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Potential Usage of Wearable Sensors in Professional Healthcare

Master of Science Thesis
in the Management and Economics of Innovation Programme

PETER STEGERSJÖ
MARKUS ULENIUS

Department of Technology Management and Economics
Division of Innovation Engineering and Management
CHALMERS UNIVERSITY OF TECHNOLOGY
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PETER STEGERSJÖ
MARKUS ULENIUS

Tutor, Chalmers: JOAKIM BJÖRKDAHL
Tutor, company: N/A

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Peter Stegersjö and Markus Ulenius

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Department of Technology Management and Economics
Division of Innovation Engineering and Management
Chalmers University of Technology
SE-412 96 Göteborg, Sweden
Telephone: + 46 (0)31-772 1000

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Markus and Peter
June 2014 Berkeley, California

Abstract

Wearable sensors are products that can measure different data points of the body, e.g. ECG, blood glucose levels, and motion levels. The field for such products is growing, both in terms of companies and their respective sensors and the number of data points that are possible to measure. At the same time, healthcare in the United States is subject to major challenges as inefficiencies, demographic changes, and increased consumer demands put pressure on healthcare delivery to renew itself. Consequently, the possibility to collect such data points with wearable sensors is thought of as an interesting solution that might end up playing an important role to improve the healthcare delivery system in the United States.

Wearable sensors and healthcare is an interesting combination for investigation to the partner company of this master's thesis, i.e. TechCo. The company hopes to find a viable business opportunity and subsequently develop products and/or services. Hence, the purpose of this master's thesis is to provide insights and recommendations to TechCo on how to consider wearable sensors in future research and development.

In order to fulfill the purpose a literature review was conducted which focused on value in healthcare, scenario creation, technology forecasting, and business opportunities and their level attractiveness. This deepened the authors' understanding of relevant topics, which in turn allowed making a combined application of the theory.

The thesis has undergone two main phases. The first one aimed to assess which healthcare application areas and diseases that have the highest level of attractiveness using wearable sensors. The second main phase aimed to make recommendations to the partner company on how to consider wearable sensors ahead. The primary methodological choice has been to conduct 22 semi-structured interviews with a cross-functional set of physicians, startup employees, academic researchers, thinkers, and industry representatives.

It turns out that diabetes, cardiovascular diseases, and care of elderly have the highest level of attractiveness for the partner company. Then, after having constructed user/patient scenarios for those three categories, generalized the value propositions offered by wearable sensors, and analyzed the current market landscape, TechCo is recommended to integrate patient data from different consumer platforms and make that data accessible to healthcare providers in their healthcare IT-systems. Thus, the eco-system of wearable sensors and healthcare is characterized by intense competition but this proposed integrating role is required and well suited for TechCo. With this recommendation TechCo is provided a way forward on how to consider wearable sensors in future research and development.

Keywords

Wearable sensors, Internet of things, healthcare, United States, TechCo, business opportunity, value creation, attractiveness, user patient scenarios, value propositions, chronic diseases, recommendations

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1 Introduction

This chapter provides an introduction to the field of study and the focal company, TechCo Corporation US. Furthermore, a problem analysis, the purpose, and the research question for the report are presented. In the end of the chapter, sections covering the focal company and delimitations are presented

1.1 Background to Wearable Sensors and its Healthcare Eco-system

According to Information Handling Services (IHS) (2013) a wearable sensor is defined as a product that is attached to the user's body during a longer period of time and includes circuitry, wireless connectivity technology, and processing capability. Exhibit 1 below illustrates what format wearable sensors can take and a sample of current and upcoming data points they are able to measure.

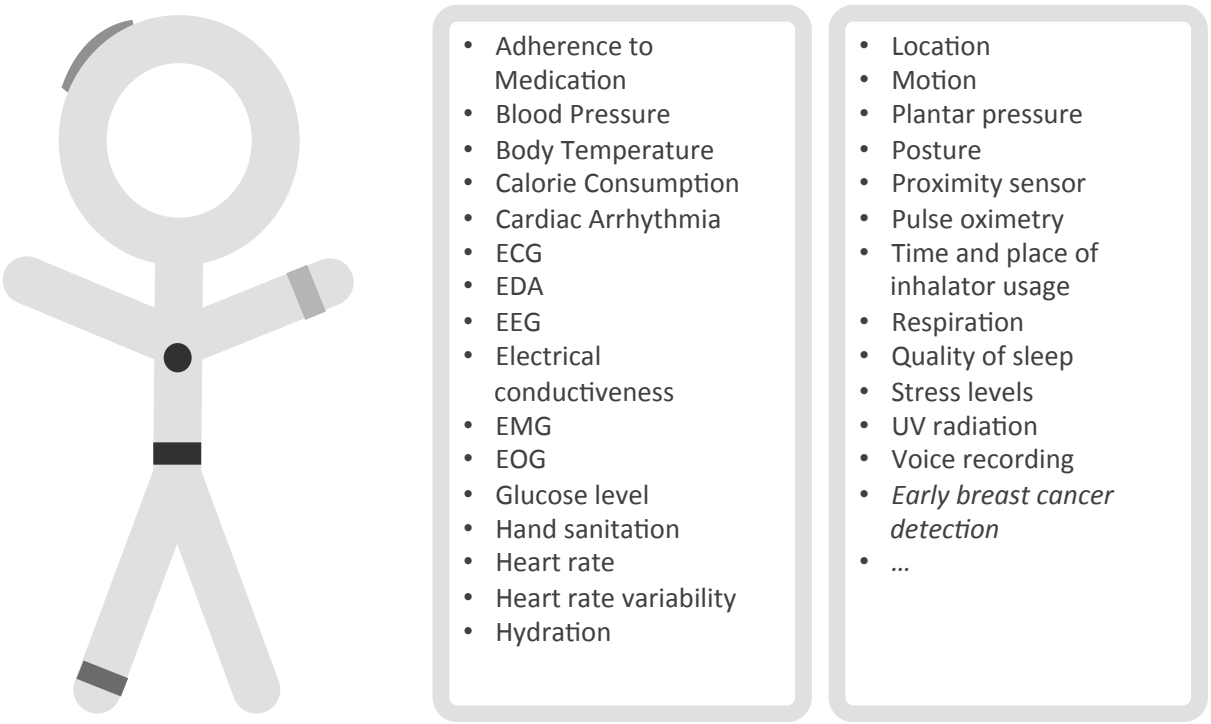

Exhibit 1: The stick man shows what formats sensors can have. The list contains a sample of current and upcoming data points that are possible to measure with wearable sensors. Source: Master thesis analysis

This thesis seeks to understand the usability of such devices in professional healthcare. However, recent developments in this domain are worth mentioning for any healthcare stakeholder and the eco-system contains many players and relations that make it complex. Exhibit 2 is an illustration of what stakeholders there are with regards to wearable sensors and professional healthcare eco-system.

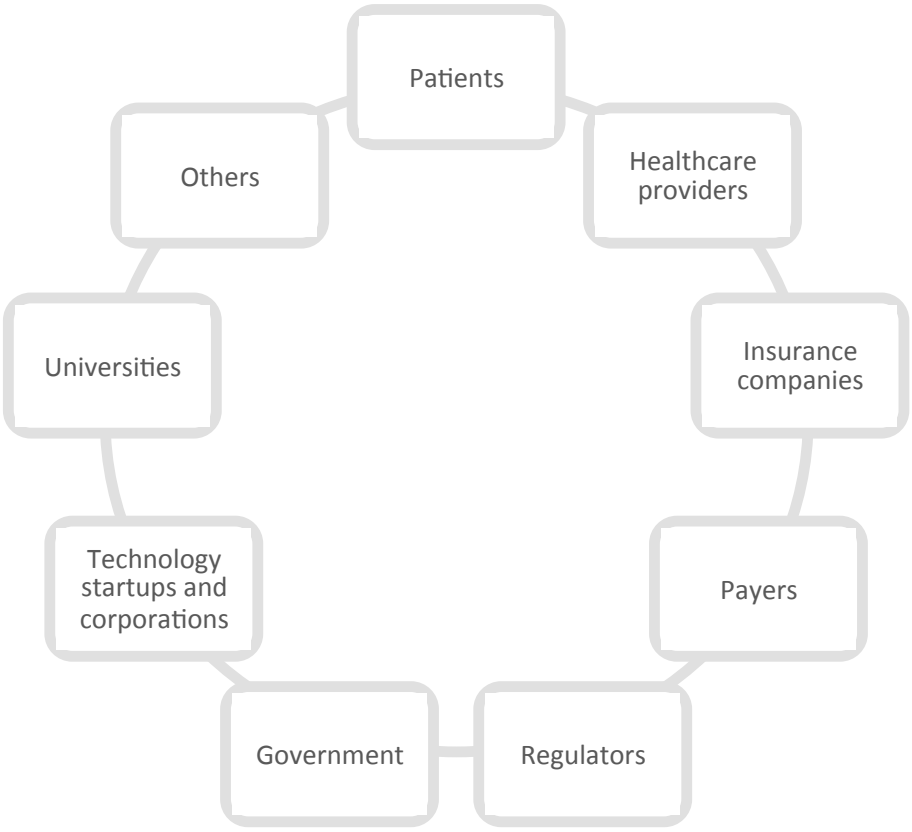

Exhibit 2: Many stakeholders and relations characterize the eco-system of wearable sensors, which makes it slow and complex. Source: Master thesis analysis

New devices are developed and launched at an impressive pace. The online database Vandrico for wearable technology devices currently presents 225 different devices of which 50 are targeted to the medical domain (Vandrico, 2014). Even more notable, Samsung and Apple entered the market in the end of May and beginning of June 2014 respectively. Samsung launched a wristband call Simband and a related data broker cloud platform called SAMI to which wearable sensor data from different devices can be uploaded and accessed (Samsung, 2014). Apple presented the Health app which uses HealthKit, a developers tool that enables health and fitness application to work together, to gather all health data at one place (Apple, 2014).

TechCo Corporation US (hereinafter referred to as TechCo), i.e. the partner company this master's thesis, conducts research related to healthcare and technology and currently sees wearable sensors as an interested field of research.

1.2 US Healthcare Challenges

According to Morgan Stanley (2014), the United States (US) healthcare system has problems with both ineffectiveness and inefficiencies. In other words, it delivers care of low quality to an extensive cost. Thus, the healthcare system in the US has serious problems and is in need of change and improvement.

In Exhibit 3 the prevalence of coronary heart disease, diabetes, and obesity among adults are presented for the period 2003 until 2010. As shown in Exhibit 3, the general trend is that the prevalence of the diseases has increased during this period of time. Obesity is the most prevalent as nearly 36 percent of the population suffers from this condition (CDC, 2014; WHO, 2014).

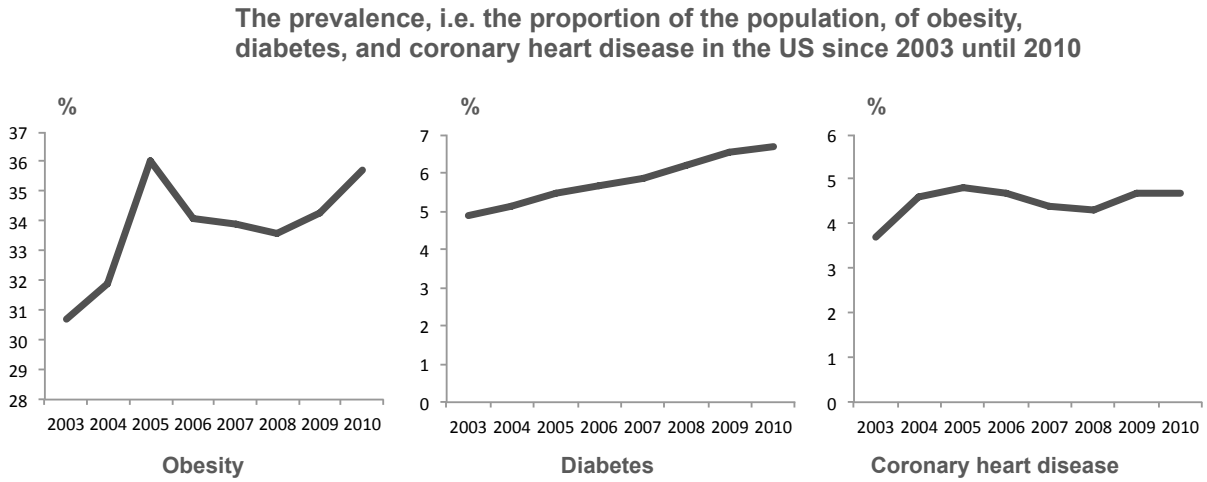

Exhibit 3: Statistics show that the prevalence of obesity, diabetes and coronary heart disease has increased between 2003 and 2010. Source: CDC, 2014

As mentioned previously, the healthcare system in the US has a huge challenge with cost. In Exhibit 4 data of healthcare spend as share of the gross domestic product (GDP) and healthcare spend per capita are presented. The healthcare spend per capita increased by 59 percent over the last 10 years, which equals approximately $3300 per person (Worldbank, 2014). Simultaneously, the healthcare spend as share of total GDP has increased by almost three percentage units. The share increased exponentially during the period from 2002 until 2009. Since 2009, the share has stabilized between 17,5 and 18 percent of total GDP. Actually, the healthcare spend as part of GDP in the US was the highest of all nations in 2013 (OECD, 2014). Hence, the interesting learning and the great challenge is that the health status of the population is developing in a negative way even though the system spends more and more resources on improving it.

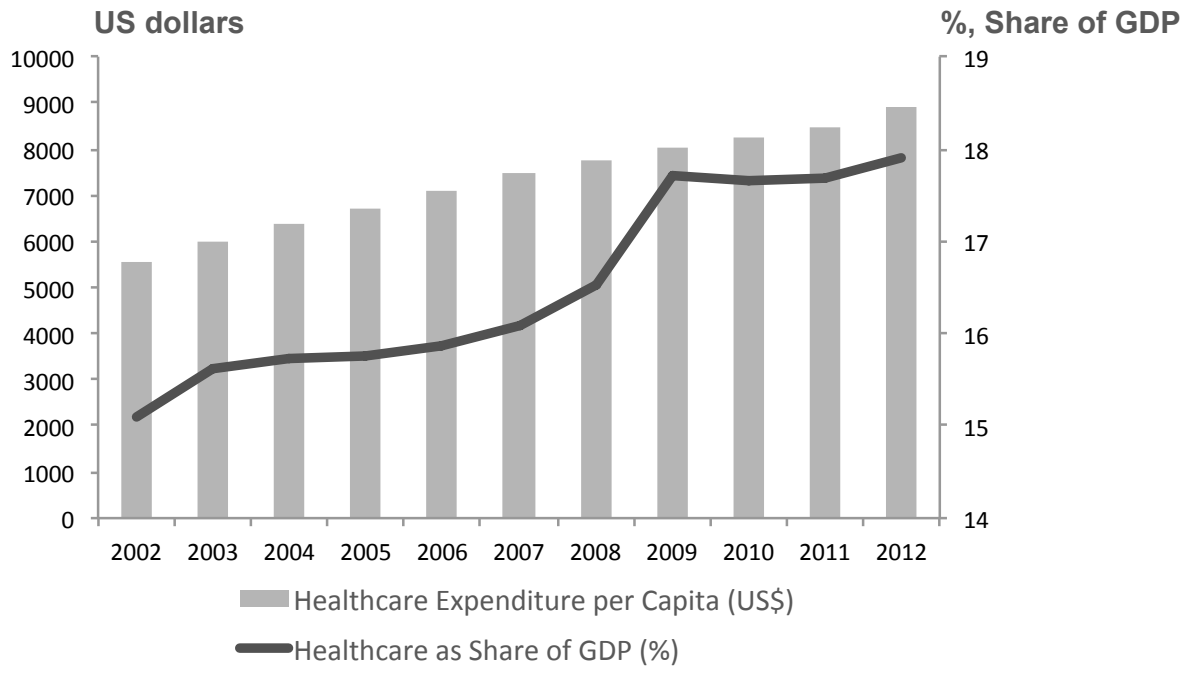

Exhibit 4: US healthcare expenditures per capita and healthcare as share of GDP are increasing. Source: Worldbank, 2014; own illustration

Even though the development seems to have been dramatic, these changes should not be a surprise for the actors within the industry. According to John McDonough[1] the long-term trends have influenced the development in this direction for the last decades. There are basically three trends that suggest that these challenges would come, namely growth in population, changes of the demographical composition and increased awareness of what the healthcare system is able to deliver.

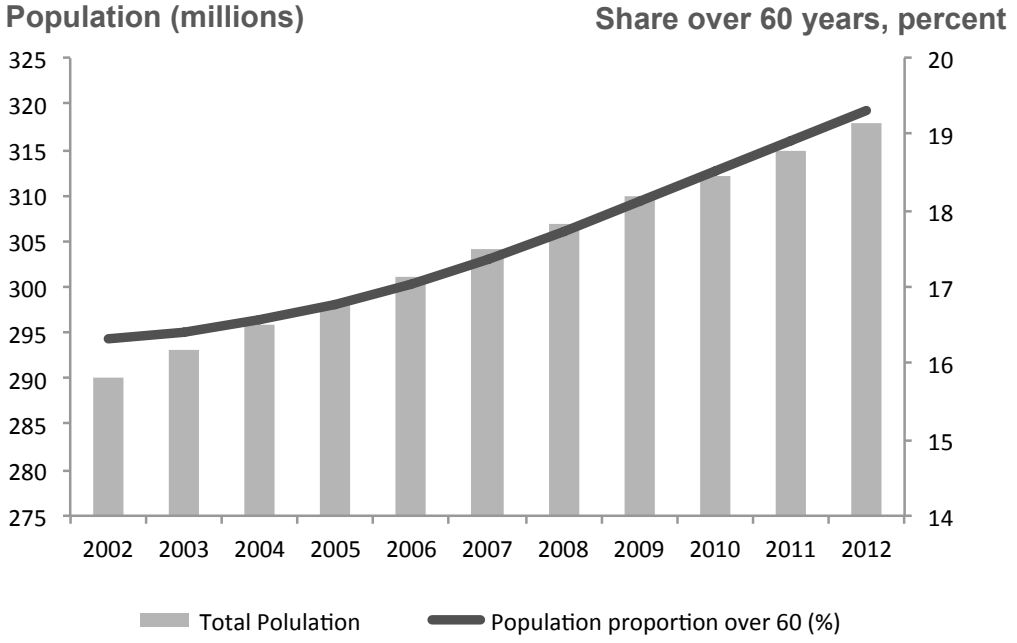

Exhibit 5: Size of US population and demographical shift during period 2002-2012. Data indicates growth of population and shift towards older population. Source: Worldbank, 2014; own illustration

- *Growing Population*
  Firstly, in Exhibit 5, the population and population growth rates from the period 2002 to 2012 are presented (Worldbank, 2014). As can be seen the, growth has been significant with increase by approximately 25 million people. Moreover, the US population is estimated to increase by 90 million until 2050, from approximately 310 million in 2010 to 400 million by 2050 (Census, 2014). The increase equals an increase by 29.2% or a compound annual growth rate (CAGR) of 0.6%. According to the historical data, the population has increased by 11.0% per decade during the period 1970-2010. Consequently, the population growth is estimated to decline from previous double-digit levels, but still the growth will be significant. For the coming decades, the population growth will be driven partly by increase in the domestic population and partly by migration from foreign countries (Worldbank, 2014).

- *Changed Demographical Composition*
  In addition to the increased population, there is an ongoing trend and change in demographical composition towards an older population, also presented in Exhibit 5 (Worldbank, 2014). As a consequence of the demographical shift

[1] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

towards a larger share of the population over age of 60 years old, the demand for healthcare will increase. The shift will increase the share of the population with multiple diseases and chronic diseases, as these are more frequent among elderly people[2]. The implication and challenge for the healthcare system is consequently that a larger share of the population will demand higher healthcare services during a longer period of time[3]. In addition, people currently spend approximately one third of their lives at work, resulting in less tax income to finance the healthcare system[4]. As the need of healthcare financing is increasing this will create a higher burden for the working population to cover.

- *Increased Awareness of Potential Healthcare Benefits*
  From a historical point of view, people have been unaware of what potential treatment healthcare providers can offer. The resulting effect has been that people have suffered from complications in an unnecessary way.[5] However, according to Ragnar Lindblad[6], people are becoming more aware of the services healthcare providers offer and have begun to demand increased amount of help for their complications. Moreover, there are diminishing boundaries between professional healthcare and wellness.[7] In Sweden there is a large, nation-wide project called "Hälsa för Mig" (Swedish: "Health for me"). The aim of the project is to build a personal healthcare check account, in which users can store all data related to their health. By this service, there will be a shift in power from the healthcare provider towards the patient.[8] As the patient becomes the owner of its healthcare data, she will be more interested in her healthcare situation and development. With an increased interest the patient will demand the best available healthcare services, independent of geographical location.[9]

1.3 Problem Description

There are growing challenges within the healthcare system, and challenges generally mean opportunities for improvement. There is a diverse set of actors that are involved in trying to solve this problem, including politicians, corporations, healthcare providers and start-ups. An emerging field, and a potential solution to the challenges in the healthcare system, is the Internet of Things (IoT) (MGI, 2013-2)

According to McKinsey Global Institute (MGI) (2013-2), IoT refers to "the use of sensors, actuators, and data communications technology built into physical objects, from roadways to pacemakers, that enable those objects to be tracked, coordinated, or controlled across a data network or the Internet". Actually, professional health is presented to be one of the areas in which the technology can have the most significant impact, equaling an economic value of $1.1-2.5 trillion on an annual and global basis (MGI, 2013-2). Until now, the hypothesis has been that chronic diseases can benefit most

[2] Git Eliasson, Project Manager Karolinska Hospital, Interviewed at February 18th 2014
[3] Adina Welander, Consultant Boston Consulting Group, Interviewed at March 18th 2014
[4] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014
[5] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014
[6] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014
[7] Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014
[8] Henrik Schildt, Project Manager NPO Sweden, Interviewed at February 26th 2014
[9] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014

from the technology, but further investigation is needed to determine which data that can actually create value for patient and healthcare providers (Topol, 2014).

IoT has potential to influence the healthcare sector in several dimensions, including healthcare facilities, pharmaceuticals, medtech, and medical devices and services (Morgan Stanley, 2014). In the area of medical devices and services, the most prominent subset is wearable sensor technologies. According to (IHS, 2013) a wearable sensor is defined as a product that is attached to the user's body during a longer period of time and includes circuitry, wireless connectivity technology, and processing capability. At a holistic level, wearable sensors offer two distinguished value propositions Firstly, the possibility of continuous monitoring of patients, and secondly they enable a shift from reactive into predictive healthcare (Morgan Stanley, 2014).

There are a lot of actors that have identified wearable sensor technologies as a potential sub-solution to the challenges in the healthcare system and there are perceptions in what fields the technology is most applicable. TechCo is an established actor within the field of medical devise technology, and is interested to start explore if it is possible to build a business model with wearable sensors in professional healthcare in the US. Further investigation on to whom, when, and how wearable sensors can create value is needed to be successful in this new field. In other words, there is uncertainty what business opportunities there are for TechCo to grab in the wearable sensor eco-system. What distinguishes successful actors from the unsuccessful ones is the solidity of their business models (Osterwalder, 2010).

1.4 Purpose and Research Questions

The purpose of this study is to provide insights and recommendations to TechCo on how to consider wearable sensors in future research and development. The aim is that these insights and recommendations can help to initiate creation of a business model for wearable sensors in professional healthcare. As a consequence, this thesis aims to develop future usage scenarios, value propositions of wearable sensors, and recommendations regarding business opportunities in order to support managerial decision-making at TechCo.

In order to fulfill this purpose, four research questions are formulated:

1. *How can potential future wearable sensor patient scenarios look like when considering relevant trends and the most attractive diseases/healthcare application areas?*
2. *For TechCo, which diseases/healthcare application areas are the most attractive ones to build a business model around using wearable sensors?*
3. *What are the general value propositions offered by wearable sensors?*
4. *What is the most viable business opportunity for TechCo with wearable sensors in the US healthcare eco-system?*

1.5 The Focal Company of this Master's Thesis

TechCo, the focal company and constituent to this master's thesis is a multinational engineering conglomerate headquartered in Europe. The company is registered at the stock exchange in Frankfurt and New York. In the year of 2013, the company reached total sales in the span €50-100 million and a net income of €2-12 million. The company

has 200-400.000 employees. TechCo is a superficial name, made up due to claimed confidentiality of the constituent.

The company has several units, including building related products, automation and industrial plant products, energy system products, drives, lightning, logistical and transportation products, and medical devices. The constituent of this master's thesis project is the corporate research department located in Berkeley, USA. The research group was established during the fall of 2013 and consists of eight people from the company and a prominent university in the San Francisco bay area. The head of the research group is a previous professor from a well-reputed university at the European mainland.

1.6 Delimitations

The focus of this report is the US healthcare system. Nevertheless, insights and information from this market can most probably be transferred into other industrialized countries with similar environments and eco-systems. However, there are some important parameters to consider when comparing to other healthcare systems, especially the balance of responsibility of healthcare actions between healthcare providers and patients as well as the fundamental difference between private and governmental reimbursement systems.

This report primarily focuses on two stakeholder groups, namely patients and healthcare providers. However, further understanding of the goals and motivations of the other stakeholders will be necessary to develop a successful product and/or service. Although the goal of this report is to understand how wearable sensors can improve patient healthcare outcomes there is also potential to reduce cost. Consequently, the value propositions presented in the analysis chapter focus on how wearable sensors support patients and healthcare providers to improve patient outcomes.

2 Theoretical Framework

This chapter presents theory that, in essence, has helped to address the thesis' research questions. In particular, the chapter covers literature about value in healthcare, attractiveness evaluations, technology forecasting, and scenario creation. The purpose is to add credibility and strength to the claims we make later in the thesis. The chapter ends with explaining the way the theory has been applied and used in this particular thesis.

2.1 Value in Healthcare

Porter (2010-1) argues that the key to improve performance and accountability in any field is dependent on having a shared goal. The goal unifies interests and actions of the parties involved in the matter. What is interesting according to Porter (2010-1) is that healthcare is subject to countless, often, conflicting goals. These include for example access to services, profitability, quality levels, cost consciousness, safety, convenience, and patient-centeredness. The list can go on and one reason behind this complexity is the many stakeholders that are involved in the healthcare system. The argument is that this fact is a major cause of slow progress of performance improvement. The answer, i.e. the goal Porter (2010-2) puts forward, is that the overarching goal must be to achieve high value for patients, with value defined as the health outcomes achieved per dollar spent (Exhibit 6 below), thus it encompasses efficiency. The numerator of the value definition, i.e. outcomes, is obviously condition-specific and multidimensional and hence needs to be considered individually and dependent on the disease/complication. Cost, the equation's denominator refers to the entire costs of the full cycle of care for the patient's medical condition (Porter, 2010-1).

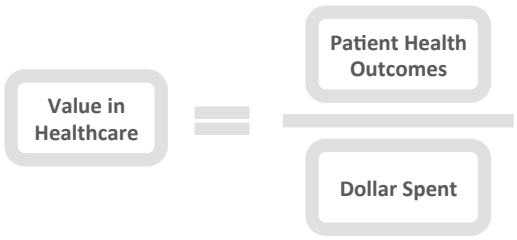

Exhibit 6: Value in healthcare is defined as patient health outcomes divided by dollar spent. Source: Porter, 2010; own illustration

This is the only goal that really matters to patients and it is most likely also a goal that all healthcare stakeholders can agree upon. For patients with more than one medical condition, value should be measured for each condition, with the presence of the other conditions used for risk adjustment. When increased value is achieved, patients, payers, providers, and suppliers can all benefit and the economic sustainability of the healthcare system can at the same time improve (Porter, 2010-2).

In order to realize this value there have to be rigorous and disciplined measurements in place that can correspond to the value definition. However, healthcare is largely new to conducting such measurements. Because value depends on results, not inputs, value in healthcare should be measured by the outcomes achieved, which logically means that today's commonly used metrics such as volume of services delivered will be outdated (Porter, 2010-3).

2.2 Attractiveness Evaluation

Aaker (2010) writes that market attractiveness, which according to his definition equals a market's profit potential, measured as the long-term return on investment achieved by its participants, will provide important input into product market investment decisions. Understanding the dynamics of the market is another objective of conducting market analyses. What one is looking for are emerging submarkets, key success factors, trends, threats, opportunities, and strategic uncertainties that can support information gathering and analysis. Aaker (2010) underlines that the content and nature of the market analysis must depend on the context but most often it should include the factors presented in Exhibit 7.

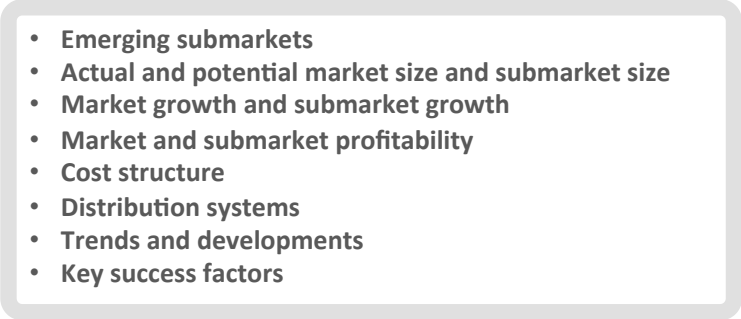

Exhibit 7: Factors to include when analyzing the attractiveness of a market. Source: Aaker, 2010; own illustration

The GE/McKinsey matrix first introduced in the 1970s by General Electric and McKinsey & Company also provides a framework for industry attractiveness assessments. However, this matrix also adds another axis to it, which is a business' strength. These two dimensions are based on a variety of different factors. Management are the ones who may decide the cutoffs points for high, medium and low industry attractiveness and business strength (Jain, 2000). Jain (2000) further on writes that developing a matrix with suitable factors that are contextualized and adapted to the firm in focus is not as easy as it might seem to be. The main difficulties lie in deciding and finding the right factors to include in the analysis and in turn weighing those factors against each other. Therefore, one should not be surprised when such analyses require a considerable amount of foresight and experience, and many days of work. The basic idea and the rationale of this matrix are showed in Exhibit 8 below.

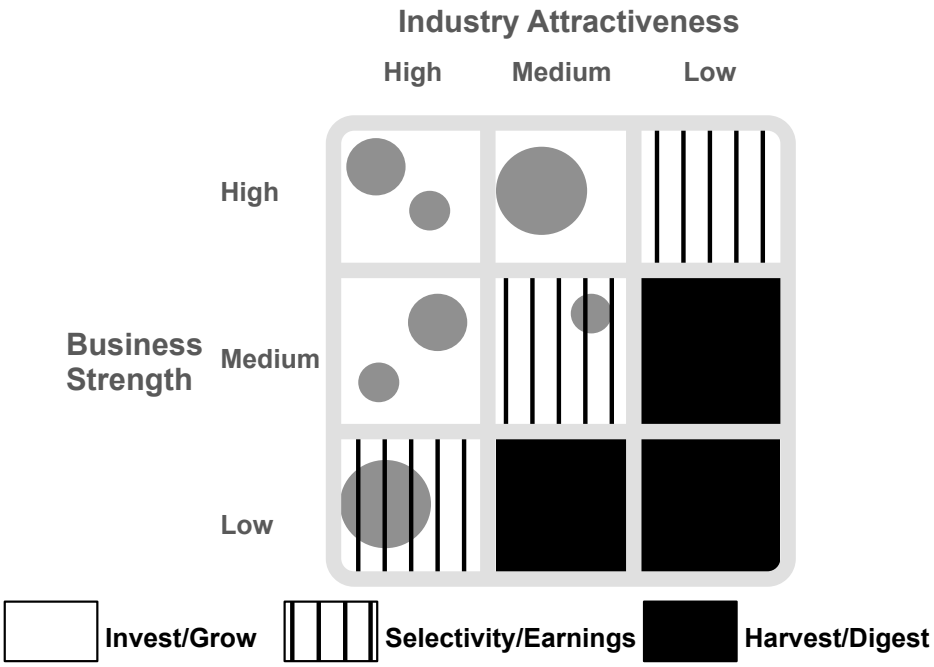

Exhibit 8: The GE/McKinsey matrix. Source: Jain, 2000; own illustration

Jain (2000) presents 18 criteria that can be included in the attractiveness assessment and proposes weights for each one of them. In addition to the criteria shown in Exhibit 7 he gives his view on how the weights can be distributed. What is worth mentioning here are the weights for market size, growth rate and industry profitability, since these factors are the ones we have chosen to take inspiration from in this particular thesis. Industry profitability is the most important one with a weight of 0.20, market size is second with a weight of 0.15, and growth rate has a weight of 0.12 (Jain, 2000).

2.3 Technology Forecasting and Scenario Analysis

Utterback and Abernathy (1975) provide a model to understand how technology develops and matures, which is important to know in order to create future scenarios and to understand the industry evolution. As Exhibit 9 shows there is usually intense product innovation in the beginning whereas the processes used to produce the products at that time are inefficient. It is the product itself that matters to innovators in contrast to the processes needed to produce them. However, product and process innovation are interrelated and thus as the rate of product innovation decreases the intensity of process innovation increases. Eventually as the dominant design is set the process innovation rate also decreases to a more stabilized level (Utterback & Abernathy, 1975).

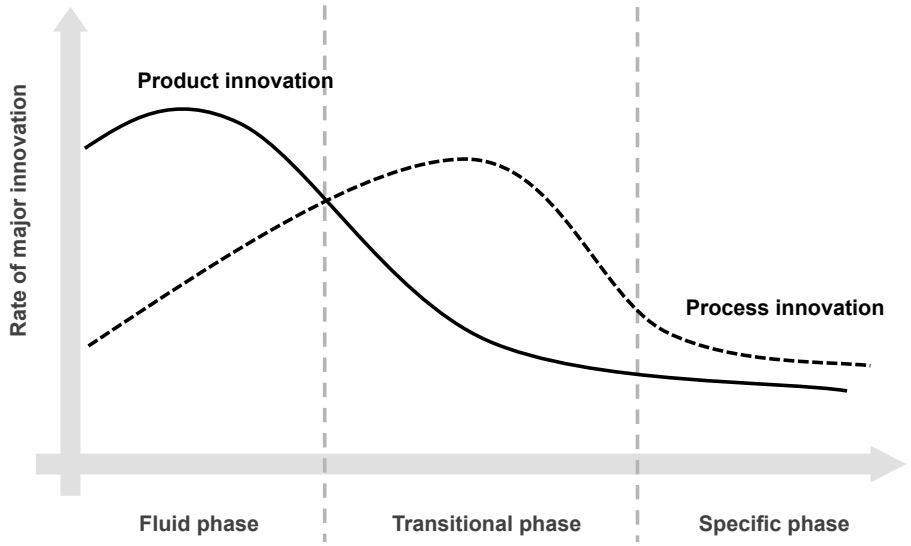

Exhibit 9: Industry evolution in terms of product innovations and process innovations. Source: Utterback & Abernathy (1975); own illustration

In the fluid phase entirely new products enter the market as a result of radical innovation breakthroughs. Products provide new possibilities and functionalities. Many firms enter the market in this phase since the potential profits are large. After a while, once a dominant design has arrived, the intense period of product innovation drops. In the transitional phase the dominant design is set, which means that the majority of the producers has adopted a certain product design. The importance turns to process innovations instead of product innovations. In the last phase, i.e. the specific phase, a dominant design has already emerged and competition shifts from differentiation to performance and costs. Production systems are more standardized and cost reductions are more important targets (Utterback & Abernathy, 1975).

Bunn and Salo (1993) go through a lot of different scenario definitions by several other authors but conclude that a general scenario can be defined as a possible evolution of the future, consistent with a clear set of assumptions. Creating scenarios can be done in several different ways. For example one can make use of exploratory scenarios and anticipatory scenarios. Exploratory scenarios' starting point is the present whose consequences are extended into to future, and thus the development incorporates forward inferences. The result by exploratory scenario constructions is likely to be realistic but not very surprising. On the other hand, anticipatory scenario creation is searching for the possible causes that can lead to a given future state. That is, its starting point is in the future, and hence it puts emphasis on goals and calla for backward explanations in contrast to consequences. The result is more surprising scenarios and therefore preferred when new options are desired (Bunn & Salo, 1993).

Forecasting in general has one major purpose, which is to allow managers to move towards anticipatory thinking. The rationale is that anticipatory thinking provides the techniques to change from a reactionary business to a more proactive one (Jones, 2003). Moreover, forecasting helps to increase the understanding of what forces are driving changes, and make future predictions based on facts and structured methods. For example, it can be useful to determine where resources should be invested, or to support strategic issues and tactics. Interestingly, although the created scenarios turn out to be inaccurate it is valuable just to go through the forecasting process, as it will aid

learning and understanding. Only by picturing the future will make the organization more prepared for whatever happens (Jones, 2003).

Coates et al. (2001) put emphasis on three parties when discussing technology forecasting analysis. Both corporations' and government agencies' needs shape the technology forecasting. The third party to impact technology forecasting is the public and the elected representatives. Technology forecasting will depend on their views about technological progress, economic competition, and the government's role in competition. In turn, the real payoffs of using technology forecasting are the application areas, not the innovations per se, which implicitly requires understanding of organizational, social and market dimensions (Coates et al., 2001). In connection to this is the theory of institutions, which is defined as the rules of the game. That means that institutions are constraints designed by humans to structure human interaction (North, 1993). These rules can be both formal, e.g. laws such as Patient Protection and Affordable Care Act (PPACA) or driving on the right hand side of the road, and informal. Beinhocker (2006) uses another concept in connection to institution, namely social technologies that are the ways of organizing people to do things, i.e. ways of getting things done. These social technologies are enablers in the sense that they reduce complexity for human interaction.

Bouwman and Duin (2003) argue that technology forecasting (especially information and communication technology, ICT) shows the technological trends in a specific technology domain, whereas scenarios cover the possible future world. Bouwman and Duin (2003) try to go through, by using technology forecasting and scenario analysis methods, insights of how ICT usage and acceptance will be like in 2010 which was seven years in advance at that point in time. The methods used to look into the future can be categorized according to their function, whether they are predictive, non-predictive or a combination of both, or whether they can be used for operational, tactical or strategic goals. Furthermore, creating scenarios normally starts by conducting a technology, social and economic trend analysis. Furthermore, when technologies are in the initial stages of the innovation process it gets more difficult to make predictions about usage and adoption. After the products are launched on the market it is easier to make judgments, e.g. by analyzing the results of market surveys. Exhibit 10 below shows how the level of uncertainty about technologies and the accuracy of prediction relate to each other as presented by Bouwman and Duin (2003).

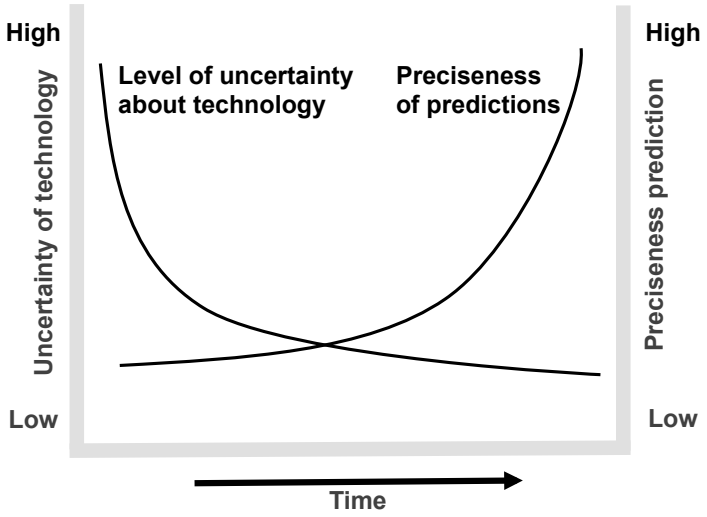

Exhibit 10: Technology forecasting in relation to how uncertainty about technology and preciseness of prediction develops to time. Source: Bouwman & Duin, 2003; own illustration

Technology forecasting, according to Bouwman and Duin (2003), is a good tool when decision makers and other people involved are eager to know what the important trends might be.

Scenario creation on the other hand, is preferred by people who think that it is impossible to make straightforward predictions and hence wise to picture different alternative futures. Bouwman and Duin (2003) writes "Scenarios are expectations regarding possible futures that provide insight into the way the future may develop based on clearly defined assumptions concerning the relationship between relevant developments". Usually trend analyses are used to provide input to the scenario creation. A well carried out scenario analysis addresses plausibility, consistency, completeness, and the validity of the underlying assumptions. The result from such analysis is that one is better of assessing future developments that are likely to have an impact on the business (Bouwman & Duin, 2003).

Looking at technology forecasting and scenario analysis in combination, the logical stream of information is that technology forecasting constitutes valuable input for the scenario analysis. In other words, scenario creation begins where technology forecasting ends, while technology forecasting is an extrapolation of evolutions that began at some point in the past. The assumption is than that those technology developments will continue for a certain time into the future but after a while uncertainty becomes too high that the accuracy of the scenarios are worthless. Also, by handing humans a central role in the scenario the technology is given a "face", which makes it more clear what services or products have a high likelihood to be used in the future (Bouwman & Duin, 2003).

Saurab (2005) includes another slightly different area in addition to technology forecasting, which is technology assessment. It is argued that this is a form of policy research, which contributes by giving a balanced appraisal to the policy maker. In other words, this is a process of analyzing the consequences of technological change. In the best case, this process succeeds to identify policy issues and evaluates the impact of alternative directions of technological progress.

2.4 Application of the Theory in this Thesis

The nature and purpose of this project implies that interpretation and combination of different theoretical models above are required for reaching the best results.

As the long-term goal for TechCo it to develop a business model we have to decide which the most attractive application areas are. Our framework to evaluate attractiveness consists of three dimensions, including size, growth and value creation potential by wearable sensors. The choice to include market size and growth are supported by the contributions of the GE/McKinsey & Company matrix, Aaker (2010), and Jain (2010). The last parameter, value creation potential by wearable sensors, comes from the contribution form Porter (2010-1) as we argue that value in healthcare is of utmost importance to the level of attractiveness. By the combination of the size, growth, and value creation potential by wearable sensors we are able to evaluate which healthcare application areas are the most interesting to TechCo to persuade for further development. Jain (2010) gives his recommendation of how to weigh different factors when evaluating attractiveness. According to Jain (2010) industry profitability is the most important one with a weight of 0.20, market size is second with a weight of 0.15, and growth rate has a weight of 0.12. In our thesis we substitute industry profitability with value creation potential by wearable sensors as we consider this to be the most important factors. Based on these research contributions, this project uses value creation potential by wearable sensors, size, and the expected growth with the respective weights 50 percent, 30 percent, and 20 percent for assessment of attractiveness of different diseases and healthcare application areas.

In order to provide the best information of value creation potential, the thesis focuses on gathering medical understanding and what kind of data physicians need to improve their healthcare delivery. According to Osterwalder, Pigneur and Clark (2010), taking the perspective of the customer can result in discovery of entirely new opportunities. To understand the environment around the customer, her daily routines and ambitions enable the innovator to reduce risk in new business model development. As mentioned previously, empathy is a commonly used technique to understand the customer, which we will do in assessment of the value creation potential by wearable sensors.

3 Methodology

This chapter first outlines the choices of research strategy and the process, data collection, data analysis, which contains conceptual models used in the project. The chapter ends with presenting the interviewee sample and a discussion about the methodology itself.

3.1 Research Strategy and Process

Initially, the problem to be addressed in this project was vaguely described. However, the overall aim, i.e. to identify and present business opportunities with wearable sensors in healthcare to TechCo, was clear. This requires deep insights and a thorough understanding of the context that wearable sensors will be used in, which consequently led us to a qualitative research strategy in contrast to a quantitative one. Emphasis is placed on understanding rather than quantification although some quantitative steps have helped increasing the qualitative understanding. In other words, the research strategy of this master's thesis has been qualitative in particular.

As previously mentioned the concrete problem to address was in the beginning loosely defined. Therefore, the process of this master's thesis has undergone a stepwise approach since that enables coming closer to the actual problem, which is in contrast to having a concrete and narrow problem from the start (Bryman & Bell, 2011). This stepwise approach means that the project can be divided into two main phases: the first one was mainly about finding out which diseases are the most attractive ones, this phase happened to take place in Sweden. The second phase primarily sought to identify business opportunities and make recommendations to TechCo of how to be successful in this new market. This phase happened to take place mainly in the US based on TechCo office in Berkeley, California. Below are more details of what have been done in each main phase and the reasons behind that.

Concurrently with performing the data collection phases, a literature study took place in order to appropriately deal with relevant concepts, and to add credibility to the claims we make in this thesis, particularly in our analysis and conclusions, by being well reversed in the field. The theoretical review of this master's thesis was, however, primarily conducted during the second main phase. As the thesis' purpose is to make recommendations to TechCo, a clear understanding of future use cases was necessary. Consequently, the team early on identified the need to increase our knowledge relating to technology forecasting and scenario creation in general and specifically for the healthcare industry. Logically, this was undertaken in the second main phase since that was the phase where those analyses were performed. However, the literature review started already in the first main phase, although less extensive, with focus on value in healthcare, value creation, and assessment of attractiveness and business opportunities.

The overall research strategy and process is presented in Exhibit 11 below.

Exhibit 11: Research design and process of this master's thesis. Own illustration

Phase 1 – Attractiveness Assessment and Healthcare Application Areas

The first phase's main purpose was to understand which diseases or healthcare application areas have some value creation potential using the technology offered by wearable sensors, and out of them conclude which one has the greatest potential. The intention was to complement the value creation potential analysis by also looking at size and growth parameters. By so doing, we were able to extend the analysis to an attractiveness level of analysis. In order to address the main research question the first main phase was in turn split into three sub-phases:

1. **Initial readings in order to get familiar with the topic and also to find out what data points are possible to measure with wearable sensors**

   As the authors of this report were entirely new to wearable sensors in particular and healthcare in general much effort was put into initial readings. Specifically, this meant that browsing the web became our primary tool to get hold of the latest white papers and articles. Since the topic of investigation is in the frontline of innovations and technology trends, other sources than white papers, articles, blogs, and various reports were impractical to get hold of. Even if there were more scientific and/or academic journals and books available it was decided that the research would benefit more from the actuality of the source than its nature. The reasoning for this choice of method is strengthened by the fact that the pace of which wearable sensor devices and their applications develop is impressive. Hence, usage of sources with just a couple of years old or more was avoided to the extent it was possible.

   Moreover, in order to find out which diseases could benefit from using wearable sensors the start of the project also contained a mapping of companies that offer wearable sensor devices. For each sensor its respective data points were mapped in a compilation sheet. Being able to present what data points are possible to collect to forthcoming interviewees was considered absolutely required. If not, interviewees in terms of physicians would have no information to respond to when asking them about potential use cases. In other words, this step resulted in a compiled file containing information about companies and startups and their

respective wearable sensors. By so doing a compilation of what data points are possible to measure using wearable sensors was made.

2. **Introductory semi-structured interviews by phone with experts in the field in order to get an initial sense of general healthcare trends, care provider needs and possibilities offered by wearable sensors**

   The second sub-phase contained the first interviews. In order to start building hypotheses about potential use cases and diseases, interviews by phone with Swedish technology and healthcare experts were conducted. Again, the web was browsed to look for people with relevant background and expertise. It was prioritized to interview, in our opinion, the most interesting persons and this was the reason for why the majority of those interviews were held during phone calls. Meeting the interviewee in live person was, all else being equal, preferred but due to time and financial constraints trips to the interviewees, most often located in Stockholm, were not prioritized.

   The strategy for these introductory interviews was to get a sense of where healthcare is heading and out of that information try to find opportunities for wearable sensors to fulfill a function. Therefore, as can be seen in the interview template (Appendices I) the interviews were centered on healthcare trends in general and healthcare technology trends in particular. Once that was done, wearable sensors were introduced by letting the interviewees basically respond freely, i.e. we avoided locking them into our own thoughts and hypotheses. In addition, we tried to extract potential diseases and other healthcare application areas that are subject to value creation potential by wearable sensors.

   This sub-phase let us make some snowballing, that is asking the interviewee after the interview was finished about other suitable interviewees. This was a natural and an efficient choice to get in contact with other helpful people.

   As these interviews progressed we revised our hypotheses and made changes accordingly. Specifically, we were able to formulate hypotheses about what diseases could benefit from wearable sensor technology. This allowed us to move into the next sub-phase.

3. **Semi-structured interviews with Swedish physicians with expertise within the most attractive diseases and healthcare application areas**

   In this third and last sub-phase expert interviews with physicians, primarily senior physicians, constituted a major part of the thesis' data collection source. The aim in this phase was partly to confirm or revise our hypotheses and partly to find out what care providers' needs are in terms of data points, i.e. different measurements of biometrics. In turn, the aim was to understand what value could be created if those data points were provided using wearable sensors instead of today's data collection habits. In other words, although the interviews were semi-structured and thus differed from one to another, the overall aim was to define the overlap of data points that care providers need and the data points that wearable sensors can provide. The reason for this is to support the research

questions, because by finding and defining this overlap of data, an assessment analysis of value creation potential was possible to perform.

In order to make the physicians respond to our questions with the same vision we introduced our definition of value, being health outcomes per dollar spent as inspired by Porter (2010-1). Exhibit 12 below illustrates this definition.

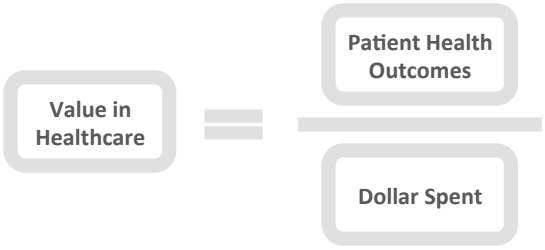

Exhibit 12: Definition of value in healthcare. Source: Porter, 2010; own illustration

We chose to focus on the numerator, i.e. health outcomes since that was what TechCo asked for. Initially TechCo wanted to know how wearable sensors can create value in professional healthcare, therefore we conducted research of how value can be defined and proposed the definition put forward by Porter (2010-2). Then, in collaboration with TechCo it was decided that our focus would be on health outcomes, consequently leaving cost aspects out of the project.

Questions and discussions were structured so that the value creation potential belonged to either direct value or indirect value where indirect value means that patient value is increased via the service of a care provider, illustration below in Exhibit 13.

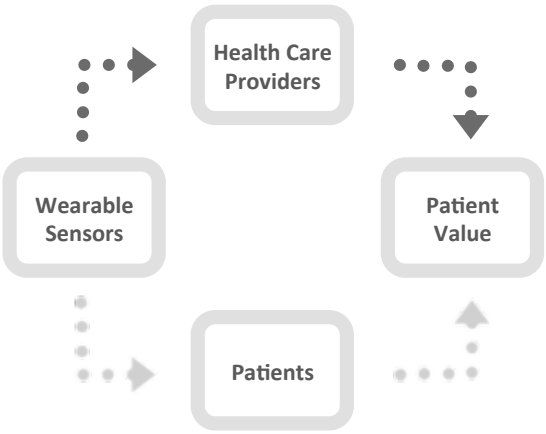

Exhibit 13: Conceptual model for value creation streams by wearable sensors in healthcare. Source: Master thesis analysis

However, being aware that wearable sensors can create value for the patient without involving any care provider (e.g. increased self knowledge about your own disease), we chose to focus on the indirect value stream. The reason behind this choice was simply because TechCo mainly is a business to business company and thus their future products and services will target and include care providers, not end consumer or patients directly. However, this does not mean that the direct value stream has be completely left out, it is also valuable to TechCo to gain knowledge about.

Another part of these interviews was to initialize the hypotheses about future healthcare scenarios. Since the next main research phase would include creating future healthcare scenarios in which wearable sensors are used the final part of these interviews focused on trying to ask the physicians what situations they could picture or imagine in the years ahead. This gave us pieces of information and hints of how the second main phase should be structured.

Phase 2 – Make Recommendations to TechCo on how to Consider Wearable Sensors

The second main phase of this master's thesis project was carried out in the US. This phase's aimed to incorporate TechCo as a company and our supervisor's wishes for what they found most fruitful. Hence, the research sought to understand the US healthcare environment, develop use scenarios, and finally to identify business opportunities for TechCo and propose recommendations for TechCo' way forward.

1. **Understand US Healthcare Environment**

   First of all, although Sweden and the US have many similarities, both are industrial countries with relatively well-developed technology systems there are many differences that need to be taken into account. Therefore, in general, this second main phase has focused on understanding the US healthcare context. In order to provide recommendations and way forward to TechCo the context in which the company operates is important. Consequently, every interview conducted in this phase more or less aimed to help us contextualize and understand the context in which wearable sensors potentially are to be used. Specifically this meant that we tried to figure out patterns of people's thoughts and attitudes in relation to the US healthcare system and the potential usage of wearable sensors. A number of interviewees with different backgrounds and expertise areas were contacted in order to enable a holistic understanding that takes into account opinions not only from one party but from several.

2. **Develop User Scenarios and Identify Value Propositions by Wearable Sensors**

   In order to fulfill the purpose of creating scenarios we decided to speak to a person with insights into US healthcare policies. Policies are the rules of the game (Holmén, 2013), i.e. the set of laws and norms in which market players take action. Therefore, understanding the role of PPACA, which is the biggest overhaul of the US healthcare system since the 1960s (Reuters, 2012) in relation to usage of wearable sensors was considered important. Luckily we managed to conduct a phone interview with one of the men behind designing the PPACA.

   In addition, interviews with wearable sensors startups were a natural step to, on one hand, understand where technology is heading (i.e. technology forecasting) and on the other hand to provide insights of the US healthcare system. By mapping where wearable sensing technology is heading allows us to spot business opportunities and create scenarios that are fruitful to TechCo. Moreover, the quantified-self community, which is a group of people who are engaged in measuring their own biometrics in order to enhance their health statuses, caught our interest. We argue that they are pioneers when it comes to wearable sensors

usage and therefore have interesting ideas and thoughts about what value these devices can bring. We reason that by understanding people who are first adopters of a certain technology helps to increase the understanding of people's motives and arguments for why one should or should not choose to adopt the technology. As a result, this thesis has tried to take advantage from two interviewees that are in the world frontline of keeping track of their own biometrics.

3. **Identify Business Opportunity and Propose Way Forward**
   Employees at TechCo have given us feedback and inquiries about what they find interesting. As an example, we decided that presenting the results to relevant employees at TechCo prior to going to the US would enable more fruitful work. We moreover had telephone conferences with TechCo employees working in other parts in the US just to make sure the focus we proposed would create value for TechCo. These talks were centered on trying to understand what could be a business opportunity for TechCo. Since wearable sensors in professional healthcare are still in its infancy there are few, if any, people who can be certain where the sources of revenues and profits will be found. However, by talking to people at TechCo we improved our understanding of what products and services that TechCo healthcare offers and in turn how and where wearable sensors are most likely to fit in.

3.2 Data Collection

This section comprises the data collection methods that have been undertaken in this master's thesis. Semi-structured interviews are the primary data collection source along with the web, articles and white papers.

Altogether 22 semi-structured interviews were conducted and they in turn laid the foundation for our recommendations and way forward. In average an interview lasted for one hour. In accordance with Bryman & Bell (2011), they were explorative in nature although we made use of an interview guide (Appendices I and II), which enables opportunities to create hypotheses and a more flexible interview process. In other words, all interviews were to some extent different from the other ones. As the interviewees said something that caught our attention we encouraged them to elaborate. As a result, the interviews with medical doctors yielded different outcomes even though the purpose when starting those interviews was more or less the same. The semi-structure was considered a sufficient methodology for this purpose, since it is flexible in terms of order of questions and there is room for clarifications. Also, the questions were designed in such a way that they became more specific further on in the interview while starting from a more general character (Holmén, 2012-1).

The reason for why the web, articles, white papers are other data sources are the sources for this master's is motivated in previous sections of chapter 3.1.

3.3 Data Analysis

To address this thesis' first research question we developed two conceptual models that could help us extract valuable insights from a lot of data. Two different models were developed where the output from the first model, i.e. the value creation potential model, constitute 50 percent of the input to the second model, i.e. the attractiveness model.

The reason we arrived at these models has its basis in our own proposal to TechCo and the adjustments that followed from TechCo employees' feedback. However, the proposals we presented to TechCo are based on reviews of literature and theory about two broad topics; the first one about how one should define value in healthcare, and the other one about business opportunity assessment frameworks. This is presented in chapter 2. After having reviewed this theory we chose to construct our own model to fulfill the purpose. The rationale behind this choice is that no theory nor model or framework we have come across could, in our opinion, address the research questions of thesis. Concretely, Porter's (2010-3) reasoning of how healthcare value should be defined is limited to the healthcare context. That is, it does not include aspects of what businesses (in our case TechCo) are trying to achieve which is profitability in the long term. The business opportunity theory is also not perfectly applicable to this research since it is argued to be too general, meaning that it is not well suited for a healthcare context in which patients' health outcomes is what drives business opportunities. Hence, we argue that by combing these two areas of theory we are able to construct a model that better addresses the aim to find out which diseases or healthcare application areas that are the most attractive ones. Exhibit 14 shows this conceptual model of our attractiveness assessment.

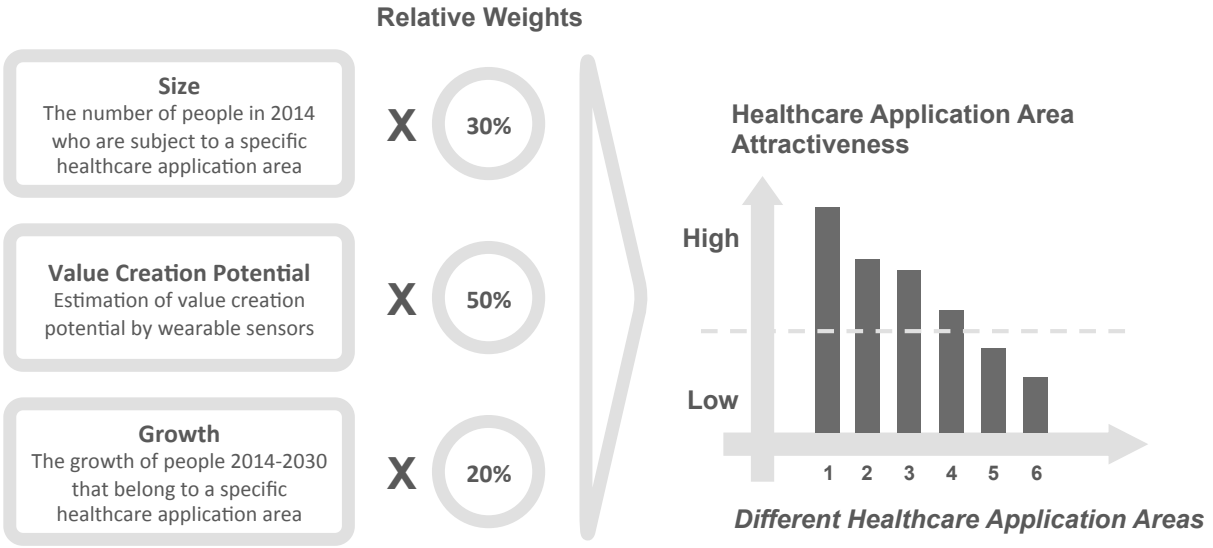

Exhibit 14: Conceptual model of how the level of attractiveness has been calculated. Source: Master thesis analysis; own illustration

The value creation potential model below (Exhibit 15) is constructed by looking on two parameters: level of importance of certain data points and level of satisfaction of those data points that wearable sensors provide. Thus, the higher level of importance and higher level of satisfaction the higher is the value creation potential by wearable sensors for that specific disease or healthcare application area. Exhibit 15 below demonstrates this logic.

The importance levels were found by follow-up emails to the physician interviewees. The physicians were first of all asked to confirm that the list of data points we had in our notes from the interview was correct, and secondly they were asked to rank each data point from 1-10 depending on their importance. 10 points represented the highest level of importance and vice versa.

The satisfaction levels were determined by our own overall knowledge about the sensors' capacities, which has improved thanks to readings, asking interviewees and talking to our TechCo supervisor. Hence, we argue that we have gained well enough insights to be able to, at least, determine the relative satisfaction levels to one another. That is for example, for sure we are able to conclude that a continuous glucose monitoring sensor, because it is already widely adopted in the Gothenburg area, has higher levels of satisfaction than the compliance pill sensor system by startup company Proteus since this sensor is still in the product development phase.

We multiplied the importance levels with the satisfaction levels and divided that sum by the number of data points. Thus, we got an average value creation potential score for each disease or healthcare application area. As previously described, this average score function as input to the attractiveness analysis. The conceptual model for determination of the value creation potential is presented in Exhibit 15.

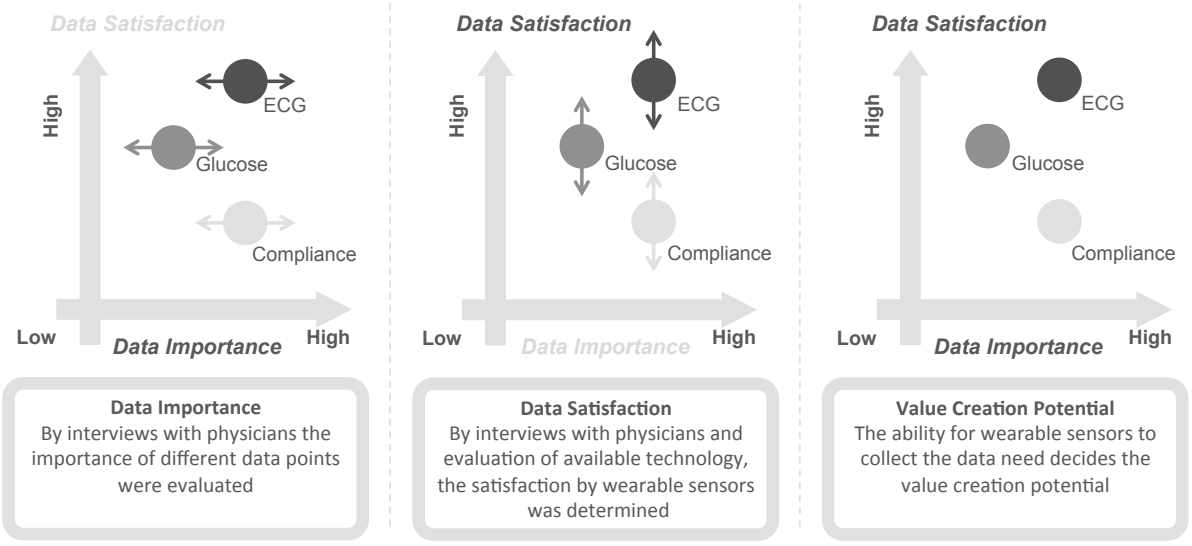

Exhibit 15: Conceptual Model for Value Creation Potential. Source: Master thesis analysis; own illustration

3.4 Sampling of Interviewees

It was early on decided that it was desired to get in contact with individuals that are industry experts in this research area. This because the technology and its applications are young and therefore knowledge of its impact is yet to reach the academic sphere. Therefore, primarily industry representatives, not academic people, were preferred. Two techniques were mainly used to find appropriate interviewees. First and foremost browsing the web led us to interesting companies, articles, and hospital departments in Gothenburg that in turn led us to suitable people. Exhibit 16 below shows the people that have been interviewed divided into five categories. Altogether 22 interviews were performed.

Towards the end of each interview the interviewee had a good sense of the research's aim and goal, which we took advantage of by asking for other appropriate people to interview. As a result several appropriate interviewees were found this way. This is a particular strength of snowballing sampling (Bryman & Bell, 2011).

Medical Doctors
- Anders Jönsson, MD, Orthopedic Disorders
- Anita Nordensson, MD, Asthma & COPD
- Ann Tammelin, MD, Hospital Acquired Infections
- Bengt Rundqvist, MD, Cardiovascular Diseases
- Björn Eliason, MD, Obesity
- Christer Nyman, MD, Geriatrics
- Claes Malmeström, MD, Neurological Diseases
- Gun Forsander, MD, Diabetes

Start-ups
- Mobjtaba Zandian, Quality Manager, Mando Group
- Todd Thompson, Corporate Development, Proteus
- Meredith Barrett, Corporate Development, Propeller Health

Thinkers
- Bob Troia, Quantified Seff – New York Area
- Rajiv Meth, Quantified Self – San Francisco Bay Area

Industry
- Adina Welander, MD, Boston Consulting Group
- Git Eliasson, Project Leader, Karolinska Hospital
- Henrik Schildt, Project Leader, Swedish NPO
- Priyanka Agarwal, MD, Center for Digital Health Innova.
- Ragnar Lindblad, Chairman, Swedish Medtech
- Reidar Gårdebäck, CEO, Medtronic Sweden AB

Academic Researchers
- Andreas Hellström, Senior Lecturer, Chalmers Center for Healthcare Improvement
- Birthe Dinesen, Associate Prof, Aalborg University
- John McDonough, Professor, Harvard School of Public Health, Healthcare Policies

Exhibit 16: List of interviewees of this master's thesis. Altogether 22 interviews were performed

3.5 Methodology Discussion

The semi-structured interviews, both with medical doctors and other interviewees went well. It was possible to get a good overview of the subject and hence we could target and formulate the questions for the next phases more precisely. The fact that we were able to dig deeper into interesting responses was really advantageous as it allowed discovering new areas of potential wearable sensor applications that beforehand were not known. Also letting them explain and elaborate when we did not really understand was helpful. On the negative side, the quality of the interviews differed quite a lot from the best to the poorest.

Validity is a generic term for different kinds of validity, but generally it refers to whether a study of a phenomenon or concept really corresponds to the actual phenomenon or concept (Bryman & Bell, 2011). In other words it implies conformance of outcomes independently of which methods are used (Holmén, 2012-2). We tried to put effort into ensuring as high validity as possible since its importance speaks for itself; without validity any conclusions become less trustworthy. Holmén (2012-2) argues that an effective way to increase validity is by triangulation, i.e. complementing and comparing different sources of data, which is done by using different types of data collection methods. This research draws on the two different sources of data in particular, i.e. interviews and third party sources. By so doing the validity dimension is improved.

Reliability refers to a study's ability to come up with the same results by repeating the same processes (Bryman & Bell, 2011). One way to increase this is by improving the clarity of research questions and their congruence with the study's features, and by triangulation (Holmén, 2012-2). Previous paragraph presents the work with triangulation. Being clear with the research questions is a tricky task as they somehow develop as the research progresses. However, this master's thesis has taken advantage of having updated research questions to present and bring to interviews in order to enable respondents to speak in accordance to the research's latest targets.

There are other aspects worth mentioning. The fact that only one physician interview per disease or healthcare application area has been conducted limits the knowledge respectively. However, in terms of diseases or healthcare application areas the purpose

is to get an overview, in contrast to deep diving into just one or two diseases. Therefore, constraints, primarily in terms of time, made it difficult to conduct more than one interview per disease or health application area.

Moreover, this thesis attempts to provide qualitative knowledge about the US healthcare system. However, a substantial part of the interviews are conducted in Sweden. The ideal situation would have been to talk solely with people in the US. Again, the setup of this master's thesis has not made that possible. Having spent the lion part of the semester in Sweden is simply the reason for this result. Also, physicians' work and knowledge in Sweden and in the US have arguably to a large extent many similarities. Thus, conclusions can be drawn independently of the interviewee's citizenship.

Even within the US healthcare systems varies a lot, which would imply that our scope is too broad. The reason for choosing the US is because TechCo has interests not only in the San Francisco bay area but in the whole country. Therefore it was logical to define the geographical scope to the country as a whole although our work while in the US has been based in the San Francisco bay area.

Finally, the satisfaction levels of different data points provided by wearable sensors would have benefited from comparisons with current medical devices, e.g. the Holter ECG device. It would have strengthened the value creation potential analysis and thus the attractiveness analysis as well. However, we leave that open for forthcoming research.

4 Results

This chapter presents the result from the data collection. The chapter consists of four major parts. It begins with current technology trends and healthcare trends, then information on specific diseases and healthcare application areas in relation to wearable sensors is presented. In the end compiled and final exhibits of the value creation potential by wearable sensors as well as the level of attractiveness is presented.

4.1 Technology Trends Related to Healthcare

This section presents technology trends that will impact the usage of wearable sensors in healthcare. The trends are twofold: Big data and Analytics in Healthcare and Rise of the Personal Cloud.

4.1.1 Big Data and Analytics in Healthcare

According to MGI (2011), there is strong evidence that big data has the potential to create significant value in private companies as well as national economies. According to the report, the data can support an increase in productivity and consequently enhance competitiveness. All previous eras of change towards increased usage of IT have resulted in productivity gains, and MGI estimates that big data can generate productivity improvements by 0.7 percent on an annual basis in the US Healthcare system. At the general level big data supports value creation in five diverse areas a presented in Exhibit 17 increased transparency, allows experimentation and learning, well specified segmentation on individuals, increased usage of automated algorithms, and new innovations.

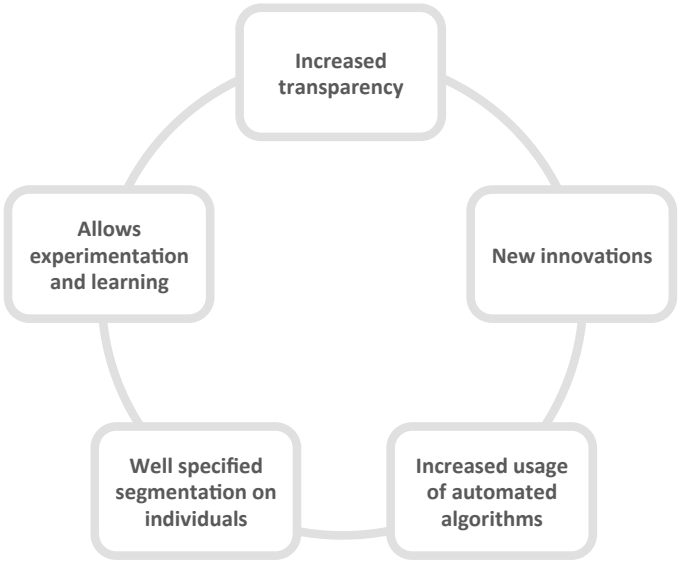

Exhibit 17: Big data support value creation in five areas. Source: MGI, 2013-1; own illustration

Increased Transparency

As mentioned previously, the healthcare system in the US has significant problems with the productivity. The challenges can be derived to the fact that there is a wide range of actors involved possessing different data and information. The actors within the system have different incentives and goals, which results in an ineffective system not focusing on the health outcomes. Given that the actor that have access to large quantities of data can gain a competitive advantage, the willingness to share data to other actors can be

limited.[10] Nevertheless, the US system has four major pools of healthcare data, including data from pharmaceutical research and development, clinical data, activity and cost data, and patient data (MGI, 2011). The greatest value and new opportunities can be revealed if these pools of data become transparent and interoperable, but new incentive systems will be a prerequisite for this change.[11]

Allows Experimentation and Learning

As data from several sources becomes transparent and accessible, entirely new opportunities for experimentation and learning open up. The access to previously separated databases will allow different kinds of experiments in healthcare outcome at an individual and group level.[12] By correlation studies it will be possible to increase knowledge on how different factors affect the health of different people in different environments. There is a trend of increasing knowledge of our health in the consumer market; hence the possibility of experimentation and learning is a strong value proposition both for healthcare providers and patients.[13] Recently there has been a shift towards evidenced-based medicine, and wearable sensors can support this development.

Well-specified Segmentation of Individuals

Big data has a large potential in the domain of segmentation of patients. At the moment, healthcare intervention plans are based on studies of large groups of patients and often miss the adjustment of the health condition of the individual patient.[14] Increased collection of data from individuals will enable person-specific assessments. Over time it will also be possible to identify sub-groups of patients and to tailor specific healthcare plans for these different groups. However, before this can be made a period of collection and analysis of the data will be necessary.[15]

Increased Usage of Automated Algorithms

A fundamental truth in big data is that more data is not necessarily better. The key will be to collect and analyze data at the right time in order to provide information, which is understandable and possible to take action upon to the receiver.[16] To analyze all data will be too burdensome for the physicians, and hence usage of algorithms will be crucial. As a result of these new requirements a new role will be needed in the healthcare environment, namely data scientists. The role of the data scientist will be to collect, analyze and present data in a way that makes sense to different actors. The same input data might need to be presented in different ways to healthcare providers and patients to make as much sense as possible to the receiver.[17] Effective usage of algorithms will allow healthcare providers to receive notifications and alarms when the healthcare status of the patient changes in a negative direction. On a general level this will enable a shift from reactive healthcare towards predictive healthcare.[18]

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[10] Todd Thompson, Corporate Development at Proteus Health, Interviewed at May 13th 2014

[11] Priyanka Agarwal, MD Samsung Center for Digital Healthcare, Interviewed at May 14th 2014

[12] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

[13] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014

[14] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

[15] Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014

[16] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

[17] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014

[18] Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014

New Innovations
Last but not least, access to data can open new possibilities to develop new innovations, ranging new products and services but also entirely new business models (ABI Research, 2014). The effort from both established companies and start-ups to seize these opportunities is huge, with new companies and products launched at an impressive pace. According to MGI (2013) the greatest potential for long-term improvement is in clinical operations, with the potential to save up to $165 billion on an annual and global basis.

4.1.2 Rise of a Personal Cloud
According to Gartner (2014) the personal cloud is one of the top strategic technology trends for 2014. The trend shifts the power from devices to services, meaning that the importance of devices will decrease, while the importance of services increases. As a result actors will put increased emphasis on access from and integration of several devices rather than the specifications of the individual devices. The personal cloud is basically a smaller cloud over which the owner has the ownership and control. Another benefit of the personal cloud is that the owner can decide to whom and when somebody should have access to the data and information stored in the cloud (Seagate, 2014).

4.2 Non-technology Trends Related to Healthcare
This section presents the six non-technology trends that will impact the usage of wearable sensors in healthcare. The trends include consumerization, demand of personalized care, Privacy of data, PPACA, remote-healthcare, accountable care organizations, and cross-industry collaborations.

4.2.1 Consumerization in Healthcare
There is a general trend in society of services and products to become more consumer centric, putting the demand of the consumer in focus. There are three trends that support this shift in the US healthcare system: desire of self-knowledge, demand of personalized care, and the possibility to bring your own device.

Desire of Self-knowledge
Originating from the San Francisco Bay area, the Quantified Self community now arranges conferences and meetings all over the world. The people in this community have diverse educational and professional background, but all have an extensive interest in building knowledge about themselves through collection and analysis of body data.[19] During recent years interest from users and developers for wellness and lifestyle applications to smartphones has been growing, and there is a multitude of applications available on Appstore and Andriod Market that allow consumers to track different sorts of data (Statista, 2014). Within the community there are examples of people that have managed to improve their health by collection, analysis, and usage of data. According to Bob Troia[20], he and his physician have been able to make use of the data collected via wearable sensors in the decision on how to improve healthcare status. Even though smartphones and their applications can be a convenient alternative for the patient, a regulatory approval from the Food and Drug administration (FDA) can help the technology to build credibility towards the physician.[21] However, neither hardware nor

[19] Rajiv Mahta, Member Quantified-Self Community, Interviewed at May 15th 2014

[20] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014

[21] Priyanka Agarwal, MD Samsung Center for Digital Healthcare, Interviewed at May 14th 2014

software have been approved as medical devices and there seems to be of low interest for FDA to develop and introduce such regulations(USAtoday, 2012).

Demand for Personalized Healthcare

As the focus in healthcare delivery shifts from general to personalized treatment plans, patients will demand products and services that meet their individual demands.[22] In fact, the healthcare market is currently changing from a business-to-business market into a business-to-consumer market.[23] Moreover, there is also a ongoing shift from describing patients as passive receivers of healthcare services towards an active party of the healthcare team around the patient, which results in engagement of the patient's own disease[24]. Git Eliasson[25] furthermore supports this as she has experienced improved patient engagement and health status via tele-health solutions in Sweden. The healthcare can be personalized in many different ways, ranging clinical treatment to research and development efforts of new pharmaceuticals. Historically, new drugs have to deliver positive result for 100 percent of the test population, otherwise state regulatory institutions do not approve it. However, consumerization can drive the change for development of more niche-products. For instance, a new drug can have a positive impact on 10% of the potential users, and if this population can be identified in advance, it will create incentives to change regulations as well as development of new drugs. To identify these people in advance, increased access to individual patient data will be essential. According to Ragnar Lindblad[26], consumerization in healthcare has to be proceeded by an increased access to patient data, since data will be the input for the design and development of personalized care.

Possibility to Bring Your Own Device

For years bring your own device policies have been implemented in several industries. As the number of different devices increases new requirements will be required of IT-systems. Actually, Gartner (2014) has selected mobile device diversity and management as one of the top ten technology strategic trends for 2014. As the variety of devices has been limited previously, there will be challenges in integrating these devices into professional IT-systems. However, as patients become consumers they will demand to use the products and devices that they prefer the most. When it comes to wearable sensors, it is the patient that will use the device on a daily basis during longer periods of time, and most likely, different patients will have different preferences. Hence, the IT-system provider will face challenges with integration of devices and different technologies.[27]

4.2.2 Privacy of Data

In general there is a trade-off between data transparency and the personal integrity of the individual patient.[28] With transparent data, the right information can be shared to the right stakeholder at the right time in order to support better health of the patient. On

[22] Birthe Dinesen, Visiting Researcher UC Davis, Interviewed at May 6th 2014

[23] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

[24] Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014

[25] Git Eliasson, Project Manager Karolinska Hospital, Interviewed at February 18th 2014

[26] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

[27] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

[28] Henrik Schildt, Project Manager NPO Sweden, Interviewed at February 26th 2014

the other hand, patients do no want to share data at other points of time[29], nor do the physicians want to be exposed to irrelevant data.[30] The requirements of data privacy of the patient is consequently not easy to understand but is key for developing health IT-solutions.

Academic research has shown that the importance of data privacy changes over time[31] and is also dependent of what health condition the patient has[32]. For instance people with diabetes do not necessarily want physicians to have access to their blood glucose data, since this will show if the patient does not follow the ordinations as prescribed. An extra glass of soda or a few pieces of candy on a Friday night will affect the glucose data negatively. On the other hand, there is other research that suggests that patients want to be monitored in such a way that the physician can contact them if their health condition is developing negatively.[33]

In addition there are also misconceptions by patients how data will be used. There are people that are afraid that their insurance companies will use the data to change premiums and coverage based on their health condition and their way of living[34]. However, there are parts of the PPACA that states that insurance companies are not allowed to alter their pricing based on such data.[35] Even though law enforces insurance companies to not make such decisions, the perception of the patient/consumer will always be the factor that determines the success. Healthcare providers, start-ups, and established companies will never be able to force the patient to use new devices and the success has to be preceded by a strong customer demand.[36] Most likely, patients will not show this demand until system providers can guarantee a high level of data privacy.[37]

4.2.3 Patient Protection and Affordable Care Act

According to McDonough[38] there are several dimensions that are important of the Patient Protection and Affordable Care Act (PPACA). Firstly, there will be significant increase in the number of American citizens that have health insurance versus those who do not. Specifically by the year of 2017 the number of uninsured will have decreased from an estimate of 55 million to 30 million. Secondly, the law is designed to improve the quality, efficiency and effectiveness of the medical care delivered in the US from a series of new incentives, programs and demonstrations. McDonough thinks that it is possible to improve quality while at the same time reduce costs thanks to the usage of wearable sensors. Thirdly, there are elements of PPACA that relates to public health prevention and wellness, i.e. it is designed to be a national prevention strategy. Lastly, there are provisions in the law that aim to improve the size and quality of the healthcare workforce.

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[29] Modjtaba Zandian, Quality Manager Mando Group, Interviewed at February 27th 2014

[30] Priyanka Agarwal, MD Samsung Center for Digital Healthcare, Interviewed at May 14th 2014

[31] Birthe Dinesen, Visiting Researcher UC Davis, Interviewed at May 6th 2014

[32] Todd Thompson, Corporate Development at Proteus Health, Interviewed at May 13th 2014

[33] Birthe Dinesen, Visiting Researcher UC Davis, Interviewed at May 6th 2014

[34] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014

[35] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

[36] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014

[37] Birthe Dinesen, Visiting Researcher UC Davis, Interviewed at May 6th 2014

[38] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

However, it should be clear that wearable sensors were not at all taken into consideration when the PPACA was designed. In terms of the development of the legislation there was nothing special about device development that triggered the policy development, rather the other way around. In general, policy makers do not consider specific devices, technologies, or applications in the development and design of new policies. Innovative devices are primarily related to the private sector, but it becomes part of the public discussion if it requires approval from the FDA. It becomes a part of policy discussion if healthcare players, such as insurance companies or self-insured employers, decide to invest in a particular device.[39]

McDonough[40] argues that there is no part of the law that will prohibit the success of wearable sensors. Because of the nature of wearable sensors, as medical devices, approval from the FDA will be influential. This is so because in order to be considered a medical device and used in professional healthcare, the device has to meet the requirement from the FDA. However, the devices can be successful and take off independent of the FDA if it is used in a non-strict medical setting and environment. This is also true in regards to the PPACA and McDonough[41] argues that it is possible that PPACA could enhance these possibilities and the success rate of wearable sensors even though it is hard to make conclusion whether there is any direct nexus between the PPACA and the success or failure wearable sensor.[42]

If it turns out that PPACA will have a positive effect on the wearable sensor market McDonough[43] specifically argues that there are provisions in Title 1 of PPACA that allows employers to vary health insurance premiums to their employees to as much as 30 percent. Hence, if wearable sensors are considered effective and attractive to employers then some employers might want to influence employees to strive for a better health situation and activities. Therefore they might want to make these devices available to their employees. In other words, this is one example where there might be some alignment between PPACA and existence of these devices.[44]

Moreover, one of the things that the law explicitly does is to prohibit insurance companies from issuing or rating policies based on the health status of the individual patient. Therefore, in some way the insurance reforms and the redesign of the law may actually make insurers somewhat more nervous and less likely to want to consider these devices because they might stray into the area called medical under writing.[45] Medical under writing is the process an insurance company uses to decide if they are to insure an individual or group, based on known or anticipated medical needs (The Free Dictionary, 2014).

In Title 3 of PPACA, which deals with the reform of the delivery system, there are a host of new innovations that seek to motivate hospitals, physician groups and other

[39] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014
[40] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014
[41] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014
[42] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014
[43] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014
[44] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014
[45] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

providers to move away from fees-for-service-payments. These innovations aim to move towards a global accountable care and value-based payment. For partners in healthcare, for example Accountable care organizations (ACOs) (see chapter 4.2.5 for more information), might be interested in wearable sensors in order to deliver care to patients within the ACO because wearable sensors might help them to improve the health of the patient. Basically, not only the insurers and the employers, but also ACOs and the healthcare delivery system might find these sensors interesting as new incentives are built for them to keep their patients healthy.[46]

Finally about PPACA, although it will be rolled out until 2022 most parts of the law will have been rolled out by the end of 2016 which means that at the time of a change in presidency the law will be established in a way that it is non-reversible. By that point in time an estimated of 25-30 million Americans will have health insurances because of the law, and the expectation is that changes at this point in time can not be very disruptive. However, there will always be changes in the policies and this is a never-ending process. There are new steps to be taken but it cannot be said at the moment what these steps might be. A new assessment of the direction of how the system should develop will probably be undertaken during 2017 regardless of which party that the new president belongs to but there are no major steps that are clear at the moment.[47]

The impact of adoption and usage of the wearable sensor technologies from the FDA will depend on the specific sensor.[48] In a sense, an approval from the FDA can make sure to the physician that the sensor collect data in a proper way and that the result can be reliable, but that is not to most important thing for ultimate adoption and usage. The major challenge will be to decide who will be responsible for the actions made on the data.[49] It is not given that the physicians will be interested in taking responsibility for the data, and hence is the impact from the data will be limited.[50]

4.2.4 Remote Healthcare and Out-patient Care

Outpatient hospital service includes essentially all medical care where the healthcare provider does not register the patient for a overnight stay in the hospital (Medicare Interactive, 2014). There are several arguments why outpatient care is positive, both in terms of improving healthcare outcomes and to reduce cost.[51] As a matter of fact, people prefer to be in their homes rather than staying in a hospital, given that the same quality of care can be delivered.[52] With wearable sensors healthcare providers are able to monitor patients remotely and intervene when deviations in the health status occur.[53] Research has shown that patients do not think it intrudes their personal integrity if the system is designed properly.[54] With this technology patients do not feel anxious and they proceed living their lives as before.

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[46] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

[47] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

[48] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014

[49] Priyanka Agarwal, MD Samsung Center for Digital Healthcare, Interviewed at May 14th 2014

[50] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

[51] Git Eliasson, Project Manager Karolinska Hospital, Interviewed at February 18th 2014

[52] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

[53] Git Eliasson, Project Manager Karolinska Hospital, Interviewed at February 18th 2014

[54] Birthe Dinesen, Visiting Researcher UC Davis, Interviewed at May 6th 2014

Moreover, being in a hospital environment is associated with risks due to the presence of microorganisms. As a matter of fact there is a risk to get additional infections while in the hospital.[55] The most common hospital acquired disease is urinary infections. However, these diseases can be avoided by compliance to basal hygiene routines.[56] To avoid hospital-acquired infections is of great importance to fragile patient groups, including elderly people and newly born children. To treat hospital-acquired infections, the healthcare provider gives antibiotic drugs to the patient.[57] However, there are indications that the usage of these drugs is being used too extensively; hence a reduction of the infections is positive. Today there are some technologies and products that allow the management functions to measure compliance to hygiene routines, but most measurements are performed with visual inspection.[58]

4.2.5 Accountable Care Organizations

Accountable care organizations (ACOs) are groups of physicians, nurses, hospitals, and other healthcare providers that form an organization responsible for delivering care of a pre-determined level of quality to patients (CMS, 2014). The goal of the organization is to coordinate different healthcare providers with to provide suitable care at the proper time. Further, the aim is to deliver better care to less expense, and as profits are generated these are distributed fairly among the partners in the ACO. To participate and being part of an ACO is entirely voluntary, but as the concept has been successful more and more actors affiliate in such arrangements. [59] As a consequence on the design of the healthcare system, healthcare providers are responsible for the care of patients up to 30 days after they have left the hospital.[60] As a matter of fact, the provider is responsible for all potential readmissions, including all potential health scenarios and not necessarily the one causing the initial admission.[61] If a patient is readmitted within the following 30 days, no extra reimbursement will be paid, and consequently, healthcare providers are incentivized to provide the best care and keep the patient healthy.[62]

4.2.6 Cross-Industry Collaborations

Collaborations among different actors with different backgrounds are going to be an important aspect to be successful in the market for wearable sensors.[63] There are actors that can collect data, users, healthcare providers, payers, insurance companies, and data integrators.[64] The great number of sensors means that it is important to figure out a system that can pull together all data.[65] The important thing is that there are win-win-situations for all actors to incentivize actors to collaborate. A key factor will be the integration and sharing of data to the different actors while necessary. Thus, integrating all of this data from different sensors will be a very important next step.[66]

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[55] Ann Tammelin, MD Healthcare Hygiene, Interviewed at March 4th 2014

[56] Ann Tammelin, MD Healthcare Hygiene, Interviewed at March 4th 2014

[57] Ann Tammelin, MD Healthcare Hygiene, Interviewed at March 4th 2014

[58] Ann Tammelin, MD Healthcare Hygiene, Interviewed at March 4th 2014

[59] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

[60] Todd Thompson, Corporate Development at Proteus Health, Interviewed at May 13th 2014

[61] John McDonough, Professor at Harvard School of Public Health, Interviewed at May 9th 2014

[62] Todd Thompson, Corporate Development at Proteus Health, Interviewed at May 13th 2014

[63] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014

[64] Priyanka Agarwal, MD Samsung Center for Digital Healthcare, Interviewed at May 14th 2014

[65] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014

[66] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014

4.3 Diseases and Healthcare Application Areas with Wearable Sensors

This sub-chapter covers the results from diseases and healthcare application areas. Each one of them follows the same structure. First is an introduction paragraph, then exhibits that shows data points mapped according to their importance on the x-axis and wearable sensors' ability to satisfy that data point, i.e. data satisfaction on the y-axis. What then follows are qualitative insights and finally there is a short conclusion. However, in Appendices III there is detailed information about each of the data points presented in the exhibits plus information about data points that cannot be delivered by wearable sensors but are still needed by the physicians.

The general hypothesis is that if wearable sensors can satisfy the data needs of healthcare providers, i.e. referred to as value creation potential, then patients are more likely to experience better health outcomes. In other words, as healthcare providers have access to more and better information they are able to provide better care. Therefore value creation for patients are better health outcomes and thus to evaluate the value creation potential of wearable sensors, an assessment of how well the sensors can collect the needed data was necessary. As presented in the methodology, the results score is based on the qualitative judgment of the master's thesis team, combined with the results from interviews with physicians and technology companies. The results are presented in Exhibit 18.

Data Points and their Satisfaction Levels by Wearable Sensors

- Blood Glucose Level – 8
- Blood Pressure – 9
- Compliance – 3
- ECG – 8
- Movement/Tremors – 8
- Movement Tracking – 9
- Oxygen Saturation – 8
- Respiration Curves – 7
- Spirometer Data – 7
- Temperature – 10
- Mobility – 10
- Pressure – 8
- Posture – 9
- Heart Rate – 10
- Fall – 10

Exhibit 18: Data points and their satisfaction level by wearable sensors; assessment of how well the sensors can measure different data points. Source: Master thesis analysis; own illustration

4.3.1 Cardiovascular Diseases

According to the Center for Disease Control and Prevention (CDC) (2014-2), cardiovascular diseases (CVDs) include multiple types of heart and vascular conditions. The most common one in the US is coronary artery disease, which can lead to heart attack, angina, heart failure, and arrhythmias. Moreover, CVDs constitute a major part of the healthcare system, both in terms of number of injuries and resources used. According to CDC (2014-2) about 600.000 people die of CVDs every year in the US, which corresponds to one in every four deaths. Coronary heart disease is the most common cause, killing nearly 380.000 people each year. In terms of heart attacks, there are 720.000 Americans who suffer from one yearly according to Heart.org (2014), the total number of patients with some kind of cardiovascular disease is 83.6 millions. The group of patients is expected to grow by 71.5 percent until 2030 (NCBI, 2011). The greatest challenge for cardiologists is acute myocardial infarction. This is a substantial

cause of deaths and many die outside the hospital. These people can have known and unknown heart diseases[67].

Importance and Satisfaction Diagram
In Exhibit 19 the data points needed for the cardiologist are presented, alongside their respective importance and satisfaction. It is obvious that many of the data points are located in the upper right corner, and consequently the value creation potential is high. The only exception is compliance, where improvement of sensors' will be necessary for future improvement.

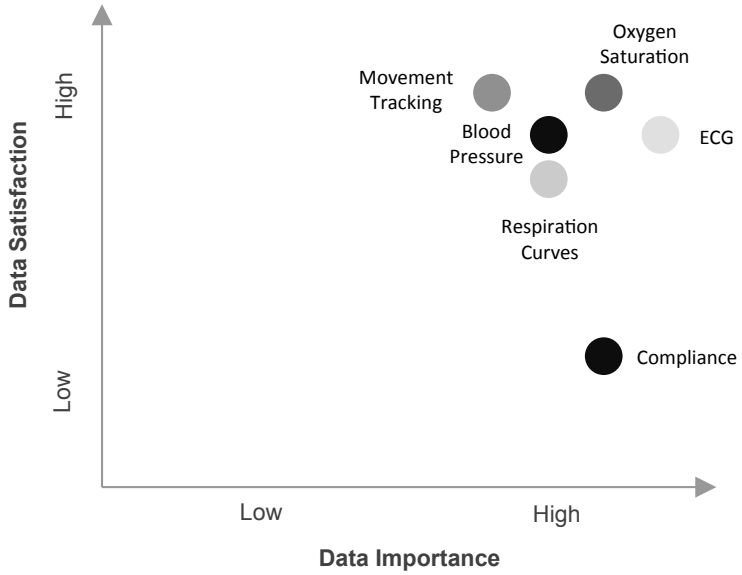

Exhibit 19: CVDs contain relatively many data points that can be provided by wearable sensors. All data points, except from compliance, are found in the upper right corner, which produces a high value creation potential. Source: Master thesis analysis; Rundqvist, 2014; own illustration

Qualitative Insights

- *Reduced Patient Anxiousness*
  Many patients with CVDs are anxious for their health condition, and these can be divided into several categories.[68] Firstly, the health outcome of cardiovascular patients is highly dependent on compliance. Wearable sensors have the potential to enhance better cooperation between patients and healthcare providers, as information about compliance becomes more transparent. Technology that can measure compliance would be useful to patients and physicians as it becomes possible to understand if the medication has been taken as ordinated and accordingly also be able to measure effectiveness and efficiency of the medication.[69]

- *Identification of Variations trough Continuous Monitoring*
  Secondly, there are CVDs that can only be diagnosed via measurement of the heart rhythm during a prolonged period of time. An example is atrial fibrillation,

[67] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014
[68] Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014
[69] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014

which is one of the triggers for stroke. By continuous measurement, both during day and night, of the heart rhythm atrial fibrillation can be identified earlier and anxiousness of patients can be reduced (Topol, 2012). The patient is able to know if e.g. fatigue is caused by atrial fibrillation, which increases the risk for stroke. Knowing the cause of fatigue can then reduce the anxiety for the patient.[70]

- *Increased Level of Convenience*
  Wearable sensors also have the potential to increase the level of convenience for the patient. Initially, there are groups of patients that think visiting the physician is troublesome. Many cardiovascular patients have to visit the physician on a recurrent basis, and if one lives in a rural area the effort to get to the doctor is a problem.[71] Moreover, some patients, especially elderly people, have substantial trouble to get out of the bed and get dressed. These patients would benefit from being able to submit their measurements remotely and visit the physician only when necessary.[72]

- *Patients Become Experts of their Own Diseases*
  By wearable sensors, cardiovascular patients will get better information of their disease. As data becomes accessible, more cardiovascular patients will be interested to measure body data. With access to data, the patient will be able to understand how behavior and choices of life impact their disease and biomarkers, and also be able to adjust to a lifestyle that is most beneficial for them. Previously there have been some systems available, but they have to be improved since today's systems are too bothersome. A particular area for improvement is data transfer, and smart phones are likely to be used for this purpose.[73]

Conclusion
In summary what turns out is that the potential for wearable sensors in CVDs is high. The group consists of 84 million people and is expected to experience significant growth on 72 percent until 2030. The value creation by wearable sensors for CVDs is high. Apart from the capturing on important data points sensors can also improve the healthcare of patient with CVDs by reducing patient anxiousness, allowing continuous monitoring, increase level of patient convenience, and enable patients to become experts of their own disease.

4.3.2 Diabetes

There are two types of diabetes, type I and type II. The major focus for this study is diabetes type I, but most of the findings can also be transferred to patients with diabetes type II. According to CDC (2014-3), diabetes is one of the major expenditures for the healthcare system in the US. The number of people with diabetes reached 40 million in 2012 (Altfutures, 2011). Moreover, Altfutures (2011) estimates that the total number of people with diabetes will grow by 34 percent by the year of 2030. To manage diabetes patients have to measure glucose level in the blood, which historically has been made by

[70] Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014
[71] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014
[72] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014
[73] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014

invasive sticks in the fingers.[74] There are several drawbacks with this technology, including large amounts of invasive sticks in the fingers, limited information on how the glucose changes during the day, and relatively high cost for equipment. The key success factor is to manage the glucose level in the right interval and at a stable level over time. The glucose level can be in four different stages; 1) in the appropriate interval, 2) under the appropriate interval limit, 3) over the appropriate interval limit, 4) continuously pending between low and high.[75]

Importance and Satisfaction Diagram

In Exhibit 20 the data points needed from a diabetic patient are presented, alongside their respective importance and satisfaction. Only two data points are needed, of which both can be measured well by wearable sensors. Consequently, the value creation potential is high.

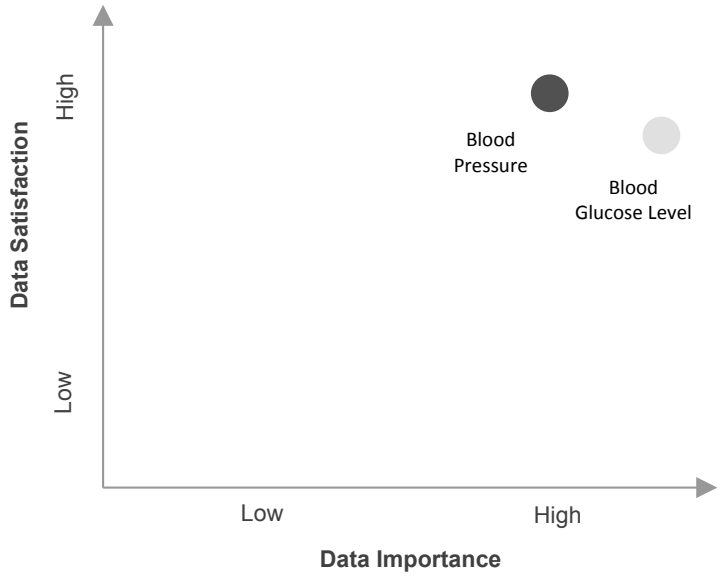

Exhibit 20: Diabetes only has two data points wearable sensors can satisfy. However, by far the most important data point is blood glucose level, which wearable sensor can provide. Source: Master thesis analysis; Forsander, 2014; own illustration

Qualitative Insights

- *Decreased number of invasive sticks*
  The value creation potential by wearable sensors for diabetic patients is extensive, and can be categorized into several classes. In the long-term perspective, wearable sensors and continuous glucose monitoring can save lives[76]. Moreover, the technology can decrease the number of invasive sticks in fingers. According to Ragnar Lindblad[77], the sticks are the most troublesome part of the disease, and not the actual insulin injections. The continuous glucose monitoring systems available today need to be calibrated twice per day. The reason for this is that the new technology measures the glucose level in the subcutaneous, a proxy for the glucose level in the blood plasma. As the

[74] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[75] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[76] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[77] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

technology becomes more easy to use, the patient can also use this during longer periods of time, which is positive for identifying longitudinal changes and variations.[78]

- *Reduced Patient Anxiousness*
  According the Adina Welander[79], one of the most prevailing benefits with continuous monitoring is the reduced level of anxiousness. By having access to the level of the glucose, the cause-effect interrelation can be more clearly understood by the patient. With a continuous glucose monitoring, the patient will not require as many hospital visits as before. For a family the new technology sets free a lot of time for other activities. Moreover, the technology helps parents of diabetic children to manage their child's disease and become less anxious about whether their child has an inappropriate glucose level. The driver for this change is the closed-loop. With the closed loop, a patient will have a sensor and an insulin pump attached to her body. The closed-loop is likely to boom in the night-care of the patients, as the level of physical activities by the patient is low. The positive benefits are apparent both in short and long term perspectives. The technology enables the patient to manage the disease, not just living with it.[80]

- *Enabled better Care Interventions*
  The medical value of wearable sensors is extensive. Unfortunately, there are no known medical methods for early detection of diabetes and hence wearable sensors cannot act preventative. Also, once a patient has diabetes she cannot be cured, and consequently there is no rehabilitation phase. However, in the treatment phase, increased data of the patient's disease can be of extensive value for the healthcare provider.[81] Wearable sensors are the force that will initiate a paradigm shift in the treatment of diabetic patients.[82] The sensors will generate an access to patient data that has previously not been available, and the information will increase from a few measurements per year to approximately 250-300 per day. The information will be of most value when the right data can be extracted at the right time. The access to data will unfold the sight of the healthcare provider into the disease of the patient, and thus be able to provide better ordinations.

- *Technology enables and supports self-care*
  According to Gun Forsander[83], self-care is an important trend in the medication of patients with diabetes. The previously established healthcare procedure is troublesome for the individual patient or parents of type I children, the staff in a kindergarten or preschool. The aim is to put the patient in charge of her own healthcare situation. To be in charge requires more knowledge, which can be created by data from wearable sensors. Moreover, the usage of wearable sensors can reduce the number of required visits at the hospital. However, which is

[78] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[79] Adina Welander, Consultant Boston Consulting Group, Interviewed at March 18th 2014
[80] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[81] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[82] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[83] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014

important to remember, some patients value the interaction and face-to-face meeting with the healthcare provider. As fewer patients visit the hospital, the resources can be spent more wisely on those patients that are in actual need of treatment.[84]

Conclusion

In summary what turns out is that the potential for wearable sensors in diabetes is high. The group consists of 40 million people and is expected to experience growth of 34 percent until 2030. The value creation by wearable sensors for CVDs is very high. Apart from the capturing on important data points sensors can also improve the healthcare of patients with diabetes by decreasing the number of invasive sticks, reducing anxiousness, enabling better care interventions, and supporting and enabling extended possibilities for self-care.

4.3.3 Asthma and COPD

It is possible to analyze asthma and COPD in common. The difference between the two is the cause but the joint symptom is swellings in the throat that need to be tempered in order to assure a well functioning respiration.[85] More than twenty-three million Americans suffer from asthma, leading to more than 500,000 hospital admissions per year; an asthma attack can be fatal, especially for children and young adults. Inhalers are a mainstay of treatment (Topol, 2012). Moreover Topol (2012) states that the ten millions of Americans who have COPD are at even greater risk of needing hospitalization than asthma patients. In 2012, 18.7 million people suffered from asthma and 12.8 suffered from COPD (CDC, 2014-7). As no data of expected growth until 2030 was identified, a proxy for growth in relation to population growth was used, resulting in a growth of 16 percent.

Data Importance/Satisfaction Diagram for COPD and Asthma

Exhibits 21 and 22 present the data points needed for a patient with COPD and asthma respectively, with their level of importance and satisfaction. Based on the results, the conclusion is that the value creating potential is similar for COPD and asthma. The most critical area for improvement is compliance.

[84] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014

[85] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

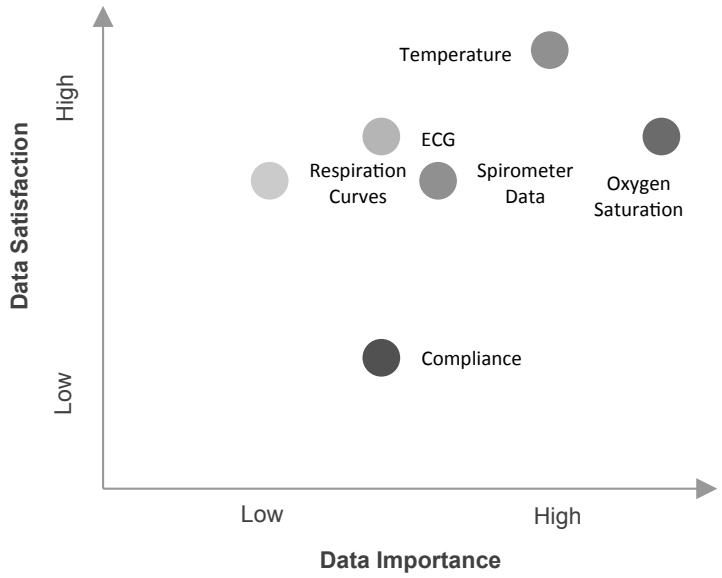

Exhibit 21: COPD is a disease that is need in of relatively many data points and wearable sensors can provide those data points in various quality. Source: Master thesis analysis; Nordensson, 2014; own illustration

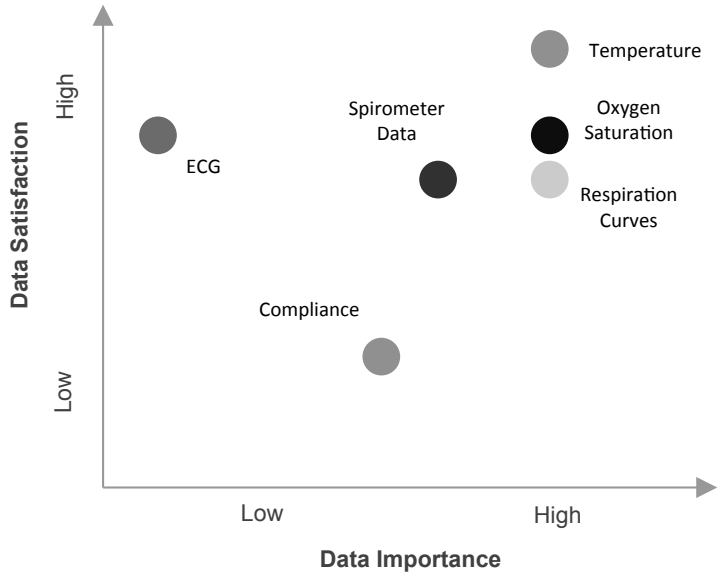

Exhibit 22: Asthma is similar to COPD, i.e. relatively many data points can be satisfied by wearable sensors but to various degree of quality. Source: Master thesis analysis; Nordensson, 2014; own illustration

Qualitative Insights

- *Identification of Negative Trends is the Most Important Aspect*
  Vital-sign monitoring and a sensor to detect reactive airways could, if signs indicated an oncoming asthma attack, potentially prevent it either by helping the patient avoid an area with high pollution or prompting the patient to preemptively take additional medications (Topol, 2012). The most important thing is to be able to detect negative trends. There is also a value in fewer visits to the hospital because one is able to detect the negative trends earlier. Also, it is good to limit the level of detoriation relapses as much as possible or else patients

may need to stay at the intensive care.[86] The trigger cause of detoriation is always important to find. For example, if patients have troubles during spring pollen might be the cause, or if troubles occur during night then the cardia is likely to be leaking up gastric. Thus, if the physician is able to spot unusual trends then they can contact the patient and change the medication in a preventative sense, because if medication works well than the patient should not have any problems. Thus the physician might have to change the base medication if the need of acute medication is increasing. This holds primarily for asthma patients because COPD patients more often have a standard base medication.[87]

- *Early Detection can Prevent other Complications and Costs*
  More continuously made measurements of meaningful data points bring value to detoriation relapses situations, since those are important to detect as early as possible in order to allows early cortisone medication and antibiotic treatment. By so doing the detoriation might not end up as serious. Early medication can also enable prevention of other complications.[88] Moreover, the biggest driver of asthma and COPD healthcare cost driver is patients who need to be at the intensive care. This happens to patients who have the most severe detoriation relapses. The second largest driver of cost is to end up at a usual asthma or COPD care department.[89]

- *Increased Data Makes Parents Less Anxious about their Children*
  One of the most distinguishable group of actors that like the to have access to more data is parents of asthmatic children.[90] When children go to school parents do not have access to any information of the health of their child, but with this information they get a better sense of when their children experience problems and can act accordingly. Children in general have problems to explain, and might even forget to provide this information if the sensors is not used, so the benefits and here have been extensive.[91] Essentially, the great benefit highlighted here is the possibility to coordinate healthcare among different actors and stakeholders, and the information can also be shared with the healthcare provider.[92]

- *Wearable Technologies Enable Better Communication*
  By making data and information available to both patients and providers in an interpretable, visualized and adjustable format helps to improve the communication between the patient and the provider.[93] It helps providers to better understand patients in terms of how well they are doing and their control of the disease, but also how sensitive the patient might be to poor air quality. This improves the conversation between the provider and the patient and also to create self-management plans. It is also very helpful to understand medication

[86] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[87] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[88] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[89] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[90] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014
[91] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[92] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014
[93] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014

adherence, which is a huge challenge for the healthcare system.[94] It helps providers to understand how well the medication they have prescribed is working. In general, understanding what is going on with the patient outside the walls of the clinic is good. It helps to do more with patients that are having a hard time and need attention. Otherwise, when seeing a patient maybe twice a year the provider really has no idea what is going on in between, which is not the case with the monitoring system.[95]

Conclusion

Asthma and COPD are similar in the projected symptoms, but with different triggering factors, which make them suitable for joint analysis. In 2012, 12.8 million people in the US suffered from COPD, and 12.7 million suffered from asthma. No data on expected growth was found, so growth with population was used as a proxy. This approach resulted in 16 percent growth until 2030. Apart from the value created by data measurements, wearable sensors can also increase care of asthma and COPD by early detection of negative trends, prevention of other diseases, reduced anxiousness, and better communication among different actors.

4.3.4 Care of Elderly

The people included in elderly care are people that are 85 years or older, and what distinguish these from other patients it that these people are sick because of age. In 2012, 5.5 million people in the US were in this demographic category and until 2030 it is expected to grow by 82 percent (Worldbank, 2014). At the same time, the category will increase its share of the total population, which poses a challenge for the healthcare system. These patients are often multi-sick, which means they are diagnosed with several chronic diseases.[96]

Importance Satisfaction Diagram

As presented in Exhibit 23 most of the data point needed from elderly patients can be collected in a satisfactory way with wearable sensors, apart from compliance to medication. Consequently, the value creation potential with wearable sensors in care of elderly is high.

[94] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014

[95] Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014

[96] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014

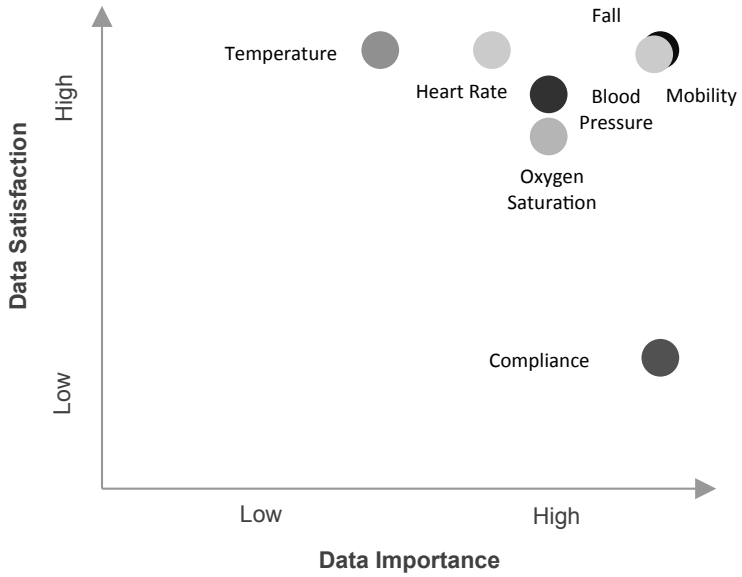

Exhibit 23: Care of Elderly have relatively many data points that wearable sensors can satisfy and the majority of those are located in the upper right corner which produces a high value creation potential. Source: Master thesis analysis; Nyman, 2014; own illustration

Qualitative Insights

- *A Holistic Perspective is Required*
  One of the greatest challenges in care of elderly is that a holistic view of the patient is required. It is not uncommon that the patients are multi-sick, which is defined as a patient with three or more diagnoses at the same time. The challenge for the physician is to be able to treat the diseases without inferring and worsening the status of the other diseases. Moreover, this requires the data collection to be broad and cover many parameters. This is a distinguishing factor from other healthcare areas. As a consequence, the care of these patients requires substantial amounts of resources. Another factor that distinguishes geriatrics from other healthcare application areas is that all parts of the care can be considered to be rehabilitation.[97]

- *Some Symptoms can Hide the Actual Disease*
  Moreover, it is particularly difficult to make proper diagnoses within the geriatric care because the symptoms for elder people can differ completely from the ordinary symptoms in some diseases. There are a few general and typical geriatric symptoms that can, unfortunately, hide basically all diseases because these are the elders' way of reacting. Falling, dizziness, pain, immobilization, incontinence, and confusion are the symptoms that the elderly, in particular, suffer from both before the disease has begun and during the treatment period. To collect these data points is a standard procedure at the beginning of any healthcare condition for the elderly. In general it would be advantageous to monitor these data points over a longer period of time. Today the data collecting process is mainly done by asking the patient and if the patient does not know its

[97] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014

relatives or other people will hopefully be able to answer. However, as soon as they are in the hospital everything is registered in the journal system.[98]

- *Elderly Want to Stay Independent Under Safe Circumstances*
  Elderly people want to stay independent as long as possible and they also prefer to stay in their own homes rather than going to nursing homes.[99] Naturally, this is only true if the same quality of healthcare can be provided.[100] Wearable sensors have the potential to collect this kind of data, and hence it can enable elderly people to stay independent and live their ordinary lives.[101] At the same time it will be very important to provide data to healthcare providers and relatives that the elderly patient is doing well and to reduce anxiousness.[102]

Conclusion
Based on these results, there care of elderly is an interesting area. The group consisted of 6 million people by 2012 and is expected to grow by 82 percent until 2030, driven by the change in demographical position. The value creation by wearable sensors for care of elderly is relatively high. Apart from the capturing on important data points sensors can also improve the healthcare of elderly patients by enabling a holistic perspective of the patient, reveal the actual symptoms, and enable elderly people to live independently for a longer period of time.

4.3.5 Neurological Diseases

This chapter includes the neurological diseases Multiple Sclerosis and Parkinson's disease. According to the CDC (2014-4) 1.4 million people had either one or both of these diseases in 2012. No data on expected growth was found, so growth with population was used as a proxy. This approach resulted in 16 percent growth until 2030.

Importance/Satisfaction diagram
In Exhibit 24 the data points needed and for care of neurological patients are presented. The number of data points needed is low, but so is also the level of satisfaction to measure these with wearable sensors. Accordingly, the potential to create value with wearable sensors in care of neurological patients is relatively low.

[98] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[99] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014
[100] Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014
[101] Bob Troia, Member Quantified-Self Community, Interviewed at May 19th 2014
[102] Todd Thompson, Corporate Development at Proteus Health, Interviewed at May 13th 2014

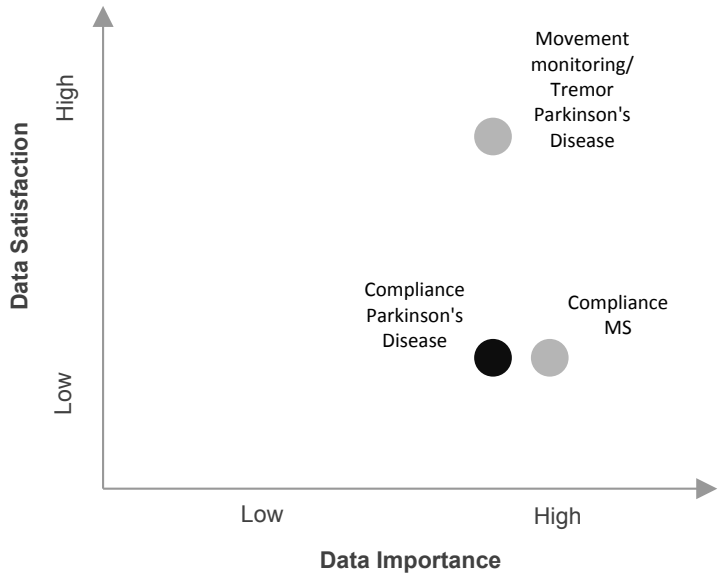

Exhibit 24: Neurological diseases, i.e. Parkinson's and Multiple Sclerosis in this master's thesis, benefit from relatively few data points of wearable sensors. In addition, the level of satisfaction is low which produces a low value creation potential. Source: Master thesis analysis; Malmeström, 2014; own illustration

Qualitative Insights

- *Increased Information Enable Better Healthcare Delivery*
  The greatest challenge with neurological diseases for the care provider is to effectively and, in an environment with many care options, assess different treatments individually. Sometimes one needs to test a treatment for every patient so that every patient has the medication with the best effect. In other words, it is challenging on an everyday basis to provide effective care for each and every individual. This applies for both Multiple Sclerosis and Parkinson. Partly, one explanation of this is insufficient information. Notably, Parkinson accounts for approximately 95% of all movement disorders. The drivers of cost for these diseases are in descending order personnel, i.e. personal assistance, loss of income for the patients, and medications.[103]

- *Wearable Sensors can Improve Healthcare Delivery*
  As of today and in general neurological care does not use any sensors. The eyes are the primary tool to provide care for patients with neurological diseases but it can e.g. be very hard to know if the walking ability has improved or not. The medicine for these diseases is furthermore very expensive and only 50 percent responds positively to the medicine and about one third do not know. Hence, if one could be certain thanks to wearable sensors it would be great. Unlike Multiple Sclerosis people with Parkinson's disease have very clear symptoms with tremors of the hands. All treatment today is to relieve symptoms, not to cure the actual disease. Regarding relevant data points for prevention and detection it is very speculative. For example they lose the sense of smell but that is probably hard to take advantage of. At the time when the tremors start then the disease is already there. Data points to use during the treatment, on the other hand, is more

[103] Clas Malmeström, MD Neurology at Sahlgrenska Hospital, Interviewed at March 10th 2014

applicable; physicians want to know how well motion/motoric functions work. If physicians get information about the movement, then he/she can change the medications, change the preparation and/or change the dosing interval**.** If the patient is well treated then the movement will work well and vice versa. Well treated is equal to prescribing the right medication, i.e. doses, type of medicine, time of consumption etcetera.[104]

- *Compliance is a Critical Factor for Intervention Success*
  The response when presenting the compliance pill is that there might be more engagement and the care provider can receive information continuously via some cloud service, which can enable fewer hospital visits. Today patients with Multiple Sclerosis take medication three times per week from which an assessment is conducted to decide if the patient needs to come to the hospital or not.[105] There can be a problem with patients who do not follow the medication prescription, because some patients do not want to be dependent on medications. Some patients are not honest about their medication intakes due to shame related issues as well. As a consequence, better medication is possible by knowing if the patients follow physicians' advices or not. Besides, due to the fact that these medicines are relatively expensive it is even more important that the medicines are taken and not thrown away.[106]

Conclusion
According to these results, the interest of neurological diseases is limited from the perspective of wearable sensors. The group consisted of 1,4 million people by 2012 and is expected to grow by 16 percent until 2030. Apart from the capturing important data points, sensors can also improve the healthcare of neurological disease patients by enabling enable better information for decision-making for healthcare providers, and enable improved medication interventions.

4.3.6 Obesity and Overweight

According to CDC (2014-5), obesity will be one of the major healthcare challenges in the US during the coming decades. As of today, 110 millions are obese and the number is expected to grow to 36 percent by the year of 2030. In the meantime, it is very hard for healthcare providers to treat patients with obesity[107]. To conquer the challenge, the healthcare providers need to individualize the healthcare and offer a set of healthcare plans instead of a one-size-fits-all approach. Obesity is disease as the risk of developing other chronic diseases is impending. Common diseases include diabetes, depression, CVDs, incontinence, menstrual irregularities, respiration problems, and sleep apnea. At the moment wearable sensors are not used for obesity care.

Importance Satisfaction of Data Measurement
In Exhibit 25 the data points needed and for care of obese and overweight patients are presented. The number of data points needed is low, and the level of satisfaction from available sensors is high. Consequently, the potential to create value with wearable sensors in care of neurological patients is high.

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[104] Clas Malmeström, MD Neurology at Sahlgrenska Hospital, Interviewed at March 10th 2014

[105] Git Eliasson, Project Manager Karolinska Hospital, Interviewed at February 18th 2014

[106] Clas Malmeström, MD Neurology at Sahlgrenska Hospital, Interviewed at March 10th 2014

[107] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

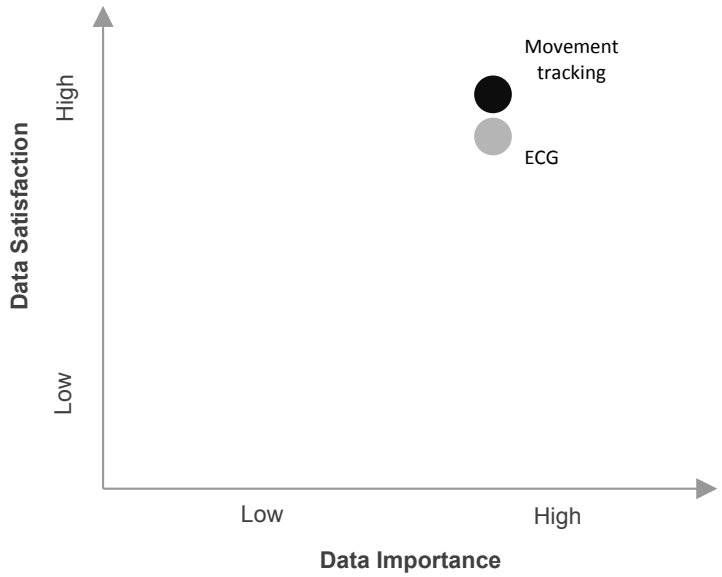

Exhibit 25: Obesity only has two data points that can be provided by wearable sensors but both the importance and the satisfaction levels are high which produces a high value creation potential. Source: Master thesis analysis; Eliasson, 2014; own illustration

Qualitative Insights

- *Better Physiological and Psychological Health Status*
  Wearable sensors can create value for obese patients during the process of healthcare interventions and in the process of recovery. During these phases the patient can get better knowledge of the disease, the effects of the intervention, and the healthcare status development.[108] To be able to see the improvement will be beneficial for the patient both in a psychological and physical dimension, and can improve the self-esteem of the patient.[109]

- *Better Self-Knowledge of Behavior*
  The increased availability to biometric patient data would increase the knowledge of the disease to the individual patient[110]. As one of the major challenges is to individualize the healthcare, wearable sensors will be the enabling technology for development of new intervention methods. Furthermore, the data allows healthcare providers to follow-up on the recommended interventions. Strictly explained, the goal for obese patients is to eat less amount of food during a longer period of time. There is technology that measures the amount of food the patient eats and the time consumed and by analyzing this data patients can receive recommendations for changes in eating behavior. According to Mubjataba, the key success factor for treatment of obesity is to get the patient aware of how the eating behavior relates to the risk of developing different diseases. When the patient possesses this knowledge the probability of successful healthcare interventions increases dramatically.

- *Better Communication Between Healthcare Providers and Patients*

[108] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014
[109] Modjtaba Zandian, Quality Manager Mando Group, Interviewed at February 27th 2014
[110] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

For this group of patients the interaction with the healthcare provider is of utter importance.[111] At the moment the interaction and communications channels are limited, and an increased communication channels and more frequent contacts can strengthen value propositions towards the patient. Another benefit is the increased validity of data. A common problem is that patients do not provide accurate data during discussions, especially regarding "soft factors" such as eating patterns.[112] With technology that guarantees validity and reliability of the input data, healthcare providers can focus their efforts on providence of healthcare recommendations rather than collecting data from the patients.[113] Lastly, eating behavior tracking sensors can be used to identify eating patterns among children that is associated to higher risk of developing obesity later in life. Accordingly, the technology can be utilized for early detection and prevention of obesity. Consequently the technology can have a massive impact in the long-term perspective, as healthcare providers can intervene in the pre-stage of over-weight and ultimately obesity. The result is fewer people with obesity and less hospital admissions per patient. Worth notice is that this technology can be applied to identify other eating disorder patterns such as anorexia and bulimia.[114]

Conclusion

Obesity is a major challenge for the healthcare system in the US, and approximately 110 million people had problems related to overweight and obesity in 2012. Until 2030 the number of obese people is expected to increase by 36%. Wearable sensors have a large potential for value creation in the healthcare delivery to obese people. The sensors can increase the knowledge of performance, behaviors, and compliance.

4.3.7 Orthopedics

This chapter describes the field of orthopedics, and pays special attention to the areas of spinal problems and repetitive strain injuries, as these are the most common complications. According to CDC (2014-6), 7.8 million people were diagnosed with spinal problems in 2012. No data was available on repetitive strain injuries. Therefore, until 2030 this patient group will increase in line with the population, which equals approximately 16 percent.

Importance Satisfaction diagram for Spinal problems and Repetitive Strain Injuries

In Exhibit 26 and 27 presents the present the data points needed from a patient with spinal problems and repetitive strain injuries, respectively, with their level of importance and satisfaction. Based on the results, the potential to create value is relatively high and is similar for both diseases.

[111] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

[112] Modjtaba Zandian, Quality Manager Mando Group, Interviewed at February 27th 2014

[113] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

[114] Modjtaba Zandian, Quality Manager Mando Group, Interviewed at February 27th 2014

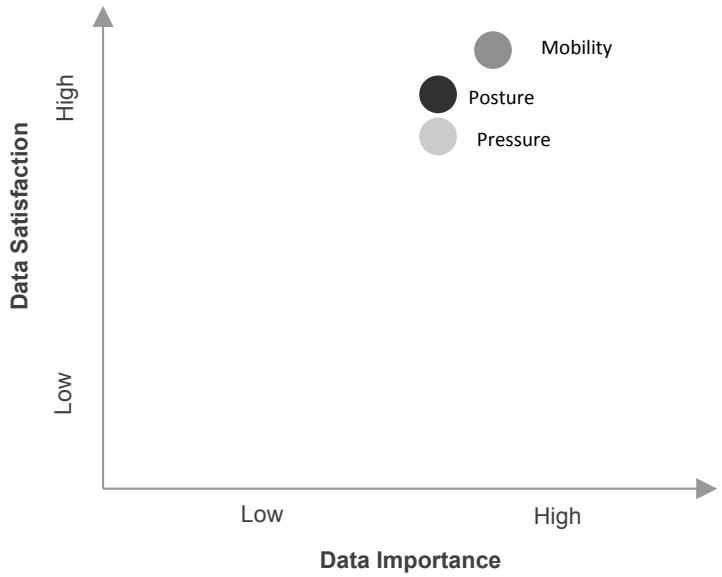

Exhibit 26: Spinal problems benefit from three data points of wearable sensors and all are found in the upper right corner which produces a high value creation potential. Source: Master thesis analysis; Jönsson, 2014; own illustration

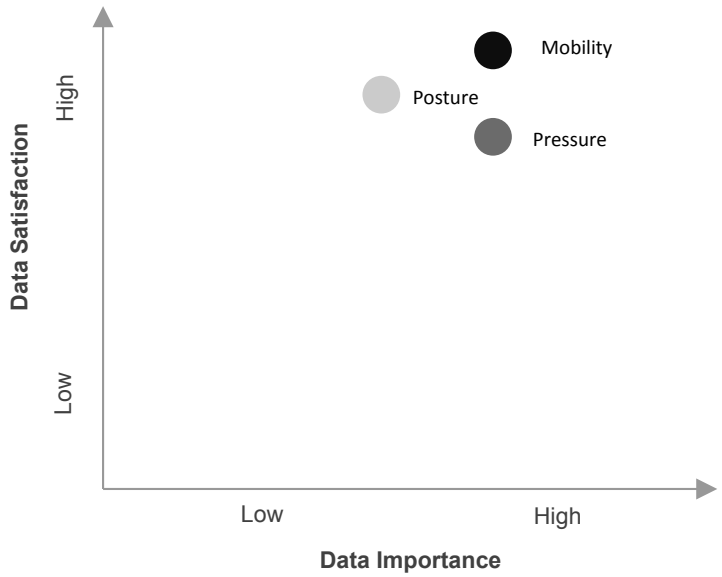

Exhibit 27: Repetitive strain injuries benefit from three data points of wearable sensors that are all relatively important and their satisfaction levels are also relatively high. Source: Master thesis analysis; Jönsson, 2014; own illustration

Qualitative Insights

- *Surgery is the Greatest Challenge*
  The challenge with orthopedic healthcare is the surgery, where the task is to repair the patients who are broken so well that they can live a normal life again as soon as possible. When the skeleton is broke metal structures are helpful. The difficult part is to find the best treatment. To get a better foundation it would be helpful to get access to assessment analyses of different treatments on a large population, which would provide insights about which method is the best one.[115]

[115] Anders Jönsson, MD Orthopedics at Sahlgrenska Hospital, Interviewed at April 15th 2014

- *Potential in Detection of Repetitive Strain Injuries*
  When it comes to detection there are possibilities for repetitive strain injuries but not for fractures. Data points that can tell whether the patient is mobile or not would be useful since the level of mobility is important when deciding the need for surgery. Surgery decisions are made up of different factors such as mobility, X-rays and pains. It is the sum of these factors that determines if surgery is an appropriate option or not.[116]

- *Increased Access to Data Can Support Decision-making*
  Today data becomes available when the patient enters the hospital but it would be great to get hold of this data by letting someone else incorporate it before the orthopedic department uses it. The orthopedics' role is to decide if surgery is the best option, hence it would be great if patients' investigations were finished when they come to the orthopedics.[117]

Conclusion
There is some value creation potential of wearable sensors in the care of orthopedic patients. Still the size of the patient group is approximately 10 million, which is relatively small. The growth of 16 percent until is 2030. However, the area is interesting as it can support decision making in what interventions to perform and can potentially also prevent some cases of repetitive strain injuries.

4.4 Value Creation Potential and Attractiveness Results

In chapter 4.3 charts for data importance and satisfaction for the different areas were presented. As described in the methodology, the quantitative evaluation of the value creation potential is based on these two input parameters. The results are presented in Exhibit 29. As can be seen the value creation potential is highest for patients with diabetes, followed by care of elderly, and CVDs. However, the data in terms of numbers for these charts come from the tables presented in Exhibit 28.

[116] Anders Jönsson, MD Orthopedics at Sahlgrenska Hospital, Interviewed at April 15th 2014

[117] Anders Jönsson, MD Orthopedics at Sahlgrenska Hospital, Interviewed at April 15th 2014

Empirical Values

Health Care Scenario	Latest Market Size (Million)	Market Growth By 2030 (%)	Value Creation Potential
Diabetes	39,7	33,8%	76,0
Cardiovascular Diseases	83,6	71,5%	61,8
Obesity	110,4	36,4%	59,5
Care of Elderly	5,5	81,8%	69,1
Asthma	18,7	15,9%	44,2
COPD	12,8	15,9%	46,3
Neurological Diseases	1,4	15,9%	33,7

Attractiveness

Health Care Scenario	Attractiveness
Diabetes	6,8
Cardiovascular Diseases	6,7
Obesity	6,6
Care of Elderly	6,3
Asthma	2,3
COPD	2
Neurological Diseases	1

Exhibit 28: The numbers that make up the components for calculating the level of attractiveness for diseases and healthcare application areas. Source: Master's thesis analysis; own illustration

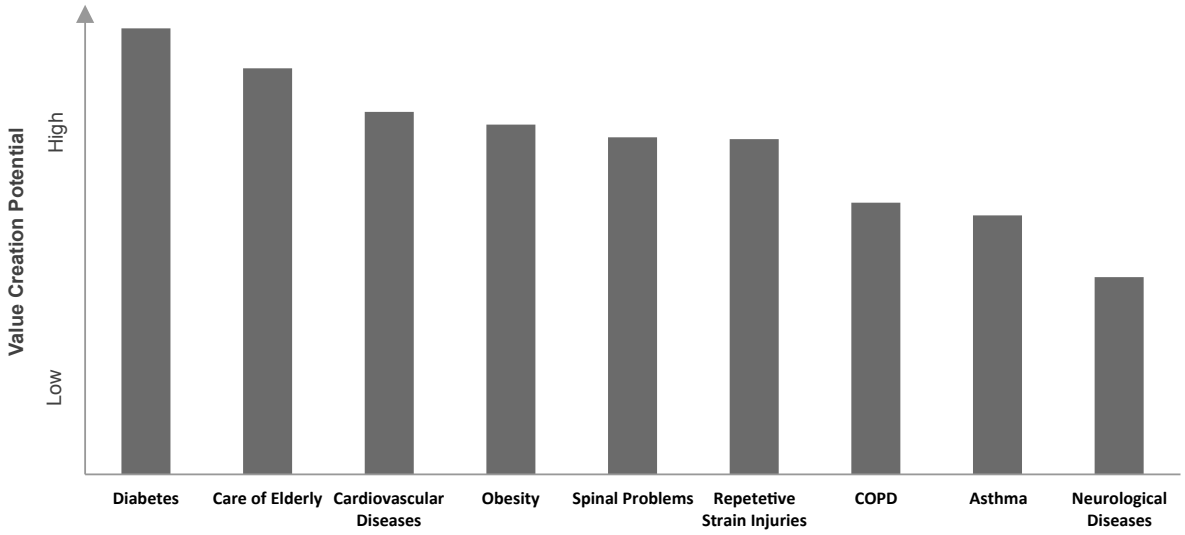

Exhibit 29: The value creation potential of wearable sensors for different diseases and healthcare application areas Source: Master thesis analysis; own illustration

One of the research questions for this project is to evaluate the attractiveness for different healthcare application areas. As presented in the theoretical framework and the methodology, the assessment of evaluation is based on three parameters: size of the population, expected population growth until 2030 and the value creation potential presented above. The results are presented in Exhibit 30.

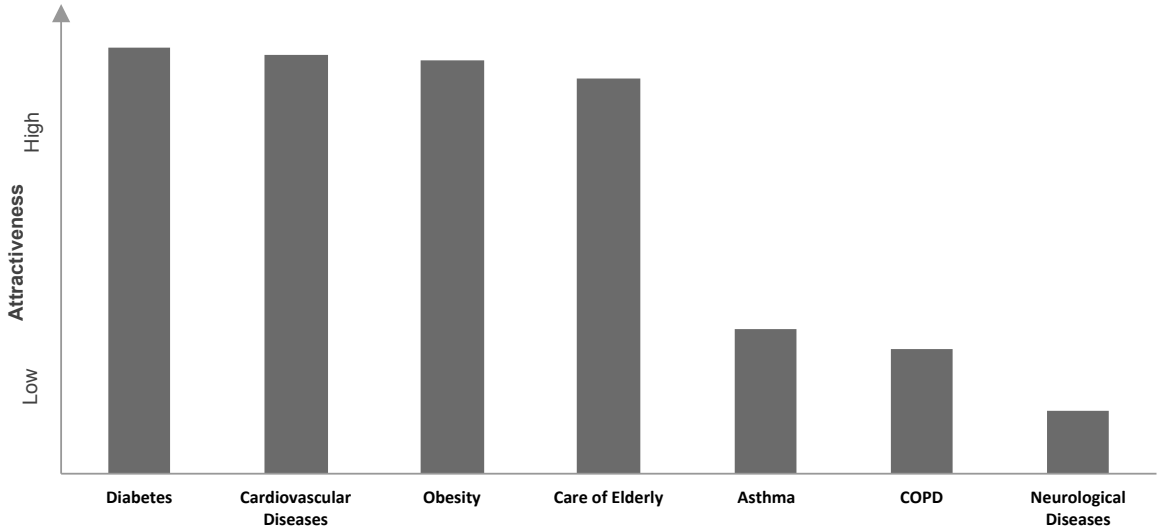

Exhibit 30: The attractiveness is shown for seven diseases and healthcare application areas. Diabetes, CVDs, obesity, and care of elderly have the highest attractiveness according to this master's thesis framework. Source: Master thesis analysis; own illustration

Based on the results in Exhibit 30 is it obvious that the most attractive application areas include diabetes, CVDs, obesity, and care of elderly. However, after input from TechCo, the project team paid less attention to obesity, as the healthcare processes for this disease are not defined. Consequently, the most attractive healthcare application areas from TechCo' perspective are diabetes, CVDs, and care of elderly. These areas will be in focus for the rest of the report, specifically for the scenario analysis.

5 Analysis

This chapter contains three sections. Firstly, future contextualized user scenarios are presented combining the insights from the results. Secondly, generalized value propositions from wearable sensors in professional healthcare are presented. Lastly, a business opportunity and supporting recommendations for TechCo' way forward are presented.

5.1 Scenario Creation

What follows next are three scenarios, i.e. three different American citizens who are in need of healthcare and that benefit from using different wearable sensors. First of all, we chose CVDs, diabetes and care of elderly since these areas are the most attractive ones according to the preceding analysis. Then, the scenarios were basically made up by taking into consideration all the important trends and influences that stand out. In addition, the scenarios are made up by input from the interviews, written sources, and discussions with TechCo. The general assumptions are that current trends will continue, and the emphasize is on the positive aspects of wearable sensors. By so doing the aim with these scenarios is to provide decision- and idea generation support about the next steps for TechCo.

5.1.1 User Scenario - Cardiovascular Diseases

Bob is 58 years old and lives in southern California in a rural area with Los Angeles as the closest big city. He is a carpenter and has a wife and three adult children. Bob has been suffering from a cardiovascular disease in the last couple of years. Specifically, he has coronary heart disease, which causes substantial anxiousness both for himself and for his family, as there is risk that he can get a myocardial infarction. Bob was, however, advised by his physician to start using a wearable sensor that can measure ECG continuously and on a regular basis. The sensor also keeps track of blood pressure, oxygen saturation, and respiration curves. Another sensor is measuring his activity levels in terms of movement. Moreover, Bob's employer is varying the health insurance premium, which was made possible in Title 1 of PPACA. Therefore, Bob's employer has encouraged him to use the wearable sensor, as his belief is that it will have positive effects on Bob's health status.

Bob's physician is eager to follow the ECG data since it gives him insights on whether Bob is getting worse. Unfortunately, Bob did not wear the sensor when the disease first occurred so the only way it could have been detected would have been to visit the hospital for a health checkup in which an old Holter ECG could have detected his disease. For two reasons this was not possible: Bob felt fine and thus had no need to perform such a checkup. Even more importantly, the healthcare system in California is hugely overloaded and physicians have little time for prevention checkups. This resulted in a heart attack at work, which he luckily survived, but it could have been detected if he had used the wearable sensor at the time and reacted to worsening biometrics.

Now, having the disease, both Bob and his family likes the fact that he uses his sensor continuously. Anxiety is reduced which means a lot to them; they know that algorithms are able to analyze his biometric data in order to detect bad trends or events. Bob's physician gets alerts when something that is worth to know is calculated by the data and its related software calculations. When Bob is experiencing fatigue he can reduce the anxiousness by using the information the sensor provides and most often he gets it confirmed that everything with his heart is in order. However, it happens that he sends

the data remotely to his physician when he is not sure about what is going on. In most cases the physician can then tell Bob that there is no reason to be worried although it has happened that the physician wants Bob to come to the hospital to take additional tests just to make sure Bob is not getting worse. If he is getting worse they can react before it gets too late.

What is really beneficial to both Bob and the healthcare system including his physician is that this sensor enables fewer visits to the hospital. For Bob it means that he does not need to drive five hours every now and then to perform the checkups and for the healthcare it means that resources are utilized more efficiently. Moreover, Bob is now thanks to his activity sensor, more motivated for exercising. Since it allows for visually displayed charts that for example show his progress he has found joy in running and cycling. Bob finds his sensors valuable so he is also using a connected body weight scale and send that data twice a day to the healthcare software system. This is another action of precaution because gaining weight unusually fast is a bad sign for people with heart disease.

An indirect result of Bob using these sensors is that the communication between him and his physician has improved. This is primarily due to the fact that Bob's own knowledge about his disease has gotten better which enables better understanding of his physician's medical advises. In addition, having access to sophisticated data over longer periods of time has made it easier to communicate about what Bob should do and not do while at the hospital. This is related to the fact that they can together watch all the data visually presented on screens and from that improve the level of conversation.

5.1.2 User Scenario - Care of Elderly

Dolly is a 93 years old woman who lives on the US east cost in an apartment by herself. Because of her age and the number of health complication she suffers from she is considered multi sick, which means that every now and then she is in need of healthcare.

Dolly is considered to be relatively poor which means that healthcare has always been unavailable to her. However, as a result of PPACA Dolly is now insured which is something she could not afford prior to the PPACA legislation. Since she is so old providing care for Dolly is sometimes difficult. For example Dolly's memory is not what it used to be. But Dolly has been handed wearable sensors in order to improve her health status.

Another policy that has had an effect on Dolly's healthcare experiences is the Outpatient care policy. In the case Dolly has had to go to the hospital for care the care providers have been able to send her home in the majority of the cases. Dolly does not like being at the hospital so she has embraced the sensors. They have enabled remote monitoring instead of having her staying in the hospital for the night while at the same time allowed for reduced costs for the hospital. In connection to this is Dolly's relatively poor immune system that is not well suited for long stays at a place where the risk of acquiring infections is high.

Dolly has lately had troubles with falls, which is a serious matter as that can cause femoral neck fractions. Hence, she is wearing a sensor that can potentially detect falls before they happen. The way it works is that data algorithms use measurements from Dolly's movement patterns, including posture and close-to-fall-movements. By analyzing

this, software provides information to her care providers about her balance levels, and thus they can see if the risk of falls is going in a risky direction. In turn, Dolly's physician can maybe change her medication or other care providers might be able to advice Dolly of safer movements. They can moreover let Dolly use different body protection products to minimize the risk of fractions in the case she falls anyway.

Since Dolly has several chronic diseases she also needs to take many different medicines and pills every day. Because Dolly is 93 years old it can be a hard task to do correctly every day and she has no care provider who helps her with this. Since a few years back, however, Dolly only takes medicine pills that contains a compliance sensor. It has actually been useful because care providers have been able to get her medication adherence levels delivered wirelessly and seamlessly and in turn phoned Dolly whenever she has forgotten or in some other way failed to adhere to her medication prescriptions. Dolly's physician has found this useful because it has allowed more precise doses of medication. Earlier the physician had to trust Dolly about what she said about her medication intake was correct, whereas now the physician has that information automatically without having to ask Dolly.

Further more, it is important that Dolly does not get immobilized as that increases the risk of basically many other health complications. Therefore, Dolly has accepted to wear a sensor that tracks her movement levels, i.e. how she is moving, and how much she is moving. One of the good things about this is that Dolly's closest relatives get notifications as soon as Dolly does not move to a certain standard. They can then call her to make sure Dolly is all right which has the effect that the relatives do not need to be worried all the time.

In general and because geriatric care is particularly challenging due to the fact that symptoms often hide the root causes, Dolly's physicians find it helpful to get hold of data not only from measurement made in the hospital but also while asleep and at home. As for all geriatric patients it is important to provide care holistically, which has been easier to do when the care providers have had reliable data as a starting point.

5.1.3 User Scenario - Diabetes

Sheryl is a physician at a hospital in downtown San Francisco and works as a specialist of care of diabetic children. Sheryl and her team are responsible for the care of a group of 200 children as part of the local accountable care organization she affiliated to three years ago. Every morning when Sheryl arrives to her office the nursing team has prepared a report for her, consisting of a list with patients that need to be prioritized for work this day. The personal information, including name and civic number, of the patient becomes displayed after algorithms have identified a person in the risk zone. The first name at top of the list is Jonathan Johnson.

Jonathan is a seven-year old boy who lives with his family in the suburbs of San Francisco. Since birth he has diabetes type 1. During his time in elementary school his parents, Sara and Charles, were constantly anxious and concerned of the health of their son. At that time, the personnel at the elementary school had to help Jonathan with measuring his blood glucose level by invasive sticks in the finger and based on the results inject the proper amount of insulin. Some days up to 25 measurements were necessary. These days were also very painful for Jonathan, partly because of the sticks but also as the process took so much time he could not really play with his friends and

focus on longer periods of learning. The equipment used was pretty expensive, and consumed a large part of the disposable income of the family. At home Sara and Charles were anxious that the blood glucose level would be to low. As a result, Jonathan had gained some extra pounds and showed tendency to develop overweight.

However, since two years ago Jonathan started to use two new products after advice by his physician Sheryl. The first product consists of a sensor and an insulin pump. The sensor continuously measures blood glucose level and the blood pressure. Based on the data from the sensor the algorithms in the pump calculate the proper amount of insulin to inject. The second product is a body scale that Jonathan uses two times per day, at the same time as he brushes his teeth. Both the sensor/pump and the scale are connected to a private cloud where the data is stored. Since Jonathan started to use the sensor, the blood glucose level has been in the proper interval and Jonathan shows no signs of overweight. Also, he is able to play with the other children, participate in physical activities, and he can concentrate much better during lectures.

In the report Sheryl received this morning the algorithm has identified that the glucose level in the blood has constantly been too high for a period of time and also Jonathan has gained some weight, which cannot be justified with his growth. Moreover, there are no signs that malfunctioning of the products have been sent. In the meeting at the clinic, Sheryl meets with Jonathan, Sara and Charles. Sara and Charles tell Sheryl that they have not changed anything regarding diet and nutrition. So Sheryl starts to ask some questions to Jonathan. It turns out Jonathan has started to eat candy that a friend gives him at school and that Jonathan has blocked the sensor at certain times to be able to do so. Based on the data Sheryl can tell Jonathan in an effective way how the candy is impacting his health, glucose levels, and his weight. As Sheryl can use the effective ways of communication Jonathan understands that he cannot proceed in the same way.

Sheryl, Sara and Charles decide to set an alarm that will be triggered if the same pattern appears again. Sheryl also tells her nursing team to put an additional alarm to look into the data from Jonathan two times during the next weeks. Later when Sheryl examines the data, she sees that the blood glucose levels are back at the normal level and that Jonathan has lost the additional weight he gained.

5.2 Value Proposition by Wearable Sensors

By analysis of the results, a set of nine general value propositions for patients and healthcare providers that wearable sensors have potential to fulfill are formulated. Recalling the value definition by Porter (2010-1) the rationale behind the following value propositions is that they can increase the patient outcome although other stakeholder can benefit as well. However, it should be explicitly stated that there are still challenges to overcome. This means that what is presented below is just potential value propositions.

- *More Convenient Vital Signs Measuring for Both Care Providers and Patients*
  Current and upcoming wearable sensors are getting smaller and are becoming more convenient to use. In addition and even more importantly, the reliability of the sensors is being improved and will continue to improve. Lastly, the number of data points that can be measured is increasing. In essence this means that measuring and collecting data about patients' vital signs with wearable sensors

instead of current devices and procedures can, in many cases, be done in a more convenient way for both care providers and patients.

This value proposition is primarily supported by analysis of the interviews with Bengt Rundqvist, Gun Forsander, Ragnar Lindblad, Reidar Gårdebäck, and Todd Thompson.

- *Fewer Hospital Visits for Patients Benefit Both Care Providers and Patients*
  Basically all healthcare stakeholders want fewer hospital visits given that the quality of care can be sustained. Wearable sensors can provide that by transmitting patient data remotely. That is, wearable sensors allow for remote home monitoring, which means that patients do not need to visit the hospital to do certain measurements, e.g. ECG or blood pressure. In particular, the US with large distances and many people having several hours of transportation to get to the hospital this is certainly valuable. Moreover, staying away from the hospital decreases the risk of acquiring infections. Further more, many patients prefer healthcare to take place at home.

  This value proposition is primarily supported by analysis of the interviews with Ann Tammelin, Bengt Rundqvist, Birthe Dinessen, Gun forsander, John McDonough, Ragnar Lindblad, and Reidar Gårdebäck.

- *Reduced Anxiousness for Patients and their Relatives*
  The level of anxiousness is an area where wearable sensors can be beneficial. This applies for not only the patient but the patient's relatives as well. The latter specifically applies for parents who can manage their children's diseases with reduced uncertainty and hence anxiousness, but also for grown up children that are concerned about the elderly relatives. In the case of patients themselves wearable sensors provide data and thereby knowledge that can assure everything is in place with regards to their specific health condition.

  This value proposition is primarily supported by analysis of the interviews with Adina Welander, Anita Nordensson, Bengt Rundqvist, Gun Forsander, Git Eliasson, Birthe Dinesen, Ragnar Lindblad, and Reidar Gårdebäck.

- *Improved Medication Interventions by Care Providers*
  Having wearable sensors data and related analysis of that data available enables better medication interventions. This means that physicians will have a trustworthier basis to prescribe medication, change doses, and change medication. In other words, wearable sensors support care providers to provide better medications to their patients. For example, measuring biometrics on a continuous basis gives the physician the whole picture of how patients respond to certain medications. That is, measurements performed while at the hospital, which in fact can be biased due to the white coat syndrome or other individual reasons, can be replaced with measurements by wearable sensors.

  This value proposition is primarily supported by analysis of the interviews with Bengt Rundqvist, Christer Nyman, Clas Malmeström, Gun Forsander, Meredith Barrett, Priyanka Agarwal, Todd Thompson.

- *More Predictive and Preventative Healthcare*
  More data opens up possibilities and by big data algorithms in place wearable sensors can provide information that can be used to make healthcare more predictive and therefore even preventative. The best healthcare is the one that is not even necessary and as healthcare is moving towards a more predictive approach in contrast to today's reactive approach, wearable sensors is one of many pieces that can enable this change.

  This value proposition is primarily supported by analysis of the interviews with Anders Jönsson, Anita Nordensson, Bengt Rundqvist, Bob Troia, Birthe Dinessen, Christer Nyman, Gun Forsander, Priyanka Agarwal, Rajiv Mehta and Todd Thompson.

- *Improved Level of Communication Between Healthcare Stakeholders*
  As patients become more aware and more knowledgeable about their own diseases communicating with their care providers becomes easier. One way to become more knowledgeable about your own disease is to follow and study the disease on a continuous basis with instant feedback, which is something that wearable sensors can provide. With increased understanding care providers will find it easier to give medical advices so that they become complied. Moreover, other stakeholders such as insurance companies, payers, employers etcetera can establish enhanced communication as a result from the data wearable sensors provide. To summarize, having a patient's full health picture at hand makes communication more transparent and reliable.

  This value proposition is primarily supported by analysis of the interviews with Bob Troia, Björn Eliasson, Gun Forsander, Henrik Schildt, Meredith Barrett, Rajiv Mehta, Todd Thompson.

- *Care Providers can Deliver More Personalized Healthcare to Patients*
  Having access to more data about single patients open up for possibilities in terms of more personalized healthcare. If care providers can access data with high quality care providers can adjust treatments in order to fit single patients, not a group of patients. What is best for one patient might not be the best solution to another patient even though they by definition have the same health complication. People have different preferences and priorities when it comes to health value. Hence, care providers would be able to deliver more personalized care if have they had access to patients' specific biometrics.

  This value proposition is primarily supported by analysis of the interviews with Anders Jönsson, Birthe Dinesen, Bob Troia, Christer Nyman, Mudjtaba Zandian,

- *Care Providers Can Make Backed Up Care Prioritizations of their Patients*
  Wearable sensors with algorithms can find the patients that are in the biggest need for care despite using fewer resources. The reason behind this is that monitoring makes it possible for care providers to receive information about the patients that have deteriorating values. In turn, care providers can prioritize and reach out to those who actually need care. The introduction of this kind of

technology will also enable a shift in workload within the workforce at hospitals. For instance, instead of a physician meeting all patients, nurses can monitor the data and only schedule meetings with physicians when necessary. In addition, hospitals will be allowed to use features of production management and supply chain to create a swift and even flow of care that reduces bottlenecks.

This value proposition is primarily supported by analysis of the interviews with Anders Jönsson, Henrik Schildt, Priyanka Agarwal, Meredith Barrett, Gun Forsander,

- *Research, Development, and Scientists Benefit by Wearable Sensors*
  Wearable sensors can improve efforts in research and development at specific corporations, but they can also create value in scientific research. With data from wearable sensors smaller patient groups with the same disease and other characteristics can be distinguished and drugs can be developed specifically for them. Being able to measure data points continuously over longer periods of time opens up possibilities that are not possible today. For example, test subjects can be followed in normal situations because they can bring the data collection device with them. Consequently, wearable sensors have the potential to provide data that enables more personalized medicine development.

  This value proposition is primarily supported by analysis of the interviews with Meredith Barrett, Rajiv Mehta, Ragnar Lindblad and Todd Thompson.

5.3 Recommendations to TechCo

This sub-chapter contains the recommendation for TechCo' way forward with wearable sensors in professional healthcare. It starts with the main recommendation and the subsequent recommendations belong to the first main recommendation.

When looking at the consumer market for both devices and platforms it is easily determined that the market and its landscape is changing rapidly. Until now the market has been characterized by a large variety of companies, products, and service offerings. Our opinion is that the market has been in a fluid phase until now, but soon there will be a consolidation of the market, and a shift into a transitional phase. As mentioned in the introduction, Samsung and Apple launched their initiatives in healthcare and wearable sensors during late May and beginning of June 2014. We believe this will be de dominant design for both devices and platforms in the consumer market. Thus, entering the consumer market is not a viable strategic choice. Exhibit 31 shows the logic of this reasoning. So, the question is what TechCo should do? What it the business opportunity for them?

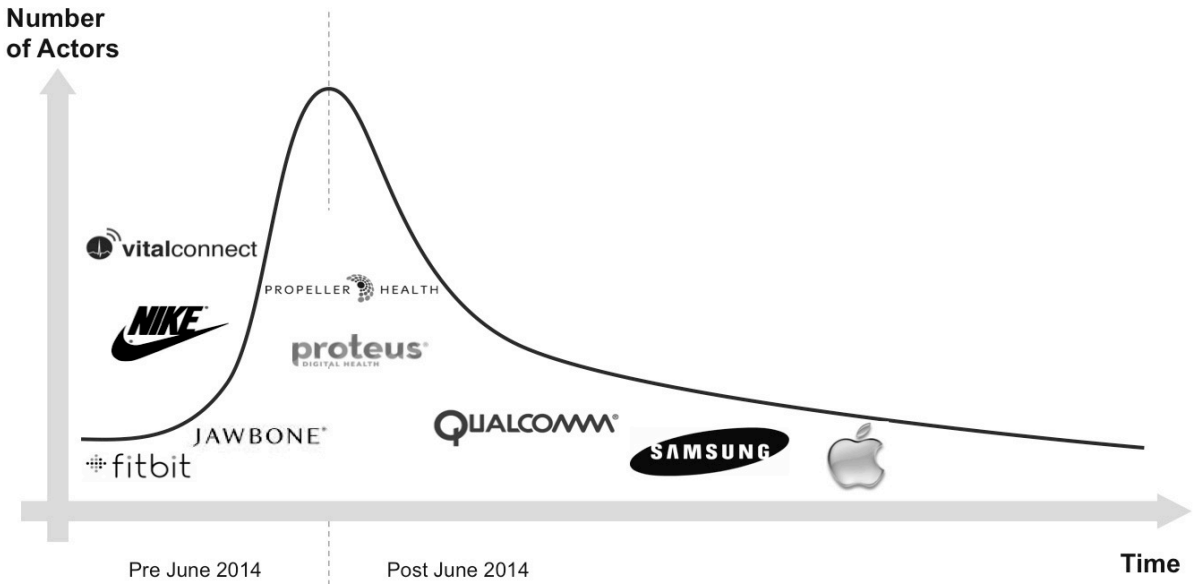

Exhibit 31: Wearable sensors and healthcare landscape. Source: Master thesis analysis; own illustration

1. **Integrate patient data from different consumer platforms and make this data accessible to healthcare providers in their healthcare IT-systems**
   The business opportunity for TechCo lies in being able to integrate data from different consumer data platforms, such as Samsung's SAMI or Qualcomm's 2Net, into healthcare IT-systems e.g. electronic health records (EHRs) in order to make the data actionable for healthcare providers. As a matter of fact, TechCo is already an established provider of medical technology to the healthcare industry. TechCo should therefore focus on this distribution channel, which includes business-to-business channels with e.g. hospitals, which is in contrast to target consumers directly. That is, TechCo should not enter the consumer market to develop their own wearable sensor or even try to grab market shares by competing with consumer-focused companies such as Apple and Samsung, as their competitive advantage is perceived as too strong. We argue that this business opportunity is huge. However, it is not in the scope of this master's thesis to evaluate its absolute or relative size in monetary terms. Exhibit 32 below is an illustration on the healthcare ecosystem, highlighting the business opportunity for TechCo.

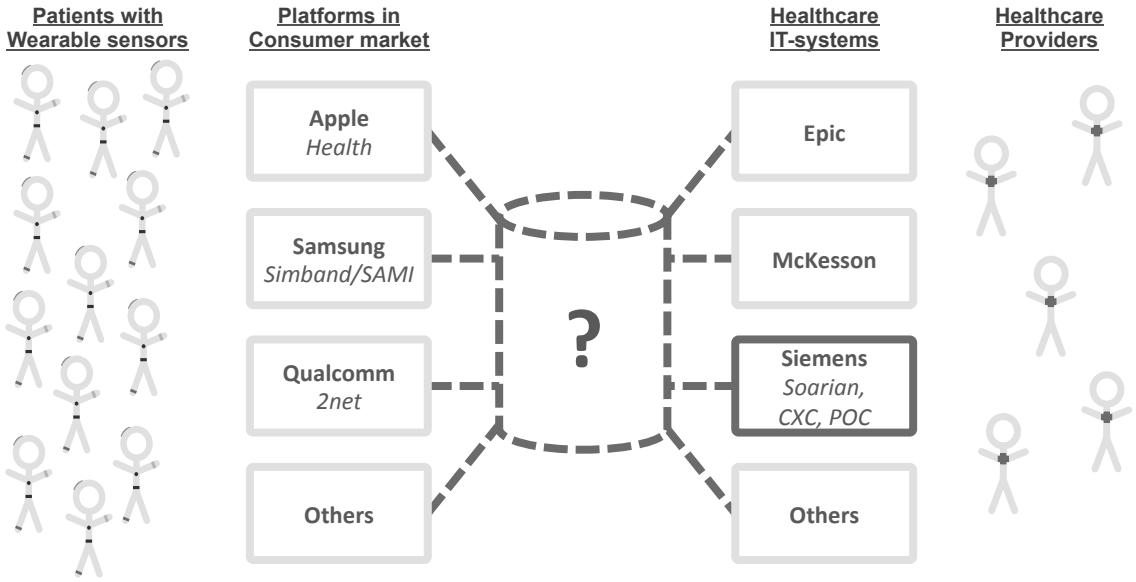

Exhibit 32: Business opportunity illustration within the ecosystem. Source: Master thesis analysis; own illustration

However, we do not believe that there will be only one actor within the area for platforms in the consumer market, nor in the market for EHRs. In order to integrate these two sides and by so doing grasping this business opportunity, we have the following sub recommendations:

1.1. Focus on chronic diseases, in particular CVDs and diabetes, and the healthcare application area care of elderly

Based on the results presented in chapter 4.4 the most attractive diseases and application areas of wearable sensors in healthcare are cardiovascular disease, diabetes, obesity and care of elderly. However, TechCo wants to remove obesity as no care processes are defined. The common characteristic for these areas is that the number of people in each area is large, the number of patients will increase until 2030, and that wearable sensors to a large extent can satisfy the data needed by physicians and hence create much value. The rationale behind this recommendation is that if TechCo can provide a lot of value to many people there will be a party in the market who is willing to pay money for that service. For further information of wearable sensors' potential to satisfy the data need, please see results in chapter 4.3 and Appendices III.

1.2. Make the patient the owner of his/her health data

Based on the results from the trends presented in chapter 4.1 and 4.2 and the combined impression from the qualitative insights from the different physicians, we argue that the patient should be the owner of his/her data. A solution that makes the patient the owner of the health data and enables sharing the data to the right actors at the proper time will be well accepted in the market. Several physicians emphasize that while managing health data, privacy for the patient should be of highest concern. Patients are willing to share their data to selected actors if they can improve their healthcare status. Healthcare providers on the other hand will not accept an overload of data and information. Big data and algorithms will be a key factor to provide these services. As a consequence and

in addition, the demand and preferences regarding the visualization of data is important and will differ between different groups of users.

1.3. Analyze to which current product(s) and/or service(s) wearable sensor will contribute to within TechCo' healthcare product portfolio

The research group should map and understand the product and service portfolio of TechCo in order to decide which of these that can actually be supported and improved by integration of wearable sensors. At the moment, the research group is targeting different internal stakeholders at TechCo, which creates confusion and interruptions of efforts. During the time for this project the focus has shifted between Soar, CXC, SOC Testing and other products. By defining to what within TechCo wearable sensors will contribute to it will be easier to develop value propositions and long-term goals.

1.4. Search for and develop current collaboration partners with actors that have complementary skills and knowledge

A distinguishable factor of other actors in the industry is that they collaborate across industries to get hold of complementary skills and knowledge. This is supported by the general trend towards more cross-industry collaborations, presented in chapter 4.2. In the case of Samsung and Apple, they have strong collaborations with medical institutions in order to integrate people with medical skills in the development and testing of new products. As the reliability of the devices and the possibility to trust the information from the devices will determine the success of the sensors, collaborating with medical institutions can also help TechCo to build additional confidence among healthcare provider. For example, University of Davis as well as UC Berkeley have already proved to be fruitful connections; hence TechCo should develop those relations further.

1.5. Conduct complementary research to understand how wearable sensors can create value by reducing the cost of care

As presented in the theory in chapter 2 and the methodology in chapter 3, this thesis focuses on how wearable sensors can create improved healthcare outcome. To really understand the value creation by wearable sensors in healthcare, it is recommended to look further into how wearable sensors can reduce the cost of healthcare delivery. The result from this report indicates that there is a strong value proposition towards patients and healthcare providers in order to increase the healthcare outcomes, but this is only half of the value definition. If TechCo can show that wearable sensors can reduce costs, TechCo can also present a strong value proposition towards healthcare payers and insurance companies. Hence, complementary interviews with insurance companies (e.g. Kaiser Permanente) and payers are recommended.

6 Conclusion

This chapter presents the conclusions and consists of two parts. The first part puts the findings of the report in relation to the purpose of the thesis, and what implications these may pose. The second part consists of three recommendations for future research within the field of wearable sensors in professional healthcare.

As presented in the introduction, the purpose of this master's thesis is to provide information and recommendations to TechCo on how to consider wearable sensors in future research and development, with special attention to the healthcare system in the US. Further, the purpose is to initiate the creation of a business model for wearable sensors in professional healthcare. In order to fulfill the purpose, the project has focused on four research questions.

Firstly, we evaluated the attractiveness of different diseases and healthcare application areas. The assessment consists of three parameters, including population size, expected growth during the next decades, and the value creation potential by wearable sensors. Interestingly, the areas with the highest potential to create value for the patient are also the most attractive ones. Based on the results, the most attractive diseases and healthcare application areas are CVDs, diabetes, and care of elderly.

The second research question is to understand how future use cases of wearable sensors in healthcare could look like. By combining current trends in technology, business, and healthcare we propose and present three different user scenarios, including CVDs, diabetes, and care of elderly. These user scenarios offer a contextualized understanding of how the life of patients with chronic diseases can be improved and changed with help of new technology.

The third research question is to understand what value propositions wearable sensors pose for patients and healthcare providers. These are generalized and not specifically related to a certain disease or healthcare application area. All together nine value propositions were identified. The value propositions are:

1. More convenient vital signs measuring for both care providers and patients
2. Fewer hospital visits for patients benefit both care providers and patients
3. Reduced anxiousness for patients and their relatives
4. Improved medication interventions by care providers
5. More predictive and preventative healthcare
6. Improved level of communication between healthcare stakeholders
7. Care providers can deliver more personalized healthcare to patients
8. Care providers can make backed up care prioritizations of their patients
9. Research, development, and academic scientists benefit by wearable sensors

The last and most important research question is to identify a business opportunity for TechCo within the healthcare eco-system, and provide recommendations for future development. We believe the most viable opportunity for TechCo lies within integrating platforms and devices in the consumer market with the IT-systems currently deployed by hospitals and healthcare providers. Although the specific design for the integration is not defined, we propose five supporting sub-sequent recommendations that will be important for TechCo to consider. The five recommendations are:

1. Focus on chronic diseases, in particular cardiovascular diseases and diabetes, and obesity and the healthcare application care of elderly
2. Make the patient the owner of his/her health data
3. Analyze to which current product(s) and/or service(s) wearable sensor will contribute to within TechCo' healthcare product portfolio
4. Search for new and develop current collaboration partnerships with actors that have complementary skills and knowledge
5. Conduct complementary research to understand how wearable sensors can create value by reducing the cost of care

As presented in the introduction, the healthcare system in the US has a challenging future. The population is increasing, there is shift in demographics towards an older population, and people are becoming more knowledgeable of what benefits healthcare services can bring. To address these challenges and solve the problem a systematic shift will be needed, and we will have to re-imagine the way to think of healthcare and healthcare delivery processes. There is a shift towards value-based healthcare, a system that will put the patient in the center. Based on the potential user scenarios and the proposed value propositions, we believe wearable sensors can be an important part of this shift. As presented in the report, wearable sensors can create extensive patient value by improved healthcare outcomes. With future research on how sensors can help to reduce cost of care, the value proposition to healthcare providers can be even stronger. Such additional research would be important to further understand where TechCo can add the most value in the healthcare ecosystem.

However, there are some challenges that need to be handled. At the current moment FDA is responsible for approval of products that are to be used as medical devices. Still, the final decision to use a device or not lies within the hands of the healthcare provider. Concerns have been expressed of what will happen if a healthcare provider does not identify abnormal variations in the data; who will in such situation be responsible for the actions made based on the data and the information? We believe that new regulations will be needed in order to get juridical definitions of who is responsible for what and when. In turn, the likelihood of acceptance and adoption among healthcare providers will increase.

Moreover, as presented in the background, the healthcare system has many different groups of stakeholders. As a systemic shift might be the only solution to the posed challenges, a solution that is beneficial to all is needed. What has been presented in this thesis is the perspective of the patients and the healthcare providers. A thorough understanding of how other groups of stakeholders will be impacted by wearable sensors is also important to analyze.

Lastly, apart from defining what the concrete business opportunity is and how integration should be made, we suggest two recommendations for future research projects. They include how to present data and information to make the most sense out of it, and what new skills and requirements will be needed in the healthcare delivery process.

As presented in the study, wearable sensors have the potential to collect extensive amounts of data from different sources and with different content. There are some healthcare areas where the development has come further, but questions still remain about what actions can actually be made based on the information from this data. Further research should focus on how to present and visualize data and information to patients, physicians, and other stakeholders. Particularly for patients, research should focus on how to present data and incentivize people to behavioral changes.

Another interesting research topic would be to understand what new skills and knowledge the introduction of wearable sensors would require in the healthcare eco-system. Currently, healthcare providers are not educated in interpreting and understanding large quantities of data, skills that will be important in the future. Is it possible to educate healthcare providers, such as physicians and nurses, with knowledge in how to interpret data? Or is it possible to educate current data scientists to understand and make sense out of medical data and information? Or would entirely new educations be needed, which educate the students in both medical and data science? How should such an education be designed? These are interesting questions that make up a base for future research.

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Appendices

Appendices 1 – Interview Template, Initial Interviews

General Introduction

1. Please describe you background, including education, previous and current work experiences.
2. What are the current trend in medicine technology
    a. Which are the most important?
    b. Why are these the most important?
3. Have you heard of wearable sensors in health care?
    a. In what context was the technology used?
    b. Do you know of any company that does this?
4. What is your opinion of the technology?
    a. Where do you think wearable sensors have the greatest impact in health care?
5. What is the value?
    a. How is the value created?
6. What actor benefit from the creation of value?

Healthcare Scenarios

For each of the following diseases, please answer the following questions (Cardiovascular disease, Cancer, Asthma & COPD, Compliance, HAI, Hospital Admissions)

7. What is the difference before and after the adoption of the new technology?
8. Why will the difference appear?
9. What need is actually met?

IT Platform and infrastructure

10. Given WS - What system requirements are needed? What is the best solution for a Hospital IT system? Do you know of any?
11. Given that wearable sensor will diffuse, how should the IT infrastructure be build?
12. How would the optimal system be built?
13. How can the variation of devices, means of communication, and technology provider be managed effectively?

Adoption and Diffusion

14. What are your experiences of adoption and diffusion of technology in health care?
15. What are the most common barriers for adoption of new technology?
16. What are the most common success factors for convince health care providers to use new technology?
17. In the context of wearable sensors, that do you believe will be the barriers and success factors?
18. For patients
19. What are your experiences of adoption and diffusion of technology in health care?
20. What are the most common barriers for adoption of new technology?
21. What are the most common success factors for convince health care providers to use new technology?

22. In the context of wearable sensors, that do you believe will be the barriers and success factors?

Final Questions

23. Do you know anybody we should talk to?
24. Can we contact you again if we have further questions?

Appendices 2 – Interview Template, Physicians

Introduction

1. We are conducting a project regarding this and this…
2. We define value = outcome/cost and we would like to find out how increased data and biometrics can create value for this [VALUE CREATION AREA]. In this interview we will focus on outcome improvements

Background - Input

3. In short, what are the greatest challenges for you as a care giver treating these patients?
4. Which data do you capture from your patients
    a. Prevention & Detection
    b. During treatment
    c. Follow-up
5. Out of this data, what is measured/captured by the care provider and what is/can be provided by the patient?
6. In which HC scenarios is this data not sufficient? Why? What data are you missing?

Value for Health Care Providers

7. What kind of data do you need from the patient in the different phases of the care cycle to deliver the best possible care?
    a. Identification/Prevention?
    b. Treatment?
    c. Follow-up?
8. What kind of data is possible to measure in the different phases? How would increased data

WS applications for this disease

9. Do you use any sensors today?
10. Do you hand them out or how are the distributed/made available?
11. For how long time do the patients use them? Is that period sufficient?
12. What do you think about patients owning their own sensors?
13. What would you expect/would you benefit from longer term measurements?
14. Today there are wearable sensors able to measure and collect data about the following biometrics related to this disease:
15. The devices available to do this are of the following types:

Outcome improvements

16. Now that you know what can be done by these WS, what outcome improvements can you see?
17. How is the outcome improved?
18. Which data is useful?
19. By using Porter's framework "The Outcome Measures Hierarchy", in which tier would you say that the outcome is improved?
20. Why?
21. At which tier is the biggest part of the outcome improvement created?
22. Please grade the data point importance from 1-10
    a. 1 – No significant impact

b. 10 – Significant impact

23. Except for the areas that you've told us, we would like you to comment on the following areas in which we have hypotheses about outcome improvements → Go through question 1-2 again for these areas

Scenario analysis

24. Now that you have a good sense about what the technology/WS can help us picture any scenarios in which these WS can create value?
25. Who is the typical patient?
26. What is it that he/she benefit from? E.g. helping to follow the physicians suggestions by monitoring the behavior.
27. What is it that you benefit you?

Appendices 3 – Required Data points per Disease or Healthcare application area

In the subsequent paragraphs the required data points per disease are presented and described. Moreover, an assessment of the importance of the data point to the healthcare provider is presented.

Required data points - Cardiovascular diseases

- *Blood pressure*
  The most commonly measure is the arterial blood pressure, which is divided into systolic and diastolic pressure. There are different kinds of methods to measure blood pressure, and different methods are preferred during different phases of the healthcare delivery process. In the phase of prevention and prevention, a 24-hour blood pressure registration can support the physician in the decision process. In this case, Rundqvist states that a longer period of data collection is not necessary. During the intervention, a more frequent access to measurement data on the central blood pressure would be valuable information. On a scale from 1-10 indicating the importance of the data point to the healthcare provider, Doctor Rundqvist selected 9.

- *Body weight*
  The body weight of the patient in valuable information as some of the diseases under the definition of cardiovascular diseases is related to changes in weight. For instance, patients who suffer from heart failure have a tendency to accumulate fluid and consequently gain weight.[118] If medication is taken as prescribed, the patient will not gain weight. By patient usage of weight scales and access to weight data, healthcare providers will be able to know if the patient has followed medication prescriptions since deviation from medication will result in changes in body weight. Consequently, healthcare providers are able to focus more on how to support the patient rather than trying to figure out if the patient has followed the prescriptions or not. Previously, the measurement has been used in the phases during intervention and rehabilitation, but with continuous access the data can also be used in prevention and detection. On a scale from 1-10 indicating the importance of the data point to the healthcare provider, Doctor Rundqvist selected 8.[119]

- *Compliance to medication*
  One of the most important aspects to know for physicians concerning their patient is how well adhere to medical prescriptions, more commonly known as compliance. Knowledge of the compliance is of significant value for the physician, as it allows him or her to evaluate the effectiveness and efficiency of the prescribed drugs and treatments. Today the level of compliance is communicated orally, which can be non-reliable and it is often hard to know if the patient is actually telling the truth. Moreover, as mentioned earlier, body weight can be used as an indicator of compliance for heart disease patients. However, a more reliable way to measure compliance would create value to the patient. On a scale

[118] Ragnar Lindblad, CEO B3IT, Interviewed at March 14th 2014
[119] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014

from 1-10 indicating the importance of the data point to the healthcare provider, Doctor Rundqvist selected 9.[120]

- *Electrocardiography*
  Electrocardiography (ECG) provides information about heart rhythms and atrial fibrillation by registration of electrical activity in the heart. Having better access to ECG of a patient can support the physician in the entire healthcare delivery process, i.e. during prevention and detection, intervention, and rehabilitation. At the moment physicians use Holter ECG devices, especially to detect diseases. The examined patient uses the machine during 24-48 hours to collect data, and then a physician analyzes variations and deviations. The collection of data during 24-48 hours is not sufficient, thus a longer collection period would be beneficial. During intervention the ECG is a powerful tool for the physician to understand if the medical recommendation he or she has made yields the desirable results for the patient. On a scale from 1-10 indicating the importance of the data point to the healthcare provider, Doctor Rundqvist selected 10.

- *Motion*
  The level of activity of the patient can be valuable for the physician in various stages of the healthcare process. If the physician includes a certain level of physical activity in the ordination during intervention and rehabilitation, wearable sensors can be create better insights on how the patient is following ordination. On a scale from 1-10 indicating the importance of the data point to the healthcare provider, Doctor Rundqvist selected 7.[121]

- *Oxygen saturation*
  Oxygen saturation is a measurement of the concentration of the dissolved oxygen in the blood. An increased access to information of the oxygen saturation can be valuable for the physician during the intervention. On a scale from 1-10 indicating the importance of the data point to the healthcare provider, Doctor Rundqvist selected 8.[122]

- *Respiration curves*
  Sleep registrations during treatment, that is measuring the respiration rates for diagnostic purposes and specific disease conditions such as sleep apnea, is valuable for the care provider. For patients with heart diseases this is of particular interest since sleep apnea is much more frequent for those patients. On a scale from 1-10 indicating the importance of the data point to the healthcare provider, Doctor Rundqvist selected 8.[123]

Required data points - Diabetes

- *Blood Glucose Level*
  The measurement of the glucose level in the blood is the most important data point for the management of the disease. The measurement is the input

[120] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014
[121] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014
[122] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014
[123] Bengt Rundqvist, MD Cardiologist at Sahlgrenska Hospital, Interviewed at March 18th 2014

parameter for the decision process of how to change doses of insulin according to the patient's needs. The data needs to be measured every day, often multiple times. Hence, an increased, continuous access is beneficial. On a scale from 1-10 indicating the importance of the blood glucose level to the healthcare provider, Doctor Forsander selected 10.[124]

- *Blood Pressure*
  Blood pressure will be interesting as a decreased pressure can be a risk indicator of loss of sensitivity. This data point is measured once per year, and an increased access to data can be valuable. On a scale from 1-10 indicating the importance of the blood pressure to the healthcare provider, Doctor Forsander selected 8.[125]

- *Body Composition*
  This measure is related to body weight, as the patient will increase the share of subcutaneous in the body. This data point is measured once per year, and an increased access to data can be valuable for the healthcare provider to ordinate better healthcare actions. On a scale from 1-10 indicating the importance of the body composition to the healthcare provider, Doctor Forsander selected 6.[126]

- *Body Weight*
  The body weight value is important in the long-term perspective, as a people sometimes eat too much in order to make sure they are in the risk zone low glucose levels. Over time, this increases the risk for obesity. Today, the measurement is only performed a few times per year; an increased data can help the healthcare provider to identify a weight changes earlier. On a scale from 1-10 indicating the importance of the body weight to the healthcare provider, Doctor Forsander selected 8.[127]

- *Smoking Habits*
  Access to smoking habits can help the healthcare provider to understand the disease better. At the moment, this data is collected by conversations with the patients. A new technology and an access to more reliable smoking data can be beneficial. On a scale from 1-10 indicating the importance of the smoking habits to the healthcare provider, Doctor Forsander selected 6.[128]

Required data points – Asthma & COPD

- *Body Weight*
  Both asthma and COPD can cause gaining weight. Today patients weigh upon arrival at the hospital. On a scale from 1-10 indicating the importance of the body weight to the healthcare provider, Doctor Nordensson selected 1 and 5 for asthma and COPD respectively.[129]

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[124] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[125] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[126] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[127] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[128] Gun Forsander, MD Diabetic Care at Sahlgrenska Hospital, Interviewed at March 12th 2014
[129] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014

- *Compliance data*
  Compliance is important for asthma and COPD patients since they have a hard time following medication prescriptions from the physician. The data about compliance will be something entirely new, because today healthcare does not know what to do about it, but it can likely be used in some context. For instance, it can probably enable better understanding of patients. Further more, information about the geographical usage of inhalation can be used to identify areas where specific or groups of individuals have respiration problems.[130] Doctor Nordensson argues that where and when patients need to use the inhalators are today collected by asking the patients although the geographical place is harder to get valuable output from.[131] The value for the patient lies in the capability to monitor compliance and understand how behavior relates to health status.[132] One can also get troubles by over-consuming inhalation, or by using the inhalator poorly. This means that one is not being able to really get the medication down the throat into the airways.[133] Moreover, challenges arise as there are asthma patients who take medication now and then and others who do not take medication when they are supposed to. Another thing, people have various body knowledge and hence feel/experience their body signals differently, which is a problem since if they do not react to negative body signals it can take too long before they get medication.[134] On a scale from 1-10 indicating the importance of compliance to the healthcare provider, Doctor Nordensson selected 5 and 5 for asthma and COPD respectively.[135]

- *Electrocardiography*
  Electrocardiography is usually measured upon arrival to the hospital, and is mostly used to determine if the patient has any infections. On a scale from 1-10 indicating the importance of the ECG to the healthcare provider, Doctor Nordensson selected 1 and 5 for asthma and COPD respectively.[136]

- *Oral Communication*
  It is important for patients not to be too breathless by everyday activities. Thus, talking to patients is an important stream of data collection. For example some patients might inform the physician that they needed to stand still twice when going to the mailbox. The levels of CO2 for COPD patients is also important but so far this cannot be made transcutaneous but only via blood samples of the veins. Also one checks their ability to walk down the hallways in the hospital in order to spot improvements or not. On a scale from 1-10 indicating the importance of the oral communication to the healthcare provider, Doctor Nordensson selected 9 and 9 for asthma and COPD respectively.[137]

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130 Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014

131 Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014

132 Meredith Barrett, Corporate Development at Propeller Health, Interviewed at May 29th 2014

133 Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014

134 Reidar Gårdebäck, CEO Medtronic Sweden, Interviewed at February 17th 2014

135 Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014

136 Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014

137 Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014

- *Oxygen saturation*
  Oxygen saturation can be measured through the skin with a clip on the finger (pulse oximetry) or in the earlobe. This is important as too low oxygen levels can cause severe consequences. The oxygen in the finger is measured every morning at patients at the hospital. Oxygen saturation is the most important data point to measure continuously.[138] On a scale from 1-10 indicating the importance of oxygen saturation to the healthcare provider, Doctor Nordensson selected 8 and 10 for asthma and COPD respectively.[139]

- *Respiration capability (PEF)*
  Measuring respiratory capability, or peak expiratory flow, is important for asthma patients. However, it is a bit technically advanced so the patient has to be educated in how to use the device.[140] The biggest challenge for physicians treating asthma and COPD is that anxiousness can also be a reason for respiration troubles. This means that it is difficult to know what is the cause of the respiration troubles. On a scale from 1-10 indicating the importance of respiration capacity to the healthcare provider, Doctor Nordensson selected 8 and 3 for asthma and COPD respectively.[141]

- *Spirometer data*
  Spirometer data is useful in the stage of prevention and detection. Spirometer measurement is a breathing test in which the airflow is measured. One measures how much air the lungs can swallow and then the percentage of this that can be pushed out through the mouth in one second. 70% is the critical limit; if the result is lower it is an indication that the person might have asthma or COPD. On a scale from 1-10 indicating the importance of the spirometer data to the healthcare provider, Doctor Nordensson selected 6 and 6 for asthma and COPD respectively.[142]

- *Temperature*
  Temperature is an important measurement upon arrival at the hospital and is analyzed in combination with ECG measurements. On a scale from 1-10 indicating the importance of the temperature to the healthcare provider, Doctor Nordensson selected 8 and 8 for asthma and COPD respectively.[143]

Required data points – Care of elderly

- *Blood Pressure*
  Blood pressure can be measured in various ways, and in the case of geriatrics both the supine and the standing blood pressure is of great importance. The health condition of elderly can vary significantly during the day, and hence a

[138] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[139] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[140] Ragnar Lindblad, Chairman Swedish Medtech, Interviewed at February 14th 2014
[141] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[142] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014
[143] Anita Nordensson, MD Asthma & COPD at Sahlgrenska Hospital, Interviewed at March 31th 2014

continuous measurement of blood pressure can be of significant value. A prolonged period of collection can be beneficial. On a scale from 1-10 indicating the importance of the blood pressure to the healthcare provider, Doctor Nyman selected 8.[144]

- *Compliance*
  Compliance and control of medication is a major problem and challenge in geriatrics. A challenge for geriatric patients is to remember to take the right medication at the right time. The most distinguishable benefits of the knowledge of compliance would be the possibility to measure effectiveness and efficiency of the prescribed medication. At the moment the physician and the patient discuss orally. A supporting system or a wearable sensor that can measure and detect that the patient has actually taken the medication as prescribed would create extensive value for the patient and the physician. On a scale from 1-10 indicating the importance of the compliance to the healthcare provider, Doctor Nyman selected 10.[145]

- *Heart Rate*
  The interval of normal heart rate does not usually change with increased age, but the ability for the heart to change from one level to another may change. Consequently, it can become harder to increase the heart rate while exercising and also to return to normal level after the exercise activity. Also, in those cases when the heart rate establishes at new normal levels, this can be valuable information for the physician when evaluating different alternatives for intervention. On a scale from 1-10 indicating the importance of the heart rate to the healthcare provider, Doctor Nyman selected 7.[146]

- *Oxygen Saturation*
  Oxygen saturation refers to the amount of dissolved oxygen in the blood, and the value has to be kept in a specific level for the body to work most effectively. Low levels of oxygen can result in various complications, including hypoexemia, compromised organ function, and respiratory and cardiac arrest. A continuous access to this data can serve as valuable input to the healthcare provider. On a scale from 1-10 indicating the importance of the oxygen saturation to the healthcare provider, Doctor Nyman selected 8.[147]

- *Temperature*
  Temperature can be used as an early warning sign of infections. However, when people become older the body can change the way it responds to infections and no change in temperature can be identified. Nevertheless a measurement of the temperature can be used as a warning signal on 70-80 percent of the cases. If fever is detected, this can help the healthcare provider to act faster. On a scale

[144] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[145] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[146] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[147] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014

from 1-10 indicating the importance of the temperature to the healthcare provider, Doctor Nyman selected 5.[148]

Geriatric Giants

- *Body Weight*
  An important ratio for diagnosing in geriatrics is body mass index (BMI). It is common for elderly patients to lose weight over time, in cases a consequence of malnutrition. Accordingly, a long-term measurement of body weight can be used for early detection of malnutrition and interventions can be made earlier. Access to this data is also important as the physician will receive knowledge on what the normal body weight is. On a scale from 1-10 indicating the importance of the body weight to the healthcare provider, Doctor Nyman selected 4.[149]

- *Body Height*
  The other parameter of the BMI-ratio is body height. In this case, the measure will not change significantly and a continuous collection of this data is not necessary. On a scale from 1-10 indicating the importance of the body height to the healthcare provider, Doctor Nyman selected 4.[150]

- *Confusion*
  Confusion is a subjective and an individual experience. Hence, it becomes hard for the physician to know if a patient really is confused or not. As this is the case, increased access to data and information regarding confusion will have limited positive value for the healthcare providers. On a scale from 1-10 indicating the importance of the temperature to the healthcare provider, Doctor Nyman selected 3.[151]

- *Dizziness*
  Dizziness is a word with many diverse definitions, and consequently it is hard for a physician to investigate as the description may vary between the physician and the patient. However, information about dizziness, in terms of how often it occurs, in what contexts, and what the effects are, can be valuable for the physician in the decision on healthcare intervention. Today the physicians collect this data by visual inspection and via oral communication, and hence it is a subjective judgment based on a limited period of time. An increased access to data can be beneficial from the physicians' perspective. On a scale from 1-10 indicating the importance of the dizziness to the healthcare provider, Doctor Nyman selected 7.[152]

- *Fall Detection*
  Falls are a major problem for the elderly and cause substantial problems in terms of fractures and injuries of the brain every year. Today this is registered by

[148] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[149] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[150] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[151] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[152] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014

observations, which means that a sensor able to register falls would be of great value. If there was better access to information regarding falls the diagnostics could improve and one would be able to perform other investigations in order to find out if there are explanations to the cause of the falls but also to provide protection of the body. The most common place for falls is in the person's bathroom. On a scale from 1-10 indicating the importance of the fall detection to the healthcare provider, Doctor Nyman selected 10.[153]

- *Feces*
  Analysis of the feces can also be interesting for the investigation of malnutrition. However, this measurement is less important compared to body weight and body height and a continuous monitoring is not necessary. On a scale from 1-10 indicating the importance of the fluid intake to the healthcare provider, Doctor Nyman selected 3.[154]

- *Fluid Intake*
  Analysis of the fluid intake can also be interesting for the investigation of malnutrition. However, this measurement is less important compared to body weight and body height and a continuous monitoring is not necessary. On a scale from 1-10 indicating the importance of the fluid intake to the healthcare provider, Doctor Nyman selected 5.[155]

- *Incontinence*
  Incontinence is valuable to the physician as it provides information on how the patient manages and has control of its own body. However, an increased access to data before the patient are in the hospital will not create additional value, as the data becomes valuable at first when the patient stays at the hospital. On a scale from 1-10 indicating the importance of the incontinence to the healthcare provider, Doctor Nyman selected 3.[156]

- *Immobilization*
  Being immobilized increases the risk for basically everything. Today motion and activity are observed by visual inspection, which basically relates to how much time the patient stays in bed. By getting more data about how active a person is, relatives can increase their knowledge of the person's health condition and reduce anxiousness. On a scale from 1-10 indicating the importance of the immobilization to the healthcare provider, Doctor Nyman selected 10.[157]

- *Pain*
  Pain is a subjective and individual based experience, where the same treatment and experience can cause different amount of pain to different people. Hence, it becomes hard for the physician to know what pain actually means to the individual patient. To improve the healthcare delivery, access to data that

[153] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
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[156] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[157] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014

contains information regarding when, where, in what environment and the duration of pain can be valuable. On a scale from 1-10 indicating the importance of the temperature to the healthcare provider, Doctor Nyman selected 8.[158]

Required data points – Neurological diseases

- *Compliance – Multiple Sclerosis*
  The ability of a patient to follow the medication as prescribed is one of the most important factors in the treatment of patients with multiple sclerosis. A technology that can track usage of medication could create value during the intervention and rehabilitation phase of the healthcare process. On a scale from 1-10 indicating the importance of the compliance to the healthcare provider, Doctor Malmeström selected 8.[159]

- *Compliance – Parkinson's Disease*
  As with compliance for patients with Multiple Sclerosis compliance to medication is a key factor for successful treatment and rehabilitation of the patient. On a scale from 1-10 indicating the importance of the compliance to the healthcare provider, Doctor Malmeström selected 7.[160]

- *Inflammation Levels in the Blood – Multiple Sclerosis*
  Information on inflammation levels in the blood is of great interest of the physician. However, the physician has to take a lumbal punction to measure the level of inflammation in the central nerve system. This is a quite complicated invasive action that is not possible to do with wearable sensors. On a scale from 1-10 indicating the importance of the inflammation levels in the blood to the healthcare provider, Doctor Malmeström selected 8.[161]

- *Tremor Monitoring - Parkinson's Disease*
  The amount of medication given to patients with Parkinson's Disease is partly based on the amount of tremor. Tremor is the non-voluntary contraction in muscles and is most commonly experienced in the hands of the patients. With access to data on tremor the physician would be able to make more informed decisions on how much medication that should be given to the patient. On a scale from 1-10 indicating the importance of the tremor monitoring to the healthcare provider, Doctor Malmeström selected 7.[162]

Required data points – Obesity

- *Blood Glucose Level*
  The level of glucose in the blood is a long-term indication of the weight development of the patient. A high level of blood glucose levels in the body

[158] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
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[160] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[161] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014
[162] Christer Nyman, MD Geriatrics at Sahlgrenska Hospital, Interviewed at April 8th 2014

results in an increased risk of gaining weight. Hence an increased access to this data in early stage can help physicians to intervene earlier. On a scale from 1-10 indicating the importance of the blood glucose level to the healthcare provider, Doctor Eliasson selected 7.[163]

- *Body Composition*
  This data is valuable as it monitors how the patient is able to lose subcutaneous and other fat over time. The measurement of body composition is a great complement to the height and weight measures. On a scale from 1-10 indicating the importance of the body composition to the healthcare provider, Doctor Eliasson selected 6.[164]

- *Body Height*
  This is one of the parameters in the calculation of BMI. On a scale from 1-10 indicating the importance of the body height to the healthcare provider, Doctor Eliasson selected 8.[165]

- *Body Weight*
  According to Björn, the weight in relation to height is the most important values as these are the input values for computation of the BMI. At the moment, healthcare providers receive this data at given points of time. On a scale from 1-10 indicating the importance of the body weight to the healthcare provider, Doctor Eliasson selected 10.[166]

- *Eating behavior*
  By analysis of the eating patterns of the patient, the healthcare provider can provide guidance on how to change behavior to reduce risk to develop obesity and/or how to loose weight. There is a large EU-financed development program called SPLENDID that aims to develop a wearable sensor that tracks eating behavior through sound analysis in the jawbone. By analysis of eating behavior of children and young adults this technology aims to identify person in risk of developing obesity in the future. On a scale from 1-10 indicating the importance of the eating behavior to the healthcare provider, Doctor Eliasson selected 6.[167]

- *Motion*
  The ability to measure movement and physical activities either by GPS or pulse variations can be powerful for compliance to exercise programs. The patient and the doctor will get a better understanding of how the patient is actually following the recommendations. The level of motion and activity is important in all phases of the healthcare process of these patients, with additional emphasis during intervention and rehabilitation. On a scale from 1-10 indicating the importance of the level of motion to the healthcare provider, Doctor Eliasson selected 7.[168]

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[163] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

[164] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

[165] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

[166] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

[167] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

[168] Björn Eliasson, MD Obesity at Sahlgrenska Hospital, Interviewed at March 11th 2014

Required data points – Orthopedics

- *Mobility*
  The level of mobility is useful if it could be objectively measured, since it is only if one is able to compare a patient's level of mobility to a normal level that it can be input to surgery decisions. On a scale from 1-10 indicating the importance of the mobility to the healthcare provider, Doctor Jönsson selected 7.[169]

- *Pain Levels*
  The level of pain experiences by the patient is of great interest. As pain is a subjective experience that varies from one individual to another the increased data can help the physician to better understand the pain of the individual patient. On a scale from 1-10 indicating the importance of the pain level to the healthcare provider, Doctor Jönsson selected 8.[170]

- *Posture*
  The posture of the patient in different situations can be useful information. The information is needed both for situation when the patient stands, sits, and lays down. On a scale from 1-10 indicating the importance of the posture to the healthcare provider, Doctor Jönsson selected 6. [171]

- *Pressure*
  The plantar pressure can be useful data to the physician. If a patient has a skewed plantar pressure it can result in repetitive strain injuries. With this information potentially some patients can avoid to develop repetitive strain injuries. On a scale from 1-10 indicating the importance of the mobility to the healthcare provider, Doctor Jönsson selected 7.[172]

[169] Anders Jönsson, MD Orthopedics at Sahlgrenska Hospital, Interviewed at April 15th 2014
[170] Anders Jönsson, MD Orthopedics at Sahlgrenska Hospital, Interviewed at April 15th 2014
[171] Anders Jönsson, MD Orthopedics at Sahlgrenska Hospital, Interviewed at April 15th 2014
[172] Anders Jönsson, MD Orthopedics at Sahlgrenska Hospital, Interviewed at April 15th 2014