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Wearables and Wearable Data in Tele-Health Applications

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WEARABLES AND WEARABLE DATA IN TELE-HEALTH APPLICATIONS

By
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ABSTRACT

Wearables and Wearable Data in Tele-Health Applications
(Under the direction of Charles Walter)

With the sudden emergence of Covid-19, Tele-Health has been forced into the forefront of healthcare. With no human contact, regular in-person doctor or clinic visits could not be made. Unfortunately, there is a gap in patient data for healthcare professionals when making diagnoses remotely. Fortunately, many users are constantly collecting some primary health data through wearables that have become commonplace in users' homes. Tapping into this unused data could provide healthcare professionals with a better picture of patients' health remotely. In this thesis, I will determine whether this wearable data can be a viable addition to Tele-Health applications, providing additional information to healthcare professionals when making a diagnosis remotely.

I hypothesize that wearable data would help patients and healthcare professionals in Tele-Health applications. To that end, I distributed an online survey to medical professionals at the University of Mississippi and the University of Mississippi Medical Center. Respondents were asked a series of questions about Tele-Health, if they wore wearable devices, trusted the data gathered from said devices, if they would recommend wearables to patients, and use the data to make diagnosis decisions. The results showed overwhelmingly that healthcare professionals believe wearable technology could greatly aid the Tele-Health communications process for both patients and healthcare workers alike. The addition of the data could help many diagnoses be more accurate and give patients better care. Overall, wearable data has a promising future in aiding Tele-Health for many years to come.

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<u>Introduction</u>

For centuries healthcare has required face-to-face, in-person interactions to diagnose patients' ailments. Most exchanges took place in either a doctor's office or through home visits, allowing doctors to take some basic measurements of the patient to diagnose their condition better. However, now that technology has reached a point where sensors the size of a quarter are highly accurate and capable of measuring various health metrics (Dunn, 2018). These small wearable sensors have allowed remote patient monitoring and practices such as Tele-health to rise to popularity, making things like house calls obsolete. Most patients and doctors alike are comfortable communicating and conducting visits using non-traditional methods (Frist 2015). This new technology can shape the future of healthcare and how patients receive diagnoses for the foreseeable future.

It is important to delineate between Tele-Health and Tele-Medicine. While often used interchangeably, the two have very distinct definitions. Tele-Medicine refers to the clinical actions of providing care over a distance by using technology (Darkins, 2005). Tele-health encompasses "education for health, public and community health, health systems development and epidemiology," and other means of promoting health via technology. In other words, Tele-Medicine is the clinical subset of the broader entity Tele-Health (Darkins, 2005)

With the sudden onset of Covid-19, a highly transmittable disease, the need for remote diagnoses and accurate data collection has never been more apparent. While current Tele-Health

systems rely primarily on patient accounts, patients are not always reliable sources of information about their health. Thus, using wearables (which are rapidly becoming ubiquitous) as a means of collecting patient health data remotely to provide additional information to medical professionals may provide more accurate and safer methods of remote diagnosis.

Tele-Health as an application and concept is very new when it comes to personal devices. With the rapid introduction of the Covid-19, many patients could not go to physical doctors' offices, or they were quarantined with the virus itself. Thus, Tele-Health applications were used in place of face-to-face visits with relative success. However, the Tele-Health applications are not capable of delivering the type of patient data that would be accessible in an office. Doctors cannot understand the patient's condition beyond what the patient can describe. With the introduction of powerful wearable devices such as the Apple Watch, significant improvements to remote health monitoring have emerged. Wearables have the power to gather a staggering amount of data for a patient in day-to-day life that can help healthcare providers get a better picture of the patients' state over a video call. To find out if this collected data would be helpful to doctors and patients alike, I created a survey that is aimed towards analyzing current Tele-Health applications, their effectiveness, how they are perceived by the medical community, if wearable device data should be a part of Tele-Health, and how wearable data can improve Tele-Health for the future. I use the data collected to develop a proof-of-concept app to record and provide doctors with this medical data to show wearable data's viability in existing Tele-health applications.

<u>Background</u>

The concept of healthcare coming to the patient is nothing new. Doctors have been dabbling with the idea since the late 1800s. The idea of using the telephone to reduce unnecessary visits or diagnosis via radio was tried nearly 100 years ago. (Institute of Medicine 2012) The biggest motivator for at-home monitoring is chronic disease, which accounts for almost 75% of healthcare expenditures. The VA (Veterans Affairs) in the early 2000s released a program to increase at-home patient monitoring with new technologies, which reduces hospital visits, readmissions, and costs for many patients who were enrolled in the program. With the advancement of technology in recent years, the concept of Tele-Medicine has become very feasible. Tele-Health has become a viable way to do healthcare with widespread access to wearable monitoring devices in the mass market.

This thesis focuses on the use of new technologies like wearable devices to aid with Tele-health applications. A common mass-market example is the Apple watch which is readily available with accurate sensors and many functionalities. This study aims to highlight current shortcomings in current Tele-health solutions and improve upon them. While also giving the doctors and professionals making diagnoses more data to go off of when diagnosing patients. They help with more accurate treatment and give the patient better overall care because the data aids with their specific situation.

With the current state of the world, Tele-Health is needed more than ever with limited human contact due to COVID-19. With such little in-person contact and data gathering,

the more important it becomes that more patient data is available to help doctors on Tele-Health applications. The additional information is why wearable data is crucial to the advancement of Tele-Health. With the ever-increasing digital world, readily available health data about patients for remote doctors is imperative to maintain a level of care and precedent set with in-person consultations. The virtual care would save patients money and time from having to travel to a doctor's office, wait, and then actually see the doctor. Tele-Health would also reduce unnecessary hospital visits, save hospital space, and time of staff for patients who are in more critical condition. Overall a transition to more accurate Tele-health with better remote data benefits all sides in the healthcare equation and will be the future of the health system.

A huge reason for the increase in popularity in Tele-health and wearable devices is the massive advancements in technology. The sensors of new wearable devices are very accurate and easy to obtain for a member of the public. "Over several days of comparing my second Apple Watch's measurements to my FDA-approved finger oximeter, Apple's readings most often differ by two or three percentage points — though they've also sometimes exactly matched, and sometimes have been as much as seven percentage points lower." (Fowler 2020) The fact that a device with so much capability, not just blood oxygen readings, is accurate within a small margin of error is very impressive. That same device can also read ECG heart sinus waves with surprising accuracy. Apple compared the "ECG app on Apple Watch to a standard 12-lead ECG taken at the same time, there was agreement between the ECG app classification of the rhythm as sinus or AFib compared to the standard 12-lead ECG."(Apple 2021) The types and amount of data this small, relatively affordable device can measure and put into a digestible format is what Tele-health needs to take the next step to become mainstream in the market.

Tele-health apps with wearable data that is accessible offer improved convenience, expanded access, and reduced cost. However, that would mean nothing if the standard of care was compromised. Numerous studies have shown that patients prefer virtual visits and that it was on par with in-person visits, if not better than those typical in-person visits (Topol, 2015). For example, Topol's 2015 study of teleconsultation with genetic counselors exhibited that teleconsultations were just as effective as in-person consultations. The Bashshur et al. (2015) study on Tele-Medicine intervention in diabetes management pointed to positive effects of telemonitoring and telescreening in glycemic control, reduced body weight, and increased physical exercise. The study found a solid and consistent correlation if evidence with improved glycemic control among persons with Type 2 diabetes along with effective screening and monitoring of diabetic retinopathy. This example corroborates the future of medicine with the correct tools and data that can be remote via Tele-Health applications with wearable monitoring devices.

There are three types of Tele-Medicine: 1) store-and-forward, 2) real-time, and 3) remote monitoring (Lyuboslavsky, 2015). Store-and-forward refers to electronic transmissions of medical information with a security protocol, such as images, documents, and videos. An example is a patient taking a picture of an inflamed joint and sending it to a Rheumatologist. The recipient on the Tele-Health app can then review the transmission and send back a diagnosis and treatment plan. This cuts down on cost and time because a simple issue was diagnosed and treated with two remote interactions versus an in-person visit. Real-time Tele-Medicine occurs when patients and providers are in separate physical locations but communicating via telephone, video, or radio with one another in real-time. This is what many people view as the status quo for Tele-health applications. This is closest to a traditional face-to-face visit but does not provide as

many efficiency benefits as store-and-forward. Remote monitoring involves the use of sensors for wearables to track patients' body function and behavior. It gives clinicians a deeper look into a patient's health and gives a better idea of what is going on. This leads to better and more accurate diagnoses. One example is a cardiologist analyzing data from a patient's Apple Watch that had ECG capability and viewing the sinus wave graphs over a period of time. Remote monitoring faces the most challenges with reimbursement but is becoming more popular with the rise in popularity of wearable fitness devices (Lyuboslavsky, 2015).

Non-traditional Tele-Health partners. Many companies that are in the IoT realm are noticing the benefits of Tele-Health and remote patient monitoring. For example, local service providers and ISP C Spire have in-house Tele-Health that patients can meet with medical providers from UMMC (University of Mississippi Medical Center). Patients can remotely call a doctor and have a conversation about what is ailing over the C Spire app. The patient can receive diagnoses, prescriptions, and much more from this. This is especially beneficial to rural communities that have less access to care. (McLeod 2018) Furthermore, with Mississippi having a substantial rural population and being one of the worst states in broadband ranking in the U.S. (C Spire 2021,) Tele-health makes a lot of sense for a company trying to provide and make the state better.

In McLeod's thesis, the writer discusses how Tele-Medicine can help improve care for Mississippians and goes into the technology's capabilities. It also analyzes some current solutions to the issues in Mississippi and how effective they are. It touches on the many benefits of remote interactions with patients and how it is beneficial to medical professionals and patients. It offers an interesting analysis of Mississippi's healthcare problem and a good solution and analysis of a solution to the problem. The writer did not obtain their own data on the subject;

she used data from a credible source, but the data was difficult to comprehend. This paper is helpful because it gives a good insight into the benefits of Tele-Health, the history, and the technical definitions of the area to help clarify the common misunderstanding. Such as the difference between Tele-Health and Tele-medicine. Besides, the paper does not work for this research because it focuses on how Tele-Health can be improved with wearables and wearable data. In contrast, their research is analyzing the local benefits of Tele-Health in counties of Mississippi. It is an analysis of current Tele-Health usage and effectiveness where this research aims towards the future of the emerging technology and how to improve it. Wearable data in Tele-Health would help improve the current care given to many in rural Mississippi due to the lack of available doctors.

In *Wearables and the medical revolution* Jessilyn Dunn, Ryan Runge, and Michael Snyder analyze how the wearable device is being used in a hospital setting and how wearables that are specifically designed for health monitoring are being used in current environments. The authors dive into the types of care the wearable technology can impact, such as prenatal care, sleep, neurology, mental health, and much more. The paper did an excellent job describing current use cases in many health sectors, some of the current government oversight with the technology because it is new, and some challenges and what the future holds for this up-and-coming technology. It doesn't dive much into the main market or commercial wearable technology such as smartwatches. Devices that the public would have access to not specific medical devices for monitoring. In that regard, this paper does not help this research because it measures the impact on Tele-Health of devices that the public can quickly obtain, such as the Apple Watch or other similar devices.

The Research *Wearable Devices in Medical Internet of Things: Scientific Research and Commercially Available Devices* by Mostafa Haghi, Kerstin Thurow, Dr. Ing. Habil, Regina Stoll, Dr. Med. Habil the authors dive into the MIoT (medical internet of things) with wearables being at the forefront of that, especially now that semiconductors inside sensors are becoming more advanced. Their focus was to identify the best commercial and scientific devices for the application of Tele-Health and in the MIoT. The research focuses on tracking types and what devices are best for tracking, such as motion, vital signs, etc. They then dive into the challenges and bottlenecks in the MIoT world. This paper helps identify the commercial devices that are viable for integration into MIoT based on their sensors. However, the devices chosen were not as capable as the newest Apple Watch 6. The research also does not show how the data can be useful in the Tele-Health scene; this is more focused on the hardware side. It shows that while this field is still new, more and more people are looking to wearable devices as the next step for the technology.

Survey Design

To examine how the current medical community views wearables' place in Tele-Health, I created a survey designed to examine the specific uses wearables may have in Tele-Health, as well as the respondents' views on the useful of wearable data in Tele-Health diagnoses. The survey was intended for medical professionals who have worked with patients and current Tele-Health applications. The survey, distributed to medical professionals at the University of Mississippi Medical Center and other medical professionals who work at the University of Mississippi, was a short (10 to 15 minutes) survey to get participants' feedback on current Tele-Health practices and how to improve Tele-Health for the future with wearable data and devices. The survey asked participants to answer questions about their attitude towards wearable devices, if they wear wearables themselves, and if respondents view wearables as reliable sources of health data. Respondents were asked how the use of wearable data could improve the level of care for remote patients, if wearable data would help aid Tele-Health diagnosis, and if they feel wearable data is the future for Tele-Health. Also, feedback on how well current Tele-Health applications have been with identifying Covid-19 cases and getting those patients the care they need. Based on the responses from the survey and suggestions made by respondents, I built a proof-of-concept iOS application to demonstrate how this wearable data can help aid in the Tele-Health process.

Research Questions

To better understand the data, I collected from the survey, I formulated ten research

questions to help guide my analysis. These questions help answer my hypothesis about the use of

wearables in Tele-Health, while also flushing out survey analysis. The research questions guided

the creation of the survey questions and provided a common theme for the survey's analysis.

1. Does wearable data hold a place in Tele-Health?
2. Does age have an effect if wearable data and devices are trusted?
3. Would healthcare providers trust this data?
4. Do healthcare providers think wearable data is accurate when measuring health metrics?
5. What health data metrics are most important?
6. How well do current Tele-Health solutions work?
7. What devices should be used to gather wearable data?
8. Is Tele-Health the future of healthcare?
9. Would healthcare professionals promote wearables and encourage use?
10. How well does the wearable help give the healthcare provider a better image of patient health?

Research Question I: Does wearable data hold a place in Tele-Health?

The biggest question that the survey stands to answer is whether or not wearable data has

a place in Tele-Health. It will help me understand healthcare professionals' attitudes towards

both Tele-Health and wearables in today's current climate. The data and analysis from this

research question will determine if wearables belong or not.

Research Question II: Does age have an effect if wearable data and devices are trusted?

Another significant research question that the survey helps answer is whether age affects if wearable devices and data are trusted. Stereotypically, older generations are more wary and less familiar with technology as a whole. I asked this question to determine if this stereotype is consistent with aptitude and feelings toward technology in general and, more specifically, wearable devices.

Research Question III: Would healthcare providers trust this data?

Question three aims to gain an understanding of how healthcare professionals see wearable data as a diagnostic tool. It is possible that healthcare professionals may not want to use wearable data for diagnostics but would want to glance at it to confirm a suspicion. If the data is seen as trustworthy by users, it will more likely be used in final implementations. However, even if the information is provided, it does not mean much if the doctors do not trust and use it.

Research Question IV: Do healthcare providers think wearable data is accurate when measuring health metrics?

Research Question IV dives into whether the medical community views the wearable devices themselves as accurate measurements of health metrics. This ties to the previous research question about the wearable data itself. However, question 4 is more aimed toward the devices, as the data itself may be useful but the hardware may not provide enough accuracy to be used. The more precise the data and the more the community trusts it, the better the user experience will be for patient care and the more useful wearable data is in Tele-Health.

Research Question V: What health data metrics are most important?

Research Question V examines what health metrics from existing wearable data types (from devices like the Apple Watch) are most pertinent to the healthcare providers potentially using wearable data to make a diagnosis. The answer to this question can help guide decisions on what devices should be used for Tele-Health applications. This question, maybe more than any other, will help guide the development of the proof of concept application, to ensure the data the application uses match with what healthcare professionals believe is most important.

Research Question VI: How well do current Tele-Health solutions work?

In order to measure wearable success and use cases, I need a good baseline and understanding of where Tele-Health implementations currently stand among the medical community. Research Question 6 will focus on how well current Tele-Health solutions are working in healthcare. I can base my research for wearables on how today's Tele-Health solutions are. From what I find out about current solutions, I can find ways to improve existing Tele-Health applications. This will enable me to fine-tune how to deliver the wearable data effectively in a final product.

Research Question VII: What devices should be used to gather wearable data?

Answering this question gives me an idea of what devices are popular, are easily attainable, and have good data tracking ability. With these factors, I can focus the research and the solutions created into a particular device for the most significant effect.

Research Question VIII: Is Tele-Health the future of healthcare?

This question gives insight into how technology, wearables, and Tele-Health are viewed in the healthcare community while also providing ideas for new developments and possible improvements to the current technology. The future of wearables in Tele-Health in healthcare looks promising as wearables continue to improve and deliver more accurate data to those who need it.

Research Question IX: Would healthcare professionals promote wearables and encourage use?

This research question explores if healthcare professionals would promote and use wearable devices. This is important to understand if the healthcare community would encourage wearable use because if they recommend a patient receiving one from insurance, personal purchase, etc., that bodes well for the technology's future. If they are confident enough to recommend it, that also means they trust it and believe it is a reliable source of data. This will help show if wearables belong in Tele-Health.

Research Question X: How well does the wearable help give the healthcare provider a better image of patient health?

Something that current Tele-Health applications can not give medical professionals is a complete picture of patient health. This looks into how wearables can provide a more accurate description and illustration of patient health over time. Data over weeks and months before visits can be analyzed to give an idea of patient health before the patient speaks to a doctor. Yet again, circling back to why wearables would be valuable and viable in Tele-Health. They can show

health professionals if what they are doing is working and provide the data to give the best care possible.

Survey Questions

The survey questions are aimed to identify whether the participants have used or are knowledgeable about Tele-Health. Once that base has been established, the survey is designed to take feedback about current Tele-health practices, ask about wearable devices and data, and take feedback about what can be done to improve current and future experiences. Some questions were free-response questions that allowed participants to share their opinion for questions that posed greater challenges than the multiple-choice answers. However, most questions used a Likert scale, which enabled participants to accurately describe how they feel towards the question by selecting a 1 through 5 answer (1 being negative 5 being positive). All questions, and their response types, are available in Table 1.

Question 1 determines respondent age group and helps answer research question 2 by determining how seasoned a healthcare provider the respondent is and help correlate later answers on wearables and how they are viewed to age/length of career. Also, this question would be used to correlate age to other questions about Tele-Health and wearables. It bolsters research question 2's argument about age having an impact on trust and use of technology.

Table 1 Survey Questions

Question	Question	Response Type
1	What age group are you in?	Age Scale
2	Do you wear a smartwatch?	Yes/No
3	If you were to buy a smartwatch or already own one, what brand is it?	Free Response
4	As a medical professional which of these options are you most likely to look at from a Tele-health app?	Multiple Choice (Daily Activity, Steps, Calorie Burned, Diet, Heart Rate, Other)
5	How satisfied are you with your current Tele-Health app?	Likert Scale
6	How useful have current Tele-health solutions been when diagnosing and dealing with Covid-19?	Likert Scale
7	How confident are you in a diagnosis or a prescription if it is given via a Tele-health application.	Likert Scale
8	How beneficial would it be to have the additional data from a smart watch in a Tele-Health app?	Likert Scale
9	Would it be useful to have self reported diet tracking data in a Tele-health app?	Likert Scale
10	Would having wearable data in a Tele-health app, sway your Tele-health diagnosis decisions?	Likert Scale
11	How reliable do you think the wearable data provided will be in the Tele-health app?	Likert Scale
12	If wearable data was provided on a Tele-Health app would you actually use it in diagnosis?	Likert Scale
13	If a wearable device was provided to your patients would you encourage them to wear it?	Likert Scale
14	If wearable data was provided would you be more likely to look at it before or after diagnosis?	Multiple Choice (Before, After, Other)
15	Would you as a health professional wear a wearable device and use a Tele-health app to help monitor your health?	Likert Scale
16	Do you see Tele-Health being prevalent in the healthcare industry in the next 5 years?	Likert Scale
17	How helpful would it be to have data of a patient's health over the past week or more before they see the health professional?	Likert Scale
18	If wearable data is provided with a Tele-health application would you, as a health professional, use it to help influence a diagnosis?	Likert Scale
19	What are your thoughts on Tele-Helath as a viable means of care?	Free Response
20	What additional features would you like to see in Tele-health applications in the future?	Free Response
21	Do you have thoughts on how to use wearable data in a Tele-Health application?	Free Response

Question 2 asks if the participants wear smartwatches and is used to understand how healthcare professionals feel about wearables. This survey question supports research question 9 because if they wear the devices independently, they are more likely to encourage patients' use. If they buy/wear them, they likely have some level of trust in wearables and see the benefit in the tech.

Question 3 in the survey gives a straightforward answer to research question 7. It asks what smartwatch the participant wears or would wear/buy. Knowing what platform is popular and accessible is essential when gauging patient use and engagement. If the device is hard to attain or has bad compatibility, patients are unlikely to wear it, and there will be no data.

Question 4 gives participants an option to pick from 6 commonly collected data types, Daily Activity, Steps, Calorie Burned, Diet, Heart Rate, or Other, to determine which they would most likely look at and use if given a choice for incoming health data. It sheds light on research question 5 and dives into what data metrics are the most important to the healthcare community. The more streamlined the data, the easier and faster diagnosis decisions can be made, leading to improved patient care.

Question 5 is used to understand how current Tele-Health implementations succeed at their goal and how respondents feel about apps without wearable data integration. This survey question helps answer research question 6, giving insight into how well current Tele-Health solutions are working. If there is disdain or feeling that existing applications are not cutting it for patient care, that is a place wearable data can step in and try to improve that experience.

Like the previous question, question 6 is more specifically focused on Covid-19 due to patients being unable or unwilling to be diagnosed in person because of quarantine. Question 6 describes how current solutions performed under worst-case scenarios, such as in a global pandemic, further answering research question 6 giving perspective as to how the healthcare community views Tele-Health currently.

Question 7 shows if healthcare professionals trust or distrust the concept of Tele-Health. It also gives an outlook if they believe in a diagnosis made remotely. This is the last question to answer research question 6. Survey question 7 allows me to see the current attitude towards Tele-Health in general and overall trust or distrust.

Question 8 asked respondents if how beneficial it would be to have wearable data accompanying a Tele-Health call. This allows me to answer research question 1 by showing if

wearable data is wanted in Tele-Health. Therefore, showing it belongs and can become an integral part of this up-and-coming technology.

Question 9 focuses on self-reported calorie and diet tracking. Research Question 10 benefits from answers to survey question 9 because the more patient data available, the more the doctor can understand the patient and provide the best care possible. The wearable device on its own cannot track calorie intake or a patient's diet. With the addition of the self-reported tracking, it allows for a more accurate picture of patient data and lifestyle because knowing what goes in and out of a patient's body is valuable information that would not be available at a brick-and-mortar office. The diet and calorie feature were added in the proof of concept app to increase patient health data.

Question 10 compares current practice, patient word of mouth, and video description, versus empirical data given by wearable data for a diagnosis decision. This allows me to answer research questions 1 and 3 because if having wearable data in app sways a diagnosis, it shows how wearable data belongs in Tele-Health and that it is trusted.

Question 11 asks how reliable the participants believe the provided data in a Tele-Health app will be. While this question does not explicitly state or ask the respondents if they trust the data, it helps shine a light on their trust in wearable data. It helps answer research question 4, allowing insight to see if the healthcare community thinks the wearable data is accurate. If the information is reliable to them, it is also trustworthy.

Question 12 helps determine if participants trusted the wearable data or not. In the question the respondents indicated if they would or would not use wearable data in a diagnosis decision. If the healthcare professional uses the data to help influence a diagnosis, it follows that

they trust the data they are being given. The data from question 12 directly correlates to research question 3, investigating if the healthcare workers trust this data.

Question 13 asks if the patient was provided a wearable device, would they, as the healthcare professional, recommend that they wear it. This directly relates to research question 9, if the healthcare community would recommend wearable devices to patients. Survey question 13 gives perspective into this essential question, understanding how well the devices are trusted to withstand new environments with patients and still report reliable data to help doctors.

Question 14 gives insight into whether the data from wearable devices is trusted or not and when the doctors would check the data, also, answering research question 3. If the answer is before diagnosis, then it is most likely trusted and will be used to help influence a diagnosis decision; however, if the answer is after the diagnosis, the data is probably not trusted and will not be used to make diagnoses. This question seems simple, yet it gives great insight into how healthcare professionals feel about the technology.

Question 15 analyzes how the respondents trust wearable technology and if they wear one on their own time. This question helps answer research question 4 by examining respondents' own experiences with wearable data. It does this by showing if a device is worn on the participant's own time, they trust it to measure their health data accurately and give them more insights into their health while not at work.

Question 16 directly asks for respondents' opinions on the future viability of the wearables in Tele-Health. It will help determine if the technology has a future in healthcare. This significantly relates to research question 8 as to whether wearables and Tele-Health are the future of healthcare. I can gain insight into how participants feel about the future of technology and how it relates to how healthcare is administered.

Question 17 asks if the healthcare provider thinks the wearable data can help look into patient health over time and determine their problems with more confidence. Again, answering research question 10. If the healthcare provider wants to see data from past weeks or months it allows them to see how their patient has been living and gives a good idea about habits and health, producing an image of patient health that would typically not be available in a traditional setting.

Question 18 is getting the answer to if the survey participants trust the data or not and if they are willing to use it to influence a diagnosis decision. Which in turn is asking if they trust the data as well. This provides answers to both research questions 1 and 3. Answering these questions shows how participants trust the data, the technology, and the future to help better aid patients.

Question 19 helps get written opinions from respondents about the future of the technology if used as a means of care versus in-person visits. If Tele-Health holds a place, then the answers from previous questions will tell if the addition of wearable data can help bolster Tele-Health's position as a way of providing care. This also provides an understanding for research question 8. This question's responses will help indicate how viable the future of Tele-Health with wearables will look like.

Question 20 is a free response question that allows healthcare professionals to share their opinions on improvements that I may not think of or other ways to utilize wearable technology to collect data or improve the Tele-Health experience. Answering research question 8, the answers to this question offer new ideas and intuition about how wearable technology can benefit the healthcare world. Getting these kinds of solutions shows how the future of wearables in Tele-Health has so much growth and possible expansion.

Question 21 is a free response on how to utilize wearable data in an application. This does not apply to any of the research questions. It was an excellent way to generate more ideas for wearable use than just what I thought. It provides a new perspective on the technology and offers new and exciting ideas that I may not have come up with.

Table 2 Survey Question Mapping to Research Questions

Question	Research Questions	Related Survey Question Numbers
1	Does wearable data hold a place in Tele-Health?	8, 10, 18
2	Does age have an effect if wearable data and devices are trusted?	1
3	Would healthcare providers trust this data?	10, 12, 14, 18
4	Do healthcare providers think wearable data is accurate when measuring health metrics?	11, 15
5	What health data metrics are most important?	4, 21
6	How well did/ do current Tele-Health solutions work?	5, 6, 7
7	What devices should be used to gather wearable data?	3
8	Is Tele-Health the future of healthcare?	16, 19, 20
9	Would healthcare professionals promote wearables and encourage use?	2, 13, 15
10	How well does the wearable help give the healthcare provider a better image of patient health?	9, 17

Question Analysis

After analyzing all the questions and responses in the survey, I can answer the research questions. For research question 1, I used survey questions 8, 10, and 18 to help answer it. In survey question 8, an overwhelming majority of the participants said they would find it useful or extremely useful to have the additional wearable data included in current applications. This corroborates that respondents and, therefore, medical professionals think this wearable data belongs in Tele-Health. Furthermore, based on existing implementations of the application would have a more accurate picture of patient health. All of these things corroborate how

wearables and wearable data belong in Tele-Health. On to question 10, over half the responses indicated that the introduction of wearable data would make them more likely to sway a diagnosis. Yet again indicating that wearables and their data are supported by the medical community and having a place with this emerging technology. Lastly, according to question number 18, over seventy percent of the responses indicated that the participants would be likely or very likely to use wearable data to influence a diagnosis. Overall, based on the answers to the question, it is clear that the healthcare community believes in wearables and their data to be a part of future Tele-Health applications.

To answer research question 2, survey question 1's answers were compared against how the rest of the survey questions were answered. This was done to see if age affected the attitude towards wearables and Tele-Health. For the most part, I had younger participants (median age group of 25-34 years old, average age group of 25-34 years old), but it appeared age did not matter if the medical professional trusted or distrusted wearable data. There were no noticeable patterns or trends that formed based on age. So, the ages of healthcare workers do not dictate how they view wearables devices and Tele-Health.

In research question 3, I used questions 10, 12, 14, and 18 to answer this critical research question. As discussed in research question 1, question 10, more than fifty percent of the responses showed how healthcare professionals would use wearable data to swing a diagnosis decision. This clearly shows how this data would be trusted if used to make a diagnosis decision. This alludes to how they are counting on the data, the technology, and its future to help better aid patients. For survey question 12, over fifty percent of respondents answered they would be likely or very likely to use the data in a diagnosis. Yet again showing how the data would be trusted if the data was provided. With such a high number trusting wearable data, this bodes well for the

implementation of wearables in Tele-Health. In question 14, almost seventy percent of responses indicated that the participants would look at this data before meeting the patient. The question reveals that most respondents trust the data because they would look at it before even meeting the patient. Finally, in question 18, as previously discussed, an overwhelming majority indicated they would be very likely to use the wearable data to influence remote diagnosis. Overall based on all response data, the healthcare community has displayed that they would trust the data coming from wearable devices.

Next, research question 4 was answered through the use of survey questions 11 and 15. On 11, almost seventy percent of responses indicated that the data would be reliable or highly reliable, suggesting that the devices gathering the data gather accurate data, further showing how the devices are perceived as valid when measuring health metrics is essential to ensure all patients get the best care possible. Furthermore, in question 15, most responses indicated that these healthcare providers would be very likely to wear a device to monitor their health on their own time. This points to these users trusting these devices and viewing them as viable and accurate means of collecting health data. The survey questions show that wearable devices are accurate and trustworthy based on the community participating in this survey.

Research Question 5 can be answered by survey questions 4 and 21. The responses indicated daily activity, steps, and heart rate were among the most answered. This shows the providers want an insight into the patients' day-to-day life, something that cannot feasibly be achieved in a doctor's office. This point illustrates how important the addition of wearable data in Tele-Health would be because it provides more data than currently available in a traditional setting. Next, in free-response question 21, the overall responses highlighted that simplicity is vital to get patients on board with the data retrieval. Still, in practice, the device is constantly

gathering patient data whether they actively monitor it or not. However, simple data metrics can be easily collected. However, more complicated metrics such as fall alerts, blood pressure, or blood oxygen content is harder to encapsulate but doable with the new Apple Watch Series 6. The more data, the better, but it can be too much at times. So keeping it manageable for the end-user is key while also supplying the most important metrics to help get patient health image across. In the end, the wearable device's health data types are critical to the success of wearable data.

Research Question 6 illuminates how well current Tele-Health applications are doing in practice. Survey questions 5, 6, and 7 shed light on that question. In 5, most answers showed that the current implementations are adequate but not exceeding expectations, indicating room for improvement in these apps based on real users' responses. This alludes to how wearable data can be inserted to make the experience exceed expectations and deliver a higher level of care to remote patients. For question 6, the responses on this were very spread out, and some thought the applications did well. Some thought they performed very poorly; however, most landed in the middle. The data illustrates how the applications can only do so much with qualitative data and how quantitative data from wearables can be inserted into the equation to improve results. Lastly, on question 7, a majority of the respondents seemed to have faith in remote diagnosis, almost fifty percent responding confident to extremely confident. This is interesting because the previous answers were not as confident in the current Tele-Health as an application. Still, when it comes to diagnosing patient issues, most seem relatively confident in the remote diagnosis.

Research Question 7 was very straightforward. It set out to find what smartwatches are accessible, popular, and work well. According to survey question 3, over 70 percent responded that the watch would be the Apple Watch, making it the obvious choice to center the proof-of-

concept application. It also shows that Apple has the best product for convenience, sensors, and accessibility.

Research Question 8 focused on the future of wearables in healthcare. Survey question 16 helps provide insight into that question. Based on survey responses, over eighty percent of responses indicated that it is very likely that Tele-Health would be prevalent in healthcare in the future. While the technology and applications are not currently meeting all needs, the technology will continue to improve due to devices like wearables. Therefore, this puts wearables in Tele-Health at the forefront of healthcare for some time to come. Question 19 collected free response answers, and the respondents reached a consensus. Tele-Health and wearables can help eliminate in-person visits for changing prescriptions or routine checks, primarily if the wearable data can provide the data healthcare providers need. This alludes to how even when not in a pandemic, Tele-Health can improve healthcare for the future by making it more convenient and time-efficient for all parties involved. Question 20 is also a free-response, asking about future options that should be available as data from smartwatches. A common answer to this question was blood oxygen content, EKG, and blood pressure. All are achievable with current wearable devices, and they can all be tied into the iOS Healthkit system for easy access to the information. Based on survey responses, the future of wearables in Tele-Health is promising, and with more time, the sensors and software will be able to provide even more accurate data.

Research Question 9 poses the question of healthcare professionals recommending and encouraging the use of wearable devices to patients. Question 2 analyzes how many respondents currently wear devices, and over fifty percent responded that they wear a smartwatch daily, and almost 30 percent wear it sometimes. This indicates that, for the most part, the healthcare community themselves is onboard with wearable technology as they use it on their own. This

also means that they would likely recommend it to patients if almost 80 percent wear it themselves. Next, question 13 asks if a device was provided to patients if they would recommend its use. Over sixty percent said they would be very likely to encourage such use. It also illustrates if the respondents feel like the device is valid and accurate if they feel like it is worth recommending to a patient to improve their care. Lastly, in question 15, as mentioned before, the participants would be very likely to wear a device independently. It is further bolstering that they trust the technology and recommend it if they wear it themselves.

Ultimately research question 10 asks about how wearable data can provide a better image of patient health, with the help of question 9, which asked participants about self-reported diet tracking. The survey results showed more than fifty percent found it very useful if self-reported diet tracking was available in the app. With this feature, the better the healthcare provider can understand their patient through data, the better care they can receive. Next, question 17 explored if having patient data from weeks and months past. The responses concluded that over seventy percent of the participants found it very useful to have a patient's health history. So they could have a better picture of the long-term health of the patient and provide better care with more available data. This wearable data could provide a snapshot of patient health from weeks and months before visiting a healthcare professional. This would give the healthcare professional a better understanding of the patient before they even speak to them. This luxury is afforded because of the power of wearable devices and was something not available currently.

Analysis

The survey's initial analysis shows how many of the questions about Tele-Health and wearable data are correlated. To understand the correlation with the Pearson method, we had a study size or an N value of 53 and to gain a p-value of less than .001 I needed an R-value greater than .351. For a p-value of less than .05, the R-value needs to be greater than .271, and for $p < .1$, the R-value needs to be greater than .2285. If my data correlated, which a lot did, most correlations R-value was greater than .351, shown in Table 3 in all of the green box colorings in the table. If it is the dark green color, that means the R-value was greater than .351, and therefore, the data is highly correlated. If the data has no color in the table, that means its R-Value is lower than .2285, and consequently, it is not very correlated. In a few cases, the table has a light green coloring it means the R-value is between .271 and .351. The data is correlated but not as strong as the dark green. This indicates these correlations are very significant and represent very correlated data.

There was a lot of correlation from this survey indicating the survey results have a strong relationship and they are significant for the purpose that the survey was intended. The results supported my hypothesis that wearables in Tele-Health will be practical and an integral part of the technology moving forward. The high correlation illustrates the validity of the survey and its data.

The questions that are not very correlated (questions 5, 6, and 7) are all questions about current Tele-Health solutions and how they felt about their use and effectiveness. These do not

correlate very well except for question 5 that asks if respondents are satisfied with current Tele-Health applications, and 6 asks if existing Tele-Health solutions are effective at diagnosing and helping patients with Covid-19. This correlation is robust between the two, and that if participants are satisfied with the app, they also think that it works well at helping with Covid-19. This makes sense because if the user is satisfied with the app and covid having obvious visual symptoms, the app will work well in that use case supporting the high correlation. This correlation sheds some light on Research Question 6. In all, there is some uncertainty in the community surrounding current applications. The data backs this because the data for recent Tele-Health questions are not significantly correlated and has mediocre scoring based on Likert responses. However, questions 5, 6, and 7 correlates very little or not at all with the remaining Likert scale questions on the survey, showing that participants' opinions on current Tele-Health applications do not affect their opinions on the usefulness of wearable data in future Tele-Health applications.

One of the most strongly correlated questions was questions 8 and 9, with an R-value of .7388, as seen in Table 3. This relates if the need for additional data in a Tele-Health app and if self-reported diet tracking would be helpful. If the participant was favorable to more data, they were also very likely to want self-reported diet tracking. This alludes to the need for more data overall. In Tele-health, it is apparent that medical professionals want more concrete and objective data to base their diagnosis and treatment on. This also helps support the fact that wearables would be a valuable addition to Tele-Health because it would help introduce the data that is wanted by healthcare professionals, which is backed by a robust correlation in the survey. Question 8 has further strong correlations that relate to Tele-Health, which is not a coincidence because 8 is asking about the addition of more data in Tele-Health from a smartwatch. This

suggests that wearables in Tele-Health will provide the additional data needed to give the healthcare user and patient the experience wanted. All of the strongly correlated questions mean the respondent thought the additional data from wearables was very beneficial to Tele-health. They thought wearable data was accurate and trustworthy and could improve patient experience and care, help with battling Covid-19, and improve diagnosis accuracy.

Another robust correlation is between questions 13 and 15. Both ask about the use of wearable devices such as smartwatches 13 pertains to patients and encourage them to wear the devices provided, and 15 relates to the healthcare professionals wearing devices to help monitor their health. The correlation data answers Research Question 9 Would healthcare professionals promote wearables and encourage use? This is interesting because if the doctor is very likely to wear a smartwatch to help monitor health on their own time, they are highly likely to recommend a patient to wear the device. The medical professionals trust the wearable devices because they would wear them on their own time and recommend them to patients who would benefit. The correlations support the fact that healthcare workers trust wearable devices and they value the data they would provide. The correlation also helps answer the research question posed earlier in the section. "Would healthcare providers trust this data?" and the answer is yes. Based on survey responses and correlations drawn from those responses, it is clear the healthcare community is very trusting of the data these devices deliver. The answers further bolstering the fact the wearables belong in Tele-Health and are the future of the industry. If the healthcare professionals support the patient by having wearable devices, it is also highly correlated to having a bigger picture of patient data. Moreover, the data help answer research question 10, and, based on the correlation data, doctors and patients alike will have a better idea of their health. Not only will this knowledge help patients in their day-to-day life it will bring about better diagnosis decisions

that are more accurate and provide the best care for the patient. This allows the doctors and nurses to see how the patient's health has been changing up to the visit and gives them information that would not be possible if the patient came into the office. This correlation supports how much wearables in Tele-Health have to offer over in patient care because it can provide service that was not possible with in-person visits recently. This data shows how Tele-Health can be benefited by the introduction to the use of wearable data.

In Table 1, it is also easy to tell how well the questions about wearables in Tele-Health were received on the Likert scale based on their average rating. With 5 being the best, most of the questions about how trustworthy, accurate, and beneficial wearables can be received a 4 and up, rating on average. This agreement indicates the immense support that wearables have from the healthcare community in how they can improve patient care and be a reliable source of data. Furthermore, current Tele-Health implementations are not exceeding expectations, with only average mean scores in the 2 to 3 range on the Likert scale. This illustrates how current Tele-Health apps are missing out on the potential that is wearable technology and data. As seen by the responses to later questions, that data would be welcomed by people who would use the applications on a day-to-day basis.

Diving further into the correlations, another interesting one is between questions 10 and 11. If a healthcare professional is likely to use the data gained from a wearable device to aid or sway a Tele-Health diagnosis decision, they also find the data being provided from a wearable device to be reliable and accurate. The correlation between these two is above the .351 threshold, making it a very fit and significant relationship between both questions. This goes without saying, though, if the doctors and nurses are confident enough in the data they are being given to help diagnose a patient and provide the patient with the best care possible. They trust the data

and its source. This alludes to how powerful the technology of wearables is. It has a very high potential to change the industry, especially with the level of trust and acceptance being shown to such unproven and untested technology. In addition, the doctors trust the data and wear it on their own time and trust their health data to it. That is one of the most prominent correlations that jumps out to me. That they not only trust it, but they trust it enough to use it themselves on their own time. While this correlation is not as strong as others in the survey, it is still significant. It cannot be overlooked because this new technology would be so quickly adopted, as seen by the high score seen for the question about wearing the device to monitor their health. Many of the respondents and, therefore, their community would back this new advancement in healthcare.

Two more highly correlated questions that make a good connection is question 13 and 18. 13 discusses if the healthcare professional would be likely to recommend and give a patient a wearable device, and 18 asks if the healthcare professional would use the Tele-Health data in their analysis. These two link well because if the doctors recommend devices, they will also use the data to help them in Tele-Health applications. The high correlation between the two of .57 indicates that these two are significant and sound data to go off. It appears that most respondents would recommend such devices, so, therefore, they will also be using the data to help make Tele-health care decisions and further asserting the point that Tele-Health has a lot to gain from introducing wearable devices. This data helps assert research questions 1 and 8, showing that wearables are here to stay and belong in the field of Tele-Health. The strong correlations between recommending devices, trusting wearable data, using the wearable data to impact care on patients, and using it to monitor their health indicate how powerful wearable devices are in the healthcare space. The healthcare community members also feel very strongly that these

devices and data have a place in Tele-Health and can bring many benefits to patient care. This

cements wearables in the future of patient monitoring and healthcare for many years to come.

Table 3

Questions	N	Mean	SD
How satisfied are you with your current Tele-Health app?	53	3.54166667	0.97774532
How useful have current Tele-health solutions been when diagnosing and dealing with Covid-19?	53	2.94444444	1.08626364
How confident are you in a diagnosis or a prescription if it is given via a Tele-health application.	53	3.30555556	0.9734343
How beneficial would it be to have the additional data from a smart watch in a Tele-Health app?	53	4.48611111	0.7504563
Would it be useful to have self reported diet tracking data in a Tele-health app?	53	4.48611111	0.78709764
Would having wearable data in a Tele-health app, sway your Tele-heath diagnosis decisions?	53	3.875	0.99204583
How reliable do you think the wearable data provided will be in the Tele-health app?	53	3.97222222	0.91885143
If wearable data was provided on a Tele-Health app would you actually use it in diagnosis?	53	4.01388889	0.84741621
If a wearable device was provided to your patients would you encourage them to wear it?	53	4.56944444	0.66769287
If wearable data was provided would you be more likely to look at it 0(Before) or 1(After) diagnosis?	53	0.30555556	0.52107389
Would you as a health professional wear a wearable device and use a Tele-health app to help monitor your health?	53	4.5	0.78722189
Do you see Tele-Health being prevalent in the healthcare industry in the next 5 years?	53	4.81944444	0.48429967
How helpful would it be to have data of patient's health over the past week or more before they see the health professional?	53	4.68055556	0.62407992
If wearable data is provided with a Tele-health application would you, as a health professional, use it to help influence a diagnosis?	53	4.19444444	0.88236061

Table 4

	Question 5	Question 6	Question 7	Question 8	Question 9	Question 10	Question 11	Question 12	Question 13	Question 15	Question 16	Question 17	Question 18
Question 5	1												
Question 6	0.492872144	1											
Question 7	-0.22074	0.21607778	1										
Question 8	0.058385111	-0.01823737	0.12157183	1									
Question 9	0.055667141	-0.00091518	0.042382053	0.73884733	1								
Question 10	0.012705513	0.019604959	-0.0474009	0.53680973	0.45770679	1							
Question 11	-0.04572539	0.040765423	0.198583455	0.48964265	0.54474684	0.6141886	1						
Question 12	-0.0602042	0.107954526	-0.00521709	0.54291481	0.49652456	0.65549215	0.56124212	1					
Question 13	0.038654172	0.024813327	0.053572976	0.64845021	0.48426279	0.47045323	0.43937601	0.5832446	1				
Question 15	0.137239777	0.082352967	0.147037405	0.67946007	0.64782953	0.5500632	0.42837279	0.51726584	0.73688623	1			
Question 16	-0.08799315	0.060982271	0.178425448	0.39990643	0.34434113	0.45072419	0.43167925	0.38370203	0.58377509	0.60955692	1		
Question 17	-0.1048313	-0.06809978	0.023828353	0.57681589	0.52129071	0.41233265	0.47553931	0.43462034	0.67929863	0.44436104	0.64528257	1	
Question 18	-0.1564539	-0.12082297	0.077434645	0.45080857	0.32842256	0.52695691	0.54528831	0.58026692	0.57442377	0.40553503	0.54474824	0.62593428	1

Proof of Concept App

I designed and built a proof-of-concept app that took into account the survey responses, such as data types preferred and how the medical professionals would use the data. According to the survey, the app takes wearable data from an Apple Watch on the iOS platform because that was by far the most popular wearable device. Over 70 percent of respondents either wear one or would wear one. In addition, Apple also has one of the best wearable devices for everyday use and health monitoring on the market.
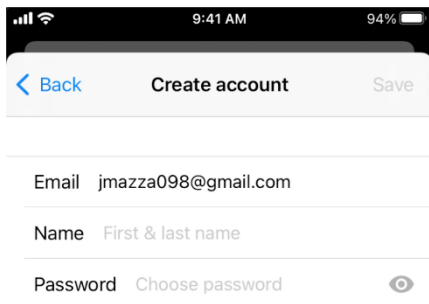
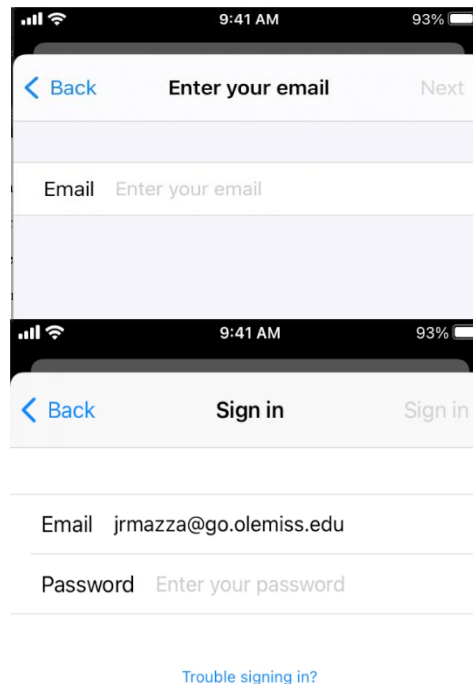*Figure 1 The create account screen when opening the application*

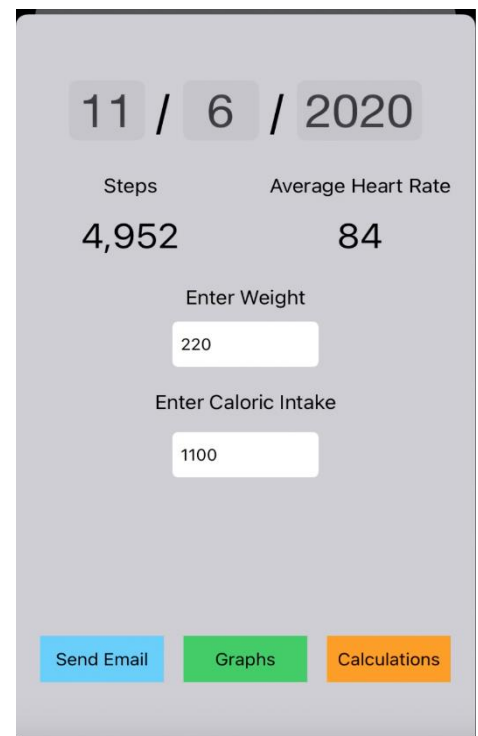*Figure 3 The login screen of the application*

Figure 2 The home page of the application

The data types selected were heart rate and steps based on the survey responses because those

were the most popular options. Therefore, they are listed front and center on the homepage, as

seen in Figure 3. The data was gathered using Apple's built-in Healthkit functionality.

When the app is opened, the user is greeted with a login screen and prompted to log in (Figure 2)

or create an account (Figure 1). Once logged in, the user is greeted with the home page visible in

Figure 3. The user would select a date they would like to retrieve their health data from a date

picker. This auto-populates the step and heart rate fields, and the weight and calorie fields can be

input by the user. The data is then aggregated based on the day's metrics and given to the user in

a readable format illustrated by Figure 3. Self-reported diet tracking was also a feature

respondent seemed to think would be helpful, so calorie and weight tracking were added to the

app. In addition, the analysis was run on steps, weight, and calories to show many. Calories a

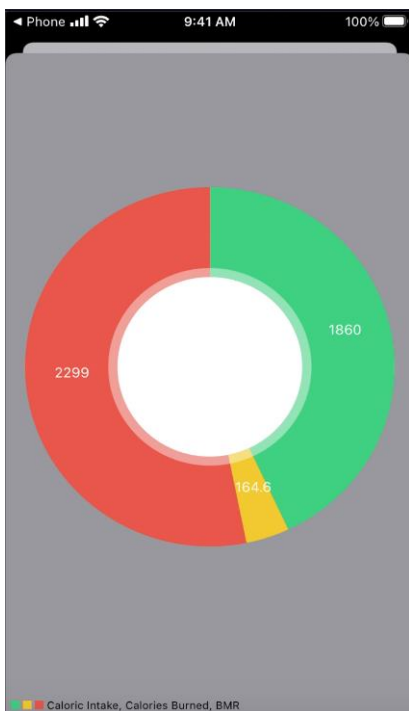patient had burned in a day (Figure 4).

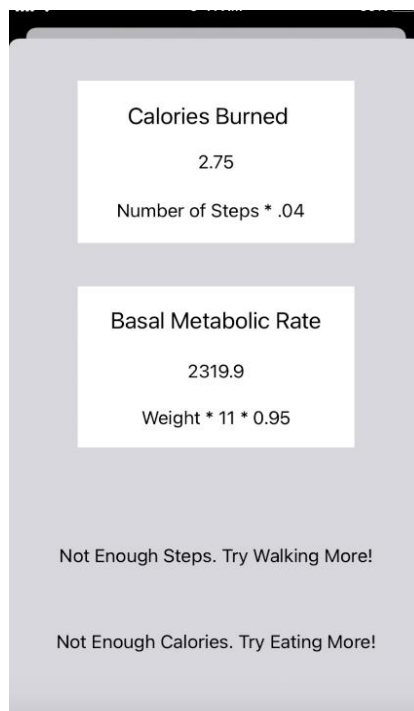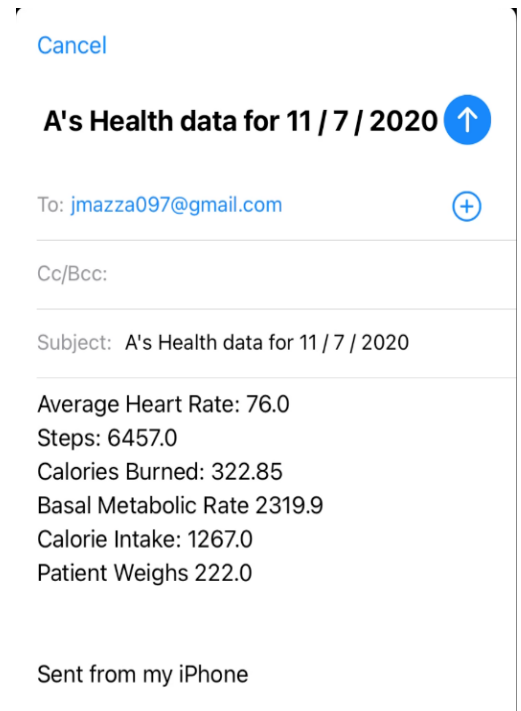|		
Figure 4 graph readouts of user data	*Figure 5 calculation metrics of user data*	*Figure 6 user health information send out screen*

The data was summed up in a calculation screen that offered warnings if too few steps were taken or too few calories were eaten, as seen in Figure 5. Furthermore, all of these calculations and data could be sent to the healthcare professional via email as a part of the wearable data transfer in Figure 6. The app is by no means a finished product; however, it is intended to show how the data can be collected very quickly and sent to healthcare professionals on the other end of Tele-Health calls. This data can help them get a better idea of the patient's health over time. This proof-of-concept application differs from current solutions because it allows users to view and send their data alongside a Tele-Health visit. This is the main goal I wanted to accomplish: transparency with the health data and being distributed to healthcare professionals for care. Overall, should lead to better care with more knowledge.

Future Work

To make the app feel more complete, I want to make a UI for data transfer that utilizes JSON protocols to move more health data to a secure viewing page for healthcare professionals. This would be a much more optimized way of sending data than the proof-of-concept email solution. I would also add more health data types and a broader date range to pick from, such as a week or a month. In addition, to increasing the data types that are accessible, I want to add data types that are becoming available such as sleep cycles, blood oxygen saturation, daily activity, and much more. These data types give a much more complete picture of a patient's health and, to some extent, a better view than what could be had in an actual doctor's office.

Furthermore, I want to make the login system more robust with an actual client and patient database backed by a hospital, not just my database. When a patient logs in, the

application can get their data to the doctor immediately without having to pull files and make the interaction even smoother. Lastly, a great addition to all of this would have an Apple Watch-specific app that way, hospitals or health providers could give out watches to help track and monitor high-risk patients. Even if they do not have an iOS device, all patients have access to the tech.

Conclusion

Based on the study results and my proof-of-concept app, I have shown how powerful wearable devices are in the healthcare space. In the study, the healthcare worker participants' responses showed how wearable data would be instrumental in a Tele-Health scenario. Many questions and data had a very significant correlation in how current Tele-Health applications are not exceeding expectations and how introducing more objective data from devices like wearables will improve patients' quality of care. While there still needs to be a lot of work done to both the applications and wearables devices themselves. The technology trajectory is headed in the right direction and looks very promising to be mainstream in the next 5 years. A big hurdle that needs to be overcome is making a wearable device that is brand agnostic while also having better sensors or features than devices like the Apple Watch to create competition and allowing for more widespread access. This leads to the data validating my hypothesis that wearables belong in Tele-Health and they are promising devices for the future of the industry. The data they can give, such as heart rate, steps, daily activity, blood oxygen levels, and much more over long periods, gives doctors a look into patient health like never before. This new picture of patient health will only help improve care but help many people who do not have access to physical doctors' offices.

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