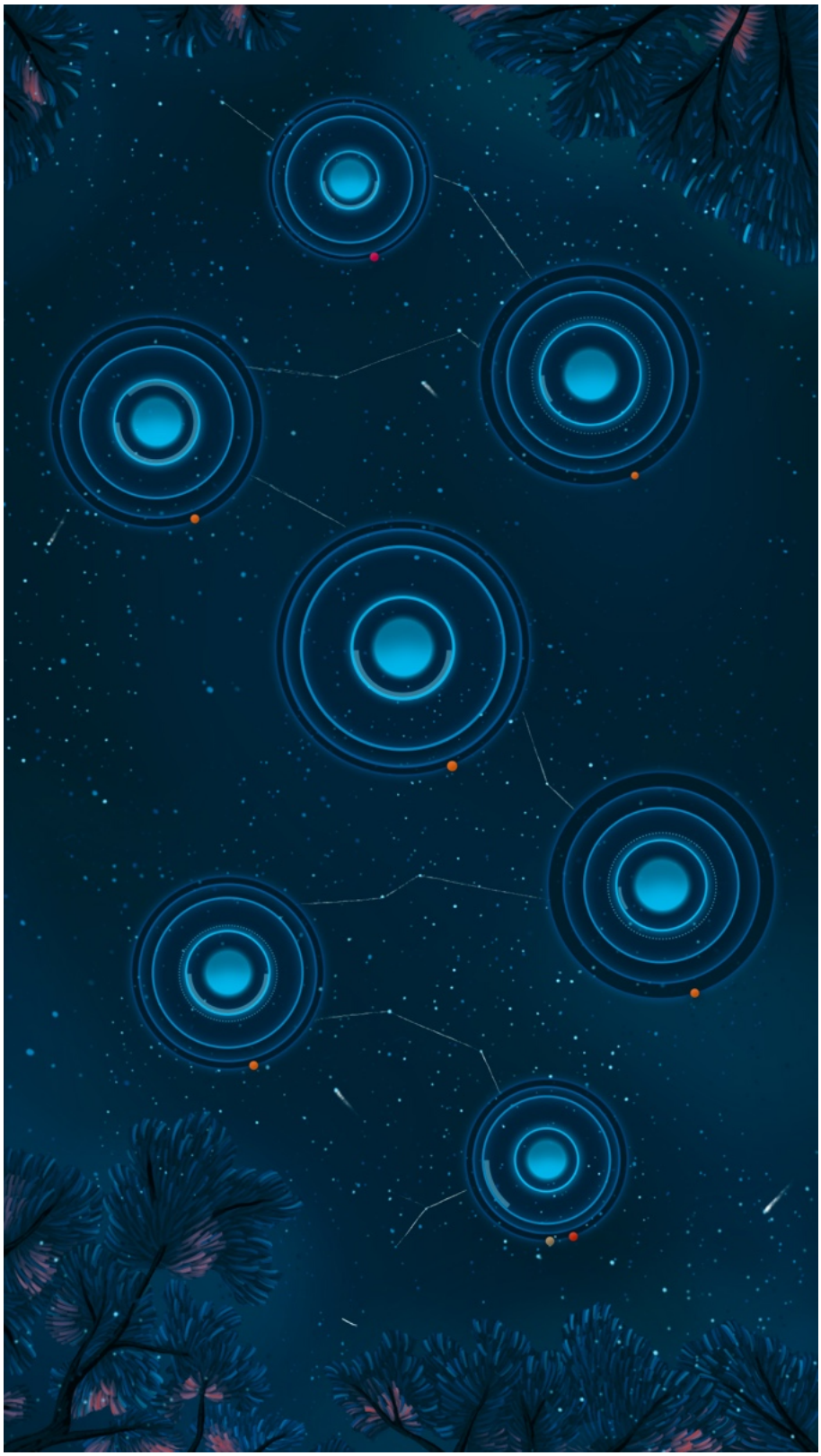

Figure 64: Restoration visualization design ambient state, prototype four.

Figure 65: Restoration visualization design interactive state, prototype four.

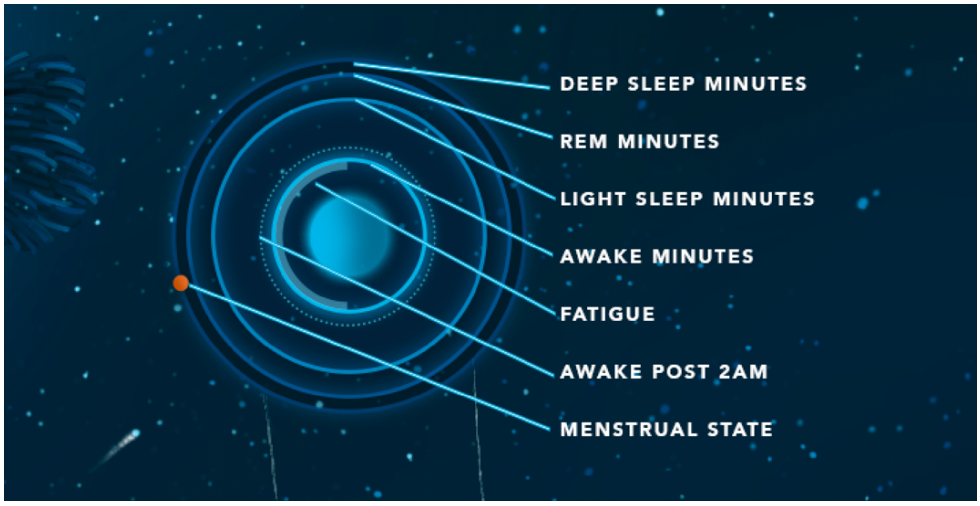

Figure 66: Restoration visualization explanation diagram, prototype four.

APPENDIX K: SOFTWARE

Wireframing & Prototyping

Adobe XD

Illustration

Procreate for iPad Pro

Design

Adobe Illustrator, Adobe Photoshop

Motion Graphics

Adobe After Effects, Adobe Photoshop

Data Sorting

Microsoft Excel

Data Visualization

Tableau, D3.js