LEVERAGING SENSORS TECHNOLOGY FOR PERFORMANCE ANALYTICS IN SPORTS

THE PHYSICAL AND PSYCHOLOGICAL IMPACTS OF WEARABLE TECHNOLOGIES ON PERSONAL HEALTH

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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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The evolution of wearable and user-friendly personal fitness tracking technologies has allowed such devices to become affordable tools for people to monitor their physical well-being. A study showed that “21% of U.S. consumers (about 57 million) currently use a dedicated QSHFT [quantified self-health and fitness tracking] device along with one of nearly 325,000 mobile health (mHealth) smartphone applications to track their health and fitness activities” (Brinson, 2020, p. 2). As technological abilities continue to expand, the capabilities of wearable devices with integrated sensors have resulted in more accurate and reliable methods of monitoring physical exercise for athletes and the general public. Due to the onset of the coronavirus disease 2019 (COVID-19) pandemic, scientists and researchers have begun to question whether or not these devices could be used to accurately monitor or detect COVID-19 related metrics (Fowler, 2020). However, as with any new promising technological innovation, there are several concerns stemming from various social groups relating to health and privacy risks that must be considered as well.

The recent advancements in sensor technology and real-time data collection have revolutionized the sports analytics and healthcare industries (Li et al., 2016). The technical project and tightly coupled STS research will analyze both the current usages and potential capabilities of wearable technologies as well as their effects on the stakeholders in their network. The goal of the technical project is to research and observe existing sensor technologies to determine how to implement COVID-19 related metrics as well as to enhance athlete performance monitoring. By analyzing data from the UVA Men’s Basketball Team and conducting controlled experiments, my team and I will be able to better understand the different types of smart devices available, how they are used for real-time monitoring, and how to fix potential flaws in their systems. Our final deliverable will be a conference paper that will be submitted to the Systems and Information Engineering Design Symposium (SIEDS) Conference in April 2021. This project is closely related to the STS research project which will be a scholarly article due at the end of March 2021 and will discuss the positive and negative effects that wearable fitness tracking technologies have on the physical and psychological health of users.

THE FUTURE OF PERFORMANCE ANALYTICS

Working alongside Systems Engineers Brian Coward, Grayson DeBerry, Caroline Glazier, and Computer Engineer Evan Magnusson and with the guidance of our advisor Mehdi Boukhechba of the Engineering Systems and Environment Department, we will be leveraging sensor technology to improve performance analytics and to determine how to measure the distance between athletes in real-time. Specifically, we will be working with the UVA Men's Basketball Team to analyze data that is being collected from smart watches that the players wear during practice. Due to the continuous advancements in smart phones and smart watches, several biometric sensors and monitors have been incorporated into wearable technologies that are allowing them to revolutionize the ways in which performance and training data can be evaluated. Coupled with low prices and an increased social media presence, wearable devices have become popular tools for people to analyze their physical activities (Li et al., 2016).

The coronavirus pandemic has caused scientists and researchers around the world to frantically attempt to discover reliable, simple, and safe ways to detect COVID-19 symptoms as well as to monitor social distancing. The technological capabilities of personal fitness devices have advanced significantly in recent years which has led researchers to question if those health tracking measurements can be leveraged as tools to help combat the coronavirus pandemic (Fowler, 2020). Another benefit of using wearable technologies that Fowler (2020) emphasizes is that they could help improve future studies by eliminating the need for participants to self-report their symptoms. Fowler adds that looking forward, "The next step will be for researchers to conduct trials where they pass real-time warnings back to study participants based on their own data" ("Turning research into a warning system," para. 3). Currently, the NFL and NBA are using Kinexon SafeZone tags to monitor social distancing and contract tracing of players by "measuring the proximity between people and the length of time interactions occur" (Golden, 2020, para. 6). Additionally, Sarlis and Tjortjis (2020) discuss the importance of performance analytics for basketball team decision making and how current analytical models can be "combined in the future with data driven sensors methodologies in each athlete and SportVU camera data" to help make predictions (p. 4).

The goal of the technical project is to analyze the ways in which the UVA Men's Basketball Team tracks athlete performance as well as potential means by which they could leverage sensor technology to monitor the distance between athletes in real-time. We will be working with researchers from the UVA Department of Kinesiology and the UVA Department of Athletics to test novel sensing methods to see how they can be incorporated in current practices, which include utilizing Huawei 2 smart watches and video-taping practices to collect data. The focus will primarily be on utilizing Bluetooth, ultrasound, and ultra-wideband (UWB) technologies in our technical analysis to compare the accuracy of distance measurements between smart devices.

This is a year-long project in which the first semester will be dedicated to exploring various methods of data collection, conducting sensor research, running controlled experiments, and analyzing collected data. The second semester will be focused on compiling our findings to write a conference paper in which we will outline our final deliverable. The final deliverable will most likely be a text mining network to assist in the collection of real-time distancing data and the comparison of different sensor technologies.

SENSOR TECHNOLOGIES

The Huawei Watch 2 consists of many sensors including an accelerometer, a heartrate sensor, and a geomagnetic sensor and features Bluetooth, GPS, and Wi-Fi connectivity (Westenberg, 2017). Moatamed et. al (2016) discusses how smart watch Bluetooth technology was leveraged in a study conducted at a rehabilitation facility to monitor the location, posture, and movement of patients. The system described involves the use of proximity sensor beacons and received signal strength intensity (RSSI) information, which "is a measurement of the power of received radio frequency (RF) signal in a wireless network" (Moatamed et. al, 2016, p. 161). The smart watch keeps track of the timestamps, the device IDs of the beacons, and their associated RSSI values (Moatamed et. al, 2016). Since "RSSI value[s] can be used to approximate the distance of the beacon from watch" (Moatamed et. al, 2016, p. 161), our team will be using a similar method to test the accuracy of Bluetooth signals in estimating the distance between two devices. An additional wearable that will be considered and compared to the Huawei watches is the Safe Spacer which uses UWB technology instead of Bluetooth (Kahn, 2020). UWB is similar to Bluetooth and Wi-Fi in that it is used for wireless communication; however, "UWB devices operate by employing a series of very short electrical pulses (billionths of a second long) that result in very wideband transmission bandwidths" (Vishwesh & Raviraj, 2018, p. 45). The abilities of UWB technologies to transfer data at much quicker rates and through potential obstacles provides an optimistic view of more accurate data transmission and social distancing measurements (Vishwesh & Raviraj, 2018).

As displayed in Figure 1 below, data from wearables is collected in their associated apps, sent to the cloud and is then available for download onto personal computers or for doctors to observe. Wearable devices have the potential to make several positive, long-term impacts in both the sports and healthcare industries, and through our project work, we hope to find an optimal solution for social distancing of athletes to be monitored in real-time.

Figure 1: The Transmission of Data from Wearables. A depiction of how data is passed through and received by different channels and users. (Søderholm, 2016).

WEARABLES CAN IMPACT MORE THAN JUST AVERAGE STEP COUNT

The increasing popularity of comfortable, affordable, and user-friendly wearable devices has benefited the companies who manufacture them by promoting ways in which they can improve people's lifestyles. According to a study conducted in Australia, "activity trackers mainly motivated users to monitor activity patterns (35.9%, $n = 85$), improve fitness (27.4%, $n = 65$) and improve health (18.1%, $n = 43$)" (Maher et al., 2017, p. 4). Additionally, the vast majority of users appreciated the real-time monitoring capabilities of these devices as well as the increase in physical activity that resulted from them wearing the fitness trackers (Maher et al., 2017). Another positive benefit of using fitness wearables that Wang et al. (2020) points out is that they can be used to assist individuals in weight loss programs and, eventually, help combat the obesity epidemic. As these technologies continue to evolve and as more sensors are added to wearables, the potential to use smart devices "to facilitate prevention, early diagnosis, and management of chronic diseases outside of conventional healthcare settings" (Wang et al., 2019, p. 748) is promising.

Although the increased motivation to get in shape and the potential for more accurate monitoring by healthcare professionals (Brinson, 2020) are reassuring benefits of wearables, there are various negative impacts of these technologies that also have to be considered (Blackstone, 2020). For example, in a previous study noted by Blackstone (2020) in regards to the effects that fitness wearables have on triggering eating disorders (ED), "nearly 30% of participants felt that fitness tracking contributed to their ED" (p. 226).

POSITIVE AND NEGATIVE PHYSCOLOGICAL EFFECTS

An underlying complication related to this subject is the relationship between fitness trackers, exercise dependence, and eating disorders. The negative effects of the increasing pressure on individuals to look and eat a certain way can potentially be amplified by the use of fitness trackers as "results show that wearable use can cross a line in which the device goes from a motivational tool to meet a particular activity goal, to a deleterious device eliciting compensatory behaviors if the goal is not met" (Blackstone, 2020, p. 229). If users become obsessed with achieving unrealistic fitness standards that they see others accomplishing online, the use of these devices can cause individuals to develop eating disorders or to partake in other harmful behaviors. However, while triggering potential mental disorders is an example of how fitness wearables can negatively impact the psychological health of users, Pakhomov et al. (2020) presents a counter-argument for a method in which wearables could be used to monitor people's mental and physical health by detecting their physiological reactions to stressful environments. Since "widely available and accessible consumer wearable fitness trackers such as Fitbit1 with HR [heart rate] sensor capabilities are able to capture changes in continuous heart rate in response to naturally occurring psychosocial stressors" (Pakhomov et al., 2020, p. 10), there is an opportunity for wearables to be used to assist in the early detection or prevention of potential diseases or other health concerns that are induced by stress.

A common problem with the advancement of new technological devices is that their promising capabilities sometimes prevent society from fully understanding the unanticipated consequences that the devices could cause. Specifically, in regards to fitness tracking devices, "Issues such as user acceptance, security, ethics and big data concerns in wearable technology still need to be addressed to enhance the usability and functions of these devices for practical use" (Wu & Luo, 2019, "Abstract"). Although wearable technologies began as a way for users to keep track of their physical activities for personal health reasons, the rise of social media has encouraged increasing amounts of people to feel obligated to share their personal fitness data with others online. In a study conducted by Hardey (2019) on avid runners in the UK who heavily use fitness trackers and their associated apps, results showed that:

> A major destabilising factor was the risk of appearing unhealthy. For some, the experience of 'bad performance' – and, thus, record of bad data – was 'too stressful' and

> it was ‘worthwhile risking injury’ so that apps and wearables would track an appropriate level of fitness activity (p. 997).

This study shows how vital it is for users to understand the consequences for publicly sharing their health data online and to realize the effects that it can have on body image perceptions. As the role of these devices continues to expand into the healthcare field, it is critical that healthcare professionals make users aware of the healthy fitness standards for their particular lifestyle as well as the proper way to use these devices if they are prescribed to monitor patterns of stress.

THE SOCIAL CONSTRUCTION OF TECHNOLOGY APPLIED TO WEARABLES

The significant impact that sports culture has on countries such as the U.S. drives highly competitive mindsets and a need for athletes to always be at the top of their game. The utilization of wearable sensors as a way to conduct more accurate measurements to improve athletic performance is a prime example of how cultural values shape the design and development of technology as stated in Johnson’s Social Construction of Technology (Johnson, 2005, p.1794).

As a result, the sports medicine and healthcare industries have benefited in numerous ways from the technological developments of wearable sensors. The Social Construction of Technology (SCOT; Johnson, 2005) “refers to a theory about how a variety of social factors and forces shape technological development, technological change, and the meanings associated with technology” (Johnson, 2005, p.1791).

For this study on wearable technologies, the SCOT methodology categorizes relevant social groups into the categories of users, healthcare professionals, regulatory agencies, the technology companies who manufacture the devices, and the people or companies who attempt to steal personal information online. Figure 2 below depicts the relevant social groups who are included in the adoption of wearable technologies as well as the problems that each group faces.

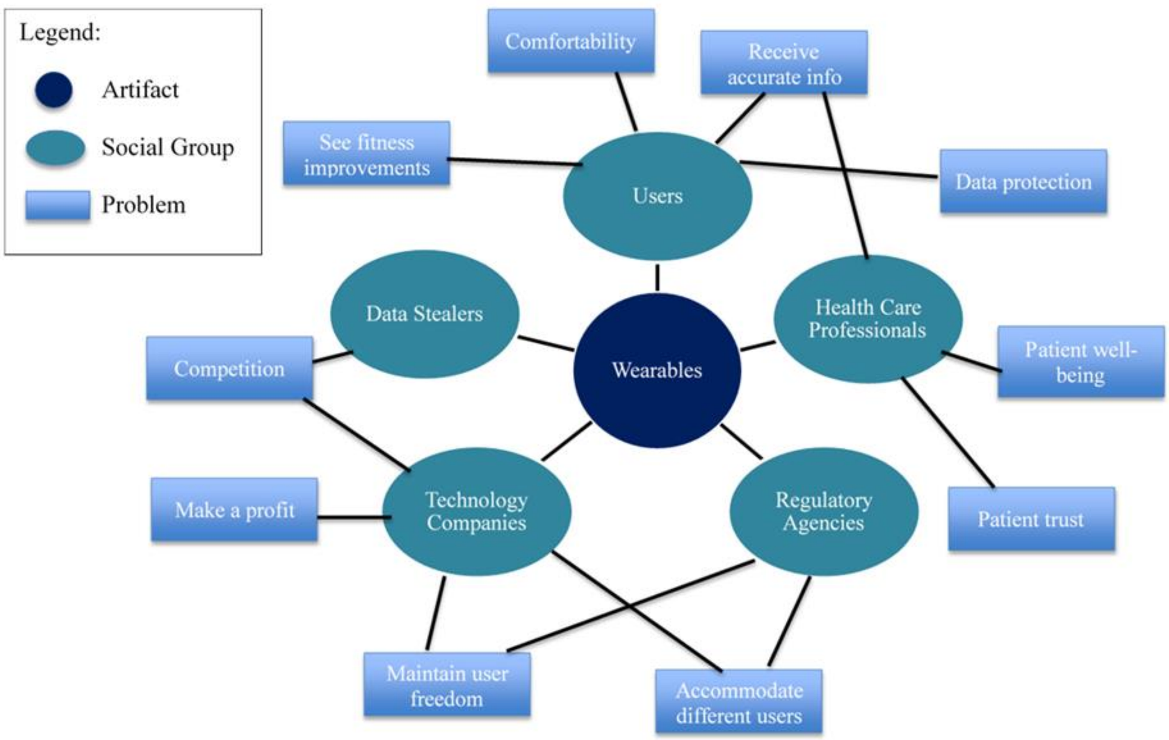

Figure 2: Relevant Social Groups and their Potential Problems with Wearable Devices. A depiction of the five social groups and the associated problems each group faces with the adoption of wearable technologies. (Adapted by Seanna Adam (2020) from Bijker et al., 1984).

The goal of the SCOT approach is to identify the various ways in which different stakeholders view a certain artifact and to analyze how each group manipulates the technology to act in a way that best benefits them. For these products to be successful, it is crucial that users feel like they are receiving accurate and helpful data and that their personal information is protected when that data is shared. Similarly, Figure 3 on page 10 shows potential solutions for how healthcare professionals can ensure their patients' well-being which includes providing personalized healthy fitness goals to strive for, suggesting limiting social media use and data sharing, and addressing concerns related to the mental health of patients in addition to their physical health.

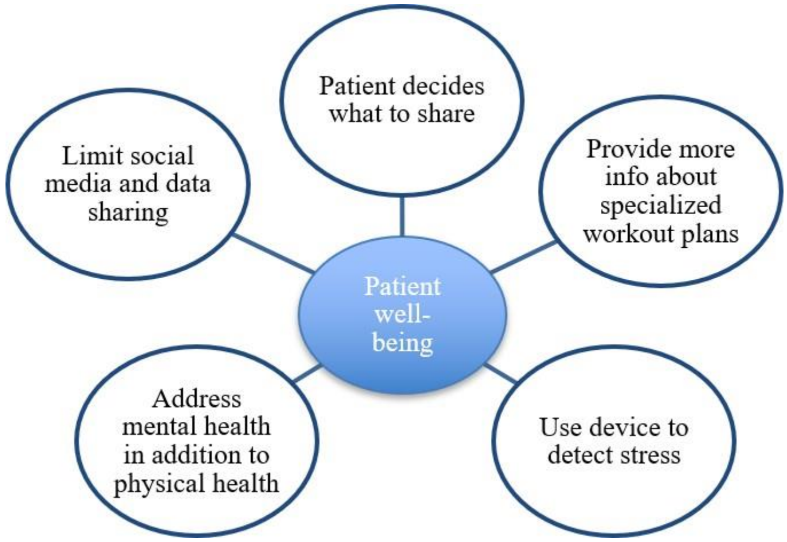

Figure 3: Solutions to the Problem of Patient Well-Being. A depiction of five potential solutions for healthcare professionals to ensure patient well-being when using wearables. (Adapted by Seanna Adam (2020) from Bijker et al., 1984).

While data flows between users and healthcare professionals, the involvement of regulatory agencies is necessary to ensure that the data is protected from potential data stealing entities. Additionally, the technology companies who manufacture these devices are mainly concerned with earning profits and it is imperative that they abide by guidelines and accurately inform the public so they do not gain too much market power (Brinson, 2020).

The STS research project will be a scholarly article detailing the impacts and underlying consequences that wearable devices have on different social groups and will relate these effects to the recent growth in data sharing and social media. Both the technical and STS papers will seek to analyze the current and potential future influences of fitness trackers on the athletic community and on the general public in regards to improving personal health and COVID-19 mitigation.

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