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INTRODUCTION TO WEARABLE HEALTHCARE TECHNOLOGY

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ABSTRACT

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The advancements in technology are enabling the creation of smaller computers than ever before; wearable technology incorporates this technology to create wearable devices to enhance the quality of human life. The amount of connected wearable devices worldwide is expected to hit the milestone of a billion devices somewhere around 2022. As healthcare is becoming increasingly prone to technology, it acts as the best platform for utilizing this wearable revolution in order to improve the quality of human life.

This thesis focused on providing a general explanation into wearable technologies as well as its potentials and risks in healthcare applications. Previous researches about this subject have generally focused on its specific aspects (privacy issues, particular technologies). Therefore, the purpose of this thesis is to explain why wearable technologies are important in layman's terms, in hopes of cultivating interest towards this promising technology. The research was executed as a literature review with some personal conclusions using the most topical academic sources.

Keywords: wearable technology, healthcare, health information technology, smart technologies, wearable sensors

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Teknologian nopea kehitys on mahdollistanut ennennäkemättömän pienten tietokoneiden valmistuksen. Puettavat teknologiat käyttävät hyväkseen näitä pieniä puettavia laitteita, joilla on tarkoitus parantaa elämänlaatua. Puettavien teknologialaitteiden määrän kasvun on odotettu saavuttavan miljardin laitteen rajan vuoden 2022 tienoilla. Koska terveydenhuolto hyötyy teknologian kehityksestä, se on oiva kohde puettavan teknologian hyödylliseen käyttöön.

Tämän tutkielman tarkoituksena on luoda yleislaatuinen selvitys puettavista teknologioista, niiden antamista mahdollisuuksista ja riskitekijöistä terveydenhuollon alalla. Aiemmat tutkimukset asiasta ovat keskittyneet lähinnä puettavan teknologian erityisiin osa-alueisiin (kuten tietosuojaan tai tiettyihin laitteisiin). Tutkielmassa esitellään puettavaa teknologiaa ja siihen liittyviä terveydenhuollon mahdollisuuksia niin, ettei siitä tarvitse olla aikaisempaa tietämystä. Puettavat teknologiat terveydenhuollossa saavuttavat varmasti lähivuosina entistä suuremman merkityksen, ja tämä tutkielma voi toimia alustuksena aiheeseen. Tutkimus tehtiin kirjallisuuskatsauksena käyttäen viimeisimpiä akateemisia tutkimuksia ja mukana on myös omia päätelmiä.

Asiasanat: puettavat teknologiat, terveydenhuolto, terveysteknologiat, puettavat sensorit, älyteknologia

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1 INTRODUCTION

The commercialization of wearable technologies has drastically increased during the last 5 years, as the size of computers has decreased and the development of smart sensors has enabled the creation of small and precise trackers for a wide array of functions ranging from smart glasses to smart bracelets. At the core of this wearable technology evolution is the wearable health tech, which is becoming more and more prone to technology. Many companies have started developing wearable devices towards implementing more sufficient ways of providing healthcare (Collier and Randolph, 2015). The various range of wearable devices are being developed in order to fill a void where human error is present. In this thesis the focus will be in explaining what wearable technology really includes, as well as both the future prospects and problems for wearable technology in healthcare. As this technology is still in its early adaption phase, various kinds of information are needed about the subject to change people's perceptions about wearable technology acceptance in healthcare. In contrast with the positive prospects of wearables from various sectors during its early days when wearable technology started being commercialized, Lee, Kim, Ryoo and Shin (2016) found out that many survey results now show that its proliferation rate into public society has not met expectations. As this subject has become more prominent during the past decade, various researches have been conducted about it. These researches have generally focused on particular aspects of wearable technology (e.g. specific technologies/sectors). Therefore, a general overview about both wearable technologies in general, as well as their healthcare applications is needed A personal motivating factor for me to take on this study was the expertise of my parents about the subject. Both of my parents are doctors (mother a hematologist and father a neurologist) in Tampere University Hospital and through them I acquired the initial information that wearable technology in healthcare has become a popular talking point. My mother also revealed to me that 50 % of the new IT-companies established in Finland are focused on healthcare technology. This shows the prospects many people see in this new field of wearable medical devices.

This study revealed that the amount of wearable devices is growing

very quickly, and that companies need to find new ways to properly utilize and secure this data flood. Future potential of wearable technology in healthcare borders the realms of science fiction, but currently its most practical usage is involved in elderly care.

1.1 Research problem and research questions

The wished outcome of this research is to conduct a literature review about wearable technologies in healthcare, and to consider the possibilities and problems it will face before becoming the next big thing in technology. The purpose of this study is to cultivate the interest about wearable technology and to emphasize the potential in healthcare developments it could bring. Before starting to go into details of wearable technology in healthcare, we start by introducing the basics of wearable technology in general. The research question is as simple as:

- **What is wearable technology?**

After discoursing the basics of wearable technology, we move onto the main research question which focuses on the potential of wearable healthcare technology as well as its main development and problem areas. The primary research question of this thesis is as follows:

- **What are the main challenges and possibilities for wearable technology in healthcare?**

By providing thorough answers for these two research questions in layman's terms, this thesis hopes to explore the potential that lays in wearable technology including its present applications as well as its future forecasts.

1.2 Research method and data acquisition

The key words to be used when conducting this research are: wearable technology, healthcare, health-IT, telemedicine, smart technologies, wearable sensors. The electronic libraries used will be the AIS Electronic Library (AISeL), JYKDOK, IEEE Xplore and Google Scholar. Since there are lot of very detailed studies published about the subject, the bibliography for this research will be about the matter in general, and not about elaborate research. The sources used will be focused on wearable technology adaptation in healthcare and its main problems/possibilities; the focus will be given on researches with most references and preferably not from Google Scholar, but given its vast coverage it will not be ignored completely.

1.3 Research structure

This research is divided to four main chapters. First chapter is Introduction, where the main concepts of wearable technology in general and wearable technology in healthcare are explained in brief, followed by research problems, questions, methods and structure with data acquisition.

The following chapter, "What is Wearable Technology?" will explain the main concepts of wearable technology, whilst also providing a short summary about the history of wearable technology. Different hyponyms of wearable technology and its progression speed are also taken into account in this chapter. The chapter will end with a short conclusion and a brief introduction about the next chapter to ease the transition.

The third chapter focuses on the main problems and possibilities that wearable technology in healthcare is likely to face. The main problems will be divided into two different sections, and the possibilities and potential of wearables technology in healthcare will be discussed in the following section.

Last chapter is the Conclusion chapter, where main points of this thesis are repeated and emphasized and the core content of this thesis is presented. Possible future studies about wearable technology in healthcare are also debated.

2 WHAT IS WEARABLE TECHNOLOGY?

Wearable technologies consist of two different components, which are wearable and body sensors. Picard and Healey (1997), define a wearable as being anything worn on the user. The body sensor refers to any devices that are being used to monitor variables and transmit that data to an online storage. For instance, these devices can be accelerometers, which measure motions along reference axes, or gyroscopes which are automated devices that "measure 3D orientation based on the principles of angular momentum" (Geoff et. al. 2014). Walker (2013), claims that "whether the product is smart, questioning advanced circuitry, wireless connectivity and independent processing capability, determines if it classifies as a wearable device". Tehrani and Michael (2014), define wearable devices (or sometimes just 'wearables') in simpler terms, as electronic technologies or computers that are incorporated into items of clothing and accessories which can be worn comfortably on the body. Figure 1 shows the characteristics of a wearable device.

Although their history traces its roots back to the 17th-century, the interest in wearables surged during the last decade with the introduction of new sophisticated devices with the potential to be used in a variety of different tasks. The most common concepts currently available for consumer use are smart watches (iWatch, Samsung Galaxy gear), smart bracelets (Fitbit, Garmin Vivosmart) and Google Glasses. The most advanced wearable devices are primarily in use in the field of military technology (Tehrani et al, 2014), especially in countries with high military budgets such as the United States. Despite these ambitious predictions about wearable technology, the market for them is still in its early adaption phase

(Sultan, 2015). The rapid rise of wearable devices has voiced multiple concerns about them with privacy implications being the biggest concern of them all. [1][2]

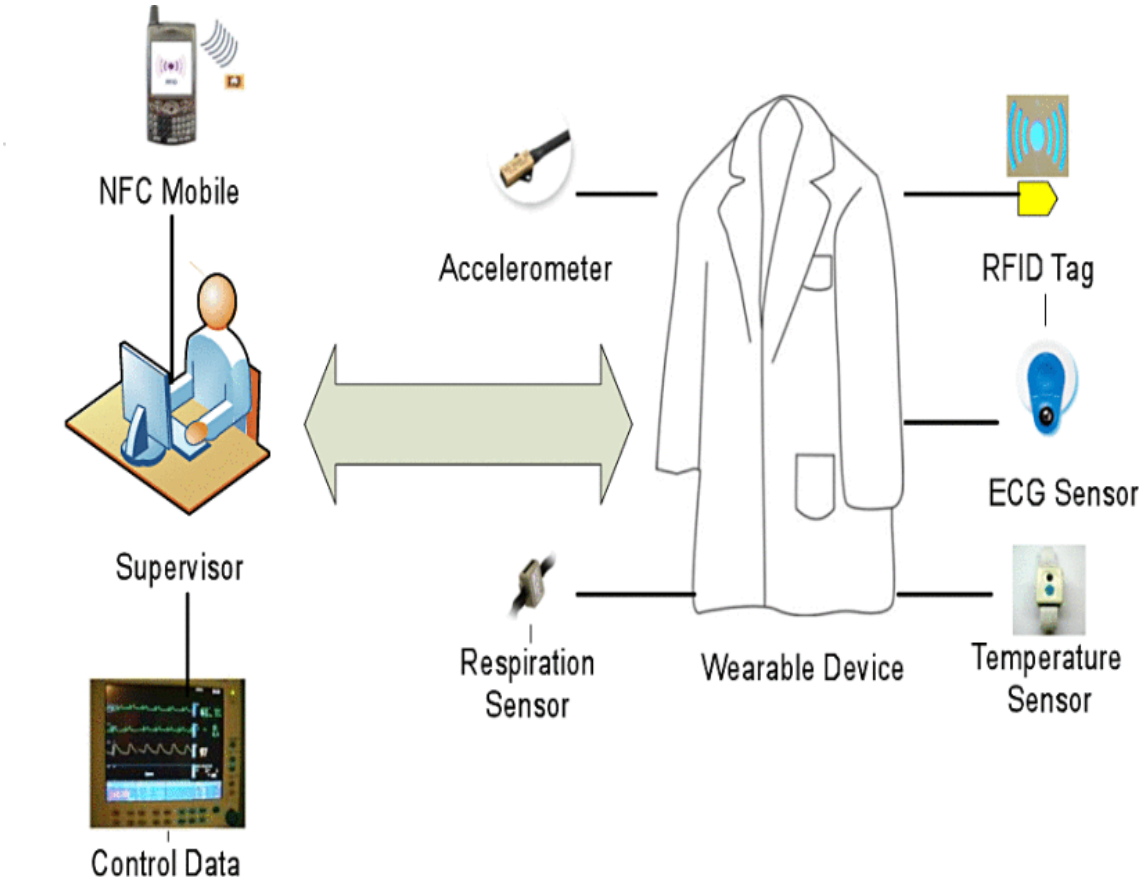

Figure 1 - Characteristics of a wearable device (Source: Applying wearable solutions in dependent environments)

2.1 A Brief History on Wearable Technology

The history of wearable technology traces its roots back to the 17th-century, when Chinese merchants came up with the idea of using a small ring titled 'The Abacus Ring' to use as a counting tool to make quick calculations. This is the first 'wearable computer' of known history and serves as a good example of how wearable devices can be used to make life easier. The next example of how simple wearable devices can revolutionize the way we function comes around 300 years later, when an unnamed German artillery officer, frustrated with having to use both hands to check on his pocket watch decided to strap it to his wrist, freeing both hands for action. This led to the generalization of the wrist watch which has since

[1] RFID = Radio-frequency identification
[2] ECG = Electrocardiography

been an essential part of every gentleman's wardrobe.

Even though the first wearable computer was developed in 1966 by Thrope and Shannon (a small analogue computer that measured the speed of a roulette wheel and transmitted predicted results to an earpiece), it wasn't until the mass production of the microchip in the 1980s that enabled humankind to create smaller and lighter computers than ever before. Many researchers and companies such as Steve Mann and Pulsar experimented with the idea of using technology to enhance human life, but the devices produced during this time were clumsy and made the wearer look more like a computer than a person. Some examples of devices created during this period are the Calculator Watch and the predecessor of Google Glasses - the EyeTap. The rapid advancements in portable computing in the early 90s contributed to the growth of interest towards wearables, and the world's first "wrist computer", was developed by Edgar Matias and Mike Riucci from the University of Toronto in 1994. In 1996, DARPA (the Defense Advances Research Project Agency), hosted the world's first "Wearables in 2005" workshop, to set future predictions about the advancement of wearables which included computerized gloves which could read RDIF tags and body mounted cameras. The explosion of consumer mobile phones lead to wearables taking a less significant role in the late 90s and early 00s, and it wasn't until late 00s that wearable technology really started to take off. Devices that supported augmented reality also got their start during this time period.

Approaching the 2010s, wearables started to incorporate IEEE, IETF and other industry standards, such as Bluetooth technology, leading to more various interfacing under the wireless personal area network (WPAN) and wireless body area network (WBAN) categories ("The History of Wearable Technology"). When Google developed its first prototype of the Google Glass and eventually released it to the general public for a starting price of 1500 USD in May 2014, numerous companies made a run into the smart wearable market, including Apple (iWatch), Samsung (Galaxy Gear), Sony (SmartWatch), and many others. These companies are now developing a vast array of different wearables such as smartwatches, fitness trackers, augmented reality game equipment (VR/mixed reality headsets) and smart clothing. The devices are developing in a rapid pace and in 10-20 years we can begin to see science fiction emerge with real life.

2.2 Introduction to Wearable Devices

Wearable devices can be divided into two distinct categories: 'wearable computers' and 'smart textiles'. Wearable computers are fashion accessories that contain the necessary electronics, usually they are bracelets or watches. They enable consumers to carry out tasks in a relatively unobtrusive and socially acceptable way leading to increased levels of productivity or enjoyment (Rackspace, 2013a). The 'smart textiles', according to Hertleer, Langenhove and Schwartz (2012), are electronics woven into the fabric, enabling products to measure and/or react to stimuli from the user or environment. The advantage that smart textiles possess over

smart computers is that they can be worn comfortably for longer periods of time without skin irritation even though they lose in the range of possible user interactions (Page, 2015). Therefore, they are more appropriate for long term monitoring applications or for circumstances where aesthetics is highly important.

2.2.1 Wearable Computers

Wearable computers are the most prominent wearables' currently available for consumer use and they have improved a lot from the awkward and obtrusive 10-pound wearable computer designed by Steve Mann from the MIT Media Lab. The most common wearables computers currently in the market are much lighter, hands-free devices including smartwatches, smart bracelets and the Google Glasses. After the introduction of Google Glasses in 2013, companies have begun a race to this market and with the rapid advancements in wearable technology new products are launching every year. Apple is developing its Apple Watch Series 3 to compete with latest Android Wear 2.0 watches, concentrating on slimmer design, more storage and LTE (Long Term Evolution) to give it an edge over its competitors. Samsung's 'Galaxy Gear' tries to attract customers by focusing on the connection between the smartwatch and the smartphone; receiving notifications on the watch enables the user to see messages without removing their phone from their pocket. The battle between mobile devices and wearable computers has been high in the past 20 years, and this effort by Samsung to link smartphones and smartwatches shows an example that maybe both of these product markets can coexist. Figure 1 shows how the confrontation between mobile devices and wearable computers is seen in newspaper/article popularity.

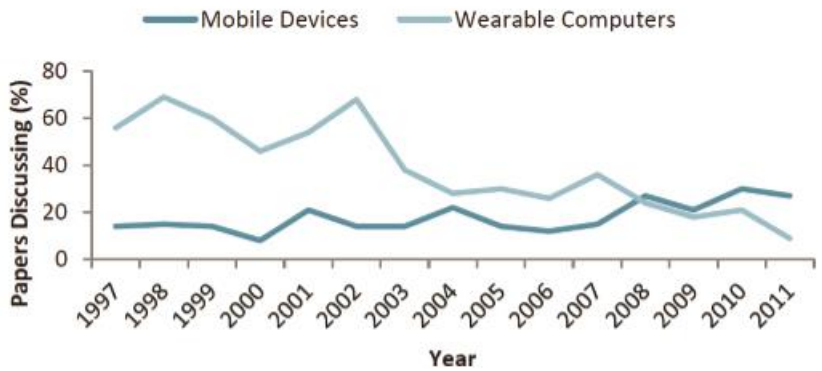

Figure 2 - Papers discussing mobile devices/wearable computers (Source: Martin, 2012)

One of the most important qualities for a wearable computer according to Pascoe (1998) is context-awareness; even though his study is almost 20 years old, the four generic contextual capabilities identified in his study still continue to be relevant. These four capabilities are: sensing, adaptation, resource discovery and augmentation. These four capabilities were tested by incorporating

them into a wearable computer prototype designed to assist an ecologist's giraffe observations in Kenya. The prototype was successful over a two-month trial, enabling the ecologist to complete more work in shorter periods with the context-aware features playing a critical role of the system's success. Around the same time, Billinghurst and Starner (1999) defined three key principles for wearable computing: mobility, augmented reality and context sensitivity. Mann (1998), goes even into more detail when defining wearable computing; he defines it in terms of three operation modes and six attributes. The three operational modes are:

- *Constancy:* The computer runs continuously to interact with the user;
- *Augmentation:* The computer serves to augment the intellect or senses of the user while the user is doing something else;
- *Mediation:* The computer may serve as an intermediary when the user is interacting with untrusted systems.

The six attributes are defined from the user's point of view and they include: unrestrictive to the user, unmonopolizing of the user's attention, observable and controllable by the user, attentive to the environment and communicative to others. These three operation modes and six attributes defined by Mann (1998), combined with the analyses of Pascoe (1998) and Billinghurst and Starner (1999) are all very important factors to influence wearable computers' adoption by users.

2.2.2 Smart Textiles

Smart textiles can be divided into two general categories: Aesthetic and Performance Enhancing. Aesthetic smart textiles generally focus on improving the outlook of the product by providing color-changing fabrics for example. Performance enhancing smart textiles can help regulate body temperature, reduce wind resistance and control muscle vibration; these smart textiles are seeing a lot of potential especially in the sports industry by allowing athletes to record and review their techniques. Stoppa and Chiolerio (2014), divide smart textiles with more detail into three different subgroups based on their abilities, these subgroups are:

- *Passive smart textiles*: only able to sense the environment/user, based on sensors;
- *Active smart textiles*: reactive sensing to stimuli from the environment, integrating and actuator function and a sensing device;
- *Very smart textiles*: able to sense, react and adapt their behavior to the given circumstances.

The potential of smart textiles is vast, with areas such as nanotechnology to coat a fabric with nano-particles to create new properties such as anti-bacterial, water-repellence, UV-protection and self-cleaning, while still maintaining

breath-ability and tactile properties of the textile (Syduzzaman, Patwary, Farhana and Ahmed). Other applications for smart textiles include optical fibers, shape memory alloys, chromic materials and phase change materials; these matters are very scientific and detailed and therefore receive less focus on this study.

2.2.3 Wearable Technology in Numbers

The growth of wearable technology during the past 5 years has been remarkably fast. An analyst company 'CCS Insight' made an estimate in 2014 that the wearable device market would grow from 9.7 million devices in 2013 to 135 devices by 2018 (CCS Insight, 2014). However, by 2016 the number of connected wearables was already 325 million, and figure 2 shows how the amount of connected wearable devices is estimated to grow during the next 4 years (Statista, 2017). This shows how remarkably fast the market for wearables is currently growing.

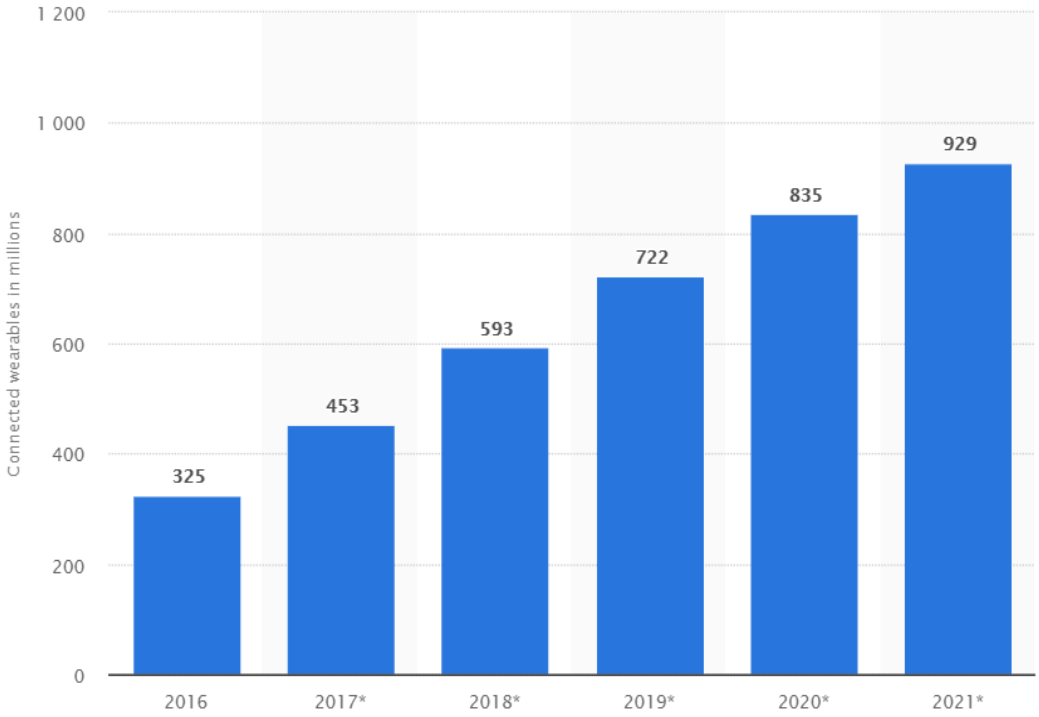

Figure 3 - Number of connected devices worldwide 2016-2021 (in millions) (Source: Statista, 2017)

While the North American and European companies run the wearables market, the biggest growth is expected to come from Asia mostly because of increasing aging population, increasing prevalence of diseases and rapid technological advancements ("Wearable Medical Devices Market", 2016).

2.3 Health Information Technology

Of the whole wearable device market, medical devices are the biggest field followed closely by fitness aids. Previous studies have proved that people generally exhibit positive attitudes towards wearable healthcare devices (Steele, 2009; Fraile, 2010). Collier and Randolph (2015), found out that the boundaries between fitness and medical types of wearable technology seem to merge regularly. Health-IT is becoming more and more influential with technology becoming ever more pervasive in healthcare ranging from individualized self-care and disease management to improvements in hospital efficiency (Collier and Randolph, 2015). Wearable technologies in healthcare are growing in rapidly with companies such as Google, Apple and Samsung allocating vast resources on researching various kinds of medical wearable devices (Gao, Li and Luo, 2015). Apple has filed at least 79 patent applications that include the word "wrist" so far (Collier and Randolph, 2015). Intel recently partnered with the Michael J. Fox Foundation for Parkinson's Research to find patterns in the data collected by wearable devices that monitor patient's symptoms (Bolluyt, 2014). Technological advancements in medical devices, launch of numerous smartphone-based healthcare apps compatible with wearable devices, rising preference for wireless connectivity among healthcare providers, increasing focus on physical fitness and growing awareness of health concerns are all factors that are driving wearable device market which is expected to be worth 12.14 Billion USD by 2021 ("Wearable Medical Devices Market", 2016). North America is expected to dominate the highly competitive market for medical wearable devices. Biggest players in the wearable device market include Fitbit Inc (U.S.), Philips Healthcare (the Netherlands), Garmin Ltd (Switzerland), Withings SA (France), Omron Corporation (Japan) and Polar Electro Oy (Finland).

2.4 Concluding remarks

In this first part of the thesis we discussed the basics of wearable devices, their history, segments and general overview of wearables in healthcare. Following the theory of a natural life cycle of a product (introduction, rise, peak, decline, and obsolescence), wearable technology is now in the rise stage or the *early adoption* phase, and even though the growth of wearable devices market has been substantial during the past 5 years there are no precedents to determine what the future will bring. The boundaries between medical wearables and fitness wearables are diminishing, as a large amount of new wearable devices is hitting the market. Big companies with capabilities to mass-produce new wearables, store the massive amounts of data they bring and continuously research new possibilities are paving the way with smaller start-ups with innovative mindsets following closely behind. Now that we have reviewed the basics of wearables in general,

it is time to go into more detail of the future prospects for medical wearables as well as the major threats they are likely to face.

3 WEARABLE TECHNOLOGY IN HEALTHCARE

Given the possibilities that wearable technology holds for medicine, it is no wonder that information about the subject is on high demand. The opportunities it could bring border the realms of science fiction, with ideas such as Iris Scanning, Smart Shirt and Invisibles currently in the ideation phase. Given the wearables' ability to collect vast amounts of medical data, Lee, Kim, Ryoo and Shin (2016) state that individualized big data has become a reality and healthcare institutions need to find ways to properly gather, secure and use this data in the most efficient way possible. Measuring the intake and consumption of calories, tracking sleep, postural correction, blood pressure and heart rate are the most fundamental applications that current wearables can provide in the field of healthcare (Lee et al, 2016). In the past, the healthcare industry has been hesitant to change (Romanov, Cho and Straub, 2012), but the advent of wearable technology and its applicability to healthcare may prove otherwise (Collier and Randolph, 2015). According to Lewy (2015), wearables in healthcare could provide additional information that integrates data from different sources, complement the clinical data that exists on the EHR (Electronic Health Record) and generate new knowledge. With the use of these wearable devices in healthcare, patients can in the future access any specialist they desire in any part of the world. The physical boundaries and distances that currently limit a specialist's area could be removed, leading to a network of "specialty" centers around the world where each hospital could focus on a particular area of medicine rather than attempt to excel in all the specialties (Park and Jayaraman, 2003).

There are still many obstacles to overcome before this technology could become mainstream; how to protect private medical information from being leaked and how to set appropriate regulations concerning their use are a few examples of the problems this technology is likely to face. Another problem especially for smaller companies is what to do with all the data that wearable devices can generate. Companies like Intel and Google possess the capacity to manage and analyze staggeringly huge amounts of information, and in the future smaller companies may rely on the methods or even infrastructure established by these data-capable companies (Bolluyt, 2014).

3.1 Problems

There are two main problems with wearable technology in healthcare:

- The data security issue of private medical information
- The "tidal wave" of data and information

The data security issue refers to the usage of the data acquired by medical wearable devices. One's personal health information contains very sensitive data, and as data privacy laws are prone for changing and some companies are known for illegally selling their user's data after going bankrupt ("FTC Press Releases", 2015), it is natural that this is a major issue. The second problem concerns the storage/analyzation issue that comes with this "tidal wave" of data; especially smaller companies face the problem of generating algorithms to receive, store, analyze and respond to this information while more data-capable companies have them already in place. Smart business intelligence is needed to treat this data flood. With the inappropriate filtering of the medical data received problems might arise as doctors receive contradictory information from the right data in the wrong place. The cost of the technology is also a barrier of implementation.

3.1.1 The security issue

Since healthcare wearables continuously collect the user's personal health information in real time, and individual's personal health information is more sensitive than other types of information such as demographic and general transaction information (Bansal, Zahedi and Gefen, 2010) healthcare wearables should be regarded as a high privacy concern product. Various previous researches have concluded that privacy of health information is of focal concern for individuals (Bodenheimer et al. 2003; Cantor 2001; Harris-Interactive et al. 2002; Masys et al. 2002; Shortlife 1999; Westin 2003). According to Rindfleisch (1997), individuals avoid healthcare in sensitive areas because of its privacy concern. Generally individuals would perform a risk-benefit analysis when asked to provide personal information to organizations, which is widely known as privacy calculus (Awad and Krishnan, 2006). Since the use of wearable healthcare devices involves the sharing of personal health information, individual's decision of adopting healthcare wearable technology involves a privacy calculus that takes into account the tradeoff between perceived benefits and perceived privacy risks (Xu, Teo, Tan and Agarwal, 2009). When the user thinks that the expected benefits that come from using the wearable device exceed its risks, he/she would choose to adopt the healthcare wearable technology. Typically society has emphasized the negative consequences of sharing personal information such as security breaches, frauds or theft of information. A study conducted by Angst (2017) was a first attempt of trying to investigate whether people really weigh the costs and benefits of potentially compromising some degree of privacy in order to get better results. The study showed strong benefits of the proper use of EHR (Electronic Health Record), but also stated that "considerable work remains with respect to the investigation of the variability in beliefs related to privacy concerns and, in particular, whether public opinion will impact the use of information technology that has been developed to store and maintain personal information" (Angst, 2017).

The anonymization of the medical information is also an important matter. Since this medical information gathered by the wearable devices will be

used in improving healthcare, it is necessary that doctors and other parties involved can have access to the data. The anonymization of this data means that they can see the data, but they cannot see which person's data it is. This enables the data to be assessed and shared between doctors without exposing anyone.

Other important questions regarding data privacy in wearable healthcare technology are as follows: who has access to the data? Who owns the data and controls it? Is the data shared with third parties? Is it sold or loaned for marketing or advertising purposes? Inadequate answers to these questions combined with bigger privacy concerns might lead to unwanted consequences and results for both the user and the company involved.

3.1.2 The information issue

The figure 2 shown in chapter 2.2.3 shows the rapid increase in the amount of connected wearables worldwide that is expected to reach the milestone of a billion devices around 2022. A billion connected wearables that all continually gather information from their users mean a wave of information that might flood the systems' of less data-capable companies. Another problem is that the existing wearable technologies that gather information are not properly integrated into the systems, meaning that the system is accessed separately by the doctor in question (Lewy, 2015). Given that this technology is still in the early adoption phase, supporting tools such as risk analyses and care pathways are not defined yet and it is still unclear how they will be implemented into the care process. The medical information gathered should be analyzed and validated, ensuring an added value for the treatment is well presented (Raghupathi and Raghupathi, 2014).

The solutions to these information issues are not easy to find, and it requires the collaboration of the healthcare professionals and patients, not just in adoption, but also in the process of development and implementation in best practice and care pathways (Lewy, 2015).

3.2 Possibilities

There are two main kinds of healthcare wearables currently in the market: fitness wearables and medical wearables. Fitness wearables include fitness trackers such as Fitbit and Samsung Gear, and they are suitable for the young and the healthy users. On the contrary, medical wearable devices are more likely to be adopted by the elder and the unhealthy users (Gao et. al, 2015). Fitness wearables focus on improving physical prowess instead of curing existing health concerns and therefore receive minuscule focus on this part.

3.2.1 For the elderly

Most elderly persons want to continue living in their own homes with the help of geriatric home care service. This sets great demands on our health care system. This is probably the biggest potential for wearable technology in the future. Using wearable technology to monitor the health of the elderly who are not staying in hospitals is where the biggest potential for improving healthcare in general lays. The elderly are being socially excluded from the newest trends such as mobile applications as the majority of the new efforts are being targeted at younger adults (Page, 2014). Kandler et. Al. (2015) found out that elderly have very different personality types compared to younger adults, resulting in decreased openness and hesitation in willingness of adopting new technologies. This issue could be resolved by integrating smart wearable devices into their daily lives (Chua et al. 2015).

It is a known fact that elderlies in general have difficulties in handling new technologies; technological advancements have been burgeoning during the 21th century and the senior citizens have troubles keeping up with the pace of the newest trends. This fact has been shown in studies such as the study by Czaja et al. (2006); figure 4 shows the general use of technology according to age group and gender. Technical self-efficacy is a term used to describe the belief that the individual themselves is or is not capable of using the technology in question (James et. Al. 1986). As wearable technology requires very little or none additional operational efforts, the self-efficacy of the elderly will be increased, motivating them to be socially inclusive with the adaptation of wearable technology. Although wearable technologies seem like the perfect solution to monitor the health of the elderly, there are still obstacles to face. As elderly have shown unwillingness of adopting new technologies and are generally more conservative than their younger counterparts, the privacy issue discussed in chapter 3.1.1 will definitely surface. Therefore, it is important for practitioners to take note of the societal issues in order to create a safer technology for everyone (Chua et. al, 2016).

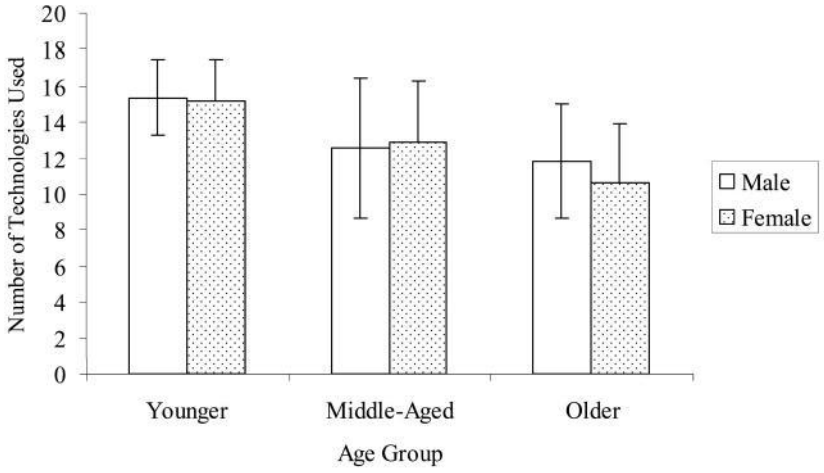

Figure 4 - General use of technology according to age group and gender (Source: Czaja et. al, 2006)

3.2.2 Future potential

The possibilities for implementing wearable technology in healthcare are endless. The FDA-approved sensor pill – the Ingestion Event Marker (IEM), monitors data in the body to make sure that medication is taken properly. There is also the Freescale KL02 chip, which is a swallowed body-monitoring smart device that sends back bio-readings via Wi-Fi to monitor or diagnose diseases. These two combined would remove the human-error of not remembering to take medicine or using the wrong kind of medicine for a disease. The smart textiles discussed in chapter 2 also include possibilities for wearable technology in healthcare; wireless sensors that can be woven into clothing can monitor patients' vital signs without requiring intrusive installment. Integrating these sensors into patient's hospital apparel would make the monitoring of patients even more functional than it is now.

IriTech released the world's first iris recognition enabled smartwatch – the FiDELYS by a crowd funding campaign in 2014. The price of the device was groundbreaking, only 200-250 $ and shows the possibility of iris recognition technology as a widespread consumer choice. According to IriTech, the FiDELYS will remove three major problems our generation is facing: The Password plague, Privacy issues and Authentication issues. By verifying your iris pattern, the FiDELYS can verify your user credentials for a variety of websites, encrypt/decrypt your data files, lock/unlock your device and act as a password replacement by an application called FYIO (For-Your-Iris-Only) (FiDELYS, 2014).

Even though everything discussed in this thesis so far implicates that wearable technology in healthcare is gaining an increasing foothold in our society, its successor might soon be here. The word 'wearable' implicates something that can be worn or taken off, which abrogates the idea of continuous monitoring that could create truly intelligent data. Implantable, microscopic sensor technology has already started to create a new market for seamlessly integrating technology into the human body – the Invisibles by Karten Design and Intel. The creation of truly invisible technology is something that sci-fi enthusiasts have been telling prophesies about for years – technology will become human. This is still far away from becoming a reality, and designers will have to start with wearables and begin thinking about how to turn someone into a body computer, rather than how to persuade these bodies to interact with computers (Karten, 2014).

4 CONCLUSION

In this study, the main concepts of wearable technology in general were accounted for and the problems and potential for its healthcare applications were examined. The study was executed as a literature review using most recent and topical academic sources. The most important findings of this study were the potential that wearable healthcare technology holds for eldercare, the increasing privacy concerns regarding wearable technology and the "tidal flood of information" that becomes an issue when individualized big data starts to generalize with the rise of wearable medical technology.

The first research question was about wearable technology in general: What is wearable technology? There are many different definitions for explaining wearable devices, but the main idea is that it involves a wearable part (a watch, bracelet, glasses etc.) and its electronic counterpart (a sensor, accelerometer, etc.) and use the data gathered by the device to improve performance (fitness wearables) or to keep track of vital health information (medical wearables). The definition of wearable technology by Tehrani and Michael (2014), defines them simply as electronic technologies or computers that are incorporated into items of clothing and accessories which can be worn comfortably on the body. The growth of the amount of connected wearable devices worldwide was shown in chapter 2.2.3, and the potential that these devices hold for healthcare is the main point of the second chapter and the main research question.

The second and primary research question was the following: What are the main challenges and possibilities for wearable technology in healthcare? This study explained that increasing privacy concerns associated with wearable technologies will be considerable, but it is vital to thoroughly examine the risk-benefit calculus that weighs the potential benefits over the possibility of compromising some degree of privacy (Angst and Agarwal, 2009). If the worst-case scenario of using the technology is the exposure of one's private medical information, whilst the worst-case scenario of not using the technology could result in jeopardizing one's health; which one is more severe? It can be also concluded that in order for the information gathered by numerous wearable devices to work properly, companies need to think of arranging ways to store, integrate, analyze and distribute this massive amount of new data. The monitoring of patients currently residing in a hospital through wearable technology would help to improve the quality of electronic health records, but it is not where wearable medical devices would bring the biggest benefits. Tracking the health of elderly people who are still living alone or with a significant other through medical wearable technology would improve the response time in case of an emergency. If the elderly person in question for example does not move normally or the bed is wet, an inspection team will be sent to check the situation. If the vital signs are continuously transmitted to a relative and the on-call emergency department of the nearest hospital, help can be provided with minimal response time.

The term ‘Individualized Big Data’ is something that the continuous use of medical wearable technology could bring forth. As big data is gaining increased attention from companies that seek to use it improve their reach and visibility, individualized big data could be used to abolish personal deficiencies. This is still ahead of its time as many hindrances remain, but the generalization of wearable technology could act as the initial chapter of completely removing all physical disabilities. Individualized big data gathered by wearable technology compared with cognitive computing could bring forth result we cannot even comprehend yet. Therefore, it is vital that these possibilities should be researched thoroughly. A proposed course of action to accomplish this utopian scenery would be the thorough planning of how to treat the massive amount of data gathered by wearable devices, more data-capable companies need to act as mentors to their smaller counterparts in order to properly integrate this new data into all systems in order for it to be used in the most efficient way possible. Data integration and processing of individualized big data, the data security aspect of sharing private medical information and an elderly-focused research of medical wearable technology are some examples for possible orientations for future research

REFERENCES

Angst, C. M., and Agarwal, A. (2009). "Adoption of electronic health records in the presence of privacy concerns : The elaboration likelihood model and individual persuasion", *MIS Quarterly 33(2)* , pp. 339-370.

Awad, N.F. and Krishnan, M. (2006). " The personalization privacy paradox: an empirical evaluation of information transparency and the willingness to be profiled online for personalization ", *MIS Quarterly* , Vol. 30 No. 1, pp. 13 - 28 .

Bansal, G., Zahedi, F.M. and Gefen, D. (2010). " The impact of personal dispositions on information sensitivity, privacy concern and trust in disclosing health information online ",*Decision Support Systems* , Vol. 49 No. 2, pp. 138 - 150 .

Billinghurst, M., and Starner, T. (1999). "Wearable devices: new ways to manage information," Computer (32:1), pp. 57-64.

Bodenheimer, T., and Grumbach, K. (2003). "Electronic Technology: A spark to revitalize primary care?" *Journal of the American Medical Association* (290:2), pp. 259-264.

Bolluyt, J. (2014). What Can Wearable Devices Really Do? Tech CheatSheet. Retrieved December 11, 2014, from http://wallstcheatsheet.com/technology/what-are-wearable-devices-really-capable-of.html/?a=viewall. Rackspace. (2013a) *The Human Cloud: Wearable Technology from Novelty to Productivity*. Rackspace, San Antonio.

Cantor, J.D. (2001). "Privacy Protections for Cybercharts: An Update on the Law," *Journal of the American Medical Association* (285:13), pp. 1767.

CCS Insight. (2014, August). Smartwatches and Smart Bands Dominate Fast-Growing Wearables Market. Retrieved from http://www.ccsinsight.com

Chua, W., Chang, K., & Bhandari, U. (2016). An Investigation of Social Inclusion through Wearable Technologies on Technical Self-Efficacies of Elderly

Collier, R., & Randolph, A.-B. (2015). Wearable Technologies for Healthcare Innovation. *SAIS 2015 Proceedings*. 18.

Czaja, S. J., Charness, N., Fisk, A. D., Hertzog, C., Nair, S. N., Rogers, W. A., and Sharit, J. (2006). "Factors Predicting the Use of Technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (Create)," Psychology and Aging (21:2), pp. 333-352.

Fraile, J., Corchado, J. and Abraham, A. (2001). " Applying wearable solutions in dependent environments ",*IEEE Transactions on Information Technology in Biomedicine* , Vol. 14 No. 6, pp. 1459 - 1467 .

FTC Requests Bankruptcy Court Take Steps to Protect RadioShack Consumers' Personal Information. (2015). Retrieved December 04, 2017, from https://www.ftc.gov/news-events/press-releases/2015/05/ftc-requests-bankruptcy-court-take-steps-protect-radioshack

Gao, Y., Li, H., & Luo, Y. (2015). An empirical study of wearable technology acceptance in healthcare. *Industr Mngmnt & Data Systems, 115*(9), 1704-1723.

Harris-Interactive, and Westin, A.F. (2002). "The Harriss Poll: #46," Harris Interactive, New York

Hertleer, C., Langenhove, L., & Schwarz, A. (2012). Smart Textiles: An Overview. In P. Kiekens & S. Jayaraman (Eds.), *Intelligent Textiles and Clothing for Ballistic and NBC Protection* (pp. 119–136). Springer Netherlands.

The History of Wearable Technology. Retrieved November 16, 2017, from http://www.redorbit.com/reference/the-history-of-wearable-technology/

IriTech. (2014). FiDELYS - The world's first iris recognition enabled smartwatch. IriTech, Inc. Retrieved December 10, 2014, from http://www.iritech.com/news-events/news/fidelys-worlds-first-iris-recognition-enabled-smartwatch 7

James E. Maddux, Larry W. Norton & Cal D. S. (1986). "Self-Efficacy Expectancy, outcome Value: Relative Effects on Behavioral Intentions". *Journal of Personality and Social Psychology*, 51(4). pp. 783 – 789

Kandler C., Anna E. K. , Birk H. and Franz J. N. (2015). "Patterns and Sources of Personality Development in Old Age". *Journal of Personality and Social Psychology*. 109 (1), pp. 175 – 191

Karten, S. (2014). Invisibles, Not Wearables, Will Profoundly Change Health Care. Fast Co.Exist. Retrieved December 11, 2014, from http://www.fastcoexist.com/3036554/wearables-week/invisibles-not-wearables-will-profoundly-changehealthcare.

Lee, J., Kim, D., Ryoo, H.-Y., & Shin, B.-S. (2016). Sustainable Wearables: Wearable Technology for Enhancing the Quality of Human Life. *Sustainability*, *8*(5), 466. MDPI AG. Retrieved from http://dx.doi.org/10.3390/su8050466

Lewy, H. (2015). Wearable technologies – future challenges for implementation in healthcare services. *Healthcare Technology Letters*, 2(1), 2–5.

Mann, S. (1998). "Wearable computing as means for personal empowerment," In *Proceeding of the 3rd International Conference on Wearable Computing* (ICWC), pp. 51-59.

Masys, D., Baker, D., Butros, A., and Cowles, K.E. (2002). "Giving Patients Access to Their Medical Records via the Internet: The PCASSO Experience," *Journal of American Medical Informatics Association* (9:2), pp. 181-191.

Page, T. (2015.) A Forecast of the Adoption of Wearable Technology. *International Journal of Technology Diffusion.* Vol. 6(2)

Page, T. (2014). "Touchscreen mobile devices and older adults: a usability study". *International Journal of Human Factors and Ergonomics*, 3(1), 65-85.

Park, S., & Jayaraman, S. (2003). Enhancing the quality of life through wearable technology. *IEEE Engineering in Medicine and Biology Magazine, 22*(3), 41-48.

Pascoe, J. (1998, October). Adding generic contextual capabilities to wearable computers. In *Wearable Computers, 1998. Digest of Papers. Second International Symposium on*(pp. 92-99). IEEE.https://www.marketsandmarkets.com/PressReleases/wearable-medical-device.asp

Raghupathi W., Raghupathi V. (2014). 'Big data analytics in healthcare: promise and potential', Health Inf. Sci. Syst., 2, (3)

Rindfleisch, T.C. (1997). "Privacy, Information Technology, and Health Care," Communications of the ACM (40:8), pp. 93-100.

Shortlife, E.H. (1999). Diffusion of Innovations, (4th Ed.) The Free Press, New York

Steele, R., Lo, A., Secombe, C. and Wong, Y.K. (2009). "Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare "*International Journal of Medical Informatics*" Vol. 78 No. 12, pp. 788 - 801.

Stoppa, M., & Chiolerio, A. (2014, July 07). Wearable Electronics and Smart Textiles: A Critical Review. Retrieved November 16, 2017, from http://www.mdpi.com/1424-8220/14/7/11957/htm

Sultan, N. (2015). Reflective thoughts on the potential and challenges of wearable technology for healthcare provision and medical education *International Journal of Information Management,* 35(5), 521-526.

Syduzzaman, M., Patwary, S. U., Farhana, K., & Ahmed, S. (2015). Smart textiles and nano-technology: a general overview. *Journal of Textile Science & Engineering*, *5*(1)

Tehrani, K., & Andrew, M. (2014, March). Wearable Technology and Wearable Devices: Everything You Need to Know. *Wearable Devices Magazine*, Retrieved from http://www.WearableDevices.com

Westin, A.F. (2003). "Social and Political Dimensions of Privacy," *Journal of Social Issues* (59:2), pp. 431.

Xu, H., Teo, H.H., Tan, B.C.Y. and Agarwal, R. (2009). "The role of push-pull technology in privacy calculus: the case of location-based services "*Journal of Management Information Systems*, Vol. 26 No. 3, pp. 135 - 173.

Zhang, J., Dibia, V., Sodnomov, A., & Lowry, P. (2015). Understanding the Disclosure of Private Healthcare Information within Online Quantified Self 2.0 Platforms. *PACIS 2015 Proceedings*. 140.