Wearable Technology & Smart Textiles

Allison Adams

Seattle Pacific University

Abstract

With data from wearables and e-textiles available in near real time, personal users and corporations alike have begun to debug the science of wearable technology. While examining the current landscape of wearable technology and smart textiles these findings explore the use of these devices across the sports, health care and first responder industries. Additionally, this paper explores the barriers to adoption that hinder widespread adoption of such technology including the interoperability of big data streams and cultural necessities of fashion and comfort.

Keywords: wearable technology, smart textiles, data, sensors

Introduction

At TechCrunch50 in 2008 Fitbit presented the idea of placing sensors into a small wearable band. To their surprise, the number of pre-orders received exceeded the small manufacturing capabilities of the startup (Marshall, 2016). This initial disruption of the wearable device industry this trend, pronounced by the historical sales of Fitbit reporting over 10 million individual sales for their manufactured devices since 2010 (IBM Corp., 2015), indicates that wearable technology is now a standard in everyday wear. Looking to the future, the predicted sale of wearable devices will reach up to $30.2 billion in 2018 (IBM Corp., 2015) demonstrating the global acceleration of wearable technology.

With data from wearables and e-textiles available in near real time, personal users and corporations alike have begun to debug the science of wearable technology data management. Wearable technology is dynamically changing how data is consumed across industries and for personal use. The purpose of this paper is to explain the current wearable technological landscape and explore this data management and analysis as it pertains across three separate industries. First, the paper will provide an overview of wearable technology concepts. The second section will introduce how the sports industry uses wearable technology to make sound business and design decisions. The third section of this paper considers the benefits provided by e-textiles to niche healthcare segments such as neonatal and geriatric care. The fourth section of this paper examines first responders, providing insight into how live streaming data is powering lifesaving decisions in highly dynamic environments. In conclusion, this paper considers the challenges facing the smart and wearable technology market.

Wearable Technology Explained

The umbrella term of wearable technology embodies a broad range of devices that track and collect data from biomechanical movements. Watches and wristbands propelled the notion of ubiquitous computing into everyday life, but no longer are poised to dominate the wearable market. Enter the increase in the development and adoption of smart or e-Textiles. Smart clothes comprise, “body sensors integrated with textile clothing” (Chen, Ma, Song, Lai, & Hu, 2016) allowing for data collection, storage and processing. These smart textiles can be classified into three distinct categories (Stoppa & Chiolerio, 2014):

Passive Textiles: As the first generation of e-textiles this group represents fabric and technology that can collect information and data from a variety of sensors, but do not inherently react to changes in their environment.

Active Smart Textiles: Fabric and technology that collect continuous information from sensors and reacts to the data input. For example, group of smart fabrics can unobtrusively sense an increase in temperature and responds with regulatory measures to counteract the change.

Very Smart Textiles: This final group of textiles possesses the qualities of both passive and active textiles, maintaining the ability to receive and process data but also, “adapt their behavior to the given circumstances” (Stoppa & Chiolerio, 2014).

Regardless of their place in the e-textile hierarchy, cultural norms require these garments to be, “convenient, comfortable, washable, highly reliable and durable” (Chen, Ma, Song, Lai, & Hu, 2016) to ensure adoption from end users. Furthermore, e-textiles must adapt to the wearers body shape and form introducing an emphasis on the placement of sensor nodes across the materials. When these strict acceptance criteria are met, e-textiles successfully provide an integrated electronic system that transforms garments into data collection and responsive articles of clothing.

Sports Industry - Product Design and Development

When a consumer makes the decision to purchase a running shoe, the amount of choices presented is staggering. To put this into perspective, a Google search of "Buy Running Shoes" returns 3,410,000 results. With each shoe looking similar, and all serving the same purpose, companies are solving the challenge to make their product distinctively stand out with wearable technology. Companies now have the ability to employ "biomechanical modeling, statistical learning, behavioral and social modeling, and integrative modeling" (Ku, et al., 2015) driving real time business manufacturing and design decisions. These models provide, "spatio-temporal and kinetic parameters during walking and running can be analyzed in clinical as well as in sportive applications" (Mitschke, Kiesewetter, & Milani, 2018) that help distinguish shoes from competitors.

These models provide companies with both customer insights and runner perception from biomechanical analysis, understanding how bodies move or react to a given shoe. This is done through factor analysis which helps drive companies to, "identify casual relationships that could direct strategy and improve decision making" (Marr, 2017). For sports companies conducting studies with wearable technology the amount of data that is collected with every footfall is enormous. Wading through this sea of data with a statistical methodology helps to identify key relationships allows for sound structures and patterns to be identified.

As a result of this big data access, specialty running companies such as Brooks Running have developed programs including Run Signature and FitStation. These programs use biometric data collected from runners to directly improve product development (Brooks Running, 2013) building shoes that respond to customers biometric data and needs. Comparably, companies such as Nike have focused on providing metrics to individual consumers with their application Nike+. With over 1.2 million runners as end users this application syncs an embedded sensor in a Nike shoe with their smart phone, displaying biometric and run statistics at the user's fingertips" (McClusky, 2009). Harnessing the power of big data and wearables propels the transformation of sports product companies into data giants. By arming consumers with the data gained from wearable technology, corporations can definitively claim that their product will best fit their consumer needs.

Similar trends can be seen in the direct to consumer wearable technology market with the introduction of the Quantified Self movement. The Quantified Self Movement is the growing trend of self-data tracking which is quickly emerging as a "mainstream phenomenon [with] 60% of U.S. adults currently tracking their weight, diet, or exercise routine, and 33% are monitoring other factors such as blood sugar, blood pressure, headaches, or sleep patterns" (Swan, 2013). To meet these demands, e-textiles provide real time feedback for individuals and allow for easy reporting and analysis, eliminating the need to be a data scientist to unpack big data sets. The majority of these garments and devices fall into the category of passive textiles completing the job of processing data and presenting the information back to the end user through a smart phone application. Examples of these devices include the sports bra from the start up Supa, selling a sports bra that records heart rate and temperature (Charara, 2017). However, there are products beginning to explore the very smart e-textiles space for direct consumers. These e-textiles deliver active responses, such as yoga pants that provide haptic vibrations based on time in a yoga pose (Hullinger, 2017) providing real time feedback allowing for dynamic changes in personal health/workout performance. While these changes in wearable technology come in various forms across the sports industry, the impact to product design is clear: data drives decisions and builds a strong customer base.

Sport Safety

Wearable technology is not just impacting how products are designed, but is also dramatically changing the landscape of sports safety. Concussions are an epidemic across all sports, high school and professional alike. With 60% of players that return to game play after suffering from a head injury display signs of reoccurring symptoms concussions/head injury prevention have garnered a significant amount of interest. A 2017 study attempted to understand the causation between impact, game play, and injury using wearable sensor nodes in parallel with video recordings to asses verified impacts in Women's Lacrosse (Caswell, et al., 2017). Non-invasive wearable technology allows for and understanding at the "micro-level aspect of player performance" (Stuart, Hickey, Morris, Odonovan, & Godfrey, 2017), providing coaches with the information that is necessary to make pragmatic decisions during game play, increasing player safety. Additionally, research from wearable technology fuels the manufacturing of products such as football helmets that can reduce the risk of concussions and injury, actively working to decrease the number of concussions per year (Rowson, et al., 2014). Wearable technology and e-textiles allow for researchers to capture data in ways that were previously impossible, directly benefiting athletes wellbeing.

Healthcare Industry

The healthcare industry can benefit from the wearable market by enabling both patients and physicians alike access to the data that they need, in real time. With smart textiles, patients are able to wear comfortable garments that help to track data directly relating to their health and recovery. Through dashboards, smart phone applications and predictive modeling healthcare is able incorporate this data into decision making and treatment plans. While these sensors and textiles have their place across the field of healthcare, neonatal and geriatric care are two areas that have high potential for benefit.

Neonatal Care

Infants that are hospitalized within Intensive Care Unit are often monitored 24 hours a day are frequently subjected to tests or procedures checking for vital signs. These infants are typically underweight, and lack the necessary strength for these exams. Wearable technology remedies several of these concerns, but applying the necessary sensors is often traumatic and irritating to the infants (Bouwstra, Chen, Feijs, & Oetomo, 2009). With the rise of popularity of smart textiles, advancements have been made for garments that adapt to the infant's body health care providers are able to monitor the infant's vitals. This enabled doctors to use the collected data to adjust treatment in an unobtrusive manner. Machine learning can be applied to these data sets, allowing for predictions to be made on future health or daily activities, such how long the baby might sleep or when they will be hungry again (Lee, 2015).

One challenge faced by these wearable textiles in regard to neonatal care is importance of not becoming faulty during skin to skin contact with another person. Not only must these e-textiles be comfortable, but they must be optimized to capture data only from the infant while they may be held by parents or doctor. An example of these smart textiles is a belt that can capture important vitals such as heartbeat, chest dilation and temperature (Ciani, et al., 2008). Through the use of embedded sensors, which wirelessly connect to software processing systems, these products continuously capture data while simultaneously providing parents a way to hug and hold their child infants (Bouwstra, Chen, Feijs, & Oetomo, 2009).

Geriatric Care

The second advance in the healthcare industry is in wearable technology that offers a discrete mechanism for providing care for the elderly. One of the most impactful contributions to care is the prediction and prevention of falls. Injuries sustained from a fall is the number one leading cause of death among older Americans (Centers for Disease Control and Prevention, 2016). Using gait and biomechanical patterns detected by wearable technology, individuals can be alerted to the risk of a fall. Comparing different sensor methodologies such as 3D accelerometers, temperature sensors and 3D Gyro placed from the feet, lower back to the ear (Jr., Vieira, Pires, & Jr., 2016) the data reveals the most accurate placement of sensors for senior care. This is critical to help aid with self-monitoring and significantly improve the quality of life for the elderly population. This is notably true for population segments that have been diagnosed with chronic conditions such as Parkinson's. Patients with chronic care will benefit from wearable sensor through the ability to monitor, "motor and non-motor symptoms over time, furthering the development of digital biomarkers for disease progression" (Lima, et al., 2017).

The use of wearable technology for senior citizens has ushered in a new system of Ambient Assisted Living. That is, enabling seniors who may be diagnosed with a chronic condition or at a distinctly high risk for an accident to continue independent living with the aid of a wearable device (Lombardi, Ferri, Rescio, Grassi, & Malcovati, 2009). Several startups have begun to pair wearable technology, data and pattern analysis to provide caregivers a complete view of individual's movements, highlighting patterns such as shuffling or excess resting (Lee, 2015) and send necessary communications to caregivers helping to monitor, manage and predict risk of falls/injuries. The healthcare industry, both geriatric and neonatal segments, will continue to benefit as wearable technology continues to develop providing more accurate monitoring devices that unobtrusively deliver value.

First Responder Industry

First responders, individuals who are trained to respond to an emergency, are a prime population segment that can benefit from wearable technology and smart textiles. The need for smart responsive textiles and wearable devices amongst first responders that in 2016 Homeland Security funded *Emerge 2016: Wearable Technology Accelerator Program*. This program is focused on mobilizing, "innovators to help first responders whose difficult and grueling job requires them to carry outdated and heavy equipment" (DHS, 2018). These wearables and e-textiles provide individuals with the data they need to make smarter decisions in a highly changing and dangerous environment.

Fire Fighters

In the United States, there are on average 121 fatalities and 82,000 injuries in the firefighting industry alone (Soukup, Blecha, Hamacek, & Reboun, 2014). The introduction of smart textiles used in tandem with personal protective equipment has the potential to decrease this number of fatalities. Considering that firefighting occurs in a highly dynamic environment there is a need for either active smart textiles or very smart textiles providing the ability for feedback within the garments. For example, when exposed to very high temperatures for long periods of time smart textiles can adjust temperatures to help regulate the body temperature of firefighters. The development of a "smart suit" for firefighters allows for the data collection of environmental variables such as carbon monoxide levels, oxygen levels or other dangerous gases. Not only do these garments collect and store data about the surrounding environment, but they are capable of transmitting the information back to a database and system that can process the raw information. For firefighters, this means that the information can be sent to headquarters (Soukup, Blecha, Hamacek, & Reboun, 2014) enabling officials to make more informed decisions, thus increasing the safety of firefighters.

Military

An additional use case smart technology amongst first responders is the use across branches of the Military. Much like firefighting, the environment in which military grade personal protective equipment is necessary is highly dynamic and necessitates quick decisions. The development of very smart textiles is being conducted, manufacturing uniforms that act as “Second Skin Uniforms” providing smart and dynamic protection from environmental chemical hazards (Stark, 2016). Additionally, embedded sensors are being used to wireless transmit information regarding geolocation and personal vitals increases the agility and the safety of soldiers (Kutilek, et al., 2017). One example of predictive modeling based data collected from these wearable devices is the Smart Body Amour from Newport Sensors. The smart wearable sensors that are embedded in the ballistic protection garments manufactured by Newport Sensors provide alerts to end users as to when a vest has experienced damage above a threshold that is deemed acceptable for wear ("TenCate acquires Smart Body Armor technology", 2015). This predictive model not only eliminates the need for manual inspection, but had the possibility to detect damage that occurs in a pattern that is not noticeable to the human eye. Amongst first responder’s decisions need to be made at a face pace. Wearable technology and e-textiles integrate data into daily decisions and actions, allowing for these fast decisions to be made – and at a higher confidence level than ever before.

Challenges

While wearable technology has a high probability of impact across several industries, the challenges of wide stream adoption must be considered. A natural byproduct of big data collection is a variety of data, meaning that the data collected is a conglomeration of structured and unstructured data. This data disorder introduces the challenge of system interoperability between wearable devices. Consumers are quickly acquiring devices to measure almost every aspect of their life. While consumers may find it helpful to have smart socks tracking their biometric movements of their feet – if the data or analysis is not able to be combined with other smart products they own the information is rendered practically useless. Often, these products may provide an open source API for data collection. While this may be helpful to a certain degree, the process of data transformation is muddled due to duplicated field names, different nomenclature and structure of data sets. Without a standardized or universal data scheme these stark differences cause integration to be a challenge without a clear solution (Arriba-Pérez, Caeiro-Rodríguez, & Santos-Gago, 2016) in the foreseeable future for wearable technology.

Additionally, smart clothes and wearable technology that is used to collect data and make predictions that could impact human life have a high risk of failure. If a sensor fails on a shirt produced to recognize signs of a heart attack in a high-risk the consequences are drastic. To mitigate this risk smart textiles must ensure that connectivity and real-time data streaming potential must be fully maximized. While risks certainly exist with the adoption of these products, smart textiles offer a solution for these monitoring challenges by offering a seamless integration into individual’s lifestyles.

Conclusion

Wearable technology is changing the way data is used in all industries and for personal use. Through the research conducted for this paper it is clear that the popularity of wearable devices is not slowing down. With one in six consumers owning and wearing such a device (Marr, 2017) the market is poised to continue to grow into the foreseeable future. The data collected from wearable devices allows for new insights into biomechanical movements and biometric vital signs fostering a culture based on data-driven decisions. These decisions are not only allowing individuals to make smarter choices about their health, but reduce injuries in sports, provide independence for senior citizens and reduce the risk of injury in highly dynamic environments.

References

Arriba-Pérez, F. D., Caeiro-Rodríguez, M., & Santos-Gago, J. (2016). Collection and Processing of Data from Wrist Wearable Devices in Heterogeneous and Multiple-User Scenarios. Sensors, 16(12), 1538. doi:10.3390/s16091538

Bouwstra, S., Chen, W., Feijs, L., & Oetomo, S. B. (2009). Smart Jacket Design for Neonatal Monitoring with Wearable Sensors. 2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks. doi:10.1109/bsn.2009.40

Brooks Running. (2013). RUN SIGNATURE: An Individual's Unique Running Form Defined by the Body's Habitual Motion Path. Retrieved February 4, 2018, from http://www.brooksrunning.com/on/demandware.static/-/Sites-BrooksRunning-Library/default/dw9f5e82b0/SS/RunSignatureWhitePaper.pdf

Caswell, S. V., Lincoln, A. E., Stone, H., Kelshaw, P., Putukian, M., Hepburn, L., . . . Cortes, N. (2017). Characterizing Verified Head Impacts in High School Girls' Lacrosse. The American Journal of Sports Medicine, 45(14), 3374-3381. doi:10.1177/0363546517724754

Centers for Disease Control and Prevention. (2016, September 22). Falls are leading cause of injury and death in older Americans. Retrieved March 5, 2018, from https://www.cdc.gov/media/releases/2016/p0922-older-adult-falls.html

Charara, S. (2017, May 18). Sabine Seymour's startup Supa is here to make the quantified self cool. Retrieved March 04, 2018, from https://www.wareable.com/meet-the-boss/supa-ai-sabine-seymour-fashion-8887

Ciani, O., Piccini, L., Parini, S., Rullo, A., Bagnoli, F., Marti, P., & Andreoni, G. (2008). Pervasive technology in Neonatal Intensive Care Unit: A prototype for newborns unobtrusive monitoring. 2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. doi:10.1109/iembs.2008.4649400

Chen, M., Ma, Y., Song, J., Lai, C., & Hu, B. (2016). Smart Clothing: Connecting Human with Clouds and Big Data for Sustainable Health Monitoring. Mobile Networks and Applications,21(5), 825-845. doi:10.1007/s11036-016-0745-1

EMERGE 2016 Accelerator Program. (2018, January 03). Retrieved March 05, 2018, from https://www.dhs.gov/science-and-technology/accelerator

Fahy, R., LeBlanc, P., & Molis, J. (2017, June). Firefighter Fatalities in the United States, 2016. Retrieved March 5, 2018, from https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics/Fire-service/osFFF.pdf

IBM Corp. (2015). The Future will be Worn. Retrieved February 4, 2018, from http://www.redbooks.ibm.com/redpapers/pdfs/redp5213.pdf

Hullinger, J. (2017, April 18). These Vibrating Yoga Pants Will Correct Your Downward Dog. Retrieved March 04, 2018, from https://www.fastcompany.com/3055510/these-vibrating-yoga-pants-will-correct-your-downward-dog

Jr., J. M., Vieira, M., Pires, M., & Jr., S. S. (2016). Sensor Fusion and Smart Sensor in Sports and Biomedical Applications. Sensors, 16(12), 1569. doi:10.3390/s16101569

Ku, J. P., Hicks, J. L., Hastie, T., Leskovec, J., Ré, C., & Delp, S. L. (2015). The Mobilize Center: an NIH big data to knowledge center to advance human movement research and improve mobility. Journal of the American Medical Informatics Association. doi:10.1093/jamia/ocv071

Kutilek, P., Volf, P., Viteckova, S., Smrcka, P., Lhotska, L., Hana, K., . . . Stefek, A. (2017). Wearable Systems and Methods for Monitoring Psychological and Physical Condition of Soldiers. Advances in Military Technology, 12(2). doi:10.3849/aimt.01186

Lee, E. (2015). Baby by the Numbers Keep tabs on your newborn with a smart ankle bracelet. IEEE Spectrum, 24-24. Retrieved March 5, 2018, from http://ieeexplore.ieee.org.ezproxy.spu.edu/stamp/stamp.jsp?arnumber=7115553&tag=1

Lee, E. (2015). Wearables for frail seniors. IEEE Spectrum, 52(9), 25-25. doi:10.1109/mspec.2015.7226602

Lima, A. L., Hahn, T., Evers, L. J., Vries, N. M., Cohen, E., Afek, M., . . . Faber, M. J. (2017). Feasibility of large-scale deployment of multiple wearable sensors in Parkinsons disease. Plos One, 12(12). doi:10.1371/journal.pone.0189161

Lombardi, A., Ferri, M., Rescio, G., Grassi, M., & Malcovati, P. (2009). Wearable wireless accelerometer with embedded fall-detection logic for multi-sensor ambient assisted living applications. 2009 IEEE Sensors. doi:10.1109/icsens.2009.5398327

Marshall, G. (2016, September 09). The story of Fitbit: How a wooden box became a $4 billion company. Retrieved February 04, 2018, from https://www.wareable.com/fitbit/youre-fitbit-and-you-know-it-how-a-wooden-box-became-a-dollar-4-billion-company

McClusky, M. (2009, June 22). The Nike Experiment: How the Shoe Giant Unleashed the Power of Personal Metrics. Retrieved March 04, 2018, from https://www.wired.com/2009/06/lbnp-nike/

Mitschke, Kiesewetter, & Milani. (2018). The Effect of the Accelerometer Operating Range on Biomechanical Parameters: Stride Length, Velocity, and Peak Tibial Acceleration during Running. Sensors, 18(2), 130. doi:10.3390/s18010130

(n.d.). Fitbit device unit sales worldwide 2010-2016 | Statistic. Retrieved March 04, 2018, from https://www.statista.com/statistics/472591/fitbit-devices-sold/

Rowson, S., Duma, S. M., Greenwald, R. M., Beckwith, J. G., Chu, J. J., Guskiewicz, K. M., . . . Brolinson, P. G. (2014). Can helmet design reduce the risk of concussion in football? Journal of Neurosurgery, 120(4), 919-922. doi:10.3171/2014.1.jns13916

Smart Clothing and Wearable Technology. (n.d.). Functional Clothing Design. Retrieved from http://scet.berkeley.edu/wp-content/uploads/Smart-Clothing-Market-Analysis-Report.pdf

Soukup, R., Blecha, T., Hamacek, A., & Reboun, J. (2014). Smart textile-based protective system for firefighters. Proceedings of the 5th Electronics System-integration Technology Conference (ESTC). doi:10.1109/estc.2014.6962821

Stark, A. (2016, August 3). Second skin' uniform protects soldiers from biological and chemical agents in the field. Lawrence Liver

Stoppa, M., & Chiolerio, A. (2014). Wearable Electronics and Smart Textiles: A Critical Review. Sensors, 14(12), 11957-11992. doi:10.3390/s140711957

Stuart, S., Hickey, A., Morris, R., Odonovan, K., & Godfrey, A. (2017). Concussion in contact sport: A challenging area to tackle. Journal of Sport and Health Science, 6(3), 299-301. doi:10.1016/j.jshs.2017.03.009

Swan, M. (2013). The Quantified Self: Fundamental Disruption in Big Data Science and Biological Discovery. Big Data, 1(2), 85-99. doi:10.1089/big.2012.0002

TenCate acquires Smart Body Armor technology. (2015, August 13). Retrieved March 05, 2018, from https://www.bodyarmornews.com/tencate-acquires-smart-body-armor-technology-newport-sensors/