Omnisense: Home-based passive health monitoring system

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Product Brief

Our goal for this project was to explore passive methods of collecting meaningful health metrics in the home environment. We sought to design a system that provides users intuitive access to a wealth of health-centered visualizations, projections, and suggestions. The intention is for users to supplement their personal aspirations to maintain or improve their health using the diverse data set collected by various sensors throughout the home. Users can access highly personalized health summaries using an array of human-centered interfaces. To provide users with a customizable experience, we intend for users to experience Omnisense through a variety of interfaces ranging from wall projections to holograms integrated within a smart watch. Our company allows users to purchase a series of biometric sensors designed to seamlessly integrate into their existing homes. Omnisense is rather unique in that it minimizes user involvement by maximizing the use of strategically placed sensors that collect data as the user carries out their day. These sensors are tuned to detect changes in key environmental parameters along with changes in key human health dimensions. Overall, this system is designed to support users in identifying the deficiencies leading to their health issues and guiding them towards solutions for a healthier lifestyle.

Background on Issue & Project Motivation

Through technological advancements and medical research, humans are continuously finding new ways to become healthier. While we have made significant strides in recent history, there are certain issues related to health and overall wellness that affect a significant portion of people today. Some of these issues include obesity, fatigue, stress, lack of energy, lack of focus, and poor sleep quality. For many people who experience these problems, it can be hard to pinpoint the exact cause of these issues and how to solve them.

One way to help determine the cause of health and wellness issues is through health metrics. These metrics, such as iron and cholesterol levels, can be determined through a variety of methods (e.g, blood test, urinalysis, stool culture) and can reveal the reason behind the negative symptoms that people experience. With a cause identified, people are better able to work towards a solution to improve their health. Unfortunately, these tests typically require a visit to the doctor and many people don't make the trip because of the time, money, and effort that it would take. What if we could integrate health metric collection methods into the everyday home, and potentially even into humans themselves? What benefits would come from having this data constantly monitored as opposed to only during the occasional trip to the doctor?

User Profile, Psychology and Needs

1. Elderly user who wants to recover from an illness
    - Name: Reginald “Reggie” Weathers
    - Age: 78
    - Location: Queens, New York
    - Sex: Male
    - About: Reggie knows he’s not getting any younger and has been getting sick rather often. He grew up in a time where healthcare was largely in doctors’ hands. The shift towards personal, democratized healthcare places him in unfamiliar territory. However, Reggie recognizes that the times are changing and is willing to introduce new technologies into his life. His aim is to have new personal health technologies help him gain some autonomy over his well-being.
    - Behavioral Considerations: Reggie received an Apple Watch for his birthday last year and has been testing out some of the available health features. He is now familiar with using digital interfaces to access his health metrics.
    - Frustrations: He would prefer a more holistic approach to his personal healthcare, something his Apple Watch can’t quite provide. Reggie also gets a bit frustrated when he needs to frequently call his doctor’s office to provide updates on his health developments.
    - Goals: Reggie wants a comprehensive healthcare solution that gives him the exact information he wants, when he wants it. He would prefer a solution that does not require him to remember to wear something on his body.
    - Relevant Features: Given his unstable health condition, Reggie wants to be notified of the changes in his health that the system detects. Additionally, Reggie’s concerned daughter would like to be informed on drastic changes to his health or any life-threatening symptoms so she can help as quickly as possible.
        - Health notifications (via app, etc.)
        - Notification sharing (e.g. family members)
        - Emergency protocol

2. Average individual with average health
    - Name: Gerald Dunne
    - Age: 55
    - Location: Cambridge, Massachusetts
    - Sex: Male
    - About: Gerald is a middle-aged man who is generally pleased with his current health status and has no specific aches or illnesses that affect his lifestyle. He realizes that he's getting older and wants to take measures to maintain his health and physical abilities. When he is not at work, Gerald is often looking after his two young children. Additionally, Gerald is the primary provider for his family and does not have spare time to go out of his way to better his health.
    - Behavioral Considerations: As a computer engineer, Gerald is knowledgeable about the backend of technology, but he has difficulty navigating the ever-changing interfaces or using voice commands like Siri or Alexa. Gerald would prefer a system that does not need him to self-report (e.g. meals, mood, workouts) and provides a frictionless experience.
    - Frustrations: Gerald has not had any success with other mobile health-tracking apps as he frequently forgets to input a meal or a workout. He often forgets to put on his wearables as well, including his Fitbit. Furthermore, he did not feel he could trust the analyses and suggestions that these apps provided given that they did not get a "full picture" of his health and lifestyle.
    - Goals: Gerald would like a system that could inform him about his health without interrupting his busy life and without the need of constant inputs. In the future, Gerald wants to take a proactive and preventative approach to his healthcare.
    - Relevant Features: Given Gerald's busy lifestyle, he values the passivity of data collection within our system. Although Gerald may occasionally want to dive deeper into his health metrics, he generally prefers a digestible summary of information that he can understand quickly.
        - Customized health summary
        - Passive data collection
        - Health abnormality predictions

3. Healthy individual with specific health goals
    - Name: Athena Harlow
    - Age: 24
    - Location: San Francisco, California
    - Sex: Female
    - About: Athena is a young professional who is training for a marathon in her spare time. Though she frequently participates in the 5K race that occurs in the city, the marathon will be the longest race she has ever run in her life thus far. Having grown up around technology, Athena is comfortable using technology in her day-to-day life including during her runs (i.e. run time, distance, route, heart rate, etc.) Athena is a marketing coordinator at a tech startup in the Bay Area for work.
    - Behavioral Considerations: Athena sports an Apple watch that connects to her smartphone and Airpods. Since she charges everything overnight, she is unable to gather any sleep data with these devices. She is excited but a little anxious for her first marathon race and would like to track her health information in preparation.
    - Frustrations: Between the cost of living in her area and her low salary at the startup, money is tight. As a young and healthy individual, health insurance is not a priority for Athena but she feels that this limits her access to important health information that could inform her training. Athena would benefit from a system that allows her access to her own information without the costly visit to a doctor.
    - Goals: Athena would like an all-encompassing healthcare system that shows her what foods work best for her body and provides a personalized exercise plan for her marathon goals. Athena is scheduled to run the marathon in one year.
    - Relevant Features: Since Athena is very conscientious about her health and motivated about achieving her health goals, she wants as much information as possible. Specifically, she wants to be provided with recommendations for ways to optimize her health and achieve her fitness aspirations. She also wants the ability to view her health metrics at the most granular level.
        - Customizable health goals and health plan
        - Health and fitness recommendations
        - Ability to view metrics at granular level

Task Analysis

Link to Miro with Task Analysis here.

Task Analysis for "Being Healthy" without our System

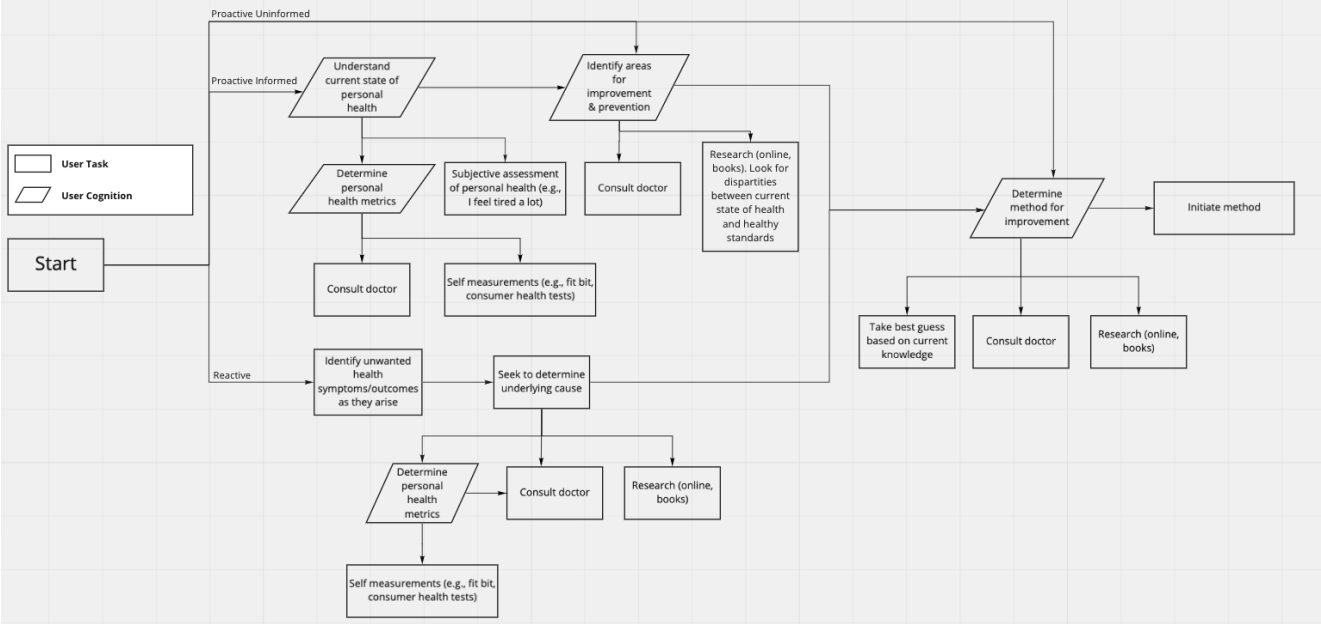

Figure 1: Task analysis for "being health" without Omnisense

Notes: This task analysis reveals three primary paths that people could take to achieve health. We referred to these paths as "Proactive uninformed," "Proactive informed," and "Reactive." We determined that while the "Proactive uninformed" and "Reactive" paths were not the ideal paths to achieve health, these are the paths that most people tend to take. The "Proactive informed" path is ideal because it involves people acting before something bad happens (sometimes before it becomes too late to intervene) and making educated decisions (removing the guesswork). However, significant roadblocks stand in this path; understanding the current state of your personal health and determining personal health metrics at a comprehensive level is very challenging and tedious for most people. Through our system, we hope to make the "Proactive informed" path more feasible, namely by providing a way for people to understand the state of their personal health by looking at important personal health metrics.

Task Analysis for "Being Healthy" with Omnisense

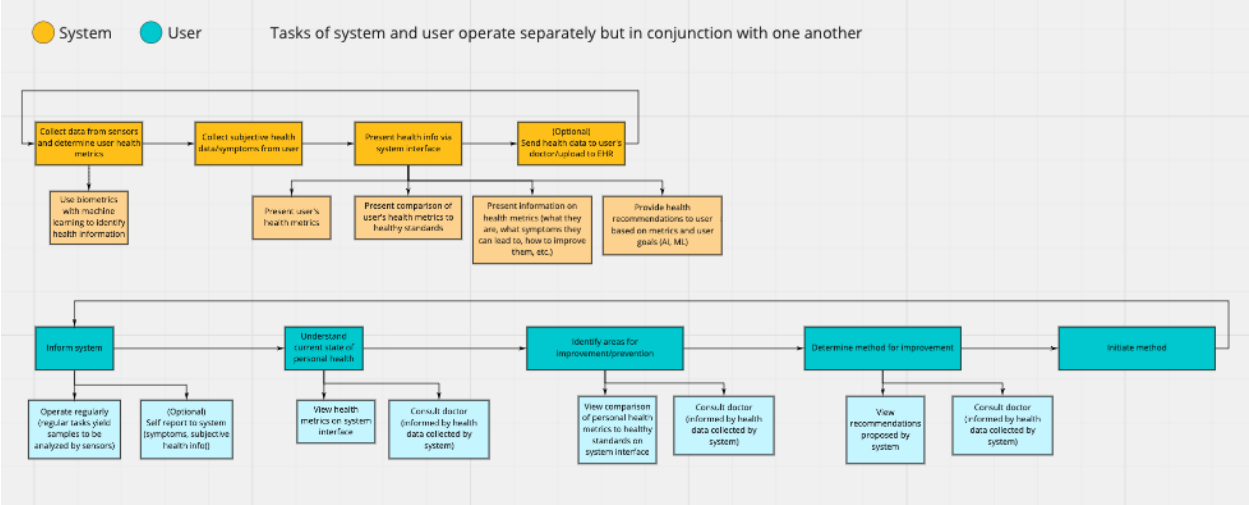

Figure 2: Omnisense Task Analysis

Notes: As indicated in the image above, the tasks of the automated system and the user operate separately but in conjunction with one another. The automated system serves to collect health data from the user and present it through the system interface. The data collection will involve the use of standard measurement procedures as well as advanced machine learning techniques that are currently on the rise. The system interface will present information such as the user's health metrics, a comparison of the user's health metrics to healthy standards, information about each metric, and health recommendations based on the data.

On the user side of this system, all the user has to do is act out their life as they normally would; the system collects data based on common daily tasks. Once data is collected and presented in a useful and digestible fashion, the user is free to follow the steps of the "Proactive informed" path of achieving health.

Solution Description

Users have the option to decide the number of sensors they would like in their homes as well as their locations (e.g. toilet, shower drain). Though multiple sensors in each room would help paint a fuller picture of health, a user may opt for fewer sensors depending on the health metrics they want to track, their fitness goals, and their budget. Once sensors are installed in the desired locations, Omnisense works automatically and will begin to track health data. See Appendix A for a list of metrics Omnisense can track.

Omnisense allows for multiple users to interact with the system as well. During setup, the user will have to create an account for themselves and any other dependents in the household, such as young children. Users will initially be asked to provide some identifiers and basic characteristics via the mobile app so Omnisense can differentiate collected data between the different users and map health metrics to the appropriate profile. This functionality allows individuals, like parents, to monitor the health of their loved ones who may be unable to track the data themselves.

Using the mobile app, users can track the status of the sensors as well as view their health metrics and health recommendations. In the future, we anticipate this interface to have evolved to include displays on bathroom mirrors (see Figure 3 below) and holograms on wearables (e.g. Apple Watch). We also expect the interfaces could easily transfer displays from one “device” to another. This feature may be useful if the user wanted to take a closer look at the metrics they saw on the bathroom mirror that morning on their smartphone on their way to work. When technology has evolved to support this, we also foresee an optional on-body monitoring device such as a smart patch or implant that can get more insight on the user’s health through blood tests.

Figure 3: Example of Future Bathroom Display

System Design and Implementation

Constraints & Requirements

At the beginning of our project, decided on a few key constraints and requirements:

- The solution must allow for passive health monitoring; the user should not have to manually input their health data to use the primary service of the system
- The solution must have an interface component
- The solution must provide insight into the overall wellness of the user
- The solution must be easy to use for users with a wide range of technical abilities
- The solution must be reasonably affordable for the average homeowner/renter
- The solution must integrate into the user's life without any major disruption in lifestyle

These constraints helped guide our brainstorming sessions in which we tailored our final version of Omnisense to meet these requirements.

Information Architecture

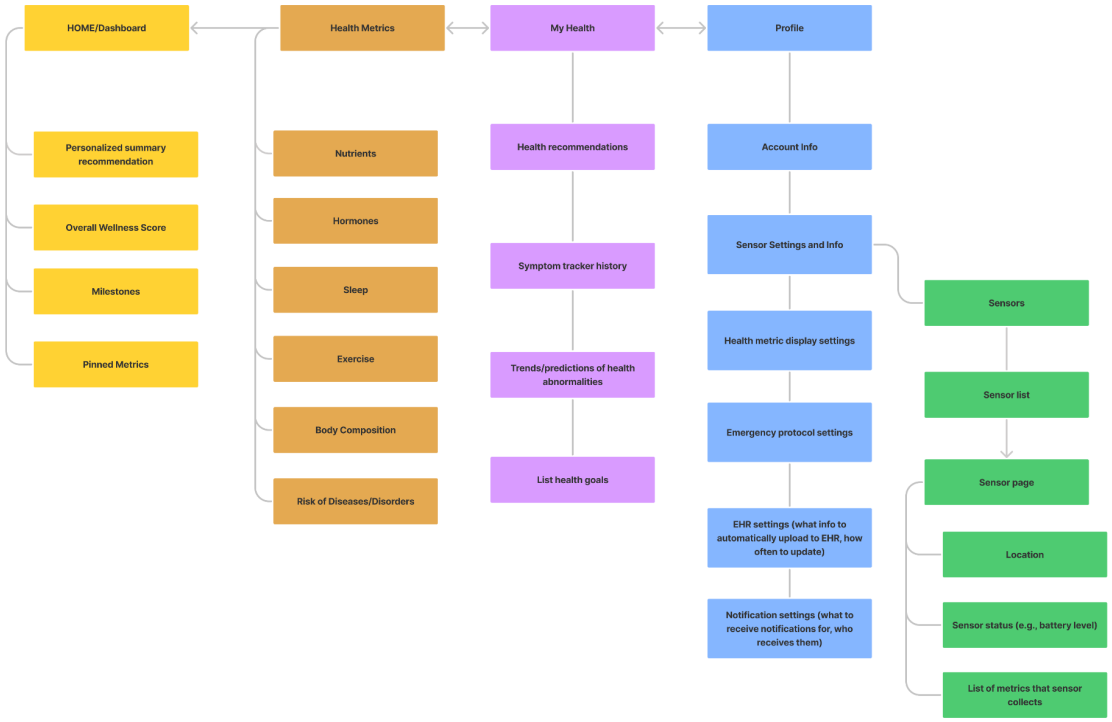

Figure 4: Information Architecture of the Omnisense Application

Final Interface Designs

Link to Figma with final interface designs here.

We have attached a few screens that best showcase the main features in the application, as well as a link to some higher-resolution images.

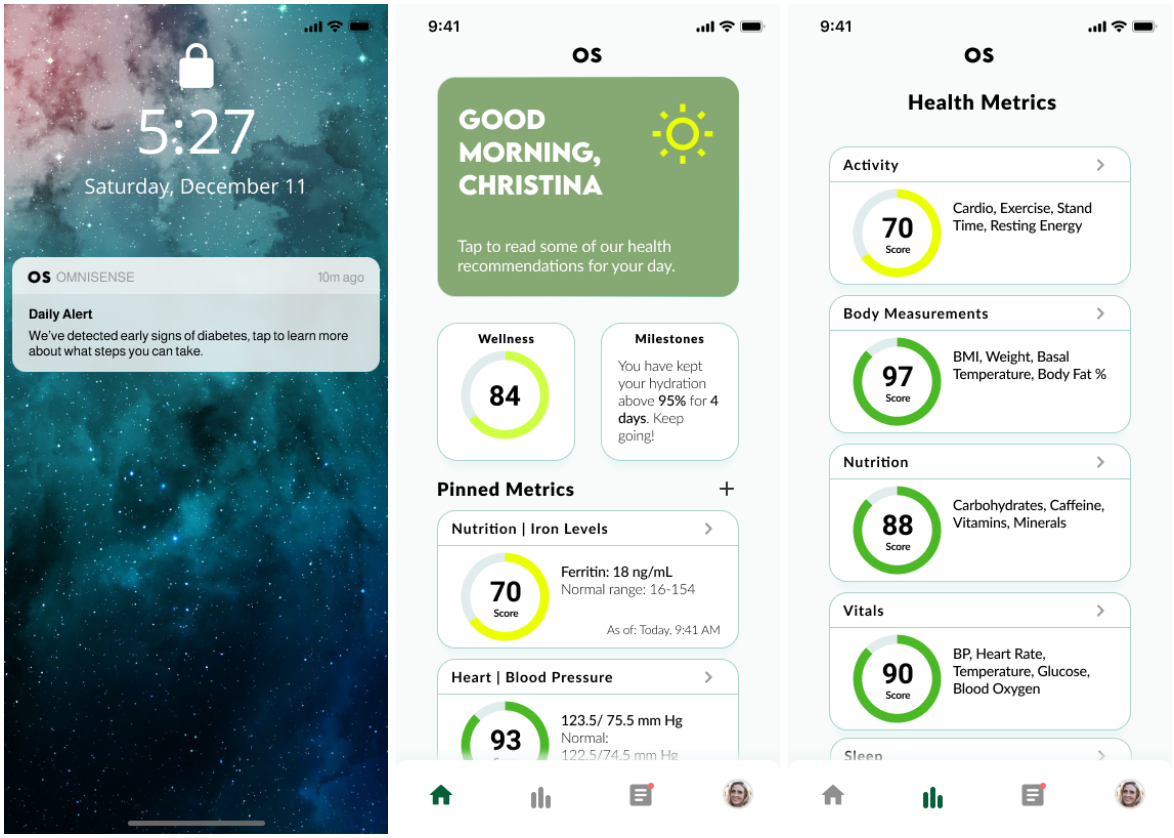

Figure 5: Interface Mockups

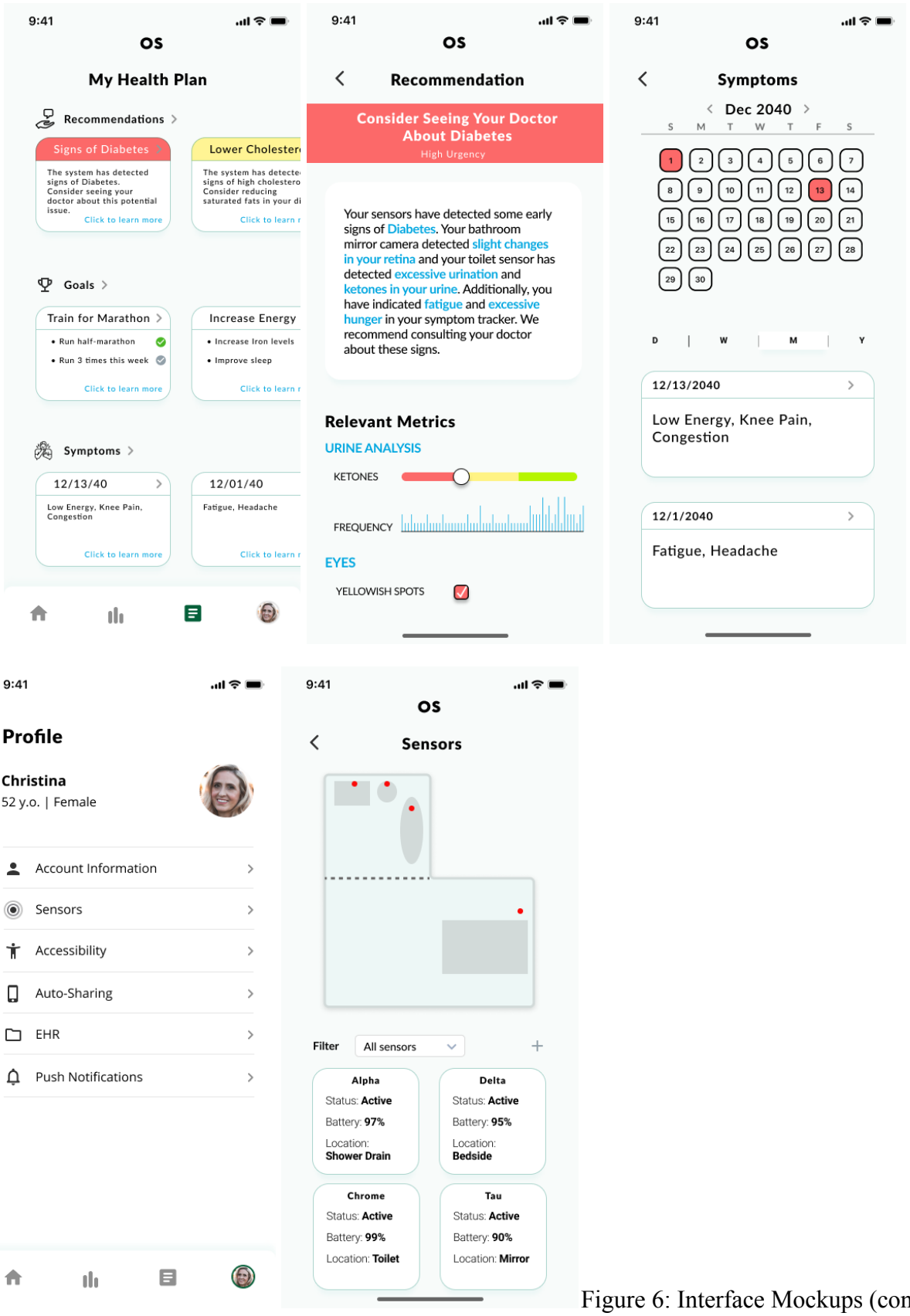

Figure 6: Interface Mockups (cont.)

Description of Interactions

The data collection aspect of Omnisense will require minimal interaction between the system and user. The user can operate in a normal fashion and go about their day-to-day lives while the sensors collect health data passively and automatically. The only effort on behalf of the user would be the optional manual entry of symptoms.

Using multiple different sensors, machine learning algorithms, and basic identifiers (provided by user in setup), Omnisense has the ability to recognize individual users and distinguish them from one another. Consequently, this system will allow for multiple different users in the same household.

Once data is collected, Omnisense has many opportunities for customization that empowers the user to take control of their health. These include the quantity and placement of sensors around the home, fitness or health goals for personalized recommendations, the ability to “pin” specific metrics on the mobile app, and system settings (i.e. notification sharing, emergency protocol).

User Walkthrough

Gerald is a 55-year-old man who is generally healthy but has recently decided to be more proactive about monitoring his health. He and his doctor have discussed that he is approaching the age where the risk of heart attacks, high cholesterol, and diabetes increases. While he is not a fan of health-wearables because he forgets to put them on, he decided to try out Omnisense because a good friend recommended it.

After browsing through the Omnisense website, Gerald settled on a starter pack that met his needs and had it shipped to his home. Once it arrived, the set-up process was generally intuitive – the environmental sensors all had diagrams and instructions for where to install them around his home and the onboarding process on the app only took a few clicks for him to set up an account. After calibrating the sensors using the app, Gerald was able to go about his day and forget about the whole thing! The next morning, after his daily wake-up routine, he received a notification on his phone from Omnisense: his overall health score was 93, he was a little dehydrated, he had a good night of sleep, and all his vitals were normal. His day was off to a great start and he didn't have to lift a finger.

Flash forward a couple months and Omnisense is now seamlessly integrated into Gerald's life. One afternoon, he receives a notification from the app alerting him to the detection of early diabetes in his system. He decides to follow the recommendation to visit his doctor for consultation. Once there, his doctor can open Gerald's electronic health record and view the data compiled by Omnisense. With all this detailed information at his disposal, the doctor can create a tailored health plan for Gerald to follow, and he is able to track his progress right from the app. At the recommendation of his doctor, he decides to include an Omnisense smart patch into his collection of data sources, and is able to painlessly attach the patch on his arm by himself. This change will help Gerald have even greater insights into his health status and allow Omnisense technology to detect future diseases earlier, so that Gerald can live a longer, healthier life.

Documentation for Operation

Get Started with Omnisense

- Step 1: Download mobile app
- Step 2: Create an account
- Step 3 (Optional): Go to Profile and Account Information to create accounts for dependents (e.g. young children)
- Step 4: Provide basic health identifiers, such as sex and age, so Omnisense can match metrics to the correct profile
- Step 5: Install sensors in home
- Step 6: Go to Profile and Sensors to ensure sensors are activated & calibrated on mobile app
- Step 7: Live your best life – Omnisense is looking out for you and your family!

How to view your health metrics on Omnisense

- Step 1: Go to Health Metrics using navigation bar
- Step 2: Scroll down to see all health metric categories
- Step 3: Click on arrow > at top right for more granular data
- Step 4: Click on individual metrics to view metric description
- Step 5: Click **Pin Metric** to pin health metric to Home page

How to set/view goals on Omnisense

- Step 1: Go to My Health Plan using navigation bar
- Step 2: View goals on My Health Plan screen
- Step 3: Click on specific goals for more information

OR

- Step 1: Go to My Health Plan using navigation bar
- Step 2: Click on Goals to view full Goals screen
- Step 3: Click on Filter to view all goals, current goals, or completed goals
- Step 4: Click on specific goals for more information

How to view recommendations on Omnisense

- Step 1: Go to My Health Plan using navigation bar
- Step 2: View recommendations on My Health Plan screen
- Step 3: Click on specific recommendations for more information

  OR

- Step 1: Go to My Health Plan using navigation bar
- Step 2: Click on Recommendations to view full recommendations screen
- Step 3: Click Filter to view recommendations based on overall urgency or specific health goals
- Click on specific recommendations for more information

How to report/view symptoms on Omnisense

- Step 1: Go to My Health Plan using navigation bar
- Step 2: Scroll down and view symptoms displayed on My Health Plan screen

  OR

- Step 1: Go to My Health Plan using navigation bar
- Step 2: Scroll down and click on Symptoms
- Step 3: Click Add Symptom or view history of symptoms over weeks/months/years

Future Directions & Limitations

In line with the nature of this assignment, much of Omnisense hinges on technology yet to be developed. Despite this, we believe that the fundamental technology supporting our health monitoring framework is far from science fiction. We are in no way experts in the technical and scientific disciplines that underlie our passive health monitoring system. However, we would like to present our thoughts on what steps would need to be taken to reach a future where this technology becomes feasible.

To begin, there needs to be further research into passive, environment-based methods of collecting human health metrics. Current environment-sensing technology is paving the way but suffers from reliably detecting biomarkers of interest. We also anticipate the need for advancements in health-oriented wearable technologies. Current initiatives to develop “smart clothes” and “smart accessories” are well underway. Health-minded shoppers have a growing selection of watches, rings, and bands to consider when shopping for a means to access various health metrics. However, more research is needed to develop high quality, minimally invasive wearable or implantable biosensors. Of course, we must also consider the behavior tendencies of our intended users. As such, it will be important for future health monitoring systems to reduce their reliance on users remembering to activate or use them.

Sensors capable of detecting a variety of human biomarkers are a cornerstone of our health monitoring system. Although technology in this space is rapidly developing, it will be decades until its accuracy and reliability is robust enough for mass market applications. Juhan Sonin, leader of GoInvo, is an outstanding talent driving the shift towards electronic health records and passive means of collecting health data. The downstream scalability of Omnisense may also be impacted by developments in cloud data storage. We anticipate our sensors collecting vast amounts of health data, so there needs to be an effective and safe method of storing huge data sets for thousands of customers.

We conclude with a discussion of potential public concerns that may impede widespread, enthusiastic adoption of passive health monitoring technologies. Firstly, public concerns over the

security of data storage have reached new heights. People recognize that companies already have access to enormous amounts of their personal data, so they might be hesitant to introduce more sensors into their lives. Then there is the public concern of who should have access to an individual's electronic health record. Omniverse can provide healthcare physicians and family members with near real-time updates on someone's health status. Although this is an optional feature, it still invites questions about how much privacy users are willing to depart with to have exceptional access to key health metrics.

Appendices

Appendix A: List of Health Metrics tracked by Omnisense

Personal Health elements (from blood test):

- Nutrients
  - Macro
    - Proteins
    - fats
    - carbohydrates
    - water
  - Micro
    - vitamins (Vitamin panel test)
      - Vitamin A
      - Vitamin C
      - Vitamin D
      - Vitamin E
      - Vitamin K
      - Vitamin B1 (thiamine)
      - Vitamin B2 (riboflavin)
      - Vitamin B3 (niacin)
      - Pantothenic acid
      - Biotin
      - Vitamin B6
      - Vitamin B12
      - Folate
    - minerals (mineral panel test)
      - Macro
        - Sodium
        - Chloride
        - Potassium
        - Calcium
        - Phosphorus
        - Magnesium
        - Sulfur
      - Trace
        - Iron
        - Zinc
        - Iodine
        - Selenium
        - Copper
        - Manganese
        - Fluoride
        - Chromium
        - Molybdenum
    - antioxidants
- Blood count
- Hormones
  - Insulin
  - Thyroid hormones (T3, T4, TSH)
  - Estrogen
  - Testosterone
- Cholesterol

Personal Health elements (from passive sensors):

- Weight and Body Composition
- Swelling
- Sleep
- Exercise capacity
- Heart rate and heart rate variability
- Blood flow
- Hormones
  - Cortisol
- Changes in skin color
  - Risk of variety of disorders, diseases and conditions, including inflammation, malignancy (cancer), organ failure, allergies, and infections (changes in skin color)
- Eyes
  - Diabetes (changes in retina)
  - Cognitive decline (blood vessel size)
  - High cholesterol (yellow or blue ring around cornea
  - Thyroid disease
  - etc.
- Hairline (risk of thyroid disease)
- Voice
  - Parkinson's
  - coronary artery disease
  - depression, ADHD
  - Concussion
  - Cardiovascular conditions
  - PTSD, TBI
- Hair follicles
  - hair mineral analysis
- Urine
  - UTI, kidney disease, diabetes
  - Acidity, concentration, protein, sugar
- Stool
  - infections
  - poor nutrient absorption
  - cancer

Appendix B: Sources Used for Background Research

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2. https://www.bbc.com/future/article/20190116-the-invisible-warning-signs-that-predict-your-future-health
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